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Original Research Article

# Classification of aquatic macroinvertebrates in flow categories for the adjustment of the LIFE Index to Costa Rican rivers

Francisco Quesada-Alvarado[a,b,*], Gerardo Umaña-Villalobos[c,d], Monika Springer[c,d], Jorge Picado-Barboza[e]

[a] Central American Institute for Studies on Toxic Substances/Instituto Regional de Estudios en Sustancias Tóxicas (IRET), Universidad Nacional, Campus Omar Dengo, Heredia, Costa Rica
[b] Regional Postgraduate Program in Biology, University of Costa Rica / Programa Regional de Posgrado en Biología, Universidad de Costa Rica, Campus Rodrigo Facio, San José, Costa Rica.
[c] Centre for Research in Marine Sciences and Limnology, University of Costa Rica/ Centro de Investigación en Ciencias Marinas y Limnología (CIMAR). Universidad de Costa Rica, San José, Costa Rica
[d] School of Biology, University of Costa Rica/ Escuela de Biología, Universidad de Costa Rica, San José, Costa Rica.
[e] Independent Consultant, Costa Rica

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ABSTRACT

The LIFE Index can be useful to determine the effect of changes in river flow on the community of aquatic macroinvertebrates and as a tool for the implementation of environmental flows. This study demonstrates how to classify aquatic macroinvertebrates into a flow category in order to adjust the LIFE Index to Costa Rica. A panel of experts was surveyed to classify the most common genera into a water velocity category, based on their experience. Also, for one-year, aquatic macroinvertebrates were collected in the low and middle basin of the Naranjo River under different velocities, and by using the TITAN2 package, their respective thresholds for current velocity were determined. Variation was observed in the responses of the expert panel; however, several taxa overlapped by more than 60% between the expert classification and the TITAN2 test results. The TITAN2 test assigned a velocity threshold to 32 genera, with the inflection point being 0.1 m/s. The expert panel served as a tool to assign a category to those genera that the TITAN2 test did not contemplate. Organisms without morphological adaptations to survive fast flowing conditions decreased in frequency above 0.1 m/s, while genera related to moderate and high velocities increased in frequency. Through the panel of experts and the TITAN2 test, it was possible to assign the most common genera in the country to a current velocity category and therefore adjust the LIFE index.



## 1. Introduction

The presence and abundance of aquatic macroinvertebrates in lotic systems depend on factors such as water quality, hydrogeomorphological characteristics, and flow variations (Teferi et al., 2013; Gallardo et al. 2014; Brooks & Haeusler, 2016). The latter is a physical habitat structurer, which in turn conditions the distribution, richness,

* Corresponding author: Instituto Regional de Estudios en Sustancias Tóxicas (IRET) Universidad Nacional, Campus Omar Dengo, Heredia, Costa Rica. 86-3000
*E-mail addresses:* francisco.quesada.alvarado@una.ac.cr (F. Quesada-Alvarado), gerardo.umana@ucr.ac.cr (G. Umaña-Villalobos), monika.springer@ucr.ac.cr (M. Springer), jorgepicadobioconsult@yahoo.com (J. Picado-Barboza).

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and diversity of species. Variations in the flow regime also influence the life cycle of many aquatic species (Bunn & Arthington, 2002; Allan & Castillo, 2007; Izquierdo & Madroñero, 2013)

Flow regime variations can be generated naturally by fluctuations in the rainfall regime due to the shift between seasons or caused either by climate change or the El Niño-Southern Oscillation (ENSO) phenomenon (Quesada, 2011). Also, flow variations can result from human activities, either by water extraction or by the construction of dams, decreasing the natural flow of water. Addressing these variations in flow, numerous ecological studies associated with droughts have been carried out (Ligeiro et al., 2013; Řezníčková, Šikulová, Pařil & Zahradkova, 2013; Chessman, 2014; Boulton, 2015; Pinheiro, Ligeiro, Lucena, Molozzi, & Castillo, 2018: Mathers, Worrall & Wood, 2019) and the impact of flow reduction on aquatic communities has been examined (Extence, Baldi & Chad, 1999; Phelan et al., 2017).

Reducing the ecological flow of a river affects the health of the ecosystem since a natural flow regime is considered the main component for maintaining a functioning ecosystem (Pastor, Ludwig, Biemans, Hoff & Kabat, 2014). Natural flow allows the renewal of substrates along the basin, and removes fine substrates such as gravel and sand from interstitial spaces, thus maintaining these habitats available for aquatic macroinvertebrates. Also, it influences the carryover of nutrients and maintains longitudinal and transverse functional connectivity from headwaters to mouths (Flotemersch, Stribling & Paul, 2006; Allan & Castillo, 2007; White et al., 2017). Therefore, to keep lotic ecosystems in good working order, five characteristics of flow must be ensured: magnitude, frequency, duration, time, and range of change (Bunn & Arthington, 2002; Allan & Castillo, 2007; Pastor et al., 2014).

Several studies have shown a response (positive or negative) in the aquatic macroinvertebrate assemblages to flow variation (*e.g.*, Extence et al., 1999; Dunbar et al., 2010). Taxa associated with slow flows tend to increase in abundance when flow decreases, while other species associated with rapid flows exhibit an opposite response (Extence et al., 1999; Řezníčková et al., 2013). In this way, certain taxa can function as indicators of flow conditions. Additionally, perturbations in community structure may occur as a direct consequence of variation in flow patterns or indirectly through changes in associated habitats (Extence et al. 1999; Dunbar et al., 2010).

Faced with this panorama, Extence et al. (1999) developed the index called "Lotic-Invertebrate Index for Flow Evaluation (LIFE)". This index consists of giving a numerical value to each taxon depending on the micro-habitat it selects, according to water velocity categories. Furthermore, it gives a higher value to organisms that are dependent on rapid and turbulent flows, since, when the flow rate decreases, the habitats that are affected in the first instance are the rapids and waterfalls (Cortes, Ferreira, Oliveira, Oliveira, 2002). Thus, the index is used to measure the assemblage response of aquatic macroinvertebrates, based on their sensitivity to changes in the flow.

Currently, in neotropical rivers there is a boom in the planning and construction of hydroelectric dams of various sizes, bringing with it the impact on flow regimes and aquatic fauna (Arantes, Fitzgerald, Hoeinghaus & Winemiller, 2019). Costa Rica is no exception since 65% of the energy produced in the country comes from hydroelectric dams (Blanco, 2012), and there is no methodology in the country that allows for determining the degree of effects or changes that occur in the assemblages of aquatic macroinvertebrates due to the decrease in flow. The LIFE index can be used to provide a baseline for the velocity preferences of a country's most common and abundant genera. These characteristics would allow it to be used to establish an adequate flow reference to protect and maintain ecological integrity in those rivers where the water resource is used. It can also be used to measure the impact of water extraction and to determine the effects of changes in the morphology of a river. Nevertheless, the LIFE index was developed in England, and hydrogeomorphological, climatological, and species composition are different in tropical rivers. Therefore, the objective of this work is to adjust the LIFE index for Costa Rica, associating aquatic macroinvertebrates to a flow category.

## 2. Materials and Methods

### 2.1. Study Site

The Naranjo River basin is located in Costa Rica's Central Pacific slope. This basin has a drainage area of 323.39 km2, which corresponds to 0.63% of the national surface (Bill 20-098, Costa Rica). The anthropogenic intervention in the basin is minimal, the main activity being agriculture (coffee and African palm) and there are no hydroelectric dams or other water extraction activities; therefore, this basin is considered as a reference.

A total of ten sampling events were carried out during one annual cycle in which the four hydrological seasons of the year were evaluated (dry, dry-to-rain transition, rainy, rain-to-dry transition). Two sites were selected, the first-named N1 (9.5120778; -84.0334194) located in the lower basin at 100 m.a.s.l., and a second site, named N2 (9.4629111; -84.0679361), in the middle basin at 620 m.a.s.l. Both sites are surrounded by very humid premontane forest, according to Holdridge's classification (Holdridge, 1964). N1 is characterized by the presence of rapids, riffles and pools. Additionally, boulders and gravel dominate the substrate, and there is contact between the water body and vegetation of the bank, which is composed of dispersed trees and grasses. In the second site, N2, rapids predominate, with substrates dominated by boulders and rocks, and both margins are covered with trees and shrubs.

In order to sample the largest number of microhabitats as determined by water velocity, at each sampling site and event, a total of ten samples were randomly collected. During the dry season and dry-to-rain transition, sampling was carried out in a transverse manner, starting on one margin and ending on the other. During the rainy season and rain to dry transition, due to the increase flow, sampling was started in a transverse manner and the river was entered as far as possible, but was then stopped and another one

**Table 1**
Group of water flow categories to associate aquatic macroinvertebrate taxa. Table modified from Extence et al., 1999.

| Group | Ecological flow association | Mean current velocity |
|---|---|---|
| I | Taxa primarily associated with rapid flows | > 1 m/s |
| II | Taxa primarily associated with moderate to fast flows | 0.2 a 1 m/s |
| III | Taxa primarily associated with slow or sluggish flows | < 0.2 m/s |
| IV | Taxa primarily associated with flowing (usually slow) and standing waters | - |
| V | Taxa primarily associated with standing waters | - |

**Table 2**
Abundance categories of each assessed taxon of aquatic macroinvertebrates obtained from sampling. Table taken from Extence et al., 1999.

| Category | Estimated abundance |
|---|---|
| A | 1-9 |
| B | 10-99 |
| C | 100-999 |
| D | 1000-9999 |
| E | 10000 + |

**Table 3**
Values of different categories of taxon abundances associated with each flow category. Table taken from Extence et al., 1999.

| | Flow groups | Abundance categories | | | |
|---|---|---|---|---|---|
| | | A | B | C | D/E |
| I | Rapid | 9 | 10 | 11 | 12 |
| II | Moderate/fast | 8 | 9 | 10 | 11 |
| III | Slow/sluggish | 7 | 7 | 7 | 7 |
| IV | Flowing/standing | 6 | 5 | 4 | 3 |
| V | Standing | 5 | 4 | 3 | 2 |

was started in a similar manner at another location upstream, until completing the 10 samples.

In each microhabitat a flowmeter (Global Water: BA1100) was submerged, depth and the velocity (at 60% percent of the depth) were determined (Leopold, Wolman, Miller, 1992). Afterwards, a D net (500-micron pore) was introduced, and the substrate was removed for 30 seconds so that the organisms were trapped in the net. The material trapped in the net was then placed in plastic bags and preserved with 85% ethanol for later separation in the laboratory. Aquatic macroinvertebrates were identified to the lowest possible taxonomic level, mostly to genus, by using the following taxonomic keys: Contreras & Harris (1998), Roldán (1998), Manzo & Archangelsky (2008), Flowers & De la Rosa (2010), Ramírez (2010) and Springer (2010). The organisms were deposited in the Aquatic Entomology collection of the Zoology Museum of the University of Costa Rica (MZUCR).

*2.2. Adjusting LIFE Index*

The LIFE index is made up of three sections. The first establishes categories according to the association of macroinvertebrates at each velocity category (Table 1). The second section corresponds to different categories of aquatic macroinvertebrate abundance (Table 2), which is evaluated by taxon recorded. The third section (Table 3) assigns a final value according to the combination of the abundance categories in each flow category, where the organisms that inhabit turbulent zones are given higher scores (Extence et al., 1999).

The first step in adjusting the index was to determine to which category (Table 1) an organism belongs; this association is general and in theory should not vary from one body of water to another. A survey was carried out with an expert panel (Beecham, Hall, Britton, Cottee & Rainer,–2005) consisting of biologists with more than five years of experience working with aquatic macroinvertebrates. In the survey the most common genera and families in the country were included, and the panel was asked to select in which category (turbulent, fast, moderate, slow, stagnant) each taxon is most frequently observed. The expert panel functions as an evaluation tool, while at the same time, it allows assigning a score to those genera that were not reported in the reference river (Rio Naranjo).

Then, with the taxa registered and identified, the TITAN test was used (Threshold Indicator Taxa Analysis; King, & Barker, 2014) to obtain the approximate velocity range that each taxon uses. This test allows us to obtain the distribution of taxa along an environmental gradient over time and space. The gradient is divided into two groups: z- which corresponds to negative classifications and responds negatively to the increase in the variable, and z+ which are positive classifications and respond positively to the increase in the gradient (Baker & King, 2010; King & Barker, 2014; Monk, et. al., 2017; Hanh, et al., 2018).

For each taxon TITAN determines an optimal point of change as the value that maximizes the association of taxa within both groups. When this point passes from low to high values the abundance and frequency of occurrence in group z- will decrease, while group z+ will increase. To determine the accuracy of the change in point value, a 500-repeat bootstrap was implemented. It allows generating two groups (purity and confidence) to evaluate the quality of response of each taxon. Purity is defined as the proportion in response to a direction (increase or decrease) when it passes the point of change that matches the observed response. Pure indicators are assigned in the same response direction. Confidence is estimated by the proportion of change points that consistently result in the significant grouping of a taxon. For this study purity and confidence were considered with ≥90 values. Through software R (R Core Team, 2019) the graphs of the answers of the panel of experts were done with the ggplo2 package (Wickham, 2016) and Threshold Indicator Taxa Analysis with the TITAN2 package (Baker, King & Kahle, 2019).

Thus, with the information provided by the panel of experts and the results of the TITAN test for the genera of the Naranjo River, it is possible to generate the association of each taxon to a velocity category within the LIFE-CR index. It is important to clarify that the work of Extence et al. (1999) contemplates species, genera, and families. However, in the case of Costa Rica only the genus level was used due to the great diversity of species, the

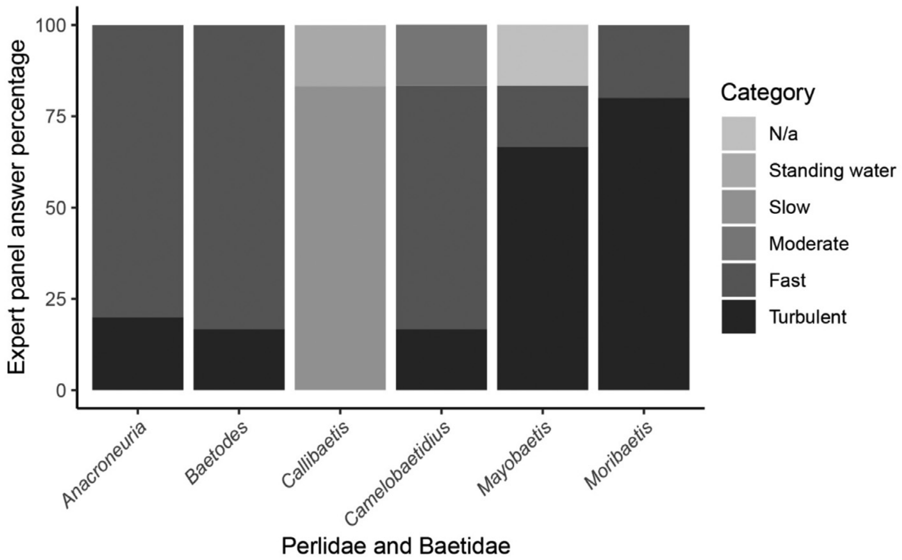


**Figure 1.** Expert panel response to velocity category for genera of the family Baetidae (Ephemeroptera) and *Anacroneuria* of the family Perlidae (Plecoptera). N/A= No Answer.

absence of taxonomic keys to the species level, and lack of larval descriptions (Springer, Echeverría & Gutiérrez, 2014).

## 3. Results

In the case of this study, in section I (Table 1), velocity category VI was eliminated due to the absence of records of organisms capable of surviving drought conditions. Thus, the first section has only five categories of flow conditions (Table 1). Sections II and III remain the same as proposed by Extence et al. (1999).

### *3.1. Expert panel*

In order to classify each genus into a velocity category, the criteria of the panel of experts was used, with a total of six participants, who classified 72 taxa into each of the categories. Here we present only the results for the genera of Baetidae (Ephemeroptera), Perlidae (Plecoptera) and Trichoptera. The rest of the genera and families can be found in the Supplementary Materials section as a summary of the answers.

According to the evaluation obtained by the panel of experts, for the family Baetidae, *Mayobaetis,* and *Moribaetis* were recorded more frequently in turbulent velocities, *Baetodes* and *Camelobaetidius* in fast velocities, and *Callibaetis* in standing water (Figure 1). The genus *Anacroneuria* was recorded by most of the panel of experts in velocities considered as fast and to a lesser extent, in the turbulent category (Figure 1).

In the case of Trichoptera, only the genus *Atopsyche* (Hydrobiosidae) was placed 100% of the time in the category of fast velocity, in which the panel of experts registers it more frequently (Figure 2). The genera *Leptonema, Smicridea* (Hydropsychidae), *Chimarra* (Philopotamidae), *Rhyacopsyche,* and *Anchitrichia* (Hydroptilidae) were classified in fast velocity, in over 50% of the responses. The genus *Phylloicus* (Calamoceratidae) is the only one that was classified in the slow velocity category. The rest of the genera showed discrepancies in the answers by the panel of experts (Figure 2).

### *3.2. Velocity category according to TITAN2*

Through sampling in the Rio Naranjo, a total of 230 microhabitats determined by water velocity were evaluated, and a total of 7742 organisms were identified in 75 genera, 38 families, and 11 orders. The TITAN test showed that the inflection point for the threshold defined by water velocity is 0.1 m/s. This suggests that slow water taxa decrease rapidly in abundance and frequency from 0.1 m/s onwards. However, the moderate and fast velocity taxa have a slight increase and then remain constant in abundance and frequency, then both z+ and z- continue to decrease (Figure 3).

The percentage of pure and reliable taxa was 43% (32 taxa). Of these, 15 taxa are indicators of moderate and rapid water velocities, and 17 of low velocities. Taxa such as *Anacroneuria, Paltostoma, Maruina, Limonia* and *Leucotrichia* had a higher response to the increase in velocity, while *Callibaetis, Epigomphus, Caenis, Limnocoris* and *Phylloicus* responded to velocities less than 0.2 m/s (Figure 4).

With the expert panel and TITAN2 test, 77 genera were classified into one of the five categories of mean current velocity. Some families were classified in a water velocity category on family level, such as Aeshnidae, Gomphidae (Odonata), Polycentropidae (Trichoptera), Gerridae, Veliidae (Hemiptera), etc. because all their genera are found in the same current velocity condition (Table 4).

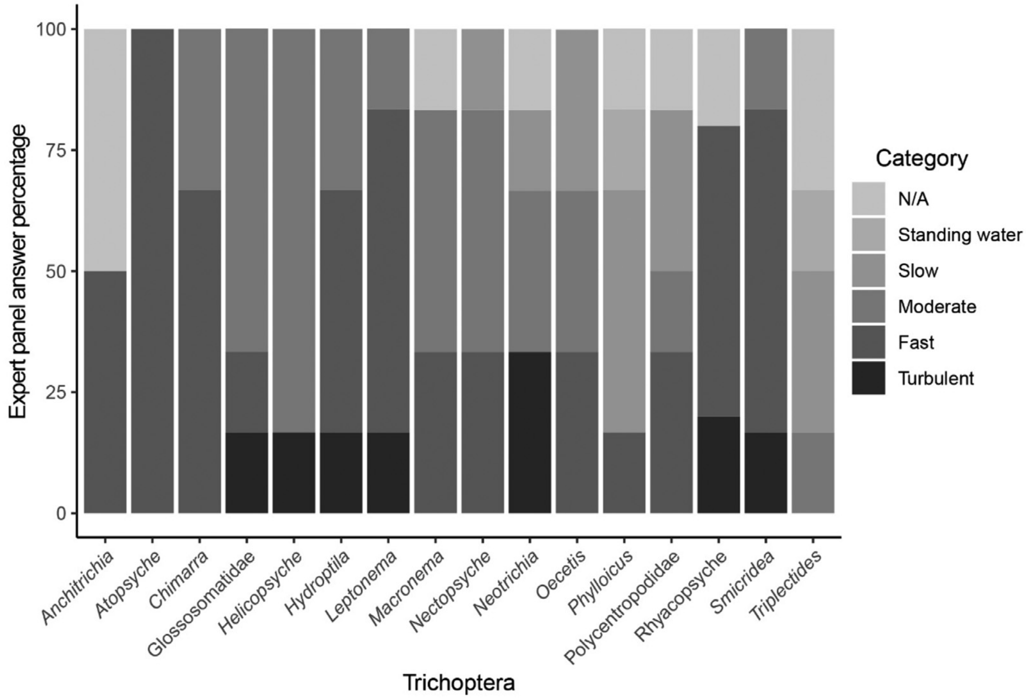


**Figure 2.** Expert panel responses to velocity category for genera of Trichoptera. N/A=No Answer.

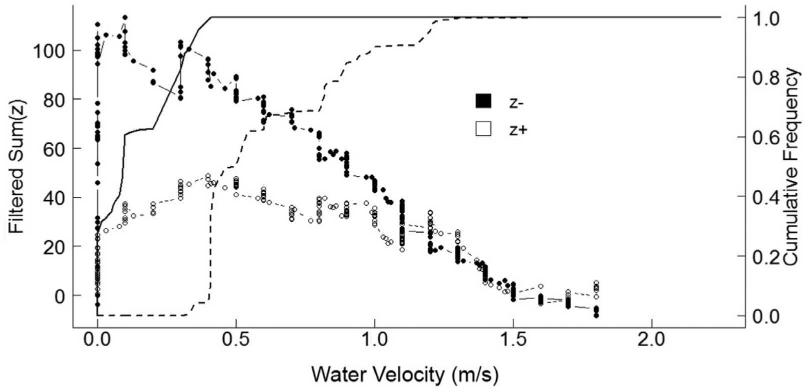


**Figure 3.** Change points (dots) for macroinvertebrate assemblage response to water velocity ($p < 0.05$; purity = 0.90, reliability= 0.90, for five minimum number of observations, 500 permutation replicates and 500 bootstrap). Negative indicator taxa (z-) are indicated by black dots and positive indicator taxa (z+) are indicated by white dots. Solid and dashed lines represent the cumulative frequency distribution of change points among 500 bootstrap replicates for sum(z-) and sum(z+) respectively.

## 4. Discussion

There is worldwide concern about the overexploitation of water resources and watercourse modifications; thus, measures have been generated to protect ecosystems and ensure aquatic biodiversity (Abell et al., 2019). The implementation of methodologies to identify the effects of alterations in water bodies has been useful in watershed management plans (Vörösmarty et al, 2010; Bunn, 2016). The LIFE index, developed by Extence et al. (1999), can be a useful tool to determine environmental flows and effects on the modification of the river channel. In this study we adapted the index for Costa Rica and classified the country's most abundant genera and families into a velocity category.

The panel of experts served as a tool to classify or calibrate the results obtained in the reference river (Beecham et al., 2005), when the velocity range in the TITAN2 test covered several categories, or to assign a value to genera not recorded. Hence, the genera *Moribaetis* and *Mayobaetis* (Ephemeroptera: Baetidae; Fig. 1) were recorded in the Naranjo River, but the TITAN2 test did not consider them because they had a confidence level lower than 90%. However, it was possible to assign them

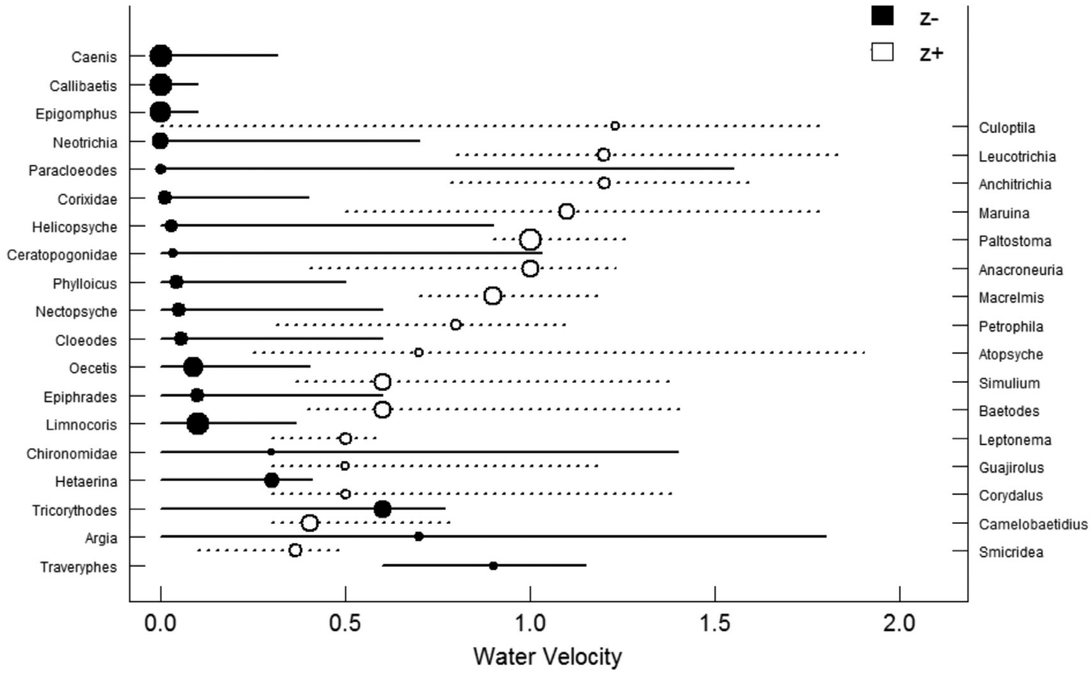


**Figure 4.** Threshold indicator taxa analysis for the water velocity (m/s). In the left column are the organisms that respond negatively to increased water velocity and are represented by black dots (z-). In the right column are the organisms that respond positively to the increased water velocity and are represented with white dots (z+). The horizontal lines represent the 5 and 90 quantiles from the bootstrapped change point distribution.

to the turbulent velocity category through the panel of experts. Nonetheless, for some genera the classification by the panel of experts may be confusing due to variability in responses. For example, in the case of the genus *Nectopsyche* (Trichoptera: Leptoceridae), 45% of responses were obtained in moderate velocity, 45% in slow, and 10% in standing water. This situation makes it difficult to assign it to a category if only this method is applied.

The TITAN test was developed in 2010, and since then few studies have been published determining the threshold of aquatic macroinvertebrates for the variable velocity (Monk, et al., 2017; Hanh et al., 2018). Therefore, this study is the first to identify the response of aquatic macroinvertebrates to this variable for a river in Costa Rica and the Central American Region. It should be noted that in this case, to adjust the index a river with a wide variation in flow, with few anthropological alterations and without hydroelectric dams was selected, in order to evaluate the range of velocities during the dry as well as rainy seasons, and therefore to obtain the greatest diversity of aquatic macroinvertebrates. TITAN2 classified organisms that respond positively (z+) to water velocity increases. However, this does not mean that the progressive increase of the variable also translates into a rise in frequency and abundance of organisms, as there is a velocity threshold, and the test identified that the tipping point for aquatic macroinvertebrates at rapid velocities is 0.5 m/s. Similar to the preference curves obtained by Gore, Layzer, & Mead (2001) for Ephemeroptera, Trichoptera and Plecoptera, which show that there is a range that organisms prefer, and at extreme velocities (>2 m/s) organisms are difficult to register.

For this study, genera belonging to the families Corydalidae, Perlidae, Crambidae, and Hydropsychidae (from the orders Megaloptera, Plecoptera, Lepidoptera and Trichoptera, respectively) responded positively to the increase in water flow, similar to the results of Hanh et al. (2018) in the Guayas River, Ecuador. On the other hand, Gomphidae, Leptohyphidae, and Leptoceridae in the Naranjo River responded negatively (z), similar to the study by Monk et al. (2017), while in Hanh et al.'s study (2018), they were classified as z+. This variation between studies may be due to the type of river where the study was conducted, or to different genera and species within the evaluated family.

TITAN2 also classified organisms that respond negatively (z-) to increases in water velocity, the tipping point being 0.1 m/s. Thus, between 0 and 0.1 m/s is the range where organisms such as *Phylloicus* (Calamoceratidae), *Oecetis, Nectopsyche* (Leptoceridae), *Epigomphus* (Gomphidae), *Hetaerina* (Calopterygidae), among others, are most frequently and abundantly found. The caddisflies classified in the z- construct cases or refuges of small grains of sand or pieces of leaves, and the dragonfly and damselfly larvae have elongated and cylindrical bodies; nether condition is suitable for colonizing high velocities (Gordon, McMahon & Finlayson, 2004). For this reason, these organisms have adapted to the microhabitats of lower velocities.

When expert responses and results obtained from the TITAN2 test make it difficult to assign a velocity category, we recommend the use of literature on body shape

**Table 4**
List of genera and families of aquatic macroinvertebrates of Costa Rica, classified according to the velocity category of the LIFE index.

| | |
|---|---|
| Insecta | |
| **Coleoptera** | |
| Dytiscidae | IV |
| Elmidae | |
| *Heterelmis* | II |
| *Hexanchorus* | II |
| *Macrelmis* | II |
| *Phanocerus* | II |
| *Pharceonus* | II |
| Gyrinidae | IV |
| Hydrophilidae | V |
| Limnichidae | V |
| Noteridae | V |
| Psephenidae | III |
| Ptilodactylidae | |
| *Anchytarsus* | II |
| Scirtidae | V |
| **Diptera** | |
| Blephariceridae | |
| *Paltostoma* | I |
| Ceratopogonidae | IV |
| Culicidae | V |
| Psychodidae | |
| *Maruina* | I |
| Simuliidae | |
| *Simulium* | II |
| Tipulidae | |
| *c.f Hexatoma* | III |
| *c.f Limonia* | I |
| *c.f Molophilus* | IV |
| *c.f Tipula* | IV |
| ***Ephemeroptera*** | |
| Baetidae | |
| *Americabaetis* | III |
| *Baetodes* | II |
| *Callibaetis* | V |
| *Camelobaetidius* | III |
| *Cloeodes* | IV |
| *Guajirolus* | III |
| *Mayobaetis* | I |
| *Moribaetis* | I |
| *Varipes* | III |
| Caenidae | |
| *Caenis* | IV |
| Heptageniidae | |
| *Eoporus* | I |
| Leptohyphidae | |
| *Epiphrades* | III |
| *Leptohyphes* | II |
| *Traverhyphes* | II |
| *Tricorythodes* | IV |
| *Vacupernius* | II |
| Leptophlebiidae | |
| *Farrodes* | II |
| *Hydrosmilodon* | II |
| *Terpides* | IV |
| *Thraulodes* | II |
| *Traverella* | II |
| *Ulmeritoides* | IV |
| Oligoneuriidae | |
| *Lachlania* | II |
| **Hemiptera** | |
| Corixidae | IV |
| Belostomatidae | |
| *Belostoma* | IV |
| *Abedus* | IV |
| *Lethocerus* | V |
| Gerridae | IV |
| Naucoridae | |
| *Ambrysus* | IV |
| *Cryphocricos* | II |
| *Limnocoris* | IV |
| *Pelocoris* | IV |
| Nepidae | |
| *Ranatra* | V |
| Notonectidae | |
| *Buenoa* | IV |
| *Martarega* | IV |
| *Notonecta* | IV |
| Veliidae | IV |
| **Lepidoptera** | |
| Crambidae | |
| *Petrophila* | II |
| **Megaloptera** | |
| Corydalidae | |
| *Corydalus* | II |
| *Chloronia* | III |
| **Odonata** | |
| Aeshnidae | V |
| Calopterygidae | |
| *Hetaerina* | III |
| Coenagrionidae | |
| *Argia* | III |
| Gomphidae | IV |
| Libellulidae | IV |
| Megapodagrionidae | |
| *Heteragrion* | IV |
| Platystictidae | |
| *Palaemnema* | III |
| Polythoridae | |
| *Cora* | II |
| **Plecoptera** | |
| Perlidae | |
| *Anacroneuria* | I |
| **Trichoptera** | |
| Calamoceratidae | |
| *Phylloicus* | III |
| Ecnomidae | |
| *Austrotinodes* | II |
| Glossosomatidae | II |
| Helicopsychidae | |
| *Helicopsyche* | III |
| Hydrobiosidae | |
| *Atopsyche* | II |
| Hydropsychidae | |
| *Leptonema* | II |
| *Smicridea* | II |
| *Macronema* | III |
| Hydroptilidae | |
| *Anchitrichia* | I |
| *Leucotrichia* | I |
| *Rhyacopsyche* | I |
| *Zumatrichia* | I |
| *Oxyethira* | III |
| *Ochrotrichia* | I |
| *Hydroptila* | III |
| *Metrichia* | III |
| Leptoceridae | |
| *Nectopsyche* | III |
| *Oecetis* | III |
| *Triplectides* | IV |
| Philopotamidae | |
| *Chimarra* | II |
| Polycentropodidae | III |
| **Crustacea** | |
| **Decapoda** | |
| Palaemonidae | |
| *Macrobrachium* | II |
| Atyidae | |
| *Atya* | II |

and life strategies that mention the type of habitat that the aquatic macroinvertebrates tend to colonize. Characteristics such as flattened bodies, presence of spiracles, strong claws, suckers, hooks and presence of silk are traits that can be found in organisms that prefer higher velocity zones (Gordon et al., 2004). Meanwhile, features such as stone shelters, oval body, and swimming legs are typical for organisms that prefer low and zero velocities.

With this study, we concluded that the panel of experts and the TITAN test are two tools that allowed us to classify the most common genera of Costa Rica to a velocity category, in order to adjust the LIFE Index. The proposed adjustment of the LIFE Index was tested in the Naranjo River, located on the Pacific slope of Costa Rica. We found a good response on the sensitivity of the index to changes in the flow (Quesada-Alvarado, et. al. paper in progress). The next step is to apply the index to measure the impact on an assembly of aquatic macroinvertebrates in other rivers that have variations in flow due to either natural or anthropic impacts.

## Declaration of Competing Interest

The authors declare no conflict of interest.

## Ethical statement

Authors state that the research was conducted according to ethical standards.

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## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ecohyd.2020.08.005.

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