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D2.5: Meta-community and trait database at the focal DRN scale for CELAC

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Abstract

Temporal flow cessation leads to complex in-stream dynamics which results in a constant rearrangement of resident communities of aquatic taxa. The DRYvER project seeks to implement a comparative meta-community approach across Drying River Networks (DRNs) to understand the role of drying in structuring aquatic community dynamics across different biomes. The purpose of this deliverable is to provide the databases of fish and aquatic macroinvertebrate diversity, and resilience/resistance traits biota exhibit to cope with drying. Databases are from three DRN located in countries that belong to the Community of Latin American and Caribbean States (CELAC) that are part of the DRYvER project. These databases will be used to make comparisons with data from the European Union (EU) DRNs to conduct a global metacommunity analysis.

The databases delivered belong to 1) The Cube River basin, located in the Chocó-Darien bioregion in **Ecuador**, 2) The Chico River basin, located in the Inter-Andean Valley of **Bolivia**, and 3) The Bom Nome River basin of the Caatinga bioregion in **Brazil**. All CELAC DRNs followed the DRYvER Project protocol for biodiversity sampling in 20 sites for the Ecuadorian DRN, 22 sites in Bolivia, and 25 in Brazil. The fish diversity database comprises 24 species found in the Cube DRN, no fish were found in Bolivian and Brazilian DRNs. The macroinvertebrates diversity database presents the total abundance of 94 taxa for Ecuador, 62 in Bolivia, and 70 in Brazil. The traits database for fish includes 10 traits selected on the basis of their potential role in providing resistance and resilience to drying. The macroinvertebrate trait database includes 16 traits and 107 taxa that resulted from the combination of CELAC countries diversity.

Keywords: Neotropics, macroinvertebrates, fish, biodiversity, biological traits, drying river networks.

Information Table

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[1] **Use one of the following codes:**
R=Document, report (excluding the periodic and final reports)
DEM=Demonstrator, pilot, prototype, plan designs
DEC=Websites, patents filing,press & media actions, videos, etc.
OTHER=Software, technical diagram, etc.
ORDP : Open Research Data Pilot

[2] **Use one of the following codes:**
PU=Public, fully open, e.g. web
CO=Confidential, restricted under conditions set out in Model Grant Agreement
CI=Classified, information as referred to in Commission Decision 2001/844/EC.

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Introduction

The Neotropical realm, spanning from México to southern South America and including the West Indies[1], is one of the most species-rich regions on Earth. Around 42.15% (4.761 species) of freshwater fish worldwide inhabit this region, harbouring the highest diversity of this group around the globe[4]. This is also true for aquatic megafauna and macrophytes[8,9] and several groups of freshwater macroinvertebrates[10]. Within Neotropical ecosystems Drying River Networks (DRNs) have been identified in the upper drainages of piedmont Bolivia rivers[12], the disconnected pools of xeric shrublands in “Caatinga” of North-eastern Brazil, and the Tropical forests of the Pacific lowlands within the Chocó Bioregion, Ecuador.

In order to contribute to the understanding of how aquatic communities respond to drying in Neotropical streams, the DRYvER project implemented a comparative metacommunity approach at the DRN scale, including three networks in the CELAC region. The objectives of this deliverable are to compile and present the CELAC DRNs databases for fish and macroinvertebrates’ diversity and to provide their corresponding resilience/resistance traits to drying.

CELAC Drying River Networks

Sampling sites across the three basins were located at different sites along an elevational gradient. The greater elevational range was for the Chico River (Bolivia) with a gradient of 3373 m starting at 2782 m a.s.l. Ecuador’s gradient is 479 m starting at 52 m a.s.l., and Brazil presents a gradient of 188 m starting at 433 m a.s.l. The length of sampling reaches varied according to main stem order: in Bolivia length varied between 25 and 110 m, while in Ecuador and Brazil varied between 50 and 150 m (Supplementary Material, Table S1)

DRNs in the Neotropics show intricated hydrological patterns across latitudes and drying effects seem stronger as DRNs get far from the Equator. General patterns observed throughout the sampling period of the DRYvER project, involved the variability of the transition months, the presence of prolonged droughts (i.e., Brazil: Bom Nome River), and the dominance of drying in the headwaters (i.e., Ecuador: Cube River and Bolivia: Chico River).

The sampling period was designed to capture the annual drying patterns and ranged from January 2021 to April 2022 for Brazil, from February to December 2021 for Ecuador, and from March to December 2021 for Bolivia. Drying patterns in the Neotropics can vary under marked seasonality from very low water levels with continuous flow in streams to disconnected pools (Figure 1).

Selected sampling sites varied across DRNs depending on accessibility and representation of drying conditions. The total sampling sites for Ecuador are 20, for Bolivia 22, and for Brazil 25. Throughout the sampling period, two sampling campaigns were carried out for fish and six campaigns for macroinvertebrates (Figure 2) according to the DRYvER protocol[18] (Working Package 2 [WP2]).

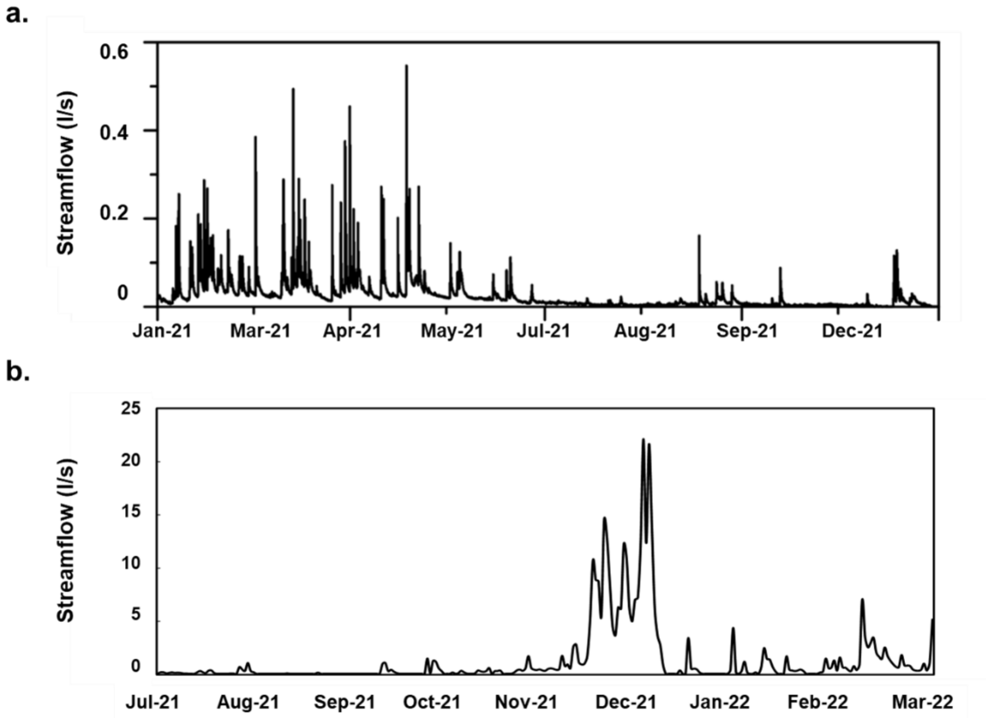

Figure 1. Daily streamflow (m³/s) from a) Site 7 in the Cube River (Ecuador) and b) Site 19 in the Chico River (Bolivia) between 2021 and 2022.

Figure 2. Examples of sampling conditions in CELAC Drying River Networks (Ecuador: Cube River), fish sampling (top panels) in the wet (a) and dry (b) seasons; sediment and microbial sampling (bottom panels) in the wet (c) and dry (d) seasons.

In Ecuador and Bolivia, the WP2 sampling was concluded in 2021. In Brazil, due to abnormal dry conditions, sampling was finished in early 2022 (April). For each sampling site, besides sampling fish and macroinvertebrates, we also collected local environmental information (i.e., state of flow, discharge, wetted width, riparian cover, embeddedness, dissolved oxygen, water temperature, algal cover, among others).

2.1 Ecuador DRN: Cube River

The Cube River basin (169 km^2 drainage area) is a seasonally intermittent system in the Chocó-Darien bioregion of Ecuador, a biodiversity hotspot, and a priority for conservation. The Cube River flows from South to North and is a tributary of the Esmeraldas River Basin in Northwestern Ecuador. The Cube River limits with the Viche River at the Northwest, with the Mache-Chindul ridge at the East, and the Bilsa Biological Reserve at the South (Figure 3). Approximately half of the headwaters of the Cube River basin overlap with the Mache-Chindul Ecological Reserve (REMACH), Fundación para la Conservación los Andes Tropicales Reserve (FCAT), and Bilsa Biological Reserve. Despite of the evidently land-cover under management, the Cube River basin, as most of the Pacific Lowlands of Ecuador, is heavily transformed by agriculture and cattle ranching practices.

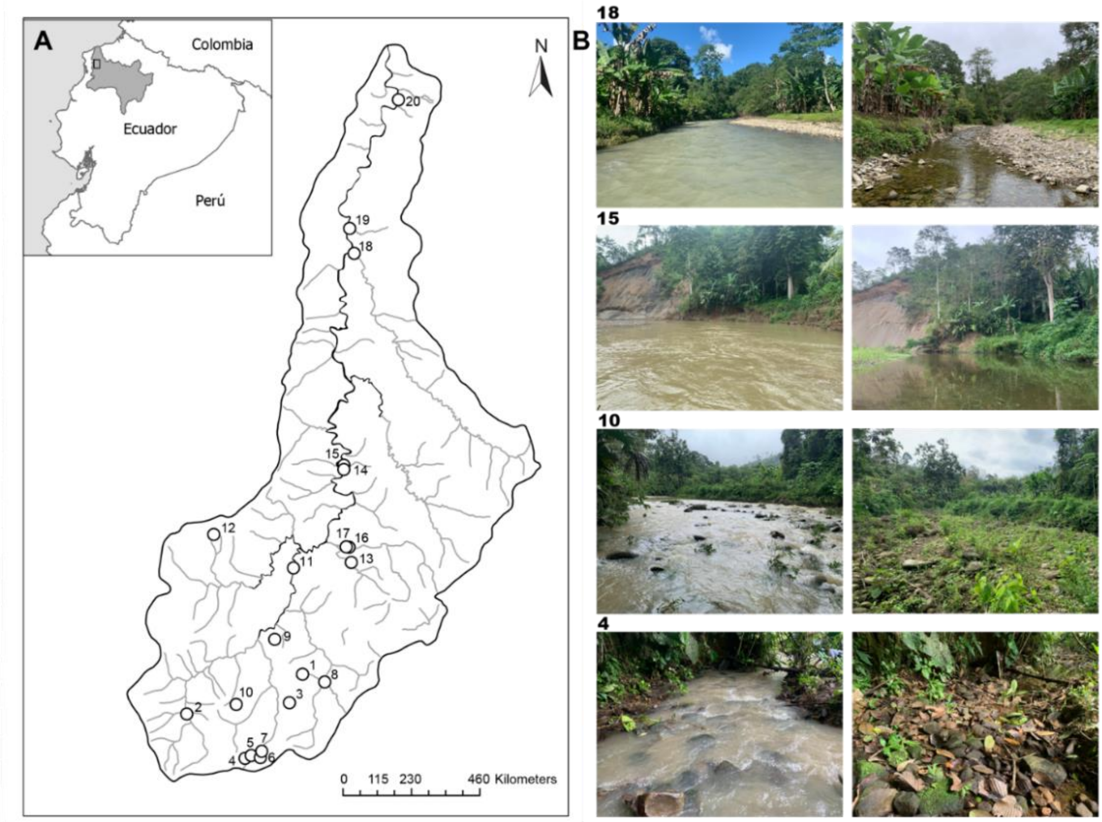

Figure 3. A) Map of the Cube River basin showing sampling sites (n=20) in this study. Gray lines denote streams and headwaters, while black lines denote the Cube River main channel. B) River and stream pictures depicting four of the 20 sampling sites shown in A) during the wet (left) and the dry (right) seasons.

2.2 Bolivia DRN: Chico River

The upper Chico River basin (~92 km^2 drainage area) (Figure 4), is a seasonally intermittent system in the ecoregion of Inter-Andean Valleys of Bolivia. This upper basin connects downstream to the main course of the Chico River, which is one of the tributaries of the Grande River, one of the longest rivers in Bolivia and part of the Amazon Basin. The headwaters of the Chico River are an important source of drinking water supply for the city of Sucre where some areas of the city tend to have water shortages during the dry season. The waters of this river are also used for agriculture and recreation in the middle and lower parts of the basin.

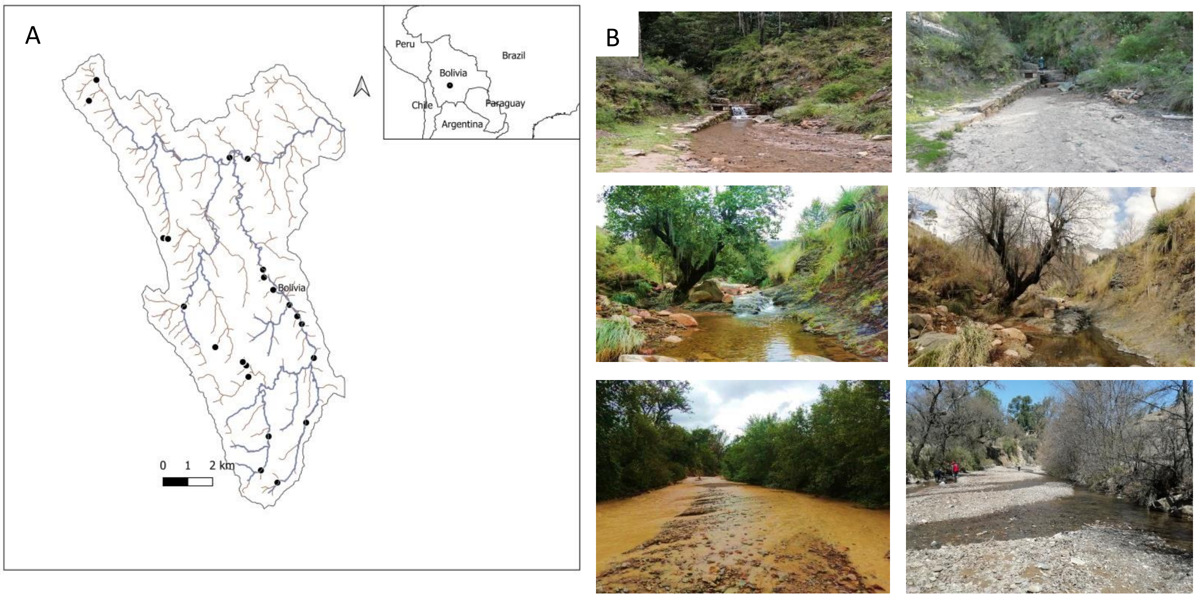

Figure 4. A) Upper Chico River basin, showing sampling sites in black points (22). B) River and stream pictures of three sampling sites during wet (left) and dry (right) seasons.

2.3 Brazil DRN: Bon Nome River

Bom Nome River basin (254 km² drainage area) is a naturally intermittent system in Northeast Brazil, being the main tributary of this system. The basin region is part of the “Drought Polygon” characterized by a semiarid climate with high spatial, seasonal and interannual variability of recurrent rains and droughts. The Phytogeographic Domain of the region is called Caatinga (which means “White Forest”), it is mosaic of Dry Forest (Sub-humid climate), Very Dry Forest (Semiarid climate) and Woodland (Arid climate) covered by a dense tropical xerophytic deciduous broadleaf vegetation physio-graphically heterogeneous. Caatinga is one of the three arid/semiarid Phytogeographic Domain in South America. The Umbuzeiro River cross the Ecological Station of Aiuaba (ESEC/Aiuaba) which is under the administration of IBAMA (Brazilian Institute of the Environment and Natural Resources). These conservation areas have as a priority function the protection of biodiversity in the Caatinga biome, and they are affected by the modification of the landscape within their bordering areas, due to the practices of extensive subsistence agriculture and livestock.

Metacommunity database

The metacommunity database for CELAC countries included the Biodiversity and the Biological traits database. These databases have been built separately for fish and macroinvertebrates.

3.1 Biodiversity database

The biodiversity database for CELAC countries is comprised of one database for fish and one for macroinvertebrates. The database was built considering names and labels of each locality and dates according to the DRYvER protocol: DRN-Site-Sampling Occasion. The process of compilation included standardization of taxa to the same taxonomic level: family for macroinvertebrates and species for fish.

The Fish Diversity Database is designed to present the results of site and sampling occasion on the right column (M2=wet and M5=dry), the name of the species on the top row of the sheet and the correspondence abundance on each cell. The Macroinvertebrate Diversity Database is comprised of three sheets, one for each CELAC country, on the right columns is listed the DRN-Site-Sampling Occasion and on the top two rows are organized macroinvertebrates class and orders and on the next row are either the taxa as order or class and the family names for most insects. The reported results are the total abundance with no standardization.

Fish diversity

The fish diversity database is reported only for the Cube River Basin in the Ecuadorian DRN, only the genera *Trichomycterus* was found in the Bolivian DRN and no fish was reported in the Brazilian DRN. In the Ecuadorian DRN with a total of 24 species found throughout the Cube River Basin on the wet and dry seasons (Figure 5). A total of 1045 fish were sampled in the wet season and 3061 fish were collected in the dry season, which were distributed in 20 and 23 species, respectively.

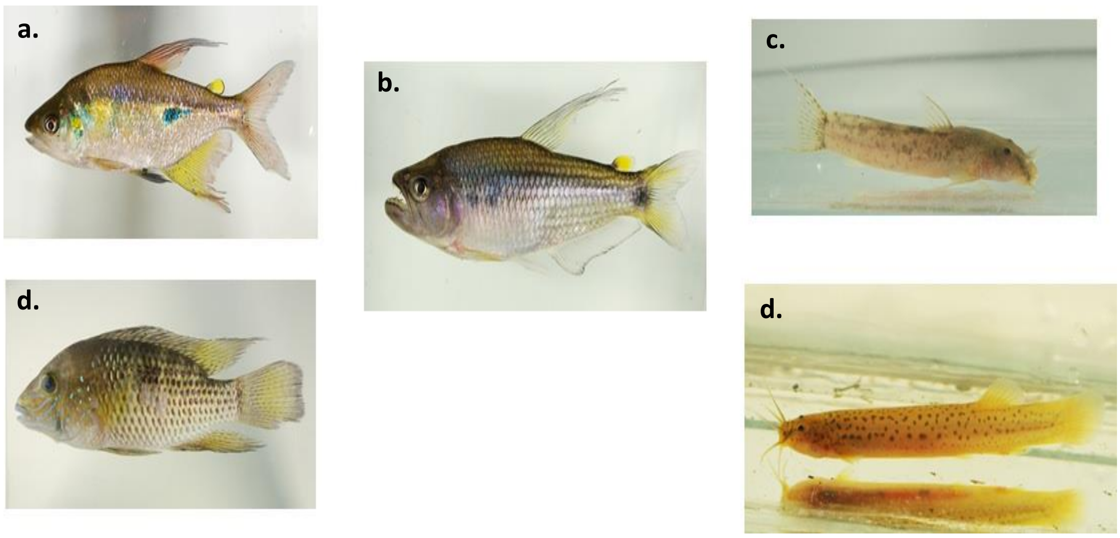

Figure 5. Fish species found in the Ecuadorian DRN (Cube Basin): *Rhoadsia minor* (a), *Pseudochalceus lineatus* (b), *Andinoacara blombergi* (c), *Astroblepus spp* (d), *Trichomycterus spilossoma* (e). Photo credits: Daniel Escobar-Camacho

Overall, 24 species were recorded in the Cube DRN (Table 1), which is 19% of the 124 species that have been reported for the Ecuadorian Western slopes and 43% are endemic to Ecuador. In the wet season, the three most abundant taxa were poecilids and characids: *Pseudopoecilia fria* (27%), *Bryconamericus ecuadoriensis* (27%), and *Rhoadsia altipinna* (14.3%). The same three species were the most abundant in the dry season with a relative abundance of 41.6%, 9.7% and 11.4%, respectively (Figure 6).

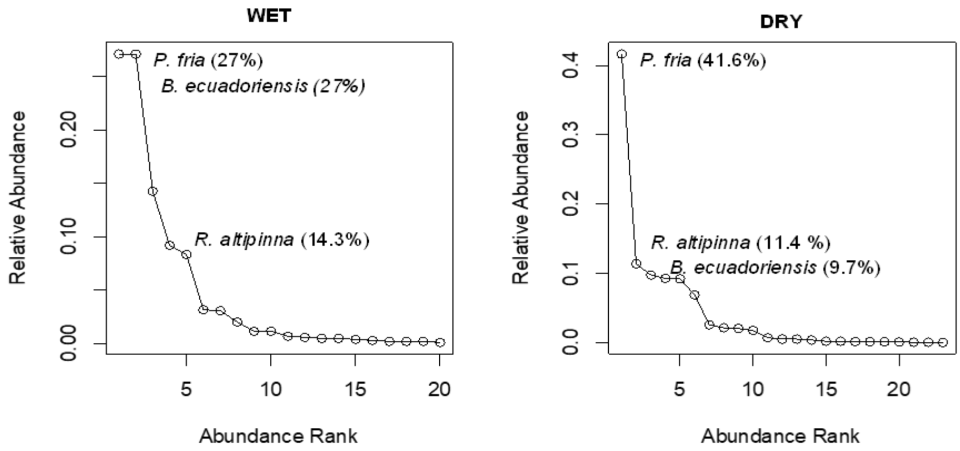

Figure 6. Fish rank-abundance plots of sampling campaigns in the wet and dry seasons in the Cube River (Ecuador).

Ten species had low abundance (<1%) in the wet season, and thirteen had low abundance in the dry season. Three introduced species were detected in this study: *Poecilia reticulata* (Guppy), *Xiphophorus maculatus* (Platy), and *Oreochromis* sp. (Tilapia).

Table 1. List of fish species found in the Cube Drying River Network in Ecuador.

Order	Family	Species
Characiformes	Characidae	*Bryconamericus ecuadoriensis*
Cichliformes	Cichlidae	*Mesoheros festae*
Characiformes	Characidae	*Bryconamericus brevirostris*
Characiformes	Bryconidaee	*Brycon atrocaudatus*
Cichliformes	Cichlidae	*Andinoacara rivulatus*
Characiformes	Characidae	*Rhoadsia altipinna*
Siluriformes	Heptateridae	*Rhamdia quelen*
Gobiiformes	Gobiidae	*Awaous transandeanus*
Siluriformes	Heptateridae	*Pimelodella grisea*
Characiformes	Lebiasinidae	*Lebiasina bimaculata*
Gobiiformes	Gobiidae	*Sicydium sp1*
Gobiiformes	Eleotridae	*Gobiomorus maculatus*
Characiformes	Erythrinidae	*Hoplias microlepis*
Mugiliformes	Mugilidae	*Agonostomus monticola*
Siluriformes	Loricariidae	*Chaetostoma aequinoctiale*
Cichliformes	Cichlidae	*Oreochromis niloticus*
Cyprinodontiformes	Poecilidae	*Pseudopoecilia fria*
Characiformes	Characidae	*Pseudochalceus lineatus*
Cyprinodontiformes	Poecilidae	*Xiphophorus maculatus*
Characiformes	Curimatidae	*Pseudocurimata boehlkei*
Siluriformes	Trichomycteridae	*Trichomycterus* sp1
Siluriformes	Astroblepidae	*Astroblepus* sp1
Cyprinodontiformes	Poecilidae	*Poecilia reticulata*
Synbrachiiformes	Synbranchiidae	*Synbranchus marmoratus*

Macroinvertebrate diversity

During the sampling period, macroinvertebrate sorting was performed between sampling campaigns. The first semester of 2022 has been dedicated to sorting and identification of taxa in Ecuador and Bolivia, in Brazil it was delayed because sampling finished later.

The identification of macroinvertebrates was only possible to family level for the three DRNs. Macroinvertebrates in Ecuador and Bolivia were significantly abundant, which required more time to sort and classify to family level. Identification to the genera level was extremely limited because the knowledge of taxonomy is not complete for all groups in the Neotropics (Table 2). The abundance reported in Table 2 corresponds to the data not uniformized by area or number of samples according to reach dimensions.

Table 2. Summary of CELAC DRNs macroinvertebrates richness and abundance during the whole sampling period. Taxa richness represents family richness for all insects and order and class for other macroinvertebrates, according to available literature.

Drying River Network	Taxa Richness	Total Abundance
Ecuador: Cube River	94	50795
Bolivia: Chico River	62	70533
Brazil: Bon Nome River	70	9106

The highest richness was recorded in the Ecuadorian DRN, followed by Brazil and Bolivia. Abundance was higher in the Bolivian DRN than in Ecuador and Brazil, this latter is almost 7-fold less than the abundance of Bolivia.

In the Ecuadorian DRN, three orders of aquatic insects comprise 80% of the macroinvertebrate's abundance: Ephemeroptera (42%), Diptera (23%), and Trichoptera (16%). Coleoptera was also important with almost 10% of the community, while Odonata and Hemiptera abundances were similar with only 1.5% of the total abundance; macroinvertebrates not identified were included in the category Others and represents 2.8% (Figure 7).

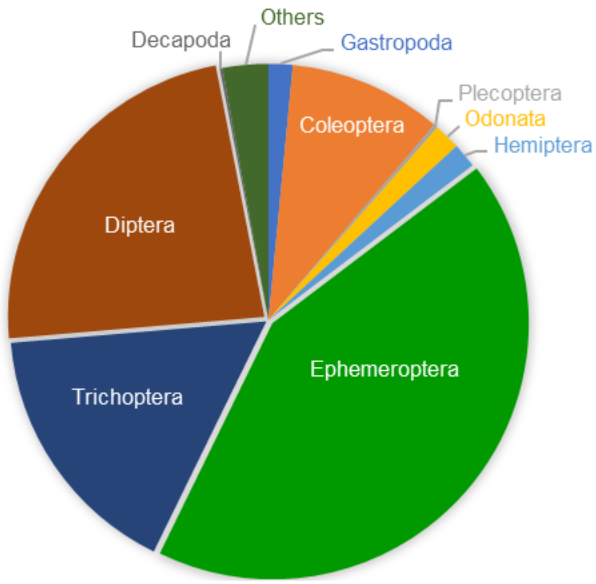

Figure 7. Proportion of macroinvertebrates orders in relation to total abundance for the Ecuadorian DRN (Cube River) during 2021 -2022.

However, few orders include taxa that have yet to be revised and are assigned as “Unknown” at the family level within the order. Pupae and adults from Diptera have been included when identification was possible and are reported within the family. For Coleoptera, larvae and adults have been identified to the family level and are presented separately (Table 3).

Table 3. Macroinvertebrates abundance from the Ecuadorian DRN collected between 2021 and 2022: family/taxa grouped by orders or class.

Ecuador					
Family/Taxa	**Abundance**	**Odonata**		**Trichoptera**	
Planariidae	155	Aeshnidae	11	Philopotamidae	1159
Chromadorea (Nematoda)	3	Gomphidae	85	Xiphocentronidae	31
Gordioidea	9	Libellulidae	329	Polycentropididae	672
Sphaeriidae	89	Calopterygidae	44	Hydropsychidae	3300
Unknown (Bivalvia)	35	Polythoridae	2	Hydrobiosidae	41
Hirudinea	12	Megapodagrionidae	48	Glossosomatidae	16
Oligochaeta	22	Coenagrionidae	298	Hydroptilidae	2168
Hydrachnidia	244	Platysticidae	26	Odontoceridae	154
Ostracoda	41	Protoneuridae	1	Calamoceratidae	257
Hyalellidae	52	Lestidae	2	Leptoceridae	391
Blattodea: Blaberidae	1	Perilestidae	1	Helicopsychidae	149
Megaloptera: Corydalidae	333	Unknown	1	Unknown	5
Lepidoptera: Crambidae	466	**Hemiptera**		**Diptera**	
Gastropods		Pleidae	2	Tipulidae	16
Ampullariidae	36	Gerridae	39	Limoniidae	38
Ancylidae	45	Veliidae	367	Psychodidae	54
Lymnaeidae	71	Mesoveliidae	40	Chironomidae	8078
Planorbidae	28	Hydrometridae	1	Ceratopogonidae	363
Thiaridae	570	Notonectidae	2	Simuliidae	2558
Cochliopidae	5	Naucoridae	312	Dixidae	9
Unknown	17	Belostomatidae	4	Culicidae	6
Coleoptera		Nepidae	5	Athericidae	2
Gyrinidae adult	4	Hebridae	16	Tabanidae	4
Noteridae	17	Aradidae	1	Dolichopodidae	21
Dytiscidae adult	47	Ochteridae	2	Empididae	74
Scirtidae adult	31	**Ephemeroptera**		Syrphidae	1
Ptilodactylidae larvae	125	Baetidae	6913	Muscidae	16
Psephenidae larvae	219	Leptophlebiidae	4257	Stratiomyidae	5
Elmidae adult	4277	Euthyplociidae	65	Unknown	587
Lampyridae adult	3	Ephemeridae	2	**Decapoda**	
Hydrophilidae adult	121	Caenidae	189	Atyidae	8
Staphylinidae adult	53	Leptohyphidae	10194	Palaemonidae	10
Unknown adult	20	Unknown	1	Trichodactylidae	1
Plecoptera				Pseudothelphusidae	65
Perlidae	125				

In the Ecuadorian DRN, Diptera were the most diverse order at the family level (16), followed by Ephemeroptera and Trichoptera with 12 families each, and Odonata with 11; Coleoptera and Gastropod were represented by 7 families each, and Decapoda by 4.

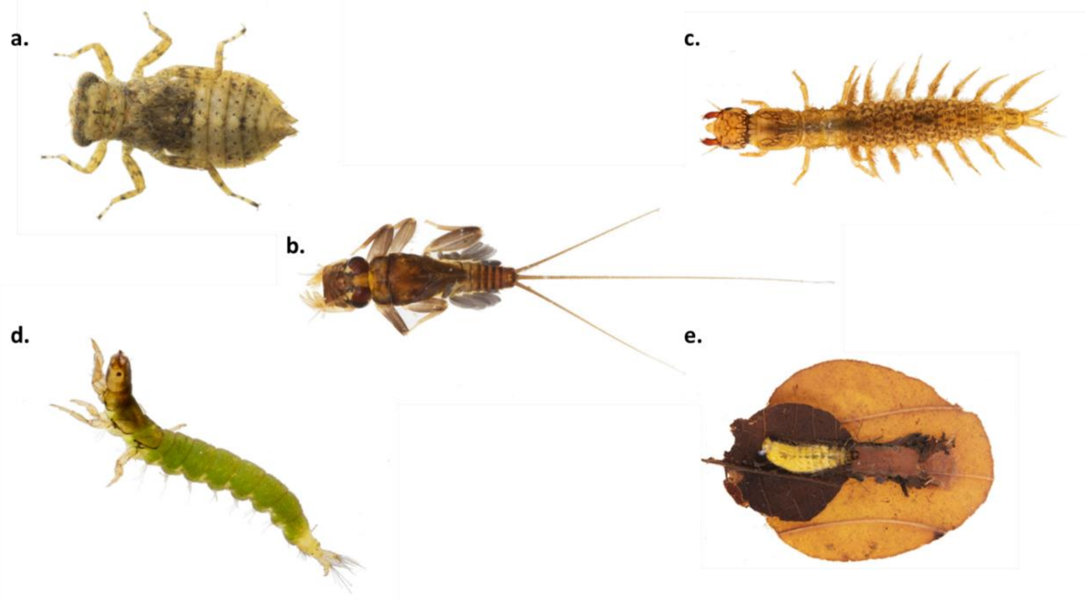

Figure 8. Some macroinvertebrate families from the Ecuadorian DRN (Cube Basin), Odonata: Libellulidae (a), Ephemeroptera: Leptophlebiidae (b), Megaloptera: Corydalidae (c), Trichoptera: Hydropsychidae (d), and Trichoptera: Calamoceratidae (d). Photo credit: Karla Barragán

The Bolivian DRN, had a similar abundance distribution pattern, with 80% of the abundance composed by three insects' orders: Diptera (50%), Ephemeroptera (22%), and Coleoptera (12%), this latter replaced the Trichoptera group found in Ecuador (Figure 9).

Macroinvertebrate richness in Bolivia comprised 62 taxa that included the taxonomic levels of family for most insects and orders/class of other macroinvertebrates (Table 4). In the Bolivian DRN, Diptera had the higher diversity with 15 families, followed by Coleoptera (10) and Trichoptera (8), Ephemeroptera and Odonata were orders with only three families, and Plecoptera and Lepidoptera with two. Coleoptera diversity have been grouped in families that include adults and larvae, however, they are reported separately for all sites in Bolivia in the WP2-CELAC-Macroinvertebrate-Diversity-Database.

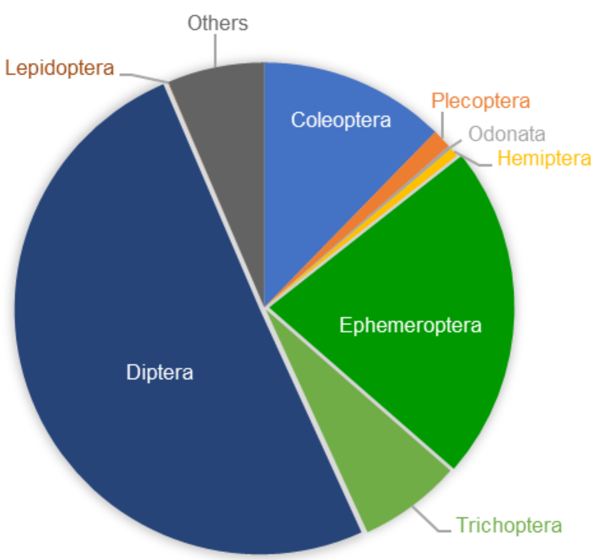

Figure 9. Proportion of macroinvertebrate orders in relation to total abundance for the Bolivian DRN (Chico River) during 2021-2022.

Table 4. Macroinvertebrates from the Bolivian DRN collected between 2021 and 2022: family/taxa and abundance grouped by orders or class.

Bolivia

Family/Taxa	Abundance
Oligochaeta	1440
Tricladida	457
Planorbiidae	11
Hyalellidae	385
Hydrachnidia	2079
Collembola	63
Copepoda	76
Neuroptera: Osmyidae	2
Megaloptera: Corydalidae	1
Coleoptera	
Dytiscidae larvae	576
Dytiscidae adult	451
Elmidae larvae	5319
Elmidae adult	487
Curculionidae	5
Gyrinidae adult	6
Hydrophilidae larvae	52
Hydrophilidae adult	57
Hydraenidae	3
Lutrochidae adult	1
Scirtidae larvae	1179
Staphylinidae adult	333
Staphylinidae larvae	192
Ptiliidae adult	4

Odonata	
Aeshnidae	145
Megapodagrionidae	4
Libellulidae	11
Hemiptera	
Corixidae	24
Gerridae	236
Hebridae	3
Naucoridae	18
Veliidae	134
Ephemeroptera	
Baetidae	10425
Leptohyphidae	83
Leptophlebiidae	5056
Trichoptera	
Calamoceratidae	1020
Helicopsychidae	508
Hydrobiosidae	92
Hidropsychidae	5
Hydroptilidae	2974
Leptoceridae	18
Philopotamidae	34
Polycentropodidae	118

Diptera	
Athericidae	131
Ceratopogonidae	1779
Chironomidae	29192
Culicidae	92
Dolichopodidae	88
Muscidae	527
Empididae	93
Ephydridae	39
Psychodidae	64
Simuliidae	645
Stratiomyidae	26
Syrphidae	4
Tabanidae	10
Tipulidae	2839
Limoniidae	3
Plecoptera	
Perlidae	157
Gripopterygidae	735
Lepidoptera	
Pyralidae	21
Noctuidae	1

In the Brazilian DRN, Ostracoda and Copepoda had a higher contribution to the total abundance than insects. However, Diptera (20%) and Ephemeroptera (11%) (Figure 10) were also dominant insect orders in Brazil like in Ecuador and Bolivia.

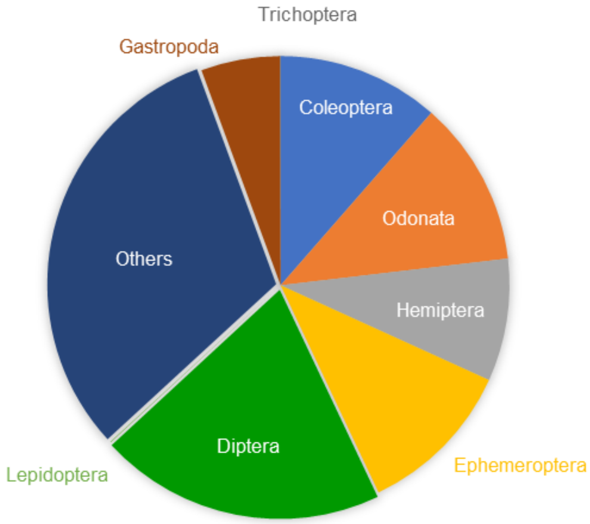

Figure 10. Proportion of macroinvertebrates orders in relation to total abundance for the Brazilian DRN (Bon Nome River) during 2021 -2022.

The Brazilian DRN presents an important diversity of macroinvertebrate families of Coleoptera and Hemiptera (12) including adults and larvae. As the most abundant order, Diptera had only 9 families that includes larvae, adults, and pupae (Table 5). No Plecoptera was found, and only one family of Trichoptera and 4 families of Ephemeroptera were collected. Although Ephemeroptera had limited diversity compared to Coleoptera and Hemiptera, their abundance is like the two others.

Taxonomic identification to the genus and even to family level across CELAC DRNs is always challenging. A comprehensive catalogue of CELAC diversity is yet to be described and this poses difficulties to process samples in a timely manner. Some groups require taxonomic and probably genetic efforts to reach to a full description to genera and/or species. Most macroinvertebrate groups required specialists' revisions to confirm morphology, the sampling of the adult stages (for insect orders), and even more extensive and intensive sampling. However, the information reported here is unique and aims at contributing the biodiversity knowledge of CELAC freshwater biodiversity in DRNs.

Table 5. Macroinvertebrate from the Brazilian DRN collected between 2021 and 2022: family/taxa and abundance grouped by orders or class.

Brazil					
Family/Taxa	**Abundance**	**Coleoptera**		**Diptera**	
Oligochaeta	165	Hydrophilidae adult	189	Chironomidae adult	2
Hyalellidae	1	Noteridae adult	54	Chironamidae	1004
Hydrachnidia	18	Hydrochidae adult	34	Chironomidae pupae	12
Collembola: Entomobryidae	1	Dryopidae adult	92	Dolichopodidae	2
Copepoda: Mesocyclops	3	Dytiscidae adult	143	Culicidae	640
Decapoda: Atyidae	98	Curculionidae adult	4	Culicidae pupae	85
Anostraca	671	Elmidae adult	5	Ceratopogonidae	53
Ostracoda	1703	Hydraenidae adult	1	Chaoboridae	5
Bivalvia unknown	3	Haliplidae adult	45	Syrphidae	11
Bivalvia: Sphaeridae	6	Hydrophilidae larvae	167	Stratiomyidae	14
Hirudiena	172	Dryopidae larvae	2	Tabanidae	5
Hemiptera		Dytiscidae larvae	296	Tipulidae	4
Belostomatidae	59	Noteridae larvae	1	**Lepidoptera**	
Corixidae	308	Lampyridae	1	Pyralidae pupae	1
Notonectidae	303	Scirtidae	2	Pyralidae larvae	1
Naucoridae	13	Coleoptera unknown	6	Crambidae	2
Nepidae	2	**Odonata**		**Ephemeroptera**	
Mesovellidae	23	Aeshnidae	178	Baetidae	821
Gerridae	6	Coenagrionidae	66	Ephemeridae	188
Pleidae	54	Gomphidae	20	Leptophlebiidae	8
Hebridae	2	Lestidae	141	Ameletidae	1
Veliidae	12	Libellulidae	596	**Gastropoda**	
Cicadidae	2	Libellulidae larva	57	Thiaridae	55
Gestacoridae	3	Protoneuridae	7	Physidae	45
		Trichoptera		Planorbidae	397
		Leptoceridae	4	Ampularidae	11

The WP2-CELAC-Macroinvertebrate-Diversity-Database comprises a total of 124 taxa and 130434 individuals collected in drying river networks during 2021 and 2022. The WP2-CELAC-Fish-Diversity-Database presents 24 taxa and 4107 individuals collected in the Ecuadorian DRN in 2021.

3.2 Biological traits database

The functional traits database was created using the CELAC fish and macroinvertebrate taxa. Information from the existing trait literature was retrieved for CELAC taxa in collaboration with EU partners who are compiling the same information for EU DRNs. Trait selection was performed considering the potential role in providing resilience and resistance to drying. Examples include physiological adaptations, the ability for individuals to move between localities or temporal resistance forms.

Fish traits to cope with drying

Functional traits were chosen and specified by Task ST2.2.1 [WP2] considering how informative they can be to describe the resistance and resilience capacity of species to drying in the Neotropics. The Fish Traits Database used different elements to evaluate the resilience and resistance (Table 6):

- **Fuzzy codes** that ranged from 0 to 3, being 0 the score less- or non-related to the trait while 3 being the score most related to the trait. All the scores placed for fuzzy codes were based on local observations in the field, during sampling and corroborating with local stakeholders as well as fishermen participating during sampling. These scores were also based on discussions with other colleagues on the matter.
- **Quantitative values** for Longevity (lifespan in years) and Reproductive Capacity (absolute fecundity) were added based on data from congeneric species and databases from the fishbase.org using the “life history tool” algorithm. Information for most species was not available because Ecuadorian species are understudied. Two values were assigned to *Longevity*, one based on literature, and one based on fishbase.org.

Despite thorough revision, data for Neotropical fish are scarce and therefore some values are still missing. The *Reproductive capacity* trait required revision and analysis of absolute fecundity values (total number of oocytes per breeding season). This information was also missing for several species. Greater reproductive capacity would enable species to have bigger populations, that when affected by drying, will have greater numbers of survivors to recolonize ecosystems. For longevity, species with greater lifespans could perform several migrations, enabling to colonize previously desiccated habitats.

The main challenge for Ecuador specifically was that very little is known regarding freshwater fish from the Western slope. More specifically endemism and small distributions limits the ecological and behavioural information.

Table 6. Traits related to drying and applied to fish collected in the Ecuadorian Drying River Network during 2021 (source: fishbase; local observations)

Trait	Rationale	Coding
Physicochemical tolerance	Ability to withstand high temperatures, low dissolved oxygen, high conductivity	Fuzzy coding
Biological tolerance	Avoiding predation, parasites or disease in crowded conditions product of drying	Fuzzy coding
Competitive ability	Outcompeting other species for food, habitat and other resources in crowded conditions product of drying	Fuzzy coding
Hydrological tolerance	Ability to occupy, spawn and recruit over a wide range of hydrological regimes	Fuzzy coding
Longevity	Increased lifelong fecundity improving survival of some individuals after desiccation	Quantitative
Dispersal ability	Ability to colonize rewetted riverbanks after desiccation	Fuzzy coding
Distribution	Higher chance of survival in a refuge such as isolated pool	Fuzzy coding
Reproductive capacity	Faster colonization after rewetting	Quantitative
Ability to burrow / survive in sediment	Moist sediment can provide refuge	Presence/absence
Resting eggs	Desiccation resistant eggs	Presence/absence
Diapause	Egg, larvae and adult diapause during drought periods	Presence/absence

Macroinvertebrate traits to cope with drying

The Macroinvertebrates Traits Database was built using traits for resilience and resistance to drying after reviewing the existing literature for the Neotropics. A total of 17 publications were used to identify traits and trait information for macroinvertebrates (see References 19-36). We included literature from North America because of more complete trait databases. For the Neotropics, previous studies done in Bolivia and Ecuador[32] provided most of the criteria used to qualify traits according to resilience and resisting to drying.

Resilience to drying*:* among the selected traits for resilience to drying, we selected characteristics like the crawling ability, borrowing, and propensity to drift because the plasticity of these traits is completely related to the extent of the hyporheic zone that might vary according to the duration of drying and previous wetted conditions (Table 7). The trait database from DISPERSE[19] provided most of the valuable information to assess traits based on dispersal characteristics.

Resistance to drying: from the traits proposed for resistance to drying, we selected among others, the physicochemical tolerance to drying conditions using the rationale of resistance to pH and conductivity, a condition characteristic of low flows. Thermal preference and the capacity to survive under hypoxic conditions have been the least addressed traits in Neotropical macroinvertebrates studies (Table 7).

The WP2-CELAC-Macroinvertebrates-Traits-Database has been built using the diversity of CELAC countries at the family and order level. The total CELAC diversity resulted in 107 taxa. Traits have been evaluated for order or class for some macroinvertebrates, but for insects have been evaluated at the taxonomic level of family. In the database taxa are listed in the right columns and the 16 traits are described in the top rows. Fuzzy codes and quantitative data are already filled for the 107 taxa considering resistance to desiccation traits, while traits for resilience such as dispersion are yet to be completed (Table 7).

Table 7. Traits applied to macroinvertebrates from CELAC DRNs, the rationale explains the resilience and resistance to drying conditions (source: DRYvER: A report on the existing European meta-community and trait database, 2022).

Trait	Rationale	Coding	Reference
Resilience to drying			
Number of reproductive cycles per year	Synchronization of emergence and desiccation survival	Fuzzy coding	Firmiano, K. R., Castro, D. M., Linares, M. S., & Callisto, M. (2021). Functional responses of aquatic invertebrates to anthropogenic stressors in riparian zones of Neotropical savanna streams. Science of the Total Environment, 753, 141865.
Propensity to drift	Tendency to be drawn in current small distances	Fuzzy coding	Kefforda, B. J., P. K. Botwe, A. J. Brooks, S. Kunz, R. Marchant, S. Maxwell, L. Metzeling, R. B. Schäfer, R. M. Thompson. 2020. An integrated database of stream macroinvertebrate traits for Australia: concept and application. Ecological Indicators 114 106280
Crawling abiity	Enduring the drought by exploting refuges	Fuzzy coding	Goncalves, I. C., Pescador, M. L., & Peters, J. G. (2020). A new genus of Euthyplociinae from Ecuador (Ephemeroptera: Euthyplociidae). *Zootaxa*, *4759* (1), 107-112.
Borrowing	Moving under rocks in the hyporheic zone	Fuzzy coding	LeRoy Poff, N., J. D. Olden, N. K. M. Vieira, D. S. Finn, M. P. Simmons, B. C. Kondratieff. 2006. Functional trait niches of North American lotic insects: traits-based ecological applications in light of phylogenetic relationships. Journal of North American Benthological Society. 25(4):730–755
Encysting	Aestivate or encyst in the dry riverbed	Presence / absence	Tomanova, S., & Usseglio-Polatera, P. (2007). Patterns of benthic community traits in neotropical streams: relationship to mesoscale spatial variability. Fundamental and Applied Limnology-Archiv fur Hydrobiologie, 170(3), 243-256.
Amored body	Easier to find refuge, cover, and avoid predation	Presence / absence	Tomanova, S., Moya, N., & Oberdorff, T. (2008). Using macroinvertebrate biological traits for assessing biotic integrity of neotropical streams. *River research and applications*, *24* (9), 1230-1239.
Diapause	Egg, larvae and adult diapause	Presence / absence	Firmiano, K. R., Castro, D. M., Linares, M. S., & Callisto, M. (2021). Functional responses of aquatic invertebrates to anthropogenic stressors in riparian zones of Neotropical savanna streams. *Science of the Total Environment*, *753*, 141865.
Resistance to drying			
Physicochemical tolerance	pH and conductivity changes in small pools	Fuzzy coding	Rader R. B. 1996. A functional classification of the drift: traits that influence invertebrate availability to salmonids. Canadian journal of fish and aquatic sciences. 54: 1211–1234
Survival under hypoxic conditions	Low oxygen usage for metabolic rate	Fuzzy coding	Tomanova, S., Goitia, E., & Helešic, J. (2006). Trophic levels and functional feeding groups of macroinvertebrates in neotropical streams. *Hydrobiologia*, *556*, 251-264.
Resting eggs	Desiccation resistant eggs between drying periods	Presence / absence	Tomanova, S., & Usseglio-Polatera, P. (2007). Patterns of benthic community traits in neotropical streams: relationship to mesoscale spatial variability. *Fundamental and Applied Limnology-Archiv fur Hydrobiologie*, *170* (3), 243-256.
Thermal resistance	Thermal preference for oviposition	Fuzzy coding	Firmiano, K. R., Castro, D. M., Linares, M. S., & Callisto, M. (2021). Functional responses of aquatic invertebrates to anthropogenic stressors in riparian zones of Neotropical savanna streams. *Science of the Total Environment*, *753*, 141865.
Body adaptations	Armoring shape and attachment ability to burrow	Presence / absence	Tomanova, S., Moya, N., & Oberdorff, T. (2008). Using macroinvertebrate biological traits for assessing biotic integrity of neotropical streams. *River research and applications*, *24* (9), 1230-1239.
Dispersal strategy	Aerial and aquatic displacement between pools	Fuzzy coding	Tomanova, S., Moya, N., & Oberdorff, T. (2008). Using macroinvertebrate biological traits for assessing biotic integrity of neotropical streams. *River research and applications*, *24* (9), 1230-1239.

Ongoing work

- The primary ongoing activity in CELAC countries is the completion of the functional traits database. Currently from the 16 traits listed, only 7 have been completed using available literature. The remaining 9 traits need to be revised with CELAC specialist and other regional experts.
- Simultaneously, CELAC countries are furthering identification to lower taxonomic levels (Genera). Ecuadorian DRN is targeting genera level to all insects, Bolivia will provide genera level to the orders of Ephemeroptera, Trichoptera, Plecoptera, and Odonata, and Brazil will provide general level to most insects including Coleoptera, that is highly diverse in this DRN.
- Future activities also include working closer to WP2 specialist to narrow the macroinvertebrate traits database and to revise any other considerations that should be included or discussed.
- Finally, the Fish Diversity Database that comprises data only from Ecuador is ready to be used for the metacommunity analysis of Neotropical fish under drying conditions, within the Ecuadorian Drying River Network.

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Supplementary Material

Table S1. CELAC countries sampling sites showing the altitudinal gradient of DRNs, and the length of reaches monitored during 2021 and 2022.

Brazil: Bon Nome River		
Sites	Length (m)	Altitude (m)
BN01	95	605
BN02	125	621
BN03	150	595
BN05	133	596
BN06	150	592
BN07	100	593
BN09	50	578
BN10	145	575
BN11	100	575
BN12	150	521
BN13	50	580
BN14	150	582
BN15	150	584
BN16	100	590
BN17	50	568
BN18	100	567
BN19	90	547
BN20	150	506
BN21	100	521
BN22	100	586
BN23	50	586
BN24	50	578
BN25	50	500
BN26	150	468
BN27	150	433

Bolivia: Chico River		
Sites	Length (m)	Altitude (m)
01D	78	3248
02D	60	3237
03D	60	3260
04R	100	3196
05C	35	3351
06A	40	3373
07C	70	3248
08A	100	3151
09S	40	3204
10S	40	3194
11F	80	3160
12PF	30	3339
13P	90	2952
14H	50	2965
15E	110	2977
16F	30	2994
17P	110	2994
18F	90	2798
19A	110	2782
20P	100	3027
21RAV	50	3254
22PG	25	2964

Ecuador: Cube River		
Sites	Length (m)	Altitude (m)
CUB 01	50	507
CUB 02	80	342
CUB 03	50	472
CUB 04	50	518
CUB 05	70	512
CUB 06	50	464
CUB 07	50	531
CUB 08	75	332
CUB 09	100	351
CUB 10	70	526
CUB 11	150	198
CUB 12	50	376
CUB 13	75	215
CUB 14	50	133
CUB 15	150	135
CUB 16	75	207
CUB 17	80	208
CUB 18	80	86
CUB 19	150	78
CUB 20	150	52