Reliability of the Stream Visual Assessment Protocol as a River Quality Evaluation Tool for Aborlan River, Philippines

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Abstract. River water quality monitoring is crucial in the conservation and maintenance of natural resources. However, most procedures demand extensive requirements, high costs, and complex data which render continuous monitoring difficult to maintain. Simpler methods which assesses visually apparent characteristics to convey the general quality of the river ecology were therefore developed. This study applied a modified version of the Stream Visual Assessment Protocol (SVAP) developed by the United States Department of Agriculture (USDA), a procedure which utilizes direct observations to state the general quality of a river and its riparian zone, to the Aborlan River in the Philippines. Its reliability as predictors of physicochemical parameters of the river were tested using correlation analysis. Results showed that SVAP is significantly correlated with temperature and TSS, and can therefore act as rapid predictors of the physicochemical values. Results of the study also indicated that local knowledge is significant in estimating the values of TSS and temperature.

Keywords: Public participation, River water quality, Sensorial Evaluation, Water quality Monitoring.

1. Introduction

Anthropogenic activities can inflict heavy impacts on the state and health of a river (Chen and Lu, 2014; Nyairo *et al*., 2015). River water quality monitoring is therefore fundamental in the preservation of its healthy state. In the Philippines, the Republic Act no. 9275, or the Philippine Clean Water Act (CWA) of 2004 stipulates a comprehensive and integrated strategy to reduce pollution through a multi-sectoral and participatory approach involving all stakeholders (Philippine Clean Water Act of 2004). The newly implemented Department of Natural Resources Administrative Order 2016-08 (DAO 2016-08) classifies water bodies in terms of their use by setting standards for water quality parameters within fresh and marine water bodies, as well as regulates and standardize the amount of effluents from the industrial structures that make their way to water bodies (DENR DAO 2016-08).

To assess the general state of rivers, comprehensive water quality investigations to characterize large watersheds include collection of surface water samples over time at various locations within the watershed and analyses of the samples for multiple chemical and biological constituents (Chappell *et al*., 2012). However, quantitative stream assessments involve taking measurements of a huge variety of physical, chemical, and biological parameters for long periods of time and can take several hours to days to complete at a site and requires high levels of training (Bartlett *et al*., 2012). Furthermore, the size and complexity of the resulting dataset make overall evaluations difficult, and as a result, uses multivariate statistical tools to evaluate environmental patterns and sources of contamination (Chappell *et al*., 2012). The Stream Visual Assessment Protocol (SVAP) developed by the United States Department of Agriculture (USDA, 1998) was developed to reduce the complexity and costs of water quality monitoring through sensorial observations. The procedure is a useful tool for watershed management plan that call for a cost-effective method of monitoring stream corridor conditions over time, including assessing the effects of stream restoration project implementation (Bartlett *et al*., 2012). This study applied the procedure to the Aborlan River in Palawan, Philippines by using the Sarno River Visual Assessment Protocol (SRVAP), a modified SVAP questionnaire and scoring matrix developed by Pandan and Ballesteros (Pandan *et al*., 2014). The SRVAP was adapted because of modifications made to suit river morphology, as well as its simplicity in terms of assessment and analysis. The assessment is composed of technical and community evaluations and the combination of the two sets of evaluations is used for classification of river water quality. Community evaluation were also conducted to test the significance of local knowledge in river water quality monitoring. The reliability of SVAP as a river water quality monitoring tool was analyzed by correlation of the SVAP scores and physicochemical parameters measured in the river.

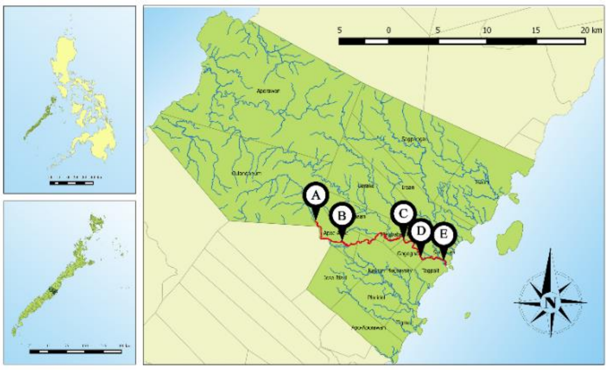

Figure 1. Location Map of the Municipality of Aborlan and the Sampling Sites

2. Materials and Methods

2.1. Area of the Study and the Sampling Sites

The area of the study is the Aborlan River, located within the municipality of Aborlan in the main island of the province of Palawan, Philippines. The river shows continuous water quality degradation based on the trends of physicochemical parameters of the river within four (4) years of monitoring (2010-2013) as reported by the Aborlan River System Management Plan (2014-2016) (ECAN Planning Division PCSD, 2014). Data shows high levels of sedimentation, as well as high concentration of pollutants which can be attributed to unsustainable quarry operations, as well as other anthropogenic activities such as those generating domestic wastes along the river. Unbalanced levels of these parameters can adversely affect the overall ecology of the river ecosystem (Dowling *et al*., 1986). Five (5) sampling stations were selected as sampling stations within the river and are labeled Site A and B at Apoc-apoc, Site C at Magbabadil, Site D at Gogognan, and Site E at San Juan (Figure 1). The sites were chosen because of their distinctive characteristics, as well as homogeneity within a sampling site.

2.2. Sampling, Field Evaluation, and Analysis

Four physicochemical parameters were measured for two (2) sampling periods two (2) days apart on January, 2016. On-site measurements were done on pH, temperature, and dissolved oxygen (DO) using the Hach HQd/IntelliCAL™ Rugged Field Kit multimeter. One-Liter water samples were collected from the sites and analyzed within 24 hours. Total Suspended Solids (TSS) was measured in the laboratory using the gravimetric method. Nine (9) elements were assessed, namely, channel condition (CD), hydrologic alteration (HA), bank condition (BC), Riparian Zone (RZ), water appearance (WA), nutrient enrichment (NE), barriers to aquatic species movement (BM), manure or human waste presence (MP), and aquatic invertebrate habitat (IH). The instrument used was a field questionnaire with multiple choices. The scores were then determined using the SRVAP scoring matrix. Visual evaluation includes technical evaluation were unanimously decided by three (3) evaluators, which is based on scientific knowledge of the morphological characteristics and the general state of the river by instantaneous observations. On the other hand, community evaluation was conducted by interviewing three (3) local respondents from each site, and is based on the experiential knowledge of the local population. The quality of the assessment site was classified using the SVAP scores, with its condition described as bad (1-2.99), poor (3-4.99), fair (5-6.99), good (7-8.99), and excellent (9-10). Correlation between the SVAP scores and the physicochemical parameters was analyzed using Microsoft Excel CORREL function. Technical scores were correlated with the corresponding physicochemical parameter for each sampling period (n=10). On the other hand, each non-technical SVAP score obtained from a respondent was correlated with the average physicochemical data from the two (2) sampling periods (n=15).

3. Results and Discussion

3.1. Aborlan River Water Quality

The physicochemical data measured from the first sampling period (1st SP), second sampling period (2nd SP) and averaged physicochemical measurements of the Aborlan River for the two (2) sampling periods are shown in Fig. 2. Results show that pH values of the sites are relatively close to each other, with its values ranging from 8.22 (2nd SP, Site C) to 8.79 (2nd SP, Site A). The highly basic nature of water in the river can be attributed to the ultramafic soil surrounding the upper parts of the river (ECAN Planning Division PCSD, 2014). The pH values measured from some sites goes beyond 8.5 but below 9.0, which indicates that these areas are outside the ideal range for primary contact recreation. Instead, these areas are only suitable for aquaculture, boating, agriculture, irrigation, livestock watering, and industrial water used for cooling (DENR DAO 2016-08). In terms of temperature, results show that the parameter has an upward trend as the river traverses downward, which can be attributed to the differences in elevation and portion of water exposed to the sun (Johnson *et al*., 2006). It has its highest value at Site D (1st SP, 32.93°C) and its lowest at Site A (2nd SP, 23.73°C). Results on DO show a steep jump to Site D (11.43, 11.11, and 11.27 mg/L for 1st SP, 2nd SP, and average, respectively) and a steep fall at Site E (5.87, 5.95, and 5.91 mg/L for 1st SP, 2nd SP, and average, respectively) in contrast with the stable slope from Sites A, B, and C. Nevertheless, all the sites are still classified as suitable as a source of water supply, and for recreational and fishing uses. Measurements of TSS shows that its peak at Site D (1st SP, 33.33 mg/L) is far from the other sites, which values ranges from 1 mg/L to 9.67 mg/L. Such levels on Site D can be attributed to the numerous anthropogenic activities within the river bank which includes pig raising, farming, and grazing (Hart, 2006). In terms of TSS, the sampling sites within the river are classified as suitable as source of public water supply, and for recreational and fishing uses in accordance to DAO 2016-08. Data from three physicochemical parameters (temperature, DO, and TSS) show that Site D consistently shows relatively extreme values which can be attributed to the increased anthropogenic activities and domestic discharges within the area, as it is located within the main road and is near the community center (poblacion) (Hart, 2006).

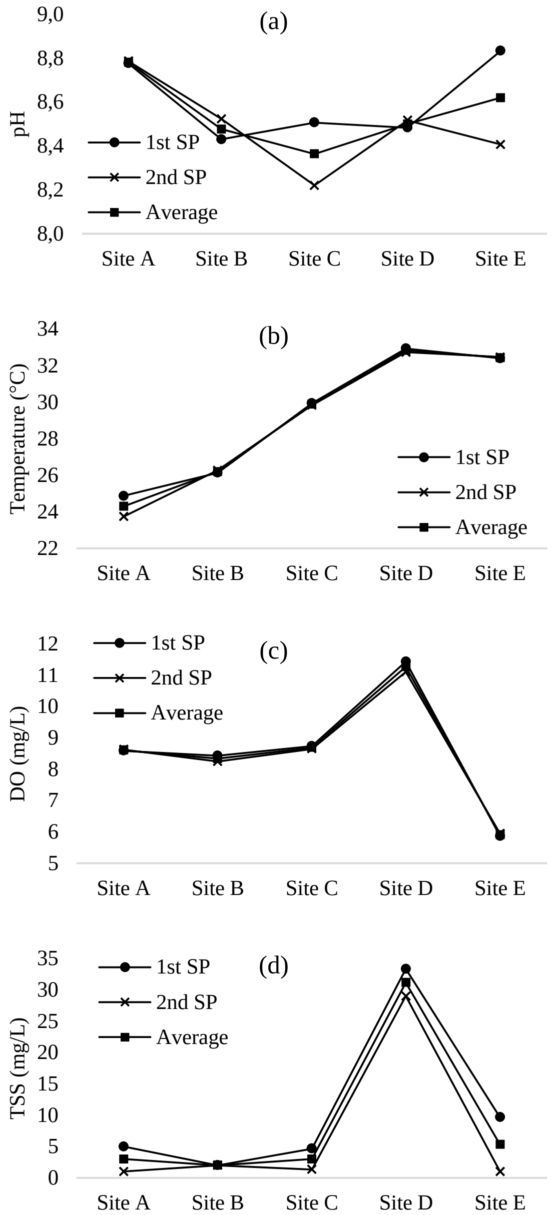

Figure 2. Measured values of (a) pH, (b) temperature, (c) dissolved oxygen, and (d) total suspended solids

3.2. Visual Assessment of the Aborlan River

Results showed that the Aborlan River is in fair to good condition, of which the quality degrades as one goes downstream, as shown in Table 1. For the technical evaluation, SVAP scores ranges from 5.67 (Site D, 2nd SP) to 8.33 (Site B, 1st SP) which indicates fair to good river quality. Lower scores however, were observed in community evaluations, where the score ranges from 4.28 (Site E) to to 7.89 (Site A). It can be inferred that because of Site A's pristine and almost unaltered surroundings (with the exception of the irrigation dam, and an unfinished picnic site), it has the highest general quality (Xia *et al.*, 2012). The lack of residents in the area, as well as its distance from the nearest paved road can also justify the good quality of the river itself. On the other hand, Site D's low scores can be attributed to its proximity to the poblacion area. Human settlements tend to develop around the area of development and growth (in this case, the poblacion), and hence the presence of multiple households a few meters away from the river can alter its quality. The presence of livestock and small agricultural patches in both sides of the river banks can also be a cause of the low quality of the river (Oksel *et al.*, 2009). Furthermore, multiple anthropogenic activities are also observed within the river which are not present on other sites of the river (with the exception of Site E, on which the width of the river and thick forested areas possibly dissipates the effects of such anthropogenic activities) (Liu et a., 2012) such as: shell/invertebrate collecting, fishing, and gardening almost adjacent to the river bank can also be attributed to the relatively low SVAP scores of the site. In terms of the elements scored, BC scored the lowest in both technical and non-technical scores. This implies that Aborlan River in general has poor bank conditions which is evident in the presence of unvegetated stretches, exposed tree roots and scalloped edges. On the contrary, IH scored the highest for both technical and non-technical scores. The high scores indicate that the presence of abundant invertebrate habitats such as fine woody debris, submerged logs, leaf packs, undercut banks, cobbles, boulders, and coarse gravel can give way to improved variety of invertebrate species within the river (USDA, 1998).

Table 1. Technical and community evaluation SVAP scores.

Site	Technical Evaluation		Community Evaluation		
	1st SP	2nd SP			
A	7.89	7.89	7.89	7.89	7.89
B	8.33	7.78	7.44	7.44	7.56
C	7.33	7.33	7.33	7.33	6.67
D	5.67	5.67	5.33	5.11	5.11
E	6.06	6.06	4.28	6.06	5.83

Legend: Excellent, Good, Fair, Poor, Bad

3.3. Data Analysis

Linear regression was done to measure the degree of relationship between SVAP scores and the physicochemical parameters. Scatter Plots are shown in Figures 3 (pH), 4 (temperature), 5 (DO), and 6 (TSS). SVAP scores are shown to have significant negative correlation with temperature (technical: R2 = 0.846; p = 0.0002, non-technical: R2 = 0.7912; p = 0.0001) and TSS (technical: R2 = 0.5332; p = 0.0218, non-technical: R2 = 0.4456; p = 0.0065). On the other hand, no significant relationship was observed between SVAP scores and pH, as well as between SVAP scores and DO. The equations generated for the prediction of temperature is given by:

temperature (°C) = 51.488 – 3.1938*SVAP Score for technical evaluation; and temperature (°C) = 46.041 – 2.5579*SVAP Score for community evaluation. On the other hand, the equations for predicting the value of TSS using SVAP is given by: TSS (mg/L) = 68.879 – 8.5681*SVAP Score for technical evaluation; and TSS (mg/L) = 50.916 – 6.3554*SVAP Score for community evaluation. The generated equations for predicting TSS yield negative values beyond their respective y-intercepts (x = 8.04 for technical scores, and x = 8.01 for non-technical scores). However, as TSS is a measure of quantity, negative values are meaningless. The results denotes that SVAP is plausible in acting as rapid estimation of the values of temperature and TSS in using either trained personnel evaluation of the instantaneous state of the area, or by utilizing local knowledge. Results also indicates that integrating local knowledge is significant in performing the method in the river, and with proper organization and utilization of these knowledge, will both empower the citizens and keep the river in a healthy state (Conrad *et al*., 2008).

4. Conclusions

The use of the modified SVAP scoring system was able to give a general view of the state and health of the Aborlan River, with classification of poor to good for the five (5) evaluation sites. The river was found to have a declining water quality as it goes downstream. A statistically significant linear relationship indicates that the procedure is reliable in the prediction of temperature and TSS. Both technical and community evaluations demonstrates plausibility in estimating the values of the two physicochemical parameters in the river. The method is therefore proven to be a cost-effective alternative for continuous water quality analysis of the Aborlan River.

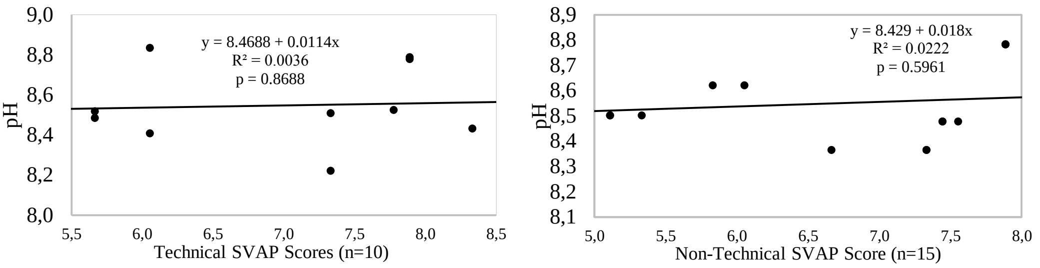

Figure 3. Scatter plots of the correlation analysis between SVAP scores and pH.

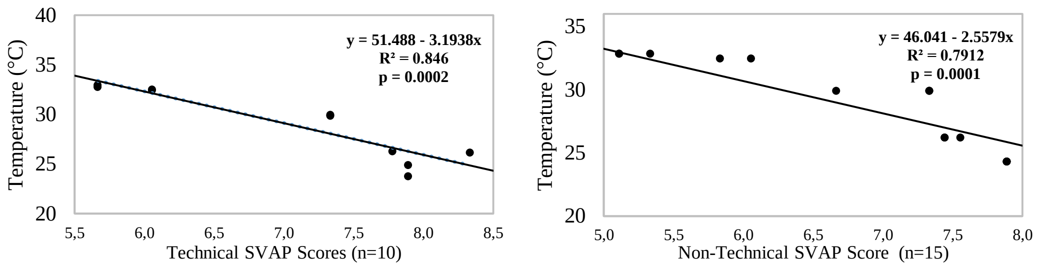

Figure 4. Scatter plots of the correlation analysis between SVAP scores and temperature.

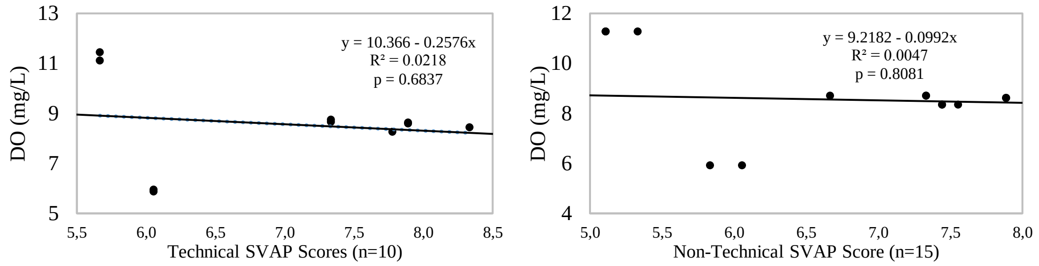

Figure 5. Scatter plots of the correlation analysis between SVAP scores and dissolved oxygen.

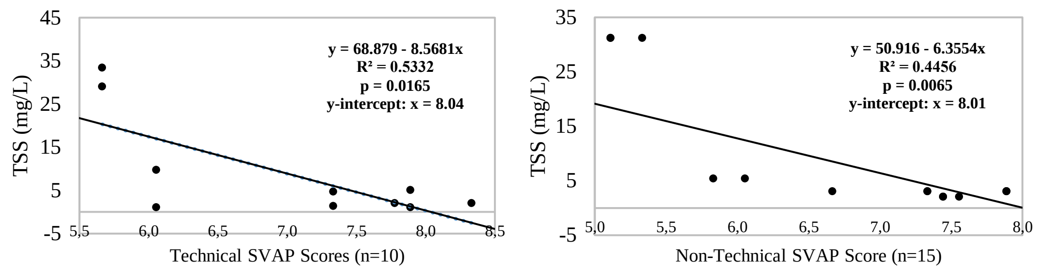

Figure 6. Scatter plots of the correlation analysis between SVAP scores and total suspended solids.

Additional validity studies are recommended to ensure the accuracy of the generated equation.

References

Bartlett A.M., and Frothingham K.M. (2012), Using the Stream Visual Assessment Protocol (SVAP) as a monitoring tool to assess stream corridor conditions over time, *Middle States Geographer*, **45**, 10-20.

Chappell R.W., Loftis J.C., Olsen R.L. (2012), Water quality sample data collection, data treatment, and results presentation for principal components analysis – literature review and Illinois River Watershed case study, *Elsevier Water Research,* **46**, 3110-3112.

Chen J., and Lu J. (2014), Effects of land use, topography and socio-economic factors on river water quality in a mountainous watershed with intensive agricultural production in East China, *PLoS One,* **9(8)**, e102714.

Conrad C.T., and Daoust T. (2008), Community-based monitoring frameworks: increasing the effectiveness of environmental stewardship, *Environmental Management*, **41**, 358-366.

Department of Environmental and Natural Resources Administrative Order Number 2016-08: Water Quality Guidelines and General Effluent Standards of 2016.

Dowling D.C., and Wiley M.J. (1986), The Effects of Dissolved Oxygen, Temperature, and Low Stream Flows on Fishes: A Literature Review, Aquatic Biology Section Technical Report 1986 (2), Illinois Natural History Survey.

Environmentally Critical Areas Network (ECAN) Planning Division. (2014), Aborlan River System Management Plan (2014-2016), Palawan Council for Sustainable Development.

Hart H.M. (2006), Effects of land use on total suspended solids and turbidity in the Little River Watershed, Blount County, Tennessee, (Unpublished Master's Thesis), University of Tennessee, Knoxville, USA.

Harvey D. (2000), Modern Analytical Chemistry, McGraw Hill, pp. 390-394.

Johnson S.L. (2006), Factors influencing stream temperatures in small streams: substrate effects and a shading experiment, *Canadian Journal of Fisheries and Aquatic Sciences*, **61**, 913–923.

Liu W., Li S., Bu H., Zhang Q., and Liu G. (2012), Eutrophication in the Yunnan Plateau Lakes: the influence of lake morphology, watershed land use, and socioeconomic factors, *Environmental Science and Pollution Research,* **19**, 858-870.

Nyairo W.N., Owuor P.O., Kengara F.O. (2015), Effects of anthropogenic activities on the water quality of Amala and Nyangores tributaries of River Maya in Kenya, *Environmental Monitoring and Assessment*, **187**.

Oksel O., Razali N., Yusoff M.K., Ismail M.Z., Pa'ee K.F., Ibrahim K.N. (2009), The impacts of integrated farming to water quality: case study on Langgas River, Kunak, Sabah, Malaysia, *International Journal of Engineering & Technology,* **9**, 341.

Pandan M.A., and Ballesteros F. (2014), A new approach to evaluate the ecological status of a river by visual assessment, *Omics International Hydrology: Current Research,* **6**.

Philippine Clean Water Act of 2004, Republic Act 9275, 12th Congress.

United States Department of Agriculture (USDA). (1998), Stream Visual Assessment Protocol (No. NWCC-TN-991), National Water and Climate Center, Portland, Oregon.

Xia L.L., and Liu R.Z. (2012), Correlation analysis of landscape pattern and water quality in Baiyangdian Watershed, *Elsevier Procedia Environmental Sciences*, **13**, 2188-2196