Water Quality Variability in the Chimehuín River Over the 2000-2025 period

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Abstract

Over the past 25 years, Junín de los Andes, a city in Northern Patagonia, has undergone significant urban expansion, nearly doubling in size. Concurrently, the Chimehuín River, a vital freshwater resource for the region, has experienced various environmental changes. This study analyzes the water quality of the Chimehuín River by examining physical-chemical parameters and macroinvertebrate populations following The GLOBE Program Hydrosphere Protocols. Historical data from 2000 to 2025 were compared with new sampling data to identify trends and potential causes of water quality variations.

This research seeks to answer the following questions: What changes have occurred in the Chimehuín River's water quality over the last 25 years? Which of the analyzed parameters have varied the most in water quality?

Results show that while physical-chemical parameters largely remain within normal ranges, fluctuations in dominant macroinvertebrate taxa and EPT% (Ephemeroptera, Plecoptera, and Trichoptera) suggest localized anthropogenic and climatic impacts. Notably, a decrease in maximum river flow was seen, likely influenced by prolonged drought periods, urbanization, and sediment deposits from volcanic activity. The 2015 Calbuco volcanic eruption contributed to a temporary decline in water quality, particularly affecting macroinvertebrate communities in the following years. However, recent data from 2025 suggest a recovery trend in both macroinvertebrate populations and water quality indices.

This study underscores the importance of long-term monitoring to assess the interplay between natural disturbances and human activities. Findings highlight the need for sustainable land-use planning and continued water quality assessments to mitigate potential future impacts. Further research should focus on integrating additional biological indicators and expanding sampling efforts to enhance understanding of long-term environmental changes in the Chimehuín River.

Keywords: Water quality, Chimehuín River, Macroinvertebrates, Volcanic impact, Anthropic impact.

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Research Questions

The following questions were made:

What changes have occurred in the Chimehuin river's water quality over the last 25 years?

Which of the analyzed parameters have varied the most in the water quality of the Chimehuin river during the last 25 years?

And the hypotheses were:

H_1: The main changes are due to the volcanic eruption and ground movements associated with the construction of road pavements.

H_2: Physical-chemical values remain normal, but fluctuations are observed in the dominant taxons and the %EPT of macroinvertebrate populations.

Introduction & Review of Literature

The Chimehuín river basin is one of the most important of the Lanín National Park, contributing 23% of the riverside environments of this park (Funes et al., 2006). The Chimehuín river starts on the border between the Andes mountains and the Patagonian steppe (MapBiomas

Argentina, 2024), flowing from Lake Huechulafquen and travelling 53 km until its end in the river Collón Cura. It also receives the waters of Curruhué and Quilquihue rivers. It has a regime regulated by Lake Huechulafquen, in times of flood, which is increasingly affecting the population due to urban growth on its shores (Bruno Cubero, 2001). New lots have been conducted, and the Chimehuín River springs and shores are being urbanized, which can lead to changes in riverbanks and water quality. The river supplies water to the city and rural areas.

The flow increases by rain in winter and by snowmelt in spring. The lowest flow happens in summer and early fall, when anglers, bathers, campers and others most commonly use it. The quality of the water and of the banks is good, but in the urban zones with more alteration of banks (Aigo et al., 2015) changes in macroinvertebrate populations are detected.

The region was affected by volcanic eruptions causing ash rain in 2011 by Puyehue-Cordón Caulle (Craig, et al., 2016a) and 2015 by Calbuco volcano (Romero et al., 2016). Numerous impacts have been documented in terrestrial and aquatic ecosystems, with varying degrees of involvement associated with the thickness of the ash, precipitation and humidity of the place. These variables also influence the recovery of ecosystems. Documented impacts in the region are: 1) Diseases in domestic and wild herbivores (Flueck, 2016), 2) Losses in agricultural production (Craig, et al., 2016a,b) 3) Changes in populations of: a) Phytoplankton (Modenutti, et al., 2013) and zooplankton in rivers and lakes (Balseiro et al., 2014) b) Trichoptera (Brand and Miserendino, 2014) and other macroinvertebrates (Lallement et al., 2014; Miserendino et al., 2012; Pepe et al., 2018) in rivers of the Andes c) Native terrestrial arthropods (Elizalde, 2014) y exotics (Masciocchi et al., 2012).

Research Methods

Methodology

Measurements were made in public places along the Chimehuín River coast following the GLOBE Program Hydrosphere Protocols (GLOBE Program, 2024a,c). Land cover data were recorded using the GLOBE Observer App (GLOBE Program, 2024b) and the MUC System (Modified UNESCO Classification) was used for classification (Bourgeault et al., 1998; GLOBE, 2024). For land cover variations analysis, Landsat satellite images were used (Gorelick, et al., 2017). For weather characterization Köppen-Geiger climate classification was used (Beck et al., 2023; Kottek et al., 2006; National Geographic, 2024).

For the physical-chemical analyses of water, the LaMotte brand kits were used to determine: a) pH, turbidity and temperature (kit used in World Water Monitoring Challenge); b) Alkalinity Test Kit Code: 4491-DR-01; c) Dissolved Oxygen Test Kit. Code: 5860-01 and d) Nitrates Test Kit. Code: 3354-01. Waterproof Pocket Testers were used to measure pH (Oakton pHTestr 10), electrical conductivity (Oakton ECTestr 11), and total dissolved solids (Oakton TDSTestr 11).

At each sampling site, the physical-chemical analysis of the water was carried out, the benthic macroinvertebrates were quantified and identified, and the land use was recorded around the river. The safety measures recommended by the GLOBE Protocols and kits guides were followed.

Several samples were taken at each site to ensure their validity. Physical-chemical and biological (benthic macroinvertebrates) analyses of sites sampled prior to 2025 done by other GLOBE students and local and international researchers. Sampling was performed between 10 am and 12 pm.

For the identification of the macroinvertebrates, a dichotomous key was used and for its analysis, the protocol of macroinvertebrates of fresh water of the GLOBE Program was followed.

The percentage of EPT richness (measured as the number of Ephemeroptera, Plecoptera and Trichoptera) was calculated on the total of species that are in the sites. The percentage of dominant taxon was also calculated on the total of the macroinvertebrates found in each site.

During samples, short videos were made by an Apple iPhone 13 mini, to document and disseminate information with the local community to raise awareness about the need to protect water quality on social media.

A linear regression model was used to analyze the trend in flow rate variation, which allowed identifying patterns and relationships between the variables studied. In addition, the Kruskal-Wallis test was applied to evaluate the historical variation in water quality based on site and year, in order to determine whether there were significant differences between the different groups. This same test was used to compare water quality between the different sites during the year 2025.

Study site

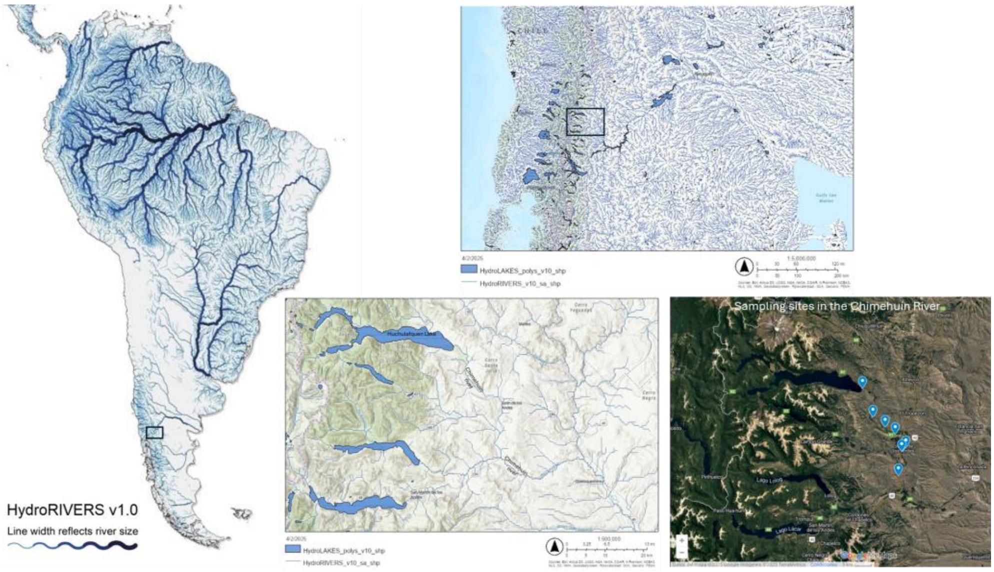

Fig. 1: Studied area: Chimehuin River. Source: HydroRIVERS v1.0 and Google Maps.

The studied area belongs to various sites in rural and urban areas of the Chimehuin River. The weather classifies as Csb (warm temperate, with dry summers). In rural areas the predominant MUC is MUC-43 (short grass) and the riverbank has grass and trees (MUC-12v). In urban areas the predominant MUC is MUC-91 and on the coast, MUC-93. And the riverbed is rocky and in very few places there is sand.

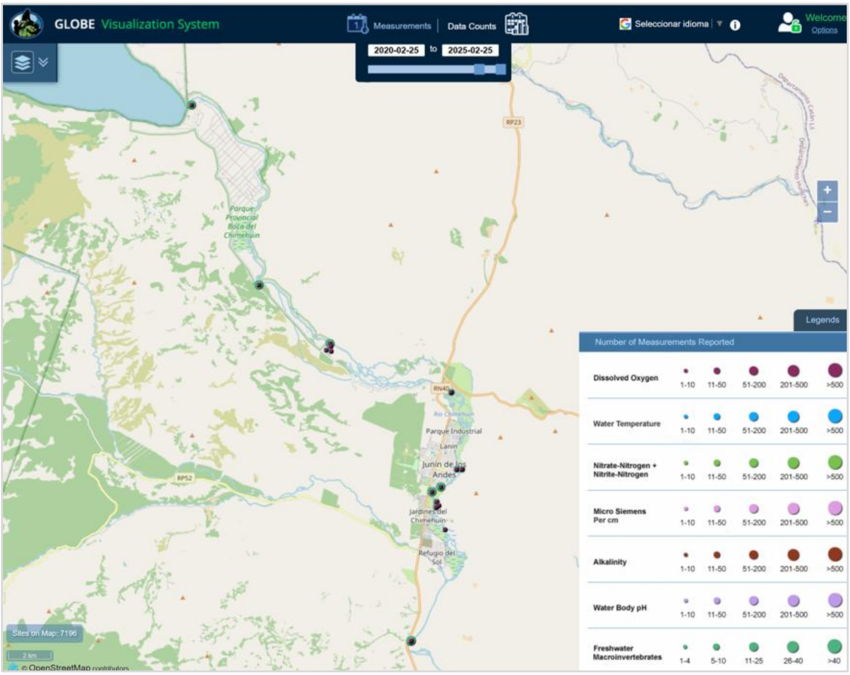

Fig. 2: Historic data of sample sites along the Chimehuin river. Source: The GLOBE Program.

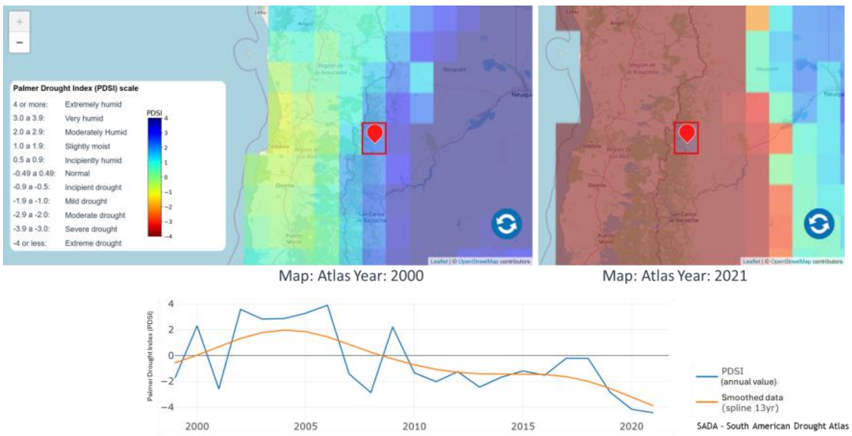

Fig. 3: Droughts map in the area. Source: SADA.

The graph shows the variation in wet and dry years. During the sampling period, there were some wet years and a prolonged drought since 2010. (Fig. 3)

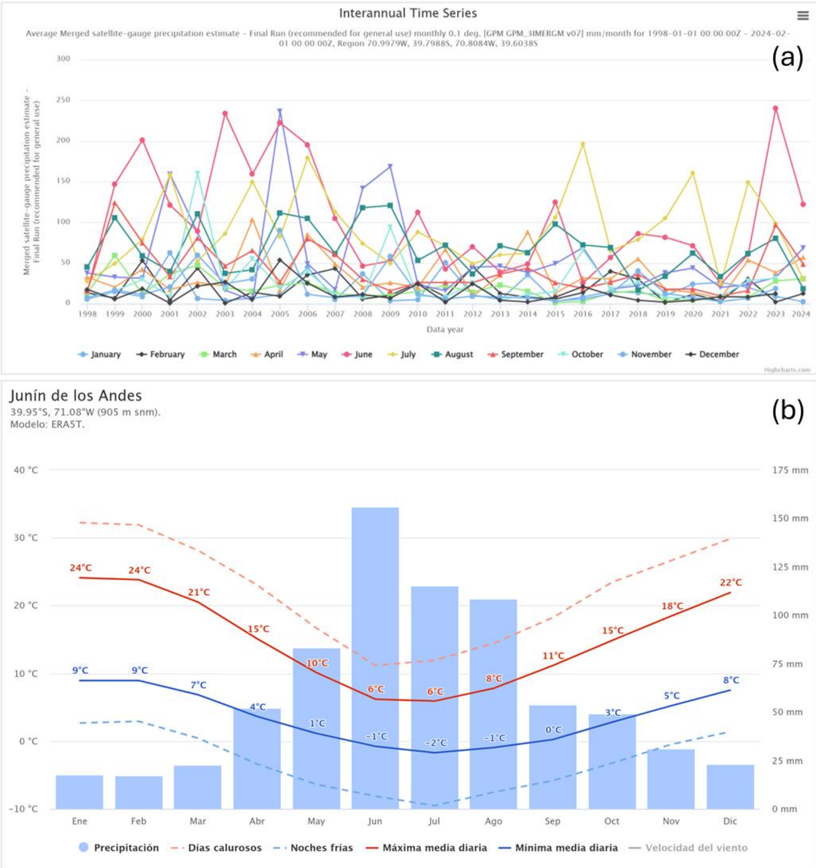

Fig. 4: Precipitations: (a) Monthly precipitations by year. Source: NASA Goddard Space Flight Center: Gioivanni (b) Climogram of Junín de los Andes. Source: Meteoblue.

Precipitation is concentrated in autumn and winter and decreases in spring and summer. Late summer and early autumn are the driest periods. Years when La Niña occurs have influenced the decrease in precipitation (Kitzberger et al., 2001).

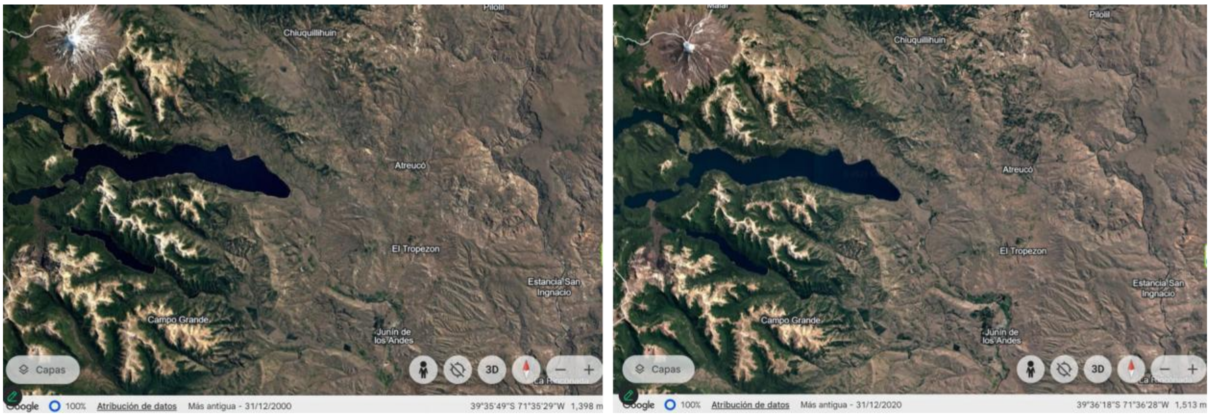

Fig. 5: LANDSAT satellite image comparison. Source: Google Earth timelapse.

On the left, fig. 5 shows the studied area in the year 2000 while on the right shows the same area in the year 2020. It is possible to observe that the Lanín volcano (on the upper left side) lost a significant amount of snow and Junín de los Andes grew almost twice its size (for more details see fig. 6). The river source can also be seen at the end of the Huechulafquen lake.

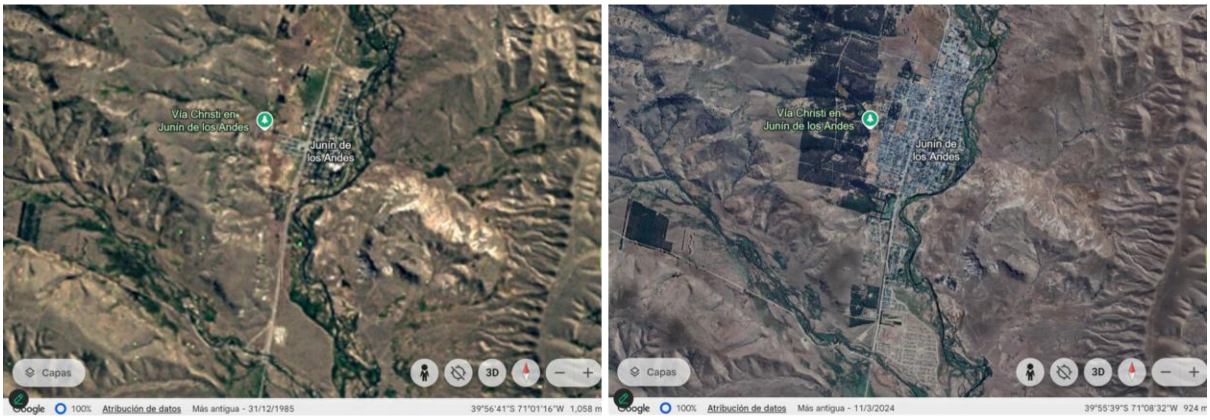

Fig. 6: Satellite comparison of Junín de los Andes in 1985 and 2024. Source: Google Earth timelapse.

Junín de los Andes is a touristic city because of its proximity to nature and outdoor activities. During the summer season, it holds up to three times its population of 19108 inhabitants (INDEC, 2022), this coincides with the dry season, when the water flow is the lowest.

The following sites were sampled in different opportunities from the 2000 until 2025. In 2015 the sites were numbered from 1 to 10 corresponding to distinct locations around the Chimehuin river. (Table 1)

Table 1: Site descriptions.

Number	Location	Description
1	Lat: -39.7961997 - Long: -71.2109311	“Boca del Río Chimehuin”, River source, rural area.
2	Lat: -39.87104 Long: -71.17445	“Herradura”, rural area.
3	Lat: -39.8975 Long: -71.1344	Rural school area, rural area.
4	Lat: -39.91601 Long: -71.09877	Nearby CEAN, rural area.
5	Lat: -39.9507 Long: -71.0642	Riverwalk, urban area.
6	Lat: -39.95835 Long: -71.0725	Lonquimay tables, urban area.
7	Lat: -39.96006 Long: -71.07745	Behind the municipal pumping station, urban area.
8	—	Unavailable
9	—	Unavailable
10	Lat: -40.02325 Long: -71.08884	“Curva de los Santos”, rural area.

For safety reasons and restrictions to public access sites 8 and 9 from 2015 research were discarded. The site with the largest amount of historical data is site 3, located at CEI San Ignacio school with data from the year 2000. The rest of the sites have data from 2015 although not all sites have yearly samples.

The river has suffered from various impacts, such as the ash rain from the eruption of the Calbuco Volcano in April 2015, which affected the entire course of the river. Site 4 received sediment contributions in 2016 during the construction of Provincial Route 61, and sampling site 5 received sediment contributions in 2014 and 2015 due to soil movements during the construction of the coastal walkway.

Results:

1. River flow analysis

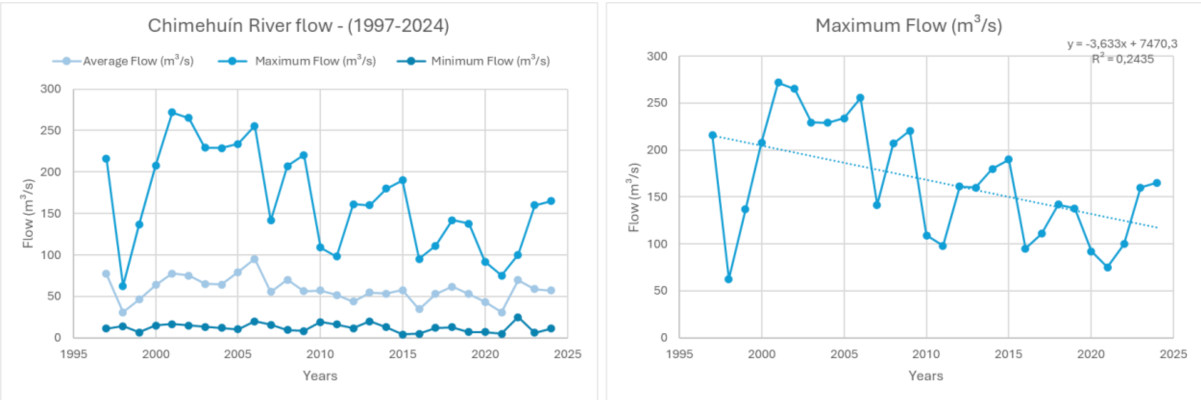

Fig.7: Annual flow variation of the Chimehuin river. Source: AIC.

The fluctuations of the minimum and mean flow of the Chimehuin River don't have significant differences while the maximum has a significant trend. The linear regression presents a significant negative slope. (Fig. 7)

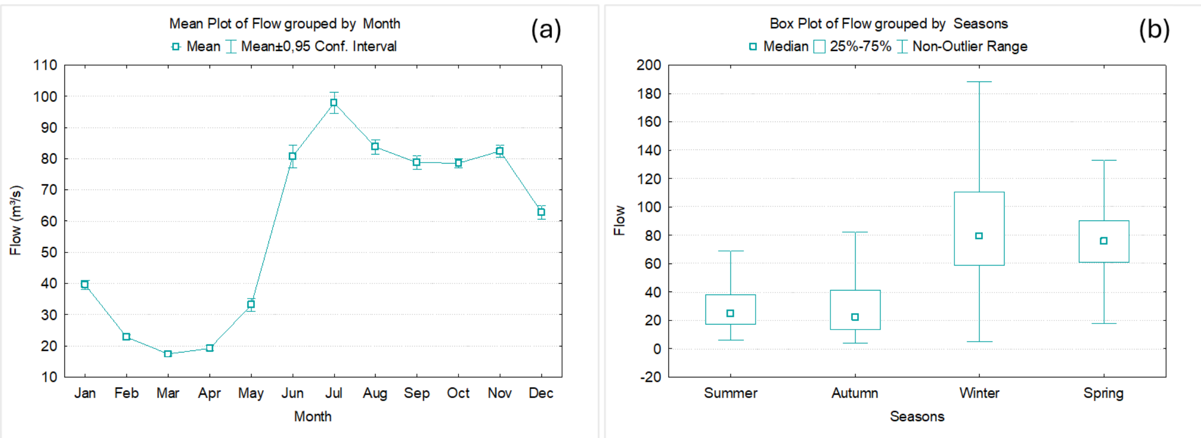

Fig. 8: Chimehuin river flow variation. (a) monthly and (b) by yearly season. From 1995 to January 2025. Source: AIC.

The flow of the Chimehuin River increases due to winter precipitation and spring snowmelt. The lowest flows are recorded in summer and early autumn, coinciding with the decrease in precipitation. The greatest variability in flow occurs in winter, influenced by precipitation. (Fig.8)

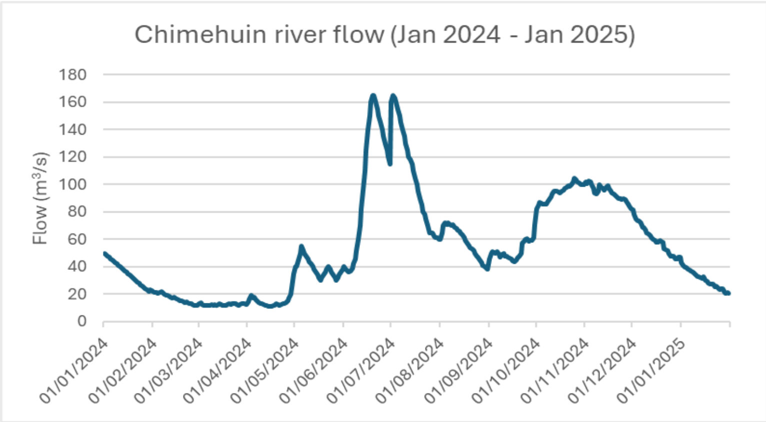

Fig. 9: Chimehuin river flow during the year previous to the sampling months and during the sampling. Source: AIC.

During the sampling period, the same flow pattern shown in the previous figure was repeated. Winter precipitation generated the main flow peak, followed by spring snowmelt, which caused the second increase in flow. (Fig. 9) In the summer of 2024/2025, little sedimentation is observed compared to previous years.

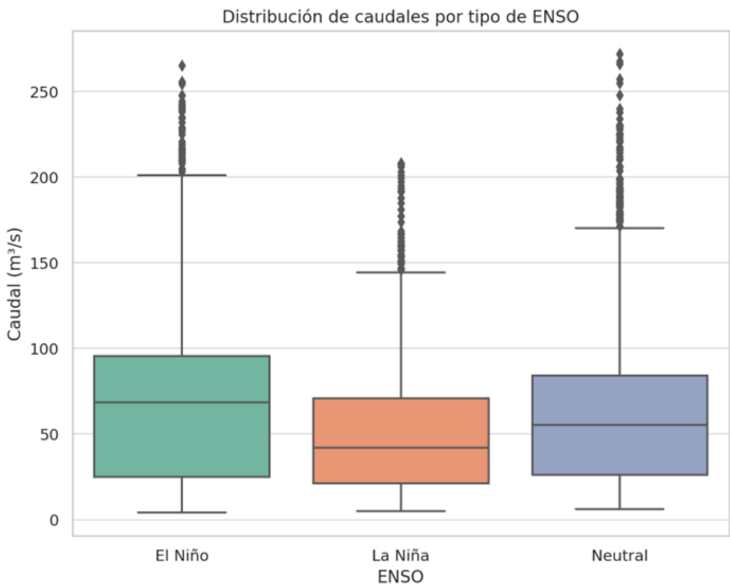

Fig. 10: Influence of the ENSO phenomena in the flow variation of the Chimehuin river. Source: AIC. Climate Prediction Center, NOAA.

The distributions of the mean annual flows of the Chimehuin River show differences in the distribution of flows. During El Niño, flows increase compared to La Niña and neutral years. During La Niña events, flows are lower and have less dispersion. On the other hand, neutral years show an intermediate distribution between both extremes, with less variability compared to El Niño. (Fig. 10)

2. Water quality analysis

2.1. Physical-Chemical analysis

Table 2: Historical physical-chemical analysis results per site, per year.

Site	Site 1					Site 2						Site 3												
Year	2015	2016	2017	2024	2025	2015	2016	2018	2023	2024	2025	2001	2002	2003	2004	2005	2006	2007	2008	2009	2015	2017	2019	2025
Water Temp	18	14	12	12	16	19	12	14	19	16	21	19	22	18	22	12	17	18	18	23	28	10	13	19
DO	5	9	8	9	9	8	8		8	8	7		9	10	7	8	9	10	10	8	7	8		8
pH	8	7	7	9	8	7	8	8	7	8	8	8	8	8	8	8	7	8	8	8	8	7	6	7
Alkalinity	30	35	40	28	20	28	32		20	28	28	25	39	30	34	60	25	18	25	25	22	24	22	24
Nitrates	0	0	0	0	0	0	0	0	0	0	0										0	0		0
Conductivity	53			50	50	58		50	50	50	50	23	24	20	50	37	42	42	42	45	57	50	40	50

Site	Site 4				Site 5				Site 6								Site 7						
Year	2015	2016	2017	2025	2015	2016	2024	2025	2015	2016	2017	2020	2022	2023	2024	2025	2015	2016	2017	2020	2023	2024	2025
Water Temp	12	12	12	18	14	12	18	17	21	12	18	12	18	19	17	19	16	10	16	17	17	17	16
DO	8	7	7	7	9	9	8	8	8	8	7	9	6	8	9	8	9	8	8	8	7	7	8
pH	7	8	7	8	8	8	8	7	8	7	7	6	7	6	8	8	7	8	7	7	6	7	7
Alkalinity	40	32	22	26	36	38	20	24	46	38	22	22	28	20	22	22	30	40	23	24	20	25	24
Nitrates	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0		0	0	0	0
Conductivity				50			50	50				50	50	60	50	60	57			50	60	50	50

Site	Site 10					
Year	2015	2016	2020	2023	2024	2025
Water Temp	22	12	17	16	14	18
DO	10	9	8	10	10	8
pH	9	8	7	6	8	7
Alkalinity	30	68	24	22	21	28
Nitrates	0	0	0	0	0	0
Conductivity	71		60	70	60	60

Temperature fluctuates between 10 and 28°C with the higher one being 28°C at site 3 in 2015. Dissolved oxygen is between normal values in all sites (>7 mg/L). pH values vary between 6 and 9, the optimal range is between 7-8,5. pH=9 is registered during the end of the summer. Alkalinity varies between 18-68 mg/L with a tendency to decrease over the last few years. Nitrates weren't registered with the utilized methods. Conductivity was stable in the last few years, fluctuating between 40-70 µS/cm. (Table 2)

Site 10 presents great pH fluctuations between years. Site 3 has data from 2001 up to 2025. Analyzed parameters are between normal values in all cases. (Table 2)

Table 3: 2025 physical-chemical results.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 10
Year	2025	2025	2025	2025	2025	2025	2025	2025
Air Temperature	29,7	32,0	23,0	24,0	21,4	23,1	25,2	23,1
Water Temperature	16	21	19	17,5	16,6	18,6	16,2	17,8
Total Dissolved Solids	30	30	30	40	40	40	40	40
Dissolved Oxygen	9	7,4	7,6	7	8,2	7,8	8	8
Turbidity	0	0	0	0	0	0	0	0
pH	8,4	7,6	7,4	7,5	7,4	7,8	7,3	7,1
Alkalinity	20	28	24	26	24	22	24	28
Nitrates	0	0	0	0	0	0	0	0
Conductivity	50	50	50	50	50	60	50	60

In 2025 the river presented unusually low sediment levels except for site 3 whose principal channel is without sediment but to both sides there are great amounts, including sediment banks.

The study showed a slight increase in TDS in the urban area, while turbidity remained at zero. The parameters dissolved oxygen, pH, alkalinity, nitrates and conductivity were within normal values. (Table 3)

2.2. Macroinvertebrate analysis

Fig. 11: EPT% by site, by year 2015-2025.

Sites present a great time variability by years. (Fig. 11)

Site 1 decreased EPT% from 2016 to 2024, improving in 2025. In 2017 and 2024 the predominant taxon were Gastropods and in 2025 the dominant taxon was Ephemeroptera.

Site 2 maintains consistent values with a good water quality trend.

Site 3 lowered its EPT% with Gastropods predominance but then recovered.

Site 4 maintained its EPT% low with Gastropods as dominant taxon.

Site 5 had low EPT%, recovering in the last few years. Dominant taxon went from Gastropods to Ephemeroptera.

Site 6 had high EPT% values except for 2016 and 2017. Ephemeroptera was always the dominant taxon except for 2017 when they were replaced by Gastropods.

Site 7 had fluctuations in EPT% and in 2016 the predominant group were Gastropods and in 2023, Diptera. It has currently been recovered.

Site 10 has fluctuations in its EPT% values alternating between Gastropods, Ephemeroptera and Trichoptera as dominant taxons.

Changes are detected between dominant groups alternating between Ephemeroptera and Gastropods. In 2025 Ephemeroptera is predominant on all sites.

In general, an improving tendency in water quality can be observed but it does not reach statistical significance.

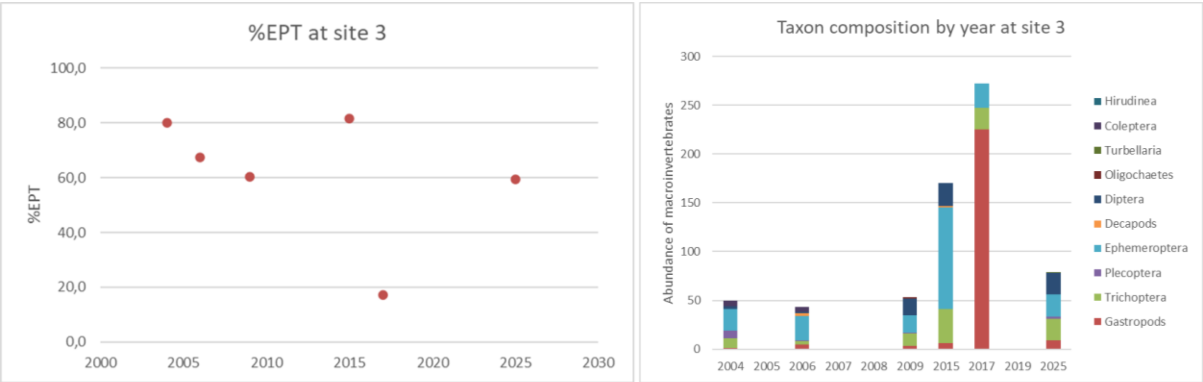

Fig. 12: %EPT and taxon composition at site 3. (2004-2025 In some years, physicochemical data are available, but macroinvertebrate data are missing).

The EPT% values were high with Ephemeroptera as dominant taxon except for 2017 when EPT% lowered and dominant taxon were Gastropods. (Fig. 12)

Table 4: 2025 Macroinvertebrate analysis results.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 10
Year	2025	2025	2025	2025	2025	2025	2025	2025
Total Macroinvertebrates	156	125	79	121	38	83	50	181
Dominant Taxon	Ephemeroptera	Ephemeroptera	Ephemeroptera	Gastropods	Ephemeroptera	Ephemeroptera	Ephemeroptera	Gastropods
Total Dominant Taxon	105	72	23	68	25	55	25	64
% Dominant Taxon	**67**	**58**	**29**	**56**	**66**	**66**	**50**	**35**
Total EPT	140	85	47	49	27	58	34	106
% EPT	**90**	**68**	**59**	**40**	**71**	**70**	**68**	**59**

Fig. 13: Comparison of Sites in 2025: %EPT and Taxonomic Composition.

The analysis of macroinvertebrates coincides with the physicochemical data, since Ephemeroptera was the dominant taxon in most sites, except in sites 4 and 10, where the anthropic impact is greater and the EPT% were lower. (Table 4 and Fig. 13)

Discussion

The Chimehuín River, located in a transitional steppe region between forest and steppe, has experienced significant environmental changes in recent years. During this period, the region faced a prolonged drought that culminated in 2023 with an El Niño episode, which significantly increased rainfall and river flow. This could be related to the absence of sediment in the riverbed.

Over the years analyzed, the population of Junín de los Andes has almost doubled, resulting in an urban expansion that has doubled the area occupied by the city since 2001. The Chimehuín River is the main source of water for the city, used for human consumption, industrial activities and recreation. Although the average flow of the river has remained stable, a tendency towards a decrease in the maximum flow is observed. The minimum flow occurs during the summer when the city receives an influx of tourists who use the river for recreation (bathers, fishers, etc.). The samples were taken during the summer because of the reduction in water quality in comparison with the rest of the seasons.

Regarding water quality, the data for 2025 indicates favorable conditions at all sampling sites. However, in 2016 and 2017, a decrease in the percentage of Ephemeroptera (Ephemeroptera, Plecoptera and Trichoptera) was recorded, accompanied by a shift in the dominant taxon from Ephemeroptera to Gastropods at several sites. This phenomenon could be linked to the combination of anthropogenic impact and ash deposition from the Calbuco volcano during 2015. In the dry period after the eruption, volcanic ash was redistributed by the wind to various sites, prolonging its effect for several years. It should be noted that it is a windy area, the average wind speed in the region ranges between 5 and 20 km/h, with episodes of greater intensity that can reach 50 km/h. Over time, the rain facilitated the incorporation of ash into the soil, mitigating its impact. Furthermore, the proximity of roads to the riverbed also contributes to the incorporation of particulate matter into the river.

At the site-specific level, site 4 had several impacts such as: the fall of volcanic ash in 2015, the paving of Provincial Route 61 in 2016, the creation of a campsite and, in recent years, the high concentration of goat livestock in a small area close to the river, which has generated a significant contribution of sediments. For its part, site 5, located on the waterfront, has shown signs of progressive recovery after a period of similar impact during the remodeling of the area. Finally, the variations in water quality at site 10 could be related to its location downstream of the city's sewage discharge, which could influence the observed variations in water quality.

The recovery of water quality in 2025 suggests an improvement in environmental conditions, although monitoring must continue to assess the persistence of these trends and the impact of future climatic events and human activities in the basin.

Due to the need of raising environmental awareness and to share the process of research with the community, short videos were posted on Instagram Reels after each sampling (Pepe, 2025).

Possible sources of error might be introduced because of changes in sampling instruments, students taking samples and continuity of sampling during the years.

Conclusion

The Chimehuín River, a crucial hydrological system in the Lanín National Park, has undergone significant environmental changes due to climatic variations and anthropogenic influences. The study confirms that while the river's average flow has remained relatively stable, a statistically significant decreasing trend in maximum flow has been observed. This is likely influenced by long-term climatic fluctuations, including the effects of El Niño and La Niña, as well as increasing urbanization along its banks. The relationship between these changes and urban expansion highlights the need for sustainable land use planning to protect water resources.

The physical-chemical analysis of the river water indicates that most parameters remain within acceptable ranges for aquatic ecosystems, though site-specific variations suggest localized anthropogenic influences. The slight increase in total dissolved solids (TDS) in urban areas also underscores the potential impact of human activities on water quality. The increase in sediments in some years due to volcanic ash and anthropogenic activity near the river altered the dominance of macroinvertebrates and the %EPT.

Macroinvertebrate analysis, particularly the EPT index, provides further insight into the river's ecological health. The dominant taxon in most sites shifted from Gastropods to Ephemeroptera in 2025, suggesting an improvement in water quality (sites 1, 3, 5, 6, 7), although these changes do not reach statistical significance. This trend, coupled with the recovery of certain sites over time, indicates resilience in the aquatic ecosystem despite historical disturbances such as volcanic ash deposition and urban development.

Overall, the study highlights the importance of continuous monitoring of the Chimehuín River to assess the long-term effects of natural events (volcanic eruptions) and human activities. The findings emphasize the need for integrated water resource management strategies that consider ecological sustainability such as urban development. Future research should focus on expanding the temporal data set, incorporating additional biological indicators.

Collaborating with mentors helps interpretation of results, gives an expert orientation supported by experience that helps define objectives, adequate research methodologies and access to resources of special relevance for the research and contribute to developing critical thinking, academic writing and communication skills.

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Acknowledgments

This research was possible because of the great support of the community, the members of the Huechulafquen Science Club that helped taking samples and looking for sites, MSc. Ana Prieto, GLOBE Mentor trainer for being the living guide of the project, Prof. Jorge Luis Pepe for technical support and assessment during these years. And thanks to Ph. D. Teresa Kennedy; Prof. of International STEM and Bilingual/ELL Education, University of Texas at Tyler for revising and orientating, MSc. Lorena Laffite; General Director of Sustainability and Biodiversity, Environment Secretary, Neuquen Province and Ph.D. Jack Imhof; National Biologist/Director of Conservation Ecology at Trout Unlimited Canada for their assessment in aquatic macroinvertebrates. Special thanks to MacroMappers: BS. MS. Lynne Harris Hehr, K-20+ Educator GLOBE Mentor trainer, BA Peggy Foletta GLOBE Mentor trainer and Ph.D. Sara Mierzwiak, GLOBE Mission EARTH, University of Toledo for guidance and resources. We extend our heartfelt appreciation to Lic. Mariana Savino, Regional Coordinator of GLOBE Latin America and the Caribbean (LAC), and Prof. Marta Kingsland, National Coordinator of GLOBE Argentina, for their continuous support. Finally, we express our deepest gratitude to all CEI San Ignacio and Huechulafquen Science Club alumni who contributed to data collection over the years.

Badges:

I AM A DATA SCIENTIST

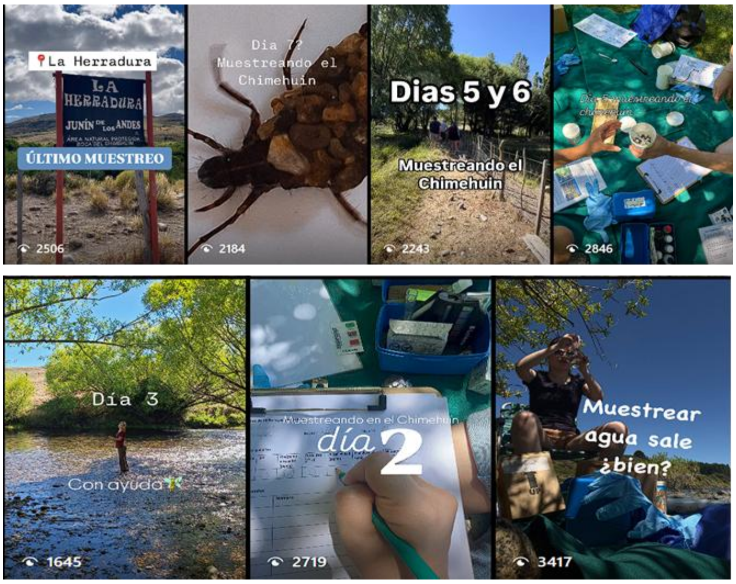
Statistical analyses were made for the interpretation of results. Historical data was taken from the GLOBE’s website and previous IVSS’s reports on the Chimehuin River water quality. Proposals for future research were made.

I WORK WITH A STEM PROFESSIONAL

Sampling and research writing were made under supervision of Mg. Ana Prieto. More professionals mentored this research (Ph. D. Teresa Kennedy; Prof. of International STEM and Bilingual/ELL Education, University of Texas at Tyler for revising and orientating, Mg. Lorena Laffite; General Director of Sustainability and Biodiversity, Environment Secretary, Neuquen Province and Ph. D. Jack Imhof; National Biologist/Director of Conservation Ecology at Trout Unlimited Canada for their assessment in aquatic macroinvertebrates).

I MAKE AN IMPACT

The Reels reached up to 3400 views, in its majority of Junin de los Andes and other parts of the Neuquen province but also reached the rest of Argentina, the US, Mexico, Canada, Brazil, Costa Rica, Kenya, and Colombia.



I AM A STEM STORYTELLER

Reels were made in Spanish with local references and in a fun and approachable way for the Junin de los Andes' community. Site 1 - Site 2 - Sites 3 and 6 - Site 4 - Site 5 - Site 7 - Site 10.