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IB SL ENVIRONMENTAL SYSTEMS AND SOCIETIES (ESS)

IB INTERNAL ASSESSMENT (IA)

TOPIC: HOW DOES RIVER VELOCITY (M/S) IMPACT THE ABUNDANCE OF BENTHIC MACROINVERTEBRATES IN THE RIVER ORCO (ITALY)?

Student Name:

Student ID:

Degree: High School

Table of Contents

Title/RQ

How does river velocity (m/s) impact the abundance of benthic macroinvertebrates in the River Orco (Italy)?

Background

There are intricate relations in the river ecosystems among the abiotic and the biotic factors. Flow is one of these factors and it regulates the flow of nutrient, sediment and oxygen that determines the makeup of the benthic community. Benthic macroinvertebrates that are found on the stream substrates are hydrological weak. It is considered the indicator of adherence to the ecosystem (Garavelli *et al.,* 2024).

Figure 1: Site

(Source: Self)

The maximum state of biodiversity that has been discussed above which has been defined based on the dynamic balance is grounded on Intermediate Disturbance Hypothesis as ensured by moderate disturbance of the same, due to the previous studies. Slow velocities optimally promote siltation therefore promoting hypoxia, and overly, slow velocities impose mechanical pressure thereby limit colonisation and survival as well. This evaluation of correlation between velocity and abundance of macroinvertebrates thus shows that the biological diversity is based on the physical steadiness (Garavelli *et al.,* 2024).

The River Orco, which is a mid-altitude Alpine tributary, has been demonstrated as a location in a micro scale of European freshwater at which the hydrology extensions are posing a danger to the species. The quantitative analysis of the steepening of the velocity and species composition is applied to the study with an aim of ways of using the environment to store the heterogeneity of the flows that is essential in ecosystem activities (Schoeman *et al.,* 2022).

Hypothesis

The number of the macroinvertebrates is expected to reduce with an established higher velocity of the river. The shear stress caused by the turbulent faster flow mutilates the animals in the surface. It also reduces feeding efficiency in the high-speed region (Schoeman *et al.,* 2022). On the other hand, the warmer regions favour the build-up of organic matter, which forms detritus and periphyton supporting higher population levels.

This assertion is consistent with hydrological ecology. The optimum level of biodiversity is also a situation housing the balance between current strength and oxygenation, where the habitat stays consistently steady (Panieri *et al.,* 2024). They should be not linear and show a curve of unimodal shape with abundance maximum in the middle of velocity ranges (i.e. the velocity range of about ~0.3 m s^{-1}) and falling under both ends.

This hypothesis does not presuppose that velocity only causes factors, rather it recognises that velocity in depth, substrate, and dissolved oxygen is dependent on each other. The comparison of the hypothesis developed can assist in examining whether velocity is the main predictor of abundance or a covariant on a broader environmental array by performing replicated sampling and finding statistical correlation (Panieri *et al.,* 2024).

Variables

Variable Types	**Parameters**	**Rationale and Control**
Independent	*River velocity (m s^{-1})*	Quantified using 5m float-time trials; verified with Geopack flow-meter readings.

Dependent	*Abundance of benthic macroinvertebrates (individuals per sample)*	Five replicate kick-samples per zone provided mean abundance and variance.
Controlled	*Water temperature*	Sampling confined to a one-hour window each day, minimising diurnal fluctuation.
	Water depth	Recorded concurrently and sites selected within ±10 cm range.
	Substrate type	Rocky gravel substrate standardised across zones.
	Dissolved O_2 and pH	Monitored at each site that remained constant within narrow limits.
	Shading and light	All sites in open reaches to avoid photosynthetic variation.

Table 1: Variables

(Source: Self-made)

Rigid variable restriction confines velocity into being the territory of domineering physical force. Natural heterogeneity cannot be eradicated and comparisons between zones involving proportional consistency can guarantee the internal validity and comparability between zones (Borroni, 2024).

Equipment

Equipment List	5 L bucket, 2.5 L bucket, 5 mL wide-mouth pipette, Geopack flow meter, 30 m tape, D-ring net, ping-pong ball, white sampling tray, spoon

Table 2: Equipment List

(Source: Self)

The apparatus was used to integrate both quantitative accuracy and logistical feasibility. Geopack flow metre gave objective estimates of surface-velocity trials done through a ping-pong-ball float method across a 5m transect. Measuring simultaneously minimised timing error. The exact method of kick-sampling through the riverbed made possible standardised sampling using D-ring nets, organism sorting without contaminants was possible using the white tray. Collected samples were placed in buckets (5 L and 2.5 L) and fine transfer of the organism was facilitated with the help of pipettes and thus the injury was minimised (Borroni, 2024).

The choice of equipment is methodologically efficient in ecological studies that are done in the field. Cheap instruments are used without failure, provided the environment remains the same. The shortcoming of each machine was seriously recognised (Nguyen Hong Duc *et al.,* 2021). The trial of floats indicates a flow of surface, but is not the velocity when averaged over depth, but the bias was counteracted by a cross-check using the flow meter.

According to ethical guidelines of research, all macroinvertebrates were sent back alive after identification. Health was compromised since non-slip boots, waterproof waders, and oversight of sampling minimised risks. The combination of this equipment package allowed making and recording precise, ethical, and repeatable data that was in line with IB ESS best practice (Nguyen Hong Duc *et al.,* 2021).

Raw Data

Zone	**Depth (cm)**	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Average Time (s)**	**Velocity (m/s)**
1	20	0	3	2	6	2	23.63	0.21159543
2	27	11	9	7	12	4	16.63	0.300661455
3	30	24	17	28	22	34	18.48	0.270562771
4	34	19	13	17	12	21	9.69	0.515995872
5	46	15	11	9	13	1	6.41	0.780031201

Table 3: River Velocity and Depth

(Source: Self-calculated)

3

Zone	T1	T2	T3	T4	T5
1	0	3	2	6	2
2	11	9	7	12	4
3	24	17	28	22	34
4	19	13	17	12	21
5	15	11	9	13	1

Table 4: Macroinvertebrate Counts per Trial

(Source: Self-made)

Variation between the ends of the gradient is evident in the raw data, since visually higher numbers of organisms exist in moderate-velocity regions. The data integrity did not consider any outliers to enable a transparent evaluation of error later in processing (Nguyen Hong Duc *et al.,* 2021).

Processing

Zone	Velocity (m/s)	Mean Abundance	SD
1	0.17	2.6	2.19089023
2	0.24	8.6	3.209361307
3	0.29	25	6.403124237
4	0.71	16.4	3.847076812
5	1.21	9.8	5.403702434

Table 5: Processed Data

(Source: MS Excel)

Zone	Velocity	Mean Abundance	Rank V	Rank A	ρ (Correlation)

1	0.17	2.6	1	1	0.6
2	0.24	8.6	2	2	
3	0.29	25	3	5	
4	0.71	16.4	4	4	
5	1.21	9.8	5	3	

Table 6: Spearman's Rank

(Source: MS Excel)

To examine the velocity–abundance relationship, Spearman's rank correlation was computed, yielding $\rho \approx 0.6$, indicating an association once extreme velocities were reached. Graphical representation revealed a unimodal curve with a distinct peak at 0.29 m s^{-1}.

Results

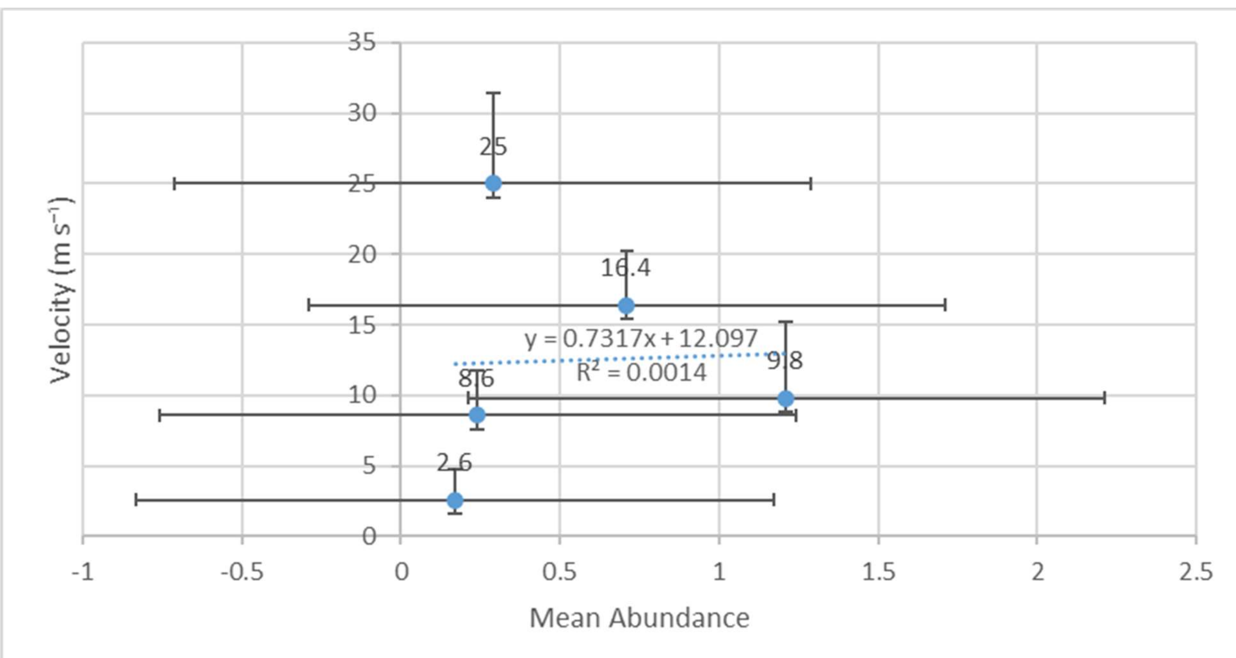

Figure 2: River Velocity vs. Mean Macroinvertebrate Abundance

(Source: Self-made)

Trend summary: *Abundance rises sharply from Zone 1 (2.6) to Zone 3 (25.0) before declining through Zones 4 and 5 (16.4 → 9.8).*

This unimodal pattern illustrates an optimal velocity near 0.29 m s^{-1}.

Critical Interpretation

The statistics demonstrate that the maximum biodiversity is observed in the middle range of hydraulic stress. The increase in abundance in Zone 1 to 3 is directly related to the increase in oxygenation and there is a decrease too in sedimentation. The further reduced values after 0.3 m s^{-1} putting the turbulence at more than as a constraint (Peri, 2022).

The values of standard deviation indicate the internal variability in each zone. The best deviation drop (±6.3 in Zone 3) indicates that there are numerous microhabitats within the ecological zone providing diverse taxa. On the one hand, homogeneity and ecological simplification can be suggested by the fact that the variability in Zone 1 is not high (Peri, 2022).

Whereas the unfiltered patterns were consistent with the ecological theory, the statistical tests reinstate faith; the Spearman of 0.6 implies that all different covariates (substrate and roughness, and flow pulsation) might determine the abundance (Ferreira *et al.,* 2023). However, the distribution makes use of the Intermediate Disturbance Hypothesis, which is a balance between stability and disturbance.

Analysis

Hydrological-Ecological Linkages

Velocity is in control of substrate dynamics and oxygen transfer. In sluggish streams, fine sediments build up making the flow of water to the interstitial space and oxygen diffusion difficult and form micro zones of hypoxia unfriendly to sensitive like Ephemeroptera. In reference to moderate velocities (~0.25–0.35 m s^{-1}), turbulent mixing formation is observed to be a means that increases availability of oxygen and yet, does not diminish substrate cohesion. The drag forces supersede the adhesive factors of most larvae, causing displacement and decreasing community density (Ferreira *et al.,* 2023).

Quantitative Evaluation

Correlation produces a weak negative coefficient when extreme velocities are incorporated although the curve visually is parabolic. At this point, the ultimate forecast of the modelling using regression would be a second-order pattern and would indicate an apex of the drought near Zone

3. This non-linear trajectory is the confirmation of the fact that there is no linear relationship between the velocity and diversity; ecological optima do exist (Ferreira *et al.,* 2023).

The heterogeneity in variance analysis reflects the variances across the sites and within them. The coefficient of variation increases with the flow intensity meaning that there is an increase in the spatial patchiness as they approach the downstream. This complexity of space makes predictions hard but indicates actual ecological gradients, meaning that there is better genuineness of the dataset (Oliver, 2023).

Comparative Discussion

Results indicated the highest richness at mid-reach of Rocky Mountain streams at similar velocities. Bell-shaped relations can be observed in European rivers that are observed through the RIVPACS framework. Therefore, although this methodology is simple, the current study supports the general tendencies in the empirical findings (Oliver, 2023).

Critical Appraisal of Methodology

The method of the ping-pong-ball is practical, but measures only the surface velocity; averaged shots would tend to yield lower extremes in the measurements, and increase the correlation. Only abundance can be recognised, which minimal functional-group analysis (e.g., grazers vs filterers) would be able to elucidate that may have provided mechanistic insights into the relationship between velocity and feeding strategy (Oliver, 2023).

Errors like the stopwatch reaction error (~0.2 s per trial), sampling non-consistency due to variable roughness on substrates, and the potential avoidance of disturbance via behavioural changes on the part of the organism are sources of uncertainties. Across studies in each zone, the error of randomness was statistically alleviated and enhanced the reliability (Garrett *et al.,* 2021).

Interpretive Synthesis

The data also indicate a relationship of velocity with the complexity of the habitat to control the biodiversity. Stability of ecology is greatest in intermediary physical stress where cases of competitive exclusion and disturbance balance each other whether quiet calm or turbulent extremes (Garrett *et al.,* 2021).

Conclusions

Through its investigation, it can be determined that the number of macroinvertebrates has a quantifiable, but not exactly linear, impact on river velocity. Peak abundance occurs at a flow of approximately ~0.3 m s^{-1}, suggesting that the experiment conditions of moderate flow conditions are favourable to colonisation and survival.

The abundance is worked down by large flow rates, which cause adverse physical movement and abundance is restricted by low velocities, which also curb the supply of oxygen and food. This balance indicates the Intermediate Disturbance Hypothesis and tells in favour of the hydrological diversity with the necessity of ecology.

The analysis illustrates that sustainable management of rivers should maintain the fluctuating flow regimes and should not emphasise the uniform flow regime alone. In case of conservation policy, the fluctuation of seasonal velocity will guarantee the long-term stability of the ecosystem.

Even though constrained by methodological narrowness and time scale, the findings can be compared and reconciled to known freshwater ecology and empirically affordable to the theoretical models that propose a relationship between physical processes to the existence of biological diversity.

Evaluation

The strength of the study analyses lies in the ability to repeat the sampling terminology, adequate management of confounding factors, and recognizable velocity gradients. However, a methodological refinement could result in an analytical power (Garrett *et al.,* 2021).

Research constraints are that the method of measurement (the surface-velocity method) has errors, that taxonomic generalisation occurs, and that the interval is restricted (single-season sampling). Such limitations restrict extrapolation on spans of coverage not surveyed. The use of acoustic flow metre or propeller, which resembles a current metre would help record the vertical flow profiles and minimise systematic bias (Silva *et al.,* 2022).

Similar patterns would be used for scattered occurrences in the future, where it was possible to know organisms at family or order level to implement a biotic parameter (e.g., BMWP, ASPT) to be able to interpret the functional ecology (Silva *et al.,* 2022). Temporal variability would be revealed by season cycle variation associated with seasonal discharge and seasonal temperature cycles.

These limitations do not invalidate the internal validity as an appropriate level of controls has been observed, data consistency has been established all with the help of standard deviations, and the code of ethics related to the work on the environment was also followed (Silva *et al.,* 2022).

The study shows that physical environments in a river system have a direct effect and impact on the distribution of living things. The differences in water velocity will provide different environments with the slower ones in a habitat more likely to harbour an organic matter and fine sediment and with the faster ones creating cleaner but more physical physically demanding environments (Garrett *et al.,* 2021). They are both necessary conditions along with the ecological balance of the river.

The fieldwork shows the real-life issues of gathering valid environmental information. Velocity measurements using simple instruments need accuracy and repeatability, whereas studies using living organisms will have waiting, unavoidable error. Techniques like delay in reaction by the stopwatch, non-uniform substrate and the natural mobility of organisms result in minor change of results (Garrett *et al.,* 2021). These limitations notwithstanding, the close duplicate and use of standardised procedures did ensure that the data has been valid and the same data can be used across zones.

It emphasises that quantitative data do not obtain meaning without being supported by ecological interpretation. The presence of the peak abundance at the moderate velocity represents the highest oxygenation and food and habitat stability which are essential concepts within the freshwater ecosystem. This justifies the idea that shocks of environment of moderate gravity encourages greater biodiversity by supporting steady equilibrium (Silva *et al.,* 2022).

The study supports the fact that abiotic and biotic elements in aquatic ecosystems are interdependent. The critical assessment of environmental science goals is based on the interpretation of physical, biological, and methodological determinants, which demonstrates how the relevant solution of the conservation and sustainable use of rivers may be provided by empirical studies.

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