Supplementary Materials

Integrated Multidimensional Modeling of Water Health and Resilience in the Cunas River Under Anthropogenic Pressure in Peru

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Table S1. Comparison of water quality classification ranges for different water quality indices (NSF-WQI, WA-WQI, CCME-WQI, and I-WQI).

NSF-WQI		WA-WQI	CCME-WQI	I-WQI
Excellent	91 - 100	0 - 25	95 - 100	< 25
Good	71 - 90	26 - 50	80 - 94	25 - 50
Medium	51 - 70	51 - 75	65 - 79	50 - 100
Poor	26 - 50	76 - 100	45 - 64	100 - 150
Very Poor	0 - 25	> 100	0 - 44	> 150

Note: The direction of the scale differs among indices. For NSF-WQI and CCME-WQI, higher values indicate better water quality, whereas for WA-WQI and I-WQI, lower values represent better water quality.

Table S2. Normality test (Shapiro–Wilk) of the physical-chemical and microbiological parameters of the water from the Cunas River, according to sampling season.

Parameter	Unit	Wet Season				Dry Season			
		Statistic W	df	Sig. (p)	Conclusion	Statistic W	df	Sig. (p)	Conclusion
Temperature	°C	0.9795	45	0.6006389459	Normal	0.9451	45	0.0332346437	Not Normal
pH	pH unit	0.5954	45	0.0000000006	Not Normal	0.6306	45	0.0000000021	Not Normal
TDS	mg/L	0.7993	45	0.0000022907	Not Normal	0.7947	45	0.0000018180	Not Normal
DO	mg/L	0.8788	45	0.0002205678	Not Normal	0.9331	45	0.0120505260	Not Normal
NO_3^-	mg/L	0.7667	45	0.0000004761	Not Normal	0.7482	45	0.0000002061	Not Normal
P	mg/L	0.6927	45	0.0000000206	Not Normal	0.7695	45	0.0000005405	Not Normal
BOD_5	mg/L	0.8600	45	0.0000669430	Not Normal	0.7694	45	0.0000005385	Not Normal
Turb	NTU	0.7144	45	0.0000000491	Not Normal	0.7154	45	0.0000000510	Not Normal
TC	MPN/100 mL	0.5848	45	0.0000000005	Not Normal	0.6289	45	0.0000000020	Not Normal

Note: Temp = Temperature; TDS = Total Dissolved Solids; DO = Dissolved Oxygen; NO_3^- = Nitrates; P = Total Phosphorus; BOD_5 = Biochemical Oxygen Demand; Turb = Turbidity; TC = Thermotolerant Coliforms; df = degrees of freedom; Sig. = statistical significance or p-value; If $p > 0.05$ = normal distribution; If $p < 0.05$ = non-normal distribution.

Table S3. Normality test (Shapiro–Wilk) of the physical-chemical and microbiological parameters in the upper, middle, and lower reaches, according to sampling season.

Parameter	Unit	River section	Wet Season				Dry Season			
			Statistic W	df	Sig. (p)	Conclusion	Statistic W	df	Sig. (p)	Conclusion
Temp	°C	Upper Reach	0.9546	15	0.5997925	Normal	0.7748	15	0.0017755	Not Normal
		Middle Reach	0.9508	15	0.5377901	Normal	0.9058	15	0.1165617	Normal
		Lower Reach	0.9326	15	0.2985911	Normal	0.9104	15	0.1372604	Normal
pH	pH unit	Upper Reach	0.3849	15	0.0000005	Not Normal	0.4055	15	0.0000007	Not Normal
		Middle Reach	0.5446	15	0.0000082	Not Normal	0.9208	15	0.1980050	Normal
		Lower Reach	0.7489	15	0.0008718	Not Normal	0.7974	15	0.0034022	Not Normal
TDS	mg/L	Upper Reach	0.8156	15	0.0058789	Not Normal	0.8171	15	0.0061465	Not Normal
		Middle Reach	0.8829	15	0.0523955	Normal	0.6556	15	0.0000865	Not Normal
		Lower Reach	0.8368	15	0.0113623	Not Normal	0.6854	15	0.0001740	Not Normal
DO	mg/L	Upper Reach	0.9588	15	0.6711197	Normal	0.9426	15	0.4160043	Normal
		Middle Reach	0.8730	15	0.0373132	Not Normal	0.9462	15	0.4673305	Normal
		Lower Reach	0.5498	15	0.0000091	Not Normal	0.8998	15	0.0944402	Normal
NO_3^-	mg/L	Upper Reach	0.8027	15	0.0039830	Not Normal	0.9207	15	0.1972767	Normal
		Middle Reach	0.9149	15	0.1607496	Normal	0.7094	15	0.0003136	Not Normal
		Lower Reach	0.7999	15	0.0036621	Not Normal	0.8748	15	0.0396676	Not Normal
P	mg/L	Upper Reach	0.8646	15	0.0281010	Not Normal	0.8534	15	0.0194335	Not Normal
		Middle Reach	0.7552	15	0.0010347	Not Normal	0.8573	15	0.0220983	Not Normal
		Lower Reach	0.7816	15	0.0021560	Not Normal	0.8796	15	0.0468296	Not Normal
BOD_5	mg/L	Upper Reach	0.7661	15	0.0013947	Not Normal	0.6434	15	0.0000656	Not Normal
		Middle Reach	0.7804	15	0.0020845	Not Normal	0.9026	15	0.1043176	Normal
		Lower Reach	0.8687	15	0.0322911	Not Normal	0.9387	15	0.3667697	Normal
Turb	NTU	Upper Reach	0.9076	15	0.1242654	Normal	0.8850	15	0.0562858	Normal
		Middle Reach	0.8497	15	0.0171857	Not Normal	0.8130	15	0.0054180	Not Normal

		Lower Reach	0.7777	15	0.0019307	Not Normal	0.8377	15	0.0116920	Not Normal
TC	MPN / 100 mL	Upper Reach	0.9148	15	0.1605278	Normal	0.7723	15	0.0016567	Not Normal
		Middle Reach	0.6897	15	0.0001933	Not Normal	0.4825	15	0.0000025	Not Normal
		Lower Reach	0.8299	15	0.0091278	Not Normal	0.8469	15	0.0156828	Not Normal

Note: Temp = Temperature; TDS = Total Dissolved Solids; DO = Dissolved Oxygen; NO_3^- = Nitrates; P = Total Phosphorus; BOD_5 = Biochemical Oxygen Demand; Turb = Turbidity; TC = Thermotolerant Coliforms; df = degrees of freedom; Sig. = statistical significance or p-value; If $p > 0.05$ = normal distribution; If $p < 0.05$ = non-normal distribution.

Table S4. Homogeneity of variances (Levene's test) for seasonal comparisons by river segment.

Parameter	Zone	Levene statistic	p-value	Homogeneity of variances
Temp	UR	0.1706	0.6827	Yes
Temp	MR	0.2175	0.6446	Yes
Temp	LR	0.0025	0.9601	Yes
pH	UR	0.0076	0.9311	Yes
pH	MR	0.3625	0.5520	Yes
pH	LR	5.1290	0.0315	No
TDS	UR	2.0612	0.1622	Yes
TDS	MR	7.0035	0.0132	No
TDS	LR	7.1800	0.0122	No
DO	UR	0.0306	0.8624	Yes
DO	MR	0.9927	0.3276	Yes
DO	LR	0.0651	0.8005	Yes
NO_3^-	UR	2.1435	0.1543	Yes
NO_3^-	MR	0.1578	0.6942	Yes
NO_3^-	LR	9.0822	0.0054	No
P	UR	0.0700	0.7933	Yes
P	MR	2.1990	0.1493	Yes
P	LR	0.0007	0.9793	Yes
BOD_5	UR	0.0000	1.0000	Yes
BOD_5	MR	2.9293	0.0980	Yes
BOD_5	LR	6.7460	0.0148	No
Turb	UR	1.9948	0.1689	Yes
Turb	MR	4.6458	0.0399	No
Turb	LR	0.0361	0.8508	Yes
TC	UR	1.4592	0.2372	Yes
TC	MR	1.9730	0.1711	Yes
TC	LR	9.3686	0.0048	No

Note: Temp = Temperature; TDS = Total Dissolved Solids; DO = Dissolved Oxygen; NO_3^- = Nitrates; P = Total Phosphorus; BOD_5 = Biochemical Oxygen Demand; Turb = Turbidity; TC = Thermotolerant Coliforms; UR = Upper Reach; MR = Middle Reach; LR = Lower Reach. Homogeneity of variances was assessed using Levene's test for datasets considered for parametric seasonal comparisons. $p > 0.05$ indicates that the assumption of equal variances was satisfied.

Table S5. Gradient lengths obtained by detrended correspondence analysis (DCA) prior to PCA.

Data	Axis 1	Axis 2	Axis 3	Axis 4	Interpretation
All seasons	1.41	0.33	0.67	0.22	Short gradient; PCA appropriate
Wet season	0.99	0.45	0.39	0.36	Short gradient; PCA appropriate
Dry season	1.47	1.08	1.08	1.09	Short gradient; PCA appropriate

Note: All first-axis gradient lengths were < 3 SD units; therefore, PCA was retained as the ordination method.

Table S6. Descriptive statistics of the physicochemical and microbiological parameters of the water in the upper reach of the Cunas River, according to sampling season.

Parameter	Unit	Statistic	Upper Reach - Wet Season									Upper Reach – Dry Season								
			Upper Reach 1			Upper Reach 2			Upper Reach 3			Upper Reach 1			Upper Reach 2			Upper Reach 3		
Temp	°C	Mean ± SD	9.82	±	0.92	11.12	±	0.80	10.04	±	0.50	11.83	±	1.42	10.80	±	0.32	10.99	±	0.57
		Range	9.00	-	11.00	10.00	-	11.95	9.50	-	10.60	10.50	-	13.60	10.43	-	11.22	10.43	-	11.68
pH	pH unit	Mean ± SD	8.22	±	1.11	8.84	±	0.11	8.74	±	0.02	8.78	±	0.04	8.23	±	0.90	8.70	±	0.06
		Range	6.23	-	8.73	8.72	-	9.00	8.71	-	8.76	8.72	-	8.83	6.62	-	8.69	8.61	-	8.76
TDS	mg/L	Mean ± SD	35.86	±	2.44	40.06	±	7.41	45.50	±	3.20	42.92	±	7.00	47.34	±	0.76	41.62	±	2.37
		Range	33.70	-	40.00	34.00	-	48.70	40.00	-	48.00	35.00	-	48.10	46.30	-	48.00	40.00	-	45.60
DO	mg/L	Mean ± SD	8.40	±	0.43	7.84	±	0.38	8.40	±	0.41	7.72	±	0.26	7.44	±	0.59	7.86	±	0.44
		Rango	7.80	-	9.00	7.20	-	8.20	8.00	-	9.00	7.30	-	8.00	6.70	-	8.00	7.30	-	8.50
NO_3^-	mg/L	Mean ± SD	0.0056	±	0.0013	0.0052	±	0.0004	0.0060	±	0.0010	0.0060	±	0.0016	0.0062	±	0.0016	0.0076	±	0.0013
		Range	0.0040	-	0.0070	0.0050	-	0.0060	0.0050	-	0.0070	0.0040	-	0.0080	0.0050	-	0.0090	0.0060	-	0.0090
P	mg/L	Mean ± SD	0.0010	±	0.0002	0.0008	±	0.0003	0.0009	±	0.0003	0.0008	±	0.0002	0.0010	±	0.0001	0.0014	±	0.0003
		Range	0.0007	-	0.0013	0.0003	-	0.0010	0.0007	-	0.0013	0.0007	-	0.0010	0.0010	-	0.0013	0.0010	-	0.0016
BOD_5	mg/L	Mean ± SD	1.40	±	0.55	1.00	±	0.71	1.60	±	0.55	1.60	±	0.55	1.60	±	0.55	1.40	±	0.55
		Range	1.00	-	2.00	0.00	-	2.00	1.00	-	2.00	1.00	-	2.00	1.00	-	2.00	1.00	-	2.00
Turb	NTU	Mean ± SD	3.19	±	0.54	3.11	±	0.55	3.21	±	0.62	3.69	±	0.43	3.61	±	0.50	4.06	±	0.33
		Range	2.70	-	4.00	2.56	-	4.00	2.50	-	3.87	3.00	-	4.00	2.78	-	4.10	3.87	-	4.65
TC	MPN / 100 mL	Mean ± SD	45.03	±	8.82	26.27	±	9.33	29.21	±	10.70	27.60	±	25.86	3.47	±	7.75	20.51	±	19.67
		Range	35.34	-	51.93	17.33	-	41.28	17.33	-	40.69	0.00	-	51.48	0.00	-	17.33	0.00	-	41.28

Note: Temp = Temperature; TDS = Total Dissolved Solids; DO = Dissolved Oxygen; NO_3^- = Nitrates; P = Total Phosphorus; BOD_5 = Biochemical Oxygen Demand; Turb = Turbidity; TC = Thermotolerant Coliforms. Values represent the mean ± standard deviation (n = 5) per sampling station.

Table S7. Descriptive statistics of the physicochemical and microbiological parameters of the water in the middle reach of the Cunas River, according to sampling season.

Parameter	Unit	Stat.	Middle Reach - Wet Season									Middle Reach - Dry Season								
			Middle Reach 1			Middle Reach 2			Middle Reach 3			Middle Reach 1			Middle Reach 2			Middle Reach 3		
Temp	°C	Mean ± SD	12.11	±	0.40	13.80	±	0.39	12.28	±	0.82	15.78	±	0.71	14.45	±	0.43	14.36	±	0.59
		Range	11.51	-	12.48	13.40	-	14.43	11.40	-	13.16	14.60	-	16.40	14.00	-	15.00	13.80	-	15.30
pH	pH unit	Mean ± SD	8.83	±	0.14	7.80	±	1.27	8.72	±	0.07	8.72	±	0.22	8.97	±	0.32	8.49	±	0.45
		Range	8.60	-	9.00	6.33	-	8.83	8.65	-	8.81	8.52	-	9.10	8.56	-	9.34	8.00	-	8.83
TDS	mg/L	Mean ± SD	13.40	±	0.55	13.52	±	1.40	14.06	±	0.93	42.10	±	3.09	98.40	±	2.19	100.18	±	0.22
		Range	13.00	-	14.00	12.00	-	15.00	13.00	-	15.00	38.00	-	45.00	96.00	-	100.01	100.00	-	100.50
DO	mg/L	Mean ± SD	6.98	±	0.13	7.65	±	0.75	8.18	±	0.28	6.12	±	0.13	5.84	±	0.67	6.95	±	0.12
		Rango	6.80	-	7.10	6.85	-	8.60	7.80	-	8.50	6.00	-	6.30	5.00	-	6.50	6.80	-	7.10
NO_3^-	mg/L	Mean ± SD	0.3300	±	0.0604	0.2020	±	0.0319	0.2660	±	0.0727	0.1946	±	0.0075	0.2100	±	0.0100	0.4140	±	0.0195
		Range	0.2400	-	0.3900	0.1600	-	0.2500	0.1800	-	0.3500	0.1850	-	0.2000	0.2000	-	0.2200	0.4000	-	0.4400
P	mg/L	Mean ± SD	0.0085	±	0.0018	0.0098	±	0.0033	0.0072	±	0.0015	0.0085	±	0.0007	0.0109	±	0.0013	0.0188	±	0.0023
		Range	0.0065	-	0.0098	0.0065	-	0.0130	0.0065	-	0.0098	0.0078	-	0.0098	0.0098	-	0.0130	0.0166	-	0.0228
BOD_5	mg/L	Mean ± SD	7.90	±	1.02	7.60	±	0.54	1.90	±	0.22	2.34	±	0.42	5.30	±	0.45	3.42	±	0.66
		Range	7.00	-	9.00	7.00	-	8.30	1.50	-	2.00	2.00	-	3.00	5.00	-	6.00	3.00	-	4.50
Turb	NTU	Mean ± SD	4.63	±	0.48	5.22	±	0.95	4.04	±	0.15	4.40	±	0.25	3.82	±	0.54	9.12	±	1.49
		Range	4.10	-	5.13	3.89	-	6.10	3.89	-	4.30	4.00	-	4.60	3.30	-	4.70	7.50	-	11.20
TC	MPN / 100 mL	Mean ± SD	387.68	±	613.60	271.26	±	54.94	291.65	±	334.22	106.80	±	9.79	270.47	±	310.49	80.57	±	56.67
		Range	99.00	-	1485.00	198.00	-	316.80	20.79	-	821.70	95.44	-	118.80	106.92	-	821.70	36.53	-	168.30

Note: Temp = Temperature; TDS = Total Dissolved Solids; DO = Dissolved Oxygen; NO_3^- = Nitrates; P = Total Phosphorus; BOD_5 = Biochemical Oxygen Demand; Turb = Turbidity; TC = Thermotolerant Coliforms. Values represent the mean ± standard deviation (n = 5) per sampling station.

Table S8. Descriptive statistics of the physicochemical and microbiological parameters of the water in the lower reach of the Cunas River, according to sampling season.

Parameter	Unit	Stat.	Lower Reach - Wet Season									Lower Reach - Dry Season								
			Lower Reach 1			Lower Reach 2			Lower Reach 3			Lower Reach 1			Lower Reach 2			Lower Reach 3		
Temp	°C	Mean ± SD	13.04	±	0.62	13.96	±	0.26	16.08	±	0.91	16.71	±	0.48	17.42	±	0.44	19.59	±	1.11
		Range	12.50	-	14.00	13.60	-	14.28	15.00	-	17.30	16.03	-	17.17	16.80	-	18.00	18.10	-	21.10
pH	pH unit	Mean ± SD	8.31	±	1.00	7.95	±	0.98	8.41	±	0.38	8.88	±	0.03	8.68	±	0.11	8.65	±	0.07
		Range	6.53	-	8.85	6.61	-	8.83	8.00	-	8.81	8.84	-	8.91	8.61	-	8.87	8.60	-	8.78
TDS	mg/L	Mean ± SD	109.10	±	8.23	112.20	±	1.79	104.26	±	5.25	44.26	±	3.28	142.94	±	2.26	151.50	±	2.88
		Range	95.00	-	116.50	110.00	-	115.00	100.00	-	110.00	40.00	-	47.00	140.00	-	146.20	148.30	-	156.00
DO	mg/L	Mean ± SD	5.26	±	0.43	5.10	±	0.12	4.58	±	1.45	4.98	±	0.15	5.36	±	0.35	5.54	±	0.36
		Rango	5.00	-	6.00	5.00	-	5.30	2.00	-	5.50	4.80	-	5.20	5.00	-	5.80	5.00	-	6.00
NO_3^-	mg/L	Mean ± SD	1.4800	±	0.0837	1.7400	±	0.2510	1.5400	±	0.2702	2.8800	±	0.3564	1.5400	±	0.0894	2.5200	±	0.2950
		Range	1.4000	-	1.6000	1.5000	-	2.0000	1.3000	-	2.0000	2.5000	-	3.2000	1.5000	-	1.7000	2.2000	-	3.0000
P	mg/L	Mean ± SD	0.0443	±	0.0044	0.0062	±	0.0004	0.0235	±	0.0157	0.0927	±	0.0036	0.0567	±	0.0014	0.1013	±	0.0155
		Range	0.0391	-	0.0489	0.0055	-	0.0065	0.0064	-	0.0391	0.0880	-	0.0978	0.0554	-	0.0587	0.0864	-	0.1206
BOD_5	mg/L	Mean ± SD	11.40	±	0.89	15.00	±	3.54	20.60	±	0.89	15.16	±	1.98	18.80	±	1.79	18.32	±	2.12
		Range	10.00	-	12.00	10.00	-	20.00	20.00	-	22.00	13.00	-	17.50	16.00	-	20.00	16.00	-	21.00
Turb	NTU	Mean ± SD	18.21	±	4.30	22.55	±	1.06	22.84	±	1.46	29.12	±	4.04	28.12	±	3.57	30.84	±	1.37
		Range	11.10	-	22.11	21.00	-	23.50	21.10	-	25.00	22.50	-	33.20	23.40	-	31.00	28.60	-	32.00
TC	MPN / 100 mL	Mean ± SD	11325.60	±	2575.52	28432.80	±	15064.99	9325.80	±	6945.68	33165.00	±	2331.23	35006.40	±	796.93	31986.90	±	3636.21
		Range	9900.00	-	15840.00	1485.00	-	35343.00	3465.00	-	19800.00	29700.00	-	35145.00	33957.00	-	36135.00	27324.00	-	36135.00

Note: Temp = Temperature; TDS = Total Dissolved Solids; DO = Dissolved Oxygen; NO_3^- = Nitrates; P = Total Phosphorus; BOD_5 = Biochemical Oxygen Demand; Turb = Turbidity; TC = Thermotolerant Coliforms. Values represent the mean ± standard deviation (n = 5) per sampling station.

Table S9. Significance tests of the physicochemical and microbiological parameters in the upper, middle, and lower reaches of the Cunas River, according to sampling season.

Parameter	Unit	Period	Test	*p*-Value	Significant difference
Temp	°C	Wet Season	Kruskal–Wallis	0.000	Yes
		Dry Season	Kruskal–Wallis	0.000	Yes
pH	pH unit	Wet Season	Kruskal–Wallis	0.185	No
		Dry Season	Kruskal–Wallis	0.591	No
TDS	mg/L	Wet Season	Kruskal–Wallis	0.000	Yes
		Dry Season	Kruskal–Wallis	0.002	Yes
DO	mg/L	Wet Season	Kruskal–Wallis	0.000	Yes
		Dry Season	Kruskal–Wallis	0.000	Yes
NO_3^-	mg/L	Wet Season	Kruskal–Wallis	0.000	Yes
		Dry Season	Kruskal–Wallis	0.000	Yes
P	mg/L	Wet Season	Kruskal–Wallis	0.000	Yes
		Dry Season	Kruskal–Wallis	0.000	Yes
BOD_5	mg/L	Wet Season	Kruskal–Wallis	0.000	Yes
		Dry Season	Kruskal–Wallis	0.000	Yes
Turb	NTU	Wet Season	Kruskal–Wallis	0.000	Yes
		Dry Season	Kruskal–Wallis	0.000	Yes
TC	MPN/100 mL	Wet Season	Kruskal–Wallis	0.000	Yes
		Dry Season	Kruskal–Wallis	0.000	Yes

Note: Temp = Temperature; TDS = Total Dissolved Solids; DO = Dissolved Oxygen; NO_3^- = Nitrates; P = Total Phosphorus; BOD_5 = Biochemical Oxygen Demand; Turb = Turbidity; TC = Thermotolerant Coliforms; *p*-Value < 0.05 = significant difference between periods; *p*-Value > 0.05 = no significant difference between periods.

Table S10. Significance tests for physicochemical and microbiological parameters in the wet and dry seasons.

Parameter	Unit	Test	*p*-Value	Significant difference
Temp	°C	Mann–Whitney U	0.000	Yes
pH	pH unit	Mann–Whitney U	0.388	No
TDS	mg/L	Mann–Whitney U	0.002	Yes
DO	mg/L	Mann–Whitney U	0.027	Yes
NO_3^-	mg/L	Mann–Whitney U	0.318	No
P	mg/L	Mann–Whitney U	0.009	Yes
BOD_5	mg/L	Mann–Whitney U	0.855	No
Turb	NTU	Mann–Whitney U	0.113	No
TC	MPN / 100 mL	Mann–Whitney U	0.781	No

Note: Temp = Temperature; TDS = Total Dissolved Solids; DO = Dissolved Oxygen; NO_3^- = Nitrates; P = Total Phosphorus; BOD_5 = Biochemical Oxygen Demand; Turb = Turbidity; TC = Thermotolerant coliforms; *p*-Value < 0.05 = significant difference between periods; *p*-Value > 0.05 = no significant difference between periods.

Table S11. Significance tests for physicochemical and microbiological parameters in the upper, middle, and lower reaches of the Cunas River, according to sampling seasons (wet and dry season).

Parameter	Unit	River section	Test	*p*-Value	Significant difference
Temp	°C	Upper Reach	Mann–Whitney U	0.038	Yes
		Middle Reach	t de Student	0.000	Yes
		Lower Reach	t de Student	0.000	Yes
pH	pH unit	Upper Reach	Mann–Whitney U	0.204	No
		Middle Reach	Mann–Whitney U	0.663	No
		Lower Reach	Mann–Whitney U	0.007	Yes
TDS	mg/L	Upper Reach	Mann–Whitney U	0.077	No
		Middle Reach	Mann–Whitney U	0.000	Yes
		Lower Reach	Mann–Whitney U	0.119	No
DO	mg/L	Upper Reach	t de Student	0.003	Yes
		Middle Reach	Mann–Whitney U	0.000	Yes
		Lower Reach	Mann–Whitney U	0.495	No
NO_3^-	mg/L	Upper Reach	Mann–Whitney U	0.071	No
		Middle Reach	Mann–Whitney U	0.850	No
		Lower Reach	Mann–Whitney U	0.001	Yes
P	mg/L	Upper Reach	Mann–Whitney U	0.089	No
		Middle Reach	Mann–Whitney U	0.004	Yes
		Lower Reach	Mann–Whitney U	0.000	Yes
BOD_5	mg/L	Upper Reach	Mann–Whitney U	0.383	No
		Middle Reach	Mann–Whitney U	0.083	No
		Lower Reach	Mann–Whitney U	0.249	No
Turb	NTU	Upper Reach	t de Student	0.002	Yes
		Middle Reach	Mann–Whitney U	0.678	No
		Lower Reach	Mann–Whitney U	0.000	Yes
TC	MPN / 100 mL	Upper Reach	Mann–Whitney U	0.029	Yes
		Middle Reach	Mann–Whitney U	0.053	No
		Lower Reach	Mann–Whitney U	0.006	Yes

Note: Temp = Temperature; TDS = Total Dissolved Solids; DO = Dissolved Oxygen; NO_3^- = Nitrates; P = Total Phosphorus; BOD_5 = Biochemical Oxygen Demand; Turb = Turbidity; TC = Thermotolerant Coliforms; *p*-Value < 0.05 = significant difference between periods; *p*-Value > 0.05 = no significant difference between periods. Student's t-test was used when both normality and homogeneity of variances assumptions were satisfied; Mann–Whitney U test was applied when these assumptions were not met.

Table S12. Comparative assessment of water health using the NSF-WQI, WA-WQI, CCME-WQI, and I-WQI indices according to the section of the Cunas River and hydrological scenario.

River section	Sector	NSF-WQI	Quality	WA-WQI	Quality	CCME-WQI	Quality	I-WQI	Quality
Upper Reach - Wet Season	1	81.45	Good	4.08	Excellent	92.64	Good	15.44	Excellent
	2	80.03	Good	4.26	Excellent	99.99	Excellent	18.31	Excellent
	3	79.27	Good	4.32	Excellent	99.99	Excellent	18.74	Excellent
Upper Reach - Dry Season	1	79.66	Good	4.59	Excellent	99.99	Excellent	19.76	Excellent
	2	86.07	Good	4.51	Excellent	99.99	Excellent	16.43	Excellent
	3	80.17	Good	5.13	Excellent	99.99	Excellent	19.73	Excellent
Middle Reach - Wet Season	1	71.85	Good	12.86	Excellent	92.23	Good	31.99	Good
	2	73.04	Good	13.60	Excellent	90.76	Good	26.14	Good
	3	68.88	Medium	10.56	Excellent	99.99	Excellent	22.59	Excellent
Middle Reach - Dry Season	1	73.39	Good	12.41	Excellent	92.64	Good	23.21	Excellent
	2	68.3	Medium	14.85	Excellent	92.23	Good	29.45	Good
	3	73.79	Good	23.65	Excellent	89.79	Good	33.98	Good
Lower Reach - Wet Season	1	59.87	Medium	51.97	Poor	70.38	Medium	136.39	Poor
	2	58.46	Medium	18.14	Excellent	71.35	Medium	253.57	Very Poor
	3	55.41	Medium	35.25	Good	63.03	Poor	139.85	Poor
Lower Reach - Dry Season	1	53.15	Medium	102.14	Very Poor	62.11	Poor	312.82	Very Poor
	2	55.51	Medium	68.13	Poor	69.38	Medium	322.24	Very Poor
	3	54.61	Medium	110.82	Very Poor	62.11	Poor	313.34	Very Poor

Table S13. Spearman rank correlation coefficients, p-values, and significance levels among physicochemical and microbiological parameters.

Parameter 1	Parameter 2	Spearman ρ	p_value	n	Significance level
pH	Temp	-0.056	0.602	90	ns
TDS	Temp	0.522	<0.001	90	***
DO	Temp	-0.749	<0.001	90	***
NO^{3-}	Temp	0.787	<0.001	90	***
P	Temp	0.829	<0.001	90	***
BOD_5	Temp	0.785	<0.001	90	***
Turb	Temp	0.776	<0.001	90	***
TC	Temp	0.757	<0.001	90	***
TDS	pH	-0.187	0.077	90	ns
DO	pH	0.099	0.354	90	ns
NO^{3-}	pH	-0.04	0.705	90	ns
P	pH	0.007	0.949	90	ns
BOD_5	pH	-0.101	0.342	90	ns
Turb	pH	-0.064	0.551	90	ns
TC	pH	-0.036	0.734	90	ns
DO	TDS	-0.643	<0.001	90	***
NO^{3-}	TDS	0.524	<0.001	90	***
P	TDS	0.436	<0.001	90	***
BOD_5	TDS	0.537	<0.001	90	***
Turb	TDS	0.534	<0.001	90	***
TC	TDS	0.496	<0.001	90	***
NO^{3-}	DO	-0.795	<0.001	90	***
P	DO	-0.717	<0.001	90	***
BOD_5	DO	-0.777	<0.001	90	***
Turb	DO	-0.732	<0.001	90	***
TC	DO	-0.765	<0.001	90	***
P	NO^{3-}	0.843	<0.001	90	***
BOD_5	NO^{3-}	0.881	<0.001	90	***
Turb	NO^{3-}	0.875	<0.001	90	***
TC	NO^{3-}	0.852	<0.001	90	***
BOD_5	P	0.794	<0.001	90	***
Turb	P	0.789	<0.001	90	***
TC	P	0.766	<0.001	90	***
Turb	BOD_5	0.854	<0.001	90	***
TC	BOD_5	0.874	<0.001	90	***
TC	Turb	0.808	<0.001	90	***

Note: Spearman's rank correlation coefficients (ϱ) were calculated using pairwise complete observations. p-values test the null hypothesis of no monotonic association between variables. Significance levels: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, ns = not significant.

Table S14. Summary of the principal component analysis (PCA) of the physicochemical and microbiological parameters of the water of the Cunas River during the wet and dry seasons.

Component	Eigenvalue	% variance	% cumulative
1	6.5777	73.09	73.09
2	1.1223	12.47	85.56
3	0.5214	5.79	91.35
4	0.3132	3.48	94.83
5	0.2877	3.20	98.02
6	0.1114	1.24	99.26
7	0.0392	0.44	99.70
8	0.0185	0.21	99.90
9	0.0087	0.10	100.00

Table S15. Summary of the principal component analysis (PCA) of the physicochemical and microbiological parameters of the water of the Cunas River during the wet season.

Component	Eigenvalue	% variance	% cumulative
1	6.9638	77.38	77.38
2	0.8918	9.91	87.28
3	0.5374	5.97	93.26
4	0.4907	5.45	98.71
5	0.0572	0.64	99.34
6	0.0450	0.50	99.84
7	0.0133	0.15	99.99
8	0.0008	0.01	100.00

Table S16. Summary of the principal component analysis (PCA) of the physicochemical and microbiological parameters of the water of the Cunas River during the dry season.

Component	Eigenvalue	% variance	% cumulative
1	6.8367	75.96	75.96
2	1.0619	11.80	87.76
3	0.6651	7.39	95.15
4	0.2611	2.90	98.05
5	0.1218	1.35	99.41
6	0.0469	0.52	99.93
7	0.0064	0.07	100.00
8	0.0001	0.00	100.00