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ARTICLE STUDY ON APPLICABILITY AND FEEDING PREFERENCES OF AQUATIC INSECTS

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ABSTRACT

Aquatic macroinvertebrates play an important role in a wide range of ecological processes. Primary production, detritus decomposition, nutrient mineralization, and downstream spiralling are just some of the processes they have a significant impact on. The categorization of functional feeding groups (FFGs) was created to make it easier to include macroinvertebrates in aquatic ecosystems research. When macroinvertebrates consume resources, their physical properties (such as the specialisation of mouth parts) and behavioural processes (such as feeding strategy) are combined in this categorization. In spite of recent advancements in macroinvertebrate identification, there is still a lack of knowledge on the FFG assignment. FFG classification has also undergone considerable alteration because of a focus on gut content analysis, which is more suited for assigning trophic guilds than using the FFG classification alone. These objectives are to present an overview of the usefulness of utilising the FFG classification, synthesise known information on aquatic insects in Latin America using the FFG, and provide basic instructions on how to allocate species to their FFGs in this research. The purpose of FFGs is to show the impact organisms may have on their habitats and the resources they use. Groups such as scrapers, shredders, and collectors-gatherers use modified mouth parts to sieve or collect small particles (1mm) accumulating on the stream bottom, while filterers use special adaptations to remove particles from the water directly. Other groups include filterers, which remove particles directly from the water. The piercers that drink plant juices by cutting or puncturing the tissue with their mouth parts and feed on vascular plants are also covered in depth. A list of aquatic insect families in Latin America, with an initial assignment to FFGs, is also provided in this section When allocating FFGs based on the contents of one's stomach, we advised care.

1. INTRODUCTION

In aquatic environments, macroinvertebrates play a significant part in a variety of activities. Invertebrates that cut or chew leaf debris play a role in processes like leaf litter degradation. Invertebrates, particularly in tiny streams, may have a significant impact on the pace at which leaves decompose. There are also major consequences on algal biomass and primary production from macroinvertebrates that devour algal resources. Because bacteria recycle nutrients, macroinvertebrates' grazing is also advantageous to them. Aquatic macroinvertebrates serve as a vital connection between lower trophic levels (such as algae and detritus) and higher trophic levels (such as fish) or microbial communities because of their role as main consumers. However, they have a dual function in the aquatic food chain, balancing energy flow while also supplying energy to higher trophic levels.

Macroinvertebrates play an important role in their ecosystems by detailing their activities and preferred resources. A population's ecological role in an ecosystem process is determined by the ways in which it feeds and the resources it consumes. Using functional feeding groups (FFG) as a means of including macroinvertebrates into investigations of aquatic ecosystem dynamics was introduced by Cummins and his co-workers. When macroinvertebrates consume resources, their physical properties (such as the specialisation of mouth parts) and behavioural processes (such as feeding strategy) are combined in this categorization. Organic matter decomposition and the generation of tiny particles, such as those from insect shredders (e.g., creatures that help break down leaves), are two classic examples of how these species contribute to ecosystem processes.

Numerous challenges stand in the way of understanding how tropical streams' ecosystems work. However, recent initiatives have substantially improved our capacity to identify aquatic macroinvertebrates using taxonomic knowledge. The lack of data on macroinvertebrate FFG assignment continues to hamper research into ecological dynamics. FFG assignments need knowledge on an organism's behaviour and morphology, which we frequently lack. This lack of information is not unexpected. FFG has often been assigned to tropical species based on evidence from temperate environments. Tropical macroinvertebrate feeding ecology has been the subject of various studies, including Cummins, Merritt & Andrade (2005). Rearing Costa Rican insects, Jackson and Sweeney (1995) determined that the insects were FFG based on their chosen food source and feeding techniques. In recent investigations in South America, researchers have attempted to allocate macroinvertebrates to FFG based on their intestinal contents.

Although there has always been some variance in the usage and assignment of FFGs, in certain tropical research FFGs are assigned based on information on the kind of food items ingested instead of their selection and feeding mechanism. We can learn a lot about tropical ecosystems from these researches, but the use of multiple methodologies may make it harder to recognise general trends and make cross-regional comparisons. Aiming to explain the FFG concept's categories, correct application, and how organisms should be allocated to categories, we compiled this evaluation. The review is broken down into three sections: (3) basic principles for correctly assigning creatures to their FFG in Latin America, as well as a review of existing material on FFG for aquatic insects in Latin America. For the most part, our purpose is to consolidate material on FFG that is presently dispersed in a variety of publications in order to assist us better understand tropical stream ecosystems.

2. FUNCTIONAL FEEDING GROUPS

When Cummins (1973) came up with the FFG category, it was immediately adopted and employed in a number of environmental activities. As a result of the development of this classification system, the River Continuum Concept has had a substantial influence on our understanding of stream ecology in temperate and tropical environments. There was some confusion and misunderstanding about the FFG category system when it was first published since it was not clearly defined in the first release. For the time being, the major objective of this categorization system is to provide information on the ecology of macroinvertebrates. In ecological functions such as nutrient mineralization and downstream spiralling, for example, macroinvertebrates play a critical role.

In view of the underlying assumption that macroinvertebrates' morphological features connected with food acquisition (e.g., mouth parts and related structures) and behavioural processes are to blame, these FFGs have been summarised (e.g., feeding behaviour). Similarly, when Cummins (1973) established FFGs and Wallace and Webster (1996) examined the role of macroinvertebrates in stream ecosystems, they both relied on the same underlying assumptions.

Scrapers: It is scrapers' mouthparts, which are specialised to cultivate particles tightly adhered to rocks and other substrates, that devour resources growing over substrates. Benthic biofilms, which are made up of bacteria, fungus, algae, and a polysaccharide matrix that covers hard surfaces in aquatic habitats, are also consumed by scrapers. Because scrapers eat algae, they may have a significant impact on primary producers in stream ecosystems. Using meta-analyses of previous research, Femi Nella and Hawkins (1995) concluded that invertebrates play a critical role in stream ecosystems by devouring producer biomass and altering algal species composition. Different scraper density may have a variety of favourable to negative impacts on algae biomass and output.

Piercers: Plant tissue and plant liquids are consumed by piercing organisms, which use sharp or biting mouthparts to consume vascular plant tissue. Small caddisfly species, such as those Hydrophilidae, which pierce individual cells to get cellular fluid, may be able to bypass the cellulose-rich cell walls of algal cells because of their cellulose content. However, while it was not originally classified by Cummins, it was later included in the first edition of his handbook on North American aquatic insects, which was later revised. The ecological significance of piercing macroinvertebrates has received little attention in the scientific community. Hydrophilidae larvae, for example, are often found in streams and have the potential to have a large influence on algal environments.

Shredders: All plant components, including leaves and wood, are sliced or eaten by shredders, which are living animals that consume all plant components. Plant waste is broken down into tiny pieces by shredders and then transported downstream or made available to other stream users. Additionally, shredders give nutrients for the ingestion of microorganisms. As a convenience, we'll refer to these groups as "consumers of coarse particulate organic matter" and "producers of fine particle organic matter" throughout this discussion (FPOM). Plant-eaters and miners such as the larvae of the Noctuid and Tortricid lepidopteran families are referred to as shredders of live plant material because they shred plant material while feeding on it. Shredders that shred plant material include detritivores and wood borers, which are the two most frequent forms of shredders. Animals that consume live plant tissue are the principal herbivores that deplete water vascular plants of their nutritional reserves. These organisms are well-known for their fondness for vascular plants, and some of them are even used as biocontrol agents against floating vascular plants in the wild. Stream ecologists have taken close attention to shredders, which are machines that consume debris. We know that macroinvertebrates are crucial in aquatic habitats because they digest decaying plant material, and this is well proven. While evidence shows that shredding macroinvertebrates increases fine particle concentrations in streams, it is unclear if these particles are of any significance to insect collectors.

Collectors: Collected particles (less than one millimetre in diameter) are sifted or collected by organisms with modified mouth parts, known as collectors or collector-gatherers, which sift or collect tiny particles (less than one millimetre in diameter) which have accumulated on the stream bottom. Small bits of leaves can be eaten by shredders, but collectors' mouths are not intended to do so, therefore they only consume the tiniest of leaf fragments. It is necessary to use collectors in order to repackage FPOM into larger particles once it has been eaten.

Collectors, or fine particle collectors, are more common in stream ecosystems where the flow is slow and there is a significant concentration of tiny particles. A few subfamilies of the Chironomidae are both collectors and main consumers, as is the case with the Chironomidae as a whole. When collecting FPOM from streams, collectors tend to consume large quantities of particles, which has an influence on the size and quality of the particles collected. The usage of collectors may produce small disturbances and re-suspension of particles in the water column, which can result in downstream transit of these particles into the environment.

Filterers: Collector-filtering organisms, often known as "filterers," have specialised characteristics that allow them to remove particles from the water column directly. Trichopteran larvae (e.g., Polycentropodid) and Simonidean, for example, employ nets to filter water or have mouth parts that are adapted to filter water.

This group's ecological job is to remove particles from the water column and limit the export of particles to downstream regions, increasing the efficiency of the ecosystem's resource utilisation. Filterers take in a wide range of particle sizes and compositions. Drifting animals are known to be a food source for certain Trichopteran larvae. As a result, they are both predators (as they eat animal tissue) and filterers (as they filter their food).

Predators: Animals that prey on other living things use a variety of tactics to catch their prey. Predators use a variety of methods to catch their prey, including modified mouth parts and behaviour. Despite the fact that many predators have large, powerful teeth for tearing apart prey, others are very specialised in their prey eating. When it comes to aquatic insects, the Odonatan’s labium, for example, is one of the most specialised structures. The beak-like mouthparts of certain Hemiptera, meanwhile, allow them to inject poison into their victim and eat tissue (e.g., Notonectid). To catch prey, other Hemiptera have adapted their legs.

Organisms that belong to more than one FFG: A wide variety of creatures with remarkable adaptations live in tropical settings. As a result, finding creatures that don't fit neatly into a single FFG or that exhibit variable behaviour and function throughout time and place is understandable. Shrimps are a good example of a single species with various FFG. Atya lannipes (Atydae) eat FPOM with modified legs covered with numerous hairs. As a result, this species may be assigned to two different FFGs based on the environment it inhabits and the behaviour it displays. Additionally, crayfish in temperate streams are known to perform several functions, and their output is typically divided across numerous FFG in studies on secondary production. As our knowledge of tropical macroinvertebrates grows, we are sure to see more instances. If a species alters its behaviour and feeding strategy over its life, it may belong to more than one FFG. Many creatures have been seen to undergo ontogenetic diet changes. Stonefly larvae are known to feed on decaying organic matter in the early stages of development before gradually transitioning to animal flesh as they grow.

Because of this, it is important to pay attention to the larval stages of insects in order to allocate them to FFG.

3. AQUATIC INSECTS AS THE MAIN FOOD RESOURCE OF FISH THE COMMUNITY

Identifying ecological interactions among fish species and other aquatic creatures, as well as resource partitioning within fish assemblages, is critical for the management of natural populations. The number of trophic guilds in fish communities is highly reliant on environmental factors. In the first few years after reservoirs are closed, piscivorous fishes might be found in great numbers due to the quantity of food. The Pantanal floodplain, for example, has a high concentration of omnivorous fish because of the region's variable seasonal climate. As a result, detritus and sediment play a significant role in the preservation of fish fauna in reservoirs and floodplains, which in turn promotes the cycling of matter and nutrients. Detritivores fish are common in these areas.

A wide variety and number of fish may be found in reservoirs since the primary food sources for the fish fauna are aquatic insects, other invertebrates, zooplankton, detritus and fish. Neotropical reservoirs are rich in aquatic insects, particularly dipterans of the Chironomidae family, as well as Ephemeroptera’s and odonats. In streams and higher-order rivers, these creatures play a vital part in the ecosystem's metabolism and serve as a food source for fishes. Fish in reservoirs rely on them as a major source of food.

3.1 Food and Feed for Aquatic Insects and Their Resource

Although water insects make up just 10% of the insect species and only 12 orders, they have a wide variety of species, despite the fact that aquatic insects only make up 10% of the insect species and only 12 orders. According to D. Dudley Williams, and Sian S. Williams, the biology, natural environment, and similarities of aquatic insect orders have been thoroughly documented. Candidate species for food and feed may be found in six of the 12 aquatic insect orders. To name a few, the Coleoptera (beetles), Diptera (flies), Ephemeroptera (mayflies), Hemiptera (bugs), Odonata (dragonfly/damselfly), and Trichoptera (flies) belong to this group (caddisflies). For centuries, it has been utilised in traditional Chinese medicine, as well as for food, and its economic importance is undeniable, according to reports from Southwest China and Japan. Despite their widespread distribution, the breeding techniques of certain insect species have improved throughout time.

The Macadam and Stock an approach was used to revise the list of edible aquatic insects. Other sources, including Jongema (2017) and Mitsuhashi (2016), were also vetted for inclusion on the list of primary sources. The list includes 329 species, 153 taxa, and 51 families from 46 countries. The number of edible water insects makes up around 15% of the overall number of edible bug species. Orders include Coleoptera, Odonata, Hemipter idea, Disteroidal, Megaloptera, Ephemeroptera, and Plecoptera, which are all arranged from highest to lowest in the phylogeny. More than three-quarters of the species in this order are predatory, and they include Coleoptera, Odonata, and Hemiptera. The naiad/larva stage of aquatic insects is the primary food source. It's common to find most species eaten in Mexico, as well as Japan, China and Thailand.

4. NUTRITIONAL AND HEALTH BENEFITS OF EDIBLE AQUATIC INSECTS

4.1 Aquatic Insect Protein and Amino Acid Composition

The protein content of aquatic insects is greater than that of typical animal foods at 59.55 percent on average. In addition, aquatic insect proteins include between 45.93–62.01 percent necessary amino acids, as well as a healthy balance of various amino acids, according to research. Aquatic insect proteins have a near ratio of necessary amino acids to human proteins, suggesting that aquatic insects have a high nutritional value. We summarised the first limiting amino acid and the highest amino acids in aquatic insects and compared them to terrestrial insects, which had quite distinct amino acid patterns. Leu is the most prevalent necessary amino acid in aquatic insects, accounting for 51.60% of their total amino acid composition (7.8 percent on average). Met + Cys (2.3 percent on average) and Trp were the most restricting amino acids (1.2 percent on average). Aquatic insects have the greatest average Glu content (11.30 percent) of any kind of organism. Comparing the necessary amino acid content of dragonfly larvae from various places, Jiang et al. observed that there was minimal change even across different species of dragonflies

Terrestrial insects' amino acid composition is getting more attention. There of 49.49 percent of necessary amino acids in terrestrial insects, and Leu is the most prevalent (7.35 percent on average). The (4.20 percent) and Trp (4.20 percent) were the most common limiting amino acids (3.61 percent on average). Glu is the most abundant amino acid in terrestrial insects, making up an average of 15.59 percent of the total. The content of tryptophan, an amino acid found in both aquatic and terrestrial insects, has been found to be different in some studies, but the difference is not significant when looking at the average data, indicating that the amino acid compositions of aquatic and terrestrial insects are similar. It's found in both terrestrial and aquatic edible insects, with a high level of Lys, for example. Aside from this important amino acid, both aquatic insects and terrestrial insects supplement grain protein in nutrition.

4.2 Fatty acid profiles in aquatic insects

Fats serve a critical function in the growth and development of insects since they are the second most prevalent dietary element (after protein). A large number of PUFAs, such as linoleic acid (18:2), linolenic acid (18:3), arachidonic acid (20:4, AA), and eicosapentaenoic acid (EPA), are considered to be abundant in aquatic insects. These PUFAs include linoleic and linolenic acids, as well as EPA and DHA (20:5, EPA). All four of these fatty acids, as well as the omega-3 and omega-6 fatty acids found in small amounts in fish and other seafood, belong to the omega-6 or omega-3 fatty acid family, which are essential to human health and can only be received from diet. The fatty acid contents of many aquatic and terrestrial insects are discussed in this article. The fatty acid content of edible terrestrial insects is the subject of considerable study. Fish oil composition is more well studied than edible aquatic insects since there are more data available. SFAs are dominated by palmitic acid (16:0) and stearic acid (18:0) to a lesser degree, while oleic acid (18:1) is the most prevalent composition among MUFAs, which is comparable to the reported terrestrial species. Except for a few species, the linoleic acid concentration (18:2) of edible terrestrial insects is greater than that of aquatic ones. Aquatic insects have much higher concentrations of PUFAs with four or more double bonds, such as AA and EPA, than terrestrial insects. UFA, palmitic and oleic acids, and odd carbon fatty acids (OCFA) make up the majority of the oil produced by dragonfly naiads, giving it the properties of general insect oil. There are AA, EPA, and docosahexaenoic acids (DHA) present in dragonfly oil, which is comparable to the fatty acids found in freshwater fish. This resemblance may be due to the aquatic life stage of dragonfly naiads. PUFAs, which have a lower melting point than SFAs or MUFAs but are nevertheless important to aquatic insects for their ability to survive in cold water, may be linked to membrane fluidity because of this. As adults, these aquatic insects were projected to need less ARA and EPA, and their levels might be so low as to be invisible when they were brought to land.

4.3 Marine Insects' Mineral Elements' Properties

For example, both aquatic and terrestrial insects contain greater levels of calcium, iron and zinc compared to conventional meat; this indicates that insect-based diets are good mineral sources. There is a large deal of variation in the mineral content of edible insects when they are classified into aquatic and terrestrial insects. Insects that live both in the water and on land may have comparable elemental compositions, such as a zinc content that is almost identical. Studies on calcium and iron levels, on the other hand, have indicated that aquatic and terrestrial insects have a significant difference. The calcium content of aquatic insects was found to be much greater (24.3–96 mg/100 g) than that of various terrestrial insects (0.0012–0.126 mg/100 g)... There is a large difference in iron concentration between aquatic and terrestrial insects, with the latter having much greater iron amounts (e.g., Lethocerus indicus 410 mg/100 g and the former having 461 mg/100 g) Selenium levels in dragonflies, a popular dish in southwest China, have long been a source of controversy because of the high selenium concentration. When it comes to China's popular edible insects, a study discovered that the average selenium content of terrestrial insects was 0.15 mg/kg, but that of aquatic insects was 0.31 mg/kg, which was twice as high as that found in terrestrial insects.

5. CONCLUSION

Aquatic macroinvertebrates play an important part in stream ecosystems, and FFG is an excellent tool for examining this function. They are a rich source of knowledge on the role of individual species in ecological processes. The correct categorization of macroinvertebrates into FFGs has enabled significant advancements in stream ecology. Perhaps the greatest example is Vannotte et al. (1980)'s River Continuum Concept. An ecosystem's ability to perform its essential functions may be affected by a wide range of external conditions, including changes in FFG composition. However, a lack of consistency in the assignment of FFGs may lead to misunderstandings and make it difficult to make comparisons across different sites. In this work, we want to contribute to the advancement of tropical studies by emphasising the significance of correctly classifying FFGs. We also expect that our current list of families will soon be replaced with a more thorough list to the genus level based on fresh Latin American research.

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