UNIVERSIDAD REGIONAL AMAZÓNICA IKIAM

FACULTAD DE CIENCIAS DE LA TIERRA Y AGUA
CARRERA DE HIDROLOGÍA

ANÁLISIS SOCIOAMBIENTAL DE CUENCAS URBANAS DEL CANTÓN TENA, CON MIRAS A ESTRATEGIAS DE RESTAURACIÓN FLUVIAL

Proyecto de investigación previo a la obtención del Título de:
INGENIERA EN CIENCIAS DEL AGUA

AUTORA
ROSSEMARY ELIZABETH SANMARTÍN MOROCHO

Napo- Ecuador
2023

UNIVERSIDAD REGIONAL AMAZÓNICA IKIAM

FACULTAD DE CIENCIAS DE LA TIERRA Y AGUA

CARRERA DE HIDROLOGÍA

ANÁLISIS SOCIOAMBIENTAL DE CUENCAS URBANAS DEL CANTÓN TENA, CON MIRAS A ESTRATEGIAS DE RESTAURACIÓN FLUVIAL

Proyecto de investigación previo a la obtención del Título de:
INGENIERA EN CIENCIAS DEL AGUA

AUTORA: ROSSEMARY ELIZABETH SANMARTÍN MOROCHO

TUTOR: PhD. JORGE EMILIO CELI SANGURIMA
CO-TUTORA: MSc. VERÓNICA PATRICIA GALLARDO REINOSO

Napo- Ecuador
2023

DECLARACIÓN DE DERECHO DE AUTOR, AUTENTICIDAD Y RESPONSABILIDAD

Tena, 14 de febrero 2023

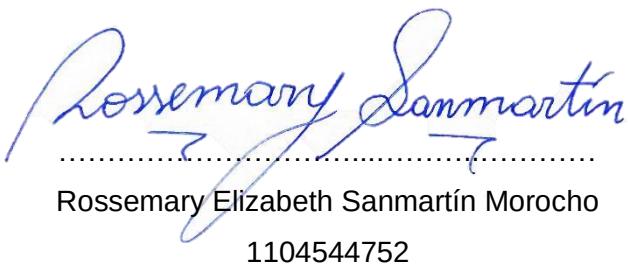
Yo, ROSSEMARY ELIZABETH SANMARTÍN MOROCHO con documento de identidad Nº 1104544752, declaro que los resultados obtenidos en la investigación que presento en este documento final, previo a la obtención del título de Ingeniera en Ciencias del Agua son absolutamente inéditos, originales, auténticos y personales.

En virtud de lo cual, el contenido, criterios, opiniones, resultados, análisis, interpretaciones, conclusiones, recomendaciones y todos los demás aspectos vertidos en la presente investigación son de mi autoría y de mi absoluta responsabilidad.

Por la favorable atención a la presente, suscribo de usted,

Atentamente,

Firma:



……

Rossemary Elizabeth Sanmartín Morocho

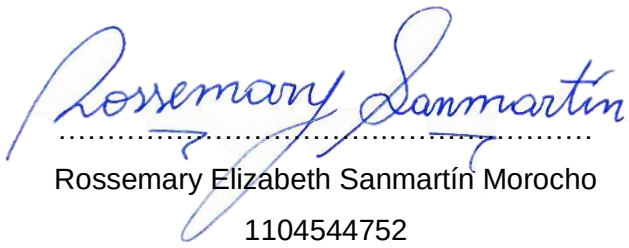
1104544752

AUTORIZACIÓN DE PUBLICACIÓN EN EL REPOSITORIO INSTITUCIONAL

Yo, ROSSEMARY ELIZABETH SANMARTÍN MOROCHO, con documento de identidad N°1104544752, en calidad de autora y titular de los derechos morales y patrimoniales del trabajo de titulación: ANÁLISIS SOCIOAMBIENTAL DE CUENCAS URBANAS DEL CANTÓN TENA, CON MIRAS A ESTRATEGIAS DE RESTAURACIÓN FLUVIAL, reconozco a favor de la Universidad Regional Amazónica Ikiam una licencia gratuita, intransferible y no exclusiva para el uso no comercial de la obra, con fines estrictamente académicos.

Así mismo autorizo a la Universidad Regional Amazónica Ikiam para que realice la publicación de este trabajo de titulación en el Repositorio Institucional de conformidad a lo dispuesto en el Art. 144 de la Ley Orgánica de Educación superior.

Tena, 14 de febrero de 2023



.....

Rossemary Elizabeth Sanmartín Morocho

1104544752

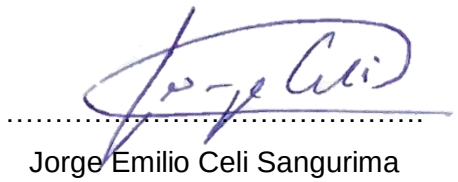
CERTIFICADO DE DIRECCIÓN DE TRABAJO DE INTEGRACIÓN CURRICULAR

Certificamos que el trabajo de integración curricular titulado: “Análisis socioambiental de cuencas urbanas del cantón Tena, con miras a estrategias de restauración fluvial”, en la modalidad de: articulo original, fue realizado por: Rossemary Elizabeth Sanmartín Morocho, bajo nuestra dirección.

El mismo ha sido revidado en su totalidad y analizado por la herramienta de similitud de contenido, por lo tanto, cumple con los requisitos teóricos, científicos, técnicos, metodológicos y legales establecidos por la universidad Regional Amazónica Ikiam, para su entrega y defensa.

Tena, 14 de febrero 2023

Firma:



……

Jorge Emilio Celi Sangurima

C.I: 1102662010

……

Verónica Patricia Gallardo Reinoso

C.I: 1600409211

AGRADECIMIENTOS

A la Secretaría Técnica de Planificación la Ciudad de Tena por brindar la información base para este estudio y colaborar con el taller “Introducción al Manejo de Cuencas Urbanas: Estudio de Caso Paushiyacu” junto con el Club Rotario Tena, Fundación Ambientalista Wiyalla, y Universidad Regional Amazónica Ikiam .

Al Anto por mostrarme que la vida es caerse y levantarse, por ser mi mejor amigo desde el día uno de clases, por retarme cada día a ser mejor y por estar conmigo siempre.

A Mika por ser mi primera amiga en la universidad, por amar mi sopa y coladas, eres mi quiteña favorita, gracias por celebrar todos nuestros triunfos en español y en señas, porque soplemos velas hasta los 1000.

A Sam por ser una amiga a todo dar, you deserve so much..

A Pablo y Oda por ser los amigos que uno necesita a veces para tener un golpe de realidad.

A Enriquito y Gonzalito por ser mis amigos contestar mis llamadas imprudentes para quejarme de todo y por ser parte mi familia…

A la Verito Capelo por su valentía...

A Vero y Jorge por ser los mejores tutores que uno podía pedir, tenerme paciencia, enseñarme y a veces también aprender conmigo.

A todos los profes que estuvieron presentes a lo largo de la carrera y a Ikiam por dejarme ser científica.

A mis compañeros de aula de los que aprendí que todos podemos brillar a nuestra manera, y se terminaron convirtiendo en compañeros de ojeras y malas noches…

A Pamela, Cami y Sol que me abrieron las puertas de su casa y se convirtieron en mi segunda familia estos meses. A Andrea por ser una mujer valiente soportar mi mal humor y por engordar juntas, you are the best friend I could ask for finish my work…

To Griffin Delin and Katie Marshall for helping to edit and proofread the manuscript. A special acknowledgment to the pitahaya man who supported me during these last 2 months, traveling through Ecuador, dancing brunjeria, teaching me more about life than water funds, buying eggs for the warmis’s house during the protest, total thank you for being my best friend during this summer, you are more awesome than the AWESOME PROJECT

A Gerardo por enseñarme que el amor puede ser bonito …

Gracias totales ….

DEDICATORIA

A mis abuelos que ya no están y extraño todos los días Rosa, Juan y Manuel

A Olivia por ser la abuelita más mimadora y paciente que la vida me pudo dar, que nunca me faltes

A mis papás Magaly y Linder porque a pesar de sus diferencias siempre están para mi

A Emilia por ser el mejor regalo que la vida me pudo dar

A mi familia Ikiam y a los amigos que ya no podrán celebrar sus logros conmigo

A mis amigos de Loja que a pesar de la distancia nunca me hicieron sentir olvidada

RESUMEN
La contaminación ambiental ha sido una preocupación en todo el mundo durante el último siglo. Ecuador no es una excepción, con una contaminación significativa en más del 60% de los ríos por debajo de los 2500 m.s.n.m. como resultado de la inadecuada gestión del agua. Dado que muchas ciudades están ubicadas cerca de los ríos, muchos de estos se han degradado progresivamente y en la actualidad esto ha disminuido la calidad del agua, la capacidad de suministro, la estructura del hábitat y el régimen el flujo. El río Paushiyacu es un ejemplo de la problemática en la cuenca amazónica, este río atraviesa zonas densamente pobladas de la ciudad de Tena y ha sido afectado por la urbanización. Desde 2001, se han desarrollado al menos dos proyectos para mejorar la calidad del agua en el río sin resultados efectivos, principalmente debido a la falta de participación de los interesados y seguimiento de los proyectos. El objetivo de esta investigación es proporcionar un diagnóstico socioambiental del estado actual y presentar un marco para la restauración del río que pueda utilizarse como línea de base para futuras decisiones. Se llevó a cabo una revisión bibliográfica y se recopiló información para la caracterización de la cuenca y el río, seguido de un análisis de gobernanza y de partes interesadas utilizando la metodología del Índice de Salud del Agua Dulce (FHI). Se encontró que la cabecera (sección 5) se encuentra en buen estado por lo que puede ser utilizada como ecosistema de referencia para la restauración de las secciones aguas abajo. Se determinó que la mejor solución sería aplicar una restauración pasiva impulsada por la eliminación de amenazas, la participación de las partes interesadas en la toma de decisiones, el aumento del acceso a la información y la aplicación de los instrumentos normativos existentes**.**
Palabras clave: ríos urbanos, restauración, gobernanza y actores

ABSTRACT
Environmental pollution has been a significant concern worldwide, during the last century. Ecuador is not an exception, with significant pollution in over 60% of the rivers under 2500 m.a.s.l. as a result of inadequate water management. Since many cities are located near rivers, many of these had been progressively degraded and nowadays this has decreased water quality, provision capacity, flow regime, and habitat structure conditions. The Paushiyacu river is an example of the problem in the Amazon basin, this river crosses densely populated areas in Tena city and has been affected by urbanization. Since 2001, at least two projects for water quality improvement in the river had been development with no effective results because the lack of stakeholder involvement and project follow-up. Here is to provide a socio-environmental diagnosis of its current state and to present a framework for river restoration that can be used as a baseline for future decisions. The approach consisted on a literature review and information compilation for river and basin characterization, followed by a governance and stakeholder analysis using the Freshwater Health Index (FHI) methodology. It was found that the headwaters (section 5) has a good state so it can be used as a reference ecosystem for the restoration of the downstream sections. It was determined that best solution would applying a passive restoration driven by threats elimination, stakeholder engagement in decision making, increase in access information and application of the existing regulatory instruments.
Key words: urban rivers, restoration, governance and stakeholders

Contenido

DECLARACIÓN DE DERECHO DE AUTOR, AUTENTICIDAD Y RESPONSABILIDAD i

AUTORIZACIÓN DE PUBLICACIÓN EN EL REPOSITORIO INSTITUCIONAL ii

CERTIFICADO DE DIRECCIÓN DE TRABAJO DE INTEGRACIÓN CURRICULAR...iii

AGRADECIMIENTOS iv

DEDICATORIA v

RESUMEN vi

ABSTRACT vii

Índice de figuras ix

Índice de tablas ix

1. **INTRODUCCIÓN** 2
2. **METÓDOS** 3
3. **RESULTADOS** 11
4. **DISCUSIÓN** 18
5. **CONCLUSIONES** 29
6. **AGRADECIMIENTOS** 30
7. **REFERENCIAS** 31

Índice de figuras

Figura 1: Ubicación del área de estudio y caracterización de la cuenca 4

Figura 2: Caracterización del río por secciones..... 12

Figura 3: SVAP vs. BMWP **.....** 13

Figura 5: Modelo de Saliencia 14

Figura 6: Relación de los índicadores de salud y amenazas, basados en PCA y HCA..... 18

Índice de tablas

Tabla 1: Lista de parámetros recolectados 5

Tabla 2: Deficiones de los indicadores y sub-indicadores de Gobernanza del agua.... 8

Tabla 3: Puntajes de priorización de secciones agurpaos por saud y amenazas..... 10

Tabla 4: Caudales en los puntos de muestreo de macroinvertebrados y puntajes de condición del río (SVAP) 13

Tabla 5: Indicadores y subindicaores de Gobernanza y actores involucrados 15

Tabla 6: Prioridad de restauración por sección, agrupados por salud y amenazas.... 17

Tabla 7: Marco para cumplir los objetivos de resturació en PRB 26

Índice de Anexos

ANEXO A: Tablas

ANEXO B: Figura

ANEXO C: Fotografías

ANEXO D: Proyecto de Restauración

Journal to submit: *Water Research*

Socio-environmental analysis of urban basins in the Ecuadorian Amazon: A view to river restoration strategies

Sanmartín Rossemary E.[1]

[1] Facultad de Ciencias de la Tierra y Agua, Universidad Regional Amazónica Ikiam, 150150, Tena, Napo, Ecuador.

Abstract

Environmental pollution has been a significant concern worldwide, during the last century. Ecuador is not an exception, with significant pollution in over 60% of the rivers under 2500 m.a.s.l. as a result of inadequate water management. Since many cities are located near rivers, many of these had been progressively degraded and nowadays this has decreased water quality, provision capacity, habitat structure and change the flow regime and habitat structure conditions. The Paushiyacu river is an example of the problem in the Amazon basin, this river crosses densely populated areas in Tena city and has been affected by urbanization. Since 2001, at least two projects for water quality improvement in the river had been development with no effective results, mainly because the lack of stakeholder involvement and project follow-up. Here is to provide a socio-environmental diagnosis of its current state and to present a framework for river restoration that can be used as a baseline for future decisions. The approach consisted on a literature review and information compilation for river and basin characterization, followed by a governance and stakeholder analysis using the Freshwater Health Index (FHI) methodology. It was found that the headwaters (section 5) has a good state so it can be used as a reference ecosystem for the restoration of the downstream sections. It was determined that best solution would applying a passive restoration driven by threats elimination, stakeholder engagement in decision making, increase in access information and application of the existing regulatory instruments.

Key words: urban rivers, restoration, governance and stakeholders

1. INTRODUCTION

Population growth is a significant concern around the world. Urban areas currently house almost half of the global population, and because many cities are developed near rivers, these are the ecosystem most affected by urban expansion. The World Water Council estimates that almost 50% of the rivers around the world are polluted, modified in several ways or at risk running dry, some of the drivers include: wastewater, litter , ground impermeability, and channelization (Guimarães et al., 2021; Perini & Sabbion, 2017). These modifications have affected the watershed dynamics and changed both chemical composition and ecosystem functionality (Jerves-Cobo et al., 2020; Perini & Sabbion, 2017; Speed et al., 2016).

Under the estimated population growth, by 2050, the new living standards will be more demanding and cause greater energy and water needs (UNESCO/ONU-Agua, 2020). Additionally, the increase in environmental degradation and global warming do not present a bright scenario for future generations. Increasing the resilience of cities should be a priority, in order to have populations that can react to new world challenges and improve their wellbeing (Ribeiro & Pena Jardim Gonçalves, 2019). Rivers provide support, regulation, provision and cultural services in cities; which means that they have an important role in city dynamics. Therefore, its degradation is an effect of incompatibility between human activities and the environment (Perini & Sabbion, 2017; Wohl et al., 2005). Good water management, including river restoration, promises to be a viable alternative to improve functionality and services to the urban area; and today, there are numerous examples of restored rivers around the world (Palmer et al., 2005; Speed et al., 2016).

The efficient diagnosis of a basin helps to establish river restoration strategies, which is defined as the recovery of the ecosystem functionality of one or more water bodies, this includes rehabilitation, enhancement, mitigation and reclamation strategies (Hychka & Druschke, 2017; Perini & Sabbion, 2017). Restoration allows the river to recover the provision of ecosystem services to be more resilient to climate change, and create water sensitive cities (Perini & Sabbion, 2017). Management and restoration models must integrate along three axes: main stakeholders, ecological factors and learning (Palmer et al., 2005). Restoration projects usually have a high cost that can be optimized if intervention areas, intrinsic purification systems (IPS) and stakeholder engagement (SE) are prioritized (Wohl et al., 2005). To achieve this, strategies based on a comprehensive

diagnosis must be utilized to provide appropriate tools to the current context for future generations.

In Ecuador by 2013, it was estimated that over 65% of the rivers below 2800 m.a.s.l., were polluted mainly because of wastewater (Sorgato, 2017). Almost 80% of wastewater in Ecuador does not receive a proper treatment, and the Amazon cities are not an exception (El Comercio, 2019; El Universo, 2020; INEC, 2016). In the city of Tena, one of the capitals of the Ecuadorian Amazon, in 2014 there were 76 wastewater discharge points that ended up directly in rivers (GAD Municipal Tena, 2014). To solve this problem, two treatment plants were built in the city, however it had not been possible to incorporate the entire city into the sewer network (Alcaldía de Tena, 2019; El Telegrafo, 2019). This carries water pollution, comfortlessness, provision decrease, flow regime and habitat changes. In this context, I aimed to diagnose the one of the most degraded basins in Tena city, the Paushiyacu river, on which the specific objectives were: i) To establish the eco-hydrological status of the Paushiyacu River basin (PRB) by collecting preliminary and secondary information; ii) to carry out an analysis of the governance and participation of stakeholders in the management of the basin, identifying socio-political protocols and restrictions as well as management strategies for the PRB; and iii) propose appropriate restoration strategies for the PRB, based on the eco-hydrological and the governance analyses.

2. METHODS

2.1. Study Area

The PRB is located in the urban area of Tena, Napo, Ecuador (Fig. 1); the river crosses densely populated urban sites. In 2010, the basin had 8662 inhabitants, even though there is no new census to the date, assuming that the population growth is homogenous and using the growth rate estimated in the last census the population nowadays is 13426 approximately (GAD Municipal Tena, 2014). The river has a length of 4 km from its headwater to the outlet, and the basin covers an area of 2,9 km^2, occupying approximately 14% of the urban area of Tena. The climate is characteristic of the Amazon region, with high rainfall exceeding 4000 mm/yr. The highest rainfalls occur from

March to July. The air temperature ranges between 21 and 25º C with an average of 23 °C, with the lowest temperatures in July and August.

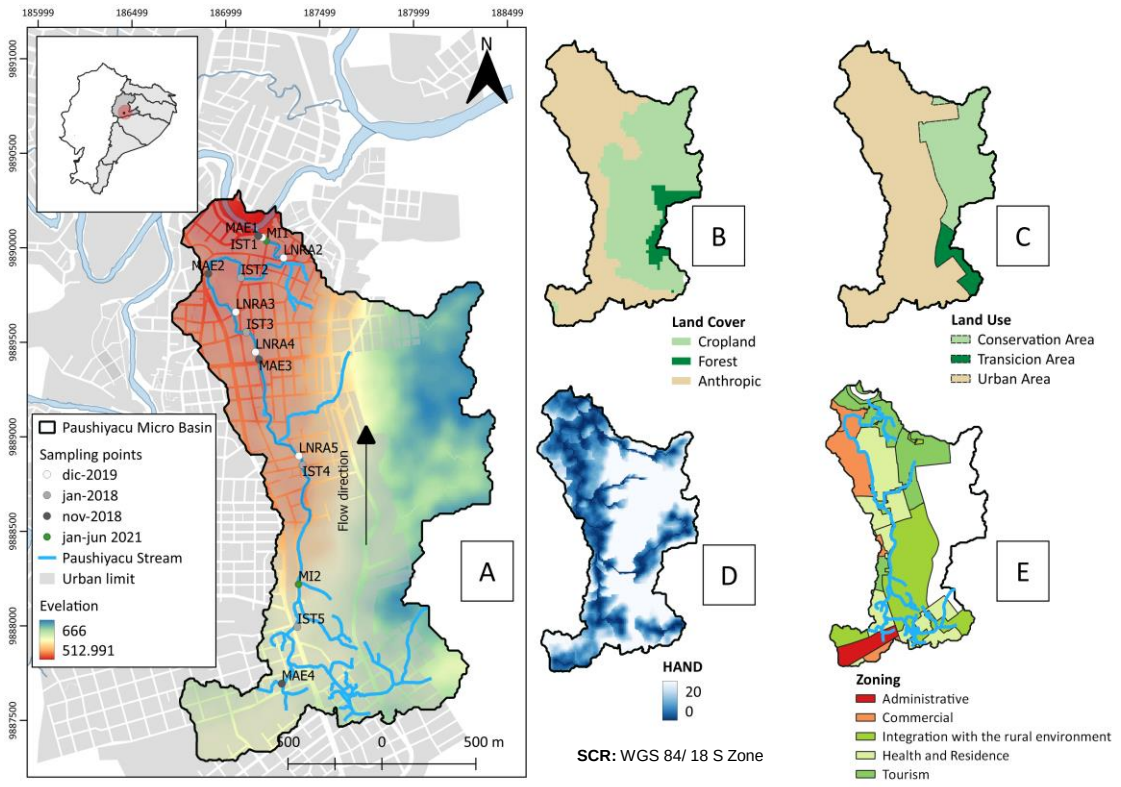


Figure 1: Location of the study area, showing Tena city area and the delimitation of the Paushiyacu River Basin, River basin characterization.
A) Elevation; sampling points: **MAE:** Environment Minister of Ecuador, **IST:** Technologic Superior Institute Tena, **LRNA:** Water Reference National Lab**, MI:** Macroinvertebrates 2021; river sections **B)** Land Cover (MAATE, 2018) **C)**Land Use (GAD Municipal Tena, 2021) **D)**HAND Model **E)** Zoning (GAD Municipal Tena, 2021)
Elaborated by: Rossemary Sanmartin

2.2. River and Basin Characterization

The data collection consisted of a literary review, as well as meetings with the entities involved in the management of the basin, experts in environmental issues, and the participation of people who have worked on projects related to the management of the Paushiyacu River; among them were the owners of properties adjacent to the river. Three visits to the river were conducted to identify key areas including those where there is a high density of infrastructure, high affluence, and low anthropogenic intervention areas. Sites such as bridges, sewer collapses, channelization, walls, pollutions points, and other areas of concern were registered with GPS and uploaded to the software QGIS for later examination.

Table 1: List of parameters collected thought the literature review and metrics grouped by Water Chemistry, Biological Condition, Hydromorphology, Ecotoxicology and Environment Descriptors

Parameter	Units	Reference
Water Chemistry		
pH		
Turbidity	NTU	
Hardness	*mg/CaCCo₃*	
Conductivity	µS/cm	
Iron	*mg/l Fe*	
COD	mg/L	
Nitrate	mg/L	(Alvear et al., 2019; Cabrera et al., 2018; Chapi & Yupangui, 2018)
Sulfate	mg/L	
Phosphate	mg/L	
TDS	mg/L	
DO	%	
Coliforms	*NMP*	
Water Temperature	*°C*	
Biological Condition		
BMWP 2018	-	(Chapi & Yupangui, 2018)
Macroinvertebrates 2021		(Rosero & Mena, 2021)
Hydromorphology Condition		
SVAP 2018		(Chapi & Yupangui, 2018)
Ecotoxicology		
Germination Index (GI)	-	(Cabrera et al., 2018)
Environment descriptors		
Infrastructure		
Land Use, Cover and zoning	%, m^2	(GAD Municipal Tena, 2021; MAATE, 2018)
Elevation	m.a.s.l.	(GAD Municipal Tena, 2021)
Orthophotos		City Planning Secretary of Tena (2021)
Channel modification extension	%	(GAD Municipal Tena, 2021)
Flood areas	m	HAND Model (Nobre et al., 2011), Google Earth Engine , City Planning Secretary of Tena
Wastewater discharges	Number of sewers discharges	GAD Cantonal Tena (Chapi & Yupangui, 2018; GAD Municipal Tena, 2014)

Elaborated by: Rossemary Sanmartin

River sections were characterized taking in consideration the available water quality information and characteristic of the area: land use, presence of infrastructure and zoning. Five sections were identified and evaluated with all collected data.

QGIS Software was used to contrast the information with the influence areas in the basin: land cover, land use, zoning and a HAND (Height Above the Nearest Drainage) model were used to understand the characteristic of each zone (GAD Municipal Tena, 2021; MAATE, 2018).

Water chemistry information per river section was integrated using the Canadian Council Ministers of Environment (CCME) Water Quality index, combined with the guidelines established in the Ecuadorian legislation (CCME, 2017a; MAE, 2003, 2015).

2.3. Instream Biological condition

The information collected from 2021 in sampling points MI and M2 (Figure 1-A) (Rosero & Mena, 2021) *(In prep.)* was integrated using the Biological Monitoring Working Party (BMWP) Score System described in (Prat et al., 2009; Uherek & Pinto Gouveia, 2014) to assess environmental quality. This approach was chosen to contrast with the information about macroinvertebrates available for 2018 (Chapi & Yupangui, 2018).

2.4. Riverine hydromorphological and habitat characterization

A Stream Visual Assessment Protocol (SVAP) was adapted and applied to the five sections delimited in order to get a numerical indicator of the stream state in terms of hydromorphological conditions and habitat (USDA, 1998), the criteria used can be reviewed in the appendices (Appendix A: Table A-1). The results were compared with the previous visual assessment run in 2018. In addition, flow velocity was measured in MI1 and MI2, using an electromagnetic flow meter HACH FH950.

2.5. Governance and Stakeholder Analysis

To obtain a referential numerical value on the governance level in the basin, the methods proposed in the Fresh Water Health Index (FHI) was used. First, the actors involved in the water management of the basin were identified using the Stakeholder Salience Model (Mitchel et al., 1997; Neville et al., 2011). For prioritizing the stakeholders and determinate the relations between each one, I used the Social network Analysis, using the software package Ucinet (Borgatti et al., 2002). The centrality measures were calculated with the network tool and the graphical representation was set using the degree of connectivity between stakeholders.

Once the main stakeholders were identified, the survey described in the Freshwater Health Index was applied. This survey includes 12 modules, each one corresponds to each sub-indicator described in Table 2, with a total of 51 questions. The values for the indicators of the governance and stakeholder's component were qualitatively determined through in a survey using a 5-point Likert-type scale that was applied to the main stakeholders in the management of the basin. This included inhabitants of the basin,

officials of governmental institutions, representatives of non-governmental organizations, representatives of the productive sector and academia. The data sets collected were analyzed in the FHI tool, allowed us to identify problems and provide a score given to each sub-indicator. In addition, relevant laws, polices and plans were compiled at the international, national and local levels, in order to be able to compare them with the results of the index and identify gaps in governance.

A workshop was developed with the municipality and a timeline was built with the information given by the participants in the taking maps. Then, a semi-structured interview was applied to the key informants identified. This information contrasted with data found in news and reports helped to build a timeline of the milestone in the PRB.

In addition, the evaluation of Ecosystem services (ES), was made through visual evaluation contrasted with the information collected in the semi structured interviews as well as the workshop. Taken as reference (Perini & Sabbion, 2017; Yeakley et al., 2016), a list of past and present ES was made taking as consideration the category of each ES.

Table 2: Water Governance indicators and sub indicators definitions

Indicator	Definition of the Indicator	Sub-indicators	Description
Enabling environment	Freshwater resource management is governed and managed by policies, legislation, market processes, and social norms.	*Water resource management*	Is a framework for managing and coordinating resource development in a basin.
		Rights to use of resource	How widely distributed water is in the basin
		Incentives and regulations	Investment in water projects
		Financial Capacity	Investment gap between funds allocated and those needed for steps to conserve water resources
		Technical Capacity	The institutions involved in water management have staff who have been trained to manage resources and who are continuously receiving training to expand their knowledge.
Stakeholder engagement	The relationships between stakeholders, as well as how transparent and accountable those interactions are.	*Access to information and knowledge*	Everyone has access to the information, which is simple to comprehend and apply while making decisions
		Participation in decision-making processes	Stakeholders are involved and participated in the decision-making process
Vision and adaptive governance	Ability to gather, analyze, and apply information in order to define goals for the basin and adjust to changing conditions.	*Strategic planning and adaptive management*	Plans and politics for strategic management
		Monitoring and learning mechanisms	Use of socioeconomic data, in conjunction with adequate physical, chemical, and biological monitoring of water resources, to inform policy and planning
Effectiveness	The results of investment decisions and policies related to water	*Enforcement and Compliance*	Degree to which laws are up help and agreement are enforced.
		Distribution of benefits from ecosystem services	Impacts of water resource management decisions, paying particular attention to vulnerable populations.
		Water-related conflicts	Presence of conflict over water services, including allocation, access, pollution, diversion, for infrastructure development.

Elaborated by: Rossemary Sanmartín
Adapted from: Conservation International, Vollmer et al. & Mohammed et al., 2021

2.6. River restoration priority assessment

For river restoration framework, reference data collected was used to identify the main concerns in the river. To integrate the information aforementioned, each category of data collected was given a score between one and five, except for toxicity, hydromorphology condition and land cover naturalness, which were categorized between one to four, using the guidelines of USDA and Nature Conservancy. The data sets were classified between threats and health of the river; category scores are described in Table 3.

A restoration priority (RP) model was defined and accounted for different levels of threats (T) and health (H) of the river (Equation 1). Each section was evaluated with the information collected.

$$RP = T + H \qquad \text{(Equation 1)}$$

Many approaches were selected in order to integrate the axes of restoration: Stakeholder, Ecological, and Learning Success (Palmer et al., 2005); and Fresh Water Health indicators: Ecosystem Vitality, Ecosystem Services and Governance (Vollmer et al., 2018, 2021) and the guidelines provided by the Society for Ecological Restoration (SER) (Gann et al., 2019). The integration of many approaches helped to establish goals and actions for each problem considering both social and environmental.

Additionally, Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA), were used to summarize the different priority indicators and to determine natural groups based on the similarities of each section. For these statistical analysis, the indicators used were normalized using the R software for both PCA and HCA (Kassambara & Mundt, 2020).

Table 3: Scores for segment prioritizing grouped by health and threats.

Category	Variable	Metric	1	2	3	4	5	Reference
Health	***Water Quality***	CCME WQI	Poor	Marginal	Fair	Good	Excellent	(Alvear et al., 2019; Cabrera et al., 2018; CCME, 2017b)
	Macroinvertebrates	BWMP	Very Critical	Critical	Questionable	Acceptable	Good	(Chapi & Yupangui, 2018; Uherek & Pinto Gouveia, 2014)
	Toxicity	$GI_{Sediment}$	High Toxicity	Toxic	Moderate Toxic	Low Toxicity		(Cabrera et al., 2018)
		GI_{Water}	High Toxicity	Toxic	Moderate Toxic	Low Toxicity		(Cabrera et al., 2018; Rodríguez Romero et al., 2014)
	Hydromorphology condition	SVAP	Poor	Fair	Good	Excellent		(Chapi & Yupangui, 2018; USDA, 1998)
Threats	***Land Cover Naturalness***	Type	CA	TS	ACS	N&SN		(Conservation International, 2017; GAD Municipal Tena, 2021; MAATE, 2018)
	Infrastructure	% Channel modification	MCM	LSCM	AHCA	LHCA	IM	(Conservation International, 2017; GAD Municipal Tena, 2021)
	Sewer Discharges	Number of discharges	>8	7-8	5-6	3-4	1-2	
	Mechanical shops	Number of mechanical	>5	4	3	2	1	
	Solid waste	SVAP	ASMES	MPSW	PSW	PSWT	NESW	(Chapi & Yupangui, 2018)
	Invasive Species	Visual Assessment Score	PISF		PIS		NEIS	

MCM: Most of the channel is modified (75-100%), **LSCM:** Large sections of the channel are modified (51-75%), **AMCA:** Almost half of the channel is affected (50%), **LHCA:** Less than the half of the channel is affected (25-49%), **IM:** Insignificant modification (0-25%), **N&SN:** Natural and semi-natural (100),**ACS:** Assisted Cultural System (60-70), **TS:** Transformed system (30-50), **CA:** Completely artificial (0-10), **ASMES:** Abundance of solid waste in the entire section(1), **MPSW:** Moderate Presence of solid waste (3), **PSWT:** Presence of solid waste in the river (Two Types 5) ,**PSW:** Presence of solid waste (7),**NESW:** No evidence of solid waste (10), **NEIS:** No Evidence of Invasive Species (10), **PIS:** Presence of Invasive Species (3), **PISF:** Presence of Invasive Species for Fishing (1).
Elaborated by: Rossemary Sanmartin

3. RESULTS

3.1. Basin context

Most of the basin is occupied by the urban area. From the zoning map, the main uses of the land in the urban area are “Integration with the rural environment” and “tourism” (Figure 2). The HAND model was used to identify the areas that are supposed to be part of the flooding area of the river with respect to the distance to the main channel. Four different studies for water quality and biodiversity characterization were run between 2018 and 2021, the sampling points as well as the sections are shown in Figure 1-A.

There are many threats for each section, some specific threats as mechanic workshops, infrastructure and sewage discharges are shown in Figure 2. The majority of infrastructure were at sections 1,2 and 3 (Fig. 2A-C). The municipality had reported that in the whole city more than 1903 properties are built in the natural protection area of the rivers arguing that the is it due to the lack of planning in the past (GAD Municipal Tena, 2014). The current local policy establishes a 10m protection area for streams and 50m for rivers (NORMA TÉCNICA USO Y GESTIÓN DE SUELO Y PLANES URBANÍSTICOS DE GADS, 2020; PDOT 2020-2023 Normativa Plan de Uso y Gestión de Suelo y Plan de Ordenamiento Integral Sustentable de La Ciudad de Tena-Pouis, 2020). Mechanic workshops and sewage discharges constitute main threats along the river.

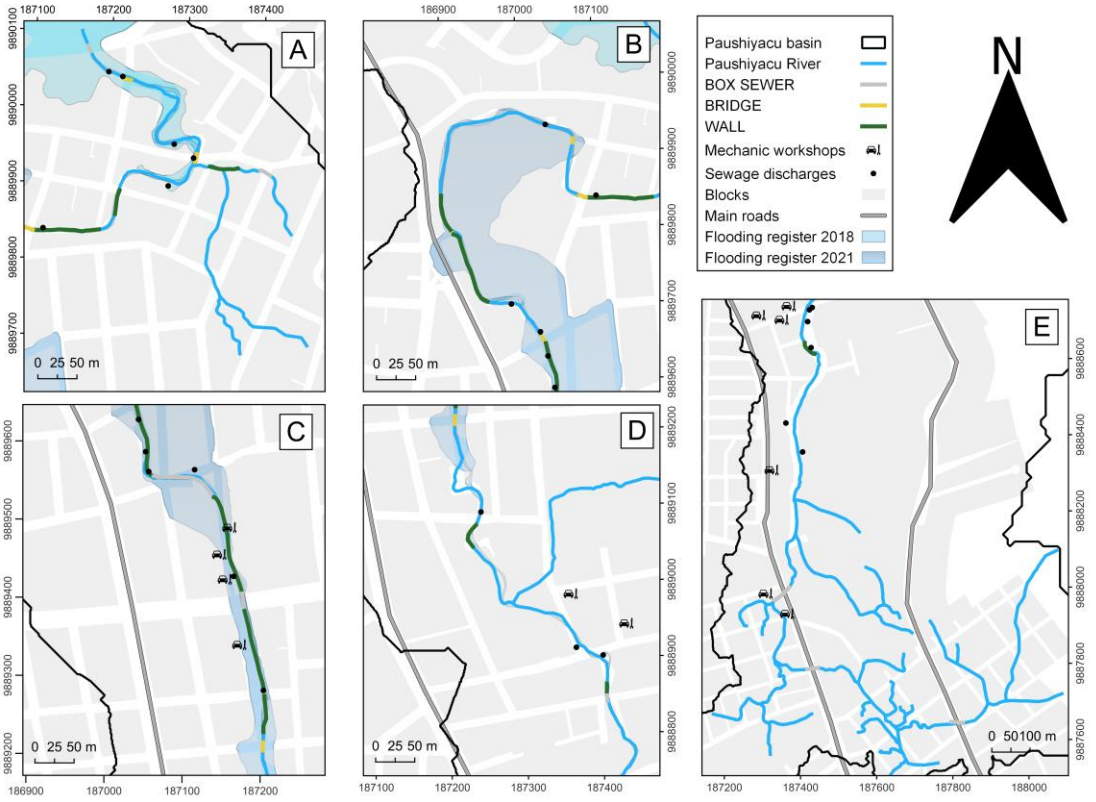


Figure 2: River characterization by section showing the main threats identified, and registered information of previous flooding events **A)** Section 1 **B)** Section 2 **C)** Section 3 **D)** Section 4 **C)** Section 5
Elaborated by: Rossemary Sanmartin

3.2. Instream biological condition and hydromorphology visual assessment

The riverine hydro-morphological condition average had a direct relation with the biological condition. The indicators selected showed that almost the whole channel of the river had been modified, and present hydrological alteration, especially from 1 to 3 section that coincide with the most densely populated areas throughout the Paushiyacu River Basin (Table 4).

In 2021, complementary studies provided the information to calculate BMWP scores for rainy and dry season for section 1 and 5. Regarding this score, section 1 had a lower quality for both, 2018 and 2021. This analysis also showed that the presence of macroinvertebrates and water quality can change with the seasonality, conserving the tendency in the 2018 BMWP (Fig. 4).

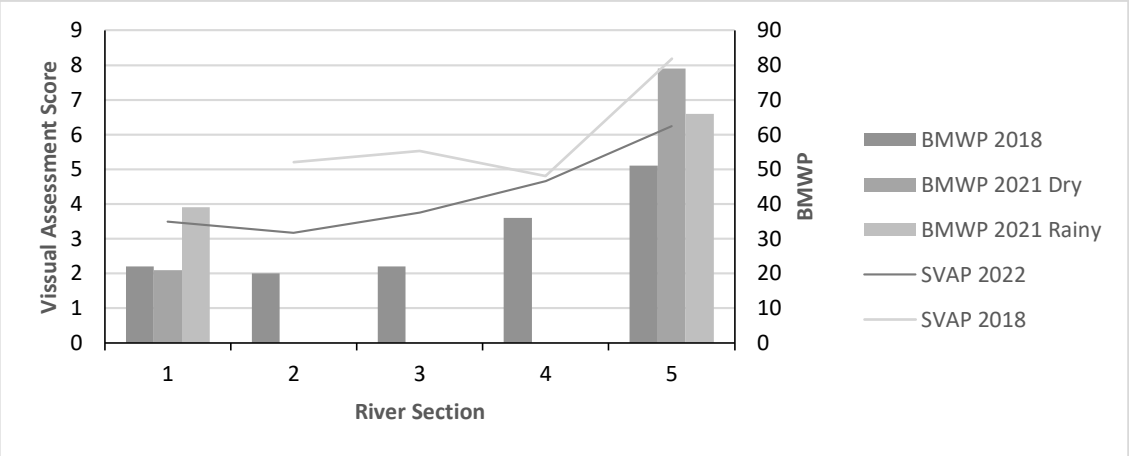


Figure 3: Visual Assessment Score (SVAP) from 2018 (ITS) vs. 2022, with BMWP 2018 ITS and BMWP from 2021
Elaborated by: Rossemary Sanmartin

Even though, some sections presented habitat condition for biodiversity development, tilapias *(Oreochromis niloticus)* are the most observed invasive species of fish in the last 25 years as reported by riverine inhabitants. The upper riparian zone (Section 5) maintains some of the natural vegetation but we can still observe that the channel condition had been engineered because of the presence of the main road, artificial pools for fishing and some houses near the river.

Table 4: Stream flow for macroinvertebrates sampling points and riverine condition scores of selected indicators along the Paushiyacu River Basin (USDA, 1998).

Indicator	River Section				
	1	**2**	**3**	**4**	**5**
Stream Flow	*MI1*				*MI2*
Discharge [m^3/s]	0.2548				0.0218
Flow velocity [m^2/s]	0.1858				0.0325
Riverine Condition					
Channel condition	3	3	2	5	5
Hydrologic alteration	3	3	2	7	7
Riparian Zone	3	5	3	5	7
Bank stability	3	3	5	5	7
Water appearance	3	1	2	3	7
Nutrient Enrichment	5	3	3	5	3
Barriers to fish movement	1	3	4	7	7
Instream fish cover	5	3	7	3	5
Pools	3	3	4	5	5
Invertebrate habitat	5	3	2	3	5
Riparian vegetation variety	3	5	7	5	7
Channel shadow	5	3	4	3	10
Average Score	3.5	3.2	3.8	4.7	6.3

Elaborated by: Rossemary Sanmartin

3.3. Governance and Stakeholders Analysis

Through the salience model it was possible to identify the stakeholders involve in the management of the basin (Fig 4). The roles of each actor are described in the discussion section.

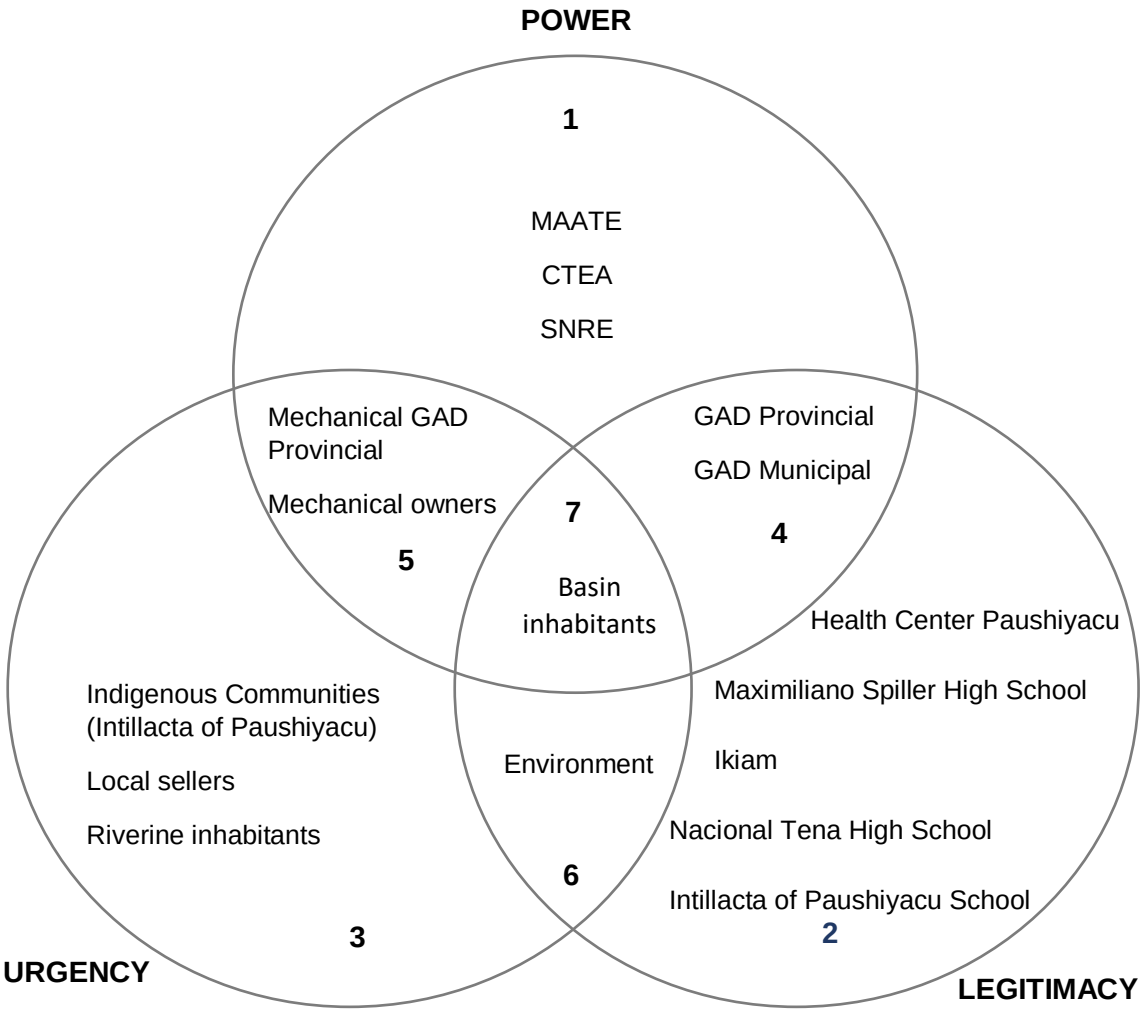


Figure 4: Salience Model for Paushiyacu river basin **1)** Dormant Stakeholder; **MAATE:** Ministry of the Environment, Water and Ecological Transition; **CTEA**: Technical Secretariat of the Amazonian Special Territorial Circumscription; **SNRE:** The National Secretariat of Risk Management 2**)** Discretionary Stakeholder **3)** Demanding Stakeholder **4)** Dominant Stakeholder **5)**Dangerous Stakeholder **6)** Dependent Stakeholder **7)**Definitive Stakeholder **8)**Non stakeholder (Mitchel et al, 1997).
Elaborated by: Rossemary Sanmartin

The social Network Analysis shows that the key stakeholders were basin and river inhabitants, including the indigenous community, meaning that they are going to be the enablers or hinderers in any decision-making process. Institutions as the decentralized

autonomous governments (GADs) were the nexus between inhabitants and stakeholders with power (**Appendix B:** Figure B-1).

The level of governance in the basin is 32/100 with lowest scores in effectiveness showing that although there are some laws, polices and plans their enforcement seems to be insufficient. Table 5 shows the scores obtained from the surveys applied and compliance with the FHI software.

Table 5: Governance and Stakeholder Major Indicators and Sub-Indicators scores obtained from the Fresh Water Health Index survey, each category is evaluated from 0 to 100, the number of relevant polices related with each indicator are shown.

Governance and Stakeholders	Score	Numbers of Relevant Laws, Polices and Plans		Source
		National	Local	
Enabling Environment	31	2		(Constitución Del Ecuador, 2008; Ley Orgánica De Recursos Hídricos, Usos Y Aprovechamiento Del Agua, 2014; United Actions, 2015)
Water resources management	25	2		(Constitución Del Ecuador, 2008; Ley Orgánica De Recursos Hídricos, Usos Y Aprovechamiento Del Agua, 2014)
Right to resource use	29	2		(Constitución Del Ecuador, 2008; Ley Orgánica De Recursos Hídricos, Usos Y Aprovechamiento Del Agua, 2014)
Incentives & Regulations	27	1	1	(Ministerio del Ambiente y Agua, 2015; Tapia, 2013)
Financial capacity	32		1	
Technical capacity	49			
Stakeholder Engagement	44			
Information access	40	1		(Ley General de Transparencia y Acceso a La Informacion Pública, 2004)
Engagement in decision-making	48	2		(Constitución Del Ecuador, 2008; Ley Orgánica De Recursos Hídricos, Usos Y Aprovechamiento Del Agua, 2014)
Effectiveness	25			
Enforcement & compliance	23			
Distribution of benefits	25			
Water-related conflict	28	1		(Ley Orgánica De Recursos Hídricos, Usos Y Aprovechamiento Del Agua, 2014)
Vision and Adaptation	29			
Monitoring mechanisms	24	2		
Strategic planning	34	1	1	(COOTAD, 2019; GAD Municipal Tena, 2021)
Fresh Water Health Index Score for Governance and stakeholders	32			Score obtained from the FHI Tool

Elaborated by: Rossemary Sanmartin

Since 2001, some water quality recovery projects for the Paushiyacu RIver have been proposed, the most important was the construction of two wastewater treatment plants for the city of Tena in 2014. The timeline depicts that many projects had been developing for the river (**Appendix B:** Figure B-2). Some landmarks such as the building of gabion walls, bridges and curvets have accelerated the growth of urbanization in the area.

During the last 50 years, the lack of appropriate management in the basin has caused a detriment of the services that the stream provided to the city. The river is no longer able to maintain the water quality by itself and neither to regulate flood flows, due to the presence of pollution and infrastructure. In terms of food provision, nowadays it mainly relies on the globally invasive fish tilapia: *Oreochromis niloticus*. In contrast with the past when native species fishing was reported along the river (Aguinda, personal communication, May 5, 2022; Alcaldía de Tena, 2020) As for the landscape, inhabitants of the area and general public who use this space have stated that the river zone is unattractive. In addition, agricultural activities were spotted near the river in section 4-5, also some small plots can be found in section 1 as part of the household food provision. In section 2, this area seems to contribute to mitigate, up to certain point, the effect of the increased flow, this zone has enough space for support high water levels, event thought is does not count with the appropriate infrastructure for support flooding (**Appendix B:** Figure B-3).

3.4. River Restoration Priority Assessment

The most affected sections were sections 1 and 3, the main problem for both is low health driven by the presence of many threats (Table 6) health in this case is referring to the favorable conditions for live support, comfort and develop in an aquatic ecosystem in this case the river , and the lack of management of at the riparian zone. In section 3 the channel has been modified in more than 80% which means that the channel does not have access to the flooding area, decreasing the efficiency of the Intrinsic Purification Systems (IPS). After analysis, the water quality from section 1 to 4 was categorized as poor while section 5 is marginal. Water quality decreases in places with greater presence of infrastructure (sections 1,2 & 3). In the upper zone (section 5) the hydro-morphological and habitat condition were better than in other sections, consequently, this area can be used as a possible reference ecosystem. The macroinvertebrate communities also had a greater presence in the upper area because of favorable conditions in contrast to the lower sections (Fig 3).

The data recollected showed that toxicity for both sediment and water were low. Natural and semi-natural cover with assisted cultural system were the main uses in section 5. On the other hand, sections 1, 2, and 3 are completely artificial, with some transformed areas in section 4. Solid waste present along the channel was an evident problem, especially in the most densely populated sections. Tilapia farms were observed during the visit to the stream (**Appendix C:** Photograph C-1) and information about tilapia fishing activities was reported in the talking maps.

Table 6: Restoration priority per section categorized by Health and Threats.

Category	Variable	River Section				
		1	**2**	**3**	**4**	**5**
Health	*Water Quality*	1	1	1	1	2
	Macroinvertebrates Presence	2	2	2	3	3
	Water Toxicity	1	1	1	1	1
	Sediment toxicity	1	1	2	2	1
	Hydromorphology Visual Assessment	1	1	1	1	2
Threat	*Land Cover Naturalness*	1	1	1	2	4
	Infrastructure	4	4	1	5	5
	Sewer Discharges	4	2	3	1	5
	Mechanical shops	0	0	2	1	3
	Solid waste	1	2	1	2	4
	Invasive Species	1	3	1	3	1
RESTORATION PRIORITY		16	17	15	21	30

Elaborated by: Rossemary Sanmartin

The Principal Component Analysis (PCA) (Fig. 5) shows that section 5 was better conserved than the rest of the river. For section 4, it was found an increasing influence of threats indicators. Section 3 presented the largest number of threats, especially related to infrastructure and sewer discharges. For sections 1 and 2, both were related with indicators of toxicity and invasive species. The Hierarchical Cluster Analysis (HCA) exposed that section 1,2, and 3 are more related considering the characteristics of each area.

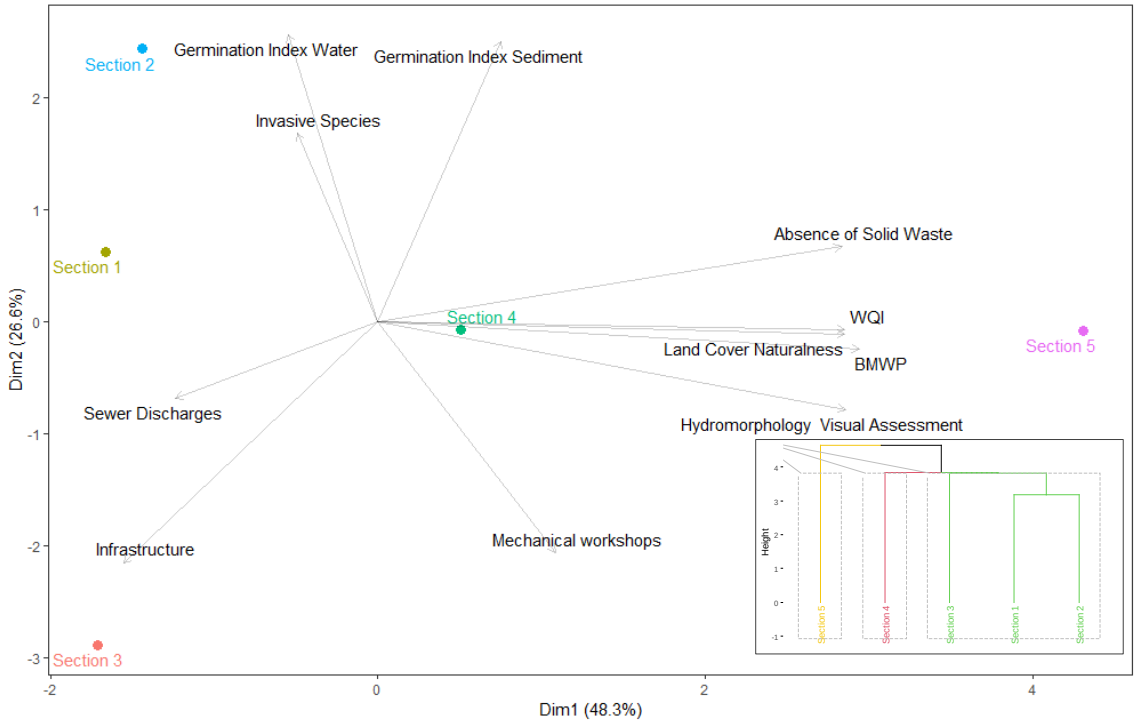


Figure 5: Relation among river sections with health and threats indicators, based on the Principal Component Analysis (main figure) and Hierarchical Cluster Analysis (inside figure)
Elaborated by: Rossemary Sanmartin

4. DISCUSSION

4.1. River and Basin Characterization

The main threat in the basin is the presence of infrastructure caused by urbanization. Together, the lack of planning and policies for both city growth and urban river management have worsened the situation not only of the Paushiyacu river, but also of other small urban basins from Tena such as Tamiayaku, Chimbadero and Mamallacta (Cabrera et al., 2018; Chapi & Yupangui, 2018; GAD Municipal Tena, 2014). Walsh et al. (2005), sums this situation up in the term “urban stream syndrome”, which describes the effect of urbanization processes on stream dynamics.

Paushiyacu river presents conditions similar to those of other rivers that cross densely populated areas. Studies conducted before demonstrate that the health of this river in terms of water quality, biological condition, toxicity and hydromorphology tend to decrease from the upper zone to the outlet (Table 6). This situation, as said by (Perini & Sabbion, 2017; Walsh et al., 2005) is usually caused by the land occupancy. In the case

of the PRB, most of it had been affected by anthropogenic activities and urbanization; the land used is integrated with the rural and residential areas in the upper zone (Section 4-5) while in the lower part (Section 1-3), the main use is commercial and residential (GAD Municipal Tena, 2021; MAATE, 2018). Some commercial activities include tourism, car washing, mechanical shops, restaurants, etc.

The presence of direct wastewater discharges is one of the main drivers of degradation. Some pollution points were identified during the visits to the river (Fig. 4). But, in 2020 the environmental department of the municipality reported more than 100 direct discharges, both pluvial and sanitary, from houses located nearby the river (El Observador, 2020). In 2001 and 2008 two projects to build sewerage infrastructure along the area were implemented; and in 2015, two wastewater treatment plants (WWTP) were built for the city, expecting to increase the water quality in the urban rivers (El Telegrafo, 2019).This infrastructure was planned to preserve the environment by returning clean water to aquatic ecosystems. During our field work, it appeared that the main problem was not the lack of infrastructure, but rather the lack of maintenance of the existence infrastructure as well as the non-connectivity of houses to the sewage network. In the outlet of the Paushiyacu river it was observed that some sewer check boxes remained uncovered affecting the comfort of neighbors who dealt with stinking odors (**Appendix C:** Photograph C-2)**.** This problem was also present in other sections of the river, even where there was a principal sewer pipe, some of the sections have fallen or exceeded their capacity, causing sewer water disposal into the river, affecting the quality and increasing the organic matter levels in the area.

Poor management of both organic and inorganic solid garbage worsens the basin contamination problem. Although, a project for the separation of organic, inorganic, and recyclable waste has been promoted in the city of Tena, citizens remain unaware and disregards this. The presence of solid litter along the channel is common; even though, some campaigns for cleaning the channel had been implemented, the problem is still present. During the field visit, it was observed that the lack of infrastructure for trash disposal is one of the contributing factors to the accumulation of garbage and, for instance, the bad quality of the water.

Despite the historical records of flooding (Fig. 2), the construction of households in the protection margins of the river is evident. As a result, unplanned and non-authorized flooding and erosion control infrastructure had been built which seems to be causing a

disruption lateral connectivity. However, neither this nor the 10m riparian buffer zone, established by the municipality, had been respected for the construction of residential areas. To mediate the effect of flooding between 1984 and 2010, gabion walls were built in the place to unsuccessfully protect the riverine constructions, as later, flooding events were reported in the talking maps. It was also reported that the last flood of 2021 was exacerbated by presence of the 90m box-type overpass built in Cuenca Street (Fig. 2). This infrastructure was built to solve problems related to traffic and to satisfy the demand of the main users of the street, but apparently hydrologic and hydraulic parameters were not taken into consideration since the level of the preexistence sewer was dropped one meter, increasing the hydraulic risk in the area (El Observador, 2021).

4.2. Instream biological condition and habitat Characterization

The stream's biological condition in 2018 and 2020 shows that macroinvertebrates like Oligochaeta, Chironomidae, Psychodidae, Acanthobdellidae and Leptohyphidae, that are tolerant to variable conditions, were found in section 1 (Chapi & Yupangui, 2018; Rosero & Mena, 2021)(*In prep.*). In this section the BMWP increased during the rainy season probably due to the fact that the factors that shape macroinvertebrates communities like substrate, vegetation and chemical gradients such dissolved oxygen, changes with seasonality (Guareschi et al., 2014). The presence of infrastructure, ground impermeability, or extreme events that drive flash floods promote the physical displacement of stream organisms and allow pollutants to arrive quicker to the main channel (Jesús-crespo & Ramirez, 2011; Walsh et al., 2005).

In general, the BMWP indicated the poor quality of the river in areas with more anthropic intervention (sections 1-3), due to the deterioration of the hydromorphological condition with gray infrastructure (Fig. 3). The channel condition in general the specific variable that define the behavior of the river in terms of the transport of material for habitat creation (Jesús-crespo & Ramirez, 2011; USDA, 1998). In this case, the channel is no longer healthy and does not present the condition to support macroinvertebrate habitats as can be observed in the SVAP score (Table 4).

In the present study, only two flows measurements were taken in section 1 (MI1) and 2 (MI2) (Table 4). The results show that the flow increases in the outlet (Table 4), however this does not necessarily mean that the river has the environmental flow to maintain aquatic life. During the workshop and personal communication with local inhabitants it was reported that 50 years ago the water level of the stream was enough to use it for swimming and fishing (Aguinda, personal communication, may 5, 2022). This is no

longer true, but it is necessary to develop a monitoring flow control program to understand these changes. Globally, flow decrease has been attributed to climate change, but it could also be explained by land use change (Perini & Sabbion, 2017; Walsh et al., 2005).

4.3. Governance and Stakeholder Analysis

Seventeen main stakeholders were identified for the management of the Paushiyacu River Basin (Fig. 4). Three of them were categorized as dormant stakeholders: 1) Ministry of the Environment, Water and Ecological Transition (MAATE) as the legal and political authority in charge of the management and regulation of environmental resources and water in the country; 2) The Technical Secretariat of the Amazonian Special Territorial Circumscription (CTEA) is the organization in charge of improving effectiveness in the planning, execution, monitoring and evaluation of the wellbeing in the Amazon region of Ecuador, as the institution that has financial capacity to develop projects for the region; and 3) The National Secretariat of Risk Management (SNRE) is the authority in charge of management and prevention of risk in the country, which has been involved in the response to some natural disasters related to the Paushiyacu Stream.

Three Educational Centers were identified as part of the discretionary stakeholders, due to the proximity to the river. For example: 1) Maximiliano Spiller High School has participated in some workshops on the state of the Paushiyacu River, especially related to pollution, this school has also been affected by the overflow of the river during the rainy season; 2) Intillacta of Paushiyacu is a school located near to one of the main tributaries of the Paushiyacu River, as claimed by the leader of the community this area and the houses located nearby do not have a sewer system, so the waste water discharges directly in the channel (Aguinda, personal communication, May 5 2022); and finally, 3) Ikiam is the only university based in Tena and has conducted research related to the quality of streams and rivers in the province of Napo including urban rivers as Paushiyacu. The Public Minister of Health (MSP) in 2019 reported that the Paushiyacu River is in a sanitary emergency, so its management should be a priority for decision makers (GAD Provincial de Napo, 2019) (For more details check **Appendix B:** Figure B-1 & B-2).

Recovery plans had been developed since 2001, nevertheless, none of them had been successfully accomplished, and the quality of the river had decreased in the last years(Cabrera et al., 2018; Chapi & Yupangui, 2018; GAD Provincial de Napo, 2019). In 2019 the Paushiyacu River was declared in sanitary emergency due to the bad quality of the water and the problems that it generated to the riverine inhabitants (GAD Provincial de Napo, 2019). In the same year, the provincial government dredged the river, to clean the channel and let the water flow, this was a civil work that was considered priority since the river was declared in sanitary emergency (GAD Provincial de Napo, 2019) .

In 2020, a *minga* (community-based work for litter recollection and desilve), took place at the PRB and infrastructure was built in certain areas that were in danger of floodings in certain months of the year (Alcaldía de Tena, 2020; Muni TV Tena, 2020). The first garbage collection gathered about 1.5 tons of trash along the intervention areas. Another *minga* took place in 2021, led by Roots & Shoots and Ikiam Regional Amazonian University; the organization reported that more than 329 kg of trash were collected only in 400 m of the stream.

Even though there are some plans, laws and policies that regulate the management of water resources in the country (Table 5), they appear to be insufficient according to the information collected and analyzed with the Governance and Stakeholders FHI instrument. These plans are aligned to the accomplishment of the Sustainable Development Goals (SDG's) for 2030, emphasizing on goals 6, 11, 13 and 15. The Freshwater Health Index (FHI) instrument was selected because it integrates the 12 principles on Water Governance established in (Akhmouch et al., 2018). The analysis showed that each principle had a low level of accomplishment. Despite the existence of some regulation instruments, the score of stakeholder engagement showed that the main problem is miscommunication between interested parts, this can be identified as an information gap (OECD, 2015).

The effectiveness and enabling environment indicator showed the existence of financial and political gaps. On the other hand, the budget allocation increased the infrastructure capacity of the city when 9 million dollars were assigned to the construction of the wastewater treatment plants (El Telegrafo, 2019) that partially solved the problem of urban rivers. The political gap is more evident in the assignment of duties at each level of government. Even though, the management of urban rivers concerns to the municipality, the negative effects of the degradation should be analyzed by areas of

influence. The distribution of ecosystem benefits is not equal along the basin since the main polluters are not the main users. Due to the fact that certain pollutants found in the city of Tena had been found downstream this basin, is an indicator of how these problems should be managed applying a multilevel approach (Capparelli et al., 2020).

The identification of ecosystem services provided a reference to establish strategies for restoring previous ESs. This type of evaluation should be made by the perception of river users, however the information collected in the current study was only used for understanding how the ecosystem functioned before the degradation. Urban rivers provide ecosystem services as provisioning, supporting, regulating and cultural services, depending of the category of the river (Perini & Sabbion, 2017; Yeakley et al., 2016). For low order streams, the ESs are mainly focused on provision and supporting, in this case it could be identified that PRB is being used for farming *Oreochromis niloticus* in its head waters which had increased the level of nutrients in the upper zone (Cabrera et al., 2018). This was also the driver of the presence of this specie along the river.

As was mentioned before, the stream was used for cultural proposes like swimming and the name Paushiyacu is derived from the kichwa word “Paushi” the local name for *Crax globulosa* a local bird common known as “Paujil”. It also was used as drinking water and, according to inhabitants, the degradation started 45 years ago (Aguinda, personal communitation,5 May 2022). Since the stream is no longer able to buffer the flooding events, many people were affected during the last extreme event and some erosion was observed in the last field campaign (**Appendix C:** Photograph C-3). Ecosystem Services were not evaluated at spatial and temporal scales since the aim of this research was only to provide a framework that can be used for future studies and decision making.

4.4. River restoration priority assessment and framework

With the restoration priority model, reference ecosystems (sections 5) and sections that need special attention were identified (sections 1-4). The main problem with the reference ecosystem was that it has latent threats that should be mitigated in the first instance of restoration. As shown in the PCA and HCA (Fig. 5), the upper zone (section 4-5) is the most preserved area but the presence of mechanical shops and infrastructure (**Appendix C:** Photograph C-4) are affecting its conditions; and this may be reason for the presence of oil in some parts of the stream (**Appendix C:** Photograph C-5).

Another problem identified is the presence of tilapia (*Oreochromis niloticus*), an african invasive fish species that has been introduced and spread all over the world, including the Amazon basin, and nowadays is the second most widely farmed fish (Doria et al., 2021; Santafe-Troncoso & Loring, 2021). In this case the presence of tilapia, despite the water quality of the stream, is common since is a pollution tolerant species that withstand changes in water conditions (Doria et al., 2021; Rahman et al., 2021). The presence of other species has been reported in the upper zone by Cabrera et al. (2018), but in the last section of the river the presence of elevated infrastructure affects the longitudinal connectivity (**Appendix C:** Photograph C-6) and seems to have changed the migration regime of species (Kondolf et al., 2006).

Even though the overall results showed that the conditions in the upper zone are good, it is necessary to look at each variable separately, since some of the values do not necessary indicate good conditions. The values for CCME-WQI for example fluctuate between 13-55, which means that the condition in the upper zone is marginal, indicating that it departs from the natural or desirable levels. In 2018, it was found that this area contained high levels of free iron, organic matter, indicating eutrophication according to the Germination Rate (GR) showed in (Cabrera et al., 2018). The anthropogenic intervention in this area is minimal in comparison to the most urbanized areas, but the presence of tilapia farms and livestock farming could affect the conditions and increase the organic matter in the place (**Appendix C:** Photograph C-7 & C-8)

The toxicity in the whole river was low, however the sediment toxicity determined by the germination index in section 3 was considerable. In 2020, high levels of metals were reported in the area, indicating that the accumulation of pollutants in sediments was directly related to domestic effluents that contained high amounts of organic matter, agrochemicals, and metals (Capparelli et al., 2020).

Four restoration goals where proposed: 1) water quality improvement; 2) decreasing of the hydraulic risk; 3) fluvial ecosystems improvement; and 4) governance and stakeholder engagement improvement based on the framework presented in (Guimarães et al., 2021; Kondolf, 2011; Palmer et al., 2005). For this case passive restoration solutions are presented since the drivers of degradation are identified, and some decisions can be made to change or restore river functionality (Kondolf & Yang, 2008). Many restoration measures (e.g., changes in the land use, reactivation of buffer zones, recovery of natural processes) can be taken in consideration as a first approach

for river recovery (Guimarães et al., 2021). Beechie et al., 2008 , suggested that the cost of restoration projects can be optimized by following the logic approach and setting clear objectives and strategies that are oriented to protect habitats, remove barriers, recover functionality and natural processes , and enhance habitat.

From the social sphere, it is proposed to start with an environmental education plan, as well as the socialization of available information on the state of the Paushiyacu River and the other urban basins of Tena. This in order to keep the inhabitants informed and reach mutual agreements for the management of the basin. Among the solutions, the integration of annual fees for implementation of green and blue infrastructure (Nature based solutions) and maintenance of green areas and existence infrastructure for hydraulic risk decrease. within the urban area is proposed. Prioritize the improvement of water quality and biodiversity, using the values presented in this work as indicators. It is proposed to generate an annual monitoring plan to evaluate the water quality, and is also recommended the implementation of a water level monitoring station to know the flow dynamics. For all of this aforementioned, a summary of the framework that should be followed for river restoration is presented in Table 7.

Table 7: Framework for river restoration to achieve the goals of Paushiyacu River Restoration

Goal	What to do?	How?	Expected Consequences
Improvement of Water Quality	Promote proper collection, disposal and treatment of solid waste	Implementation of garbage collection points along the river	- Decrease the presence of garbage in the channel and in the riparian area
		Implementation of an environmental education plan for the schools and high schools in the city, especially with the ones located near by the river	- Increase the environmental awareness and initiate a river recovery protection citizen collective by educational institutions
		For sections 4 and 5, the main threats must be removed (e.g,. artificial tilapia pools)	- Decrease the level of organic matter and presence of invasive species as tilapia
	Promote sewage collection and treatment	In section 5, 4 & 3 the implementation of a control for mechanical shop wastewater disposal. Bio filters can be implemented next to each threat	- Decrease the impact of the mechanical and increase the water quality specially in the upper stream area
	Foster sustainable drainage solutions	In section 2, the space allows for the building of an artificial wetland that can be used as a filtration system and also as a hotspot point for local biodiversity	- Water quality increase
		Promote the creation of local polices that incentive the preservation of areas that can be used as green areas for the city	- Create sustainable tourism places
		In section 5, the reactivation of tourism areas (e.g:water fall located in the upper zone)	- Create a waterfall effect, reactivating the green areas and the upper zone. This can followed by an economic plan reactivation for new activities in the area
	Implement a water quality monitoring plan	For each section presentenced in this study, a sampling and monitoring program should take place at least twice a year to control the changes in the water quality. The minimum of variables that should be considered are: Coliforms, pH, BOD5, Nitrate, Phosphate, Temperature changes, Turbidity, Total dissolved solid, Dissolved Oxygen. This could be complemented with macroinvertebrates and toxicology analysis.	- Have an annual report of the state of the stream and improve transparency between the government and population. - Control of possible contamination sources
Decrease of Hydraulic Risk	Implement a protection flood-prone areas plan	Socialize the risk of living in the flooding area	- Workshops with the SGRE and the riverine inhabitants
		Increase the protection areas for streams	- Include in the land use plan of the city
		Stabilize the banks	- Reforestedriparian areas with native species, and GBI building in the risk

			areas identified to decrease the flooding risk
		Create a risk contingency plan for flood control.	- Establishment of safe places in case of emergency - Budget allocation for natural disaster contingency
		Plan control urban sprawl/ Provide regular housing	- Regulation of constructions in Tena - Decrease the risk disasters caused by building in problematic areas
	Create river protection areas like river parks, green corridors and environmental protection areas	Promote incentives for green tourism projects in the area	- Increase the participation of local sellers in green initiatives
	Maintenance of the current infrastructure like the curvets, box-type sewers, and walls	Create a monitoring, maintenance and control schedule during the year for the existence infrastructure	- Increase the water quality and decrease the flow obstruction
	Implement a flow monitoring plan	Build two hydrologic stations in the Paushiyacu River in section 5 and 1.	- Increase the knowledge about the flows in Paushiyacu river
Improvement of Fluvial Ecosystems	Re-establish riparian vegetation, if possible with native species	Restore the riverine in section where possible	- Increase the IPS
	Create hot spots and aquatic habitats	In sections (2), (4) & (5), build bio filters (e.g. like artificial wetland) For section (3) & (1), lineal wetlands can be built as bio filters	- Increase water quality - Distribution of Species
	Remove the invasive species	Reconnect the river	- Increase the presence of native species in the river vs. non-native species
	Preserve/ Recover River banks	Include river banks as part of the planning program	- Increase the connectivity between natural and gray infrastructure environment - Increase urban biodiversity
	Recover the longitudinal, horizontal and vertical connection of the river	Remove the barriers if possible	- In section (1), remove the barrier to connect the stream with the River Tena
			- In section (3), reconnect the channel with the floodplain, regenerate the riparian areas
			- Increase the presence of native species

Improve the governance	Improve the multilevel participation in decision making (Stakeholder engagement)	Workshops with the different stakeholders identified in this study. Involve potential stakeholders as: NGO´s, environmental foundations, academia and private sector	- Increase the effectivity of decision making processes
	Promote the diffusion of scientific studies that shows the state of the river	Diffusion campaigns for socialization of the results presented in different studies.	- Increase the understanding of having clean and functional river in urban areas
	Implement waterfront regulation and plans for urban river management	Include in the planning of the city the conservation of riverine places and reformulate local policies to give incentives for riparian conservation	- Increase the participation of the inhabitants of the basin in the recovery and conservation of river ecosystems
	Promote the transparency regarding projects, goals and results in order to increase credibility	Create a website with basic information of projects' development by the local government with updates of each state of the development of the project.	- Increase the participation of the inhabitants and users of the basin in the recovery and conservation of river ecosystems
	Increase the technical capacity and create synergy between the academy and decision makers	Regular capacitation for technicians and financial capacity increase to integrate students as part of the studies.	- Increase the level of knowledge about water management in urban areas
	Create monitoring mechanisms for the accomplishment of the goals of projects	Increase the participation of the inhabitants in the monitoring and regulation processes Promote the creation of the program "Guardians of the rivers", considering community leaders, educational centers, and potential stakeholders	- Increase the efficiency of control mechanism in urban basins - Increase the participation of inhabitants in the construction of sustainable cities
	Increase the financial capacity of the city for water and environment management	Use the Paushiyacu river as a case of study in order to apply for international funding	- More attention for urban rivers and water management in Ecuador

Elaborated by: Rossemary Sanmartin

The framework presented (Table 7) should be enough to start thinking about solutions not only for the PRB, but for Amazon urban rivers in general. Along the city of Tena, there are many urban basins that can follow a similar approach to increase the eco-hydrological processes. Many of the suggestions presented in this study need to be socialized with the stakeholders involved; and, to avoid past problems like non-participation in decision making exercise. In order to increase the level of any kind of involvement, the stakeholders should include transparency, information and budget assignation.

5. CONCLUSIONS

The quality of the PRB has decreased during the last 50 years due to the advance of unplanned urbanization. Health indicators scores decreased from the headwaters to downstream zone, as these zones are located in the most populated areas that count with more infrastructure and have been modified according to the need of the inhabitants. The stakeholder and governance analysis produced a score of 32 over 100, which means that the principles of governance have not been effectively accomplished. From previous recovery plans, it is evident that the lack of participation of the different stakeholders is one of the main problems. Increasing access of information and knowledge is the first step to involve the stakeholders in the decision-making process.

Section 5 should be taken as the reference ecosystem for restoration considering the elimination of the threats identified, such as mechanical shops and tilapia pools. All the infrastructure present in the river should be evaluated to propose possible future solutions to improve lateral, longitudinal and vertical connectivity. The effects of removing the infrastructure must be taken into consideration before any decision.

The framework presented in this study (Table 7) can help decision makers to assess new projects in order to improve the management and governance, not only of water but the city itself. Application of the existent plans, laws and policies could be the first step to start a passive restoration including the social dimension. Integrating some possible stakeholders, such as NGO's and environmental foundations could improve control mechanisms, as well as the creation of specific grassroots movements dedicated to the protection and conservation of urban rivers of Tena and other Amazonian cities of Ecuador.

It is necessary to understand the importance of this rivers for the Amazon basin, since the majority of this are the headwaters of important rivers (e.g. Napo, Putumayo, Amazonas). Some pollutants from the urban areas have been found downstream, so plans for restoration that includes pollutants removal should be addressed as a priority in the next years. It is also important to start to identify non-punctual pollution sources and to model some scenarios for pollution deposit. As a recommendation, emergent pollutants that have been found in other urban rivers and downstream, should be measured to assess water quality, and to understand this pollutants behavior along bigger basins.

6. ACKNOWLEDGMENTS

To the Technical Secretariat of planning of Tena City for provide the information for the accomplishment of this study and collaborated with the workshop “Introducción al manejo de Cuencas Urbanas: Caso de estudio Paushiyacu” with Rotary Club Tena, Fundación Ambientalista Wiyalla, and Universidad Regional Amazonica Ikiam. Thanks to Bryan Rosero, Christopher Mena, Kevin Miño, Pablo Vasconez, Jose Basantes for the support in the field work. Also to the inhabitants of the Basin specially to Marina Aguinda, Eduardo Vayas and Diogenes Ochoa for accompanying and guiding the field visits, and their help in understanding the main problems of the river.

7. REFERENCES

Akhmouch, A., Clavreul, D., & Glas, P. (2018). Introducing the OECD Principles on Water Governance. *Water International*, *43*(1), 5–12. https://doi.org/10.1080/02508060.2017.1407561

Alcaldía de Tena. (2019). *INFORME DE RENDICIÓN DE CUENTAS 2019*.

Alcaldía de Tena. (2020). *Descontaminación Estero Paushiyacu*. https://www.facebook.com/watch/?v=311122779981529

Alvear, D., Carrillo, H., Martinez, D., & Oñate, V. (2019). *Contaminación del estero Paushiyacu: Análisis del rol de la gobernanza y su potencial para la restauración de la microcuenca.*

Constitución del Ecuador, 449 Registro Oficial 67 (2008). http://www.asambleanacional.gov.ec/documentos/constitucion_de_bolsillo.pdf

Ley Orgánica De Recursos Hídricos, Usos Y Aprovechamiento Del Agua, Registro Oficial 32 (2014).

Beechie, T., Pess, G., Roni, P., & Giannico, G. (2008). Setting River Restoration Priorities: A Review of Approaches and a General Protocol for Identifying and Prioritizing Actions. *North American Journal of Fisheries Management*, *28*(3), 891–905. https://doi.org/10.1577/m06-174.1

Borgatti, S. ., Everett, M. ., & Freeman, L. . (2002). *Ucinet for Windows: Software for Social Network Analysis. Harvard*. https://sites.google.com/site/ucinetsoftware/home

Cabrera, M., Pereira, L., & Capparelli, M. (2018). *Evaluación de las condiciones de contaminación del agua de las quebradas Tamiayacu, Paushiyacu y Mamayacta de la ciudad de Tena, provincia de Napo*.

Capparelli, M. V., Moulatlet, G. M., Abessa, D. M. de S., Lucas-Solis, O., Rosero, B., Galarza, E., Tuba, D., Carpintero, N., Ochoa-Herrera, V., & Cipriani-Avila, I. (2020). An integrative approach to identify the impacts of multiple metal contamination sources on the Eastern Andean foothills of the Ecuadorian Amazonia. *Science of the Total Environment*, *709*, 136088. https://doi.org/10.1016/j.scitotenv.2019.136088

CCME. (2017a). CCME Water Quality Index user´s manual 2017 Update. *Canadian Water Quality Guidelines for the Protection of Aquatic Life*, 1–5. http://www.ccme.ca/files/Resources/calculators/WQI User's Manual (en).pdf

CCME. (2017b). CCME Water Quality Index user´s manual 2017 Update. In *Canadian Water Quality Guidelines for the Protection of Aquatic Life*. http://www.ccme.ca/files/Resources/calculators/WQI User's Manual (en).pdf

Chapi, D., & Yupangui, R. (2018). *Evaluación de la calidad del agua de los esteros Paushiyacu, Tamiahurco, Chimbadero y Dunduyacu de la ciudad del Tena, mediante la identificación de macro invertebrados bentónicos, para proponer una normativa legal que aporte a la restauración de su ecosi* [Instituto Tecnológico Superior Tena]. https://es.scribd.com/document/399907705/TESIS-AMBIENTAL

Ley General de Transparencia y Acceso a la Informacion Pública, 1 Registro Oficial Suplemento 337 1 (2004). www.lexis.com.ec

NORMA TÉCNICA USO Y GESTIÓN DE SUELO Y PLANES URBANÍSTICOS DE GADS, 1 (2020).

Conservation International. (2017). *Freshwater Health Index Manual del usuario*. https://manual.freshwaterhealthindex.org/Getting_Started.html

COOTAD. (2019). Código Orgánico de Organización Territorial Desentralizado, COOTAD. *Registro Oficial Suplemento 303 de 19-Oct.-2010*, 1–180. http://www.ambiente.gob.ec/wp-

content/uploads/downloads/2018/05/COOTAD.pdf

Doria, C. R. da C., Agudelo, E., Akama, A., Barros, B., Bonfim, M., Carneiro, L., Briglia-Ferreira, S. R., Nobre Carvalho, L., Bonilla-Castillo, C. A., Charvet, P., dos Santos Catâneo, D. T. B., da Silva, H. P., Garcia-Dávila, C. R., dos Anjos, H. D. B., Duponchelle, F., Encalada, A., Fernandes, I., Florentino, A. C., Guarido, P. C. P., … Vitule, J. R. S. (2021). The Silent Threat of Non-native Fish in the Amazon: ANNF Database and Review. *Frontiers in Ecology and Evolution*, *9*(June), 1–11. https://doi.org/10.3389/fevo.2021.646702

El Comercio. (2019). *Aguas servidas, un riesgo para los ríos del país*. https://www.elcomercio.com/tendencias/ambiente/aguas-servidas-riesgo-rios-ecuador.html

El Observador. (2020). *Con una minga ciudadana se realizó la limpieza del estero Paushiyacu*. https://elobservador.ec/con-una-minga-ciudadana-se-realizo-la-limpieza-del-estero-paushiyacu/

El Observador. (2021). *Iniciaron los trabajos en la calle Cuenca*. https://elobservador.ec/iniciaron-los-trabajos-en-la-calle-cuenca/

El Telegrafo. (2019). *El tratamiento de aguas servidas marca la agenda ambiental en Tena*. https://www.eltelegrafo.com.ec/noticias/ecuador/1/tratamiento-aguas-servidas-agenda-ambiental-tena

El Universo. (2020). *Más del 90 % de los municipios del Ecuador no tratan las aguas residuales de acuerdo a la normativa*. https://www.eluniverso.com/noticias/2020/12/20/nota/8409829/agua-servicios-basicos-ecuador/

GAD Municipal Tena. (2014). *Actualización Plan de Desarrollo y Ordenamiento Territorial diagnóstico*. http://app.sni.gob.ec/sni-link/sni/PORTAL_SNI/data_sigad_plus/sigadplusdiagnostico/1560000270001_PDOT ACT 2014_DIAGNOSTICO_sigad2 sug_senplades1_BD_20-02-2015_08-58-05.pdf

PDOT 2020-2023 Normativa plan de uso y gestión de suelo y plan de ordenamiento integral sustentable de la ciudad de tena-pouis, 772 (2020). https://tena.gob.ec/images/convocatoria/NORMATIVA-PLAN-DE-USO-Y-GESTIN-DE-SUELO.pdf

GAD Municipal Tena. (2021). *Actulización del Plan de ordenamiento territorial del cantón Tena para el período 2021-2033, el plan de uso y gestión del suelo urbano y rural del cantón tena 2021-2033 y el Plan de ordenamiento urbanístico integral sustentable de la ciudad de Tena*.

GAD Provincial de Napo. (2019). *Unidad de riego y drenaje realiza el desazolve y ampliación del estero Paushiyaku*. https://napo.gob.ec/website/index.php/informativo/16-articulos-destacados/484-unidad-de-riego-y-drenaje-realiza-el-desazolve-y-ampliacion-del-estero-paushiyaku

Gann, G. D., McDonald, T., Walder, B., Aronson, J., Nelson, C. R., Jonson, J., Hallett, J. G., Eisenberg, C., Guariguata, M. R., Liu, J., Hua, F., Echeverría, C., Gonzales, E., Shaw, N., Decleer, K., & Dixon, K. W. (2019). International principles and standards for the practice of ecological restoration. Second edition. *Restoration Ecology*, *27*(S1), S1–S46. https://doi.org/10.1111/rec.13035

Guareschi, S., Laini, A., Racchetti, E., Bo, T., Fenoglio, S., & Bartoli, M. (2014). How do hydromorphological constraints and regulated flows govern macroinvertebrate communities along an entire lowland river? *Ecohydrology*, *7*(2), 366–377. https://doi.org/10.1002/eco.1354

Guimarães, L. F., Teixeira, F. C., Pereira, J. N., Becker, B. R., Oliveira, A. K. B., Lima, A. F., Veról, A. P., & Miguez, M. G. (2021). The challenges of urban river restoration and the proposition of a framework towards river restoration goals. *Journal of Cleaner Production*, *316*(July). https://doi.org/10.1016/j.jclepro.2021.128330

Hychka, K., & Druschke, C. G. (2017). Adaptive Management of Urban Ecosystem Restoration: Learning From Restoration Managers in Rhode Island, USA. *Society and Natural Resources*, *30*(11), 1358–

1373. https://doi.org/10.1080/08941920.2017.1315653

INEC. (2016). *Estadística de información ambiental económica en Gobiernos Autónomos Descentralizados Municipales 2015 (Agua y Alcantarillado)*. *2015*, 30. http://www.ecuadorencifras.gob.ec/documentos/web-inec/Encuestas_Ambientales/Municipios_2015/Documento_Tecnico-Gestion_de_Agua_y_Alcantarillado_2015.pdf

Jerves-Cobo, R., Benedetti, L., Amerlinck, Y., Lock, K., De Mulder, C., Van Butsel, J., Cisneros, F., Goethals, P., & Nopens, I. (2020). Integrated ecological modelling for evidence-based determination of water management interventions in urbanized river basins: Case study in the Cuenca River basin (Ecuador). *Science of the Total Environment*, *709*, 136067. https://doi.org/10.1016/j.scitotenv.2019.136067

Jesús-crespo, R. De, & Ramirez, A. (2011). *The use of a Stream Visual Assessment Protocol to determine ecosystem integrity in an urban watershed in Puerto Rico*. *36*, 560–566. https://doi.org/10.1016/j.pce.2010.11.007

Kassambara, A., & Mundt, F. (2020). Package 'factoextra.' *CRAN- R Package*, 84. https://cran.r-project.org/package=factoextra

Kondolf, G. M. (2011). Setting goals in river restoration: When and where can the river "heal itself"? *Geophysical Monograph Series*, *194*, 29–43. https://doi.org/10.1029/2010GM001020

Kondolf, G. M., Boulton, A. J., Daniel, S. O., Poole, G. C., Rahel, F. J., Stanley, E. H., Wohl, E., Bång, A., Carlstrom, J., Cristoni, C., & Huber, H. (2006). Process-Based Ecological River Restoration : Visualizing Three- Dimensional Connectivity and Dynamic Vectors to Recover Lost Linkages. *Ecology and Society*, *11*(2).

Kondolf, G. M., & Yang, C. N. (2008). Planning River Restoration Projects: Social and Cultural Dimensions. *River Restoration: Managing the Uncertainty in Restoring Physical Habitat*, 41–60. https://doi.org/10.1002/9780470867082.ch4

MAATE. (2018). *Sistema Único de Información Ambiental (SUIA)*. Mapa Interactivo. http://suiadoc.ambiente.gob.ec/web/suia/inicio

MAE. (2003). Texto Unificado de Legislación Secundaria de Medio Ambiente, TULSMA. *Registro Oficial Edición Especial 2 de 31-Mar.-2003*, *3399*, 1–578. www.lexis.com.ec

MAE. (2015). Revision Del Anexo 1 Del Libro Vi Del Texto Unificado De Legislacion Secundaria Del Ministerio Del Ambiente: Norma De Calidad Ambiental Y De Descarga De Efluentes Al Recurso Agua. *Registro Oficial No. 387*, *97*, 1–40. http://extwprlegs1.fao.org/docs/pdf/ecu155128.pdf

McClain, M. . (2008). E cohydrology. In *Ecohydrology: Processes, Models and Case Studies. An approach to the sustainable management of water resources* (pp. 207–222).

Ministerio del Ambiente y Agua. (2015). Marco institucional para incentivos ambientales. Acuerdo Ministerial 140. *Registro Oficial Edición Especial 387 de 04-Nov.-2015*, 1–45. http://www.silec.com.ec/WebTools/LexisFinder/DocumentVisualizer/FullDocumentVisualizerPDF.aspx?id=AMBIENTE-MARCO_INSTITUCIONAL_PARA_INCENTIVOS_AMBIENTALES

Mitchel, R. K., Angle, B. R., & Wood, D. J. (1997). Anticipating informed consent: an empirical approach. *Academy of Management Review*, *22*(4), 852–886. https://doi.org/10.1037/h0035597

Mohammed, I. N., Bolten, J. D., Souter, N. J., Shaad, K., & Vollmer, D. (2022). Diagnosing challenges and setting priorities for sustainable water resource management under climate change. *Scientific Reports*, *12*(1), 1–15. https://doi.org/10.1038/s41598-022-04766-2

Muni TV Tena. (2020). *MINGA EN EL ESTERO PAUSHIYACU*. https://www.facebook.com/watch/?v=3377972445657556

Neville, B. A., Bell, S. J., & Whitwell, G. J. (2011). Stakeholder Salience Revisited: Refining, Redefining, and Refueling an Underdeveloped Conceptual Tool. *Journal of Business Ethics*, *102*(3), 357–378. https://doi.org/10.1007/s10551-011-0818-9

Nobre, A. D., Cuartas, L. A., Hodnett, M., Rennó, C. D., Rodrigues, G., Silveira, A., Waterloo, M., & Saleska, S. (2011). Height Above the Nearest Drainage - a hydrologically relevant new terrain model. *Journal of Hydrology*, *404*(1–2), 13–29. https://doi.org/10.1016/j.jhydrol.2011.03.051

OECD. (2015). OECD Principles on Water Governance. Draft for consulation at the 7th World Water Forum. *Report*, *May*, 1–23.

Palmer, M. A., Bernhardt, E. S., Allan, J. D., Alexander, G., Shah, J. F., Galat, D. L., Hart, D. D., Jenkinson, R., Lave, R., & Sudduth, E. (2005). *Standards for ecologically successful river restoration*. 208–217. https://doi.org/10.1111/j.1365-2664.2005.01004.x

Perini, K., & Sabbion, P. (2017). Urban Sustainability and River Restoration. In *Urban Sustainability and River Restoration*. https://doi.org/10.1002/9781119245025

Prat, N., Rios, B., Acosta, R., & Rieradevall, M. (2009). Los macroinvertebrados como indicadores de calidad de las aguas. In E. Domínguez & H. R. Fernández (Eds.), *Macroinvertebrados bentónicos sudamericanos* (pp. 231–254).

Rahman, M. L., Shahjahan, M., & Ahmed, N. (2021). Tilapia farming in Bangladesh: Adaptation to climate change. *Sustainability (Switzerland)*, *13*(14), 1–20. https://doi.org/10.3390/su13147657

Ribeiro, P. J. G., & Pena Jardim Gonçalves, L. A. (2019). Urban resilience: A conceptual framework. *Sustainable Cities and Society*, *50*(May). https://doi.org/10.1016/j.scs.2019.101625

Rodríguez Romero, A. J., Robles Salazar, C. A., Ruíz Picos, R. A., López López, E., Sedeño Díaz, J. E., & Rodríguez Dorantes, A. (2014). Índices de germinación y elongación radical de Lactuca sativa en el biomonitoreo de la calidad del agua del rio chalma. *Revista Internacional de Contaminacion Ambiental*, *30*(3), 307–316.

Rosero, B., & Mena, C. (2021). *Paushiyacu Macroinvertebrates characterization*.

Santafe-Troncoso, V., & Loring, P. A. (2021). Traditional food or biocultural threat? Concerns about the use of tilapia fish in Indigenous cuisine in the Amazonia of Ecuador. *People and Nature*, *3*(4), 887–900. https://doi.org/10.1002/pan3.10235

Skinner, K. S., & Bruce-Burgess, L. (2005). RESTORATION PROTOCOLS- KEY COMPONENTS F R MEETING THE REQUIREMENTS OF THE WATER FRAMEWORK DIRECTIVE (WFD) Technical issues. *Water and Environment Journal*, *19*(2), 135–142.

Sorgato, V. (2017). *Muestras de agua de los ríos del país ponen en alerta sobre la contaminación*. https://www.elcomercio.com/tendencias/sociedad/muestras-laboratorio-rios-alerta-contaminacion.html#:~:text=2017 14%3A41-,Muestras de agua de los ríos del,en alerta sobre la contaminación&text=Adamary tiene 15 años y,rostro se llena de granos.

Speed, R. A., Li, Y., Tickner, D., Huang, H., Naiman, R. J., Cao, J., Lei, G., Yu, L., Sayers, P., Zhao, Z., & Wei, Y. (2016). A framework for strategic river restoration in China. *Water International*, *41*(7), 998–1015. https://doi.org/10.1080/02508060.2016.1247311

Tapia, L. (2013). Compilación Actualizada de Incentivos Ambientales. In *Rev Soc Quím Perú* (Vol. 80, Issue 3). https://www.ambiente.gob.ec/wp-content/uploads/downloads/2013/11/1-Incentivos-ambientales1.pdf

Terneus Jácome, E., & Yanez-Moretta, P. (2018). Principios fundamentales en torno a la calidad del agua, el uso de bioindicadores acuáticos y la restauración ecológica fluvial en Ecuador. *La Granja*, *27*(1), 36–50. https://doi.org/10.17163/lgr.n27.2018.03

Uherek, C. B., & Pinto Gouveia, F. B. (2014). Biological monitoring using macroinvertebrates as

bioindicators of water quality of maroaga stream in the maroaga cave system, presidente figueiredo, amazon, Brazil. *International Journal of Ecology*, *2014*. https://doi.org/10.1155/2014/308149

UNESCO/ONU-Agua. (2020). Agua y cambio climático. In *UNESCO* (Vol. 167, Issue 3618).

United Actions. (2015). *Take Action for the Sustainable Development Goals*. https://www.un.org/sustainabledevelopment/sustainable-development-goals/

USDA. (1998). *Svap*. *December 1*(NWCC Technical Note 99-1).

Vollmer, D., Bezerra, M. O., Martínez, N. A., Ortiz, O. R., Encomenderos, I., Marques, M. C., Serrano-Durán, L., Fauconnier, I., & Wang, R. Y. (2021). Can we take the pulse of environmental governance the way we take the pulse of nature? Applying the Freshwater Health Index in Latin America. *Ambio*, *50*(4), 870–883. https://doi.org/10.1007/s13280-020-01407-8

Vollmer, D., Shaad, K., Souter, N. J., Farrell, T., Dudgeon, D., Sullivan, C. A., Fauconnier, I., MacDonald, G. M., McCartney, M. P., Power, A. G., McNally, A., Andelman, S. J., Capon, T., Devineni, N., Apirumanekul, C., Ng, C. N., Rebecca Shaw, M., Wang, R. Y., Lai, C., … Regan, H. M. (2018). Integrating the social, hydrological and ecological dimensions of freshwater health: The Freshwater Health Index. *Science of the Total Environment*, *627*, 304–313. https://doi.org/10.1016/j.scitotenv.2018.01.040

Walsh, C. J., Roy, A. H., Feminella, J. W., Cottingham, P. D., Groffman, P. M., & Morgan, R. P. (2005). The urban stream syndrome: Current knowledge and the search for a cure. *Journal of the North American Benthological Society*, *24*(3), 706–723. https://doi.org/10.1899/04-028.1

Wohl, E., Angermeier, P. L., Bledsoe, B., Kondolf, G. M., Macdonnell, L., Merritt, D. M., Palmer, M. A., Poff, N. L., & Tarboton, D. (2005). *River restoration*. *41*, 1–12. https://doi.org/10.1029/2005WR003985

Yeakley, J. A., Ervin, D., Chang, H., Granek, E. F., Dujon, V., Shandas, V., & Brown, D. (2016). Ecosystem Services of Streams and Rivers. *River Science: Research and Management for the 21st Century*, 335–352. https://doi.org/10.1002/9781118643525.ch17

Appendices

Appendix A: Tables

Table A-1: Stream Visual Assessment parameters with scores

Indicador	1	3	5 or 7	8	10
Channel condition	Channel is actively downcutting or widening. >50% of the reach with riprap or channelization. Dikes or levees prevent access to the flood plain.	Altered channel; <50% of the reach with riprap and/ or channelization. Excess aggradation; braided channel. Dikes or levees restrict flood plain width.	Evidence of past channel alteration, but with significant recovery of channel and banks. Any dikes or levies are set back to provide access to an adequate flood plain.		Natural Channel: no structures, dikes, No evidence of downcutting or excesive lateral cutting
Hydrologic alteration	No flooding; channel deeply incised or structures prevent access to flood plain or dam operations prevent flood flows. Or Withdrawals have caused severe loss of low flow habitat. Or Flooding occurs on a 1year rain event orless.	Flooding occurs only once every 6 to 10 years; channel deeply incised. Or Withdrawals significantly affect available low flow habitat for biota.	Flooding occurs only once every 3 to 5 years; limited channel incision. or Withdrawals, although present, do not affect available habitat for biota.		Flooding every 1.5 to 2 years. No dams, no water withdrawals, no dikes or other structures limiting the stream's access to the flood plain. Channel is not incised.
Riparian Zone	Natural vegetation less than a third of the active channel width on each side. Or Lack of regeneration.or Filtering function severely compromised.	Natural vegetation extends a third of the active channel width on each side. Or Filtering functionmoderately compromised.	Natural vegetation extends half of the active channel width on each side.	Natural vegetation extends one active channel width on each side. Or If less than one width, covers entire flood plain.	Natural vegetation extends at least two active channel widths on each side.

Bank stability	Unstable; banks may be low, but typically are high; some straight reaches and inside edges of bends are actively eroding as well as outside bends (overhanging vegetation at top of bare bank, numerous mature trees falling into stream annually, numerous slope failures apparent).	Moderately unstable; banks may be low, but typically are high (flooding occurs 1 year out of 5 or less frequently); outside bends are actively eroding overhanging vegetation at top of bank, some mature trees falling into steam annually, some slope failures apparent).	Moderately stable; banks are low (at elevation of active flood plain); less than 33% of eroding surface area of banks in outside bends is protected by roots that extend to the baseflow elevation.		Banks are stable; banks are low (at elevation of active flood plain); 33% or more of eroding surface area of banks in outside bends is protected by roots that extend to the base-flow elevation.
Water apperance	Very turbid or muddy appearance most of the time; objects visible to depth < 0.5 ft; slow moving water may be brightgreen; other obvious water pollutants; floating algal mats, surface scum, sheen or heavy coat of foam on surface. or Strong odor of chemicals, oil, sewage, other pollutants.	Considerable cloudiness most of the time; objects visible to depth 0.5 to 1.5 ft; slow sections may appear pea-green; bottom rocks or submerged objects covered with heavy green or olive-green film. or Moderate odor of ammonia or rotten eggs.	Occasionally cloudy, especially after storm event, but clears rapidly; objects visible at depth 1.5 to 3 ft; may have slightly green color; no oil sheen on water surface.		Very clear, or clear but tea-colored; objects visible at depth 3 to 6 ft (less if slightly colored); no oil sheen on surface; no noticeable film on submerged objects or rocks.
Nutrient Enrichment	Pea green, gray, or brown water along entire reach; dense stands of macrophytes clog stream; severe algal blooms create thick algal mats in stream.	Greenish water along entire reach; overabundance of lush green macrophytes; abundant algal growth, especially during warmer months.	Fairly clear or slightly greenish water along entire reach; moderate algal growth on stream substrates.		Clear water along entire reach; diverse aquatic plant community includes low quantities of many species of macrophytes; little algal growth present.
Barries to fish movement	Drop structures, curlverts, dams, or diversion (>1 foot drop) within the reac	Drop structures, sulverts, dams or diversion (<1 foot drop) within 3 miles of the reach	Drop structures, survents, dams, or diverions(<1 foot drop) within the reach	Seasonal water widthdrawls inhibit movement within the reach	No barriers

Instream fish cover	None to 1 cover type available	2 to 3 cover types available	4 to 5 cover types available	6 to 7 cover types avaible	>7 cover types available
Pools	Pools absent, or the entire bottom is discernible.	Pools present, but shallow; from 5 to 10% of the pool bottom is obscure due to depth, or the pools are less than 3 feet deep.	Pools present, but not abundant; from 10 to 30% of the pool bottom is obscure due to depth, or the pools are at least 3 feet deep.		Deep and shallow pools abundant; greater than 30% of the pool bottom is obscure due to depth, or the pools are at least 5 feet deep.
Invertebrate habitat	None to 1 type of habitat.	1 to 2 types of habitat. The substrate is often disturbed, covered, or removed by high stream velocities and scour or by sediment deposition.	3 to 4 types of habitat. Some potential habitat exists, such as overhanging trees, which will provide habitat, but have not yet entered the stream.		At least 5 types of habitat available. Habitat is at astage to allow full insect colonization (woody debris and logs not freshly fallen).
Riparian vegetation variety	One type of vegetation predominates	Little varied	Medium Varied	Varied	Highly varied
Channel shadow	<5%	6-25%	26-50%	51-75%	>76%

Elaborated by: Rossemary Sanmartín

Appendix B: Figures

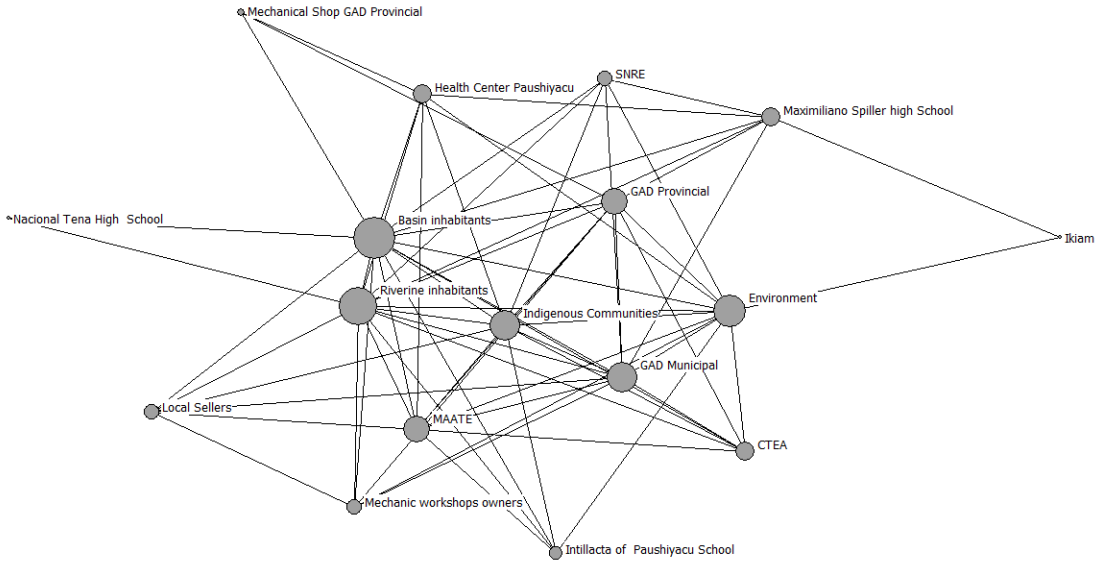


Figure B-1: Social Network Analysis using the degree of connectivity, the bigger nodes shows major relations between stakeholders.

Elaborated by: Rossemary Sanmartín

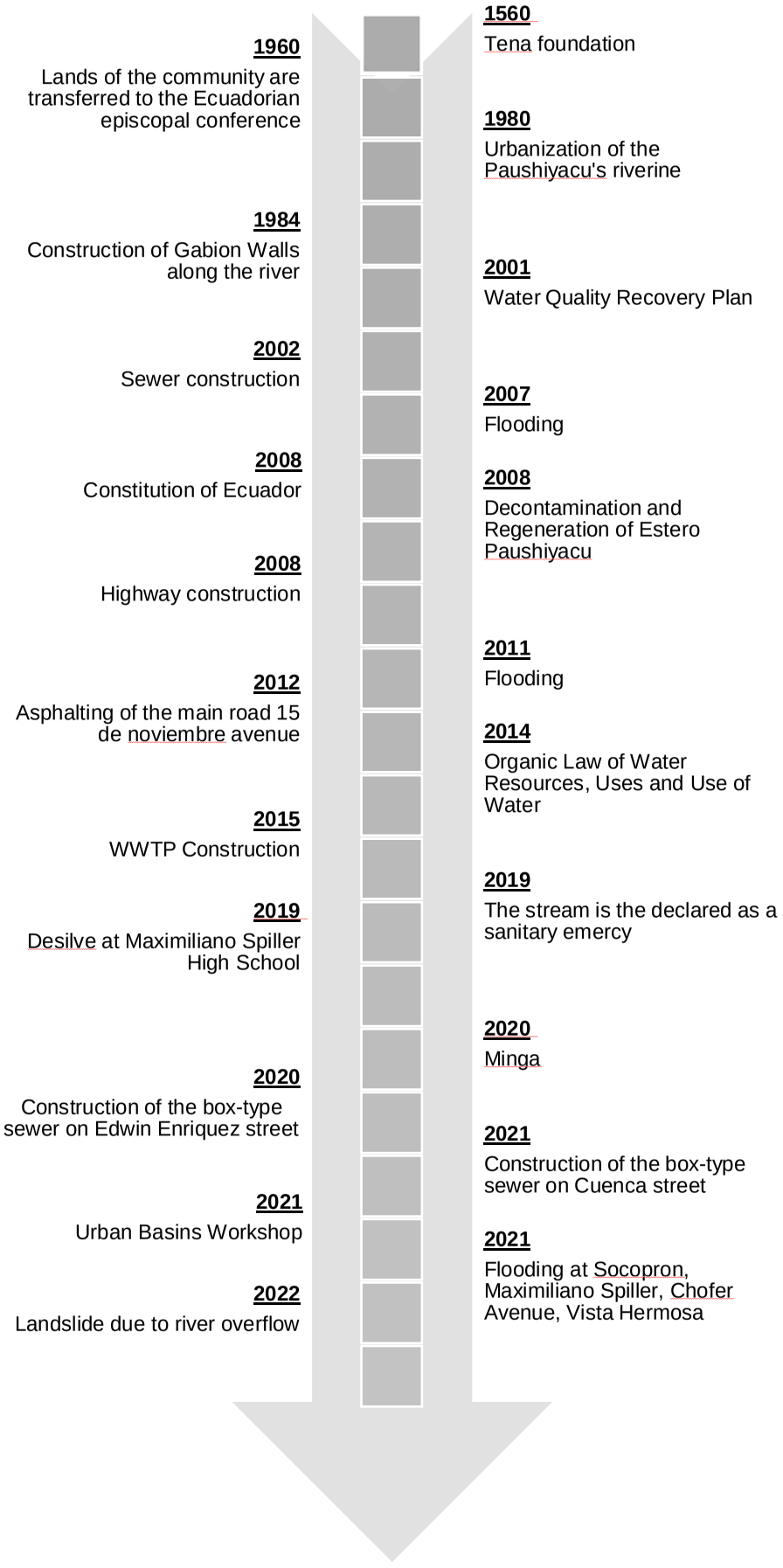


Figure B-2: Timeline with the significant landmarks in the Paushiyacu River.
Elaborated by: Rossemary Sanmartín

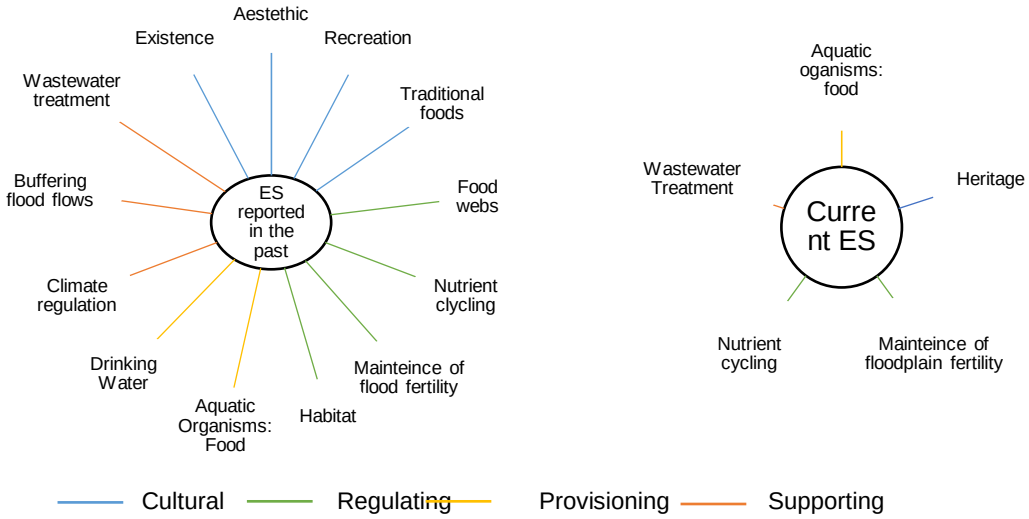


Figure B-3: Main ES identify for the Paushiyacu River Basin.

Elaborated by: Rossemary Sanmartín

Appendix C: Photographs
Photograph C-1:

Photograph C-2:

Photograph C-3:

Photograph C-4:

Photograph C- 5:

Photograph C-6:

Photograph C-7:

Photograph C-8:

Appendix D: Proyecto de recuperación

Título del proyecto: Rehabilitación de espacios aledaños al estero Paushiyacu: reintegrando el río al área urbana

Duración del proyecto: 3 años

Antecedentes y justificación:

El crecimiento poblacional es una preocupación a nivel mundial, actualmente de acuerdo a Naciones Unidas, las áreas urbanas albergan a casi la mitad de la población mundial. Los ecosistemas más afectados debido a la expansión urbana son los ríos. El Consejo Mundial del Agua estima que casi el 50% de los ríos en todo el mundo están contaminados, modificados o en riesgo de secarse, entre las principalescausas se encuentran: agua residual, basura, impermeabilidad del suelo y canalizaciones(Guimarães et al., 2021; Perini & Sabbion, 2017). Estos factores han cambiado la dinámica de la cuenca, así como la funcionalidad del ecosistema y la composición química(Jerves-Cobo et al., 2020; Perini & Sabbion, 2017).

Con el crecimiento estimado para el 2050, los estándares de vida serán más exigentes incrementando las necesidades de energía y agua(UNESCO/ONU-Agua, 2020). Sumado a esto el cambio climático no presenta un escenario alentador para las futuras generaciones, en este sentido aumentar la resiliencia en las áreas urbanas debe ser una prioridad, considerando los retos para el futuro. La restauración fluvial propone ser una de las soluciones para la construcción de ciudades sostenibles, y se define como la recuperación de la funcionalidad ecosistémica de uno o más cuerpos de agua, esto permite que los cuerpos de agua puedan prestar una serie servicios ecosistémicos. Restaurar cuerpos de agua urbanos suele ser complicado debido a la urbanización, densidad poblacional, contaminación creciente, entre otros factores que dificultan la implementación de los planes de restauración. Generalmente los proyectos de restauración suelen tener un costo elevado, sin embargo, se pueden considerar alternativas que involucren los sistemas de purificación intrínsecos de los ríos y la participación directa de las comunidades ribereñas, que pueden además ayudar como fiscalizadores del éxito de un proyecto (Hychka & Druschke, 2017).

Los procesos de restauración fluvial no solo implican la recuperación del paisaje sino también de la dinámica de los ríos y los sistemas de purificación intrínsecos que incluyen: planicies de inundación, humedales, zonas ribereñas, zonas hiporréicas y

otras morfologías propias de cada cuenca (McClain, 2008). Todos estos procesos se incluyen dentro de las soluciones basadas en la naturaleza (NBS) e infraestructura verde y azul, conceptos que nacen a partir del año 2002. Estos conceptos han venido tomando fuerza durante los últimos años, sobre todo dentro de la planificación para la construcción de ciudades debido a que ofrecen soluciones viables, aprovechando las características de la naturaleza. En países más desarrollados se han implementado NBSs para cumplir con algunos de los objetivos para el desarrollo sostenible (ODSs), propuestos por Naciones Unidas para el 2030.

En este sentido se propone que las estrategias de restauración sean adecuadas a la cuenca, y se complementen con estrategias de evaluación que permitan saber si las acciones planteadas están funcionando o no, sobre todo si lo que se busca es mantener la compatibilidad entre las actividades humanas y el entorno natural.

En el caso de las cuencas urbanas del cantón Tena, su degradación, de acuerdo con la población, se remonta a menos de 30 años por lo que se puede decir que es son cuencas que está en un estado transicional. Esto implica que su estado podría ser reversible si se aplican protocolos y restricciones adecuadas que recuperar gran parte de la cuenca (Kondolf & Yang, 2008). Además, se propone aplicar medidas preventivas e implementar de estructuras verdes y azules con el fin de reducir la degradación de la cuenca. La razón por la que se deben realizar las socializaciones con las comunidades ribereñas es porque, muchas veces, los procesos de restauración implican que se remuevan construcciones de zonas específicas. Uno de los principales problemas en las cuencas urbanas del cantón Tena es la descarga directa de aguas residuales por lo que la intervención de los gobiernos locales es necesaria para la remoción de estos focos de contaminación.
Desde el año 2001 se han propuesto varios proyectos de descontaminación de aguas en el cantón sobre todo para el estero Paushiyacu, que de acuerdo al GAD cantonal de Tena es el más afectado por una serie de actividades antrópicas, por lo que su recuperación es una prioridad. Sin embargo, estos planes han fracasado debido a que no se ha realizado un diagnóstico integral que involucre a los actores sociales, en este sentido la presente propuesta busca dar a conocer los resultados de la tesis denominada “Análisis Socio-ambiental de las cuencas urbanas del cantón Tena; con miras a estrategias de restauración fluvial”.

Para llevar a cabo cualquier proyecto de restauración es necesario realizar un diagnóstico de factores tanto ambientales como sociales, siendo el segundo el que determina el éxito o fracaso de la estrategia que se aplique. La restauración de los

cuerpos de agua debe constituir una prioridad para los gobiernos actuales ya que puede minimizar costos a largo plazo. El incorrecto manejo de los recursos hídricos puede desencadenar eventos como desastres naturales (inundaciones), epidemias y problemas de salud que afectan principalmente a los sectores menos favorecidos incrementando desigualdad social.

Una restauración fluvial ideal incluye una recuperación ecológica e hidrológica, de tal manera que los cuerpos de agua recuperen las condiciones necesarias para prestar servicios ecosistémicos. Para esto es necesario identificar los siguientes aspectos: dinámica fluvial, biodiversidad local, resiliencia, y compatibilidad entorno social y ambiental (Terneus Jácome & Yanez-Moretta, 2018). La restauración de ríos urbanos permite dar cumplimiento a los ODSs 6, 11 y 15 que hacen referencia al agua limpia, ciudades sostenibles y la salud de los ecosistemas terrestres.

A pesar de que actualmente en el país no se priorice la restauración de los cuerpos de agua, la Constitución de la República del Ecuador (2008) dictamina que:

> **"Art. 411.-** El Estado garantizará la conservación, recuperación y manejo integral de los recursos hídricos, cuencas hidrográficas y caudales ecológicos asociados al ciclo hidrológico. Se regulará toda actividad que pueda afectar la calidad y cantidad de agua, y el equilibrio de los ecosistemas, en especial en las fuentes y zonas de recarga de agua. La sustentabilidad de los ecosistemas y el consumo humano serán prioritarios en el uso y aprovechamiento del agua.
>
> **Art. 412.-** La autoridad a cargo de la gestión del agua será responsable de su planificación, regulación y control. Esta autoridad cooperará y se coordinará con la que tenga a su cargo la gestión ambiental para garantizar el manejo del agua con un enfoque ecosistémico."

A continuación (Fig 1), se presentan algunos de los nuevos espacios para lograr la restauración efectiva tomando en cuenta el estado actual de la cuenca. Se tomó además como consideración las áreas prioritarias de intervención y los beneficios a largo plazo que generaría el proyecto.

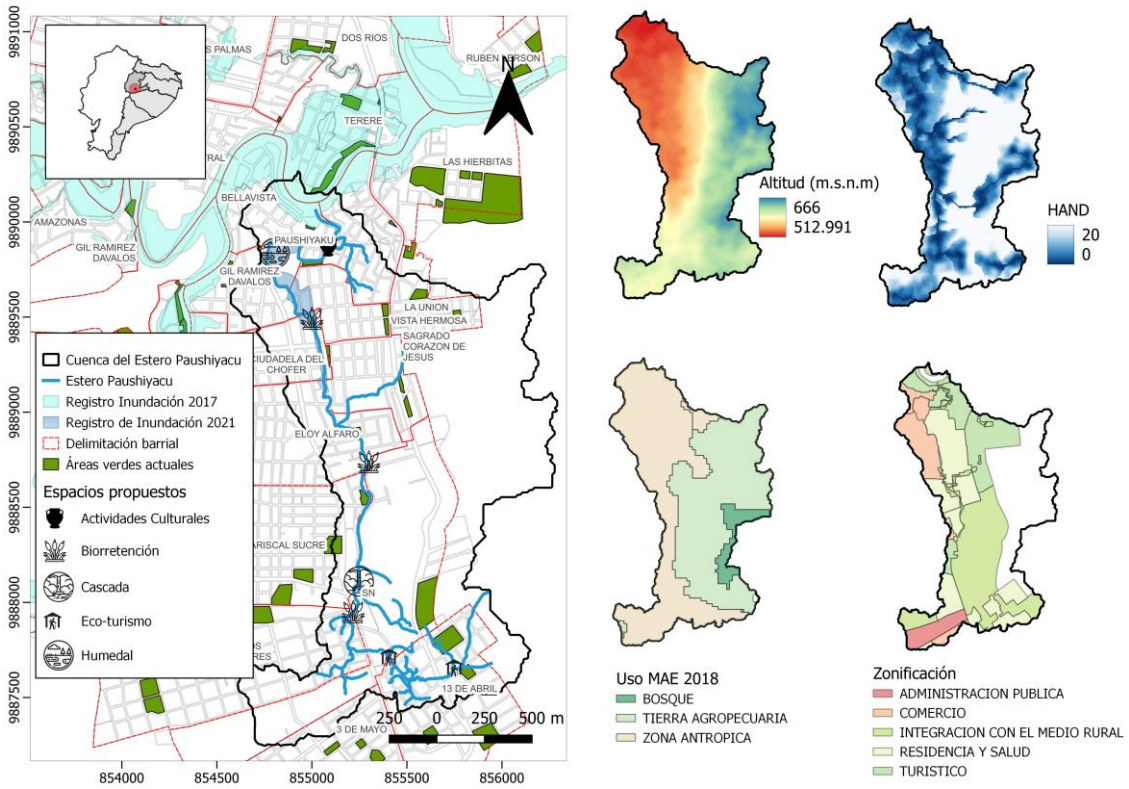


Figura 1: Área de estudio.
Elaborado por: Rossemary Sanmartín

Análisis de actores

A nivel de la Amazonía, se habla mucho de los sistemas de purificación intrínsecos (IPS), pero esto se aplica más para cuencas de mayor tamaño, en donde los IPS pueden ayudar a retener contaminantes y depurar la cuenca además que de que devuelve su conectividad lateral, horizontal y vertical (McClain, 2008). En las zonas urbanas, el panorama es más complicado, ya que se debe analizar el entorno socio-económico y su compatibilidad con el medio ambiente, en donde se busque involucrar a la mayor cantidad de actores políticos y sociales que permita solucionar los conflictos socio ambientales que se puedan presentar en el proceso (Skinner & Bruce-Burgess, 2005).

Actualmente existen 17 actores principales involucrados en la gestión del Estero Paushiyacu .Tres de ellos fueron categorizados como actores dormantes: 1) Ministerio de Medio Ambiente, Agua y Transición Ecológica (MAATE) como autoridad legal y política encargada de la gestión y regulación de los recursos ambientales y el agua en el país; 2) La Secretaría Técnica de la Circunscripción Territorial Especial Amazónica (CTEA) es el organismo encargado de mejorar la efectividad en la planificación, ejecución, seguimiento y evaluación del bienestar en la región amazónica del Ecuador, como la institución que tiene capacidad financiera para desarrollar proyectos para la

región; y 3) La Secretaría Nacional de Gestión del Riesgo (SNRE) es la autoridad encargada de la gestión y prevención del riesgo en el país, la cual ha estado involucrada en la respuesta a algunos desastres naturales relacionados con el Estero Paushiyacu.

Se identificaron tres Centros Educativos como parte de los actores discretos, por la cercanía al río. Por ejemplo: 1) La Unidad Educativa Maximiliano Spiller ha participado en algunos talleres sobre el estado del río Paushiyacu, especialmente relacionado con la contaminación, este colegio también ha sido afectado por el desbordamiento del río en época de lluvias; 2) Intillacta de Paushiyacu es una escuela ubicada cerca de uno de los principales afluentes del río Paushiyacu, según el líder de la comunidad esta zona y las casas ubicadas aledañas no cuentan con sistema de alcantarillado, por lo que las aguas residuales vierten directamente en la canal (Aguinda, comunicación personal, 5 de mayo de 2022); y finalmente, 3) Ikiam es la única universidad con sede en Tena y ha realizado investigaciones relacionadas con la calidad de los arroyos y ríos de la provincia de Napo incluyendo ríos urbanos como Paushiyacu. El Ministerio Público de Salud (MSP) en 2019 informó que el río Paushiyacu se encuentra en emergencia sanitaria, por lo que su manejo debe ser una prioridad para los tomadores de decisiones (GAD Provincial de Napo, 2019).

Como actores demandantes se consideraron los vendedores locales, la comunidad indígena “Intillacta de Paushiyacu” y los pobladores ribereños. Algunos negocios locales como restaurantes, hoteles o tiendas también se han visto afectados, principalmente por el mal estado del riachuelo que genera descontento entre las personas que visitan el lugar.

Algunos actores peligrosos también son los principales contaminadores del estero Paushiyacu, como el taller mecánico que pertenece al Gobierno Provincial de Napo, talleres mecánicos privados y lavadoras de autos. Los gobiernos autónomos descentralizados, tanto municipales como provinciales, tienen el poder político para desarrollar acuerdos para la recuperación del estero, y también tienen un interés legítimo en mejorar la calidad del río en términos de comodidad y calidad de vida para los habitantes de la ciudad.

A continuación, se presenta la red de actores para el estero Paushiyacu (Fig 2), se destaca las relaciones de los habitantes de la cuenca y el rol de los gobiernos locales para la efectividad de cualquier proyecto a ejecutarse.

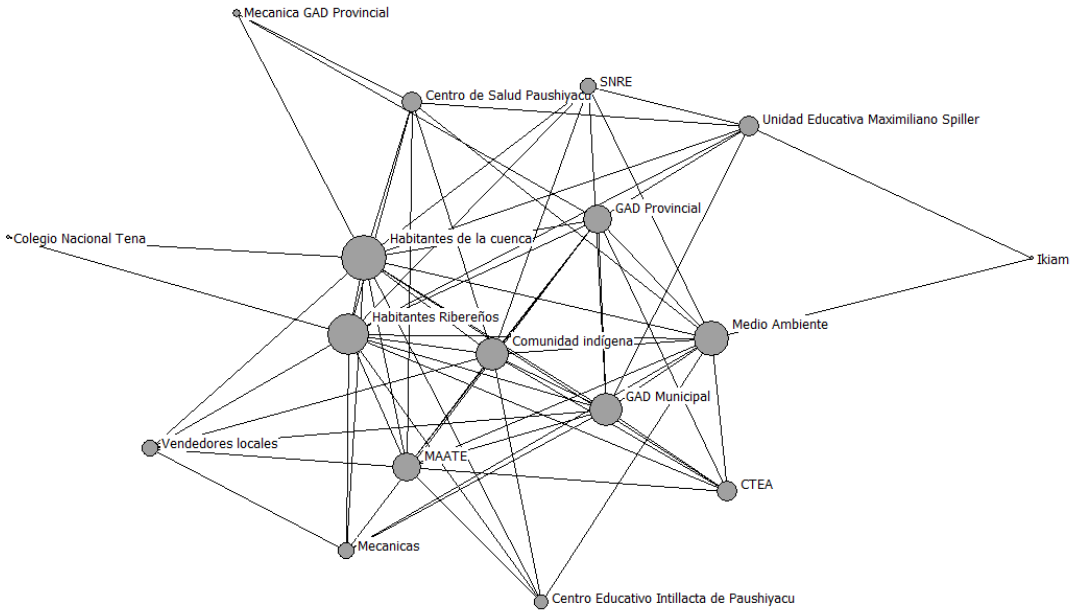


Figura 2. Análisis de redes sociales y actores para es Estero Paushiyacu
Elaborado por: Rossemary Sanmartín

FORTALEZAS

- La restauración con la inclusión de actores locales utiliza una tecnología sencilla y de pocos gastos.
- Existen convenios entre el municipio e IKIAM.

DEBILIDADES

- Bajos niveles de comunicación, compromiso e integración sobre los problemas ambientales y sus posibles soluciones entre los actores locales incluyendo los decisores.
-Falta de mecanismo de participación

Falta de credibilidad

-No existe un inventario sobre las riquezas naturales y culturales que inluya fauna, flora e importancia cultural

FODA

OPORTUNIDADES

-Existen estructuras organizativas con condiciones favorables para el trabajo con la comunidad.

-Acceso a la información proveniente de los municipios.

-Se cuenta con el apoyo del municipio para este tipo de proyectos.

-La Universidad Regional Amazónica Ikiam cuenta con conocimientos y voluntad para capacitar a los actores locales sobre el cuidado y la conservación del patrimonio natural y cultural

-Recursos Internacionales Disponibles

AMENAZAS

-Falta de conciencia ambiental de los usuarios de los espacios aledaños al estero.

-Deterioro progresivo debido a la falta de gestión.

-Urbanización descontrolada sin planifiación.

-Presencia de especies invasoras.

-El deseo de la población de continuar su estilo de vida.

Figura 3. Análisis FODA
Elaborado por: Rossemary Sanmartín

Objetivo General

Integrar áreas verdes, como estrategia para la conservación y recuperación de la cuenca del Estero Paushiyacu con el fin de mitigar el cambio climático y aumentar la resiliencia de la ciudad de Tena, mediante el fomento de la economía naranja que permita a los habitantes del sector tener nuevas actividades económicas que giren al alrededor del medio ambiente y la cultura.

Objetivos específicos

- Reducir la degradación del Estero Paushiyacu, mediante la activación centros de interpretación cultural en la zona de recarga hídrica de la cuenca y en la comunidad indígena Intillacta de Paushiyacu

- Generar condiciones habilitantes para la restauración del Estero Paushiyacu, mediante la recuperación de los sistemas de purificación intrínsecos y la eliminación de los focos de contaminación a lo largo del estero para mejorar la calidad de agua y el ecosistema fluvial.

	DESCRIPCIÓN NARRATIVA	INDICADORES	MEDIOS DE VERIFICACIÓN	SUPUESTOS
Objetivo General	Integrar áreas verdes, como estrategia para la conservación y recuperación de la cuenca del Estero Paushiyacu para mitigar el cambio climático y aumentar la resiliencia de la ciudad de Tena, mediante el fomento la economía naranja que permita a los habitantes del sector tener nuevas actividades económicas que giren al alrededor del medio ambiente y la cultura.			
Objetivo Específico 1	Generar condiciones habilitantes para la restauración del Estero Paushiyacu, mediante la implementación de mecanismos de control y políticas para la eliminación de los focos de contaminación a lo largo del estero para mejorar la calidad del agua y el ecosistema fluvial.	• Finalizado el primer año se habrá informado al 50 % de la población sobre las condiciones actuales del estero y la relevancia del proyecto para la recuperación ambiental. • Finalizado el proyecto se espera contar con el apoyo de las instituciones gubernamentales y no gubernamentales para erradicar las fuentes de polución del estero Paushiyacu incrementando la resiliencia del ecosistema y creando “hot spots” de biodiversidad • Aumento del porcentaje de personas informadas sobre la situación e Estero	• Informe de gestión de riesgos luego del primer año de implementación del proyecto • Manual Economía Naranja en acción • Informe final del proyecto • Acuerdos firmados	• Las comunidades están dispuestas a participar del proyecto • Voluntad Política de las instituciones responsables del estado
Objetivo Específico 1	Reducir la degradación del Estero Paushiyacu, mediante la activación centros de interpretación cultural en la zona de recarga hídrica de la cuenca y en la comunidad indígena Intillacta de Paushiyacu	• En los tres primeros meses se espera integrar al 50% habitantes ribereños al proyecto. • Al finalizar el segundo año del proyecto se ejecutó 5 talleres de formación y/o empoderamiento para permitan a los actores involucrados (población aledaña, comunidades, etc.); adquirir conocimientos,	• Registros de asistencia a talleres y firma de convenios • Guía de Educación ambiental para habitantes de la cuenca, y estudiantes de escuelas y colegios	• No existe limitaciones por la propiedad de las terrenos aledaños, los dueños de las zonas de recarga hídrica están dispuestos a ceder estos terrenos a la administración local

		valores y habilidades que faciliten una amplia, responsable y eficaz participación para la prevención y solución de los problemas ambientales locales. • Aplicación de los conocimientos adquiridos, (manejo de residuos, reciclaje, macroinvertebrados), (¿qué hacen?) reciclan, rehúsan, ejecución de que aprendieron utlización eficiente • Finalizado el proyecto se habrán habilitado el 60% de los senderos aledaños al estero Paushiyacu • Finalizado el proyecto se habrán habilitado dos centros de interpretación cultural	(Caso de Estudio Paushiyacu) • Guía de Economía Naranja • Página web para seguimiento de proyectos orientados a la recuperación de ríos • Registro del colectivo Creación de un coelctivo (Registro en MIES) Proyecto "Guardianes del río" • Informe de cumplimento de actividades (documentos de entrega) habilitación de espacios	• Existe predisposición de las comunidades aledañas para participar activamente en rehabilitación y restauración del Estero Paushiyacu • El sector no está autorizado para urbanizar • No existen estragos por la pandemia del COVID 19

Objetivo 1			
Generar condiciones habilitantes para la restauración del Estero Paushiyacu, mediante la recuperación de los sistemas de purificación intrínsecos y la eliminación de los focos de contaminación a lo largo del estero para mejorar la calidad de agua y el ecosistema fluvial.			
DESCRIPCIÓN NARRATIVA	INDICADORES	MEDIOS DE VERIFICACIÓN	SUPUESTOS
Producto 1.1 Informe del Estado del Arte del Estero Paushiyacu			
Actividad 1.1.1 Recopilación de estudios previos	• En el primer mes del proyecto se espera contar con un informe completo sobre el estado del estero	• Informe de Estado del Arte	• Toda la información está disponible y no hay cambios mayores en los meses de

			ejecución de las fases preliminares
Actividad 1.1.2 Taller comunitario	• En el segundo mes se realizará un taller con los actores involucrados para presentar el estado del arte del estero y actualizar la información del árbol de problemas	• Registro de asistencia • Memoria fotográfica • Acta de reunión • Árbol de problemas actualizado	
Actividad 1.1.3 Redacción y socialización de resultados con las autoridades locales	• En el tercer mes se redactará un informe sobre el estado el estado del arte y los talleres realizados	• Árbol de problemas verificado	• Los problemas no han cambiado en los últimos 10 años
Actividad 1.1.4 Establecimiento del equipo a cargo de la colaboración transdisciplinaria	• Finalizado el cuarto se contará con un equipo multidisciplinario que se encargue de estructurar las líneas de investigación para dirigir proyectos e investigaciones orientadas a resolver problemas existentes en el sitio.	• Conformación del equipo • Registro de asistencia a reuniones • Perfiles de los miembros del equipo	• Se cuenta con al menos un experto en cada área de investigación del proyecto
Actividad 1.1.5 Estructuración del banco de proyectos	• En el mes quinto y sexto se definirán los proyectos a ejecutarse en corto y mediano plazo, priorizando la importancia del estero Paushiyacu como sitio demostrativo	• Banco de proyectos • Encargos de cada área de investigación	• Existen posibles fuentes de financiamiento para cada proyecto y estudiantes interesados en participar
Producto 1.2 Creación de propuesta de ordenanza para manejo de desechos e implementación de espacios verdes en áreas urbanas			

Actividad 1.2.1 Reunión de trabajo 1	• En la semana uno del mes siete, se definirán las líneas de acción de las ordenanzas propuestas	• Informe reunión 1	• Existe la voluntad política para la implementación de una ordenanza
Actividad 1.2.2 Reunión de trabajo 2	• En la segunda semana del mes siete se realizará una mesa de trabajo con el equipo de colaboración transdisciplinaria, miembros del cabildo y presidentes barriales	• Informe reunión 2	
Actividad 1.2.2 Redacción de propuesta	• Finalizado el mes ocho se habrá estructurado una propuesta de orientada a mejorar la distribución de espacios en la ciudad, así como el manejo de residuos. Todo esto en el marco del cumplimento del PDOT actual.	• Propuesta para el cabildo	
Actividad 1.2.4 Socialización de la propuesta con el cabildo	• Para el mes nueve se entregará la propuesta para el debate, corrección y aprobación en el cabildo.	• Informe de la socialización	
Producto 3.2 Página web			
Actividad 3.2.1 Concurso para el diseño y mantenimiento de la página web	• En el mes diez se realizará una convocatoria a creadores digitales y programados para la creación del sitio web y manejo de redes sociales	• Resultado del concurso	
Actividad 3.2.2 Creación de la página web	• En el mes 11 se creará el sitio oficial con la información recolectada organizada de forma sistemática	• Página web	
Actividad 3.2.2 Difusión a través de medios oficiales	• Para el mes 12 se habrá concluido con la aplicación como sitio demostrativo y se esperar crear un espacio con oportunidades de financiamiento para nuevos proyectos	• Informe de aplicación	• Se cuenta con el respaldo de instituciones dispuestas a financiar proyectos futuros por la relevancia del sitio

Objetivo 2
Reducir la degradación del Estero Paushiyacu, mediante la activación centros de interpretación cultural en la zona de recarga hídrica de la cuenca y en la comunidad indígena Intillacta de Paushiyacu

DESCRIPCIÓN NARRATIVA	INDICADORES	MEDIOS DE VERIFICACIÓN	SUPUESTOS
Producto 2.1 Informe de talleres y campañas de creación de condiciones habilitantes para la generación de espacios verde-azules dentro del área correspondiente al estero Paushiyacu			
Actividad 2.1.1 Socialización del análisis socio-ambiental	• En el primer mes del segundo año se realizará un ciclo de talleres para socializar el levantamiento de información ejecutado en los meses anteriores con los diferentes actores involucrados	• Facturas de equipos adquiridos: cámara, software tratamiento de datos, material didáctico, impresiones diseño de infografías • Registro de asistencia • Registro fotográfico • Registro de mapas parlantes	• La confiabilidad de los habitantes es alta, y no existen conflictos de interés
Actividad 2.1.2 Taller “Conociendo los macro invertebrados”	• En los meses dos y tres del segundo año se realizarán talleres teórico prácticos con estudiantes de los diferentes centros educativos para conocer la biodiversidad local enfocada específicamente al reconocimiento de especies de macroinvertebrados	• Facturas de los equipos adquiridos cámaras, softwares para tratamiento de datos, material didáctico, impresiones, diseño de infografías • Registro fotográfico del taller • Registro de asistencia • Grabaciones del taller	• Se cuenta con la participación de la academia como parte de los procesos formativos

Actividad 2.1.3 Taller “Metabolismo urbano”	• En el cuarto mes del segundo año se llevará a cabo una serie de talleres en los que se espera socializar con la población el concepto de metabolismo urbano para concientizar a la ciudadanía sobre las prácticas que afectan al medio ambiente	• Informe sociodemográfico • Mapas temáticos de caracterización	• Se cuenta con la participación de la academia como parte de los procesos formativos
Actividad 2.1.4 Concurso “Conociendo el Paushiyacu: cuentos y relatos”	• En el quinto y sexto mes del segundo año se llevará a cabo un concurso para estudiantes de primaria y secundaria en el que se presenten de manera escrita relatos relaciones al Estero Paushiyacu. • En el quinto mes se realizarán talleres de escritura	• Informe del estado actual de la cuenca • Registro fotográfico de las áreas de interés • Facturas de material de oficina e impresiones	• Se cuenta con la participación de la academia como parte de los procesos formativos • No hay falta de credibilidad al gobierno local por lo que ayudarán en la difusión de los eventos en los distintos planteles educativos
Producto 2.2 Creación del colectivo “Guardianes del río”			
Actividad 2.2.1 Reunión con los colectivos ambientales existentes en la ciudad de Tena	• Durante los meses 4 y 5 del segundo año se llevarán a cabo reuniones con los representantes de los colectivos ambientales presentes en la ciudad de Tena, como parte de la creación del colectivo guardianes del río	• Actas de reuniones • Registros de asistencia	• Los intereses de los colectivos se alinean a los objetivos del nuevo colectivo
Actividad 2.2.2 Socialización con los presidentes de los barrios y líderes comunitarios pertenecientes a la cuenca del Estero Paushiyacu	• Para el mes 6 del segundo año se espera socializar la iniciativa con los líderes comunitarios	• Registro fotográfico • Lluvia de ideas Árbol de problemas actualizado	• Se cuenta con la participación de todos los líderes de las comunidades ligadas a la gestión del Estero Paushiyacu
Actividad 2.2.3	• Durante los meses seis y siete del segundo año se espera definir las líneas de acción del colectivo considerando:	• Estatutos del colectivo • Directiva	

Definición de las líneas de acción del colectivo	- Relevancia para la comunidad - Áreas prioritarias • Misión y visión del colectivo		
Actividad 2.2.4 Llamado a la ciudadanía en general a ser parte del colectivo	• Para el octavo mes del segundo año se presentará el colectivo a la ciudadanía general como parte de las actividades de integración comunitaria.	• Registro de reuniones • Registro de visitas a comunidades	
Producto 2.3 Redacción guía de educación ambiental “Caso de Estudio Paushiyacu”			
Actividad 2.3.1 Definición y estructuración de los resultados preliminares de los productos 1.1 y 1.2	• Durante el noveno mes del segundo año se realizará un taller para dar a conocer las condiciones habilitantes del proyecto	• Registro de asistencia • Registro fotográfico	
Actividad 2.3.2 Redacción de guía metodológica	• Guia para centros educativos y población en general incluye: - Estado Actual del río - Actores involucrados - Proceso de creación de colectivos - Árbol de problemas y árbol de objetivos para proyectos futuros - Talleres orientados al arte • Esta actividad se realizará del noveno al doceavo mes del segundo año	• Guía impresa y digital	
Producto 2.4 **Guía metodológica** **“Fomentando la economía**			

naranja: Caso de Estudio Paushiyacu ”			
Actividad 2.4.1 Socialización del proyecto con las comunidades aledañas al estero principalmente las ubicadas en la zona de recarga e Intillacta de Paushiyacu	• Durante el primer mes del tercer año se realizará un taller para dar a conocer las condiciones habilitantes del proyecto	• Registro de asistencia • Registro fotográfico	
Actividad 2.4..2 Levantamiento de información sobre los principales servicios culturales que ofrece el Estero Paushiyacu	• Durante el segundo y tercer mes del tercer año se realizarán visitas a las comunidades y familias directamente relacionadas con el Estero Paushiyacu para entender y conocer el valor cultural del sitio, incluyendo los sitios arqueológicos	• Mapas parlantes • Entrevistas y relatos hablados	
Actividad 2.4.2 Redacción de guía metodológica	• Para el cuarto mes del tercer año se espera contar con una guía que será entregada a cada familia que pueda estar involucrada dentro del proyecto tomando en cuenta su actividad socio-económica actual y la predisposición a participar	• Guía presentada a las comunidades • Capacitaciones actores involucrados	
Producto 2.5 Rehabilitación y creación de espacios para los centros de interpretación cultural			
Actividad 2.5.3 Habilitación de los centros comunitarios como spots de difusión de cultura y tradición	• Del quinto al noveno mes del tercer año se espera habilitar los centros comunitarios como puntos turísticos dentro de la ciudad de Tena	• Consentimiento de los dueños de las propiedades para y uso y compensación de las áreas de intervención	

Actividad 2.5.4 Habilitación de centros de hospedaje comunitario	• Durante el décimo mes del tercer se espera habilitar espacios comunitarios para hospedaje, así como áreas de camping	• Consentimiento de los dueños de las propiedades para y uso y compensación de las áreas de intervención	
Actividad 2.5.5 Habilitación de senderos para visitar las áreas de recarga hídricas y cascada ubicadas en la parte alta de la cuenca	• Como parte del proyecto comunitario se esperar dar mantenimiento a los senderos existentes y habilitar nuevos espacios comunitarios una vez identificadas las áreas más importantes, así como la ubicación de basureros a lo largo del río incluyendo campañas de reciclaje.	• Consentimiento de los dueños de las propiedades para y uso y compensación de las áreas de intervención	

Cronograma de actividades

No	Actividad	Mes	Reponsables	Recursos	Costo
1	Informe del Estado del Arte del Estero Paushiyacu	1	Ejecutores del proyecto	Honorarios profesionales Insumos	2400 100
2	Recopilación de estudios previos	2	Ejecutores del proyecto	Honorarios profesionales Insumos	2400 100
3	Taller comunitario	3	Ejecutores del proyecto	Honorarios profesionales Insumos	2400 200
4	Redacción y socialización de resultados con las autoridades locales	4	Ejecutores del proyecto	Honorarios profesionales	2400
5	Establecimiento del equipo a cargo de la colaboración transdisciplinaria	4	Ejecutores del proyecto	Honorarios profesionales	7200
6	Estructuración del banco de proyectos	5 &6	Ejecutores del proyecto	Honorarios profesionales	7200
7	Reunión de trabajo 1	7	Ejecutores del proyecto	Honorarios profesionales	7200
8	Reunión de trabajo 2	7	Ejecutores del proyecto	Honorarios profesionales	7200

9	Redacción de propuesta	8	Ejecutores del proyecto	Honorarios profesionales	7200
10	Socialización de la propuesta con el cabildo	9	Ejecutores del proyecto	Honorarios profesionales	7200
11	Concurso para el diseño y mantenimiento de la página web	10	Ejecutores del proyecto	Publicidad	500
12	Creación de la página web	11	Ganadores del concurso página web	Honorarios profesionales y compra dominio	6000
13	Difusión a través de medios oficiales	12	Ejecutores del proyecto /GAD locales	Humano	0
14	Socialización del análisis socio-ambiental	13	Ejecutores del proyecto/ URAI	Honorarios profesionales Insumos	1200 100
16	Taller “Conociendo los macro invertebrados”	14 &15	Ejecutores del proyecto/ URAI	Humano	0
17	Taller “Metabolismo urbano”	16	Ejecutores del proyecto/ URAI	Humano	0
18	Concurso “Conociendo el Paushiyacu: cuentos y relatos”	16 & 17	Ejecutores del proyecto/ URAI / Club de lectura / GAD Provincial y Municipal	Premios	1000
19	Reunión con los colectivos ambientales existentes en la ciudad de Tena	16 & 17	Ejecutores del proyecto	Humano	7200
20	Socialización con los presidentes de los barrios y líderes comunitarios pertenecientes a la cuenca del Estero Paushiyacu	18	Ejecutores del proyecto	Humano	7200
21	Definición de la línea de acción del colectivo	18 & 19	Ejecutores del proyecto / Colectivos Ambientales / Líderes comunitarios	Humano	2400

22	Llamado a la ciudadanía en general a ser parte del colectivo	20	Ejecutores del proyecto / Colectivos Ambientales / Líderes comunitarios	Humano	2400
23	Definición y estructuración de los resultados preliminares de los productos 1.1 y 1.2	21	Ejecutores del proyecto	Honorarios profesionales	1200
24	Redacción de guía metodológica “Educación Ambiental en el Paushiyacu ”	21, 22, 23, 24	Ejecutores del proyecto	Honorarios profesionales	1200
25	Socialización del proyecto con las comunidades aledañas al estero principalmente las ubicadas en la zona de recarga e Intillacta de Paushiyacu	25	Ejecutores del proyecto	Honorarios profesionales	1200
26	Levantamiento de información sobre los principales servicios culturales que ofrece el Estero Paushiyacu	26 & 27	Ejecutores del proyecto	Honorarios profesionales	2000
27	Redacción de guía metodológica “Fomentando la economía naranja”	28	Ejecutores del proyecto /URAI / Ministerio de Cultura/ Comunidades	Honorarios profesionales	2000
				Gastos de publicación	3000
28	Habilitación de los centros comunitarios como spots de difusión de cultura y tradición	29, 30 , 31 & 32	Ejecutores del proyecto /URAI / Ministerio de Cultura/ Comunidades	Humano	0
				Honorarios profesionales, materiales	5000
29	Habilitación de centros de hospedaje comunitario	32	Ejecutores del proyecto /URAI / Ministerio de Cultura/ Comunidades	Gastos de construcción	10000

30	Habilitación de senderos para visitar las áreas de recarga hídricas y cascada ubicadas en la parte alta de la cuenca	33	Ejecutores del proyecto /URAI / Ministerio de Cultura/ Comunidades	Humano, implementación de señalética	3000
TOTAL					109800

Cronograma de entregables

No	Resultado	Num. De la Actividad Enlazada	Mes	Responsables	Tipo de entregable
1	Guía metodológica "Educación Ambiental en el Paushiyacu"	14, 15,16,17,18,19,20,21, 22,23 & 24	24	Ejecutores del proyecto	Verificado
2	Guía metodológica "Fomentando la economía naranja "	19, 20, 21, 22, 23, 24, 25 & 26	28	Ejecutores del proyecto	Verificado
3	Página web	TODAS	11	Ganadores del consurso / Ejecutores del proyecto	Verificado
4	Informe Final del proyecto	TODAS	33	Ejecutores del proyecto	Verificado

Bibliografía

Akhmouch, A., Clavreul, D., & Glas, P. (2018). Introducing the OECD Principles on Water Governance. *Water International*, *43*(1), 5–12. https://doi.org/10.1080/02508060.2017.1407561

Alcaldía de Tena. (2019). *INFORME DE RENDICIÓN DE CUENTAS 2019*.

Alcaldía de Tena. (2020). *Descontaminación Estero Paushiyacu*. https://www.facebook.com/watch/?v=311122779981529

Alvear, D., Carrillo, H., Martinez, D., & Oñate, V. (2019). *Contaminación del estero Paushiyacu: Análisis del rol de la gobernanza y su potencial para la restauración de la microcuenca.*

Constitución del Ecuador, 449 Registro Oficial 67 (2008). http://www.asambleanacional.gov.ec/documentos/constitucion_de_bolsillo.pdf

Ley Orgánica De Recursos Hídricos, Usos Y Aprovechamiento Del Agua, Registro Oficial 32 (2014).

Beechie, T., Pess, G., Roni, P., & Giannico, G. (2008). Setting River Restoration Priorities: A Review of Approaches and a General Protocol for Identifying and Prioritizing Actions. *North American Journal of Fisheries Management*, *28*(3), 891–905. https://doi.org/10.1577/m06-174.1

Borgatti, S. ., Everett, M. ., & Freeman, L. . (2002). *Ucinet for Windows: Software for Social Network Analysis. Harvard*. https://sites.google.com/site/ucinetsoftware/home

Cabrera, M., Pereira, L., & Capparelli, M. (2018). *Evaluación de las condiciones de contaminación del agua de las quebradas Tamiayacu, Paushiyacu y Mamayacta de la ciudad de Tena, provincia de Napo*.

Capparelli, M. V., Moulatlet, G. M., Abessa, D. M. de S., Lucas-Solis, O., Rosero, B., Galarza, E., Tuba, D., Carpintero, N., Ochoa-Herrera, V., & Cipriani-Avila, I. (2020). An integrative approach to identify the impacts of multiple metal contamination sources on the Eastern Andean foothills of the Ecuadorian Amazonia. *Science of the Total Environment*, *709*, 136088. https://doi.org/10.1016/j.scitotenv.2019.136088

CCME. (2017a). CCME Water Quality Index user´s manual 2017 Update. *Canadian Water Quality Guidelines for the Protection of Aquatic Life*, 1–5. http://www.ccme.ca/files/Resources/calculators/WQI User's Manual (en).pdf

CCME. (2017b). CCME Water Quality Index user´s manual 2017 Update. In *Canadian Water Quality Guidelines for the Protection of Aquatic Life*. http://www.ccme.ca/files/Resources/calculators/WQI User's Manual (en).pdf

Chapi, D., & Yupangui, R. (2018). *Evaluación de la calidad del agua de los esteros Paushiyacu, Tamiahurco, Chimbadero y Dunduyacu de la ciudad del Tena, mediante la identificación de macro invertebrados bentónicos, para proponer una normativa legal que aporte a la restauración de su ecosi* [Instituto Tecnológico Superior Tena]. https://es.scribd.com/document/399907705/TESIS-AMBIENTAL

Ley General de Transparencia y Acceso a la Informacion Pública, 1 Registro Oficial Suplemento 337 1 (2004). www.lexis.com.ec

NORMA TÉCNICA USO Y GESTIÓN DE SUELO Y PLANES URBANÍSTICOS DE GADS, 1 (2020).

Conservation International. (2017). *Freshwater Health Index Manual del usuario*. https://manual.freshwaterhealthindex.org/Getting_Started.html

COOTAD. (2019). Código Orgánico de Organización Territorial Desentralizado, COOTAD. *Registro Oficial Suplemento 303 de 19-Oct.-2010*, 1–180. http://www.ambiente.gob.ec/wp-content/uploads/downloads/2018/05/COOTAD.pdf

Doria, C. R. da C., Agudelo, E., Akama, A., Barros, B., Bonfim, M., Carneiro, L., Briglia-Ferreira, S. R., Nobre Carvalho, L., Bonilla-Castillo, C. A., Charvet, P., dos Santos Catâneo, D. T. B., da Silva, H. P., Garcia-Dávila, C. R., dos Anjos, H. D. B., Duponchelle, F., Encalada, A., Fernandes, I., Florentino, A. C., Guarido, P. C. P., … Vitule, J. R. S. (2021). The Silent Threat of Non-native Fish in the Amazon: ANNF Database and Review. *Frontiers in Ecology and Evolution*, *9*(June), 1–11. https://doi.org/10.3389/fevo.2021.646702

El Comercio. (2019). *Aguas servidas, un riesgo para los ríos del país*. https://www.elcomercio.com/tendencias/ambiente/aguas-servidas-riesgo-rios-ecuador.html

El Observador. (2020). *Con una minga ciudadana se realizó la limpieza del estero Paushiyacu*.

https://elobservador.ec/con-una-minga-ciudadana-se-realizo-la-limpieza-del-estero-paushiyacu/
El Observador. (2021). *Iniciaron los trabajos en la calle Cuenca*. https://elobservador.ec/iniciaron-los-trabajos-en-la-calle-cuenca/
El Telegrafo. (2019). *El tratamiento de aguas servidas marca la agenda ambiental en Tena*. https://www.eltelegrafo.com.ec/noticias/ecuador/1/tratamiento-aguas-servidas-agenda-ambiental-tena
El Universo. (2020). *Más del 90 % de los municipios del Ecuador no tratan las aguas residuales de acuerdo a la normativa*. https://www.eluniverso.com/noticias/2020/12/20/nota/8409829/agua-servicios-basicos-ecuador/
GAD Municipal Tena. (2014). *Actualización Plan de Desarrollo y Ordenamiento Territorial diagnóstico*. http://app.sni.gob.ec/sni-link/sni/PORTAL_SNI/data_sigad_plus/sigadplusdiagnostico/1560000270001_PDOT ACT 2014_DIAGNOSTICO_sigad2 sug_senplades1_BD_20-02-2015_08-58-05.pdf
PDOT 2020-2023 Normativa plan de uso y gestión de suelo y plan de ordenamiento integral sustentable de la ciudad de tena-pouis, 772 (2020). https://tena.gob.ec/images/convocatoria/NORMATIVA-PLAN-DE-USO-Y-GESTIN-DE-SUELO.pdf
GAD Municipal Tena. (2021). *Actulización del Plan de ordenamiento territorial del cantón Tena para el período 2021-2033, el plan de uso y gestión del suelo urbano y rural del cantón tena 2021-2033 y el Plan de ordenamiento urbanístico integral sustentable de la ciudad de Tena*.
GAD Provincial de Napo. (2019). *Unidad de riego y drenaje realiza el desazolve y ampliación del estero Paushiyaku*. https://napo.gob.ec/website/index.php/informativo/16-articulos-destacados/484-unidad-de-riego-y-drenaje-realiza-el-desazolve-y-ampliacion-del-estero-paushiyaku
Gann, G. D., McDonald, T., Walder, B., Aronson, J., Nelson, C. R., Jonson, J., Hallett, J. G., Eisenberg, C., Guariguata, M. R., Liu, J., Hua, F., Echeverría, C., Gonzales, E., Shaw, N., Decleer, K., & Dixon, K. W. (2019). International principles and standards for the practice of ecological restoration. Second edition. *Restoration Ecology*, *27*(S1), S1–S46. https://doi.org/10.1111/rec.13035
Guareschi, S., Laini, A., Racchetti, E., Bo, T., Fenoglio, S., & Bartoli, M. (2014). How do hydromorphological constraints and regulated flows govern macroinvertebrate communities along an entire lowland river? *Ecohydrology*, *7*(2), 366–377. https://doi.org/10.1002/eco.1354
Guimarães, L. F., Teixeira, F. C., Pereira, J. N., Becker, B. R., Oliveira, A. K. B., Lima, A. F., Veról, A. P., & Miguez, M. G. (2021). The challenges of urban river restoration and the proposition of a framework towards river restoration goals. *Journal of Cleaner Production*, *316*(July). https://doi.org/10.1016/j.jclepro.2021.128330
Hychka, K., & Druschke, C. G. (2017). Adaptive Management of Urban Ecosystem Restoration: Learning From Restoration Managers in Rhode Island, USA. *Society and Natural Resources*, *30*(11), 1358–1373. https://doi.org/10.1080/08941920.2017.1315653
INEC. (2016). *Estadística de información ambiental económica en Gobiernos Autónomos Descentralizados Municipales 2015 (Agua y Alcantarillado)*. *2015*, 30. http://www.ecuadorencifras.gob.ec/documentos/web-inec/Encuestas_Ambientales/Municipios_2015/Documento_Tecnico-Gestion_de_Agua_y_Alcantarillado_2015.pdf
Jerves-Cobo, R., Benedetti, L., Amerlinck, Y., Lock, K., De Mulder, C., Van Butsel, J., Cisneros, F., Goethals, P., & Nopens, I. (2020). Integrated ecological modelling for evidence-based determination of water management interventions in urbanized river basins: Case study in the Cuenca River basin (Ecuador). *Science of the Total Environment*, *709*, 136067. https://doi.org/10.1016/j.scitotenv.2019.136067
Jesús-crespo, R. De, & Ramirez, A. (2011). *The use of a Stream Visual Assessment Protocol to determine ecosystem integrity in an urban watershed in Puerto Rico*. *36*, 560–566. https://doi.org/10.1016/j.pce.2010.11.007
Kassambara, A., & Mundt, F. (2020). Package 'factoextra.' *CRAN- R Package*, 84. https://cran.r-project.org/package=factoextra

Kondolf, G. M. (2011). Setting goals in river restoration: When and where can the river “heal itself”? *Geophysical Monograph Series*, *194*, 29–43. https://doi.org/10.1029/2010GM001020

Kondolf, G. M., Boulton, A. J., Daniel, S. O., Poole, G. C., Rahel, F. J., Stanley, E. H., Wohl, E., Bång, A., Carlstrom, J., Cristoni, C., & Huber, H. (2006). Process-Based Ecological River Restoration : Visualizing Three- Dimensional Connectivity and Dynamic Vectors to Recover Lost Linkages. *Ecology and Society*, *11*(2).

Kondolf, G. M., & Yang, C. N. (2008). Planning River Restoration Projects: Social and Cultural Dimensions. *River Restoration: Managing the Uncertainty in Restoring Physical Habitat*, 41–60. https://doi.org/10.1002/9780470867082.ch4

MAATE. (2018). *Sistema Único de Información Ambiental (SUIA)*. Mapa Interactivo. http://suiadoc.ambiente.gob.ec/web/suia/inicio

MAE. (2003). Texto Unificado de Legislación Secundaria de Medio Ambiente, TULSMA. *Registro Oficial Edición Especial 2 de 31-Mar.-2003*, *3399*, 1–578. www.lexis.com.ec

MAE. (2015). Revision Del Anexo 1 Del Libro Vi Del Texto Unificado De Legislacion Secundaria Del Ministerio Del Ambiente: Norma De Calidad Ambiental Y De Descarga De Efluentes Al Recurso Agua. *Registro Oficial No. 387*, *97*, 1–40. http://extwprlegs1.fao.org/docs/pdf/ecu155128.pdf

McClain, M. . (2008). E cohydrology. In *Ecohydrology: Processes, Models and Case Studies. An approach to the sustainable management of water resources* (pp. 207–222).

Ministerio del Ambiente y Agua. (2015). Marco institucional para incentivos ambientales. Acuerdo Ministerial 140. *Registro Oficial Edición Especial 387 de 04-Nov.-2015*, 1–45. http://www.silec.com.ec/WebTools/LexisFinder/DocumentVisualizer/FullDocumentVisualizerPDF.aspx?id=AMBIENTE-MARCO_INSTITUCIONAL_PARA_INCENTIVOS_AMBIENTALES

Mitchel, R. K., Angle, B. R., & Wood, D. J. (1997). Anticipating informed consent: an empirical approach. *Academy of Management Review*, *22*(4), 852–886. https://doi.org/10.1037/h0035597

Mohammed, I. N., Bolten, J. D., Souter, N. J., Shaad, K., & Vollmer, D. (2022). Diagnosing challenges and setting priorities for sustainable water resource management under climate change. *Scientific Reports*, *12*(1), 1–15. https://doi.org/10.1038/s41598-022-04766-2

Muni TV Tena. (2020). *MINGA EN EL ESTERO PAUSHIYACU*. https://www.facebook.com/watch/?v=3377972445657556

Neville, B. A., Bell, S. J., & Whitwell, G. J. (2011). Stakeholder Salience Revisited: Refining, Redefining, and Refueling an Underdeveloped Conceptual Tool. *Journal of Business Ethics*, *102*(3), 357–378. https://doi.org/10.1007/s10551-011-0818-9

Nobre, A. D., Cuartas, L. A., Hodnett, M., Rennó, C. D., Rodrigues, G., Silveira, A., Waterloo, M., & Saleska, S. (2011). Height Above the Nearest Drainage - a hydrologically relevant new terrain model. *Journal of Hydrology*, *404*(1–2), 13–29. https://doi.org/10.1016/j.jhydrol.2011.03.051

OECD. (2015). OECD Principles on Water Governance. Draft for consulation at the 7th World Water Forum. *Report*, *May*, 1–23.

Palmer, M. A., Bernhardt, E. S., Allan, J. D., Alexander, G., Shah, J. F., Galat, D. L., Hart, D. D., Jenkinson, R., Lave, R., & Sudduth, E. (2005). *Standards for ecologically successful river restoration*. 208–217. https://doi.org/10.1111/j.1365-2664.2005.01004.x

Perini, K., & Sabbion, P. (2017). Urban Sustainability and River Restoration. In *Urban Sustainability and River Restoration*. https://doi.org/10.1002/9781119245025

Prat, N., Rios, B., Acosta, R., & Rieradevall, M. (2009). Los macroinvertebrados como indicadores de calidad de las aguas. In E. Domínguez & H. R. Fernández (Eds.), *Macroinvertebrados bentónicos sudamericanos* (pp. 231–254).

Rahman, M. L., Shahjahan, M., & Ahmed, N. (2021). Tilapia farming in Bangladesh: Adaptation to climate change. *Sustainability (Switzerland)*, *13*(14), 1–20. https://doi.org/10.3390/su13147657

Ribeiro, P. J. G., & Pena Jardim Gonçalves, L. A. (2019). Urban resilience: A conceptual framework. *Sustainable Cities and Society*, *50*(May). https://doi.org/10.1016/j.scs.2019.101625

Rodríguez Romero, A. J., Robles Salazar, C. A., Ruíz Picos, R. A., López López, E., Sedeño Díaz, J. E., & Rodríguez Dorantes, A. (2014). Índices de germinación y elongación radical

de Lactuca sativa en el biomonitoreo de la calidad del agua del rio chalma. *Revista Internacional de Contaminacion Ambiental*, *30*(3), 307–316.

Rosero, B., & Mena, C. (2021). *Paushiyacu Macroinvertebrates characterization*.

Santafe-Troncoso, V., & Loring, P. A. (2021). Traditional food or biocultural threat? Concerns about the use of tilapia fish in Indigenous cuisine in the Amazonia of Ecuador. *People and Nature*, *3*(4), 887–900. https://doi.org/10.1002/pan3.10235

Skinner, K. S., & Bruce-Burgess, L. (2005). RESTORATION PROTOCOLS- KEY COMPONENTS F R MEETING THE REQUIREMENTS OF THE WATER FRAMEWORK DIRECTIVE (WFD) Technical issues. *Water and Environment Journal*, *19*(2), 135–142.

Sorgato, V. (2017). *Muestras de agua de los ríos del país ponen en alerta sobre la contaminación*. https://www.elcomercio.com/tendencias/sociedad/muestras-laboratorio-rios-alerta-contaminacion.html#:~:text=2017 14%3A41-,Muestras de agua de los ríos del,en alerta sobre la contaminación&text=Adamary tiene 15 años y,rostro se llena de granos.

Speed, R. A., Li, Y., Tickner, D., Huang, H., Naiman, R. J., Cao, J., Lei, G., Yu, L., Sayers, P., Zhao, Z., & Wei, Y. (2016). A framework for strategic river restoration in China. *Water International*, *41*(7), 998–1015. https://doi.org/10.1080/02508060.2016.1247311

Tapia, L. (2013). Compilación Actualizada de Incentivos Ambientales. In *Rev Soc Quím Perú* (Vol. 80, Issue 3). https://www.ambiente.gob.ec/wp-content/uploads/downloads/2013/11/1-Incentivos-ambientales1.pdf

Terneus Jácome, E., & Yanez-Moretta, P. (2018). Principios fundamentales en torno a la calidad del agua, el uso de bioindicadores acuáticos y la restauración ecológica fluvial en Ecuador. *La Granja*, *27*(1), 36–50. https://doi.org/10.17163/lgr.n27.2018.03

Uherek, C. B., & Pinto Gouveia, F. B. (2014). Biological monitoring using macroinvertebrates as bioindicators of water quality of maroaga stream in the maroaga cave system, presidente figueiredo, amazon, Brazil. *International Journal of Ecology*, *2014*. https://doi.org/10.1155/2014/308149

UNESCO/ONU-Agua. (2020). Agua y cambio climático. In *UNESCO* (Vol. 167, Issue 3618).

United Actions. (2015). *Take Action for the Sustainable Development Goals*. https://www.un.org/sustainabledevelopment/sustainable-development-goals/

USDA. (1998). *Svap*. *December 1*(NWCC Technical Note 99-1).

Vollmer, D., Bezerra, M. O., Martínez, N. A., Ortiz, O. R., Encomenderos, I., Marques, M. C., Serrano-Durán, L., Fauconnier, I., & Wang, R. Y. (2021). Can we take the pulse of environmental governance the way we take the pulse of nature? Applying the Freshwater Health Index in Latin America. *Ambio*, *50*(4), 870–883. https://doi.org/10.1007/s13280-020-01407-8

Vollmer, D., Shaad, K., Souter, N. J., Farrell, T., Dudgeon, D., Sullivan, C. A., Fauconnier, I., MacDonald, G. M., McCartney, M. P., Power, A. G., McNally, A., Andelman, S. J., Capon, T., Devineni, N., Apirumanekul, C., Ng, C. N., Rebecca Shaw, M., Wang, R. Y., Lai, C., … Regan, H. M. (2018). Integrating the social, hydrological and ecological dimensions of freshwater health: The Freshwater Health Index. *Science of the Total Environment*, *627*, 304–313. https://doi.org/10.1016/j.scitotenv.2018.01.040

Walsh, C. J., Roy, A. H., Feminella, J. W., Cottingham, P. D., Groffman, P. M., & Morgan, R. P. (2005). The urban stream syndrome: Current knowledge and the search for a cure. *Journal of the North American Benthological Society*, *24*(3), 706–723. https://doi.org/10.1899/04-028.1

Wohl, E., Angermeier, P. L., Bledsoe, B., Kondolf, G. M., Macdonnell, L., Merritt, D. M., Palmer, M. A., Poff, N. L., & Tarboton, D. (2005). *River restoration*. *41*, 1–12. https://doi.org/10.1029/2005WR003985

Yeakley, J. A., Ervin, D., Chang, H., Granek, E. F., Dujon, V., Shandas, V., & Brown, D. (2016). Ecosystem Services of Streams and Rivers. *River Science: Research and Management for the 21st Century*, 335–352. https://doi.org/10.1002/9781118643525.ch17