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# Effects of floods on macroinvertebrate communities in the Zarin Gol River of northern Iran: implications for water quality monitoring and biological assessment

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## Abstract

**Background:** The timing, magnitude, and duration of extreme hydrological disasters have the potential to threaten the species diversity and river habitats. On August 8, 2014, and August 19, 2017, disastrous floods struck mountainous regions of Iran's Zarin Gol River basin. Macroinvertebrate communities were studied at seven upstreams prior to the floods in June 2014 and 2017 and after the floods in September 2014 and 2017 and 9 months after the second flood in June 2018. The effects of floods on macroinvertebrate communities, recovery rate of macroinvertebrate community resilience and influencing factors were investigated.

**Results:** Despite the fact that extreme floods were the only reason of the disruption, the effects of biological water quality assessment metrics after the disaster were comparable to those of heavily polluted waters. Biological indicators revealed that the communities were unaffected prior to the floods, and the water quality remained within acceptable limits. Following the disasters, the density of macroinvertebrates declined, and biological indicators demonstrated the severe depletion of water quality. Community indicators (species richness, percent model affinity (PMA), and Ephemeroptera, Plecoptera, and Trichoptera (EPT) richness) rebounded after 9 months (June 2018), demonstrating that Zarin Gol River's macroinvertebrate communities could recover even after the severe impact of the floods. As a result, macroinvertebrate samples taken from flood-affected areas revealed that extreme flooding, rather than a decrease in water quality, causes a loss of diversity and abundance.

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**Conclusion:** Because of shifts in hydrological regimes in streams around the world, understanding the short-term impacts of strong flooding and the comparatively quick recovery of macroinvertebrate ecosystems has important consequences for bio-assessment programs after severe floods.

**Keywords:** Macroinvertebrate, Climate change, Bio-assessment, Hydrology

## Introduction

Because of the increased heat capacity of the atmosphere, climate change has raised concerns about rising river floods (Bonada et al. 2007). These fears are bolstered by evidence of widespread economic damage caused by floods in various parts of the world, particularly Asia and Iran (Mohammadi et al. 2006). Any variation in river floods can be a deciding factor in flood control and flood risk zoning. However, due to insufficient space and the number of hydrometric stations, existing experiments are unable to show a signal of steady climate change on a continental and country scale in flood discharge measurements. River floods are one of the most costly natural disasters. The global total annual damage is projected to be around USD 104 billion, and this figure is predicted to rise as a result of industrial development, urbanization, intensified agricultural activity, and climate change (Biswas and Tortajada 2016). Recent heavier floods are the result of the atmosphere's increased heat capacity and the presence of increasingly massive rainfalls, which has exacerbated the situation. Current findings, though, cannot depict the magnitude of the flood discharge over extended stretches of time. In Iran, there has been a climate change signal in flood discharges linked to annual time shifts of flood incidence over the last five decades. The flood that occurred on August 11, 2017, in the Zarin Gol River basin in Golestan Province killed three people and cost the economy approximately USD 500,000 (Rajabizadeh et al. 2020). The hydrological regime appears to be a major variable that influences river morphology and existing environmental factors, community composition and diversity (Lake 2007), life cycle and ecological adaptations of organisms (Poff et al. 2006), and habitat processing rate (Power et al. 1995). As a result, a better understanding of the interaction between river hydrology and biological characteristics is critical for successful environmental flow control (Anderson et al. 2006; Poff et al. 2006).

When there is flooding in running aquatic environments, the increased water flow pushes the substrate, washes out microorganisms, and transports macroinvertebrates and fish (Foster et al. 2020). Large woody debris (LWD) entrained in floodwaters, causing problems in riparian corridors and altering channel water temperatures and sediment composition (Danehy et al., 2012; Gholizadeh and Motamedi, 2020). Floods cause species to leave their local habitat, reducing biodiversity and density (Fornaroli et al. 2019). Many macroinvertebrate species have

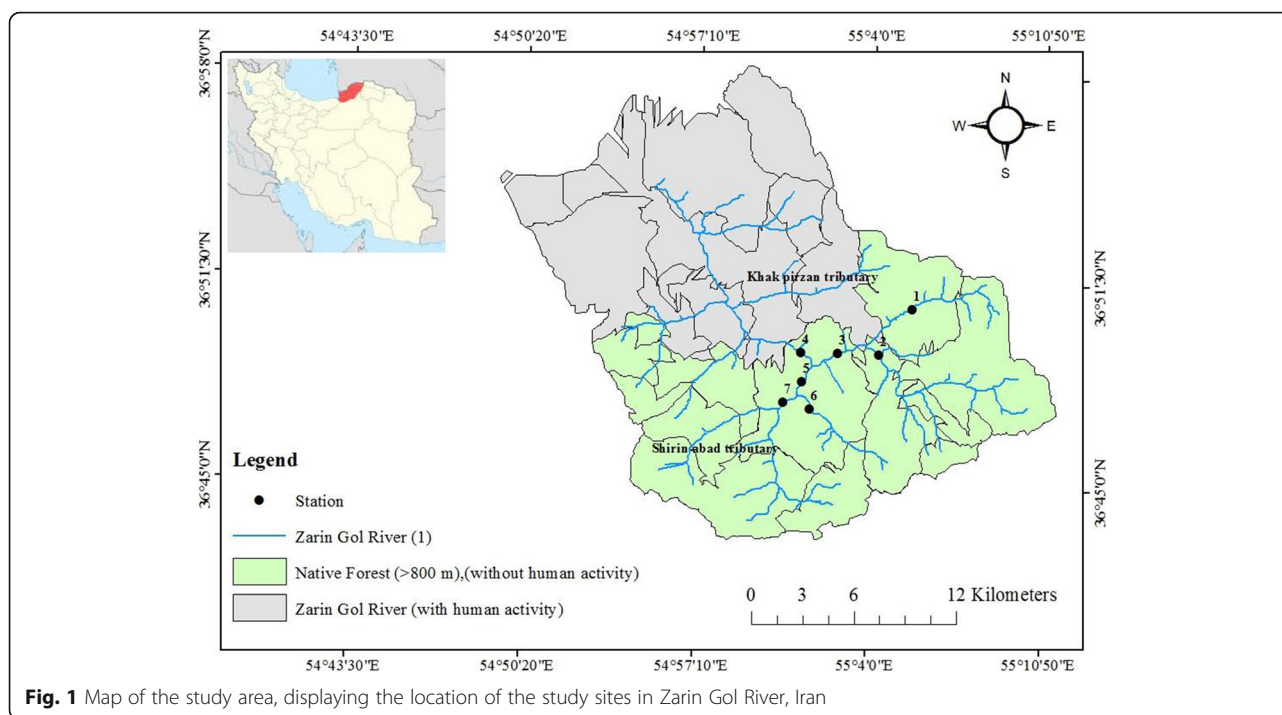
adapted their nature, life cycles, or reproductive ability to survive extreme flooding or rapid recovery (Foster et al. 2020). Floods caused by climate change may have an impact on the resistance of macroinvertebrate species in specific areas (Fornaroli et al. 2019). Macroinvertebrates are important components of river ecosystems because they provide food for higher trophic levels both within and outside of waterways (Bae et al. 2014). Furthermore, in some cases, they regulate consumption and periphyton, and they can influence ecosystem processes (Graça et al. 2018). Macroinvertebrates are being used as indices of river quality (Stark and Phillips 2009).

It would be beneficial to identify any identifiable shifts in macroinvertebrate richness, distribution, and community composition with the time of the flood disruption around a river. They can be used to forecast the outcomes of various environmental flow scenarios. The current study's goal (primary purpose) is to better evaluate the impact of flooding on macroinvertebrate communities and to determine how long it takes for macroinvertebrate communities to recover. Data from the Zarin Gol River in Iran's northern Alborz Mountains were used to compare standard bio-assessment metrics and community composition. Surveys were undertaken before and after flooding incidents to gather data. Pre- and post-flood data were gathered in June and September 2014 and 2017, respectively, for two flooding incidents that occurred in August 2014 and 2017. Furthermore, new data was gathered in June 2018 (9 months after the second flooding incident in August 2017) to assess the recovery time. A high-quality temperature and streamflow data would increase understanding of the consequences of hydrologic disruption and recovery times for macroinvertebrate assemblages, allowing regulatory bio-monitoring systems to distinguish climate-driven effects from water quality disruptions. In this report, adequate guidelines for adjusting current ecological indices and developing new ecological indices are proposed.

## Materials and methods

### Study area

Zarin Gol River is one of the Gorgan-Rud tributaries with its geographical location of longitude 54° 57' and latitude 35° 52'. The maximum volumetric discharge of river water is  $150 \times 10^6 \text{ m}^3/\text{year}$  with the sandy gravel-bed river (Gholizadeh et al. 2017). The sampling sites were located in the indigenous forest area of the basin (Fig. 1).



**Fig. 1** Map of the study area, displaying the location of the study sites in Zarin Gol River, Iran

The forest cover of the area consisted of mostly oak, European hornbeam (*Parrotia persica*), maple, Lindens (*Zelkova carpinifolia*), and English yew (*Taxus baccata* L.) with an average canopy cover of 52.7%, stretched over 81.7% of the total area. Rangelands cover most of the upper elevations of the basin and around some of the villages including 10.1% of the basin (Nasr Nasrabadi 1998).

The downstream areas of the river, which are affected by human activities, were excluded from this study. Therefore, only the impacts of natural disturbance were included as significant factors in shaping benthic macroinvertebrate communities in the study area.

The catchment area and its maximum elevation were about 342.82 km<sup>2</sup> and 2800 m, respectively. Heavy rainfall caused the flood events that occurred in this stream in the summer (August 2014 and 2017) because the permeability of soil is low while the soil slope is high (Fig. 2). The historical hydrographs analyzed in this study were from 1987 to 2017. The first survey before the higher water levels (the floods), conducted in June 2014 and 2017, was regarded as a reference sample. Figure 3 presents two of the floods, illustrating the relevant variables derived from the flood hydrograph. Due to high discharge, the water level rose significantly on August 8, 2014 (average rainfall of 27.5 mm in less than 24 h), August 19 and 20, 2017 (average precipitation of 22.5 mm) (Fig. 3), and 9 months later (June 2018); the data were collected to examine the recovery of communities.

### Macroinvertebrate collection

Macroinvertebrates were collected by a Surber sampler (900 cm<sup>2</sup> area and 250-μm mesh size) with 3 replications (diagonal transect across a riffle for 10 m and all sample collected in different parts of the same riffle) from 7 stations (3 replications × 7 stations × 5 months = 105 samples) along the Zarin Gol River, Iran, 1 month before (June 2014 and 2017) and after the flood (September 2014 and September 2017) and 9 months after the flood (June 2018). Samples were preserved in formaldehyde (final concentration 4%) until further analysis and poured the contents of the sieve into the tray to separate the organisms from the underlying particles under the stereoscope. Macroinvertebrates were identified in the level of family or genus based on valid keys (Pennak 1953; Needham 1976; Pescador et al. 2004).

### Biological measurement criteria

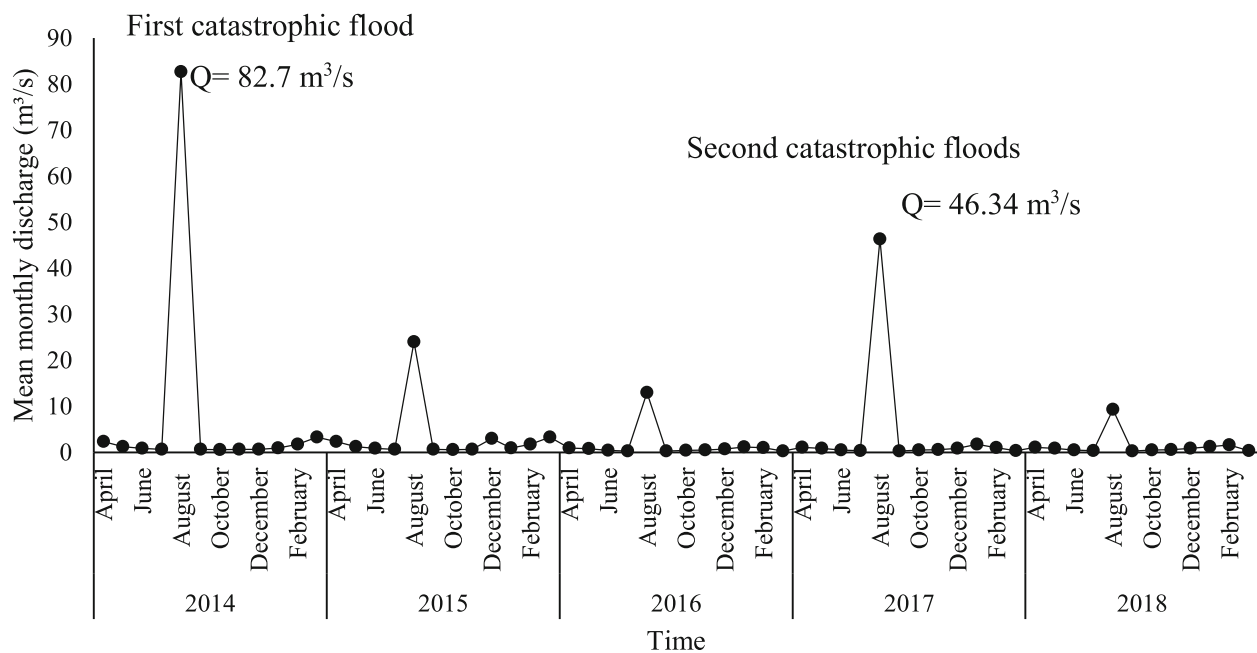
To evaluate the effects of environmental factors on aquatic life in the running waters, data from macroinvertebrate communities were collected utilizing a multimetric index of biodiversity. The multimetric index of biotic integrity is known as the Biological Assessment Profile (BAP) score, which is used for the biological assessment of water quality. BAP includes four components such as species richness, Ephemeroptera-Plecoptera-Trichoptera (EPT) richness, Hilsenhoff Biotic Index (HBI) (Hilsenhoff 1987), and percent model affinity (PMA) (Novak and Bode 1992). The result of each criterion is placed on a standard 10-criterion scale, and then, the average of these values is



**Fig. 2** Flood effects in Zarin Gol River, August 2014 (a, b) and August 2017 (c, d). Panels a and c show station 1 and panels b and d show station 4

computed. A four-tiered scale of water quality (non-impacted:  $BAP > 7.5$ , slightly impacted:  $BAP 5-7.5$ , moderately impacted:  $BAP 2.5-5$  or severely impacted:  $BAP < 2.5$ ) has been established for the obtained BAP Score (NYSDEC 2012). The results of sampling in the middle or extreme classes show significant effects on aquatic life, which are

included in the list of disturbed waters. Samples with a low organism density usually need a higher percentage of samples for processing, while samples with high organism density generally need a small percentage of samples for processing to reach the same subset of 100 organisms.



**Fig. 3** Annual hydrograph (average of each month over the period of record available) for the Zarin Gol River. The figure shows intra-annual variability of discharge data and August constituted maximum discharge in 2014 (discharge ( $Q$ ) =  $82.7 \text{ m}^3/\text{s}$ ) and 2017 (discharge ( $Q$ ) =  $46.34 \text{ m}^3/\text{s}$ )

### Statistical analysis

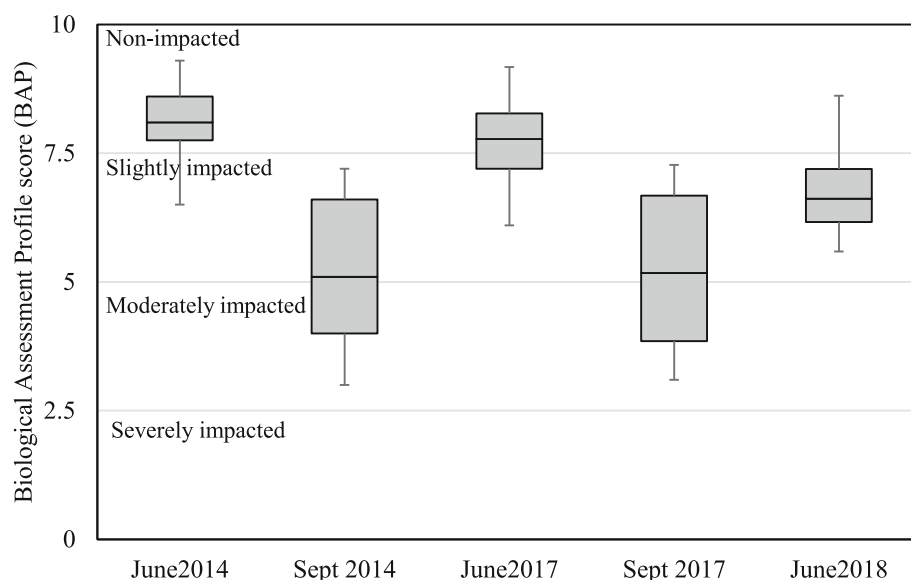
Two analyses were applied to illustrate the total effects of floods on macroinvertebrates assemblages, to indicate how specific taxonomic groups were affected, and also to represent how the rate of different indices and the composition of the assemblages are recovered after the floods. In the first step, analysis of variance (ANOVA) and multiple-comparisons procedures (Tukey test) were utilized to determine if the BAP scores, component metrics, and density changed significantly ( $\alpha = 0.05$ ) among the five sampling events. Therefore, this test determines whether the impact of flooding was significant and how long each metric takes to be recovered.

Second, multivariate methods with PRIMER-E Version 6 software were applied to measure temporal changes in community composition. A square-root transformation was used for macroinvertebrate and Bray-Curtis distance (Primer-E Ltd) was applied to analyze the community similarities between samples. A one-way analysis of similarities (ANOSIM) test was applied to examine the null hypothesis indicating that there are no differences between the periods of surveys (Clarke and Gorely 2006). Permutation distribution of the R-statistic in ANOSIM was used to measure differences in community composition at survey periods (Clarke and Gorely 2006). There are no differences in community composition with values close to 0 ( $R < 0.25$ ) whereas there is a significant difference in the community composition with the values close to 1 ( $R > 0.75$ ) (Clarke and Gorely 2006). Also, a nonmetric multidimensional scaling ordination (nMDS) was used to illustrate the similarity of macroinvertebrate communities between the survey periods

(before, after the flood, and recovery time) and to demonstrate information on the Bray-Curtis distance matrix. The evaluation of categorized composition was performed by nMDS at all stations before and after the flood and during the recovery period. Considering the distance, and the location of the samples in the species ordination space relative to the floods, some inferences were drawn about the resistance, resilience, and recovery of macroinvertebrate communities. Similarity percentage (SIMPER) analysis was conducted to identify taxa that contributed greatly to sample dissimilarity between sets detected in the nMDS (Clarke and Gorely 2006). SIMPER conducted paired comparisons of all samples; therefore, these comparisons could determine which species generate the most difference between the surveys (Clarke and Gorely 2006). Using the groups of studies that illustrated the most changes in community composition, sampling stations were classified into three classes of flood effects. These classes were demonstrated as before the flood (June 2014 and 2017), after the flood (September 2014 and September 2017), and recovery time (June 2018). To calculate the mean of differences between the three classes, SIMPER was applied based on the occurrence of individual species.

### Results

Four criteria available in the BAP index demonstrated that the flood caused by heavy precipitation in a short time had adverse effects on water quality in the Zarin Gol River basin. The mean BAP scores of seven sampling stations demonstrated water quality was not affected before the flood (Fig. 4). In the studies conducted pre- and



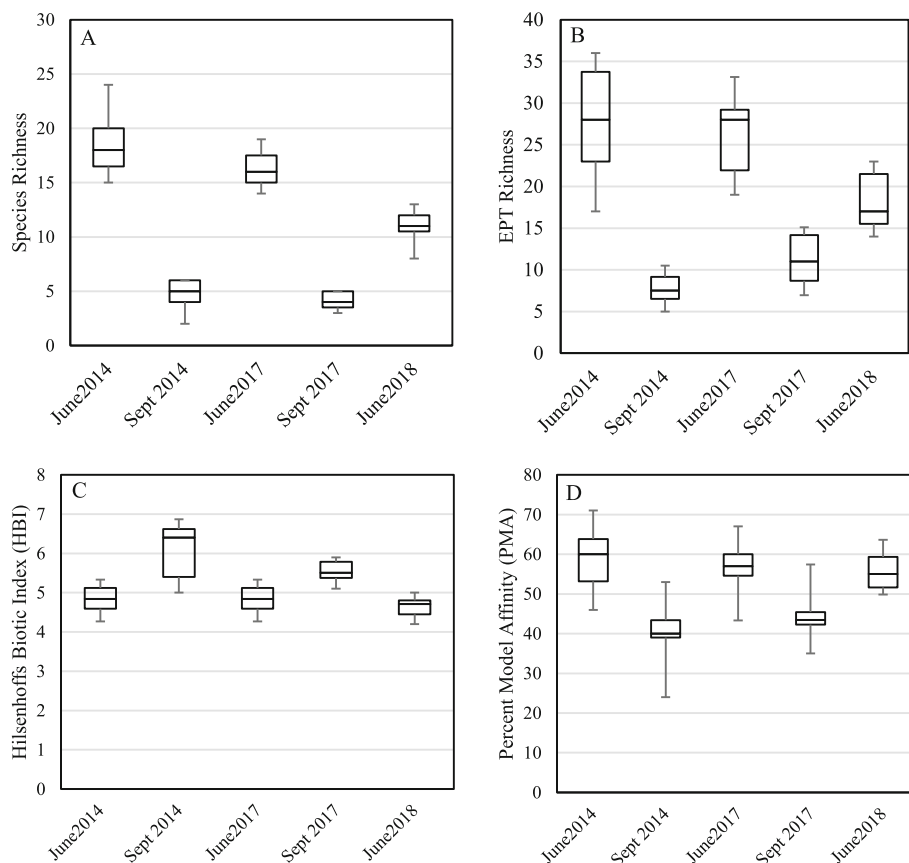
**Fig. 4** Boxplots showing the median, 25th and 75th percentiles (shaded boxes), and outliers for the bioassessment profile (BAP) scores in all macroinvertebrate samples collected at seven sampling sites grouped by study month and year

post-flooding events in August 2014 and 2017, the mean BAP scores for pre-flooding was 5.53 which would rate water quality as non-impacted. While the mean BAP score in September 2017, roughly 3 weeks after the floods, was only 4.89, which suggested moderately impacted water quality. In September 2014 and September 2017, immediately after the flood, BAP scores showed that the water quality has changed from slightly to moderately impacted water quality. In June 2018 (9 months later), the mean BAP score was close to the pre-flood level, i.e., it was not impacted (Fig. 4). For all metrics except HBI, the results of the ANOVA and Tukey tests showed that there was a significant difference between the available communities in September 2014 and September 2017 surveys ( $P < 0.05$ ). The average BAP scores and other component measurement criteria were partially restored in June 2018. Pre-flood surveys had significant differences from the post-flood surveys (Fig. 5).

Contrary to the response of other criteria, a partial decrease in the mean Hilsenhoff Biotic Index (HBI) was observed in the months before the flood and recovery period compared to the period after the flood. At the

time of the study, however, there was no significant difference between any component criteria in terms of the rate and level before the flood different from the pre-flood level (Figs. 4 and 5). The results of the ANOVA test of seasonal surveys of the stations in Zarin Gol River showed that there are no statistically significant differences between BAP scores between seasons from non-flood-affected flows. This catchment area is extremely valuable to be compared with the results of other mountainous regions in rivers because their properties are very similar. For instance, like mountainous regions in rivers around the world, these catchment areas covered with jungles are not permeable and have been slightly developed; on the other hand, more than 50% of their area is located at or above 1000 m (Table 1). These results support the conclusion that the differences observed in the Zarrin Gol River are due to the effects of flood events, and they are not seasonal.

Similar to the BAP, Spp, EPT, and PMA, paired multiple comparison test (Tukey test) showed that the percentage of samples isolated did not differ significantly between the two periods of the surveys before the floods.



**Fig. 5** Boxplots illustrating the median, 25th and 75th percentiles and outliers for **a** species richness; **b** Ephemeroptera, Plecoptera, and Trichoptera richness (EPT) richness; **c** Hilsenhoff's Biotic Index (HBI); and **d** percent model affinity (PMA) in all macroinvertebrate samples collected at seven sampling sites grouped by study month and year

**Table 1** List of macroinvertebrates which cumulatively account for >50% of the dissimilarity (Diss/SD) between sample event groups. Values represent their percent contribution to the dissimilarity between sample groups. Sample groups are categorized as pre-flood (Pre.), post-flood (Post.), and recovery (Rec.)

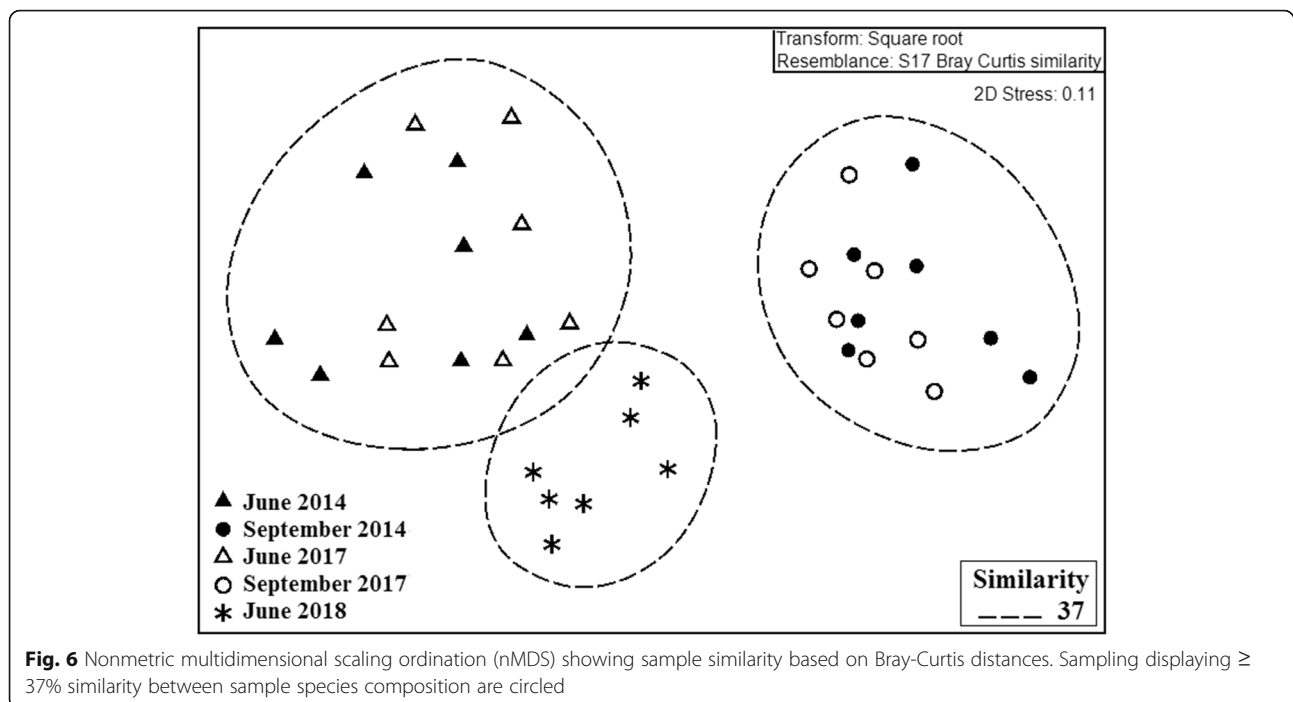
Macro-invertebrate	Diss/SD			
	Pre. vs. Post (2014)	Pre. vs. Post (2017)	Pre. vs. Rec. (2017–2018)	Post. vs. Rec. (2017–2018)
Chironomidae	2.62	3.82	1.47	2.05
Caenis sp.	2.15	2.08	2.27	
Pseudocoleon sp.	1.99	1.85	1.66	1.79
Baetis sp.	2.62	2.3	1.65	2.5
Hemerodromia sp.	0.7	0.75	0.72	
Chrysops sp.	0.68	0.74	0.72	
Atrichopogon sp.	0.66	0.83	0.85	
Lumbrociidae sp.	1.18	1.19	1.07	1.23
Lachlania sp.	2.01	1.68	2.75	
Rhithrogena sp.	1.21	1.22	1.26	
Simulium sp.	1.26	2.33	1.11	1.98
Chrysomeridae sp.	0.75	0.76	0.76	
Tipula sp.	1.44	1.57	1.43	
Athrix sp.	1.05	1.1	1.15	0.84
Hydropsyche sp.	1.96	2.59	2.06	2.67
Limna sp.	0.74	0.6		
Bibiocephala sp.	1.1	1.02		
Tabanus sp.	1.43		1.43	0.74
Forcipomiinae sp.	0.74	0.75	0.74	

Macroinvertebrates studied immediately after the floods (September 2014 and September 2017) revealed that there were few or no at the stations. The mean percentage of sample ordered to achieve the target sample of 100 organisms was between 39 and 58% before the flood, and it was significantly lower than these percentages after two floods in September despite an increase in the density of the samples.

The results of nMDS show that there were close similarities between the composition of macroinvertebrate communities at all stations before the flood surveys (June 2014–2017) and 9 months after the flood surveys (June 2018) (Fig. 6). This indicates that macroinvertebrate communities were recovered 9 months after the flood to evaluate the conditions. The stations were obtained immediately after the flood, distinct from other times (Fig. 6). The categorization indicates that community composition at most sites in June 2014–2017 was different from other times. The results of the ANOSIM test, which assesses differences in community composition between surveys, validated the observations from the nMDS and the responses of the bioassessment criteria. The results of ANOSIM showed that there was a significant difference in the community composition between the surveys ( $R = 0.59$ ,  $P < 0.05$ ). Therefore, such results

confirm the study hypothesis indicating that there is a difference in community composition between surveys.

SIMPER analysis of different benthic macroinvertebrate species can explain the differences between the observations in ANOSIM and nMDS ordination. Three categories of the flood effects could be identified by applying the information obtained from the SIMPER analysis indicating the most significant difference in community composition. The categories are pre-flood (June 2014–June 2017), response or the effect (September 2014 and September 2017, respectively), and recovery (June 2018). Differences between the three categories were calculated via SIMPER analysis based on the occurrence of individual species. The results of this analysis were comparable to those of ANOSIM, and it was seen that there were differences in the composition of benthic macroinvertebrate communities immediately after the flood. Also, there was less difference in the recovery period than after the flood, while there were minimal differences in the surveys before the flood and after the flood. In particular, the following species can be achieved due to differences between the categories (Table 1): *Baetis* sp. (Ephemeroptera: Baetidae) and Diptera: Chironomidae were fairly responsible for the lack of distinction between before the flood and response conditions; however,



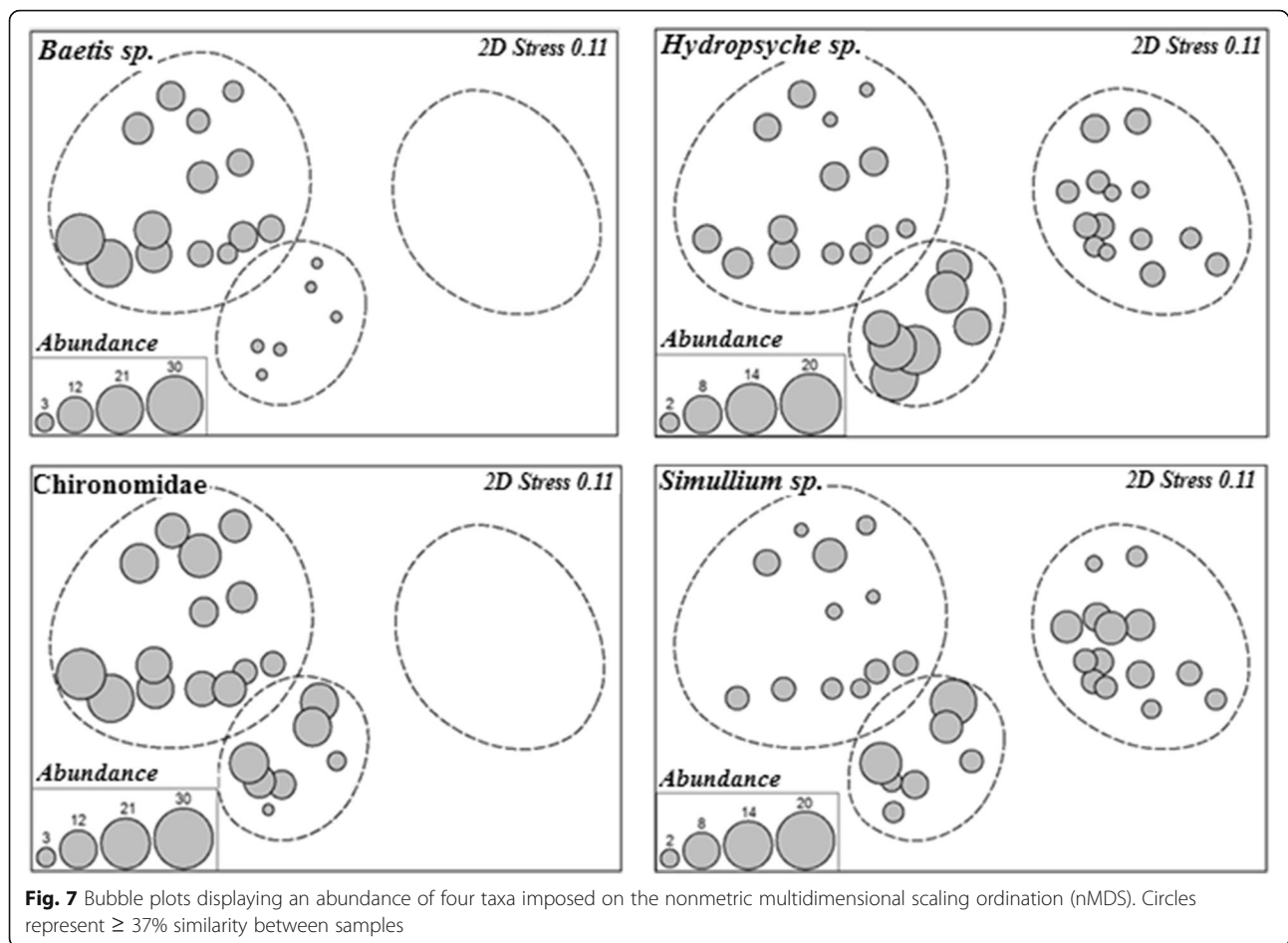
*Simullium* sp. (Diptera: Simuliidae) and *Hydropsyche* sp. (Trichoptera: Hydropsychidae) were partly responsible for the lack of distinction between recovery and after the flood conditions. The density of these species was compared in the three classes (Fig. 7) and the differences showed that the species in high abundance before the floods such as *Hydropsyche* sp. and *Simullium* sp. continued in the response phase. On the contrary, the species with low abundance before the occurrence of events such as *Baetis* sp. and Chironomidae were absent from most samples immediately after the flood.

## Discussion

Flooding incidents in Zarin Gol River in Ali-Abad Katol, Golestan Province, in July 2014 and July 2017 were two of the most severe floods in the Zarin Gol River basin in recent years. Heavy rains on August 8, 2014, and August 10–11, 2017, caused casualties and property damage in the Zarin Gol River basin. Floods were most common in the Zarin Gol River basin according to the spatial distribution of floods. One of the most serious environmental consequences of the flooding events has been the degradation of habitat, which has resulted in significant biodiversity loss. However, in recent decades, heavy exploitation of pastures and cultivated fields has resulted in flooding and erosion (Gholizadeh and Alinejad 2018). Deforested areas of sloped agricultural land, for example, can cause significant erosion during heavy rainfall and flooding events (Huang et al. 2014).

As the climate changes, severe floods are likely in various magnitudes in the future; however, peak water flow timing becomes less predictable (Ledger and Milner 2015). The study shows that the environmental impacts will change depending on time and the frequency of extreme floods. The abundance and species diversity of benthic macroinvertebrates is decreased due to the high volume of seasonal precipitation. Following a flood, the release or velocity of water flow rises abruptly, with the potential to kill vegetation and surface substrates by washing the riverbed (Gibbins et al. 2005). The composition and stabilization of the substrate adjust the distribution and abundance of benthic macroinvertebrates at local or large scales (Foster et al. 2020); thus, it was predicted that abrupt changes in substrate composition caused by the flood would greatly alter the number of species. Furthermore, increased cross-sectional stress can play a significant role in macroinvertebrate extinction (Bond and Downes 2003).

The Zarin Gol River study found that biological monitoring programs in rivers that have been hydrologically altered (possibly as a result of floods and droughts) would yield inaccurate results by using current indices. As a result, these indices may signify pollution as the primary disturbance, while natural and hydrological disturbances may be considered the only disturbances of nature. Significant fluctuations in benthic macroinvertebrate assemblages in the Zarin Gol stream after the flood can thus mean that it is critical to analyze the recovery time before the standard biological measurement



criterion in a monitoring program; it may reveal the true state of water quality. The disparity in the mean BAP score in the Zarin Gol River before and after the flood and recovery time is one of the study's most striking findings.

The findings of studies performed prior to and after flood incidents in August 2014 and 2018 revealed that the mean BAP scores in August and September were 5.53 and 4.89, respectively. This is a substantial decrease given that the pre-flood samples from 2014 and the post-flood samples from September 2014 were taken in fewer than three weeks. The sudden drop in BAP scores after the flood shows that certain organisms were temporarily eliminated from the system. Other research found that some species were decreased and restored to pre-flood stages, while others were removed (Milner et al. 2018; Mathers et al. 2020). These community changes were visible in typical species richness and diversity measurements, as well as community quality measurements (Mathers et al. 2020; Woodward et al. 2015). Hydrological disturbances have been found to induce errors in the biological measurement of water quality. As a result, future research should concentrate

on identifying flood-resistant yet pollution-sensitive plants in order to develop pollution-focused measures of ecological quality.

The disparities in measuring parameters had little to do with the nature and seasonal variations of the macroinvertebrate community's composition. The majority of long-term research on macroinvertebrate communities extract samples annually over the same month(s) in order to predict seasonal variations in community composition based on normal growth and emergence patterns.

However, further sampling was carried out 9 months after the flood in order to obtain an instant answer to flood incidents and to better understand how communities improve. As a result, it is impossible to ignore that the variation in the sampling cycle calls into question the reported variations in community measuring metrics, such as BAP; it also raises the doubt that the result is nothing more than seasonal differences in community composition (e.g., natural differences expected in non-flood conditions in all years).

Flooding can have a significant impact on the macroinvertebrate species in the Zarin Gol River, influencing

the invertebrate abundance and community composition through shifting substrate and sediment load. The findings revealed that when the average daily flow in the Zarin Gol River exceeds 20 m<sup>3</sup>/s, macroinvertebrate communities are disturbed, owing to a substantial rise in sediment transport caused by higher flow velocity. Higher water flow velocity and movement of stream substrate dramatically change macroinvertebrates. As a result, it causes physical harm to certain organisms and reduces macroinvertebrate food supplies by decreasing algal biomass and small and large organic matter particles (Gholizadeh and Heydarzadeh 2019). Erosion is also exacerbated by a rise in suspended sediment load and the flow of large particles downstream of the Zarin Gol River as a result of increased runoff. Furthermore, suspended sediments can cause some invertebrates to lose respiratory functions. The inconsistency of the river's instability with food supplies seems to have the greatest impact on community composition. These creatures are dominated by collectors (*Baetis* sp. and Chironomidae), filters (Hydropsychidae), and filter collectors (Simuliidae). Larvae of *Baetis* sp. and Chironomidae can be primarily fed by terrestrial particulate matter that reaches the river during floods, while they may consume Hydropsychidae in the form of filamentous fungi. A small number of sedentary species, such as Gastropods, have been collected, most likely because they are more vulnerable to substrate movement than mobile insects.

Heavy precipitation occurred during our investigation, and sampling revealed that Scraper species such as Hydropsychidae and Simuliidae were more frequent than at other periods of the surveys. This difference in abundance refers to species body shape. Hydropsychidae, for example, has a flat body shape and a high resistance to heavy flooding, allowing it to quickly adhere to boulders or stones (Bae et al. 2014). On the other side, as the swept and disturbed habitat is replaced and preserved, a wide range of species with viable feeding classes can be found in abundance. Streams with various heterogeneous substrates may provide more shelter and colony during floods, while streams with homogeneous channels are more affected by floods and have more time to recover (Fisher et al. 1982; Gholizadeh and Pakravan 2019). Despite increased flood discharge in the summer of 2014 (due to heavier rainfall than in 2017), stable streambeds (embedded rocks) were discovered to provide a safe haven for macroinvertebrates in floods. Small floods may also help to preserve habitat heterogeneity and the diversity of benthic macroinvertebrates in spotted streams (Robinson et al. 2004).

## Conclusion

The impact and recovery of macroinvertebrate assemblages in the Zarin Gol River after the 2014–2017 floods

provided important information about the effects of flood disturbance on biological assessment approaches. The outcomes of biological water quality assessment metrics resembled those of highly polluted waters, but the only disturbance was severe flooding. Local community recovery was relatively quick, and it was completed by June of the following year, in 2018. Also, macroinvertebrate density was significantly reduced, though it recovered the following year. As a result, it is recommended that the analysis of biological monitoring data within 1 year of the flood not be limited to monthly and/or seasonal studies. Such suggestions should be fully considered in regulatory water quality monitoring programs to ensure that water-quality issues are not confused with climate-induced impacts.

## Abbreviations

BAP: Biological Assessment Profile; EPT: Ephemeroptera-Plecoptera-Trichoptera; HBI: Hilsenhoff Biotic Index; PMA: Percent Model Affinity; ANOVA: Analysis of variance; ANOSIM: One-way analysis of similarities; nMDS: Nonmetric multidimensional scaling ordination; SIMPER: Similarity percentage

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## Disclosure

I declare that the present study is the result of several years of research by the research institute and it has nothing to do with the government. I am also the only author and researcher of this study that I have no connection with the government.

## Author's contributions

Conceptualization, writing—original draft preparation and editing: Mohammad Gholizadeh. The author has read and agreed to the published final version of the manuscript.

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## Availability of data and materials

Data are available on request from the authors only based on logical requests.

## Declarations

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

Not applicable

### Competing interests

The authors declare that there are no competing interests regarding the publication of this paper.

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## References

- Anderson EP, Freeman MC, Pringle CM (2006) Ecological consequences of hydropower development in Central America: impacts of small dams and water diversion on neotropical stream fish assemblages. *River Res Appl* 22(4): 397–411. <https://doi.org/10.1002/rra.899>
- Bae MJ, Chon TS, Park YS (2014) Characterizing differential responses of benthic macroinvertebrate communities to floods and droughts in three different

- stream types using a self-organizing map. *Ecohydrology* 7(1):115–126. <https://doi.org/10.1002/eco.1326>
- Biswas AK, Tortajada C (2016) Counting the costs of floods in China. *Policy Forum*. <http://www.policyforum.net/counting-costs-floods-china>
- Bonada N, Rieradevall M, Prat N (2007) Macroinvertebrate community structure and biological traits related to flow permanence in a Mediterranean river network. *Hydrobiologia* 589(1):91–106. <https://doi.org/10.1007/s10750-007-0723-5>
- Bond NR, Downes BJ (2003) The independent and interactive effects of fine sediment and flow on benthic invertebrate communities characteristic of small upland streams. *Freshw Biol* 48(3):455–465. <https://doi.org/10.1046/j.1365-2427.2003.01016.x>
- Clarke KR, Gorely RN (2006) PRIMER v6: User Manual/Tutorial. PRIMER-E Ltd, Plymouth, UK
- Danehy RJ, Bilby RE, Langshaw RB, Evans DM, Turner TR, Floyd WC, et al (2012) Biological and water quality responses to hydrologic disturbances in third-order forested streams. *Ecohydrology* 5:90–98.
- Fisher SG, Gray LJ, Grimm NB, Busch DE (1982) Temporal succession in a desert stream ecosystem following flash flooding. *Ecol Monogr* 52(1):93–110. <https://doi.org/10.2307/2937346>
- Fornaroli R, Calabrese S, Marazzi F, Zaupa S, Mezzanotte V (2019) The influence of multiple controls on structural and functional characteristics of macroinvertebrate community in a regulated alpine river. *Ecohydrology* 12(2):e2069. <https://doi.org/10.1002/eco.2069>
- Foster A, Claeson S, Bisson P, Heimbürg J (2020) Aquatic and riparian ecosystem recovery from debris flows in two western Washington streams, USA. *Ecol Evol* 10(6):2749–2777. <https://doi.org/10.1002/ece3.5919>
- Gholizadeh M, Alinejad M (2018) Assessment of spatial variability of some affecting parameters on water quality of Zarin Gol River in Golestan province. *Iran J Environ Sci* 16(1):111–126
- Gholizadeh M, Heydarzadeh M (2019) Functional feeding groups of macroinvertebrates and their relationship with environmental parameters (case study: in Zarin-Gol River). *Iran J Fish Sci* 19(5):2532–2543
- Gholizadeh M, Motamedi R (2020) Effects of habitat destruction on seasonal floods and management in river basin: a case study of Zarrin Gol River. *Iran J Utiliz Culti Aqua* 9(2):33–44
- Gholizadeh M, Pakravan M (2019) Investigation of benthic macroinvertebrate based on bio-indicator in Zarin-Gol River, Golestan Province. *Iran J Environ Sci Tech* 21(8):221–232
- Gholizadeh M, Toomaj A, Hossienidost S (2017) Modeling habitat requirements of riverine stone loach, *Paracottitis hircanica* (Teleostei: Nemacheilidae) in the Zarin Gol River, Caspian Sea basin, Iran. *Iran J Ichthyol* 4(4):340–351
- Gibbins CN, Scott E, Soulsby C, McEwan I (2005) The relationship between sediment mobilisation and the entry of Baetis mayflies into the drift in a laboratory flume. *Hydrobiologia* 533(1–3):115–122. <https://doi.org/10.1007/s10750-004-2401-1>
- Graça MA, Callisto M, Barbosa JEL, Firmiano KR, França J, Júnior JFG (2018) Top-down and bottom-up control of epilithic periphyton in a tropical stream. *Freshw Sci* 37(4):857–869. <https://doi.org/10.1086/700886>
- Hilsenhoff WL (1987) An improved biotic index of organic stream pollution. *Great Lakes Entomol* 20:31–40
- Huang WC, Weng MC, Chen RK (2014) Levee failure mechanisms during the extreme rainfall event: a case study in Southern Taiwan. *Nat Hazards* 70(2):1287–1307. <https://doi.org/10.1007/s11069-013-0874-9>
- Lake PS (2007) Flow generated disturbances and ecological responses: floods and droughts. In: Wood PJ, Hannah DM, Sadler JP (eds) *Hydroecology and ecohydrology: past, present and future*. Wiley, Chichester (UK), pp 75–92
- Ledger ME, Milner AM (2015) Extreme events in running waters. *Freshw Biol* 60(12):2455–2460. <https://doi.org/10.1111/fwb.12673>
- Mathers KL, White JC, Fornaroli R, Chadd R (2020) Flow regimes control the establishment of invasive crayfish and alter their effects on lotic macroinvertebrate communities. *J Appl Ecol* 57(5):886–902. <https://doi.org/10.1111/1365-2664.13584>
- Milner AM, Picken JL, Klaar MJ, Robertson AL, Clitherow LR, Eagle L, Brown LE (2018) River ecosystem resilience to extreme flood events. *Ecol Evol* 8(16):8354–8363. <https://doi.org/10.1002/ece3.4300>
- Mohammadi A, Mosaedi A, Tahmasebi A (2006) Flood characteristics of Gorgan Roud river in Gonbad hydrometric station. *Proceedings of 2nd National Conference on Watershed and Soil & Water Management*. Kerman, Iran, pp 2255–2261
- Nasr Nasrabadi M (1998) Investigation of effective factors on flooding in order to present management methods in several watersheds of Golestan province. Thesis Master of Watershed Management, Gorgan University of Agricultural Sciences and Natural Resources
- Needham JG (1976) A guide to the study of freshwater biology. Holden, San Francisco, p 107
- Novak MA, Bode RW (1992) Percent model affinity: a new measure of macroinvertebrate community composition. *J North Am Benthol Soc* 11(1):80–85. <https://doi.org/10.2307/1467884>
- NYSDEC (2012) Standard operating procedure: biological monitoring of surface waters in New York State. New York State Department of Environmental Conservation, Stream Biomonitoring Unit, Albany, p 159
- Pennak RW (1953) Freshwater invertebrates of United States. The Ronald Press Company, p. 769
- Pescador ML, Rasmussen AK, Harris SC (2004) Identification manual for the caddis fly (Trichoptera) larvae of Florida. Department of Environmental Protection, Florida
- Poff NL, Olden JD, Pepin DM, Bledsoe BP (2006) Placing global streamflow variability in geographic and geomorphic contexts. *River Res Appl* 22(2):149–166. <https://doi.org/10.1002/rra.902>
- Power ME, Parker G, Dietrich WE, Sun A (1995) How does floodplain width affect floodplain river ecology? A preliminary exploration using simulations. *Geomorphology* 13(1–4):301–317. [https://doi.org/10.1016/0169-555X\(95\)00039-8](https://doi.org/10.1016/0169-555X(95)00039-8)
- Rajabizadeh Y, Ayyoubzadeh SA, Zahiri A (2020) Flood survey of Golestan province in 97–98 and providing solutions for its control and management in the future. *Iran J Ecohydrol* 6(4):921–942
- Robinson CT, Aebischer S, Uehlinger U (2004) Immediate and habitat-specific responses of macroinvertebrates to sequential, experimental floods. *J North Am Benthol Soc* 23(4):853–867. [https://doi.org/10.1899/0887-3593\(2004\)023<0853:IAHROM>2.0.CO;2](https://doi.org/10.1899/0887-3593(2004)023<0853:IAHROM>2.0.CO;2)
- Stark JD, Phillips NR (2009) Seasonal variability in the macroinvertebrate community index: Are seasonal correction factors required? *New Zeal J Mar Fresh* 43(4):867–882. <https://doi.org/10.1080/00288330909510045>
- Woodward G, Bonada N, Feeley HB, Giller PS (2015) Resilience of a stream community to extreme climatic events and long-term recovery from a catastrophic flood. *Freshw Biol* 60(12):2497–2510. <https://doi.org/10.1111/fwb.12592>

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