Bulletin of Regional Natural History

Formerly **Bollettino della Società dei Naturalisti in Napoli**

The effect of hydrogeomorphological disturbances on the macroinvertebrate communities in two Mediterranean watersheds with different land management criteria

Anna Corapi*, Luana Gallo, Lucio Lucadamo

DOI https://doi.org/10.6093/2724-4393/9709

***Correspondence:** anna.corapi@unical.it

Affiliation: Department of Biology, Ecology and Earth Sciences, University of Calabria

Conflict of Interest: The authors declare that they have no conflict of interest.

Financial Disclosure Statement: The authors declare that no specific funding was received for this work.

Submitted: 16 Nov. 2022
Revised: 24 Dec.2022
Accepted: 27 Dec. 2022

Associate Editor: Marco Guida

Abstract

A macroinvertebrates sampling campaign was performed between May 2009 and June 2010 in two Calabrian (South Italy) watersheds, Trionto river (Ionian coast) and Savuto river (Tyrrhenian coast). Results showed that the development of exceptional rainfalls, interacting with sides degradation due to timber harvesting and diffuse fires, promoted in Trionto watershed a very strong hydrogeomorphological perturbation resulting in long lasting effects on macroinvertebrate communities. On the other hand, Savuto river was mostly affected, upstream by permanent water regimentation while a more sustainable land management preserved the watercourse from severe impacts due to winter rains.

Keywords: macroinvertebrates, rainfall, fine sediment transport, physical-chemical water column data.

Riassunto

Un campionamento di macroinvertebrati è stato effettuato tra maggio 2009 e giugno 2010 in due bacini idrografici della Calabria (Sud Italia), il fiume Trionto (costa ionica) e il fiume Savuto (costa tirrenica). I risultati hanno dimostrato che lo sviluppo di piogge eccezionali, insieme alla compromissione dei versanti a causa del disboscamento e degli incendi diffusi, hanno promosso nel bacino del Trionto una forte alterazione idrogeomorfologica che ha avuto effetti duraturi sulle comunità di macroinvertebrati. Il fiume Savuto, invece, è risultato maggiormente interessato, a monte, da una regimentazione permanente delle acque, mentre una gestione più sostenibile del territorio ha preservato il corso d'acqua da gravi impatti dovuti alle piogge invernali.

Parole chiave: macroinvertebrati, precipitazioni piovose, trasporto di sedimenti fini, dati fisico-chimici della colonna d'acqua

How to cite

A. Corapi, L. Gallo, L. Lucadamo (2022). The effect of hydrogeomorphological disturbances on the macroinvertebrate communities in two Mediterranean watersheds with different land management criteria. Bulletin of Regional Natural History (BORNH), Bollettino della Società dei Naturalisti in Napoli. Vol. 2, n. 3, pp. 9 -27 ISSN: 2724-4393.

Introduction

In Mediterranean regions, temperature and rainfall show clear seasonal trends, with dry and warm late spring-summer periods and rainy and relatively cold autumn-winter periods. The macroinvertebrate communities exhibit biotic control of their structure in low-flow months (Bonada et al., 2007), mainly due to the number and intensity of intraspecific and interspecific interactions, whereas its re-establishment in high-flow months depends on the intensity of discharge increases as well as the time elapsing between two such events (Dudgeon et al., 2006; Jaiswal and Pandey, 2021). However, when the levels of anthropization are high, human pressures can overlap with natural hydrological disturbances, making it difficult to separate their relative contribution and resulting in fragile, more or less simplified communities prone to quick degradation following a natural perturbation. In this context geomorphological alterations are the most long-lasting anthropogenic impacts (Goudie, 2020; Oglecki et al., 2021) because of permanent habitat destruction, hydrological modification and change or loss of autochthonous or allochthonous productivity sources (Allan, 2004; Elosegi et al., 2010; Kaplan and Cory, 2016; Shields et al., 2021). As regard Calabria region (South Italy), although the Ionian side is warmer and drier than the Tyrrhenian side, it experiences the effect of North African atmospheric disturbances, resulting in tropical cyclones with extremely intense rainfall (Greco et al., 2020). On the other hand, tectonic activity and the lithology (granites, gneiss, mica-schists and phyllites that are deeply altered and broken) of the middle and southern parts result in the formation of sandy dishomogeneous masses that are easily eroded and highly crumbling (Melidoro, 1966; Cortese, 1983). Intense reforestation efforts devoted to reducing the side instability were thwarted by massive forest exploitation (Bombino, 2009) and very high fire frequency and intensity during summer season (Regione Calabria, 2018). Agriculture is diffuse, involving about 50% of regional surface. However, when arboriculture (vineyards and olive trees) prevails on sowable soils it reduces the risks of sides degradation. In the view of the above mentioned scenarios, and the increased frequency in flash floods events promoted by developing climatic changes, a monitoring campaign involving macroinvertebrate assemblages was carried out, between 2009 and 2010 in two watersheds, one Ionian (Trionto river) and one Tyrrhenian (Savuto river) showing different land management criteria and fire hazard of sides and climate characteristics. The aims of the work were: 1) to evaluate if macroinvertebrate communities show a variation mainly associated to temporal (seasonal) or spatial (from upstream to downstream) trends, 2) to detect the factors mainly driving general community parameters changes, 3) to analyze the communities structure and related most characterizing taxa as well as the representativeness of functional feeding groups.

Materials and Methods

Study area

Table 1 reports the main characteristics of the two watersheds, whereas Figure 1 shows the location of the sampling stations along the watercourses ranging, in case of Trionto, from 1000 m a.s.l. to 136 m a.s.l. and in case of Savuto from 1235 m a.s.l. to 167 m a.s.l.
Sides in the Trionto watershed are affected by severe soil erosion (DiMase and Iovino, 1988) especially in the middle upper part where very high slopes combined to timber harvesting and an extremely high fire hazard (Coschignano et al., 2019; PSR Calabria, 2014-2020) results in both an erosion rate of 0.92 mm/yr in the 40% of the total area (Olivetti et al., 2012) and triggering landslide events ranging between 21 and 100 per year, from 1921 to 2010 (Gariano et al. 2018). In the middle-lower part of the

Table 1: Natural and anthropogenic characteristics of the Trionto and Savuto watersheds.

Length of river (km)	Watershed surface (km^2)	Total inhabitants of main towns	Geology	Land use
Trionto River				
40	288	14564	Conglomerates and Sandstones, Granites, Granodiorites, Gneiss, Clays	**Middle-upper part**: permanent meadows, mixed forests, broadleaf and coniferous forests, intensive timber harvesting. **Middle-lower part**: sowable fields, olive groves, mixed annual and permanent crops, mixed forests, permanent meadows.
Savuto River				
55	411	10221	Gneiss, Phyllites, Clays, Quartzite-Clays	**Middle-upper part**: broadleaf forests, vineyards, orchards, sowable fields, permanent meadows. **Middle-lower part**: mixed annual and permanent crops, mixed forests, olive groves, sowable fields, permanent meadows.

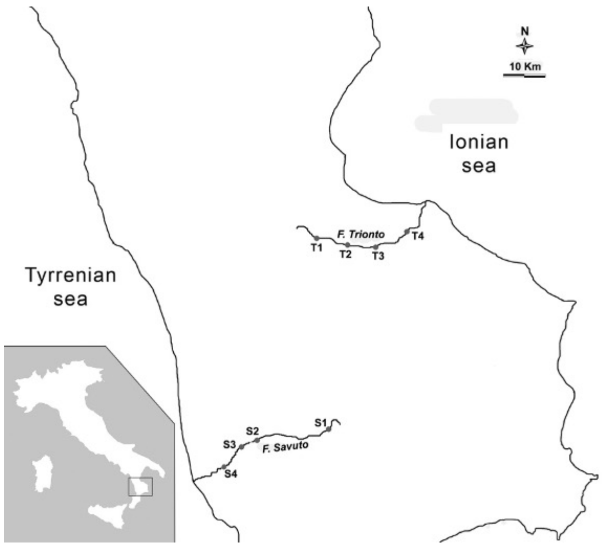

Figure 1: Placement of sampling sites along watercourses.

watershed, prevailing land components are extended olive groves and sowable fields.

Permanent meadows and crops and olive and vineyards cover 65% of Savuto watershed surface, to whom should be added more than 5000 hectares of woods included in farms (ARSAC, 2021). Fire hazard shows a patchy distribution ranging from very high to very low level. The increase in slope together with predominance of phyllitc schists, in the middle-lower part of watershed, result in virtual high erosion rates (0.60-0.80 mm/yr) (Le Pera and Sorriso-Salvo, 2000), however compensated by less soil exploitative agriculture. Indeed, the landslide events frequency ranged from 11 to 50 per year, again between 1920 and 2010 (Gariano et al., 2018). In the upper reaches, damming of the river at Poverella location resulted in the formation of a relatively small multipurpose reservoir (1 billion cubic metres) (Viceconte, 2004). The rainfall trends are consistent with the Mediterranean climate of Calabria, although Trionto watershed shows a higher frequency and intensity of very strong precipitation events i.e. days with more than 100 mm of rain per day (Protezione Civile, 2010) (Table 2).

Sampling and analytical procedures

Macroinvertebrates, water-column chemistry and substrate percentage composition were monitored from May 2009 to June 2010 on

Table 2: Rainfall data from the ARPACAL (Environmental Protection Agency of Calabria Region) database. The Longobucco and Rogliano pluviometric stations are located in the upper-middle parts of the two watersheds while the Cropalati and Savuto stations are in the lower-middle parts (available chronology: Longobucco 89 years, Cropalati 87 years, Savuto 77 years, Rogliano 90 years, all data up to 2010 except Savuto up to 2001).

Rainfall	Trionto		Savuto	
	Longobucco	Cropalati	Rogliano	Savuto
Total % of rainy days	24.7	19.9	26.44	31.65
Mean amount of rain (mm) y^{-1}	1277	1016	1164	1355
Total number of days with >100 mm of rainfall	59	82	5	10
Total % of days with >100 mm of rainfall	0.734	1.29	0.057	0.112
Total % of rain associated with rainfalls >100 mm	7.24	13.48	0.613	1.12
Mean Spacing Time (years) between two >100 mm rainfalls	1.44	1.04	24.52	4.5
Minimum and maximum (days) Spacing Times between two >100 mm rainfalls	1-3330	1-1813	1713-16780	1-6935

the following dates: May 25th, October 10th, March 25th and June 8th. Daily and monthly rainfall measurements (included three months before May 2009) came from the ARPACAL database (2022). The monthly amounts of rain were used in place of discharge variation due to the lack of stream gauges and because there is a well-known correlation between them (Ankan and Ekmekci, 1985; Gregory and Walling, 1973; Kelly et al., 2019; Pandzic and Trninic, 1999; Rebora et al., 2016; Rhoads, 2020). Macroinvertebrates samplings were conducted following a time-standardized multi-habitat proportional semi-quantitative sampling procedure (Lucadamo et al., 2008). The samples were separated from sediment and stored in 70% alcohol. Once in the laboratory, all sampled organisms were counted and identified at the family level under a Leica stereomicroscope (except for a few taxa identified at the genus level for calculation of the Extended Biotic Index) (Campaioli et al., 1994; Sansoni, 1988; Tachet, 2000). This allowed estimation of the following community parameters: Abundance, Taxonomic Richness (TR), No. EPT (Ephemeroptera, Plecoptera and Trichoptera) Taxa, Dominating Taxon (DT) (i.e. the taxon with the highest percentage within the sampled community whose value suggests the development of a perturbation when approaches 50%, Lucadamo et al., 2008, Extended Biotic Index (EBI) (Ghetti, 2001), Biological Monitoring Working Party (BMWP) (Alba-Tercedor and Sanchez-Ortega, 1988), Shannon index (calculated at family level, see Karr and Chu 1999, Zu et al. 2020), Functional Feeding Group (FFG) classification (Merrit and Cummins, 2007) and PC-RO (Precocious Colonizers-Remaining Organisms) ratio (Gallo et al. 2010). The last is the ratio between the abundance of taxa most frequently indicated in the literature as typical of the first stages of biological colonization (including the families Chironomidae, Simuliidae (Diptera) and Hydropsychidae (Trichoptera), and the genus *Baetis* (Ephemeroptera)) (Hemphill and Cooper, 1983; Downes and Lake, 1991; Ulfstrand et al., 1974; Peckarsky, 1986; Hershey and Lamberti, 2001), defined here as Precocious Colonizers, and the organism abundance of all other taxa (RO). pH, temperature and conductivity were determined in the field with a multiparameter probe (Hanna Instruments, model HI991300), whereas dissolved O_2 and relative saturation percentage were measured with an oximeter (Hanna Instruments, model HI9143). NH_4^+, NO_3^-, PO_4^{3-}, suspended solids and Chemical Oxygen Demand (COD) were evaluated in a 2-litres water sample according to APAT-CNR/IRSA methods (2003). Percentage substrate composition was estimated based on a visual criterion (EPA, 2010) and, at the same time, the Coarse Substrates - Sand ratio (CS/S) was calculated as a measure of the prevalence in erosive or depositional processes (Lucadamo et al., 2010). Spatial and temporal changes of macroinvertebrates communities structure and general community parameters were analysed using respectively Multi-Response Permutation Procedure (MRPP) and Indicator Species Analysis (ISA) and 1 Way Analysis of Variance with post hoc comparison (Tukey test), whereas association between abiotic factors and community parameters was tested by calculation of parametric correlation coefficient (Person). Multivariate Analyses were performed by PC-ORD (version 4) software and uni e bivariate analyses by Minitab (version 16) software.

Results

Analysis of the monthly rainfall clearly revealed (Fig. 2) a lower total amount of rain collected by each of the two rain gauge stations in the Trionto watershed compared to the Savuto station but a strong rainfall peaked at both Trionto watershed stations in September 2009. Indeed, 84.38% (499.4 mm) and 48.97% (192.6 mm) of the September rainfalls were concentrated in three days at Longobucco station (24th, 25th and 26th September) and in one day (25th September) at Cropalati station, respectively. As regard the physical-chemical data of water-column the mean pH values of both watersheds were largely consistent with the nature of the geological substrates (Table 3). When the average values of conductivity measured at the lowest station are compared between Trionto and Savuto watersheds, the load in ions/charged molecules was much higher in the former (413 µS cm^{-1}) vs the latter (274 µS cm^{-1}). The outcome of Trionto river probably is ascribable to the significant levels in suspended solids and maybe in COD but

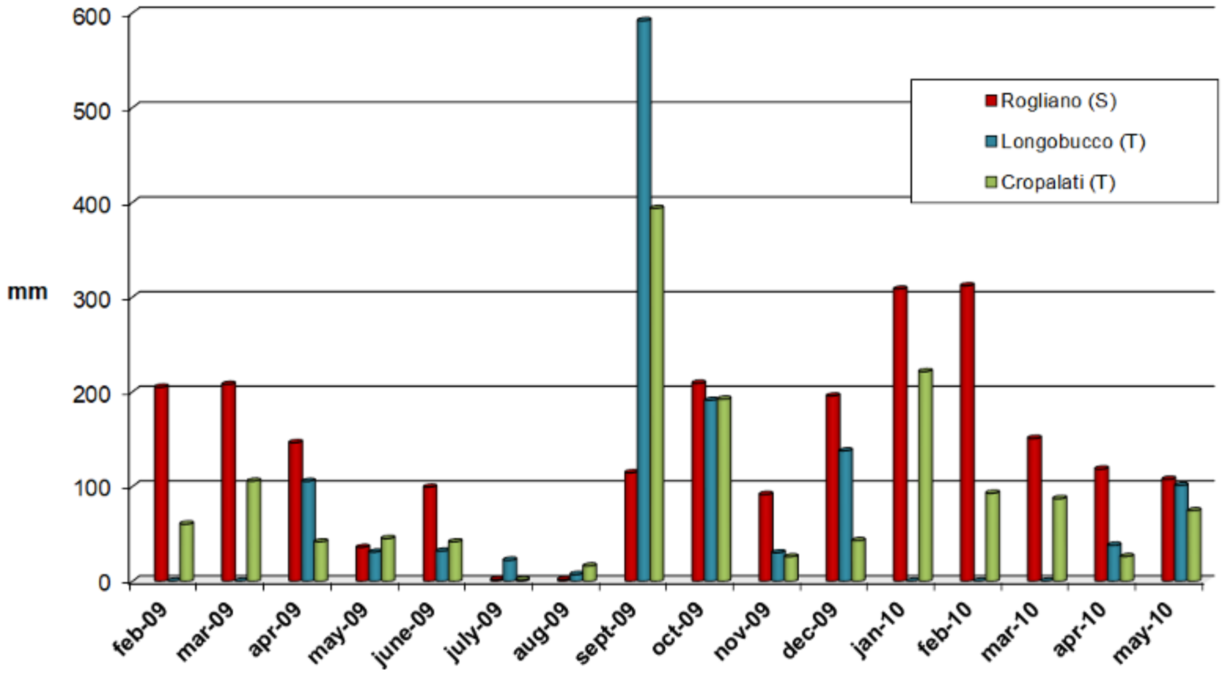

Figure 2: Pluviometric levels detected at rain gauge stations in Trionto (Longobucco and Cropalati) and Savuto (Rogliano) watersheds. S = Savuto, T = Trionto.

Table 3: Mean values of the water-column parameters related to each of the studied watersheds.

Parameters	Trionto river	Savuto river
pH	7.94	7.74
Temperature (°C)	18.27	17.48
Conductivity (µS cm^{-1})	245.50	235.63
COD (mg O_2 L^{-1})	28.21	15.47
O_2 (mg L^{-1})	8.86	9.43
% O_2	91.13	96.09
Solidi sospesi (mg L^{-1})	65.66	21.57
NH_4^+(µgg L^{-1})	2.76	43.26
NO_2^-µgg L^{-1})	0.20	0.22
NO_3^-(µgg L^{-1})	2.32	3.51
PO_4^{2-}(µgg L^{-1})	8.52	14.69
CS/FS	9.93	4.73
% Sand	26	18.75

Table 4: Macroinvertebrates community parameters. PC/RO = Precocious Colonizers/Remaining Organisms of community; EBI = Extended Biotic Index; BMWP = Biological Monitoring Working Party; WQC = Water Quality Class; EWQ = Excellent Water Quality; NC = Not Calculated; A = Absent; (*) Dominating taxon was considered absent when no organisms were collected or the residual number was so small that the condition of taxa dominance was considered meaningless (Lucadamo et al., 2008). Environmental impairment detected by water quality indexes if EBI<10 and BMWP<101.

Station	Date	No. Taxa	No. Taxa EPT	Abundance	Dominating taxon (%)	PC/RO	EBI	WQC-EBI	BMWP	WQC-BMWP	Shannon index
T1	05/09	35	15	632	38.92	0.614	11	I	200	EWQ	2.143
	10/09	17	9	233	A*	0.913	6	III	116	I	1.379
	03/10	9	5	72	A*	0.425	8	II	50	III	2.784
	06/10	18	9	1475	39.1	0.535	9	II	104	I	1.488
T2	05/09	35	18	883	35.02	0.634	10	I	223	EWQ	2.247
	10/09	-	-	-	A*	0.000	-	V	-	NC	0
	03/10	15	10	104	A*	0.372	7	III	108	I	1.826
	06/10	19	11	2533	61.65	0.904	8	II	123	I	1.205
T3	05/09	20	10	1350	46	0.887	8	II	120	I	1.520
	10/09	-	-	-	A*	0.000	-	V	-	NC	0
	03/10	10	6	47	A*	0.818	-	V	67	II	1.458
	06/10	18	7	1768	52.26	0.939	7	III	101	I	1.197
T4	05/09	14	5	820	38.29	0.894	7	III	63	II	1.687
	10/09	-	-	-	A*	0.000	-	V	-	NC	0
	03/10	1	-	2	A*	0.000	-	V	4	NC	0
	06/10	13	4	1223	52.08	0.975	6	III	56	III	1.032
S1	05/09	19	8	209	A*	0.519	8	II	88	II	1.974
	10/09	7	4	217	A*	0.977	7	II	91	II	0.599
	03/10	7	4	36	A*	0.583	4	IV	45	III	1.579
	06/10	14	8	836	70.33	0.748	9	II	90	II	1.036
S2	05/09	17	11	1764	56.85	0.864	9	II	123	I	1.383
	10/09	28	11	1096	22.11	0.354	10	I	162	EWQ	2.383
	03/10	6	4	9	A*	0.556	-	V	39	III	1.676
	06/10	23	11	988	39.67	0.789	9	II	140	I	1.783
S3	05/09	14	7	607	37.6	0.831	7	III	84	II	1.582
	10/09	19	10	975	26.76	0.691	9	II	126	I	1.841
	03/10	4	4	5	A*	0.600	0	V	29	V	1.054
	06/10	18	8	878	44.43	0.871	8	II	98	II	1.511
S4	05/09	13	8	604	33.44	0.815	8	II	94	II	2.005
	10/09	17	8	530	26.45	0.666	8	II	117	I	1.932
	03/10	-	-	-	A*	0.000	-	V	-	NC	0
	06/10	13	6	448	59.24	0.882	7	III	68	II	1.438

not to the nutrient concentrations that result to be respectively 15 (NH_4^+), 1.5 (NO_3^-) and 1.7 (PO_4^{2-}) times higher in Savuto water-column. Such a result is consistent with the high potential soil erosion of Trionto watershed sides, and the need to support the trophic requests of permanent crops in Savuto watershed with mineral nitrogen and phosphorous (Lawniczak et al., 2016).

The mean values of O_2 saturation percentage were substantially good (Ghetti, 2001), although some sub-optimal levels were detected at the Trionto stations, perhaps due to prolonged fine sediment deposition. The worst level of O_2 saturation percentage was recorded at station S1 in October 2009, owing to a prolonged period of regimentation coupled with the previous high number of degree-days (Vannote and Sweeney, 1980).

Table 4 shows the values of the general community parameters calculated in occasion of the 4 sampling dates. When their variation is matched to that of abiotic drivers, as cumulative effect at the levels of both watersheds, the only significant association were found with rainfalls, suspended solids and ratio between Coarse Substrates and Sand (CS/S) with values of Pearson coefficient mostly indicating negative correlations, ranging from -0.475 to -0.836, except in case of covariance between amount of precipitations and PC/RO and CS/S (Table 5).

Table 5: Statistically significant Pearson correlation coefficient between abiotic drivers and community parameters calculated at the level of both watersheds (CS/S = Coarse Sediments/Sand).

Correlations	**r**	**r^2**	**p**
Rainfalls-Shannon index	-0.836	0.698	0.01
Rainfalls-N. of Taxa	-0.714	0.509	0.047
Rainfalls-N. of EPT	-0.773	0.597	0.024
Rainfalls-PC/RO	0.561	0.314	0.033
Rainfalls-EBI	-0.735	0.540	0.038
Rainfalls-CS/S	0.720	0.518	0.044
Suspended solids-Abundance	-0.475	0.225	0.006
Suspended solids-PC/RO	-0.546	0.001	0.298
CS/S-Shannon index	-0.716	0.512	0.046

The comparison of mean community parameters made between both watersheds and stations selected within each watersheds do not show any significant difference suggesting the missing of relevant spatial gradients developing along the rivers. This is the consequence of the very high average slopes of sides together with the short length of the watercourses making the rhytral morphology dominant for about ¾ of the length.

On the contrary, Anova performed on the sampling dates (Table 6) clearly indicates that most of the variation affecting communities is associated to the seasonality. Indeed, in case of Trionto river four parameters (Shannon index, N. of Taxa, Abundance and Dominating taxon) showed significant values of F, whereas Savuto river displayed such an outcome for N. of Taxa, N. of EPT Taxa and Dominating Taxon.

As regard the water quality indexes applied to the present study EBI detected as well more cases of environmental alterations than BMWP (Gallo et al., 2003) as the presence of a higher amount of stenoecious taxa in the upper tract of Trionto compared to Savuto river with both of them clearly showing strong value changes associated to sampling dates. In addition, the indexes suggested that, in absence of hydro-geomorphological pressures, most of the stations are

Table 6: Statistically significant results of 1-way ANOVA and post hoc multiple comparison (Tukey test) performed on the 4 different sampling dates, separately per each watershed.

Watershed	Month	Taxon	Indicator Value	p
Trionto	March 2010	Taenyopterigidae	71.5	0.035
	June 2010	Baetidae	67.9	0.003
		Ephemerellidae	78.4	0.037
		Chironomidae	91.1	0.009
		Simuliidae	67.8	0.033
	May 2009	Glossosomatidae	100	0.003
		Dixidae	75	0.021
		Hydropsychidae	54.5	0.026
		Tabanidae	100	0.003
Savuto	October 2009	Leuctridae	70.7	0.016
	June 2010	Ephemerellidae	73.9	0.007
		Ceratopogonidae	80	0.01
		Tipulidae	75	0.03

characterized by a sub-optimal suitability to host well-structured communities. When the same analysis is transferred at the level of community structure (family composition) the result matches that obtained for the general communities parameters. Performing a Multiresponse Permutation Procedure (MRPP) on the whole database (stations-sampling dates x collected taxa), a significant value of test statistic T resulted only when using as factor the sampling dates (Trionto: T=-4622, Chance-corrected within group agreement A=0.3110, Probability of a smaller or equal delta p=0.00092, Savuto: T=-4.9903, Chance-corrected within group agreement A=0.2047, Probability of a smaller or equal delta p=0.00028).

Indicator Species Analysis devoted to the identification of families responsible of this temporal segregation revealed that within the range of statistically significant Indicator Values, 61% were associated to the Trionto sampling dates (May, March and June) while only 23% gave the same result for Savuto

Table 7: Statistically significant results of Indicator Species Analysis performed on the database.

Watershed	Parameters	F	p	SSD
Trionto	Shannon index	3.56	0.048	May 09> October 09
	N. of Taxa	6.47	0.007	May 09 > October 09, March 10
	Abundance	24.48	<0.00005	May 09 > October 09, March 10 June 10 > May 09, October 09, March 10
	Dominating Taxon	106.03	<0.00005	May 09 > October 09, March 10 June 10 > May 09, October 09, March 10
Savuto	N. of Taxa	5.75	0.011	May 09, October 09, June 10 > March 10
	N. of EPT Taxa	5.47	0.013	May 09, October 09, June 10 > March 10
	Dominating Taxon	9.04	0.002	June 10 > October 09, March 10 May 09 > March 10

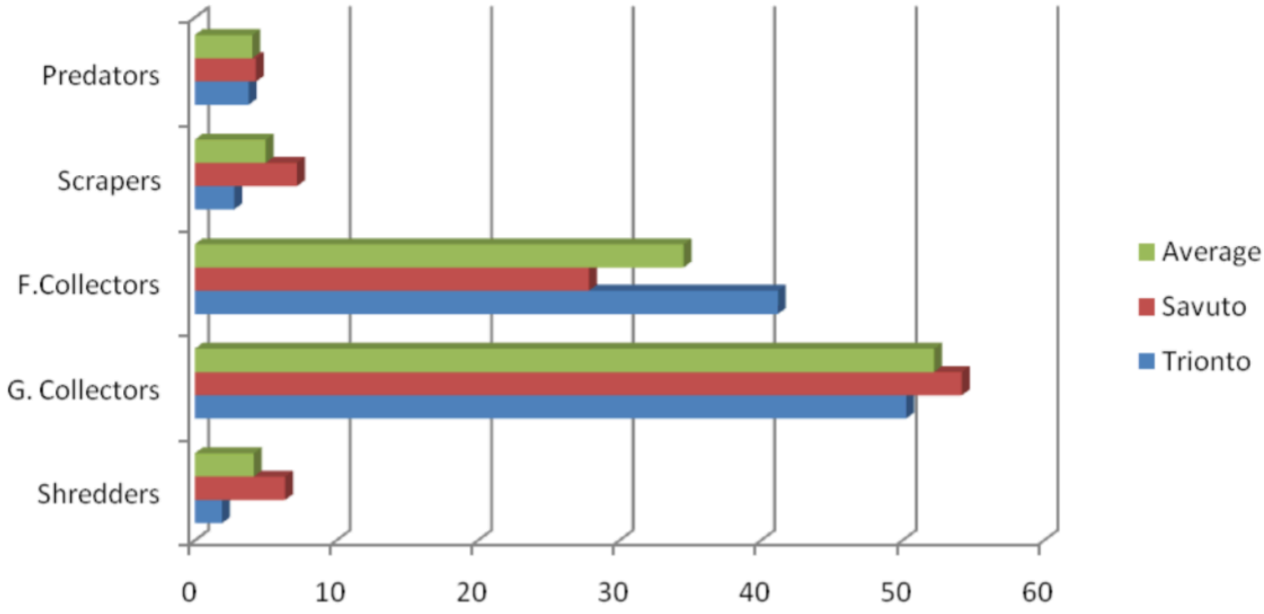

Figure 3: Representativeness of Functionl Feeding Groups in the monitored watersheds (means across stations and sampling dates). F = Filtering, G = Gathering.

watershed (October, June) (Table 7) suggesting a less frequent occurrence of family-specific selective conditions in case of the latter.

Analysis of representativeness of functional feeding groups revealed that the collectors contributed 86.8% of total sampled organisms (Figure 3). Savuto percentage in shredders and scrapers were respectively 3.31 and 2.58 times higher than those of Trionto river indicating better levels of allochthonous and autochthonous primary productivity in the case of the former watercourse. On the other hand, Trionto watershed showed a comparable percentage of gathering collectors but an amount of filtering collectors around 50% higher than that of Savuto. The average value of Filtering Collectors - Gathering Collectors ratio equals to 0.819, suggesting a remarkable load of suspended FPOM (Merrit and Cummins. 2007), that resulted to be 60% higher than that detected in Savuto river (0.514).

Discussion

The three months preceding the beginning of the monitoring period were substantially lacking of significant precipitation events and this suggests that the structure of the macroinvertebrates communities recorded in May 2009 would be passing under the control of biotic factors (Monk et al., 2006; Poff and Ward, 1989) except in the presence of human pressures that favour the settlement of taxa tolerating environmental alterations, a result that seem to be detected by values registered by Shannon index (Ravera, 2001), EBI and BMWP (Table 4).

The remarkable precipitation that took place at the end of September 2009 in the Trionto watershed can be really considered exceptional. In fact, such a high amount falling in a few successive days has never been recorded at the Longobucco station (minimum: 232 mm, maximum: 404 mm) and only once (516 mm in three days) in 1930 at the Cropalati station suggesting a recurrence time of 80 years. The average value of CS/S of Trionto watershed was about the double of that of Savuto watershed (Table 3). This ratio equalled to 50 at station T2 in October sampling, while reduced to 0.5-0.7 at downstream stations in October and March, suggesting a remarkable flushing of fine sediments in upper tract resulting in substrate armouring a phenomenon that produces strong habitat simplification and depression of biological colonization (Svendsen et al., 2009; Addy et al. 2016). On the other side, a comparable deleterious effect on macroinvertebrates community may arise from excess in fine sediment deposition, especially when sand approaches 40-50% in substrate composition (Spindler, 2004; Lucadamo et al., 2010) a process that took place in the lower-middle part of watershed (stations T3 and T4) following upstream flushing. Our data suggests that particularly high value in flow (following extremely infrequent rainfalls) and riverbed disturbance temporary depressed taxa richness and biodiversity, i.e. promoting disappearing of families as indicated by 1-way ANOVA (Table 6). On the other hand, change in abundance, included significant niche dilatation, persisted until June 2010 (Table 6). They were related to both increase of suspended solids (Table 4), probably as a consequence of removal of organisms inhabiting exposed surfaces, and dispersion strategies as indicated by ISA (Table 7) showing as characterizing families, in the last sampling date, Chironomidae, Baetidae and Simuliidae, typical r-strategy taxa, that were less represented in the May 2009 sampling (- 20%). EBI and BMWP displayed a similar result as a consequence of the weight, in their calculation, of these euriecious organisms that contributed to lowering the respective final scores.

Post-flood recovery times are usually shorter than that recorded in our study for fauna pre-adapted to frequent floods (Collins et al., 1981; Fisher et al., 1982; Mundahl and Hunt, 2011; Rader et al., 2007; Scrimgeour, 1988), as should be the case for the Trionto watershed given the historical pluviometric data. Several factors can have contributed to such an outcome.

First of all, the interaction between sides soil erosion, caused by poor land management criteria, and a very strong rainfall (and discharge) event. Indeed, scientific literature suggests that relevant factors promoting increase in as well superficial and sub-superficial runoff as load in fine sediments to watercourses are timber harvesting and forest fires associated to strong precipitations (Bruijnzeel, 2004; Cook et al., 2020; Richardson and Béraud, 2014; Soulis et al., 2021; Schawrtz et al., 2021), the former constantly affecting Trionto watershed and the latter occurring just during the present sampling campaign. Secondly, the timing of the exceptional rainfalls; in fact, most of the strongest daily rains in the Trionto watershed occur, based on historical data, between October and February and only 7-8% in September, suggesting that the effect of the hydrogeomorphological disturbance on benthic communities could have been exacerbated by the unusual timing of such extremely intense short-term precipitation, compromising sensitive life stages of macroinvertebrates organisms such as egg lying or emergence (Ghetti, 2001; Cattaneo et al., 2006; Allan and Castillo, 2007). Thirdly, a potential involvement of hyporheos, suggested by the macroscopic morphological change experienced by riverbed, destroying most of refuge zones (Goudie, 2020), may have contributed to delay the appearance, in the communities, of stenoecious taxa, with a slower colonization capacity.

The hydrogeomorphological temporal changes occurred in Savuto river did not involve the organisms abundance but rather the short lasting variations of on local-scale spatial heterogeneity and associated number of taxa (Table 6). The timing of watercourse disturbance was different from that of Trionto, because the strongest rainfalls occurred in winter, with manifestation of severe communities impairment associated to the March 2010 sampling (Table 6). On the contrary, water quality and Shannon indexes pointed to an improvement of environmental conditions in half of the stations in October sampling and in the view of crops grown in the Savuto watershed (especially vine-yards and olive-yards) (Eynard and Dalmasso, 1990; Istruzione Agraria Online, 2010; Rossi, 2010) it can be associated to a reduction of chemicals (fertilizers and pesticides) fluxes to hydrological network. A different trend was detectable at station S1 due to the regimentation promoted by river damming. Indeed, in three out of four sampling dates the segment showed clear effect of the reservoir activities i.e. drop in oxygen, sand accumulation and large woody debris heaped on riparian zones, suggesting a remarkable interruption of river connectivity with related consequences on macroinvertebrates communities (Allan and Castillo, 2007; Pringle, 1996). In fact, same rheophilous families, adapted to relatively high current values (Ghetti, 2001), like Hydropsychidae, Lepidostomatidae, Athericidae and Blephariceridae, well represented in the other tracts, disappeared. As regard the other stations, only that closest to the mouth resulted to be still affected by a drop in EBI and biodiversity levels in June 2010 compared to the values of May 2009 probably due to the cumulative effect of hydrogeomorphological and chemicals impact (maximum load in sediments, fertilizers and pesticides). The analysis of feeding functional structure is consistent with the previous environmental picture (Table 8). Indeed, FPOM results to be the most abundant energy resource in both watersheds, a condition typically detected in unstable watercourses (Johnson et al., 2018; Kelso and Baker, 2020; Jenneau et al., 2018; Jacinthe et al., 2004). However, the filtering collectors are much more represented in Trionto probably also due to the higher potential erodibility of sides. This result shows a satisfying match with that of average concentration of COD: it is 28.2 in Trionto and 15.5 in Savuto with a ratio of 1.82, again supporting the dilation of niches of suspended FPOM feeders detected in the former. Accordingly to the more conservative agriculture practiced in Savuto watershed, the condition of riparian woods seem to be better than that of Trionto as indicated by the higher average amount of shredders collected and the peaks in October and June respectively of Leuctridae and Tipulidae, well known consumers of Coarse Particulate Organic Matter (CPOM). On the other side, the much lower levels of suspended solids in Savuto, probably results in a lower water-column turbidity promoting a better colonization of benthic primary productivity utilizers.

Conclusions

The very intense tectonic activity and peculiar lithology of Calabria coupled with strong rainfalls make the watercourse network susceptible to severe fluctuations in flow and sediment load. The results of the present work suggested that when anthropogenic pressures, like those causing further changes in discharge variation and sediment fluxes from the valley sides interact with the aforesaid environmental background, the natural short-to-medium-term physiognomic evolution of river channels is strongly impaired, resulting in severe disturbances to the freshwater macroinvertebrates. In such a condition the main trophic resource was the FPOM resulting from land run off and sediment resuspension because of the absolute reduction in benthic primary productivity and riparian CPOM. In the case of the Trionto River a very strong rainfall pulse perturbation was coupled with diffuse timber harvesting and fires resulting in an extreme hydrogeomorphological alteration. This consisted, upstream in riverbed armouring and consequently, downstream in substantial burial of substrate both severely delaying the recovery of macroinvertebrate communities. Damming in the Savuto River caused permanent flow abatement and hydrological connectivity interruption which changed rhithral physiognomy to one looking like a potamal morphology, eliminating more rheophilous taxa. The communities of lower reaches, because of a better sides soil management and a less severe rainfall perturbation, being pre-adapted to climatic alteration, quickly recovered. Due to the lack of any other relevant pressure systematically affecting the watercourses, toxic fluxes of agriculture chemicals driven by irrigation run-off may be considered the main factor, in the low-flow period, causing a general depression of biodiversity in both watersheds although the magnitude of its effect was not investigated.

Author contributions

All the authors equally contributed to this work

References

Addy S., Cooksley S., Dodd N., Waylen K., Stockan J., Byg A., Holstead K. (2016). River Restoration and Biodiversity – Nature-Based Solutions for Restoring the Rivers of the UK and Republic of Ireland. IUCN – National Committee United Kingdom and CREW. https://www.crew.ac.uk/.

Alba-Tercedor J., Sanchez-Ortega A. (1988). Un metodo rapido y simple para evoluar le calidad biologica de las aguas corrientes basado en el de Halliwell (1978). *Limnetica*, **4**(1): 51-56.

Allan. J.D. (2004). Landscapes and rivercapes: the influence of land use on stream ecosystems. *Annu. Rev. Ecol. Evol. Syst.*, **35**(1), 257-284. https://doi.org/10.1146/annurev.ecolsys.35.120202.110122.

Allan. J.D., Castillo M.M. (2007). Stream Ecology - Structure and Function of Running Waters. 2nd Ed. Dordrecht: Springer.

Ankan A., Ekmekci M. (1985). A multidimensional approach to rainfall-streamflow relationship in Manavgat river basin. Turkey. Karst Water Resources. In *Proceedings of the Ankara - Antalya*

Symposium. IAHS Publications no. 161, pp. 57-65.

APAT-CNR/IRSA (2003). Metodi analitici per le acque (Vol. I. II). Roma. Quaderni APAT.

ARSAC (2021). Rapporto di ricerca – l'agricoltura nell'area del Savuto e percezione degli impatti dei cambiamenti climatici in agricoltura. A cura di dr. Angelo De Simone. Centro Divulgazione Agricola n. 9 Amantea. https://www.arsacweb.it/wp-content/uploads/2021/05/ARSAC-RAPPORTO-DI-RICERCA-Lagricoltura-nellarea-del-Savuto.pdf.

Arpacal (2022). Centro Funzionale Multirischi. Dati Storici. https://www.cfd.calabria.it.

Bombino G. (2009). La difesa del suolo in Calabria dopo l'Unità d'Italia. In Atti del Convegno "La Scienza nel Mezzogiorno dall'Unità d'Italia ad Oggi". 16-17 Ottobre. Reggio Calabria: Accademia delle Scienza Detta Dei XI.

Bonada N., Rieradevall M., Prat N. (2007). Macroinvertebrate community structure and biological traits related to flow permanence in a Mediterranean river network. *Hydrobiologia*, **589**, 91-106. https://doi.org/10.1007/s10750-007-0723-5.

Bruijnzeel A. (2004). Hydrological functions of tropical forests: not seeing the soil for the trees? *Agric. Ecosyst. Environ.*, **104**(1), 185-228. https://doi.org/10.1016/j.agee.2004.01.015.

Campaioli S., Ghetti P.F., Minelli A., Ruffo S. (1994). Manuale per il Riconoscimento dei Macroinvertebrati delle Acque Dolci Fluviali Vol. I. Trento: Provincia Autonoma di Trento.

Cattaneo A., Salmoiraghi G., Gazzera S. (2006). The rivers of Italy. In C.E. Cushing, K.W. Cummins, G.W. Minshall (Eds) *River and Stream Ecosystems of the World*, pp. 479-505. Berkeley and Los Angeles: University of California Press.

Collins J.P., Young G., Howell J., Minckley W.L. (1981). Impact of flooding in a Sonoran Desert stream including elimination of an endangered fish population (*Poeciliopsis o. occidentalis*, Poeciliidae). *Southwest. Nat.*, **26**(4), 415-423. https://doi.org/10.2307/3671085.

Cook T.L., Snyder N.P., Oswald W.W., Paradise K. (2020). Timber harvest and flood impacts on sediment yield in a postglacial. mixed-forest watershed. Maine. USA. Anthropocene, **29**, 100232. https://doi.org/10.1016/j.ancene.2019.100232.

Cortese E. (1983). Descrizione geologica della Calabria. Villa S. Giovanni: Casa del libro editrice. pp. 338.

Coschignano G., Nicolaci A., Ferrari E., Cruscomagno F., Iovino F. (2019). Evaluation of hydrological and erosive effects at the basin scale in relation to the severity of forest fires. *IForest*, **12**(5), 427-434. https://doi.org/10.3832/ifor2878-012.

Dimase A.C., Iovino F. (1988). Capacità d'uso dei suoli dei bacini idrografici del Trionto. Nicà e torrenti limitrofi (Calabria). Pubblicazione no. 4,pp. 1-56. Cosenza: CNR. Istituto di Ecologia ed Idrologia Forestale.

Downes B.J., Lake P.S. (1991). Different colonization patterns of two closely related stream insects (*Austrosimulium* spp.) following disturbance. *Freshwater Biol.* , **26**(2), 295-306. https://doi.org/10.1111/j.1365-2427.1991.tb01736.x.

Dudgeon D., Arthington A.H., Gessner M.O., Kawabata Z.I., Knowler D.J., Leveque C., Naiman R.J., Prieur-Richard A.H., Soto D., Stiassny M.L.J., Sullivan C.A. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biol. rev. biol. Proc. Camb. Philos. Soc.*, **81**(2), 163-182. https://doi.org/10.1017/S1464793105006950.

Elosegi A., Diez J., Mutz M. (2010). Effects of hydromorphological integrity on biodiversity and functioning of river ecosystems. *Hydrobiologia*, **657**(1), 199-215. https://doi.org/10.1007/s10750-009-0083-4.

EPA (2010). Habitat Assessment and Physicochemical Parameters Chapter 5. Part B. http://water.epa.gov/scitech/monitoring/srl/bioassessment/upload/0000_00_00_monitoring_rbp_wp61pdf_ch_05.pdf. Accessed 18 December 2009.

Eynard I., Dalmasso G. (1990). Viticoltura moderna - manuale pratico. Milano: Ulrico Hoepli Editore. pp. 782.

Fisher S.G., Gray L.G., Grimm N.B., Busch D.E. (1982). Temporal succession in a desert stream ecosystem following flash flooding. *Ecol. Monographs*, **52**(1), 93-110. https://doi.org/10.2307/2937346.

Gallo L., De Filippis A., Mezzotero A., Voelz N.J., Lucadamo L. (2010). Assessment of the effect of hydrological variations on macrobenthic communities in pools and riffles of a Mediterranean stream. *Environ. Monit. Assess.*, **166**(1-4), 125-137. https://doi.org/10.1007/s10661-009-0989-3.

Gallo M. (2003). Monitoraggio biologico dei principali fiumi presenti nel parco nazionale del Pollino attraverso l’utilizzo di tre diversi indici biotici. Tesi di laurea in Scienze Naturali. Facoltà di Scienze Matematiche. Fisiche e Naturali. Università degli Studi della Calabria.

Ghetti P.F. (2001). Indice Biotico Esteso – I macroinvertebrati nel controllo della qualità degli ambienti di acque correnti. Trento: Provincia Autonoma di Trento.

Goudie A. (2020). The human impact in geomorphology – 50 years of change. *Geomorphol.*, **366**(1), 106601. https://doi.org/10.1016/j.geomorph.2018.12.002.

Gray L.J., Ward J.V. (1982). Effects of sediment releases from a reservoir on stream macroinvertebrates. *Hydrobiologia*, **96**(2), 177-184. https://doi.org/10.1007/BF02185433.

Greco A., De Luca D.L., Avolio E. (2020). Heavy Precipitation Systems in Calabria Region (Southern Italy): High-Resolution Observed Rainfall and Large-Scale Atmospheric Pattern Analysis. *Water*, **12**(5), 1468. https://doi.org/10.3390/w12051468.

Gregory K.J., Walling D.E. (1973). Drainage basin form and processes. London: Edward Arnold.

Hemphill. N., Cooper. S.D. (1983). The effect of physical disturbance on the relative abundances of two filter-feeding insects in a small stream. *Oecologia*, **58**(3), 378-382. https://doi.org/10.1007/BF00385239.

Hershey A.E., Lamberti G.A. (2001). Aquatic insect ecology. In J.H. Thorp & A.P. Covich (Eds). Ecology and classification of North American freshwater invertebrates, 2nd edition, pp. 733-775. San Diego: Academic Press.

Istruzione Agraria Online (2010). Grano o frumento tenero – *Triticum* spp. Atlante delle coltivazioni erbacee: cereali. https://

www.agraria.org/coltivazionierbacee/granotenero.htm.

Jacinthe, P.-A., Lal R., Owens L.B., Hothem D.L. (2004). Transport of labile carbon in runoff as affected by land use and rainfall Characteristics. *Soil Tillage Res.*, **77**(2), 111-123. https://doi.org/10.1016/j.still.2003.11.004.

Jaiswal D., Pandey J. (2021). River ecosystem resilience risk index: A tool to quantitatively characterize resilience and critical transitions in human-impacted large rivers. *Environ. Pollut.*, **268**, 115771. https://doi.org/10.1016/j.envpol.2020.115771.

Jeanneau L., Rowland R., Inamdar S. (2018). Molecular fingerprint of particulate organic matter as a new tool for its source apportionment: changes along a headwater drainage in coarse, medium and fine particles as a function of rainfalls. *Biogeosciences*, **15**(4), 973-985. https://doi.org/10.5194/bg-15-973-2018.

Johnson E.R., Inamdar S., Kan J., Vargas R. (2018). Particulate Organic Matter Composition in Stream Runoff Following Large Storms: Role of POM Sources, Particle Size and Event Characteristics. *J. Geophys. Res. Biogeosci.*, **123**(2), 660-675. https://doi.org/10.1002/2017JG004249.

Kaplan L.A., Cory R.M. (2016). Dissolved Organic Matter in Stream Ecosystems: Forms. Functions. and Fluxes of Watershed Tea. In J.B Jones & E.H. Stanley (Eds) *Stream Ecosystems in a Changing Environment*,Chapter 6, pp. 241-320. Academic Press: Cambridge. MA. USA.

Kelly L., Kalin R.M., Bertram D., Kanjaye M., Nkhata M., Sibande H. (2019). Quantification of Temporal Variations in Base Flow Index Using Sporadic River Data: Application to the Bua Catchment. Malawi. *Water*, **11**(5), 901. https://doi.org/10.3390/w11050901.

James R. Karr and Ellen W. Chu, Restoring Life in Running Waters: Better Biological Monitoring: (1999) Island Press, Washington D.C. ISBN 1–55963–674–2, 206

Kelso J.E., Baker M.A. (2020). Organic Matter Is a Mixture of Terrestrial, Autochthonous, and Wastewater Effluent in an Urban River. Frontiers in Environmental. *Science*, **7**, 202. https://doi.org/10.3389/fenvs.2019.00202.

Lawniczak A.E., Zbierska J., Nowak B., Achtenberg K., Grześkowiak A., Kanas K. (2016). Impact of agriculture and land use on nitrate contamination in groundwater and running waters in central-west Poland. *Environ. Monit. Assess.*, **188**(3), 172. https://doi.org/10.1007/s10661-016-5167-9.

Le Pera E., Sorriso-Salvo M. (2000). Weathering. erosion and sediment composition in an high gradient river. Calabria. Italy. *Earth Surf. Process. Landf.* , **25**(3), 277-292. https://doi.org/10.1002/(SICI)1096-9837(200003)25:33.0.CO;2-Z. .

Lucadamo L., De Filippis A., Mezzotero A., Vizza S., Gallo L. (2008). Biological and chemical monitoring of some major Calabrian (Italy) rivers. *Environ. Monit. Assess.* **146**(1-3), 453-471. https://doi.org/10.1007/s10661-007-0091-7.

Lucadamo L., Mezzotero A., Voelz N.J., Gallo L. (2010). Seasonal changes of abiotic and biotic gradients downstream a multiple use reservoir in a Mediterranean river. *River Res. Appl.*, **28**(1), 103-117. https://doi.org/10.1002/rra.1440.

Melidoro G. (1966). Scorrimenti gravitativi quaternari di argille scagliose ofiolitifere e frane indotte nei depositi pleistocenici dei dintorni di Cassano Jonio. *Geologia Applicata ed Idrogeologia*, **1**, 89-91.

Merrit R.W., Cummins K.W. (2007). Trophic Relationships of Macroinvertebrates. In R. Hauer & G.A. Lamberti (Eds) *Methods in Stream Ecology*, 2nd Edition,pp. 585-609. Academic Press. Elsevier.

Monk W.A., Wood P.J., Hannah D.M., Wilson D.A., Extence C.A., Chadd R.P. (2006). Flow variability and macroinvertebrate community response within riverine systems. *River Res. Appl.*, **22**(5), 595-615. https://doi.org/10.1002/rra.933.

Mundahl N.D., Hunt A.M. (2011). Recovery of stream invertebrates after catastrophic flooding in south eastern Minnesota. USA. *J Freshw Ecol.* , **26**(4), 445-457. https://doi.org/10.1080/02705060.2011.596657.

Oglecki P., Ostrowski P.S., Utratna-Zukowska M. (2021). Natural and Geomorphological Response of the Small Lowland River Valley for Anthropogenic Transformation. *Resources*, **10**(10), 97. https://doi.org/10.3390/resources10100097.

Olivetti V., Cyr A.J., Faccenna C., Granger D.E. (2012). Uplift history of the Sila Massif. deciphered from cosmogenic 10Be rates and river longitudinal profile analysis. *Tectonics*, 31(3), TC3007. https://doi.org/10.1029/2011Tc003037.

Pandzic K., Trninic D. (1999). Relationship between monthly precipitation, the Sava river discharge and large-scale circulation. *Geofizika*, **16/17**, 53-63. http://geofizika-journal.gfz.hr/Vol_1617/geofizika_1617_19992000_53-63_pandzic.pdf.

Peckarsky B.L. (1986). Colonization of natural substrates by stream benthos. *Can. J. Fish. Aquat.*, **43**(3), 700-709. https://doi.org/10.1139/f86-085..

Poff N.L., Ward J.V. (1989). Implications of streamflow variability and predictability for lotic community structure: a regional analysis of streamflow patterns. *Can. J. Fish. Aquat.*, **46**(10), 1805-1818. https://doi.org/10.1139/f89-228.

Pringle C.M. (1996). Atyid shrimps influence the spatial heterogeneity of algal communities over different scales in tropical montane streams. Puerto Rico. *Freshw. Biol.*, **35**(1), 125-140. https://doi.org/10.1046/j.1365-2427.1996.00487.x.

Protezione Civile (2010). Guida alla consultazione del bollettino di vigilanza meteorologica nazionale. www.protezionecivile.i/download/glossario_legendameteo.pdf. Accessed 13 January 2011.

PSR Calabria 2014- 2020. Cartografia e Zonizzazione. http://www.calabriapsr.it/cartografia-e-zonizzazione.

Rader R.B., Voelz N.J., Ward J.V. (2007). Post-Flood Recovery of a Macroinvertebrate Community in a Regulated River: Resilience of an Anthropogenically Altered Ecosystem. *Restor. Ecol.*, **16**(1), 24-33. https://doi.org/10.1111/j.1526-100X.2007.00258.x.

Ravera O. (2001). A comparison between diversity. similarity and biotic indices applied to the macroinvertebrate community of a small stream: the Ravella river (Como Province: Northern Italy). *Aquat. Ecol.*, **35**, 97-107. https://doi.org/10.1023/A:1011433813309.

Rebora N., Silvestro F., Rudari R., Herold C., Ferraris L. (2016). Downscaling stream flow time series from monthly to daily scales using an auto-regressive stochastic algorithm: StreamFARM. *J. Hydrol.*, **537**, 297-310. https://doi.org/10.1016/j.jhydrol.2016.03.015.

Regione Calabria (2018). Piano regionale per la prevenzione e la Lotta attiva agli incendi boschivi. Art. 3 Legge n. 353 del 21 Novembre 2000 (Legge Quadro in materia di incendi boschivi). Art. 3 L.R. 51 del 22 Dicembre 2017 (Norme di attuazione della legge 21 novembre 2000 n. 254). https://www.regione.calabria.it/website/portalmedia/2018-05/pianoAIB20182.pdf

Rhoads B.L. (2020). The Dynamics of Drainage Basins and Stream Networks. In: Rhoads B.L. (Ed) *River Dynamics: Geomorphology to Support Management*,pp. 15-46. Cambridge: Cambridge University Press. https://doi.org/10.1017/9781108164108.002.

Richardson J.S., Béraud S. (2014). Effects of riparian forest harvest on streams: a meta-analysis. *J. Appl. Ecol.*, **51**(6), 1712-1721. https://doi.org/10.1111/1365-2664.12332.

Sansoni G. (1988). Atlante per il Riconoscimento dei Macroinvertebrati dei Corsi d'Acqua Italiani. Provincia Autonoma di Trento: Trento.

Schawrtz J.Y., Oakley N.S., Alessio P. (2021). Assessment of a Post-Fire Debris Flow impacting El Capitan Watershed. Santa Barbara County. California. USA. *Environ. Engin. Geosci.*, **27**(4), 423-437. https://doi.org/10.2113/EEG-D-21-00008.

Scrimgeour G.J., Davidson R.J., Davidson J.M. (1988). Recovery of benthic macroinvertebrates and epilithic communities following a large flood. in an unstable braided New Zealand River. *N. Z. J. Mar. Freshwater Res.*, **22**(3), 337-334. https://doi.org/10.1080/00288330.1988.9516306.

Shields R., Pyron M., Arsenault E.R., Thorp J.H., Minder M., Artz C., Costello J., Otgonganbat A., Mendsaikhan B., Altangerel S., Maasr A. (2021). Geomorphology variables predict fish assemblages for forested and endorheic rivers of two continents. *Ecol Evol.*, **11**(23), 16745-16762. https://doi.org/10.1002/ece3.8300.

Spindler P. (2004). Stream Channel Morphology and Benthic Macroinvertebrate Community Associations in the San Pedro River and Verde River Basin. 1999-2002. Arizona Department of Environmental Quality. Water Quality Division. Hydrologic Support and Assessment Section. Surface Water Monitoring and Standard Unit. St., Phoenix. Open File Report 04–01. https://www.azdeq.gov/environ/water/assessment/download/corr.pdf.

Svendsen K.M., Renshaw C.E., Magilligan F.J., Nislow K.H., Kaste J.M. (2009). Flow and sediment regimes at tributary junctions on a regulated river: impact on sediment residence time and benthic macroinvertebrate communities. *Hydrol Process.*, **23**, 284-296.

Tachet H., Richoux, P., Bournaud M., Usseglio-Polaterra P. (2000). Invertébrés d'Eau Douce-systematique. Biologie Ecologie. CNRS Editions. Paris.

Ulfstrand S., Nilsson L.M., Stergar A. (1974). Composition and diversity of benthic species collectives colonizing implanted substrates in south Swedish stream. *Scand. Entomol.*, **5**(2), 115-122. https://doi.org/10.1163/187631274X00146.

Vannote R.L., Sweeney B.W. (1980). Geographic analysis of thermal equilibria: a conceptual model for evaluating the effect of natural and modified thermal regimes on aquatic insect communities. *Am. Nat.*, **115**(5), 667-695.

Viceconte G. (2004). Calabria – Il sistema idrico. Quaderno n°9. Quadro Comunitario di Sostegno per le Regioni Italiane dell'Obiettivo 1. Programma Operativo Nazionale di Assistenza Tecnica e di Sistema (PONATAS) 2000-2006. Progetto operativo Risorse idriche II stralcio funzionale. https://sirsi.infrastrutturetrasporti.it/reserved/StudidiSettore/Quaderno_9.pdf.

Zu Y., van der Werf W., Liu W., Axmacher J.C. (2020) Predictability of species diversity by family diversity across a global terrestrial animal taxa, *Glob. Ecol. Biogeogr.*, **29**(4), 629-644.

Bulletin of Regional Natural History (BORNH) ISSN 2724-4393.