**Appendix S1.**

**Table S1**. List of Bita River Basin fish species included in the analysis of functional trait diversity.

|  |
| --- |
| Species |
| Clupeiformes |
| Engraulidae |
| *Amazonsprattus scintilla* |
| *Anchoviella guianensis* |
|  |
| Characiformes |
| Crenuchidae |
| *Ammocryptocharax elegans* |
| *Elachocharax pulcher* |
| *Melanocharacidium dispilomma* |
| *Poecilocharax weitzmani* |
|  |
| Erythrinidae |
| *Hoplias malabaricus* |
|  |
| Cynodontidae |
| *Hydrolycus armatus* |
|  |
| Serrasalmidae |
| *Catoprion mento* |
| *Pristobrycon striolatus* |
| *Serrasalmus altuvei* |
|  |
| Hemiodontidae |
| *Argonectes longiceps* |
| *Bivibranchia fowleri* |
| *Bivibranchia velox* |
| *Hemiodus gracilis* |
| *Hemiodus immaculatus* |
| *Hemiodus semitaeniatus* |
| *Hemiodus unimaculatus* |
|  |
| Anostomidae |
| *Anostomus ternetzi* |
| Species |
| Anostomidae |
| *Pseudanos winterbottomi* |
| *Leporinus friderici* |
| *Leporinus fasciatus* |
| *Schizodon scotorhabdotus* |
|  |
| Curimatidae |
| *Curimatopsis evelynae* |
| *Cyphocharax spilurus* |
| *Steindachnerina argentea* |
| *Steindachnerina sp* |
|  |
| Lebiasinidae |
| *Copella arnoldi* |
| *Copella nattereri* |
| *Copella sp* |
| *Nannostomus eques* |
| *Nannostomus marilynae* |
| *Nannostomus trifasciatus* |
| *Nannostomus unifasciatus* |
|  |
| Chalceidae |
| *Chalceus macrolepidotus* |
|  |
| Ctenoluciidae |
| *Boulengerella cuvieri* |
| *Boulengerella lateristriga* |
|  |
| Gasteropelecidae |
| *Carnegiella marthae* |
|  |
| Bryconidae |
| *Brycon melanopterus* |
| *Brycon pesu* |
|  |
| Acestrorhynchidae |
| *Acestrorhynchus falcirostris* |
| *Acestrorhynchus microlepis* |
| *Acestrorhynchus minimus* |
| *Heterocharax leptogrammus* |

**Table S1**. Continued

|  |
| --- |
| Species |
| Acestrorhynchidae |
| *Loncogenys ilisha* |
|  |
| Characidae |
| *Acestrocephalus sardina* |
| *Aphyocharax alburnus* |
| *Astyanax bimaculatus* |
| *Brittanichthys sp* |
| *Bryconamericus sp* |
| *Charax condei* |
| *Creagrutus phasma* |
| *Hemigrammus elegans* |
| *Hemigrammus geisleri* |
| *Hemigrammus micropterus* |
| *Hemigrammus microstomus* |
| *Hemigrammus newboldi* |
| *Hemigrammus rhodostomus* |
| *Hemigrammus schmardae* |
| *Hemigrammus sp* |
| *Hemigrammus sp "pseudomicropterus"* |
| *Hemigrammus stictus* |
| *Hyphessobrycon acaciae* |
| *Hyphessobrycon diancistrus* |
| *Hyphessobrycon sweglesi* |
| *Knodus cinarucoense* |
| *Microschemobrycon callops* |
| *Microschemobrycon casiquiare* |
| *Moenkhausia ceros* |
| *Moenkhausia collettii* |
| *Moenkhausia copei* |
| *Moenkhausia lepidura* |
| *Moenkhausia oligolepis* |
| *Moenkhausia sp "blanco"* |
| *Paracheirodon innesi* |
| *Parapristella georgiae* |
| *Phenacogaster megalostictus* |
| *Priocharax ariel* |
| *Tetragonopterus argenteus* |
| *Tyttobrycon sp* |
| Species |
| Gymnotiformes |
| Hypopomidae |
| *Hypopygus lepturus* |
| *Microsternarchus bilineatus* |
|  |
| Rhamphichthydae |
| *Gymnorhamphichthys rondoni* |
|  |
| Sternopygidae |
| *Eigenmannia macrops* |
|  |
| Siluriformes |
| Auchenipteridae |
| *Auchenipterichthys longimanus* |
| *Tatia galaxias* |
| *Tatia marthae* |
| *Tatia nigra* |
|  |
| Callichthyidae |
| *Corydoras sp* |
|  |
| Cetopsidae |
| *Cetopsidium morenoi* |
|  |
| Doradidae |
| *Acanthodoras cataphractus* |
| *Amblydoras bolivarensis* |
| *Leptodoras linnelli* |
| *Physopyxis lyra* |
| *Platydoras hancockii* |
| *Scorpiodoras heckelii* |
|  |
| Heptapteridae |
| *Gladioglanis sp* |
| *Mastiglanis asopos* |
| *Microglanis poecilus* |
|  |
| Heptapteridae |
| *Phenacorhamdia anisura* |
| *Pimelodella sp* |

**Table S1**. Continued

|  |
| --- |
| Species |
| Loricariidae |
| *Acestridium colombiensis* |
| *Ancistrus macropthalmus* |
| *Ancistrus sp* |
| *Dekeyseria scaphirhyncha* |
| *Farlowella vittata* |
| *Parotocinclus eppleyi* |
| *Pterygoplichthys gibbiceps* |
|  |
| Pimelodidae |
| *Pimelodus albofasciatus* |
|  |
| Pseudopimelodidae |
| *Batrochoglanis villosus* |
|  |
| Trichomycteridae |
| *Haemomaster venezuelae* |
| *Ochmacanthus alternus* |
| *Paravandellia sp* |
|  |
| Synbranchiformes |
| Synbranchidae |
| *Synbranchus marmoratus* |
|  |
| Cichliformes |
| Cichlidae |
| *Aequidens tetramerus* |
| *Apistogramma hongsloi* |
| *Apistogramma minima* |
| *Biotodoma wavrini* |
| *Biotoecus dicentrarchus* |
| *Cichla orinocensis* |
| *Crenicichla wallacii* |
| *Dicrossus filamentosus* |
| *Geophagus dicrozoster* |
|  |
| Cyprinodontiformes |
| Poeciliidae |
| *Fluviphylax pygmaeus* |
| Species |
| Beloniformes |
| Belonidae |
| *Belonion dibranchodon* |
|  |
| Perciformes |
| Eleotridae |
| *Microphilypnus ternetzi* |

**Table S2.** Functional traits used for fishes of the Bita River. Metrics and ratios for ecomorphological traits follow Winemiller (1991); feeding and defense trait definitions follow Winemiller et al. (2015).

|  |  |  |
| --- | --- | --- |
| Functional category | Trait | Metric, ratio, or definition |
| Locomotion | Standard length (SL) | Linear measurement (mm) |
| & | Relative body depth | Maximum body depth/SL |
| Habitat use | Rel. body depth below midline | Body depth below midline/Max. body depth |
|  | Rel. body width | Maximum body width/SL |
|  | Rel. caudal peduncle length | Caudal peduncle length/SL |
|  | Rel. caudal peduncle depth | Caudal peduncle depth/Max. body depth |
|  | Rel. caudal peduncle width | Caudal peduncle width/Max. body width |
|  | Rel. dorsal fin height | Dorsal fin height/SL |
|  | Rel. dorsal fin length | Dorsal fin length/SL |
|  | Rel. caudal fin length | Caudal fin length/SL |
|  | Rel. caudal fin height | Caudal fin height/SL |
|  | Rel. anal Fin height | Anal Fin height/SL |
|  | Rel. anal fin length | Anal fin length/SL |
|  | Rel. pectoral fin height | Pectoral fin height/SL |
|  | Rel. pectoral fin length | Pectoral fin length/SL |
|  | Rel. pelvic fin length | Pelvic fin length/SL |
|  | Rel. pelvic fin height | Pelvic fin height/SL |
|  | Shape of caudal fin | 0) absent, 1) rounded, 2) truncate, 3) forked |
|  | Swim bladder length | Linear measurement (mm) |
|  | Lateral line | 0) absent, 1) incomplete, 2) interrupted, 3) complete |
| Feeding | Rel. head length | Head length/SL |
|  | Rel. head depth | Head depth/Max. body depth |
|  | Rel. head width | Head width/Max. body width |
|  | Eye position | Distance of pupil from ventral head margin/Head depth |
|  | Rel. eye diameter | Eye diameter/Head length |
|  | Mouth position | 1) superior, 2) terminal, 3) subterminal, 4) inferior |
|  | Rel. mouth width | Mouth width/Head width |
|  | Rel. mouth height | Mouth height/Head height |
|  | Number of barbels | number |
|  | Jaw protrusion | 0) absent, 1) present |
|  | Tooth shape | 0) absent, 1) unicuspid (rasping), 2) multicuspid (crushing), 3) short conical (grasping), 4) long conical (piercing), 5) triangular serrated (shearing) |
|  | Gill rakers | 0) absent, 1) short & blunt, 2) intermediate length or long & sparse, 4) long & numerous |
|  | Gut length | Linear measurement (mm) |
| Defense | Spines | 0) none, 1) few short & weakly serrated, 2) few long or few short & strongly serrated, 3) many long (dorsal, anal), 4) long & massive |
|  | Venom | 0) none, 1) pectoral & dorsal spines with venom |
|  | Armor | 0) none, 1) massive skull, 2) thin bony plates covering body, 3) thick bony plates covering body |
|  | Crypsis | 0) none, 1) mottling for blending with vegetation, 2) mimicry of vegetation of woody debris |

**Table S3.** Abiotic variables measured in each section of the study area; values are untransformed mean ± standard error.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Category | Variable | High | Mid-high | Mid-low | Low |
| Water  parameters | pH | 8.9 ± 0.33 | 6.89 ± 0.18 | 7.88 ± 0.26 | 8.55 ± 0.67 |
|  | Conductivity | 3.76 ± 0.16 | 4.48 ± 0.09 | 31.4 ± 11.36 | 7.16 ± 1.22 |
|  | Water temperature | 28.1 ± 0.39 | 28.89 ± 0.25 | 29.3 ± 0.44 | 30.76 ± 0.89 |
|  | Dissolved oxygen | 10.92 ± 0.49 | 9.42 ± 0.53 | 8.83 ± 0.69 | 8.20 ± 1.25 |
|  | Total solids | 2.68 ± 0.09 | 3.2 ± 0.06 | 19.15 ± 7.62 | 5.06 ± 0.81 |
| Substratum | (%) Cobble (6–25 cm) | 14 ± 14 | 7.5 ± 7.5 | 0 ± 0 | 0 ± 0 |
|  | (%) Sand (0.06–2 mm) | 63 ± 16.85 | 42.5 ± 12.13 | 37.14 ± 12.06 | 46.66 ± 29.05 |
|  | (%) Mud or silt (<0.06 mm) | 16 ± 16 | 46.66 ± 12.92 | 50.71 ± 11.06 | 46.66 ± 24.03 |
| Instream cover | (%) Filamentous algae | 10 ± 5.47 | 1.66 ± 1.12 | 1.42 ± 0.97 | 0 ± 0 |
|  | (%) Large woody debris | 8 ± 3.74 | 8.33 ± 3.21 | 8.57 ± 2.53 | 6.66 ± 3.33 |
|  | (%) Grass | 2 ± 2 | 0 ± 0 | 0 ± 0 | 0 ± 0 |
|  | (%) Small woody debris | 14 ± 2.45 | 17.08 ± 3.91 | 13.21 ± 3.21 | 20 ± 10 |
|  | (%) Submerged roots | 8 ± 5.83 | 2.5 ± 1.79 | 10 ± 3.18 | 3.33 ± 3.33 |
|  | (%) Overhanging terrestrial vegetation | 2 ± 2 | 3.75 ± 2.22 | 8.21 ± 2.65 | 6.66 ± 3.33 |
|  |  |  |  |  |  |
| **Table S3.** Continued | | | | | |
| Category | Variable | High | Mid-high | Mid-low | Low |
|  | (%) Submerged leaf packs | 29 ± 11 | 37.08 ± 8.22 | 28.57 ± 4.90 | 33.33 ± 12.01 |
| Channel  morphology | Depth (1: <1m; 2:>1-2m; 3:>2m) | 2.80 ± 0.20 | 2.50 ± 0.15 | 2 ± 0.18 | 2.33 ± 0.33 |
|  | Width (m) | 26.22 ± 10.04 | 45.18 ± 11.05 | 51.57 ± 10.25 | 55.39 ± 36.72 |
|  | Flow (1: High; 2: Medium; 3: Low) | 2 ± 0.31 | 1.25 ± 0.17 | 1.28 ± 0.12 | 1 ± 0 |
| Local riparian  buffer | Width of riparian buffer (m) | 2.8 ± 0.2 | 2.5 ± 0.15 | 2 ± 0.18 | 2.33 ± 0.33 |
|  | (%) Stream shaded by tree canopy | 0.34 ± 0.17 | 0.23 ± 0.07 | 0.22 ± 0.06 | 0.2 ± 0.1 |
|  | Area Riparian Forest (ha) | 18.14 ± 3.26 | 40.04 ± 3.44 | 52.39 ± 4.16 | 47.90 ± 8.23 |
|  | Area Savanna (ha) | 51.81 ± 2.61 | 27.50 ± 4.29 | 11.32± 4.71 | 10.12 ± 7.89 |
| Landscape  variables | Altitude (m) | 86.8 ± 0.58 | 70.92 ± 0.63 | 64.29 ± 1.31 | 48.67 ± 1.20 |
|  | Near to roads (1: Presence; 0: Absence) | 0.80 ± 0.20 | 0.33 ± 0.14 | 0.29 ± 0.13 | 1 ± 0 |
|  | Near to crop areas (1: Presence; 0: Absence) | 0.40 ± 0.24 | 0 ± 0 | 0.14 ± 0.1 | 1 ± 0 |
|  | Stream order (1 to 4) | 3.20 ± 0.58 | 3.33 ± 0.63 | 3.57 ± 1.31 | 2.67 ± 1.20 |
|  | Distance to the Río Orinoco (km) | 627 ± 2.975 | 380 ± 2.29 | 256 ± 3.12 | 19 ± 2.45 |

**Table S4.** Functional α diversity metrics (mean ±SD) for fish assemblages based on functional trait analyses that included samples for the entire Bita River Basin and analysis for the four sections separately.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Scale | FRic | FDiv | FEve | FDis | FSpe | FOri |
| Entire Basin | 0.27±0.22 | 0.74±0.12 | 0.43±0.15 | 0.33±0.15 | 0.36±0.09 | 0.16±0.07 |
| High | 0.19±0.2 | 0.73±0.12 | 0.43±0.22 | 0.28±0.14 | 0.36±0.05 | 0.17±0.1 |
| Mid-high | 0.24±0.22 | 0.78±0.13 | 0.46±0.13 | 0.32±0.17 | 0.38±0.1 | 0.16±0.09 |
| Mid-low | 0.32±0.21 | 0.71±0.08 | 0.41±0.13 | 0.35±0.13 | 0.36±0.06 | 0.16±0.03 |
| Low | 0.27±0.17 | 0.74±0.06 | 0.39±0.06 | 0.3±0.1 | 0.33±0.04 | 0.14±0.02 |

**Table S5**. Results of the functional diversity indices and the standardized effect sizes (SES), based on the null modeling approach. Statistically significant values are shown in bold type. Negative/positive SES values represent under/over trait dispersion.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Site** | **Section** | **FRic** | | **FDiv** | | **FEve** | | **FDis** | | **FSpe** | | **FOri** | |
| **FD** | **SES** | **FD** | **SES** | **FD** | **SES** | **FD** | **SES** | **FD** | **SES** | **FD** | **SES** |
| E1 | High | 0.31 | 0.62 | 0.73 | -0.34 | 0.67 | -0.34 | 0.39 | -1.43 | 0.43 | -1.43 | 0.33 | 1.55 |
| E2 | High | 0.08 | -1.45 | 0.81 | 1.61 | 0.40 | **-4.85** | 0.26 | **-2.94** | 0.32 | -2.94 | 0.11 | **-3.05** |
| E3 | High | 0.05 | -1.75 | 0.78 | 0.93 | 0.48 | **-3.46** | 0.15 | **-4.32** | 0.32 | -4.32 | 0.09 | **-3.49** |
| E4 | High | 0.47 | **2.18** | 0.81 | 1.52 | 0.52 | **-2.83** | 0.46 | -0.59 | 0.39 | -0.59 | 0.20 | -1.03 |
| E5 | High | 0.01 | **-2.15** | 0.51 | **-5.81** | 0.07 | **-10.38** | 0.14 | **-4.45** | 0.31 | -4.45 | 0.11 | **-3.12** |
| E6 | Mid-high | 0.65 | **3.80** | 0.91 | **4.21** | 0.41 | **-4.62** | 0.27 | **-2.84** | 0.39 | -2.84 | 0.11 | **-2.98** |
| E7 | Mid-high | 0.31 | 0.69 | 0.72 | -0.75 | 0.32 | **-6.24** | 0.24 | **-3.22** | 0.32 | -3.22 | 0.11 | **-3.02** |
| E8 | Mid-high | 0.06 | -1.70 | 0.81 | 1.49 | 0.69 | -0.01 | 0.53 | 0.36 | 0.43 | 0.36 | 0.18 | -1.46 |
| E9 | Mid-high | 0.04 | **-1.84** | 0.46 | **-7.22** | 0.40 | **-4.91** | 0.05 | **-5.61** | 0.27 | **-5.61** | 0.08 | **-3.69** |
| E10 | Mid-high | 0.08 | -1.46 | 0.80 | 1.22 | 0.57 | -1.92 | 0.31 | **-2.43** | 0.32 | -2.43 | 0.18 | -1.54 |
| E11 | Mid-high | 0.12 | -1.09 | 0.72 | -0.54 | 0.22 | **-7.92** | 0.23 | **-3.33** | 0.32 | -3.33 | 0.11 | **-3.05** |
| E12 | Mid-high | 0.04 | **-1.83** | 0.80 | 1.37 | 0.55 | **-2.30** | 0.59 | 1.01 | 0.61 | **1.01** | 0.40 | **3.09** |
| E13 | Mid-high | 0.19 | -0.44 | 0.80 | 1.39 | 0.40 | **-4.92** | 0.52 | 0.25 | 0.45 | 0.25 | 0.18 | -1.57 |
| E14 | Mid-high | 0.59 | **3.25** | 0.94 | **4.87** | 0.47 | **-3.71** | 0.29 | **-2.65** | 0.35 | -2.65 | 0.12 | **-2.91** |
| E15 | Mid-high | 0.36 | 1.17 | 0.77 | 0.71 | 0.47 | **-3.73** | 0.20 | **-3.75** | 0.33 | -3.75 | 0.11 | **-3.01** |
| E16 | Mid-high | 0.01 | **-2.16** | 0.89 | **3.65** | 0.56 | **-2.13** | 0.50 | -0.06 | 0.46 | -0.06 | 0.21 | -0.85 |
| E17 | Mid-high | 0.38 | 1.32 | 0.70 | -1.26 | 0.41 | **-4.61** | 0.17 | **-4.07** | 0.29 | **-4.07** | 0.11 | **-3.02** |
| E18 | Mid-low | 0.36 | 1.14 | 0.80 | 1.40 | 0.41 | **-4.64** | 0.41 | -1.09 | 0.40 | -1.09 | 0.16 | **-2.03** |
| E19 | Mid-low | 0.28 | 0.35 | 0.68 | -1.66 | 0.52 | **-2.91** | 0.28 | **-2.80** | 0.36 | -2.80 | 0.10 | **-3.14** |
| E20 | Mid-low | 0.13 | -1.03 | 0.70 | -1.21 | 0.27 | **-7.06** | 0.30 | -2.48 | 0.32 | -2.48 | 0.17 | -1.75 |
| E21 | Mid-low | 0.50 | **2.43** | 0.74 | -0.27 | 0.41 | **-4.75** | 0.39 | -1.39 | 0.38 | -1.39 | 0.13 | **-2.53** |
| E22 | Mid-low | 0.32 | 0.79 | 0.66 | **-2.13** | 0.47 | **-3.67** | 0.31 | -2.34 | 0.33 | -2.34 | 0.16 | **-1.86** |
| E23 | Mid-low | 0.00 | **-2.24** | 0.61 | **-3.51** | 0.08 | **-10.29** | 0.25 | **-3.13** | 0.35 | -3.13 | 0.13 | **-2.51** |
| E24 | Mid-low | 0.33 | 0.83 | 0.69 | -1.31 | 0.42 | **-4.52** | 0.10 | **-4.91** | 0.28 | **-4.91** | 0.10 | **-3.33** |
| E25 | Mid-low | 0.75 | **4.74** | 0.83 | **2.12** | 0.49 | **-3.33** | 0.54 | 0.41 | 0.48 | 0.41 | 0.16 | **-1.97** |
| E26 | Mid-low | 0.51 | **2.52** | 0.72 | -0.68 | 0.49 | **-3.43** | 0.54 | 0.48 | 0.43 | 0.48 | 0.23 | -0.44 |
| E27 | Mid-low | 0.52 | **2.62** | 0.77 | 0.66 | 0.53 | **-2.72** | 0.45 | -0.60 | 0.39 | -0.60 | 0.19 | -1.42 |
| E28 | Mid-low | 0.06 | -1.70 | 0.63 | **-2.89** | 0.30 | **-6.53** | 0.23 | **-3.29** | 0.25 | **-3.29** | 0.15 | **-2.25** |
| E29 | Mid-low | 0.41 | 1.63 | 0.57 | **-4.45** | 0.46 | **-3.87** | 0.32 | **-2.26** | 0.30 | **-2.26** | 0.18 | -1.49 |
| E30 | Mid-low | 0.06 | -1.67 | 0.78 | 0.94 | 0.42 | **-4.55** | 0.24 | **-3.29** | 0.32 | -3.29 | 0.17 | **-1.85** |
| E31 | Mid-low | 0.24 | 0.05 | 0.79 | 1.00 | 0.55 | **-2.38** | 0.49 | -0.17 | 0.41 | -0.17 | 0.18 | -1.55 |
| E32 | Low | 0.37 | 1.18 | 0.68 | -1.60 | 0.32 | **-6.27** | 0.41 | -1.15 | 0.38 | -1.15 | 0.16 | **-2.01** |
| E33 | Low | 0.07 | -1.58 | 0.75 | 0.02 | 0.43 | **-4.40** | 0.28 | **-2.68** | 0.31 | -2.68 | 0.14 | **-2.46** |
| E34 | Low | 0.37 | 1.20 | 0.80 | 1.33 | 0.43 | **-4.37** | 0.21 | **-3.61** | 0.31 | -3.61 | 0.12 | **-2.82** |
| % Significant values | | 35.29 | | 29.41 | | 91.18 | | 55.88 | | 17.65 | | 67.65 | |

**Table S6.** P-values of the two-tailed test for null modelling approach applied to the functional beta diversity data among locations. Values greater or equal to 0.975 indicate than an observed value is higher than expected by chance and lower or equal to 0.025 lower than expected.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | E13 | E14 | E15 | E16 | E17 | E18 |
| E1 | 0.501 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| E2 | **0.980** | 0.501 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| E3 | **1.000** | **0.004** | 0.501 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| E4 | 0.504 | 0.399 | 0.196 | 0.501 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| E5 | **1.000** | 0.031 | **0.100** | 0.946 | 0.501 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| E6 | **1.000** | 0.800 | 0.143 | 0.925 | 0.271 | 0.501 |  |  |  |  |  |  |  |  |  |  |  |  |
| E7 | **0.990** | 0.252 | 0.733 | **0.995** | 0.216 | 0.873 | 0.501 |  |  |  |  |  |  |  |  |  |  |  |
| E8 | **0.999** | 0.998 | **1.000** | **1.000** | **0.996** | **1.000** | **0.999** | 0.501 |  |  |  |  |  |  |  |  |  |  |
| E9 | **1.000** | **0.003** | 0.110 | **0.994** | 0.039 | 0.777 | 0.082 | **0.994** | 0.501 |  |  |  |  |  |  |  |  |  |
| E10 | **0.996** | **0.001** | 0.244 | 0.868 | 0.133 | 0.927 | 0.094 | 0.915 | **0.004** | 0.501 |  |  |  |  |  |  |  |  |
| E11 | **1.000** | **0.001** | **0.001** | 0.537 | **0.011** | 0.170 | 0.451 | **1.000** | **0.001** | **0.002** | 0.501 |  |  |  |  |  |  |  |
| E12 | 0.594 | 0.893 | **0.984** | **0.998** | 0.964 | **0.980** | 0.917 | **0.998** | 0.965 | **0.988** | 0.968 | 0.501 |  |  |  |  |  |  |
| E13 | **1.000** | 0.154 | **0.002** | 0.829 | 0.058 | 0.036 | 0.311 | **1.000** | 0.101 | 0.125 | **0.001** | **0.999** | 0.501 |  |  |  |  |  |
| E14 | 0.840 | **0.994** | 0.954 | 0.875 | **0.994** | 0.707 | 0.940 | **1.000** | **0.983** | **0.991** | 0.922 | **0.991** | 0.938 | 0.501 |  |  |  |  |
| E15 | **0.997** | 0.061 | **0.017** | 0.792 | 0.255 | 0.201 | 0.426 | **0.996** | 0.092 | 0.096 | **0.001** | 0.916 | **0.006** | 0.583 | 0.501 |  |  |  |
| E16 | **0.994** | **0.996** | **1.000** | **0.998** | **0.980** | **0.999** | **0.991** | 0.248 | **0.996** | **0.988** | **0.998** | 0.972 | **0.998** | **0.998** | **0.997** | 0.501 |  |  |
| E17 | **0.994** | 0.463 | 0.941 | 0.966 | 0.661 | **0.996** | **0.010** | **0.996** | 0.198 | 0.118 | 0.737 | **0.996** | 0.972 | **1.000** | 0.973 | **0.998** | 0.501 |  |
| E18 | **1.000** | 0.042 | 0.390 | 0.973 | 0.285 | 0.573 | 0.282 | **0.988** | 0.026 | 0.130 | 0.065 | **0.999** | 0.243 | 0.609 | **0.001** | **0.998** | 0.671 | 0.501 |
| E19 | **0.999** | 0.382 | 0.044 | 0.900 | 0.144 | 0.164 | 0.813 | **1.000** | 0.431 | 0.743 | 0.168 | **0.987** | 0.068 | 0.719 | 0.437 | **0.998** | **0.996** | 0.663 |
| E20 | **0.997** | **0.012** | 0.720 | 0.840 | 0.281 | **0.999** | **0.003** | 0.802 | 0.053 | **0.001** | 0.190 | **0.998** | 0.657 | **0.984** | 0.365 | **0.978** | 0.020 | 0.121 |
| E21 | **1.000** | 0.386 | 0.066 | 0.841 | 0.369 | 0.435 | 0.852 | **1.000** | 0.109 | 0.521 | 0.110 | **0.996** | 0.290 | 0.402 | 0.397 | **0.997** | 0.974 | 0.148 |
| E22 | **1.000** | 0.355 | 0.242 | 0.992 | 0.495 | 0.137 | 0.931 | **1.000** | 0.337 | 0.701 | 0.284 | 0.974 | 0.508 | 0.559 | 0.109 | **0.994** | **0.998** | 0.167 |
| E23 | 0.966 | 0.080 | 0.453 | 0.949 | 0.171 | 0.634 | 0.376 | 0.958 | 0.238 | 0.239 | 0.164 | 0.930 | 0.436 | 0.974 | 0.353 | **0.978** | 0.184 | 0.573 |
| E24 | **0.981** | 0.350 | 0.949 | **0.992** | 0.706 | **0.999** | 0.081 | 0.886 | 0.610 | 0.087 | 0.798 | 0.964 | 0.973 | **1.000** | 0.850 | **0.976** | **0.010** | 0.649 |
| E25 | **0.992** | **1.000** | **0.995** | 0.953 | **0.995** | 0.652 | **0.980** | **1.000** | **0.999** | **1.000** | **0.999** | **1.000** | 0.963 | 0.082 | **0.979** | **0.998** | **0.999** | 0.882 |

**Table S6**. Continued

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | E13 | E14 | E15 | E16 | E17 | E18 |
| E26 | 0.919 | 0.959 | **0.984** | **0.995** | 0.969 | 0.926 | 0.593 | **1.000** | 0.907 | **0.970** | 0.940 | 0.893 | 0.969 | **0.004** | 0.389 | **0.994** | **1.000** | 0.601 |
| E27 | 0.928 | 0.212 | 0.435 | 0.899 | 0.165 | 0.665 | 0.046 | 0.954 | 0.085 | 0.274 | 0.380 | 0.909 | 0.307 | 0.190 | **0.008** | **0.985** | 0.958 | **0.002** |
| E28 | **1.000** | 0.103 | 0.047 | **0.983** | **0.002** | 0.160 | 0.797 | **1.000** | 0.037 | 0.134 | **0.011** | **0.984** | 0.012 | **1.000** | 0.522 | **0.996** | 0.969 | 0.382 |
| E29 | **0.991** | 0.970 | 0.139 | 0.904 | 0.861 | 0.041 | **0.999** | **1.000** | 0.926 | **0.998** | 0.432 | 0.829 | 0.334 | 0.091 | 0.087 | **0.994** | **1.000** | 0.915 |
| E30 | **0.999** | **0.006** | 0.383 | 0.857 | 0.175 | 0.814 | 0.044 | 0.760 | **0.014** | **0.009** | 0.053 | **0.983** | 0.600 | 0.921 | 0.200 | 0.944 | 0.072 | 0.054 |
| E31 | **0.993** | 0.476 | 0.462 | **0.998** | 0.310 | 0.782 | 0.578 | **0.985** | 0.049 | 0.139 | 0.165 | 0.948 | 0.379 | 0.165 | 0.104 | **0.985** | **0.997** | 0.038 |
| E32 | **1.000** | 0.409 | 0.473 | 0.928 | 0.556 | 0.626 | 0.531 | **1.000** | 0.265 | 0.882 | 0.490 | 0.919 | 0.235 | 0.239 | 0.312 | **1.000** | **0.999** | 0.160 |
| E33 | **0.991** | **0.003** | 0.269 | 0.939 | 0.191 | **0.993** | 0.044 | 0.942 | **0.004** | **0.001** | **0.016** | **0.979** | 0.304 | **0.996** | 0.239 | **0.997** | 0.095 | 0.300 |
| E34 | **0.988** | 0.332 | 0.570 | 0.908 | 0.416 | 0.461 | 0.721 | **1.000** | 0.514 | 0.510 | 0.252 | 0.733 | 0.541 | **0.006** | 0.126 | **0.996** | **1.000** | 0.167 |

**Table S6**. Continued

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | E19 | E20 | E21 | E22 | E23 | E24 | E25 | E26 | E27 | E28 | E29 | E30 | E31 | E32 | E33 | E34 |
| E19 | 0.501 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| E20 | 0.945 | 0.501 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| E21 | **0.004** | 0.805 | 0.501 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| E22 | 0.147 | 0.925 | **0.001** | 0.501 |  |  |  |  |  |  |  |  |  |  |  |  |
| E23 | 0.479 | 0.424 | 0.226 | 0.360 | 0.501 |  |  |  |  |  |  |  |  |  |  |  |
| E24 | **0.985** | 0.042 | 0.965 | **0.979** | 0.278 | 0.501 |  |  |  |  |  |  |  |  |  |  |
| E25 | 0.733 | **0.999** | 0.857 | 0.881 | **0.988** | **1.000** | 0.501 |  |  |  |  |  |  |  |  |  |
| E26 | 0.950 | 0.929 | 0.955 | 0.967 | **0.983** | 0.889 | **0.004** | 0.501 |  |  |  |  |  |  |  |  |
| E27 | 0.642 | 0.113 | 0.302 | 0.072 | 0.295 | 0.627 | 0.269 | **0.007** | 0.501 |  |  |  |  |  |  |  |
| E28 | 0.033 | 0.757 | 0.583 | 0.517 | 0.162 | **0.995** | **1.000** | **0.999** | 0.726 | 0.501 |  |  |  |  |  |  |
| E29 | 0.420 | **1.000** | 0.212 | 0.037 | 0.634 | **0.998** | 0.489 | 0.347 | 0.245 | 0.771 | 0.501 |  |  |  |  |  |
| E30 | 0.781 | **0.008** | 0.331 | 0.369 | 0.750 | 0.111 | 0.969 | 0.806 | 0.055 | 0.378 | 0.912 | 0.501 |  |  |  |  |
| E31 | 0.684 | 0.235 | 0.391 | 0.102 | 0.792 | 0.877 | 0.410 | 0.030 | **0.001** | 0.511 | 0.065 | 0.160 | 0.501 |  |  |  |
| E32 | 0.305 | 0.942 | 0.670 | 0.668 | 0.751 | **0.999** | 0.281 | 0.057 | **0.016** | 0.501 | 0.283 | 0.803 | 0.075 | 0.501 |  |  |
| E33 | 0.835 | **0.001** | 0.676 | 0.802 | 0.133 | 0.087 | **1.000** | 0.973 | 0.368 | 0.399 | **0.998** | 0.033 | 0.514 | 0.814 | 0.501 |  |
| E34 | 0.553 | 0.804 | 0.639 | 0.559 | 0.781 | 0.987 | 0.556 | **0.002** | **0.005** | 0.729 | 0.094 | 0.423 | **0.003** | **0.002** | 0.621 | 0.501 |

**Table S7**. Variation in Functional β diversity (FBeta) and its components; functional turnover (FTurn) and functional nestedness-resultant (FNes), within each section of the Bita River Basin, calculated using PERMDISP and “TukeyHSD” pot-hoc test. diff stands for difference between river sections. Statistically significant values (p< 0.05) are shown in bold type.

|  |  |  |
| --- | --- | --- |
| FBeta | diff | p-value |
| Low-High | 0.143 | 0.415 |
| Mid\_high-High | 0.017 | 0.994 |
| Mid\_low-High | -0.069 | 0.722 |
| Mid\_high-Low | 0.160 | 0.221 |
| Mid\_low-Low | 0.075 | 0.787 |
| Mid\_low-Mid\_high | -0.085 | 0.328 |
| FTurn |  |  |
| Low-High | -0.197 | 0.079 |
| Mid\_high-High | 0.031 | 0.946 |
| Mid\_low-High | -0.130 | 0.118 |
| Mid\_high-Low | 0.228 | **0.013** |
| Mid\_low-Low | 0.067 | 0.759 |
| Mid\_low-Mid\_high | -0.161 | **0.003** |
| FNes |  |  |
| Low-High | -0.088 | 0.868 |
| Mid\_high-High | -0.061 | 0.887 |
| Mid\_low-High | -0.041 | 0.958 |
| Mid\_high-Low | 0.028 | 0.993 |
| Mid\_low-Low | 0.047 | 0.965 |
| Mid\_low-Mid\_high | 0.019 | 0.989 |

**Table S8**. Environmental and spatial variables selected by the forward selection procedure for functional beta diversity and its components functional turnover and functional nestedness (Jaccard dissimilarity). Only statistically significant values (p< 0.05) are shown. Functional beta diversity (FBeta), functional turnover (FTurn) and were functional nestedness (FNes) calculated for the entire basin and each section.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Variables | FBeta | | FTurn | | FNes | |
| R2 | p | R2 | p | R2 | p |
| **Environmental** | |  |  |  |  |  |
| % SubRoots | 0.18 | 0.01 |  |  |  |  |
| % Cobble | 0.10 | 0.02 | 0.36 | 0.003 |  |  |
| Elevation | 0.09 | 0.03 | 0.10 | 0.002 |  |  |
| % Leafpacks | 0.08 | 0.02 | 0.03 | 0.041 |  |  |
| % Lwoode |  |  | 0.18 | 0.001 |  |  |
| % Swoode |  |  | 0.09 | 0.002 |  |  |
| pH |  |  | 0.04 | 0.018 |  |  |
| Cond |  |  |  |  | 0.18 | 0.005 |
| % Mud |  |  |  |  | 0.11 | 0.029 |
| % Grass |  |  |  |  | 0.08 | 0.043 |
| % FilAlgae |  |  |  |  | 0.10 | 0.011 |
| °C |  |  |  |  | 0.07 | 0.024 |
| **Spatial** |  |  |  |  |  |  |
| V3 | 0.13 | 0.01 |  |  | 0.09 | 0.033 |
| V6 | 0.10 | 0.02 |  |  | 0.12 | 0.028 |
| V7 | 0.10 | 0.02 |  |  | 0.10 | 0.045 |
| V16 | 0.08 | 0.02 | 0.19 | 0.004 |  |  |
| V10 |  |  |  |  | 0.08 | 0.038 |

**Table S9**. Variation partitioning analysis for functional beta diversity and its components functional turnover and functional nestedness (Jaccard dissimilarity) and selected groups of environmental and spatial variables. AdjR2= adjusted R2 for the percentage of variation and p= p-value, with significant values (p< 0.05) are shown in bold type. E= environmental variation, S= spatial variation, E+S= Total explained variation, E|S= Pure environmental variation, S|E= Pure spatial variation, b= Variation shared by environmental and spatial factors, and R= Unexplained variation (Residual).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Component** | FBeta | | FTurn | | FNes | |
| AdjR2 | p | AdjR2 | p | AdjR2 | p |
| **Jaccard dissimilarity** |  |  |  |  |  |  |
| E | 0.10 | **0.001** | 0.43 | **0.001** | 0.25 | **0.007** |
| S | 0.12 | **0.001** | 0.11 | **0.025** | 0.35 | **0.001** |
| E+S | 0.21 | **0.001** | 0.54 | **0.001** | 0.45 | **0.002** |
| E|S | 0.08 | **0.001** | 0.43 | **0.001** | 0.10 | **0.002** |
| S|E | 0.11 | **0.001** | 0.12 | **0.001** | 0.20 | **0.001** |
| b | 0.01 |  | 0.00 |  | 0.15 |  |
| R | 0.79 |  | 0.46 |  | 0.55 |  |