Ecological Flow Requirements for Aquatic Macroinvertebrates in the Arequipa Region, Peru

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Introduction & Motivation

Introduction:
- Aquatic macroinvertebrates are often investigated to assess the biological integrity of water bodies and stream health
- Instream sampling and identification of macroinvertebrates are costly and time-intensive, especially for large scale assessments

Goal:
- Develop a methodology to evaluate stream health in the Arequipa region as a function of macroinvertebrate diversity and environmental flow parameters

Objectives:
- Find a macroinvertebrate index relevant to the High Andes region
- Determine the macroinvertebrate taxa expected in the study area
- Create a macroinvertebrate index predictive model based on ecologically relevant hydrological flow parameters

Methodology

Macroinvertebrate Index Selection:
- Macroinvertebrate assemblages vary regionally, and many macroinvertebrate indices have been developed to reflect this variation
- The Andean Biotic Index (ABI) was selected for this study due to its focus on macroinvertebrates inhabiting Andean areas higher than 2,000 meters above sea level

Data Collection:
- Macroinvertebrate samples were taken at two sites in the lower Pulpera River and five sites in the upper Colca River. Samples were taken using Surber samplers
- Five samples were taken at each site, although, due to time constraints, only one from each site was analyzed for this study

Study Area:
- Area: 3,215 km^2
- Located in the Camaná River Basin
- 1 water diversion to the Quilca-Vitor-Chili River Basin
- Study watershed receives water from the Condorama reservoir

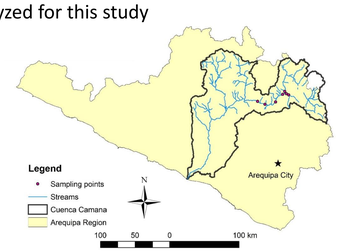


Figure 1. Camaná River Basin containing study area

Baetidae

Chironomidae

Planaria

Figure 2. Macroinvertebrate taxa found in study area

Figure 3. Surber sampler for macroinvertebrates (ASLO – aslo.net)

Methodology (Cont.)

Soil and Water Assessment Tool (SWAT) Model Development:
- SWAT was used to delineate the watershed and stream network. Running the SWAT simulation resulted in streamflow data for all reaches in the study area

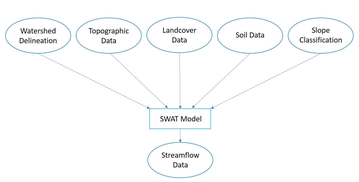
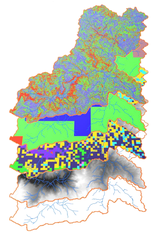


Figure 4. Data layers composing the SWAT model



MATLAB Hydrological Index Tool (MHIT):
- MHIT was used to obtain 171 ecologically relevant hydrological indices representing magnitude, frequency, duration, timing, and rate of change of flow

Two-Phase Model Development:
- Phase #1: Partial Least Square Regression (PLSR) technique was used to estimate 3 stream health indices and associated errors
- Phase #2: Adaptive Neuro-Fuzzy Inference System (ANFIS) was used for final predictions

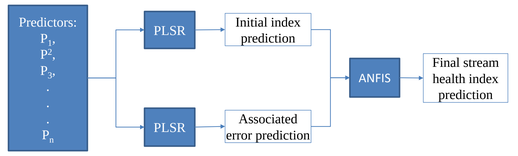


Figure 5. Two-phase stream health predictive model [1]

Results & Discussion

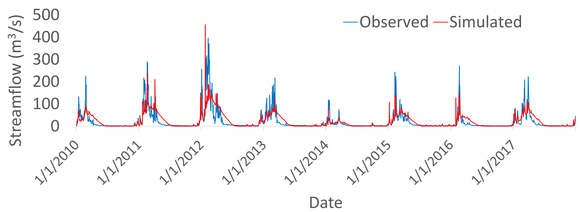


Figure 6. SWAT model calibration results

- The model was calibrated for 2010-2017
- The calibration point used was Bocatoma Tuti
- Model performance:
  - NSE: 0.584
  - PBIAS: -0.086
  - R^2: 0.586

Table 1. Andean Biotic Index (ABI) Water Quality Classes

Water Quality Class	ABI Score
Excellent	>74
Good	45 – 74
Moderate	27 – 44
Poor	11 – 26
Bad	<11

- Of the seven sites sampled, 1 had bad water quality, 5 had poor water quality, and 1 had moderate water quality, according to ABI water quality class cutoffs for Peru [2]

Table 2. Andean Biotic Index (ABI) Score at Sampling Sites

Sampling Site	ABI Score
1	20
2	16
3	22
4	29
5	2
6	18
7	15.5*

* The ABI score for site 7 is the average of the ABI scores for two samples taken at very similar geographic locations, one a few hundred meters upstream from the other

Results & Discussion (Cont.)

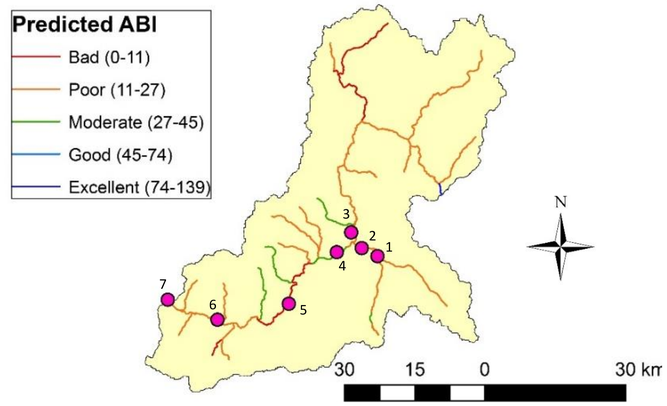


Figure 7: Macroinvertebrate Index Predictive Model Results

Table 3. Predicted Water Quality for Study Area Reaches

Water Quality Class	# of Reaches
Excellent	1
Good	0
Moderate	9
Poor	70
Bad	21

- Most reaches were predicted to have poor water quality or worse
- The root-mean-square error (RMSE) for the stream health predictive model was 0.04
  - This high correlation is likely due to overfitting caused by a limited number of inputs (7) compared to predictors (171)

Future Work

- Incorporate the four additional macroinvertebrate samples taken at each site to improve ABI score accuracy
- Collect macroinvertebrate data for a larger extent of the river to expand the reach of the predictive model
- Create a stream health predictive model for the Chili River, where macroinvertebrate samples were also taken

References

[1] Abouali, M., Nejadhashemi, A.P., Daneshvar, F. and Woznicki, S.A., 2016. Two-phase approach to improve stream health modeling. *Ecological informatics*, *34*, pp.13-21.
[2]Ríos-Touma, B., Acosta, R. and Prat, N., 2014. The Andean Biotic Index (ABI): revised tolerance to pollution values for macroinvertebrate families and index performance evaluation. *Revista de Biología Tropical*, *62*, pp.249-273.

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