Ecological responses of three urban watercourse stretches after implementation of one-off recovering interventions: an integrated assessment

Kristiane Primo[1], Alexandre da Silva[1], Rosiane e Silva[1], Beatriz Olimpio[1], Gabriela Silva[1], and Ana Paula Silva[2]

[1]UNESP
[2]Federal University of Itajubá

April 8, 2021

Abstract

Faced with the anthropic activities of urban streams stretches through rectification with concrete, there is a concern about the modifications of the aquatic habitats and consequent ecological damages to the ecosystems. Based on biophilic engineering, there is a great opportunity to idealize and test interventions to revitalize such hampered ecosystems. Hence, we verified the performance of biological and organic factors, after the implementation of one-off interventions in three rivers using biophilic handmade materials and structural elements in their fixation. We carried out the project in urban stretches of concrete bed streams, located in Sorocaba-SP, Southeast of Brazil. In two years, we conducted biweekly in situ and laboratory measurements to characterize the study sites, idealize, scale, implement the projects, and, evaluate the ecological responses of the implementations. We collected sampling in two points: upstream and downstream interventions. We evaluated the performance of the interventions through the analysis of SWOT (Strengths, Weaknesses, Opportunities, and Threats) factors and by using the Analytic Hierarchy Process (AHP). We presented the results through a decision-making matrix for stakeholders, which indicated that our ideas are of low cost and easy to implement. Then, we got the following scenario of SWOT priorities: opportunity (58.55%), strength (24.71%), threat (10.74%), and weakness (6.00%). They demand constant efforts for maintenances and they need adjustments to a better understood by residents and the watershed management. We concluded that the strengths observed in the project turn our idea replicable in any part because it attaches the idea of caring about the environment through biophilic techniques, and the weaknesses are liable to modifications (improvements) in future projects that consider such proposal.

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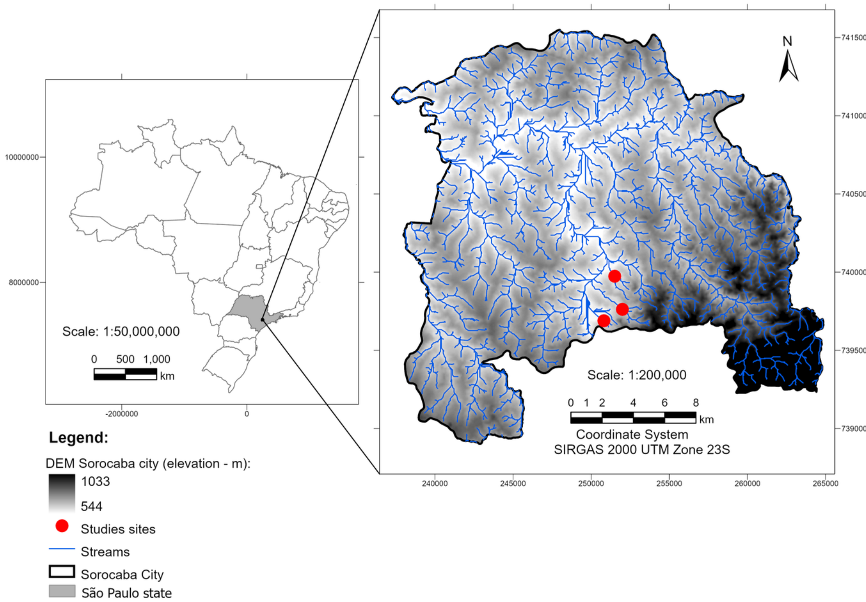
External Factors	Internal Factors	
	Strengths (S)	Weaknesses (W)
Opportunities (O)	Positive/Positive criterion	Positive/Negative criterion
Threats (T)	Negative/Positive criterion	Negative/Negative criterion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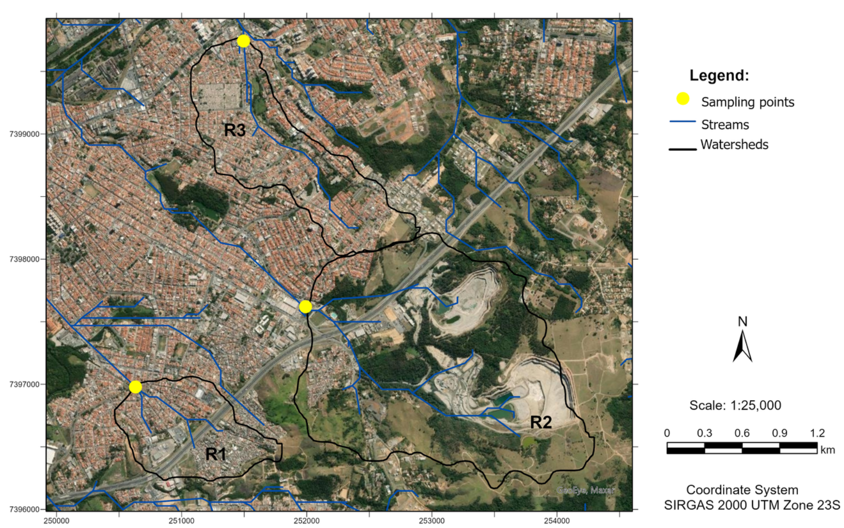
544
Studies sites
Streams
Sorocaba City
São Paulo state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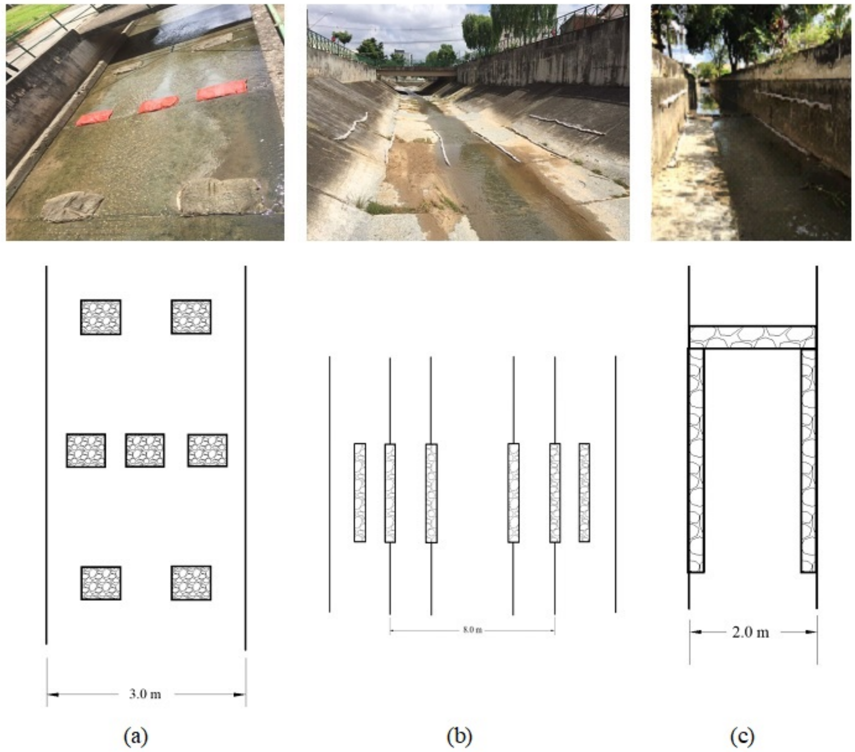
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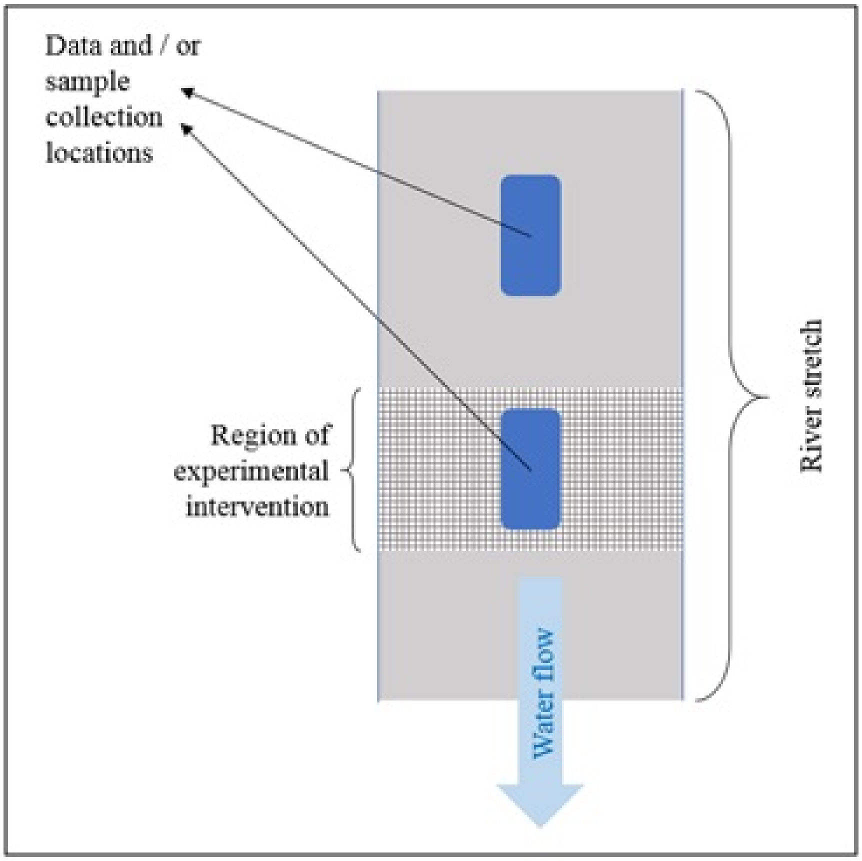
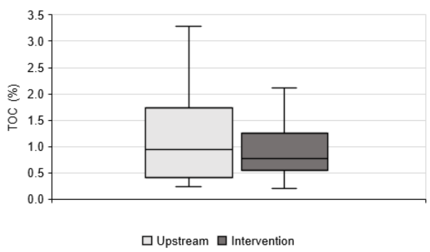
(a)
(b)
(c)

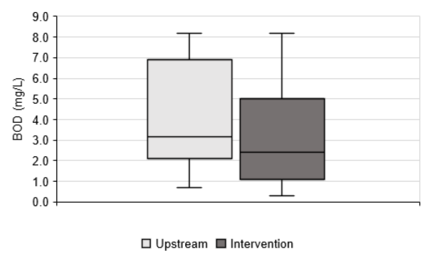

Data and / or sample collection locations
Region of experimental intervention
River stretch
Water flow

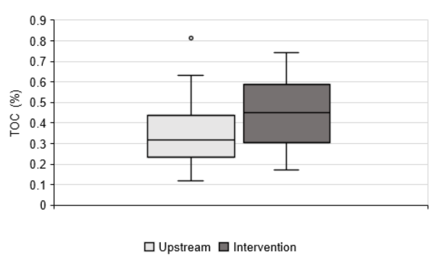
Variable	Procedure
Total organic carbon (TOC) of the sediment	We collected and transported the samples of sediments to the laboratory (approximately 1L each sample), and after remaining in an oven (at 100°C) and subsequently in a muffle (at 550°C) and desiccation, we calculated the organic carbon content through the equation (1): $$C = \frac{P_1 - P_2 \cdot 100}{M} \cdot f \quad (1)$$ Where: C: organic carbon content of the sediment (%); P_1: dried mass after oven (g); P_2: dried mass after muffling incineration (g); M: initial sample mass (g); f: conversion factor: the amount of organic matter to organic carbon content. This coefficient assumes that organic matter contains 58% of organic carbon (Aleksandrova and Naidenova, 1976 apud Jankauskas *et al.*, 2006).
Biochemical oxygen demand (BOD)	We used the electrometric method to measure the dissolved oxygen content using an Instrutherm model Mo-900 oximeter, previously calibrated. To determine the BOD, therefore, we measured the initial oxygen concentration of water samples in situ. Then, we stored the samples in appropriate bottles in the laboratory at the appropriate chamber with a standardized, controlled temperature (20°C). After 5 days incubated in the chamber, we checked the final levels of oxygen contained in the samples and we determined the BOD value using the equation (2): $$BOD = DO_i - DO_f \cdot \frac{V_{bottle}}{V_{sample}} \quad (2)$$ Where: DO_i: initial dissolved oxygen concentration (mg?L^{-1}); DO_f: final dissolved oxygen concentration (mg?L^{-1}); V_{bottle}: total volume of the bottle (mL); V_{sample}: total sample volume (mL). In terms of standardization, Hocking (2005) recommends that for the determination of BOD samples need a dilution, especially if they are samples from sewage stations, for instance. In our case, we observed that the water of the river dilutes the sewage, hence, we understood that there was no necessity for dilution of samples with distilled water. Hence, we manipulated our samples always with the original concentration (i.e. no diluted).
Invertebrate animals	We collected invertebrate animals with a Surber sampler. We positioned the sampler always counter to the current and always at the same time of the day, which made it possible to establish a homogeneity in the development of the specimens, which included several stages of development immatures (larvae and pupae). Initially, we carefully removed the larvae from the Suber and placed them in a flask with water. In the laboratory, we removed the larvae from the water with the aid of a small plastic sieve, carefully dried them witha paper towel, and quantified them.
Emergence and development of vascular plants	Following the recommendations of Gann *et al.* (2019), we took photographs throughout the project period to evidence the ecological responses and the possible achievement of our objectives for the interested parties. We took the pictures monthly as a record and analysis of specimen development in the streams. Additionally, we collected samples of the plants and delivered them to plants taxonomists for identification of the species.

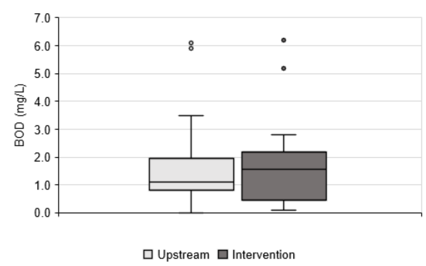
Property		**R1**	**R2**	**R3**
Area (km^2)		0.73	3.30	1.25
Perimeter (km)		3.60	7.68	5.83
Highest and lowest altimetry, and topographic range (meters)		660 - 544 = 116	729 – 580 = 149	620 – 560 = 60
Average slope ($m.m^{-1}$)		4.7	4.3	2.6
Number of headwaters and hierarchical order (in parenthesis)		4 (2)	13 (2)	5 (3)
Land cover categories (percentages)	Natural Remnant Vegetation	9.9	13.5	11.2
	Pasture	5.8	17.9	6.9
	Uncovered soil	9.7	8.9	0.1
	Urbanized sites	74.6	37.6	81.7
	Mining	0.0	22.1	0.0

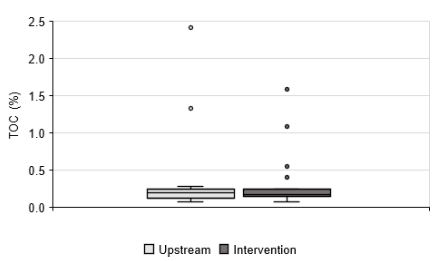
Statistical tests	**TOC of the sediment (%)**			**BOD of the water (mg L^{-1})**		
	R1	**R2**	**R3**	**R1**	**R2**	**R3**
Shapiro-Wilk test	$p < 0.05$	$p > 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
Hypothesis testing						
p (two-tailed)	0.1701[a]	0.0774[b]	0.5277[a]	0.0571[a]	0.6529[a]	0.3088[a]
p (one-tailed)	0.0851[a]	0.0387[b]	0.2639[a]	0.0285[a]	0.3265[a]	0.1544[a]

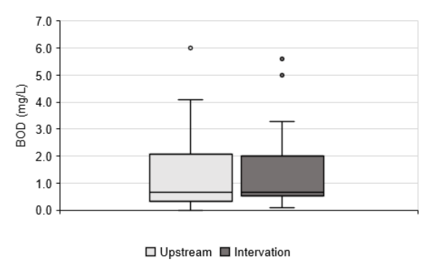










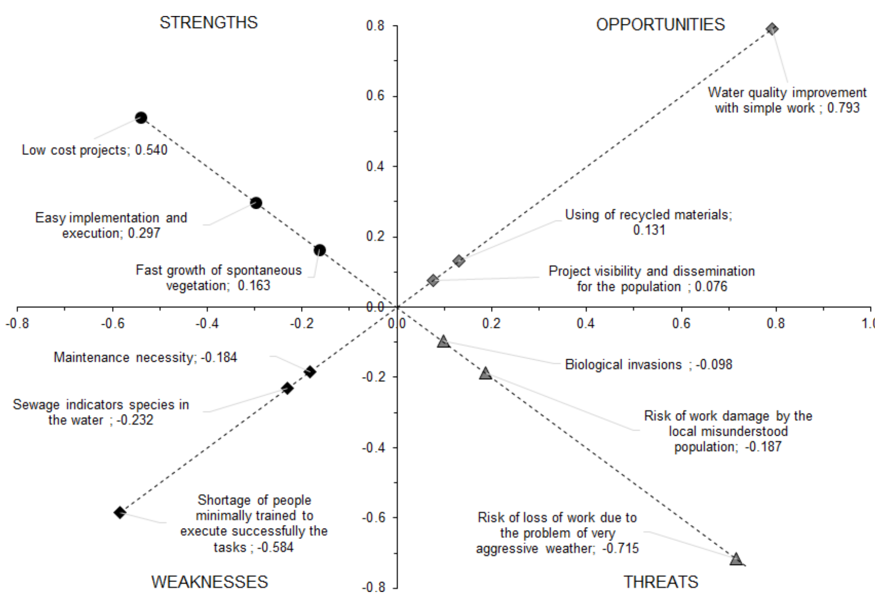


(a) (b) (c)

(a) (b) (c) (d)

	Strengths (S)	Weaknesses (W)
Internal factors	Low-cost projects (S1) Easy implementation and execution (S2) The fast growth of spontaneous vegetation (S3)	Maintenance necessity (W1) Shortage of people minimally trained to execute successfully the tasks (W2) Sewage indicators species in the water (W3)
	Opportunities (O)	Threats (T)
External factors	Using of recycled materials (O1) Project visibility and dissemination for the population (O2) Water quality improvement with simple work (O3)	The vulnerability of biological invasions (T1) Risk of work damage by the local misunderstood population (T2) Risk of loss of work due to the very aggressive weather (T3)

SWOT group	Group priority (%)	CR[1] of the group	SWOT factors	The priority of the factor within the group (%)[2]	Overall priority of the factor (%)
Strengths	24.71	0.008	Low-cost projects (S1)	53.96	13.34
			Easy implementation and execution (S2)	29.70	7.34
			The fast growth of spontaneous vegetation (S3)	16.34	4.04
Weaknesses	6.00	0.046	Maintenance necessity (W1)	18.40	1.10
			Shortage of people minimally trained to execute successfully the tasks (W2)	58.42	3.50
			Sewage indicators species in the water (W3)	23.18	1.39
Opportunities	58.55	0.019	Using of recycled materials (O1)	13.12	7.68
			Project visibility and dissemination for the population (O2)	7.60	4.45
			Water quality improvement with simple work (O3)	79.28	46.41
Threats	10.74	0.002	Biological invasions (T1)	9.77	1.05
			Risk of work damage by the local misunderstood population (T2)	18.70	2.01
			Risk of loss of work due to very aggressive weather (T3)	71.53	7.68



	Strength (S)	**Weakness (W)**
Opportunity (O)	Improve water quality and urban landscape, in streams previously investigated with potential for revitalization, throughout low-cost and easy execution bioengineering works.	Disseminate the knowledge of the river restoration subject through the publication of works for the academic environment recognition and arouse the interest of investors and public managers in this theme.
Threat (T)	More involvement of the population, with the issuing of alerts to the project monitors, especially after events of intense rain and fast response of the streams water levels.	We recommend a previous study of the sediment dynamics of the streams, verification of the use and occupation of the soil, and flow regime, for a better choice of the type of work and place of implementation, foreseeing the maintenance reduction.