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Miami, Florida

THE VULNERABILITY OF AQUATIC SYSTEMS OF THE UPPER NAPO RIVER BASIN
(ECUADORIAN AMAZON) TO HUMAN ACTIVITIES

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This thesis, written by Jorge Emilio Celi-Sangurima, and entitled The Vulnerability of Aquatic Systems of the Upper Napo River Basin (Ecuadorian Amazon) to Human Activities, having been approved in respect to style and intellectual content, is referred to you for judgment.

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DEDICATION

To the ones that gave me life, love, inspiration, and the means to pursue this calling in life.

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ABSTRACT OF THE THESIS

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Aquatic ecosystems exhibit different vulnerabilities to anthropogenic disturbances. I examined this problem in the Upper Napo River Basin (UNRB), Ecuador. I ranked from 1 to 5 aquatic ecosystem uniqueness, health and threats. I stratified the basin into five Ecological Drainage Units (EDU), 48 Aquatic Ecological Systems (AES), and 203 macrohabitats. I found main threats (habitat conversion/degradation, land development, mining, oil industries, and water diversion) cover 54% of the UNRB, but have different scores and extents in each EDU. I assessed the health of 111 AESs, under three land use treatments, by analyzing the streamside zone, physical forms, water quality, aquatic life, and hydrology. Overall, health of AESs varied from 5 to 2.58, with 5 being the highest level of health. Threats and health of AESs were inversely related ($F=34.119$, $P<0.001$), based on which I determined an overall vulnerability of 2.55 ± 0.59 . Performing GAP analyses I determined that macrohabitats outside conservation areas should be priorities in the UNRB.

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1. INTRODUCTION

Tropical river ecosystems are threatened by a broad spectrum of human activities, including land use conversion, flow regulation and alteration, urbanization and development of infrastructure, as well as overexploitation of fisheries, introduction of exotic species, and industrial activities (McClain 2002). Effects of these activities range from alteration/degradation of river channels, declines in the amount and quality of water resources, and degradation of aquatic habitats and diversity loss (Bruijnzeel 1996, Trombulak and Frissell 2000, Hodnett et al. 2001, Krishnaswamy et al. 2001, Simon and Townsend 2003, Mol and Ouboter 2004, Mungai et al. 2004). The Millennium Ecosystem Assessment (MEA) concluded that the main direct drivers of change in biodiversity and ecosystems in inland waters worldwide are habitat change, pollution, and invasive species (MEA 2005). Trends show that the impacts of these factors on freshwater ecosystems are increasing rapidly, at a pace greater than that affecting their terrestrial counterparts (McNeely et al. 1995, Revenga and Mock 2000). Also of consideration is the fact that most conservation measures (e.g. definition and creation of nature reserves) have been addressed to enhance terrestrial habitats and biota, rather than riverine systems (Naiman et al. 2005).

Impacts to aquatic biodiversity occur widely and at different scales. In general terms, it is recognized that the number of species is declining, the distribution of species is more homogeneous, and the ranges and/or population sizes of several taxonomic groups are smaller (MEA 2005). It is also appreciated that freshwater ecosystems have the highest proportion of species threatened with extinction (due to loss of wetlands and decrease of water quality) (Revenga and Mock 2000). For instance, the extinction of North American Freshwater fauna is five times higher than that of terrestrial fauna (0.1); which to some extent is related to the extinction of 123 species, and to the classification of 21.3 % of fishes as threatened (Ricciardi and Rasmussen 1999). On the other hand, Brazil, which has more than 2000 freshwater fish species,

recognizes that 6.3% of them (134) are threatened (Agostinho et al. 2005). Even though these examples reflect the severity of the problem worldwide, these numbers could be underestimated for tropical regions. Tropical ecosystems are more diverse than temperate ones, and the effects of human activities have been studied to a lower extent in these regions (Groombridge and Jenkins 1998, Pringle et al. 2000).

Addressing this problem requires regional assessments that map conditions and threats and prioritize needs based on vulnerability and value (Harris and Silveira 1999, Pressey et al. 2000, Pressey and Taffs 2001, Noss et al. 2002). I examined these issues in an important river basin in Ecuador, one of the main Andean tributaries to the Amazon Basin. The Napo River Basin (NRB) drains a third of the Ecuadorian Amazon and has important biodiversity value and supports development and human livelihoods (Mittermeier et al. 1999, Ruiz 2000, Messina and Walsh 2001). It includes several kinds of terrestrial ecosystems (Palacios et al. 1999, Valencia et al. 1999) that are drained by a large variety of aquatic systems. Levels of aquatic diversity of the NRB are high (562 species of fish), and represent approximately 80 % of freshwater fishes of Ecuador (Galacatos et al. 2004).

This region has supported many changes in its ecological and cultural systems and faces many environmental problems (Ruiz 2000, Sierra 2000). Human activities in the NRB have had several effects on the aquatic systems of the region. The most common are: changes in water discharge and timing, changes in erosion and sedimentation rates, increases in the content of nutrients in the water, increases in levels of pathogens and toxins in waters, and consequently changes in the abundance and composition of aquatic biota (Galárraga 2000, Vanacker et al. 2003). On the other hand, conservation approaches have been focused mainly on terrestrial habitats and biota, which have contributed to the severity of the problem in the region. If these trends in the in the management and conservation of aquatic ecosystems continue at the same

pace, the loss of diversity and services that they provide will be uncontrollable. To address this problem it is important to understand the status and vulnerability of the aquatic systems to human activities.

The goal of this research was to characterize the main aquatic systems in the Upper Napo River Basin (UNRB), to assess and map their health and vulnerability, and to provide input to efforts to address critical aquatic problems and develop more sustainable methods of using the region's resources. Achieving this goal required that the following objectives be met:

1. Classify the aquatic systems of the UNRB.
2. Identify and map the threats to these systems.
3. Assess and map the current state of health of the aquatic systems and the impacts of human and natural interventions on them.
4. Assess and map the vulnerability of the aquatic systems to the main identified threats.
5. Identify priority areas and measures to improve the management of the aquatic systems.

For this purpose several technical approaches (e.g. GIS, field assessments of biota and physical habitats, and water and sediment analyses) were used to evaluate key attributes of the ecosystems. In this study I describe the main findings and methodological approaches used to characterize the ecosystems, and to assess the level of threats they face. Also I provide details about the procedures used to determine their level of health, and the results of this approach. Finally, I combine results from these approaches in a model that describes the level of vulnerability of the different aquatic systems of the region. The usage of several approaches permitted the definition of priority areas for the conservation of aquatic diversity of the UNRB.

2. STUDY AREA

2.1. Physiographic information

The UNRB has an area of 21,680 Km², is located in the northern part of the Ecuadorian Amazon and southern Colombian highlands, and its elevation ranges from 250 to 5850 m.a.s.l. (Figure 1). Its weather is similar to the average conditions of the Ecuadorian Amazon (Pourrut and Gómez 1995, Ayabaca 2004). Most locations have two defined seasons, rainy and dry. Average annual precipitation varies from 3000 to 6000 mm in the lowlands and foothills, and from 1000 to 2000 mm in the highlands. Average temperature ranges from 0 to 25 °C across the altitudinal range (Pourrut *et al.* 1995).

The main tributaries from the highlands are the Aguarico, Coca, and Napo Rivers, which transport white waters (waters loaded with large amounts of sediment). Mountainous rivers are fed by highland lakes and wetlands, as well as by glaciers, snowfields and rainwater. They collect water that passes through páramo ecosystems and mountain forest that grows over volcanic soils and heavily leached lands (Steinitz-Kannan *et al.* 1983). These rivers are characterized by high slope gradients and precipitation, which translate into elevated levels of kinetic energy, and consequently high levels of erosion and morphological change (Räsänen 1993, Pourrut and Gómez 1995). Their discharges have a distinct peak during the rainy season, but fluctuate widely during the year, especially in response to local rainstorms. The sediment load of these rivers can be very high. For instance, according to Galárraga (2000) 7 million tons/year is the average input of the Coca River into the Napo, which represents a main determinant of the physical systems downstream. Upper parts of rivers travel through deep valleys and have channels with abundant pools and riffles. Lower segments have more braided and meandering valleys, and in many cases are influenced by clear water (transparent waters without large sediment loads) rivers from the

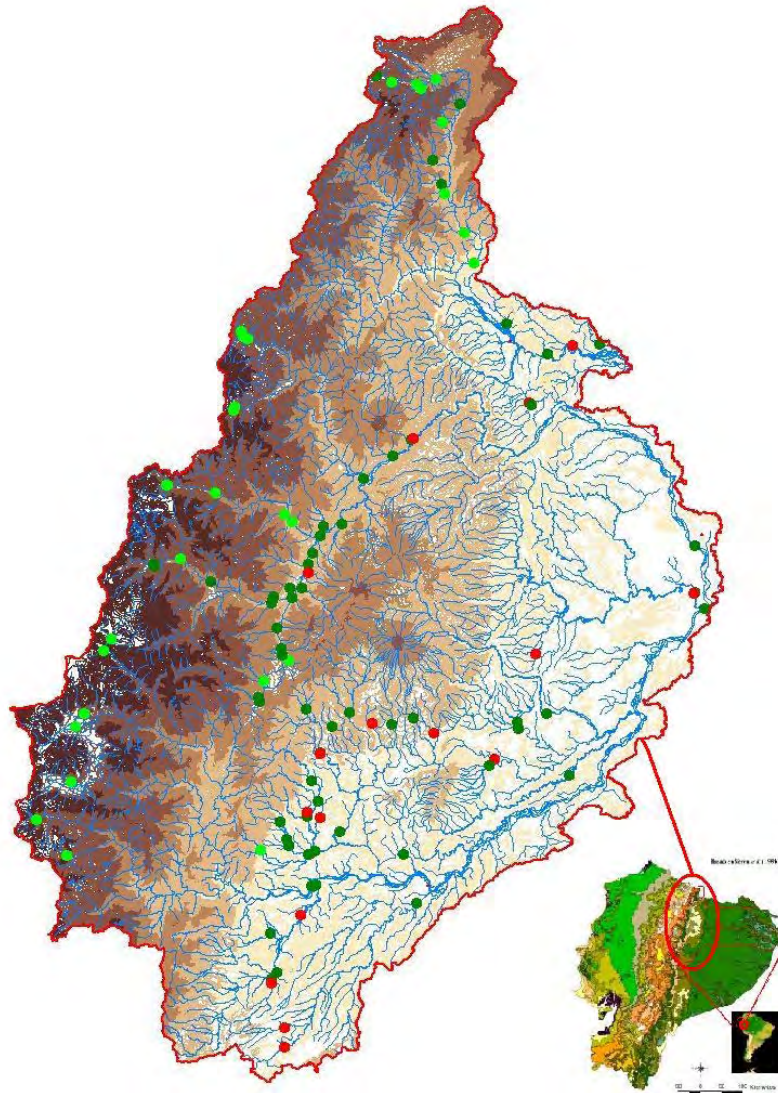


Figure 1. Sampling locations in the Upper Napo River Basin.

foothills and black water (water rich in tannins, but without large sediment loads) rivers from the lowlands. Segments of white water rivers in the lowlands meander and have shifting channels caused by continuous rates of sedimentation and erosion of river banks (Räsänen 1993). These ecosystems interact with extensive floodplains, where many different landforms are developed through this process (levees, islands, parallel and seasonal channels, oxbow lakes, etc.).

2.2. Patterns of resource utilization

Traditionally, Amazonian indigenous nationalities had subsistence livelihoods (Josse and Barragán 2001). Currently, demographic and cultural changes among locals, and the arrival of immigrants have changed the way natural resources are used (CONAMU 1999 in Galárraga 2000). In many cases, this has caused the conversion of large extensions of native forest to simple agricultural and pastoral systems (Pearman 1995). Also, local land management has been interconnected to several industrial activities. Forestry industries have exploited large areas of community forests, as well as forestry patrimony areas (usually buffer zones of nature preserves). Approximately 30% of industrial timber is produced in the Ecuadorian Amazon, which equals 800,000 m³ of wood extracted per year (Ruiz 2000). Forestry management entails opening roads in large areas through which, using heavy machinery, the most valuable trees (more than 60 cm dbh) are extracted. Mining and oil companies, supported by the State, control large claims over most of the Ecuadorian Amazon (Ruiz 2000). In some cases oil and mining exploration and exploitation has been permitted in national parks (e.g. Maxus-YPF in the Yasuní National Park), while in others their borders have been modified for the same purposes (e.g. Caiman-City-AEC and PetroEcuador in the Cuyabeno Wildlife Preserve). Other important industrial and agricultural activities (e.g. African palm, naranjilla and tea plantations, fish and poultry farming, etc.) are developed close to the largest towns in the region. Alternative agroforestry practices have been implemented in some areas at small scales. Other important activity/plan in the region is the regulation of river flows, mostly for generation of electricity, irrigation or domestic water production (Galárraga 2000). Several projects intend to increase the electrical capacity of the country by damming the main tributaries of the Napo River (Aguarico and Coca Rivers), while other projects already (or plan to) divert water flow for urban consumption and irrigation (Galárraga 2000, Echavarría 2002).

Five national parks and reserves cover approximately 9800 Km² of the UNRB (Ruiz 2000). However, in terms of available resources, attained organizational results, and achieved conservation goals, their efficiency has been very low (Josse and Cano 2001). Additionally, the Sumaco Biosphere Reserve adds 7280 Km² to the areas of conservation and sustainable use of natural resources, which totals almost 80% of the UNRB (Valarezo et al. 2002). Despite this large coverage in the region, many native ecosystems are below the minimum 10% objective of conservation goal (Josse and Cano 2001), but also a large percentage of these protected areas is already converted or degraded.

3. METHODS

3.1. Classification of aquatic systems

I classified the aquatic systems (watersheds) of the UNRB using spatial data in a Geographic Information System (GIS), and following a modified version of the Freshwater Initiative (FI) Approach of The Nature Conservancy (Groves et al. 2002, Higgins et al. 2005). This approach includes a hierarchical classification of aquatic systems, beginning with large-scale Ecological Drainage Units (EDUs). EDUs are contiguous groups of catchments that share common zoogeographic and physiographic characteristics (Higgins et al. 2005). They are a means of subdividing large watersheds and evaluating expected patterns of aquatic biodiversity based on surrogate variables (Higgins et al. 2005). I defined EDUs combining geology, vegetation, and hydrology layers, and grouping watersheds that have similar resulting patterns above confluences of main rivers or other main physiographic features in the watersheds (e.g. waterfalls, or sudden increases in terrain slope). I reclassified geology and vegetation layers from thematic maps of the country (Sierra 1996, PROMSA 2003) (Table 1). I used a 90m resolution gap-corrected Digital Elevation Model (DEM) (Shuttle Radar Topography Mission) to define watersheds/river segments, river networks, and a derived Stream orders grid, using Hydrological Modeling, WWF-Hydro, and Stream Order Tools, respectively, in ArcView 3.2 (ESRI). I performed an analyses of similarities (ANOSIM one way analysis – PRIMER v5) of Normalized Euclidean Distances of areas under different combinations of geology and vegetation inside each catchment to determine if EDUs were significantly different among each other (Clarke and Gorley 2001). Additionally, I performed pair wise comparisons to determine which EDUs were significantly different from others.

Table 1. Categories of variables employed in the hierarchical classification of aquatic systems of the Upper Napo River Basin.

Ecological Drainage Units				Aquatic Ecological Systems							
Geology		Vegetation		Elevation (m)		Slope (%)		River's order		Riverine connectivity	
Category	Name	Category	Name	Category	Name	Category	Name	Category	Name	Category	Name
1	alluvial rocks	1	White water flooded forests	1	< 600	1	0 - 2.5	1	1 & 2	1	2 & 3
2	clays	2	Black water flooded forests	2	600 - 1300	2	2.5 - 7.5	2	3 & 4	2	4 & 5
3	clays-sandstones	3	High mountain evergreen forests	3	1300 - 3600	3	7.5 - 20	3	5 & 6	3	6 & 7
4	calcareous clays	4	Low mountain evergreen forests	4	> 3600	4	> 20	4	7 & 8	4	8
5	intrusive rocks	5	Piedmont evergreen forests								
6	extrusive rocks	6	Lowland evergreen forests								
7	metamorphic rocks	7	Cloud mountain forests								
8	sandstones	8	High mountain grasslands								
9	heterogeneous sediments	9	Lowlands grasslands								
		10	High mountain moist shrubs								
		11	Perpetual snow cover								
		12	Herbaceous paramo								
		13	Cushion paramo								
		14	Espeletia's shrub paramo								

In a similar fashion, I defined Aquatic Ecological Systems (AES) for each EDU (Higgins et al. 2005). For the minimum unit of analysis I superimposed recategorized data on river orders, elevation, gradient, and riverine connectivity (based on the order of the lower adjacent reach) to the watershed/river segment layer, and determined distinct aquatic macrohabitats (Table 1). I used the 90m DEM to construct elevation and gradient maps of the basin. I grouped macrohabitats into AES based on their similarities and distribution inside each EDU. I used actual values of mean slope and mean elevation, and river orders and connectivity of each macrohabitat to conduct analyses of similarities (ANOSIM one way analysis - PRIMER v5) of Normalized Euclidean Distances of combinations of these variables to determine if AESs were significantly different from each other (Clarke and Gorley 2001). I performed pair wise comparisons to determine which AESs were significantly different from others and to regroup similar ones using iterative analyses of similarities. Additionally, I performed abundance analyses of AESs, and macrohabitats within EDUs, and all over the region to determine their degree of uniqueness. I obtained an index of uniqueness (or degree of irreplaceability) of systems, being the scarcer the more unique (5) and the more common the less unique (1).

3.2. Assessment of threats

I determined threats to EDUs and AESs using metrics that provided information about possible impacts of human activities (Allan et al. 2001, Karwan et al. 2001, Messina and Walsh 2001) (Table 2). I obtained metrics from thematic maps of the country and redefined them within the GIS (PROMSA 2003). I defined the level of forest conversion and degradation grouping current Land Use Land Cover (LULC) categories into three general levels of alteration of the original vegetal cover (EcoCiencia 2004a). I determined levels of threat of urbanization and infrastructure development assessing distances to current towns and roads (PROMSA 2003).

Table 2. Information used for the assessment of threats in the Upper Napo River Basin.

Threat	Criteria	Metric	Category				
			5	4	3	2	1
Land cover conversion and degradation	Land use / land cover	kind of	agricultural /		barren lands /		primary
		conversion	urban lands		secondary forest		vegetation
Urban development and other built up	Degree of imperviousness, sewage source	location of	presence of		1 km buffer of		absence
		towns / roads	towns / 0.5km buffer of roads		roads		
Oil industry	Land modification / erosion, toxic contamination	Kind of activity	oil pipelines	concessions under exploitation	concessions under exploration		absence
Mining	Land modification / erosion, toxic contamination	Kind of activity	concessions under exploitation	concessions under exploration			absence
Water diversions	Modification of hydrological patterns / loss of connectivity	Kind of activity	under execution		under construction	under planning	absence

I defined levels of threat from oil, mining, and water diversion concessions based on kind of activity and current status of extractive projects (EcoCiencia 2004b). I categorized metrics from 1 to 5, where 5 represents the highest level of threat to aquatic ecosystems. I added up categorized metrics to obtain an overall qualification of threats, and redefined them from 1 to 5, weighting the percentages of area covered under each category in each watershed/river segment. For this purpose I used Spatial Analyst Tool in ArcView 3.2. Additionally, I obtained separate qualifications of each threat for each EDU and AES following the same spatial analysis procedure.

3.3. Assessment of health

I conducted a field assessment, from June to August 2004, to evaluate the degree of health of the AESs. I followed a modified version of the physical habitat assessment of EPA (Barbour et al. 1999) (Appendix 1). I sampled 111 watersheds, representing 58% of the defined AESs, under three land use treatments (1 = pristine, 2 = semi-disturbed, and 3 = disturbed). I assigned these treatments to each watershed in relation to the percentage of area covered with original vegetation (or without obvious anthropogenic uses) according to current LULC maps (EcoCiencia 2004a). I categorized watersheds completely covered with original vegetation as pristine, those that have more than 50 % of original cover as semi-disturbed, and those that have less than 50% of original cover as disturbed (Appendix 2).

During this assessment I gathered information about five components of ecosystems: streamside zone, physical form, water quality, hydrology, and biota that provide reliable information about the condition of aquatic ecosystems (Karr 1991, Ladson et al. 1999, Norris and Thoms 1999) (Appendices 3-6). The first two components were used to determine the degree of health of AESs based on seven categorical variables (Appendix 3). In relation to the streamside

zone I evaluated the lateral continuity (width of riparian vegetation) and the structural intactness (percentage of disturbed vs. undisturbed areas). For the physical form I assessed the bank stability (percentage of eroded areas), the habitat stability (epifaunal substrata) and diversity (pool variability in low gradient “<1%” systems, and velocity depth regime in high gradient “>1%” systems), the degree of modification of the channel (presence and kind of artificial barriers), and the segment sinuosity (sinuosity ratio in low gradient systems, and frequency of riffles in high gradient systems). I assigned categories of health, ranging from 1 (low) to 5 (high), to different criteria under each variable (Table 3). Qualifications from the seven categorical variables were added up to obtain a general qualification of health for each watershed. I ranked qualifications of health of reference (pristine) systems to a maximum of five to assign final values of health to other systems under other conditions (Appendix 3).

I performed an additional assessment of health for each watershed based on non-categorical variables from the water quality, and hydrological components (Appendix 4 & 5). I measured *in situ* the pH, specific conductance ($\mu\text{S}/\text{cm}^2$), temperature ($^{\circ}\text{C}$), turbidity (NTU), and salinity (%) using a Horiba U-10 meter, and the total hardness ($\text{mg}/\text{l CaCO}_3$) using a HACH kit (1452-01). I calculated concentrations of suspended solids (SS) (mg/l) filtering water samples (500 ml to 4 l) with pre-weighted cellulose nitrate membrane filters (Whatman 0.45 μm , 47 mm), and re-weighting them after drying for 72 hours at room temperature. I collected at each location duplicate 60 ml water samples for laboratory analyses. In the laboratory, I measured DOC (mg/l) using a Shimadzu TOC- V total carbon analyzer. I measured NO_3 (μM), PO_4 (μM), NH_4 (μM), total phosphorus (μM), and total nitrogen (μM) using a Technicon AutoAnalyzer II System following standard procedures (Clesceri et al. 1998). I assessed *in situ* several hydrological variables: channel morphology (gradient, river width and depth at current level and at bank full), bed stability (relative distribution of sizes of bed materials), proportion of major habitats (pools, riffles, runs), and magnitude of flows (2030R Flowmeter General Oceanics Inc.).

Table 3. Categorical variables, and metrics used to assess the degree of health of rivers in the Upper Napo River Basin.

Category	Variable	Metric	5	4	3	2	1
Streamside zone	lateral continuity	width of riparian vegetation	>18 m	12-18m	6-12m	0.5-6 m	0 m
	structural intactness	% undisturbed area / % disturbed area	> 90/10	70/30 - 90/10	50/50 - 70/30	30/70 - 50/50	< 30/70
Physical forms	bank stability	evidence of degree of erosion	Stable/ <5%	Moderate stable / 5- 20%	Low stable / 20 - 60 %	Moderate unstable / 60 - 80 %	Unstable / > 80 %
	habitat stability	epifaunal substrata (low/high gradient)	>50 / >70%	40-50% / 60-70%	20-40% / 20-60%	10-20% / 20-40%	<10% / <20%
	habitat diversity	pool variability (low gradient)* / velocity-depth regime (high gradient)**	4 even /4 present	>LD <Sh / 3 w. FSh	>Sh <D / 2 Fsh & SSh	SSh / 2 D	absent / SD
	artificial modification of channel	presence and kind of artificial barriers	Absent	In bridges	40-80% channel.	80-100% channel.	100% channel.
	segment sinuosity	sinuosity ratio (low gradient) / frequency of riffles (high gradient)	>4 / <7	3 / 7 to 12	2 / 12 to 18	1 / 18 to 25	channel straight / > 25

* LSh = large shallow, LD = large deep, SSh = small shallow, SD = small deep

** SD = slow deep, SSh = slow shallow, FD = fast deep, FSh = fast shallow

I performed analyses of similarities (ANOSIM two way analysis -Primer v5) of four rooted normalized Euclidean Distances of water quality and hydrological variables to determine if land use treatments or AESs in each EDU were significantly different from each other (Clarke and Gorley 2001). I performed pair wise comparisons to determine which treatments and systems were significantly different from others. Also, I determined which combination of variables explained most of the variability among samples using BVSTEP routine of PRIMER v5. Additionally, I categorized, from 1 to 5, ten variables that have a predicted trend of change under different treatments in order to obtain a qualification of health based on water quality and hydrological variables.

Finally I performed an assessment of health according to the aquatic biota component (Appendix 6). For this purpose, I conducted a multi-habitat qualitative sampling of aquatic macroinvertebrates using a D-net during five minutes (Barbour et al. 1999). I preserved samples in ethanol (75%) and transported them to the laboratory for macroinvertebrate sorting and identification. Most specimens were identified at the genus level, and in some cases to the family level, using dichotomous keys (Merrit and Cummins 1996, Roldán 1996, Fernández and Domínguez 2001).

I used two kinds of information from aquatic macroinvertebrates to evaluate the degree of health of sampled locations: compositional information of aquatic communities, and Benthic Indexes of Biotic Integrity (BIBI): # of families, # of genera, # taxa of Coleoptera, # taxa of Ephemeroptera, # taxa of Hemiptera, # taxa of Megaloptera, # taxa of Odonata, # taxa of Plecoptera, # taxa of Trichoptera, # taxa of intolerant organisms, # of pollution intolerant families (Modified Family Benthic Index, MFBI) (Plafkin et al. 1989), and # taxa of Non-Chironomidae. I performed analyses of similarities (ANOSIM two way analysis -Primer v5) of Bray-Curtis coefficients of square rooted compositional variables, and normalized Euclidean distances of

BIBIs variables, to determine if treatments or systems in each EDU were significantly different from each other (Clarke and Gorley 2001). I performed pair wise comparisons to determine which treatments, and systems were significantly different from others according to the two macroinvertebrate assessments. Finally, I determined which variables explained most of the variability among samples using BVSTEP analysis (PRIMER 5), and obtained a qualification of health, from 1 to 5, based on biological variables (BIBIs) that had a predicted trend to the impacts of human activities.

3.4. Assessment of vulnerability

I defined a vulnerability (V) model that accounted for the different levels of uniqueness (U), threats (T), and health (H) of aquatic systems: $V = U + T + H$

Based on the relationship ($H = mT + b$) that I found between the degree of health and the level of threat of sampled ecosystems, where m = slope and b = intercept on the y axis, I determined the level of vulnerability of non sampled aquatic systems, using the following formula: $V = U + T + 5(mT + b)/(mT_{\min} + b)$. To confirm the relationship between threats and health I employed a categorical regression model (CATREG, SPSS 12) between these two main derived variables.

4. RESULTS AND DISCUSSION

4.1. Classification of aquatic systems

Using the FI Approach I defined five EDUs in the UNRB (Figure 2, Table 4). Performing analysis of similarities based on the geological and land cover information I found that the EDUs were significantly different from each other ($R=0.307$, $P=0.001$, $n=2620$ polygons). Through the pair wise comparisons I found that every EDU differed from the others. The most similar EDUs were EDUs 2 (Quijos headwaters) and 3 (Jatunyacu headwaters) ($R=0.022$, $P=0.049$). Most of EDUs 2 and 3 originate in the Central Andean Range above tree line (3600 m) on snow-capped volcanoes (up to 5850 m), and high elevation grasslands (páramos). They drain terrains composed of extrusive, intrusive and metamorphic rocks, and constitute the headwaters of the Coca and Napo Rivers, respectively. Despite the many common physiographic features between these adjacent EDUs, they are separated by approximately 300 Km of reaches of rivers of up to seventh order. Based on the notion that large river reaches, or sudden geomorphic changes in river channels can act as barriers to the distribution of some aquatic biota (Groombridge and Jenkins 1998), as is the case of EDUs 2 and 3, I assumed these two regions are biologically distinct. EDU 1 (Aguarico headwaters) also originates in the Central Andean Range and in part of the Eastern Andean Range (Cordillera Real Oriental) over similar terrains, but its headwaters are born at lower elevations in shrubby and forested ecosystems. This EDU is separated from the adjacent EDU 2 by 700 Km of river segments. Therefore, I expect this EDU to be even more distinct in terms of aquatic biodiversity. Remaining EDUs, 4 (Sumaco Watersheds) and 5 (Guacamayos Cordillera Watersheds) originate in forested ecosystems around 2000 m on the Eastern Andean Range. EDU 4 drains a volcanic region, while most of EDU 5 develops over an older inactive region. Extrusive and calcareous rocks are more common in EDU 4, and intrusive rocks are more abundant in EDU 5.

UNRB EDUs

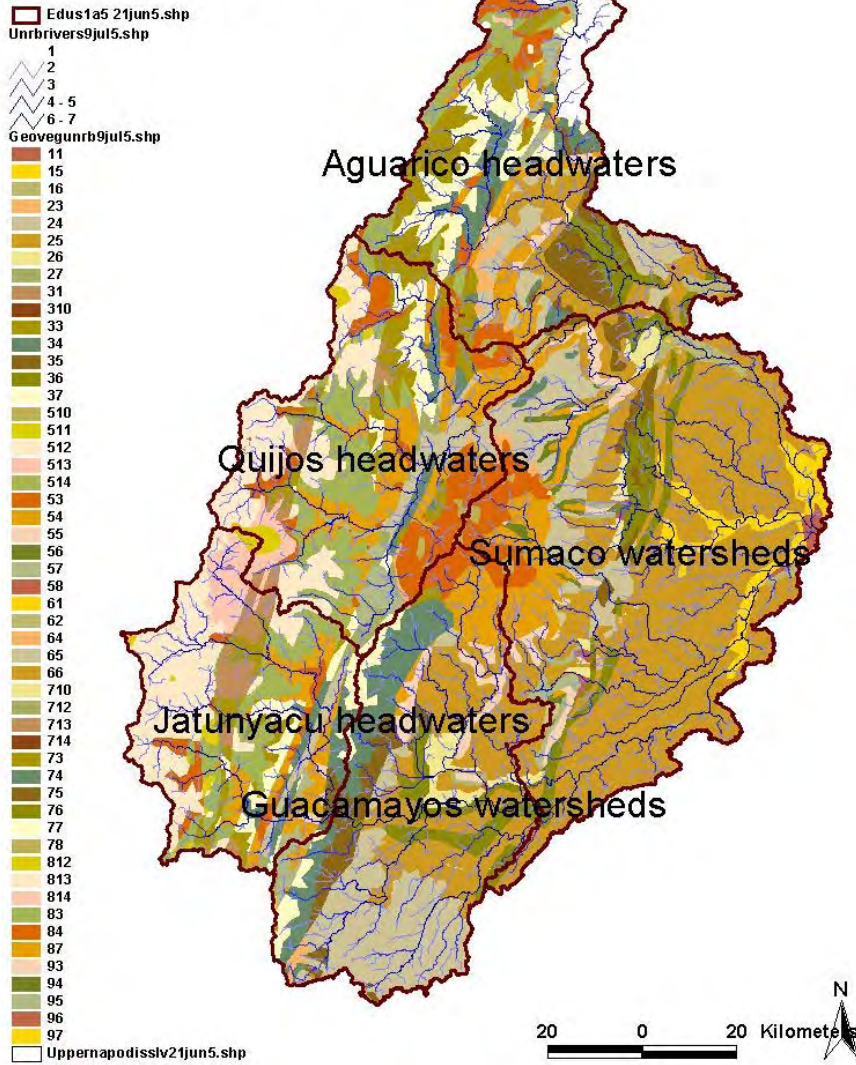


Figure 2. Ecological Drainage Units of the Upper Napo River Basin based on combinations of vegetation and geology.

Superimposing information about elevation, slope, river orders and connectivity, I found 203 kinds of aquatic macrohabitats among 1342 watersheds/river segments (Table 4). I grouped these into 89 systems and clustered them into 48 distinct AESs through iterative analyses of

Table 4. Ecological Drainage Units, Aquatic Ecological Systems, and macrohabitats of the Upper Napo River Basin.

EDU	Name	Area	Area under	Mean	Mean	AES	macrohabitat's	macrohabitat's	average uniqueness
			conservation	elevation	slope		richness	richness	abundance
		(Km²)	status (Km²)	(m)	(%)	richness	richness	abundance	& (range)
1	Aguarico headwaters	3891.1	1516	1735.65	17.99	12	36	248	3.44 (1-5)
2	Quijos headwaters	3886.6	3203	2445.33	17.83	9	30	259	2.97 (1-5)
3	Jatunyacu headwaters	2928	1330	2834.99	18.09	7	29	177	3.62 (1-5)
4	Sumaco watersheds	6952.8	2529	653.76	6.38	14	63	411	3.38 (1-5)
5	Guacamayos Cordillera watersheds	4021.7	1242	928.79	9.8	6	45	247	3.64 (2-5)
total		21680	9820			48	203	1342	3.41 (1-5)

similarities (Table 4). EDUs 4 and 5 had the highest macrohabitat richness (63 and 45, respectively), followed by EDUs 1 and 2. EDU 4 also had the highest number of AESs, followed by EDUs 2, and 1. On the other hand, EDUs 5 and 3 had the highest ecosystem uniqueness (3.64 and 3.62 over 5), defined by the proportion of unique/rare macrohabitats present in the EDUs (Table 4). Richness of macrohabitats in each EDU appears to be partially related to the size of these regions, and probably influenced by large environmental variability of the terrain (i.e. EDU 1) (Table 4). On the other hand, uniqueness values reflect the relative abundance of macrohabitats along the whole context of the UNRB, and provide more insight on the distribution and abundance of possible aquatic systems in the region. Also, the usage of macrohabitats for uniqueness estimations was more adequate than that of AESs because they were more comprehensive surrogates of biodiversity than AESs. Even though AESs permitted the synthesis of information and performance of practical comparisons among watersheds under different levels of health and threats.

This classification of aquatic systems of the UNRB is not definite, but it is the first such classification of Amazon systems in Ecuador. More importantly it sets a base for conservation assessment and prioritization of aquatic systems in the region. It shows possible patterns of aquatic diversity based on surrogate environmental conditions and emphasizes the watershed approach in the definition of conservation goals (Naiman et al. 1998). As seen in the next sections, threats and condition of aquatic habitats are largely dependent on conservation issues at the level of watersheds.

4.2. Assessment of threats

The Upper Napo River Basin had an overall level of threat of 1.77 ± 0.57 (over a maximum of 5) (Table 5). This relatively low level of threat for the region is due to the fact that

Table 5. Threat scores and extent in the Upper Napo River Basin by Ecological Drainage Units. On bold are the activities that had higher scores and extent in each EDU.

Threat	UNRB		EDU 1		EDU 2		EDU 3		EDU 4		EDU 5	
	score	extent (%)	score	extent (%)	score	extent (%)	score	extent (%)	score	extent (%)	score	extent (%)
Water diversion projects	1.44	28.01	1.36	36.27	1.57	29.48	2.69	99.49	1.06	6.05	1.11	5.13
Conversion & degradation of the land cover	1.84	23.09	1.55	15.48	1.55	16.77	1.06	1.54	2.05	27.88	2.58	43.19
Buffered roads	1.39	12.81	1.59	18.75	1.51	16.59	1.42	13.66	1.24	8.34	1.33	11.04
Buffered towns	1.29	7.12	1.38	9.47	1.19	4.69	1.02	0.47	1.34	8.59	1.39	9.72
Oil activities	1.92	30.23	1.47	15.25	1.26	7.39	1	0	2.59	53.02	2.44	47.89
Mining concessions	1.11	5.29	1.19	9.54	1.01	0.68	1.03	1.42	1.07	2.69	1.27	13.36
Added threats	1.77	53.64	1.5	32.65	1.46	30.1	1.2	18.42	2.03	76.14	2.3	81.42

large areas (83.1 %) remain under the lowest levels (1 & 2) of threat, while a small area (6.6 %) falls under the two highest levels (4 & 5) of threat. The most threatened EDU was EDU 5 – Guacamayos Cordillera Watersheds (2.30), and the least threatened corresponded to EDU 3 – Jatunyacu headwaters (1.20) (Table 5). Overall, the most threatened AES in the region was system 43 (EDU 5) with a level of threat of 2.87, and the least was system 34 (EDU 4) with a 1.01 level of threat. The most threatened AES per EDU were systems 2 (EDU 1), 14 (EDU 2), 22 (EDU3), 30 (EDU 4), and 43 (EDU 5) (Figure 3).

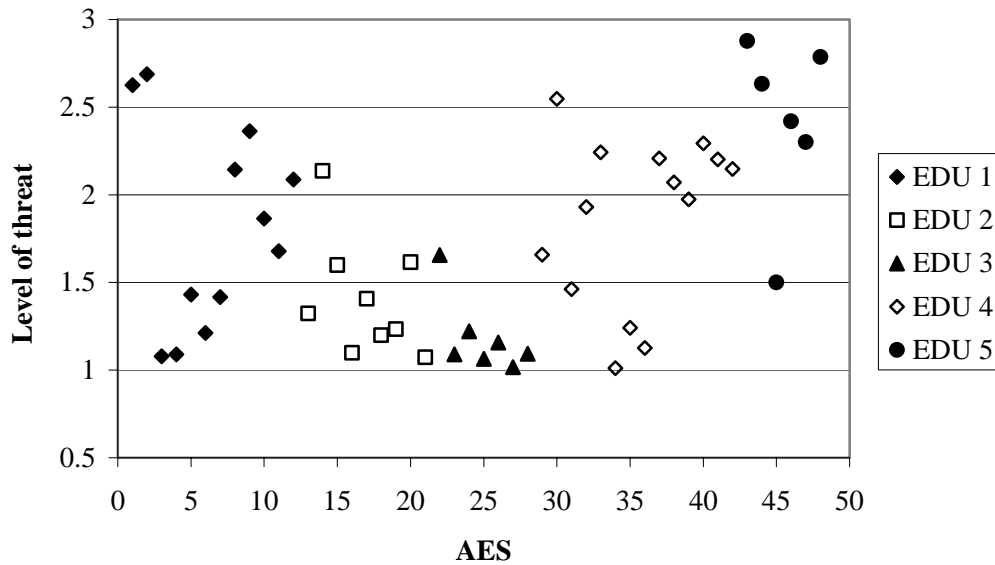


Figure 3. Level of threats of Aquatic Ecological Systems (AESs) of the Upper Napo River Basin.

The most widespread threat in the region is oil concessions (30.2 % mostly under a category of 4) (Table 5). Water diversion projects are the second most widespread threat (28.0 % at category 2, 4 and 5). Conversion and degradation of land cover was the third most widespread threat (18.1 % classified as a level 5 threat, and 4.1 % as a 3 level threat). Buffered roads covered 6.6 and 6.2 % of the basin, at level 5 and level 3, respectively. Human settlements and mining

concessions threatened 7.1 and 5.3 % of the region, at level 5 and level 3, respectively. Table 5 and Figure 4 show how these activities threaten EDUs and AES, respectively.

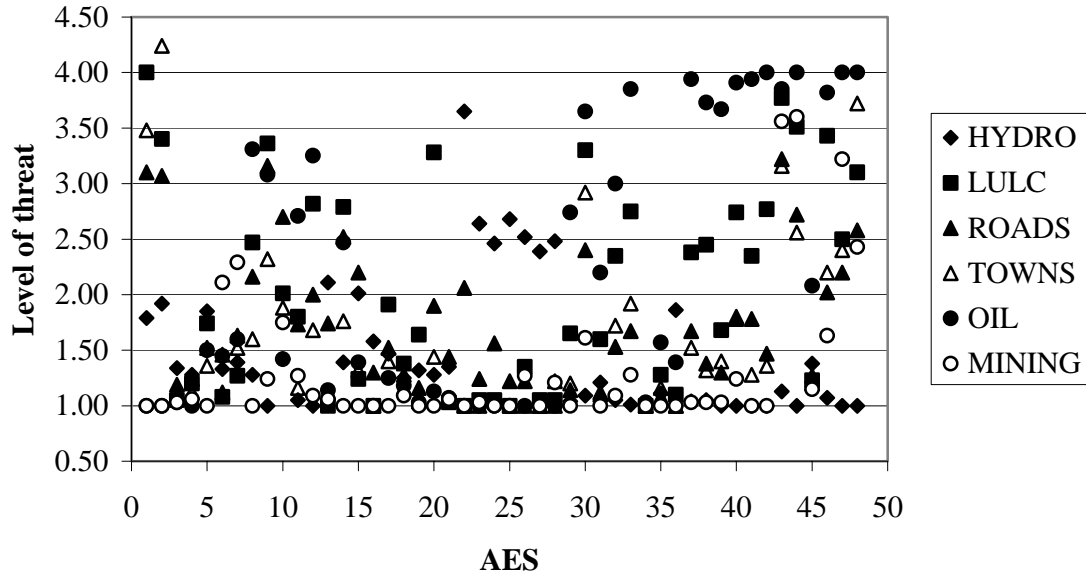


Figure 4. Separate threats of Aquatic Ecological Systems (AESs) in the Upper Napo River Basin. HYDRO = Water diversion projects, LULC = Land cover conversion and degradation, ROADS = Buffered roads, TOWNS = Buffered towns, OIL = Oil activities, MINING = Mining concessions.

Highly threatened EDUs and AES are affected by cumulative effects of activities of large extent and high levels of threat. EDU 5 had the higher level of threat because it had the larger percent of converted/degraded land cover, towns, and mining concessions. Also, it had the second largest relative extent of oil concessions. These patterns of threats also reflect the level of development of the different sectors, the historical use of resources (e.g. EDU 5 had the oldest contemporaneous concentration of human settlements in the region), and their physiographic conditions (e.g. on average EDU 5 had one of the lowest slopes of the terrain) (Table 4). Low slope terrains, with older settlements, are prone to support more activities, and therefore to have larger cumulative effects on their environment. On the other hand, steeper terrains and harsher

environments had lower probabilities of having cumulative threats, though their habitats could be more sensitive to human activities (Luijten et al. 2001, Vanacker et al. 2003). Despite the fact that categories of threats reflected the current or potential effects of human activities, their nature (e.g. intensity, magnitude, duration) must be considered when evaluating their effects on the environment (Downs and Ambrose 2001). For instance, towns and roads might have localized effects on rivers, but the intensity of their impacts could be very high. On the other hand, oil concessions or water diversion projects cover extensive areas, in many cases under a relatively low level of threat, but their widespread effects could be felt in the mid to long term. The severity of their impacts might vary with the mitigation measures implemented during the different phases of these projects. However, the low level of enforcement of environmental laws, and some misconceptions about the nature and utilization of aquatic resources (as reflected in some laws and regulations) do not promote their application in the country. Closely linked to this problem are the conservation status of aquatic systems, and consequently their degree of health

4.3. Assessment of health

4.3.1. Physical habitat assessment

According to the physical assessment of health the 111 studied watersheds had an average level of health of 4.28 ± 0.58 over a maximum level of 5. The highest level of health (5) was found under reference conditions of several systems (Table 6). The lowest level of health (2.87) was recorded for AES 8 (EDU 1). Despite AES 8 is not the most threatened AES in EDU 1 (Aguarico headwaters), it obtained a low health rank because the structure and continuity of

Table 6. Degree of health of sampled Aquatic Ecological Systems of the Upper Napo River Basin.

Health		EDU 1	EDU 2	EDU 3	EDU 4	EDU 5
Physical habitat health (range)		4.55 +- 0.66 (5 - 2.87)	4.45 +- 0.54 (5 - 3.13)	5 +- 0 (5)	3.84 +- 0.36 (4 - 3.01)	3.98 +- 0.38 (5 - 3.11)
Water Quality-hidrological health (range)		4.46 +- 0.59 (5 - 3.31)	4.29 +- 0.63 (5 - 2.98)	5 +- 0 (5)	3.83 +- 0.36 (4 - 3)	3.94 +- 0.39 (5 - 3.04)
BIBIs health (range)		4.39 +- 0.93 (5 - 2.39)	4.13 +- 1.13 (5 - 0.55)	5 +- 0 (5)	3.77 +- 0.71 (4 - 2.00)	3.63 +- 0.55 (5 - 2.00)
Overall degree of health		4.49 +- 0.55 (5 - 3.56)	4.29 +- 0.65 (5 - 2.58)	5 +- 0 (5)	3.81 +- 0.44 (4 - 2.91)	3.91 +- 0.39 (5 - 2.91)
% of healthy systems (5)		62.5	39.47	100	0	3.03
# of sampled systems		16	38	8	16	33

riparian vegetation, and the bank and habitat stability of the sampled system (Duvino River) were fairly low (2 to 3 over 5). Non-point source pollution at the sampling location was evident, and its land use was largely represented by pastures, residential and industrial (oil) facilities. Conversely, EDU 3 – Jatunyacu headwaters had the larger number (8) of AESs under the highest level of health, in relation to the number of sampled systems in that EDU. EDU 3 is the least intervened EDU mostly because of the inhospitable environment and the scarcity of roads. Even though it has some modification of land cover, mostly by agricultural and ranching practices, most rivers in this EDU had well preserved riparian vegetation and fair bank stability. In some cases, the riverine habitat stability has been affected to some extent (up to 2 over 5) by ranching practices (e.g. Valle River), but the adding of scores from other variables gave an overall good physical health of these rivers. EDU 4 – Sumaco watersheds had the larger number (16) of systems with some degree of alteration. Approximately half of the terrain of this EDU is located at relatively low elevation, and in many areas the land cover has been converted extensively. Also this EDU has the second highest level of threat of the region, which apparently is related to the degradation of riverine systems of this EDU. These results agree with the main findings obtained through the assessment of threats, showing that the degree of health of the habitat had a significant inverse relationship with the level of threats ($r^2=0.438$, $F=29.569$, $P<0.001$, $n=111$).

4.3.2. Water quality and hydrology

Based on the water quality and hydrological assessment I found significant differences among treatments ($R=0.222$ $P=0.034$) and AESs ($R=0.319$ $P=0.001$) between sampled watersheds. Performing separate analyses for each EDU, I did not find significant differences among treatments, except in EDU 2 ($R=0.367$ $P=0.045$). In other cases, as EDU 3, the absence or small number of replicates in some of the treatments limited the outcome of these analyses. On

the other hand, I found significant differences among AESs in EDUs 2 ($R=0.355$ $P=0.007$) and 4 ($R=0.444$ $P=0.021$). However, according to the pair wise comparisons some AESs had similar water quality and hydrological characteristics. Using a relatively large sample ($n=111$) it was possible to determine differences among semi-disturbed and disturbed conditions ($R=0.368$ $P=0.001$), and similarities among pristine and semi-disturbed conditions ($R=0.31$ $P=0.934$). These results suggest that severe land use treatments have a strong effect on these features of aquatic ecosystems in the region. Similarities among pristine and disturbed conditions might reflect the low number of samples amongst treatments (24 and 26 respectively) based on the number of possible permutations performed in the analysis; but also the large variability of water quality and hydrological condition along the range. The large number of variables (17 out of 21) that explains 95.7 % of the variability among samples confirms this hypothesis. Variables responsible of this variability were: % pools, average river width and depth, temperature, pH, hardness, salinity, DOC, TP, NO_3 , NH_4 , SS, velocity, and % of bedrock, cobbles, boulders, and sand.

Average degree of health of sampled watersheds based on categorizations of variables with unidirectional response to change was 4.20 ± 0.58 . EDU 3 had the higher level of health, followed by EDUs 1 and 2 (Table 6). EDUs 4 and 5 had the lower average levels of health. Also, EDU 2 had the AES (15) with the lowest level of health (2.98). This system, the Papallacta River, reflects the cumulative effects of intense organic pollution from the town of Papallacta upstream of the sampling location, as well as the diversion of its flow for the generation of electricity. Changes in water chemistry and scouring of the habitat are noticeable, and clearly are caused mostly by these two activities. Overall, results from the water quality and hydrological assessment agree with main findings based on the physical assessment of health ($r^2=0.819$, $F=166.704$, $P<0.001$, $n=111$). Also, as with the physical assessment I found a significant inverse relationship between the water quality-hydrological degree of health and the level of threats of sampled AES ($r^2=0.292$, $F=16.139$, $P<0.001$, $n=111$). Considering that locations were sampled

only once it is important to find that there is a clear relationship between the degree of health, based on the water quality and hydrology, and the level of threats of these locations.

4.3.3. Aquatic Macroinvertebrates

Based on the relative abundances of aquatic macroinvertebrates I did not find significant differences among treatments ($R=0.026$ $P=0.583$) in sampled watersheds. Using benthic integrity biotic indexes (BIBI) I found a better separation of treatments ($R=0.11$ $P=0.08$), and significant differences in EDU 5 ($R=0.183$ $P=0.048$), the most threatened EDU. Overall, on both assessments (relative abundances and BIBIs) I found significant differences among systems ($R=0.324$ $P=0.001$, $R=0.332$ $P=0.001$, respectively). Using relative abundances I found significant differences among systems in EDUs 1 and 2 ($R=0.695$ $P=0.003$ and $R=0.282$ $P=0.014$, respectively), while using BIBIs I found significant differences in EDUs 2 ($R=0.422$ $P=0.001$) and 5 ($R=0.215$ $P=0.048$). Performing the BVSTEP analysis I found that eight variables explained 96.2% of the variability among samples: # genus, # taxa of Coleoptera, Hemiptera, Odonata, Plecoptera, and Trichoptera, plus the # of intolerant taxa, and the MFBI. Large variability of these variables reflects very different health condition of sampled locations. Categorizing BIBIs with reference values I found an average level of health of 4.09 ± 0.90 among sampled watersheds. EDU 3 had the highest level of health, followed by EDUs 1 and 2 (Table 6). EDU 1 to 3 had higher scores for categorizations of taxa of Odonata, Plecoptera, and Trichoptera typical families of healthy environments. On the other hand, EDU 4 and 5 obtained larger scores for taxa of Coleoptera and Hemiptera, which are more abundant in less healthy riverine ecosystems. AESs 15 and 17 (EDU 2) had the lowest levels of health among sampled systems (Table 6), which is associated to the proximity of human settlements. The Papallacta and Tumiguina Rivers (AES 15) and the Victoria River (AES 17) drain the terrains of Papallacta and Cuyuja towns, respectively. Low scores for these rivers are presumably associated with sewage

and nearby roads from these towns. I found significant relationships between the BIBIs degree of health and the physical ($r^2=0.563$, $F=48.270$, $P<0.001$, $n=111$) and water quality-hydrological ($r^2=0.70$, $F=129.367$, $P<0.001$, $n=111$) categorizations; as well as a significant inverse relationship with the level of threat ($r^2=0.195$, $F=9.887$, $P<0.001$, $n=111$). Apparently, the degree of BIBIs health is more closely related to the water quality and hydrological conditions of the rivers, rather than to the physical habitat. This result is very obvious in the Papallacta River, which recorded the lowest scores in the BIBIs and water quality-hydrological assessments of health. Despite differences in the relationships between the three assessments, overall they agree in their relationship with the level of threats of AES.

On average the aggregated level of health (from the three assessments) of sampled watersheds was 4.19 ± 0.60 and ranged from highest degree (5) of reference conditions to 2.58 of AES 15 (EDU 2) (Table 6). Overall EDU 3 had the highest level of health because it consists mainly of reference locations; while EDUs 4 and 5 had the lowest degree of health due to the more common presence of disturbed systems. I found a significant relationship between the overall degree of health and the level of threat of 27 sampled AESs ($r^2=0.560$, $F=34.119$, $P<0.001$, $n=108$) (Figure 5). Similarly, this result is very significant because it included three different categorizations under a wide range of environmental conditions. Also, the relationship between threats and health expressed in Figure 5 permitted to extrapolate this pattern of health to non-sampled systems in the region, which was necessary for the assessment of vulnerability of systems in the UNRB.

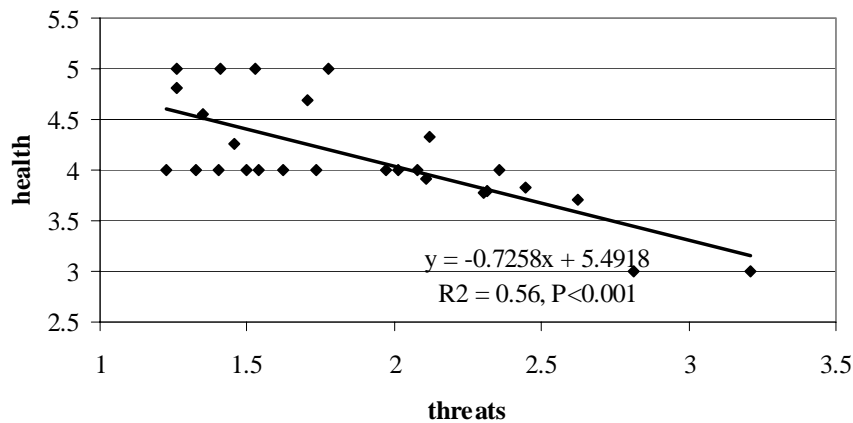


Figure 5. Relationships between level of threat and degree of health of Aquatic Ecological Systems (AESs) of the Upper Napo River Basin.

4.4. Assessment of vulnerability

According to the actual assessment of vulnerability the Upper Napo River Basin had an average degree of vulnerability of 2.55 ± 0.59 over a maximum category of five. Most of the UNRB is classified as having relatively low levels of vulnerability (54 and 11 % at levels 2 and 1, respectively), and about 13% of the area is under levels 4 and 5. Vulnerability levels vary from one EDU to another and depending on the system under consideration. Overall the most vulnerable EDU was EDU 5 with an average level of 2.66 ± 0.44 , followed by EDUs 4 (2.53 ± 0.46) and 1 (2.40 ± 0.40) (Figure 6). The least vulnerable EDUs were EDU 3 (2.14 ± 0.24) and EDU 2 (2.18 ± 0.41). In general, the most vulnerable system was AES 11 (EDU 1) with a degree of vulnerability of 3.84 ± 1.09 (Figure 7). On the contrary, system 23 (EDU 3) was the least vulnerable to current threats, with a qualification of 1.37 ± 0.37 (Figure 7). High vulnerability levels of EDUs 4 and 5 are mostly attributed to a high degree of habitat uniqueness, the healthy condition of ecosystems (which permits the maintenance of large levels of biodiversity), and large levels of threats. Despite the high level of threats in EDUs 4 and 5, some systems are in good condition because many activities are still in the planning phase. However, this situation could

change rapidly once these projects enter the implementation phase or spread over the region as planned.

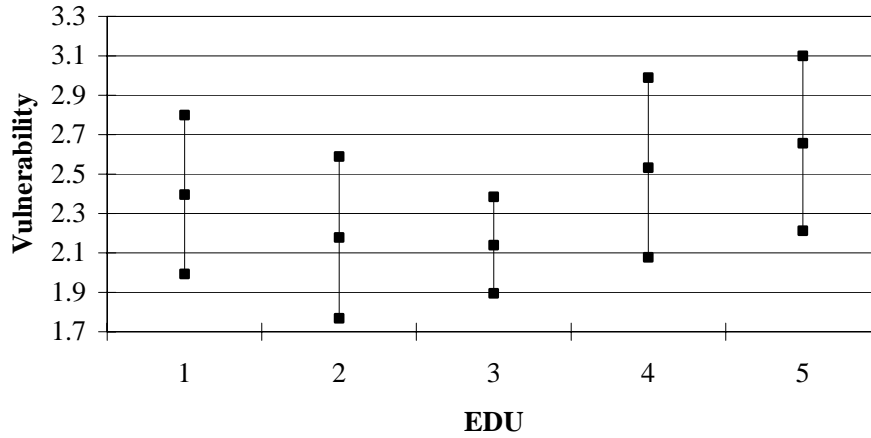


Figure 6. Average vulnerability of AESs by EDUs of the UNRB.

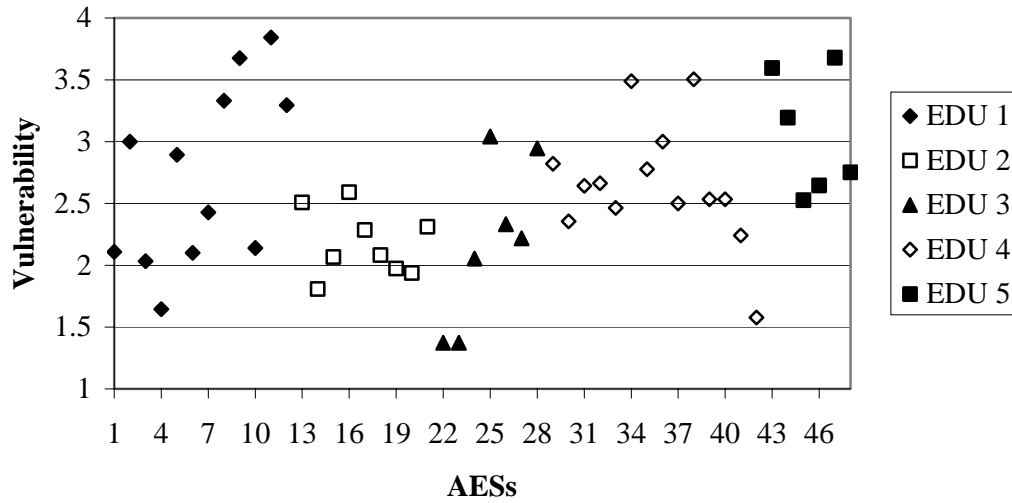


Figure 7. Levels of vulnerability of AESs of the UNRB.

In relation to this, I would like to indicate that even though EDUs 2 and 3 are the least vulnerable EDUs of the region, these results could change drastically if development projects take

over the area. According to the assessment of health (BIBIs) of systems in EDU 2, they are very sensitive to the impacts of human activities. Smaller, and simpler systems are less resistant than larger and more complex ones, and therefore more sensitive to the effects of human activities. EDU 3 had similar physiographic features to EDU 2, therefore levels of sensitivity could be similar, and vulnerability to biodiversity loss could be even larger due to its higher level of habitat uniqueness.

High levels of vulnerability of EDU 4 are accounted for mostly by large areas under pristine conditions, relatively high levels of uniqueness, and very high levels of threats. While this EDU is not the most vulnerable in the study area, its high level of habitat richness makes it particularly important in terms of biodiversity conservation. Probably, this EDU has the highest levels of genus or family richness for some animal groups, if habitat patterns are proportionally related, and due to its large extent in the UNRB. The fact that it has large areas of low-relief terrain, suitable to the development of several human activities, makes EDU 4 very vulnerable to diversity loss. Also, the level of inhabitation of this EDU is relatively high, which could largely affect the condition of AESs of the region, as seen in more densely populated areas like lower EDU 4 and EDU 5. EDU 1 and 5 also have high levels of habitat diversity, and probably similar levels of species richness; however, due to extensive degradation of aquatic systems (specially in EDU 5) levels of diversity could already be affected. EDU 1 still has large areas under pristine condition, especially in the highlands, which might have relatively higher levels of vulnerability than other areas in the same EDU.

In order to determine more effectively the level of vulnerability of aquatic systems of the UNRB, results should be viewed at the level of macrohabitats, or AES. For instance, EDU 1 had the most vulnerable AESs of the region, but also in conjunction with EDUs 4 and 5 had the larger number of AESs above the average level of vulnerability of the UNRB (Figure 7). On the other

hand, EDU 3 had the least vulnerable systems, but also (similarly to EDU 2) the lower number of systems above the average vulnerability level. Another fact that influences the level of vulnerability of these regions is the relative level of conservation determined by the presence of natural reserves. For instance, EDU 5 has the lowest relative extent under legal conservation status in the UNRB (31%), while EDU 2 has more than 80% of its area under this category (Table 4). According to this perspective, overall levels of vulnerability are higher (3.10 ± 0.93), and larger areas are under relatively high levels of vulnerability (43 and 7% at category 4 and 5, respectively). Areas at the lowest levels of vulnerability cover 33% of the UNRB. Also, systems located outside reserves are relatively more vulnerable than systems inside reserves and should be considered as priorities for conservation action in the UNRB (Figure 8). EDUs 1 and 4 have the largest number of AESs with vulnerability levels above the average for the UNRB (nine in both cases), while EDUs 2 and 3 AES have none and two, respectively (Figure 8). AES 47 (EDU 5) is the most vulnerable system (4.66 ± 1.45), while AES 18 is the least vulnerable (1.49 ± 0.33)

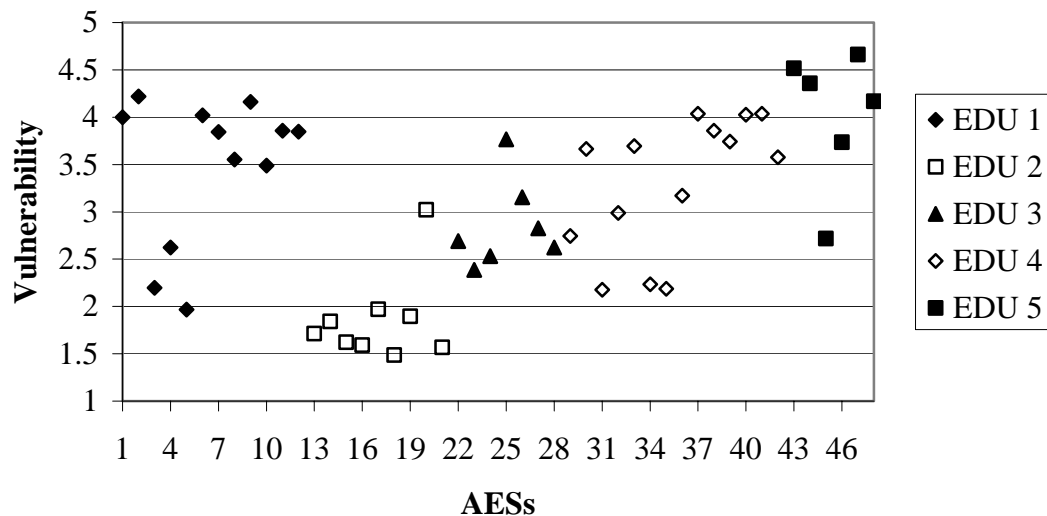


Figure 8. Levels of vulnerability of AESs of the UNRB considering their conservation status in the Ecuadorian National System of Protected Areas (SNAP).

(Figure 8). AES 47 is located outside conservation areas, while AES 18 is represented in two conservation areas in the highlands. However, modeled vulnerability values showed that even legal conservation status does not promote conservation of ecosystems, when there are local inhabitants, and conflicting interests involved. These results suggest that conservation should take place inside and outside reserves, through the application of sustainable practices, and measures that mitigate the impacts of human activities or improve the condition of systems already affected.

Another concept already being applied in the UNRB, but with several limitations and constraints due to its nature and several socio-economic problems, is the implementation of wider categories of conservation. Most of EDU 4 and part of EDUs 5 and 2 are currently part of the Sumaco Biosphere Reserve (SBR), which has a total extent of 9319 Km², and includes 2053 Km² of core areas (Sumaco Galeras National Park) and the remaining areas as buffer and transitional zones. The goal of this management category is to promote the protection of the environment and the integral development of the rural and urban populations of the SBR (Valarezo et al. 2002). The implementation of this goal is limited by growing anthropogenic threats that are already degrading the natural and cultural resources, the high levels of poverty and low local development, and the limited technical and managerial capacity of involved institutions in the SBR. The management plan of the SBR addresses these problems in a general way, but does not provide complete guidelines to facilitate its implementation. It lacks information about the current state of some components of the landscapes, and about the details of the approaches that should be followed to reach planned objectives. In this context, this study provides information about the condition, and threats of riverine systems in the SBR, and indicates on which systems actions should be prioritized. For instance, northern Andean headwaters (Cofanes, Chingual, and Due watersheds) of the Aguarico River, which might be the most biologically distinct area of the UNRB, should be considered as a potential bi-national conservation area of the region (Figure 9).

This could promote the conservation of biodiversity, and the social stability of the region. Similarly, larger areas of the Jatunyacu headwaters, one of the most unique EDUs, should be included in conservation areas that improve the terrestrial and riverine connectivity of ecosystems (Figure 9). Integrated watershed management practices should be applied in the Cosanga and Quijos Rivers (EDU2), lower EDU 4, and EDU 5. The creation of private reserves, the development of alternative and sustainable sources of income (tourism, rafting, carbon sequestration, provision of water resources, etc.) the promotion of reforestation and remediation activities, and the enforcement of environmental regulations should be considered seriously by local governments, socio-environmental organizations, and developing institutions in EDUs 4 and 5. Even though these EDUs are the most conflicting in terms of economic and political interests in the UNRB, they also have many opportunities for the development of different alternative and sustainable practices.

Other approaches in the region, as is the case of the Condor Bioreserve, propose the implementation of a similar concept, but at a larger scale. This approach promotes the connectivity of five national parks and reserves through the inclusion of other conservation areas, and the development of sustainable practices in surrounding areas. The feasibility of this project depends on the political will of all the stakeholders involved, from local inhabitants to governmental and international organizations. Also it depends on financial stability, and mostly on institutional challenges among involved organizations. The application of sustainable management practices in the region requires the inclusion of conservation goals in the objectives of a variety of institutions, and a common perspective about the vision of the region. Main limitations to achieve these goals are the disconnect of laws and regulations, the restricted market competitiveness of biodiversity and environmental services in the country, the persistence of separate views and plans for the region, and the lack of comprehensive guidelines for the application of sustainable practices. Overall, this situation is even more problematic in relation to

the aquatic systems of the region, mostly because of a generalized misconception of their role and condition, and by their relatively limited consideration when scheduling conservation goals.

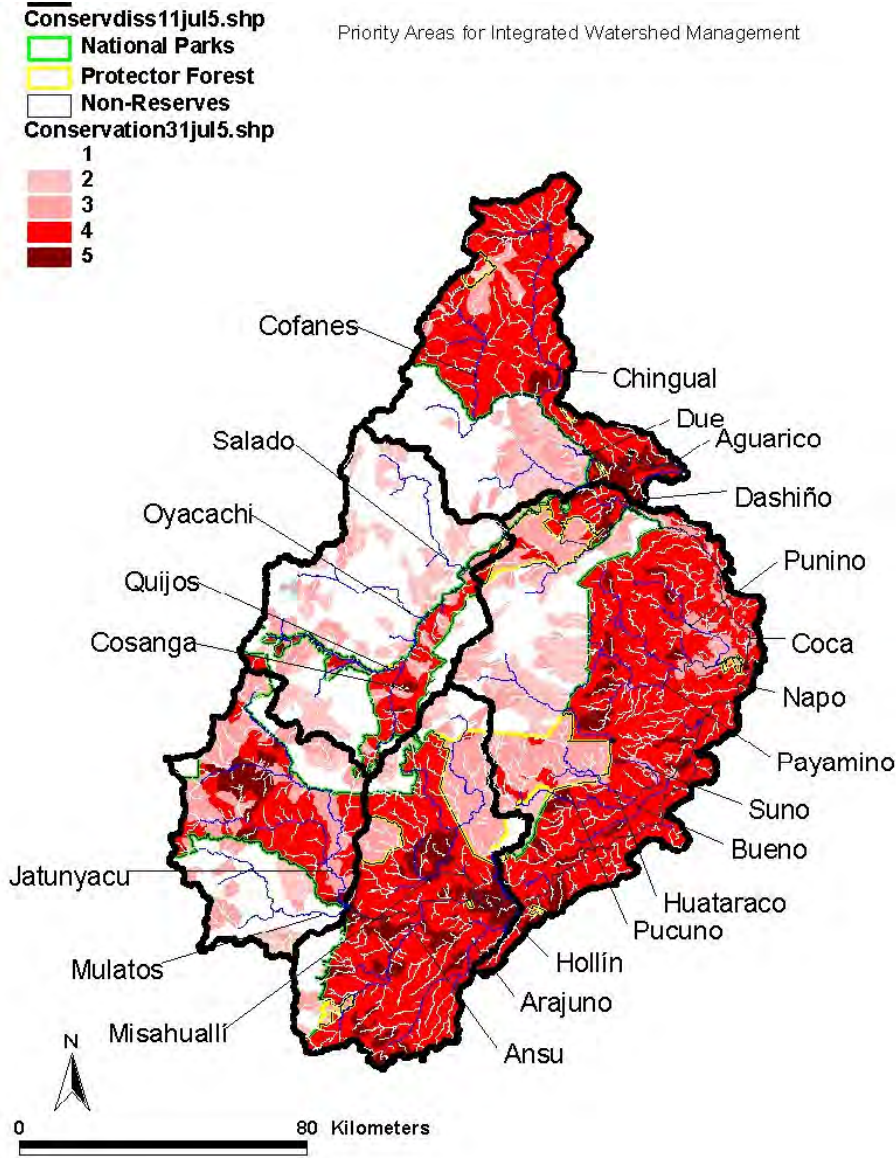


Figure 9. Priority areas for conservation action and integrated watershed management in the UPRB.

Based on the main findings of this study I suggest framing conservation action in the UNRB in a watershed approach. This allows levels of diversity of the region to be evaluated in a

more comprehensive way, for land planning to be applied under natural arrangements, and for agreements to be facilitated among stakeholders. The superimposition of other patterns of diversity to the surrogate patterns defined in this study would permit priority areas to be determined for the conservation of wide levels of diversity. The utilization of natural borders of watersheds, and other physiognomic features of the landscape would permit conservation areas to be redefined, and best management practices to be assigned to different areas of the region considering their biological and cultural values. The recognition of upstream and downstream effects of human activities by involved stakeholders would facilitate the discussion of common goals and approaches, and improve the condition of watersheds and life quality. Some basic measures that need to be considered are the revision of criteria and standards of environmental regulations that deal with a wide range of human activities in the region, as well as the mechanisms that would permit their enforcement. For instance, the definition of protected areas along river channels, and the setting of mechanisms to control erosion processes and the release of effluents are essential to maintain the health of aquatic systems in the region. Regarding these points, it is necessary to work closely with local environmental agencies, socio-environmental organizations, and other stakeholders to define mechanisms to apply these measures. Scheduling a program to monitor the condition of riverine systems would improve the knowledge of these systems, and permit the evaluation of impacts of implemented practices. The application of the principles of adaptive management would facilitate their implementation and improvement along the time. This study sets a baseline for the monitoring of aquatic systems in the UNRB. It recognizes the natural variability of aquatic systems in the region, shows how they are affected by different human activities, and what variables have better responses to these effects. In order to plan a program of monitoring of aquatic systems these patterns should be considered, goals should be determined, and users should be identified.

5. CONCLUSIONS

Overall, I conclude that the Upper Napo River Basin is very vulnerable to human activities and that several measures need to be taken to avoid the degradation of aquatic systems of the region and the irreversible loss of aquatic biodiversity and environmental services. More specifically, I state the following conclusions:

- According to the classification of aquatic systems, using surrogate variables of biodiversity, the UNRB has a high level of diversity of aquatic ecological systems and macrohabitats.
- Threats are widespread in the UNRB, but their extent and magnitude vary depending on the EDU or AES under consideration.
- Threats are closely related to the physiognomy of the landscapes, to the presence of distinct natural resources, and related human settlements. For instance, oil concessions threaten larger areas in the lowlands where the resource is more abundant. Similarly, water diversion projects threaten larger extensions in the highlands because there is more demand for water resources in the neighboring inter-Andean valleys. Land cover conversion and degradation are ubiquitous and threaten aquatic systems relatively independently of their location, but mostly to their proximity to human settlements and roads.
- Overall, physical habitat, water quality, and hydrological variables respond clearly to changes in the land cover, and show differences among systems.
- Qualifications based on physical habitat, water quality-hydrology, and BIBIs variables give similar patterns of health of aquatic systems, and indicate the responsiveness of these components of riverine systems to human activities, as illustrated by the inverse relationship found between degree of health and level of threat.

- Overall the UNRB is very vulnerable to human activities, though some systems are more vulnerable than others based on their degree of uniqueness (irreplaceability) and health, assuming that better conditions support larger levels of diversity.
- High levels of vulnerability of aquatic systems located under legal conservation status indicate that the efficacy of conservation areas and development activity plans should be reviewed.
- In spite of this, priorities for conservation action should be focused on buffer zones of reserves and national parks, as well as on corridors that maintain the connectivity of aquatic ecosystems.

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APPENDICES

Appendix 1. Field form employed in the physical and water quality-hydrological assessments of Aquatic Ecological Systems of the Upper Napo River basin.

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET
(page 1)

STREAM NAME		LOCATION	
STATION #	GPS CODE	STREAM CLASS	
COORDINATES		RIVER BASIN	
INVESTIGATORS		ELEVATION _____ m	
FORM COMPLETED BY		DATE	
		TIME _____ AM PM	
WEATHER CONDITIONS	Now	Past 24 h	Has there been a heavy rain in last 7 days?
	<input type="checkbox"/> storm <input type="checkbox"/> rain <input type="checkbox"/> showers <input type="checkbox"/> % cloud cover <input type="checkbox"/> clear/sunny	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> Yes <input type="checkbox"/> No Air temperature _____ C Other _____
SITE LOCATION/MAP	Draw a map of the site and indicate the areas sampled (or attach a photograph)		
WATERSHED FEATURES	Predominant Landuse		Local Watershed NPS Pollution
	<input type="checkbox"/> Forest <input type="checkbox"/> Field/pasture <input type="checkbox"/> Agricultural <input type="checkbox"/> Residential	<input type="checkbox"/> Commercial <input type="checkbox"/> Industrial <input type="checkbox"/> Other _____	<input type="checkbox"/> No evidence <input type="checkbox"/> Potential sources <input type="checkbox"/> Obvious sources Local Watershed Erosion <input type="checkbox"/> None <input type="checkbox"/> Heavy <input type="checkbox"/> Moderate
STREAM CHARACTERIZATION	Stream Subsystem		Stream Type
	Perennial Stream origin Glacial Lake Swamp and bog	Intermittent Spring-fed Mixture Other _____	Black water White water Clear water Catchment Area _____ km²

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET

(page 3)

WATER QUALITY	Temperature _____ C Specific conductance _____ mS/cm ² Dissolved Oxygen _____ mg/l pH _____ Turbidity _____ NTU Color _____ Transparency _____ m Hardness _____ Salinity _____ % Alkalinity _____ Code of sample for total N and P _____ Code of sample for C:N in SS _____ Code of sample for DOC _____ Code of sample for SS _____																																																						
SEDIMENT/ SUBSTRATE	<table style="width:100%; border: none;"> <tr> <td style="border: none;"> Water Odors <input type="checkbox"/> normal/none <input type="checkbox"/> petroleum <input type="checkbox"/> fishy <input type="checkbox"/> chemical <input type="checkbox"/> sewage <input type="checkbox"/> other _____ </td> <td style="border: none;"> Water surface Oils <input type="checkbox"/> Slick <input type="checkbox"/> Sheen <input type="checkbox"/> Globbs <input type="checkbox"/> Flecks <input type="checkbox"/> None <input type="checkbox"/> Other _____ </td> </tr> </table> <table style="width:100%; border: none;"> <tr> <td style="border: none;"> Odors <input type="checkbox"/> normal <input type="checkbox"/> anaerobic <input type="checkbox"/> none <input type="checkbox"/> petroleum <input type="checkbox"/> sewage <input type="checkbox"/> other _____ <input type="checkbox"/> chemical </td> <td style="border: none;"> Oils <input type="checkbox"/> absent <input type="checkbox"/> slight <input type="checkbox"/> moderate <input type="checkbox"/> profuse Code of sample for C:N in benthic sediments _____ </td> </tr> </table>	Water Odors <input type="checkbox"/> normal/none <input type="checkbox"/> petroleum <input type="checkbox"/> fishy <input type="checkbox"/> chemical <input type="checkbox"/> sewage <input type="checkbox"/> other _____	Water surface Oils <input type="checkbox"/> Slick <input type="checkbox"/> Sheen <input type="checkbox"/> Globbs <input type="checkbox"/> Flecks <input type="checkbox"/> None <input type="checkbox"/> Other _____	Odors <input type="checkbox"/> normal <input type="checkbox"/> anaerobic <input type="checkbox"/> none <input type="checkbox"/> petroleum <input type="checkbox"/> sewage <input type="checkbox"/> other _____ <input type="checkbox"/> chemical	Oils <input type="checkbox"/> absent <input type="checkbox"/> slight <input type="checkbox"/> moderate <input type="checkbox"/> profuse Code of sample for C:N in benthic sediments _____																																																		
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HYDROLOGY	Surface velocity _____ m/s Width bank full 1 _____ m Width BF 2 _____ m Width BF 3 _____ m Depth bank full 1 _____ m Depth BF 2 _____ m Depth BF 3 _____ m Dam Present <input type="checkbox"/> Yes <input type="checkbox"/> No Floodplain development Total number of landforms _____ Number of kinds of forms _____ Description of diversion facilities <div style="border: 1px solid black; height: 40px; width: 100%;"></div>																																																						
AQUATIC LIFE	Code of sample of aquatic macroinvertebrates _____ Observations <div style="border: 1px solid black; height: 30px; width: 100%;"></div> Indicate the dominant type and record the dominant species present <input type="checkbox"/> rooted <input type="checkbox"/> rooted submerged <input type="checkbox"/> rooted floating <input type="checkbox"/> free floating <input type="checkbox"/> emergent <input type="checkbox"/> floating algae <input type="checkbox"/> attached algae dominant species present _____ portion of the reach with aquatic vegetation _____ %																																																						
<table style="width:100%; border: none;"> <tr> <th align="left" colspan="3">Inorganic components of Substrate</th> <th align="left" colspan="3">Organic components of Substrate</th> </tr> <tr> <th style="border: 1px solid black;">Substrate type</th> <th style="border: 1px solid black;">Diameter (mm)</th> <th style="border: 1px solid black;">% Composition in Sampling Reach</th> <th style="border: 1px solid black;">Substrate type</th> <th style="border: 1px solid black;">Characteristics</th> <th style="border: 1px solid black;">% Composition Sampling Reach</th> </tr> <tr> <td style="border: 1px solid black;">Bedrock</td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;">Detritus</td> <td style="border: 1px solid black;">CPOM</td> <td style="border: 1px solid black;"></td> </tr> <tr> <td style="border: 1px solid black;">Boulder</td> <td style="border: 1px solid black;">>256</td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;">Muck-Mud</td> <td style="border: 1px solid black;">FPOM</td> <td style="border: 1px solid black;"></td> </tr> <tr> <td style="border: 1px solid black;">Cobble</td> <td style="border: 1px solid black;">64 to 256</td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;">Marl</td> <td style="border: 1px solid black;">grey, shell fragments</td> <td style="border: 1px solid black;"></td> </tr> <tr> <td style="border: 1px solid black;">Gravel</td> <td style="border: 1px solid black;">2 to 64</td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> </tr> <tr> <td style="border: 1px solid black;">Sand</td> <td style="border: 1px solid black;">0.06 to 2</td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> </tr> <tr> <td style="border: 1px solid black;">Silt</td> <td style="border: 1px solid black;">0.004 to 0.06</td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> </tr> <tr> <td style="border: 1px solid black;">Clay</td> <td style="border: 1px solid black;"><0.004</td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> </tr> </table>		Inorganic components of Substrate			Organic components of Substrate			Substrate type	Diameter (mm)	% Composition in Sampling Reach	Substrate type	Characteristics	% Composition Sampling Reach	Bedrock			Detritus	CPOM		Boulder	>256		Muck-Mud	FPOM		Cobble	64 to 256		Marl	grey, shell fragments		Gravel	2 to 64					Sand	0.06 to 2					Silt	0.004 to 0.06					Clay	<0.004				
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Appendix 2. Sampled locations in the Upper Napo River Basin from June to August 2004. R. = river, us. = upstream, ds. = downstream.

site	stream name	location	EDU	AES	land use	zone	UTM coordinates		elevation (m)	date	time
							X (m)	Y (m)			
1	Toruno R.	us. Tambo R.	3	25	1	17 M	800366	9920140	3670	06/23/04	15:44
2	Valle R.	ds. Yanahurco R.	3	22	1	17 M	802373	9923066	3612	06/24/04	10:25
3	Tambo R.	us. Toruna R.	3	24	1	17 M	800232	9920182	3642	06/24/04	13:20
4	Langoa R.	us. Ana Tenorio R.	3	24	1	17 M	791224	9898382	3482	06/26/04	14:35
5	Chalupas R.	ds. Blanco Chico R.	3	24	1	17 M	799316	9907221	3554	06/27/04	12:13
6	Ana Tenorio R.	us. Langoa R.	3	24	1	17 M	798243	9890088	3287	06/28/04	14:05
7	Antisana R.	us. La Mica lagoon	3	22	1	17 M	808659	9940620	3923	06/29/04	13:00
8	Jatunhuayco R.	ds. tunel 2	3	24	1	17 M	806781	9937805	3855	06/29/04	15:15
9	Oyacachi R.	us. Salvefaccha R.	2	13	1	17 M	821733	9976418	3420	07/03/04	16:15
10	Cariyacu R.	us. Oyacachi R.	2	15	1	17 M	832917	9974675	2759	07/04/04	13:15
11	Salvefaccha R.	us. Oyacachi R.	2	13	1	17 M	821465	9976439	3431	07/05/04	9:50
12	Arturo R.	us. Azuela R.	2	13	1	18 N	172219	10010286	3414	07/06/04	10:30
13	Boquerón R.	us. Azuela R.	2	13	1	18 N	171336	10010829	3426	07/07/04	15:10
14	Azuela R.	ds. San Marcos lagoon	2	13	1	18 N	170794	10012182	3434	07/07/04	16:40
15	San Pedro R.	us. Azuela R.	2	13	1	18 N	170804	10012115	3436	07/07/04	17:20
16	Plazas R.	us. Volteado R.	2	13	1	18 M	169219	9994332	3520	07/08/04	12:30
17	Volteado R.	us. Plazas R.	2	13	1	18 M	169060	9993661	3504	07/08/04	14:05
18	Tumiguina R.	us. Papallacta R.	2	15	2	17 M	818615	9957616	3024	07/14/04	11:00
19	Papallacta R.	us. Tumiguina R.	2	15	2	17 M	818453	9958052	2988	07/14/04	12:30
20	Chalpi R.	us. Papallacta R.	2	17	1	17 M	824689	9959280	2643	07/14/04	14:20
21	Victoria R.	us. Papallacta R.	2	17	2	17 M	831758	9954118	2293	07/14/04	15:45
22	Sucio R.	us. Chingual R.	1	4	2	18 N	215528	10051971	1775	07/16/04	14:45

site	stream name	location	EDU	AES	land use treatment	zone	UTM coordinates		elevation (m)	date	time
							X (m)	Y (m)			
23	Palmar R.	us. Chingual R.	1	6	2	18 N	217417	10046410	1312	07/16/04	16:30
24	no name R.	us. Chingual	1	4	1	18 N	217707	10060957	1981	07/17/04	8:30
25	La Pava R.	us. Chingual R.	1	7	2	18 N	221784	10065233	2016	07/17/04	10:00
26	La Chorrera R.	us. Chingual R.	1	4	1	18 N	216234	10070932	2585	07/17/04	12:05
27	Soche R.	us. Chingual R.	1	4	1	18 N	212818	10068742	2807	07/17/04	13:30
28	Agua Clara R.	us. Chingual R.	1	4	1	18 N	211841	10069808	2869	07/17/04	15:00
29	Chingual R.	us. Minas R.	1	1	2	18 N	202374	10071652	3133	07/20/04	13:50
30	Minas R.	us. Chingual R.	1	4	1	18 N	205853	10070190	2968	07/20/04	15:00
31	Las Juntas R.	us. Chingual R.	1	7	1	18 N	218375	10044215	1214	07/21/04	8:35
32	La Chispa R.	us. Chingual R.	1	7	1	18 N	222863	10035143	926	07/21/04	10:15
33	El Recodo R.	us. Chingual R.	1	7	1	18 N	225111	10028044	771	07/21/04	12:15
34	Cabeno R.	us. Aguarico R.	1	12	2	18 N	232636	10013765	616	07/21/04	14:00
35	Chonta R.	us. Aguarico R.	1	8	2	18 N	242261	10006728	565	07/21/04	15:50
36	Cascales R.	us. Aguarico R.	1	12	2	18 N	254426	10009105	417	07/22/04	9:20
37	Duvino R.	us. Aguarico R.	1	8	3	18 N	248065	10008689	443	07/22/04	10:50
38	Tigre R.	us. Dashino R.	4	37	2	18 M	238404	9994790	467	07/22/04	13:45
39	Dashiño R.	us. Tigre R.	4	33	3	18 M	237909	9995337	543	07/22/04	15:05
40	Lupi R.	us. Tena R.	5	46	2	18 M	181888	9891879	489	07/26/04	10:00
41	Pano R.	us. Inchillayacu R.	5	45	1	18 M	175340	9890819	780	07/26/04	12:40
42	Colonso R.	us. Tena R.	5	45	2	18 M	181442	9893530	581	07/26/04	15:55
43	Tena R.	us. Shitig R.	5	45	2	18 M	179807	9897570	695	07/26/04	17:30
44	Inchillagui R.	us. Misahuallí R.	5	46	2	18 M	186253	9898675	583	07/27/04	8:45
45	Shicama R.	us. Misahuallí R.	5	46	3	18 M	186185	9899761	587	07/27/04	10:30
46	Calmitoyacu R.	us. Misahuallí R.	5	46	2	18 M	188686	9902216	594	07/27/04	12:30
47	Misahuallí R.	at Chimbiyacu	5	46	2	18 M	187278	9907135	733	07/27/04	13:55

site	stream name	location	EDU	AES	land use treatment	zone	UTM coordinates		elevation (m)	date	time
							X (m)	Y (m)			
48	Osayacu R.	us. Jondachi R.	5	46	3	18 M	189342	9913486	877	07/27/04	15:30
49	Jondachi R.	us. Urcusique R.	5	45	2	18 M	185929	9923914	1266	07/27/04	17:15
50	Montana R.	us. Quijos R.	2	17	3	18 M	210859	9987085	1225	07/28/04	14:50
51	Márquez R.	us. Quijos R.	2	17	2	18 M	210347	9986820	1238	07/28/04	16:25
52	Malo R.	us. Quijos R.	2	20	2	18 M	206044	9983080	1284	07/28/04	17:25
53	Salado R.	us. Quijos R.	2	14	2	18 M	199379	9977728	1302	07/28/04	18:30
54	Bombón R.	us. Quijos R.	2	20	2	18 M	194173	9967166	1445	07/29/04	10:35
55	Santa Rosa R.	us. Quijos R.	2	17	2	18 M	190005	9966495	1483	07/28/04	11:55
56	Oyacachi R.	us. Quijos R.	2	14	2	18 M	189240	9964349	1470	07/29/04	12:45
57	San Juan Grande R.	us. Oyacachi R.	2	17	1	18 M	180938	9969243	1710	07/29/04	14:55
58	San Juan Chico R.	us. Oyacachi R.	2	17	1	18 M	182669	9967662	1669	07/29/04	15:40
59	Cauchillo R.	us. Quijos R.	2	19	2	18 M	187417	9960324	1600	07/29/04	17:00
60	Parcayacu R.	us. Quijos R.	2	17	3	18 M	186388	9955717	1603	07/29/04	18:00
61	Sardinas R.	us. Quijos R.	2	17	2	18 M	186389	9957807	1562	07/30/04	8:10
62	Borja R.	us. Quijos R.	2	20	2	18 M	184969	9952053	1577	07/30/04	9:00
63	Sardinas Chico R.	us. Quijos R.	2	17	2	18 M	182206	9952163	1715	07/30/04	10:10
64	Parada Larga R.	us. Quijos R.	2	17	2	18 M	178341	9950032	1757	07/30/04	11:15
65	Chontayacu R.	us. Hollín R.	5	46	2	18 M	192040	9919733	1114	08/03/04	12:25
66	Hollín Chico R.	us. Hollín R.	5	46	2	18 M	196110	9923148	1070	08/03/04	14:25
67	Chalcayacu R.	us. Hollín R.	5	46	3	18 M	201419	9920513	1057	08/03/04	16:05
68	Guamaní R.	us. Hollín R.	5	46	2	18 M	206019	9920220	1092	08/03/04	17:15
69	Pucuno R.	us. Pingullo R.	4	29	2	18 M	210917	9921757	994	08/04/04	9:00
70	Pingullo R.	us. Pucuno R.	4	32	3	18 M	215841	9918216	893	08/04/04	10:35
71	Cotapino R.	us. Pucuno R.	4	37	2	18 M	228806	9910646	370	08/04/04	13:45
72	Pucuno R.	us. Cotapino R.	4	33	3	18 M	229869	9912226	378	08/04/04	15:05

site	stream name	location	EDU	AES	land use treatment	zone	UTM coordinates		elevation (m)	date	time
							X (m)	Y (m)			
73	Huataracu R.	us. Hishpano R.	4	33	2	18 M	235566	9919297	347	08/04/04	17:45
74	Tupapishcu R.	us. Payamino R.	4	37	3	18 M	239466	9936783	376	08/05/04	9:30
75	Huacito R.	us. Payamino R.	4	40	3	18 M	276438	9951038	273	08/05/04	11:35
76	Payamino R.	us. Napo R.	4	30	2	18 M	276566	9951151	274	08/05/04	13:00
77	Napo R.	us. Coca R.	4	30	2	18 M	279008	9947448	262	08/05/04	15:30
78	Coca R.	us. Napo R.	4	30	2	18 M	276642	9962179	278	08/05/04	16:50
79	Suno R.	us. Napo R.	4	35	2	18 M	242193	9923012	406	08/06/04	8:25
80	Lipino R.	us. Chalcacayacu R.	4	37	2	18 M	235353	9920902	382	08/06/04	10:35
81	Chalcacayacu R.	us. Lipino R.	4	39	2	18 M	235215	9920851	388	08/06/04	11:25
82	Bueno R.	us. Pucuno R.	4	33	2	18 M	247506	9908426	317	08/06/04	15:15
83	Pano R.	us. Tena R.	5	46	2	18 M	186683	9889972	509	08/08/04	13:25
84	Tena R.	us. Pano R.	5	46	2	18 M	186554	9890050	523	08/08/04	14:45
85	Hollín R.	ds. Jondachi R.	5	43	3	18 M	193814	9895237	462	08/09/04	10:10
86	Lushián R.	us. Misahuallí R.	5	46	3	18 M	189388	9898440	528	08/09/04	10:26
87	Pusuno R.	us. Misahuallí R.	5	46	2	18 M	208799	9890084	534	08/09/04	16:35
88	Chonta R.	us. Cosanga R.	2	17	1	18 M	181912	9935272	1908	08/10/04	8:30
89	Aliso R.	us. Cosanga R.	2	17	1	18 M	176017	9930359	2134	08/10/04	9:35
90	Cosanga R.	us. Aliso R.	2	17	2	18 M	174940	9926674	2123	08/10/04	10:38
91	Aragón R.	us. Cosanga R.	2	17	2	18 M	175173	9925710	2131	08/10/04	11:48
92	Yanayacu R.	us. Cosanga R.	2	17	2	18 M	180282	9936506	1894	08/10/04	14:00
93	Arenillas R.	us. Cosanga R.	2	20	2	18 M	180129	9938093	1826	08/10/04	14:45
94	Bermejo R.	us. Cosanga R.	2	17	2	18 M	179060	9942706	1795	08/10/04	15:30
95	Quijos R.	us. Cosanga R.	2	14	2	18 M	178075	9949457	1710	08/10/04	17:23
96	Machángara R.	us. Quijos R.	2	17	2	18 M	177899	9948601	1808	08/11/04	8:20
97	Cosanga R.	us. Quijos R.	2	14	2	18 M	182617	9949808	1572	08/11/04	10:10
98	Jatunyacu R.	us. Anzu R.	5	43	2	18 M	187238	9882718	394	08/12/04	9:04

site	stream name	location	EDU	AES	land use treatment	zone	UTM coordinates		elevation (m)	date	time
							X (m)	Y (m)			
99	Anzu R.	us. Jatunyacu R.	5	48	2	18 M	188332	9882882	398	08/12/04	10:55
100	Poroto R.	us. Anzu R.	5	47	3	18 M	184705	9875895	453	08/12/04	12:30
101	Ila R.	us. Anzu R.	5	46	2	18 M	177718	9871557	531	08/12/04	16:10
102	Piatúa R.	us. Anzu R.	5	46	2	18 M	179197	9862244	539	08/12/04	17:15
103	Llandia R.	us. Anzu R.	5	46	3	18 M	178030	9859730	570	08/12/04	18:15
104	Arus.uno R.	us. Rivadeneira R.	5	46	3	18 M	181128	9844888	923	08/13/04	
105	Rivadeneira R.	us. Arus.uno R.	5	46	3	18 M	181128	9849468	819	08/13/04	7:05
106	Anzu R.	us. Llandia R.	5	46	2	18 M	177870	9860821	562	08/13/04	9:22
107	Puni R.	ds. Pinchoyacu R.	5	46	2	18 M	177718	9895237	513	08/13/04	11:25
108	Piocullín R.	us. Anzu R.	5	47	2	18 M	188072	9882532	430	08/13/04	13:55
109	Arajuno R.	us. Napo R.	5	48	2	18 M	211724	9878630	424	08/13/04	17:05
110	Misahuallí R.	ds. Tena R.	5	46	3	18 M	187962	9890629	476	08/14/04	6:28
111	Jondachi R.	ds. Osayacu R.	5	46	2	18 M	189324	9913770	842	08/14/04	8:50

Appendix 3. Physical habitat qualifications of sampled locations in the Upper Napo River Basin.

site	AES	land use treatment	Streamside zone			Physical forms					Total	
			lateral continuity	structural intactness	bank stability	habitat stability	habitat diversity	channel alteration	sinuosity/ bends	Physical qualification	habitat qualification	
1	25	1	5	5	3.5	2	4	5	5	29.5	5.0	
2	22	1	5	4.5	4	2	4	4	5	28.5	5.0	
3	24	1	5	5	4.5	3	4	5	5	31.5	5.0	
4	24	1	5	5	3	3	4	5	5	30	5.0	
5	24	1	5	5	4.5	2	4	5	4	29.5	5.0	
6	24	1	5	4.5	4	4	5	5	5	32.5	5.0	
7	22	1	5	4	4	3	3	4	5	28	5.0	
8	24	1	5	5	4.5	2	5	5	5	31.5	5.0	
9	13	1	5	4.5	4	4	5	5	5	32.5	5.0	
10	15	1	5	5	5	3	4	5	5	32	5.0	
11	13	1	5	4.5	4	2	4	5	5	29.5	5.0	
12	13	1	5	1	1	5	4	5	5	26	5.0	
13	13	1	5	5	4.5	5	4	5	5	33.5	5.0	
14	13	1	5	5	5	5	4	5	4	33	5.0	
15	13	1	5	1	1	3	3	4	5	22	5.0	
16	13	1	5	2.5	3	5	4	5	5	29.5	5.0	
17	13	1	5	5	4	5	5	5	5	34	5.0	
18	15	2	5	3	4	5	2	4	5	28	4.4	
19	15	2	5	2	4	2	2	4	1	20	3.1	
20	17	1	5	5	5	4	4	4	5	32	5.0	

site	AES	land use treatment	Streamside zone			Physical forms				Total	
			lateral continuity	structural intactness	bank stability	habitat stability	habitat diversity	channel alteration	sinuosity/bends	Physical qualification	habitat qualification
21	17	2	5	4	5	3	2	4	5	28	4.9
22	4	2	5	5	5	5	4	4	5	33	5.0
23	6	2	5	2	3	5	4	4	5	28	4.0
24	4	1	5	5	5	5	5	4	5	34	5.0
25	7	2	5	3.5	5	4	5	4	5	31.5	5.0
26	4	1	5	2.5	4	5	5	4	5	30.5	5.0
27	4	1	3	5	5	5	2	4	5	29	4.8
28	4	1	5	4	4	5	4	4	5	31	5.0
29	1	2	5	1	3	5	1	4	3	22	4.0
30	4	1	5	2	3	4	4	4	5	27	5.0
31	7	1	5	3	2.5	5	5	4	5	29.5	5.0
32	7	1	5	3	4	5	5	4	5	31	5.0
33	7	1	2	1	2.5	5	3	4	5	22.5	5.0
34	12	2	3	2	4	2	3	4	0	18	4.0
35	8	2	3.5	3	4	5	5	4	5	29.5	4.0
36	12	2	3	4	4	5	3	4	3	26	4.0
37	8	3	2	2	3	2	4	4	4	21	4.0
38	37	2	3	4	4.5	5	3	4	3	26.5	4.0
39	33	3	3.5	3	3.5	3	2	4	3	22	3.3
40	46	2	2.5	4	4	2	4	4	5	25.5	4.0
41	45	1	3	4	5	4	5	5	5	31	5.0
42	45	2	2.5	2.5	4	5	4	5	5	28	4.5
43	45	2	3	4	4	5	4	4	5	29	4.7

site	AES	land use	Streamside zone	Physical forms						Total	Physical habitat qualification
	treatment		lateral continuity	structural intactness	bank stability	habitat stability	habitat diversity	channel alteration	sinuosity/bends		
44	46	2	4	2.5	3.5	5	4	3	5	27	4.0
45	46	3	2	1	3	3	4	5	3	21	3.1
46	46	2	2	1.5	4	5	4	5	5	26.5	4.0
47	46	2	2.5	1	4	4	4	4	5	24.5	4.0
48	46	3	2	2.5	3.5	3	4	4	5	24	4.0
49	45	2	2.5	3	4	5	4	5	5	28.5	4.6
50	17	3	3	3	3	5	3	4	5	26	4.6
51	17	2	1	1	1	4	4	4	5	20	3.5
52	20	2	3.5	3	4	5	2	4	3	24.5	4.0
53	14	2	3	2.5	3	5	4	4	5	26.5	4.0
54	20	2	4	3	4	4	4	5	5	29	4.0
55	17	2	4	1.5	2.5	4	4	5	5	26	4.6
56	14	2	2	2	3	5	4	4	5	25	4.0
57	17	1	3.5	1.5	3.5	5	4	4	5	26.5	5.0
58	17	1	5	3	4	5	4	4	5	30	5.0
59	19	2	5	4	4.5	5	3	4	5	30.5	4.0
60	17	3	3	1	2	4	3	5	5	23	4.1
61	17	2	4	1	1.5	4	3	4	5	22.5	4.0
62	20	2	3.5	2	3	5	3	5	5	26.5	4.0
63	17	2	5	1.5	2.5	3	4	3.5	5	24.5	4.3
64	17	2	5	1	1.5	2	4	3.5	5	22	3.9
65	46	2	3	1	3	4	3	4	5	23	4.0

site	AES	land use treatment	Streamside zone			Physical forms				Total	
			lateral continuity	structural intactness	bank stability	habitat stability	habitat diversity	channel alteration	sinuosity/bends	Physical qualification	habitat qualification
66	46	2	4	2.5	4.5	2	5	5	5	28	4.0
67	46	3	3	3	3.5	5	4	4	5	27.5	4.0
68	46	2	3.5	4	5	5	5	4	5	31.5	4.0
69	29	2	3	3	3.5	5	4	4	5	27.5	4.0
70	32	3	3	4	3.5	4	5	4	4	27.5	3.0
71	37	2	4.5	5	4.5	5	3	5	3	30	4.0
72	33	3	3	3.5	5	5	4	5	3	28.5	4.0
73	33	2	4.5	5	4.5	5	3	5	5	32	4.0
74	37	3	4	4	5	5	5	4	5	32	4.0
75	40	3	2	1	3	2	2	5	5	20	3.0
76	30	2	3	1	4	1	1	4	3	17	4.0
77	30	2	3.5	1.5	3	1	1	3.5	3	16.5	4.0
78	30	2	3	2	4	1	1	4	2	17	4.0
79	35	2	3	4	3	5	5	5	5	30	4.0
80	37	2	5	5	5	5	5	5	4	34	4.0
81	39	2	5	5	5	5	5	5	5	35	4.0
82	33	2	3	2.5	3.5	1	2	4	3	19	4.0
83	46	2	3	2.5	3.5	4	3	3	1	20	3.0
84	46	2	4	3.5	4	4	3	3	1	22.5	3.3
85	43	2	5	4	5	5	5	4	5	33	4.0
86	46	3	2.5	3.5	4.5	5	4	4	5	28.5	4.0
87	46	2	3	4	4.5	4	4	5	5	29.5	4.0

site	AES	land use treatment	Streamside zone			Physical forms				Total	
			lateral continuity	structural intactness	bank stability	habitat stability	habitat diversity	channel alteration	sinuosity/bends	Physical qualification	habitat qualification
88	17	1	3	1.5	3.5	4	4	5	5	26	4.6
89	17	1	3	4	4	5	4	4	5	29	5.0
90	17	2	2	3	3	5	3	5	5	26	5.0
91	17	2	5	5	3	3	5	5	5	31	5.0
92	17	2	4	1	1	5	3	4	5	23	4.1
93	20	2	4	3.5	4.5	5	3	5	5	30	4.0
94	17	2	4	1	1	4	3	4	5	22	3.9
95	14	2	2.5	3	4	5	4	5	5	28.5	4.0
96	17	2	5	2	4	4	5	3	5	28	4.9
97	14	2	5	5	5	4	4	5	5	33	4.0
98	43	2	5	4	3	5	4	5	5	31	4.0
99	48	2	2.5	3	4	5	4	4	4	26.5	4.0
100	47	3	3	3	4	2	1	5	3	21	4.0
101	46	2	2	3	4	3	3	5	5	25	4.0
102	46	2	2.5	3.5	4	5	3	4	5	27	4.0
103	46	3	2	1.5	1.5	5	4	3	5	22	3.3
104	46	3	2	1	2.5	5	4	4	4	22.5	3.3
105	46	3	2	2.5	2	5	4	4	5	24.5	3.6
106	46	2	5	4.5	4.5	5	4	5	4	32	4.0
107	46	2	3	4	4.5	4	4	5	5	29.5	4.0
108	47	2	2	4	4	4	3	5	5	27	4.0
109	48	2	3	2.5	2	2	4	4	3	20.5	4.0
110	46	2	4.5	3	5	4	4	4	3	27.5	4.0
111	46	2	2	2	3	4	4	4	5	24	4.0

Appendix 4. Water chemistry data of sampled locations in the Upper Napo River Basin.

site	AES	land use	temperature	specific conductance	pH	turbidity	hardness	DOC	TP	TN	PO ₄	NO ₃	NH ₄	SS
		treatment	(°C)	(µS/cm ²)		(NTU)	(mg/l CaCO ₃)	(mg/l)	(µM)	(µM)	(µM)	(µM)	(µM)	(mg/l)
1	25	1	10.6	0.076	6.9	3	33	2.75	0.32	12.16	0.27	8.80	0.69	3.53
2	22	1	8.8	0.017	6.77	5	51	3.03	0.62	10.04	0.23	0.74	3.90	2.88
3	24	1	11.7	0.085	7.64	99	35	2.28	2.99	15.00	0.61	9.11	3.22	5.40
4	24	1	11.2	0.182	8.4	3	87	1.97	3.54	2.69	1.84	0.00	2.05	6.25
5	24	1	10.3	0.055	7.56	5	34	4.43	4.05	4.48	0.09	0.92	2.61	10.30
6	24	1	9.6	0.029	7.69	6	17	4.02	0.85	2.88	0.45	0.15	2.30	7.13
7	22	1	10.5	0.158	8.2	40	4	2.73	7.63	4.37	2.05	0.69	3.49	6.39
8	24	1	10.5	0.143	8.01	10	4	6.72	1.03	10.72	0.36	3.07	2.47	13.20
9	13	1	9.7	0.055	7.38	2	34	2.32	1.87	23.40	0.33	1.31	7.05	14.90
10	15	1	9.8	0.047	7.76	9	21	2.56	1.87	3.79	0.12	1.21	1.14	21.00
11	13	1	7.7	0.03	7.59	1	11	2.36	1.13	0.85	0.14	0.07	1.95	61.43
12	13	1	7.3	0.038	7.24	9	15	2.46	3.94	1.96	0.97	1.27	2.84	102.80
13	13	1	9.2	0.052	7.6	21	21	1.77	1.06	4.53	0.78	1.21	5.02	2.38
14	13	1	10.5	0.032	7.49	1	15	1.95	1.36	2.61	0.17	1.52	2.10	2.30
15	13	1	9.7	0.097	7.67	7	40	2.93	3.45	0.80	1.57	0.53	3.47	1.25
16	13	1	7.7	0.028	7.91	17	12	0.87	0.52	4.21	0.45	1.07	2.34	1.69
17	13	1	8.5	0.025	7.84	7	12	1.51	0.25	2.41	0.09	0.62	3.62	1.30
18	15	2	11.1	0.269	7.79	4	59	1.69	3.70	15.53	1.11	8.50	4.04	1.10
19	15	2	11	0.295	7.69	4	88	1.87	0.95	7.20	0.72	3.62	4.07	1.87
20	17	1	10.1	0.067	7.75	10	33	1.62	0.50	1.97	0.21	1.08	3.77	3.38
21	17	2	10.6	0.079	7.82	8	40	1.70	0.30	4.21	0.09	1.18	2.50	2.40
22	4	2	12.1	0.013	6.87	38	5	2.58	1.14	13.28	0.15	1.52	2.56	2.86

site	AES	land use	temperature	specific conductance	pH	turbidity	hardness	DOC	TP	TN	PO ₄	NO ₃	NH ₄	SS
	treatment		(°C)	(µS/cm ²)		(NTU)	(mg/l CaCO ₃)	(mg/l)	(µM)	(µM)	(µM)	(µM)	(µM)	(mg/l)
23	6	2	15.3	0.033	7.35	30	15	3.26	1.42	9.53	0.89	4.52	3.28	2.10
24	4	1	11.4	0.052	7.56	2	15	2.46	6.95	4.37	1.05	2.44	2.70	2.33
25	7	2	12.2	0.022	7.68	3	6	3.16	0.89	3.41	0.75	2.83	4.27	3.90
26	4	1	9.8	0.015	7.12	34	5	5.29	0.81	2.93	0.55	1.18	6.93	2.75
27	4	1	8.5	0.009	7.14	154	4	8.77	6.73	14.29	1.66	2.58	5.69	5.25
28	4	1	9.4	0.014	7.18	30	5	5.06	1.57	6.08	0.89	3.21	3.89	3.23
29	1	2	14.7	0.032	7.07	4	12	2.08	1.37	11.15	0.43	0.38	2.23	4.10
30	4	1	13	0.03	7.14	2	17	2.29	1.02	13.39	0.33	0.04	3.33	4.70
31	7	1	16.3	0.056	8.47	3	30	0.88	0.99	11.57	0.09	2.38	2.92	3.38
32	7	1	17.2	0.028	8.4	5	17	1.19	0.64	6.83	0.28	2.12	2.16	2.09
33	7	1	21.3	0.024	7.57	35	10	0.81	1.41	7.36	0.23	1.50	2.82	3.33
34	12	2	23.3	0.034	7.41	49	17	3.69	5.43	7.52	0.43	1.49	2.67	6.57
35	8	2	22.4	0.009	7.28	8	4	1.33	0.39	6.93	0.17	1.23	2.49	8.86
36	12	2	22.2	0.022	7.25	13	7	2.09	0.78	4.11	0.17	1.04	3.49	4.08
37	8	3	22.6	0.012	7.33	12	4	0.50	0.90	5.17	0.15	1.60	5.44	6.40
38	37	2	24.4	0.1	7.64	8	54	1.44	10.78	5.65	1.48	3.94	2.42	3.00
39	33	3	25.2	0.042	7.62	3	22	1.20	5.82	14.51	0.42	0.94	4.26	1.75
40	46	2	21.4	0.022	7.5	14	7	6.57	1.11	4.53	0.46	5.31	1.47	2.98
41	45	1	19.8	0.02	7.17	39	7	1.37	1.19	4.61	0.64	4.03	2.43	7.75
42	45	2	22.6	0.02	7.39	9	7	0.85	0.47	8.69	0.41	5.30	2.38	1.60
43	45	2	20	0.021	7.69	13	7	0.61	8.57	11.25	0.68	5.22	2.15	2.80
44	46	2	19.9	0.017	6.65	20	6	1.54	0.98	12.37	0.38	6.61	2.22	3.40
45	46	3	22	0.026	7.27	19	10	0.79	0.43	9.71	0.25	3.47	10.21	3.81
46	46	2	21.3	0.02	7.55	4	6	0.96	1.02	7.84	0.53	6.06	0.00	3.40

site	AES	land treatment	use temperature (°C)	specific conductance (µS/cm2)	pH	turbidity (NTU)	durezza (mg/l CaCO ₃)	DOC (mg/l)	TP (µM)	TN (µM)	PO ₄ (µM)	NO ₃ (µM)	NH ₄ (µM)	SS (mg/l)
47	46	2	19.8	0.02	7.59	27	7	3.02	0.55	7.41	0.46	1.74	4.28	17.60
48	46	3	20.8	0.03	7.83	23	13	0.54	2.17	17.39	0.22	3.53	0.89	3.07
49	45	2	17.1	0.013	7.5	7	5	0.77	1.58	16.00	0.23	4.21	1.61	10.50
50	17	3	18.8	0.437	8.71	4	255	1.01	14.37	6.45	3.67	3.42	1.31	2.75
51	17	2	18	0.612	8.59	6	306	0.80	13.96	169.81	3.74	35.16	2.80	8.63
52	20	2	17.8	0.127	8.02	17	85	1.80	3.24	4.05	1.45	1.11	3.03	9.70
53	14	2	15.5	0.06	7.85	133	34	1.34	0.63	2.61	0.34	0.68	2.28	4.00
54	20	2	16.9	0.043	7.13	5	17	0.87	1.99	8.01	0.91	5.29	2.83	3.15
55	17	2	16.6	0.112	8.01	237	68	2.02	1.50	5.76	0.71	1.56	3.18	11.20
56	14	2	14.8	0.054	7.76	29	34	1.73	0.51	4.80	0.25	2.24	2.75	4.89
57	17	1	13.9	0.057	8.01	19	34	1.50	1.69	4.21	0.25	1.30	2.31	7.33
58	17	1	15.6	0.089	7.94	13	51	1.26	1.48	2.88	0.47	2.02	2.40	6.13
59	19	2	17.7	0.045	7.7	3	34	1.53	1.42	3.09	0.99	1.39	2.22	13.10
60	17	3	17.4	0.041	6.9	2	17	1.50	2.72	3.73	0.56	1.62	1.84	14.66
61	17	2	13.2	0.045	7.32	253	34	2.90	1.65	7.41	0.40	1.88	2.31	8.47
62	20	2	13.8	0.023	7.01	203	17	3.73	1.03	7.36	0.53	2.65	3.08	10.38
63	17	2	13.6	0.043	7.8	70	34	2.27	0.89	15.25	0.58	2.15	3.31	20.71
64	17	2	13.3	0.048	7.93	132	34	2.50	4.18	4.75	0.37	2.72	3.46	14.00
65	46	2	19.9	0.019	6.78	15	8	0.67	0.98	12.16	0.06	1.37	1.85	6.15
66	46	2	20	0.02	7.6	133	7	1.14	2.18	8.96	0.21	3.31	5.45	29.20
67	46	3	19.8	0.02	7.23	1	7	0.27	0.67	17.12	0.31	4.15	4.38	10.07
68	46	2	18.6	0.038	7.82	4	14	0.84	0.60	8.96	0.47	5.01	2.95	8.00
69	29	2	18.2	0.038	7.81	23	12	1.91	1.08	7.95	0.74	7.74	2.48	8.55

site	AES	land use	temperature	specific conductance	pH	turbidity	durezza	DOC	TP	TN	PO ₄	NO ₃	NH ₄	SS
		treatment	(°C)	(µS/cm ²)		(NTU)	(mg/l CaCO ₃)	(mg/l)	(µM)	(µM)	(µM)	(µM)	(µM)	(mg/l)
70	32	3	19.6	0.018	7.47	22	7	0.93	0.81	22.88	0.31	9.39	1.59	17.50
71	37	2	24.4	0.058	8.29	3	9	0.59	0.66	13.60	0.52	4.98	1.80	9.87
72	33	3	21.8	0.032	7.63	77	13	1.73	0.49	12.48	0.11	1.94	1.55	13.04
73	33	2	22.4	0.035	7.88	35	16	0.89	0.33	12.53	0.21	3.93	2.00	15.00
74	37	3	22.3	0.027	7.93	1	11	0.45	0.36	8.00	0.20	0.99	1.56	10.85
75	40	3	24.5	0.016	6.8	7	7	2.44	0.69	6.56	0.45	5.18	3.36	13.48
76	30	2	25.8	0.06	7.52	10	28	1.57	0.91	8.27	0.40	2.31	2.60	17.40
77	30	2	23.7	0.058	7.55	377	29	1.65	0.58	5.17	0.38	4.37	2.63	24.14
78	30	2	21.9	0.086	8.07	590	45	2.54	0.38	15.09	0.27	1.41	1.20	12.13
79	35	2	20.3	0.093	7.72	3	28	1.76	0.70	6.24	0.61	4.90	6.19	16.42
80	37	2	23.8	0.046	7.81	11	21	1.33	0.85	5.57	0.56	4.44	3.35	21.64
81	39	2	22.2	0.047	8.32	2	20	1.10	0.90	11.63	0.36	5.16	2.15	20.30
82	33	2	27.5	0.059	7.5	15	51	1.77	0.71	10.35	0.42	5.62	4.14	16.33
83	46	2	20.1	0.016	6.53	66	7	2.12	0.26	9.12	0.16	4.16	3.10	12.53
84	46	2	20.2	0.017	7.065	46	7	1.87	0.52	4.96	0.42	2.17	5.82	14.64
85	43	2	18.8	0.028	7.39	19	10	0.81	0.44	12.85	0.36	6.47	2.68	32.29
86	46	3	21.2	0.107	8.14	9	54	1.69	2.09	13.65	1.77	7.34	2.87	26.11
87	46	2	20.4	0.047	8	20	25	2.42	0.76	11.63	0.69	4.87	2.96	26.25
88	17	1	13.1	0.02	7.33	3	7	1.28	0.44	5.97	0.43	3.69	3.10	21.00
89	17	1	10.2	0.061	8.05	123	30	1.20	0.34	6.35	0.25	3.28	3.34	20.40
90	17	2	10.4	0.085	8.06	10	47	1.35	0.25	6.19	0.18	2.90	3.77	12.85
91	17	2	13.3	0.095	7.94	6	51	1.13	0.23	2.35	0.13	1.21	2.43	52.60
92	17	2	13.9	0.095	7.93	8	68	1.52	0.66	6.99	0.62	3.01	3.68	20.46
93	20	2	14.3	0.028	7.61	93	17	1.04	0.42	8.64	0.34	3.19	2.58	14.53
94	17	2	14.2	0.144	7.97	116	85	1.37	0.47	7.09	0.52	3.74	3.16	28.30

site	AES	land use	temperature	specific conductance	pH	turbidity	hardness	DOC	TP	TN	PO ₄	NO ₃	NH ₄	SS
		treatment	(°C)	(µS/cm ²)		(NTU)	(mg/l CaCO ₃)	(mg/l)	(µM)	(µM)	(µM)	(µM)	(µM)	(mg/l)
95	14	2	13.3	0.138	7.95	25	4	1.62	0.45	6.83	0.49	3.79	4.58	37.50
96	17	2	12.8	0.091	8.07	2	3	0.96	0.98	6.77	0.91	2.30	3.17	32.70
97	14	2	13.4	0.087	8.65	16	3	1.68	0.38	6.40	0.33	3.25	2.66	42.75
98	43	2	17.3	0.078	8.07	62	36	0.93	0.38	9.49	0.26	2.98	2.78	18.55
99	48	2	23	0.028	7.43	11	30	1.00	0.21	12.75	0.13	1.69	2.96	49.75
100	47	3	24.7	0.02	7.25	5	8	1.84	0.33	4.35	0.20	0.68	4.31	30.09
101	46	2	27.4	0.016	7.83	6	6	0.60	0.15	9.33	0.07	1.17	1.61	40.90
102	46	2	21.7	0.015	7.47	15	5	0.76	0.26	1.39	0.18	1.08	3.81	25.94
103	46	3	23.1	0.059	8.01	147	32	1.12	0.66	2.29	0.68	1.64	4.43	44.60
104	46	3	20.7	0.026	7.1	2	14	2.08	0.20	10.24	0.13	2.04	2.48	50.50
105	46	3	20.4	0.046	7.46	1	23	1.01	0.36	4.91	0.27	3.35	2.77	93.29
106	46	2	20.7	0.029	7.91	56	15	2.22	0.35	10.45	0.26	3.75	2.42	155.20
107	46	2	22.7	0.065	8.7	15	37	1.10	0.87	6.40	0.51	4.79	2.38	175.60
108	47	2	24.8	0.039	7.83	8	17	1.48	0.30	3.47	0.30	1.33	2.28	208.00
109	48	2	25.3	0.056	7.72	18	26	1.17	0.50	6.03	0.24	3.45	3.91	171.29
110	46	2	20	0.027	7.44	8	12	0.77	0.42	2.56	0.27	1.87	3.51	164.60
111	46	2	17.7	0.017	7.74	12	7	1.54	0.33	1.76	0.24	0.65	2.96	577.71

Appendix 5. Hydrological data of sampled locations in the Upper Napo River Basin. LWD = Large Woody Debris.

site	AES	land use	gradient	rifle	run	pool	river	depth	number	velocity	river	depth	bedrock	boulder	cobble	gravel	sand	silt	LWD	
			(%)	(%)	(%)	(%)	(m)	(m)	gravel bars	(m/s)	width bank full	bank full	(%)	(%)	(%)	(%)	(%)	(%)	(%)	
		treatment																		
1	25	1	3	60	0	40	5.53	0.50	1	71.95	0.32	2.00	0	40	20	20	20	0	0	
2	22	1	1	30	0	70	7.93	1.00	0	71.57	0.37	2.50	0	40	20	20	10	10	0	
3	24	1	3	70	20	10	10.20	0.70	1	121.84	0.32	3.00	0	40	20	20	20	0	0	
4	24	1	4	50	20	30	8.10	0.50	1	64.18	0.80	2.00	0	40	30	20	5	5	0	
5	24	1	1	30	20	50	12.50	1.50	0	50.37	0.71	2.50	0	20	50	20	10	0	0	
6	24	1	1	50	30	20	9.63	0.50	0	174.12	0.36	2.50	0	10	60	20	10	0	0	
7	22	1	1	50	50	0	3.53	0.40	0	112.24	0.66	1.40	0	5	40	30	25	0	0	
8	24	1	1	50	20	30	3.03	0.40	0	65.43	0.65	1.20	0	20	30	20	20	10	0	
9	13	1	1	30	30	40	7.07	0.83	0	118.29	0.40	2.50	0	0	10	50	30	10	0	
10	15	1	6	60	40	0	12.43	1.50	0	91.04	0.68	5.00	0	40	30	20	10	0	0	
11	13	1	1	40	30	30	2.70	0.30	0	98.33	0.46	1.23	0	0	50	30	10	10	0	
12	13	1	8	70	30	0	4.22	0.50	0	96.13	0.34	3.00	0	40	20	20	20	0	1	
13	13	1	8	10	50	40	3.97	0.60	1	80.10	0.56	2.50	0	50	30	15	5	0	1	
14	13	1	1	40	40	30	4.47	0.60	0	63.03	0.59	2.00	0	30	50	20	0	0	0	
15	13	1	3	60	20	20	3.78	0.30	1	93.63	0.05	1.80	0	30	30	20	20	0	0	
16	13	1	5	30	40	30	5.67	0.50	1	92.67	0.43	2.50	0	40	20	30	10	0	1	
17	13	1	1	20	20	60	4.37	1.50	0	39.52	0.66	3.70	0	5	10	65	15	0	5	
18	15	2	5	30	60	10	8.67	0.60	0	208.08	0.75	2.10	0	30	40	20	10	0	1	
19	15	2	0.5	10	10	80	8.03	0.40	0	66.39	0.77	1.50	0	5	10	70	15	0	0	
20	17	1	5	50	20	30	11.83	1.00	0	98.14	0.58	4.00	0	50	30	15	5	0	1	
21	17	2	6	50	50	0	9.17	0.80	0	75.31	0.73	2.50	0	55	30	8	2	0	5	
22	4	2	6	60	40	0	16.00	2.50	1	120.78	0.75	5.00	0	70	15	10	0	0	5	
23	6	2	7	50	30	20	11.67	1.50	1	67.82	0.66	3.50	0	55	25	10	5	0	5	
24	4	1	8	50	30	20	5.87	0.50	0	101.98	0.60	4.00	5	40	25	15	10	0	5	

site	AES	land use	gradient	rifle	run	pool	river	depth	number	velocity	river	depth	bedrock	boulder	cobble	gravel	sand	silt	LWD
							width		gravel		width	bank							
		treatment	(%)	(%)	(%)	(%)	(m)	(m)	bars	(m/s)	bank	full	(%)	(%)	(%)	(%)	(%)	(%)	(%)
25	7	2	6	40	35	25	7.00	0.40	1	105.81	0.50	2.50	10	20	30	20	15	0	5
26	4	1	6	60	30	10	5.57	0.50	1	146.78	0.29	2.50	0	30	50	15	5	0	1
27	4	1	6	40	60	0	13.33	2.00	0	63.89	0.85	4.50	0	60	30	10	0	0	0
28	4	1	7	60	30	10	5.80	0.70	0	231.39	0.50	2.60	0	40	30	20	10	0	2
29	1	2	1	80	20	0	5.93	0.25	0	39.33	0.62	0.80	0	1	54	40	5	0	0
30	4	1	6	50	25	25	8.10	0.40	3	108.21	0.57	2.00	0	30	30	25	10	0	5
31	7	1	9	40	30	30	8.50	0.70	1	99.77	0.66	2.70	10	30	30	15	10	0	5
32	7	1	8	50	25	25	21.33	1.00	0	64.28	0.83	3.50	0	60	20	10	8	0	2
33	7	1	7	50	20	30	12.30	0.50	0	90.56	0.81	3.00	0	50	20	20	10	0	1
34	12	2	0.5	40	0	60	33.67	1.00	1	49.31	0.58	7.00	0	20	30	20	10	10	10
35	8	2	1	30	20	50	17.33	1.00	1	73.49	0.56	4.00	0	40	20	20	20	0	1
36	12	2	0.5	40	0	60	26.00	1.20	0	69.26	0.80	4.00	0	25	20	15	15	15	10
37	8	3	2	40	0	60	16.00	2.00	0	49.31	0.63	5.00	0	30	20	20	15	10	5
38	37	2	0.5	60	0	40	23.00	0.50	0	77.23	0.70	3.50	0	5	25	40	15	5	10
39	33	3	1	60	0	40	28.67	0.70	0	44.99	0.64	4.90	0	5	25	45	20	5	0
40	46	2	2.5	40	0	60	12.83	0.80	0	74.73	0.42	4.50	0	10	30	30	30	0	2
41	45	1	5	40	30	30	20.00	1.20	0	71.37	0.60	5.00	0	40	20	10	30	0	1
42	45	2	2	70	30	0	10.40	0.60	0	112.72	0.41	2.00	0	30	30	30	10	0	2
43	45	2	8	40	60	0	25.33	1.20	1	74.16	0.47	5.50	0	40	25	20	10	0	5
44	46	2	1	50	0	50	33.00	1.00	1	138.14	0.43	3.50	0	20	40	30	10	0	2
45	46	3	0.5	30	0	70	13.00	2.00	0	40.48	0.62	5.00	10	10	20	40	20	0	0
46	46	2	1	70	0	30	17.83	1.00	1	153.11	0.60	5.00	0	30	30	20	20	0	0
47	46	2	2	50	30	20	36.33	1.20	3	126.63	0.66	7.00	0	40	30	20	10	0	1
48	46	3	15	30	30	40	12.83	2.00	1	143.52	0.57	6.00	0	60	10	15	10	0	5
49	45	2	15	50	20	30	10.53	1.00	0	110.52	0.53	4.00	0	40	30	20	10	0	0
50	17	3	6	90	0	10	13.80	0.50	1	114.16	0.38	4.00	0	30	35	25	10	0	2

site	AES	land use	gradient	rifle	run	pool	river	depth	number	velocity	river	depth	bedrock	boulder	cobble	gravel	sand	silt	LWD
							width		gravel		width	bank							
		treatment	(%)	(%)	(%)	(%)	(m)	(m)	bars	(m/s)	bank	full	(%)	(%)	(%)	(%)	(%)	(%)	(%)
51	17	2	5	70	20	10	13.50	0.50	1	106.20	0.45	3.50	0	30	25	20	20	0	5
52	20	2	1	70	0	30	39.33	0.80	2	121.84	0.61	4.50	0	20	30	30	20	0	0
53	14	2	4	50	50	0	203.50	1.50	0	66.87	0.82	7.00	0	20	30	25	20	0	5
54	20	2	4	60	40	0	18.67	1.50	2	81.06	0.62	4.50	0	30	35	20	5	0	10
55	17	2	4	50	30	20	14.33	1.20	0	71.76	0.54	4.50	0	30	20	40	10	0	0
56	14	2	3.5	40	40	20	33.67	3.00	1	154.17	0.38	11.00	0	35	25	20	20	0	0
57	17	1	7	50	30	20	17.00	0.80	1	119.25	0.44	5.00	0	40	30	10	20	0	1
58	17	1	4	90	10	0	9.83	0.70	0	119.34	0.47	3.50	0	30	25	20	20	0	5
59	19	2	4	70	30	0	17.50	0.50	1	194.84	0.73	2.50	0	20	50	20	10	0	0
60	17	3	3	90	0	10	10.33	0.50	1	188.89	0.39	2.00	0	20	40	30	10	0	0
61	17	2	3	70	30	0	33.67	2.00	1	133.73	0.72	4.00	0	30	30	30	10	0	0
62	20	2	1	70	30	0	100.67	1.00	3	161.94	0.62	3.00	0	10	40	30	10	0	10
63	17	2	12	40	30	30	22.33	0.70	2	120.00	0.59	2.50	0	20	20	45	10	0	5
64	17	2	2	70	10	20	13.67	0.70	1	110.00	0.49	2.50	0	10	30	40	20	0	0
65	46	2	1	70	0	30	21.67	0.60	1	111.11	0.67	3.50	0	40	20	10	30	0	2
66	46	2	15	0	80	20	25.70	2.00	1	179.31	0.67	4.00	50	20	10	10	5	0	5
67	46	3	3	60	10	30	21.67	0.60	2	100.00	0.67	3.00	0	40	35	10	10	0	5
68	46	2	2	50	10	40	12.33	0.80	1	88.24	0.54	3.80	0	40	35	20	5	0	1
69	29	2	2	60	20	20	22.33	1.00	0	113.64	0.61	4.50	0	30	30	15	20	0	5
70	32	3	2	10	20	70	9.17	1.50	0	83.08	0.71	4.00	20	30	20	10	10	0	10
71	37	2	1	30	70	0	26.00	1.00	0	142.55	0.17	3.50	0	5	35	55	0	0	5
72	33	3	0.5	30	70	0	47.33	1.50	0	219.57	0.69	4.00	0	50	30	10	10	0	0
73	33	2	1	80	0	20	94.33	0.60	4	76.67	0.77	5.00	0	20	40	25	15	0	1
74	37	3	1	60	0	40	28.00	2.50	0	17.61	0.89	5.50	0	30	30	20	20	0	0
75	40	3	0.005	0	0	100	11.40	4.00	0	8.33	0.34	9.00	0	0	0	0	0	100	0
76	30	2	0.005	0	0	100	89.33	6.00	0	16.16	0.81	10.00	0	0	0	0	0	100	0
77	30	2	0.005	0	0	100	619.00	8.00	0	82.67	0.85	3.00	0	0	0	0	0	100	0

site	AES	land use	gradient	rifle	run	pool	river width	depth	number gravel bars	velocity	river width bank full	depth bank full	bedrock	boulder	cobble	gravel	sand	silt	LWD
		treatment	(%)	(%)	(%)	(%)	(m)	(m)		(m/s)			(%)	(%)	(%)	(%)	(%)	(%)	(%)
78	30	2	0.05	0	0	100	156.67	4.00	0	140.00	0.89	3.00	0	0	0	0	0	100	0
79	35	2	2	70	0	30	187.00	1.00	2	82.54	0.84	4.00	0	30	30	20	15	0	5
80	37	2	1	30	0	70	29.00	0.60	0	47.37	0.67	5.00	0	15	30	30	20	0	5
81	39	2	1	30	0	70	37.33	1.50	0	22.00	0.66	9.00	0	20	30	20	25	0	5
82	33	2	0.5	50	50	0	20.00	1.50	0	80.95	0.50	8.50	0	0	0	0	95	0	5
83	46	2	1	100	0	0	30.67	1.00	0	101.33	0.62	4.00	0	0	25	30	40	0	5
84	46	2	1	80	0	20	47.67	1.00	1	151.43	0.65	4.50	0	10	30	30	30	0	2
85	43	2	1.5	30	30	40	108.67	1.25	1	144.21	0.75	3.00	0	20	30	40	10	0	1
86	46	3	2	40	30	30	13.50	0.80	0	81.43	0.55	2.80	0	35	20	40	5	0	1
87	46	2	2	80	20	0	25.00	1.50	0	150.00	0.63	4.50	30	45	20	5	0	0	0
88	17	1	2	30	10	60	18.67	0.70	0	66.02	0.70	2.50	0	30	25	20	25	0	1
89	17	1	5	100	0	0	24.00	0.80	1	96.00	0.67	2.80	0	30	25	30	10	0	5
90	17	2	2	100	0	0	33.00	0.80	2	151.81	0.66	2.50	0	20	40	30	10	0	0
91	17	2	1.5	30	30	40	44.00	1.00	0	83.19	0.49	3.50	0	10	30	30	20	0	10
92	17	2	5	100	0	0	11.00	0.60	0	126.92	0.26	3.00	0	40	30	25	5	0	1
93	20	2	1.5	70	10	20	9.27	0.50	0	118.92	0.39	2.50	0	30	30	30	10	0	0
94	17	2	7	70	30	0	17.00	0.50	0	137.21	0.38	3.00	0	30	20	20	20	0	10
95	14	2	2	100	0	0	39.67	2.00	1	122.50	0.68	5.50	0	70	20	10	0	0	1
96	17	2	10	50	20	30	10.50	0.50	1	81.33	0.53	2.00	0	40	20	30	5	0	5
97	14	2	1.5	70	0	30	34.67	2.00	0	102.00	0.76	6.00	0	30	30	20	20	0	0
98	43	2	1	100	0	0	143.00	2.00	3	166.13	0.90	8.00	0	40	30	15	10	0	5
99	48	2	1	60	0	40	120.00	1.50	0	241.79	0.53	5.00	0	20	30	30	20	0	0
100	47	3	0.05	100	0	0	16.00	0.30	0	53.85	0.61	2.50	0	3	5	80	5	5	2
101	46	2	1.5	100	0	0	14.67	0.50	0	61.54	0.44	2.50	0	30	20	40	10	0	0
102	46	2	2.5	100	0	0	65.67	0.60	1	58.82	0.75	3.00	0	30	40	15	10	0	5
103	46	3	2.5	60	30	10	36.33	0.60	1	130.67	0.50	3.00	0	40	30	20	5	0	5
104	46	3	1	10	10	80	18.67	0.60	0	15.90	0.79	2.50	0	30	40	20	10	0	1

site	AES	land use	gradient	rifle	run	pool	river	depth	number	velocity	river	depth	bedrock	boulder	cobble	gravel	sand	silt	LWD
			(%)	(%)	(%)	(%)	(m)	(m)	gravel	(m/s)	width	bank	(%)	(%)	(%)	(%)	(%)	(%)	(%)
		treatment							bars		bank	full							
105	46	3	1.5	30	20	50	22.00	0.60	0	85.71	0.77	2.50	0	40	30	25	5	0	0
106	46	2	1	20	0	80	54.00	1.50	0	39.07	0.48	4.00	0	50	30	10	10	0	1
107	46	2	1.5	40	30	30	20.67	0.60	0	111.11	0.62	3.50	0	20	30	40	10	0	0
108	47	2	1	50	20	30	16.50	0.30	0	73.33	0.71	2.50	0	10	30	40	20	0	0
109	48	2	0.5	0	0	100	66.33	3.00	0	21.59	0.64	15.00	0	5	5	5	80	0	5
110	46	2	0.5	70	0	30	135.00	2.00	0	141.89	0.71	5.00	0	5	25	40	30	0	1
111	46	2	4	50	20	30	22.00	2.00	1	105.33	0.73	5.00	0	35	15	30	20	0	1

Appendix 6. Benthic Integrity Biotic Indexes based on aquatic macroinvertebrates of sampled locations in the Upper Napo River Basin. Col. = Coleoptera, Eph. = Ephemeroptera, Hem. = Hemiptera, Meg. = Megaloptera, Odo. = Odonata, Ple. = Plecoptera, Tri. = Tricoptera, non-Chi. = non-Chironomidae Diptera, int. = intolerant.

site	land use treatment	AES	# family	# genus	number of taxa									dominance (%)	tolerants (%)	predators (%)
					Col.	Eph.	Hem.	Meg.	Odo.	Ple.	Tri.	non-Chi.	int.			
1	1	25	8	8	0	0	0	0	0	0	2	7	0	96.18	98.47	0.76
2	1	22	9	9	1	1	0	0	0	0	2	8	2	92.36	95.64	1.45
3	1	24	7	9	2	1	0	0	0	0	0	7	1	71.43	94.29	0.00
4	1	24	15	22	6	0	0	0	0	0	8	21	5	73.45	95.10	1.88
5	1	24	13	18	6	1	0	0	0	1	3	17	7	87.83	93.75	2.63
6	1	24	18	26	6	3	0	0	1	1	4	24	7	68.18	59.92	1.24
7	1	22	10	11	2	0	0	0	0	0	1	10	1	92.06	97.27	1.24
8	1	24	13	14	1	1	0	0	0	0	2	12	2	87.35	92.99	1.98
9	1	13	11	13	1	3	0	0	0	0	1	11	4	81.47	92.67	0.86
10	1	15	12	14	1	3	0	0	0	1	3	13	5	85.09	76.32	0.00
11	1	13	13	15	2	1	0	0	0	1	4	14	5	67.49	85.71	0.00
12	1	13	11	13	1	1	0	0	0	0	2	11	3	76.54	55.56	3.70
13	1	13	10	12	2	1	0	0	0	0	2	10	2	86.97	87.74	0.77
14	1	13	8	8	0	0	0	0	0	0	1	7	0	96.17	100.00	0.00
15	1	13	8	9	2	2	0	0	0	0	1	8	3	82.05	61.54	5.13
16	1	13	15	18	3	1	0	0	0	1	5	17	4	71.43	46.13	5.06
17	1	13	10	10	1	0	0	0	0	1	0	9	2	79.22	80.52	7.79
18	2	15	4	5	2	0	0	0	0	0	0	5	2	77.78	11.11	0.00
19	2	15	7	8	0	0	0	0	0	0	0	5	1	80.68	99.79	55.41
20	1	17	1	2	2	0	0	0	0	0	0	2	2	100.00	0.00	0.00

site	land use treatment	AES	# family	# genus	number of taxa									dominance (%)	tolerants (%)	predators (%)
					Col.	Eph.	Hem.	Meg.	Odo.	Ple.	Tri.	non-Chi.	int.			
21	2	17	4	5	4	0	0	0	0	0	0	5	2	66.67	33.33	0.00
22	2	4	10	10	7	0	0	0	0	0	0	10	1	58.82	88.24	17.65
23	2	6	4	9	6	1	0	0	0	0	0	9	5	57.14	35.71	0.00
24	1	4	5	7	4	1	0	0	0	0	0	7	4	42.86	14.29	0.00
25	2	7	13	17	10	1	1	0	0	0	0	17	5	66.35	19.23	3.85
26	1	4	6	8	5	0	1	0	0	0	0	7	2	50.00	50.00	20.00
27	1	4	2	3	3	0	0	0	0	0	0	3	1	100.00	40.00	0.00
28	1	4	5	6	5	0	0	0	0	0	0	6	2	72.73	63.64	9.09
29	2	1	14	16	2	3	0	0	0	0	3	15	4	80.22	79.75	1.58
30	1	4	21	29	6	3	1	0	0	1	6	27	7	68.98	53.77	1.66
31	1	7	12	16	4	6	0	1	1	1	0	15	11	76.69	3.38	1.13
32	1	7	19	30	5	9	0	0	0	1	3	28	14	65.84	13.58	1.23
33	1	7	11	16	2	7	2	0	0	0	1	13	7	74.49	14.29	3.06
34	2	12	14	17	4	6	3	0	1	0	0	16	7	68.75	15.00	6.25
35	2	8	13	19	3	8	1	0	1	0	0	17	10	71.58	15.79	2.11
36	2	12	17	23	3	7	1	1	3	1	2	21	12	32.35	33.82	16.18
37	3	8	12	14	3	5	1	0	2	0	1	12	6	45.16	45.16	12.90
38	2	37	21	33	6	10	2	0	6	1	2	32	15	50.16	20.06	3.45
39	3	33	11	12	4	3	0	1	1	0	1	11	7	61.90	54.76	4.76
40	2	46	18	26	10	4	1	1	2	1	1	25	14	36.89	23.30	16.50
41	1	45	12	22	5	4	0	1	0	1	3	19	11	60.66	27.87	6.56
42	2	45	18	23	8	3	0	1	2	1	3	22	10	33.33	35.90	17.95
43	2	45	10	14	1	5	0	1	0	1	2	14	8	63.79	13.79	3.45
44	2	46	20	29	7	6	3	1	1	1	4	27	12	34.67	42.67	8.00
45	3	46	11	15	3	5	4	1	1	0	0	12	7	65.96	8.51	72.34

site	land use treatment	AES	# family	# genus	number of taxa									dominance (%)	tolerants (%)	predators (%)
					Col.	Eph.	Hem.	Meg.	Odo.	Ple.	Tri.	non-Chi.	int.			
46	2	46	13	21	3	9	3	1	1	1	1	19	14	57.55	48.11	8.49
47	2	46	15	21	7	5	1	1	1	1	3	20	12	49.00	15.00	5.00
48	3	46	18	33	11	9	0	0	2	1	3	31	19	47.52	29.79	2.13
49	2	45	16	28	6	9	2	1	1	0	5	27	15	59.06	25.73	2.92
50	3	17	17	25	7	4	1	1	0	1	4	23	14	86.64	6.61	3.04
51	2	17	8	9	1	3	0	1	1	0	1	8	4	68.18	22.73	22.73
52	2	20	18	24	8	5	1	1	0	1	4	23	12	76.33	4.16	1.87
53	2	14	10	13	1	6	0	1	0	1	2	12	9	70.34	7.22	1.14
54	2	20	25	34	10	7	1	0	2	1	7	33	15	55.67	32.02	2.22
55	2	17	11	14	3	5	0	0	0	1	2	13	8	67.61	14.08	0.00
56	2	14	10	15	5	5	0	0	0	1	2	14	11	65.10	4.03	0.00
57	1	17	13	18	4	6	0	0	0	1	2	17	10	65.77	12.75	0.00
58	1	17	14	21	5	6	0	1	0	1	3	19	11	78.98	7.55	0.81
59	2	19	17	28	8	7	1	1	0	1	3	25	16	55.96	21.30	0.72
60	3	17	11	15	2	5	0	0	0	1	3	14	8	89.51	8.18	0.26
61	2	17	11	13	6	3	0	0	0	0	1	12	6	47.83	26.09	8.70
62	2	20	16	22	9	5	0	0	0	1	1	22	9	55.26	18.42	0.88
63	2	17	9	12	2	5	0	0	0	1	0	11	8	59.09	13.64	0.00
64	2	17	15	19	4	5	0	0	0	1	2	18	10	81.22	5.58	0.76
65	2	46	15	25	8	4	0	1	1	1	2	24	13	40.00	41.11	8.89
66	2	46	9	14	5	3	0	1	0	0	0	13	6	71.19	74.58	1.69
67	3	46	20	26	7	6	0	1	1	1	6	25	13	63.14	36.86	2.12
68	2	46	10	16	4	6	0	0	0	1	3	16	12	62.90	14.52	0.00
69	2	29	16	25	6	9	3	0	0	1	2	23	15	44.09	15.05	5.38
70	3	32	20	33	7	6	2	0	3	1	5	31	13	36.54	38.46	12.50

site	land use treatment	AES	# family	# genus	number of taxa									dominance (%)	tolerants (%)	predators (%)
					Col.	Eph.	Hem.	Meg.	Odo.	Ple.	Tri.	non-Chi.	int.			
71	2	37	19	34	9	10	1	1	3	1	4	32	19	44.60	22.30	7.67
72	3	33	19	32	8	10	4	1	0	1	3	29	17	32.46	14.91	12.28
73	2	33	20	31	9	9	1	1	2	1	2	30	18	41.43	17.86	5.71
74	3	37	16	25	8	5	2	1	2	1	2	21	14	36.57	18.29	7.43
75	3	40	4	5	0	2	0	0	0	0	1	4	2	87.50	37.50	0.00
76	2	30	5	5	3	1	1	0	0	0	0	5	2	77.78	11.11	22.22
77	2	30	1	2	0	0	2	0	0	0	0	0	0	100.00	0.00	100.00
78	2	30	5	5	0	1	1	0	0	0	0	4	1	75.00	50.00	25.00
79	2	35	16	27	13	7	1	1	0	1	2	26	19	54.52	13.04	3.68
80	2	37	14	24	7	6	3	0	2	1	3	22	14	38.10	27.38	17.86
81	2	39	14	25	6	7	3	1	0	1	3	22	16	41.67	19.70	12.12
82	2	33	5	7	0	5	0	0	1	0	0	6	5	76.47	41.18	23.53
83	2	46	2	2	0	0	0	0	0	0	0	1	0	100.00	100.00	0.00
84	2	46	12	16	3	5	1	1	0	1	0	15	10	32.35	20.59	14.71
85	2	43	9	10	2	0	3	0	1	0	1	9	1	68.18	81.82	18.18
86	3	46	12	20	7	9	0	0	0	0	0	18	12	49.18	26.23	0.00
87	2	46	5	7	3	3	0	0	0	0	0	7	4	70.59	29.41	23.53
88	1	17	16	25	6	5	0	1	0	1	5	22	13	56.27	20.79	1.08
89	1	17	11	13	2	5	0	0	0	1	1	12	8	72.31	6.15	0.51
90	2	17	11	16	1	7	0	0	0	1	3	15	9	79.34	6.27	0.00
91	2	17	14	23	3	9	0	1	0	1	2	22	14	62.42	13.42	2.68
92	2	17	14	20	5	5	0	0	0	1	4	19	10	47.89	21.13	0.94
93	2	20	19	28	10	6	0	0	0	1	7	27	14	63.41	12.60	0.00
94	2	17	8	9	1	4	0	1	0	0	1	8	5	67.74	22.58	6.45
95	2	14	7	11	1	5	0	0	0	1	0	9	7	69.09	15.45	0.00

site	land use treatment	AES	# family	# genus	number of taxa									dominance (%)	tolerants (%)	predators (%)
					Col.	Eph.	Hem.	Meg.	Odo.	Ple.	Tri.	non-Chi.	int.			
96	2	17	8	9	1	4	0	0	0	1	1	8	6	94.40	7.09	0.00
97	2	14	17	22	6	5	0	0	0	1	5	21	10	65.89	13.58	1.32
98	2	43	8	10	3	3	0	1	0	1	1	10	8	76.00	6.00	2.00
99	2	48	7	9	1	3	1	0	1	1	0	6	5	68.97	20.69	6.90
100	3	47	19	26	4	8	3	1	4	1	0	24	14	67.66	65.27	9.58
101	2	46	13	22	6	5	3	1	1	1	1	18	12	61.54	11.54	10.26
102	2	46	17	30	6	8	1	1	2	1	3	27	17	54.59	25.60	5.56
103	3	46	11	20	6	6	2	1	1	1	1	19	14	48.50	16.74	5.15
104	3	46	19	34	9	9	3	1	1	1	4	31	19	38.50	40.57	3.62
105	3	46	18	31	11	7	1	0	2	1	4	27	15	68.02	69.69	2.15
106	2	46	15	23	5	5	3	1	2	1	3	18	11	43.24	20.27	18.92
107	2	46	12	16	4	5	0	0	0	1	2	15	10	48.19	38.55	0.00
108	2	47	17	26	6	4	3	1	2	1	4	23	11	31.63	47.96	13.27
109	2	48	1	3	0	3	0	0	0	0	0	3	3	100.00	0.00	0.00
110	2	46	13	24	4	9	0	1	2	1	1	22	16	63.74	12.87	1.75
111	2	46	12	18	4	5	1	1	0	1	2	16	10	65.50	12.28	7.02