CUSTOMIZATION OF THE STREAM VISUAL ASSESSMENT PROTOCOL (SVAP) TO EVALUATE THE ECOLOGICAL CONDITION OF A POLLUTED RIVER: THE CASE OF SARNO RIVER, CAMPAGNA REGION, ITALY

BALLESTEROS F.C.JR.[1,*], PANDAN M.A.[1], NADDEO V.[2] and BELGIORNO V.[2]

[1] Environmental Engineering Graduate Program, University of the Philippines, Diliman, Quezon City 1101, Metro Manila, Philippines, [2] Sanitary Environmental Engineering Division (SEED), Department of Civil Engineering, University of Salerno, via Ponte don Melillo, 84084 Fisciano (SA), Italy, *Rm 317, NEC Building, University of the Philippines Diliman, Quezon City 1101 Philippines
E-mail: balleste@gmail.com

ABSTRACT

Most water management methodologies require comprehensive studies involving much data, time and scientific expertise. Strategies using sensorial evaluation were thus considered as this represents a method with minimal cost and makes use of local knowledge. This study applied the Sarno River Visual Assessment Protocol (SRVAP), a modified version of the Stream Visual Assessment Protocol (SVAP) developed by the United States Department of Agriculture, to Sarno River, Italy and tested its reliability as a tool for river assessment. The new approach in the customization of the SVAP to the Italian river is detailed in this paper. Changes gave emphasis to the utilization of the weighted-average method and the incorporation of local knowledge into the assessment. The resulting procedure proved to be a good representative of the general conditions of Sarno River.

Keywords: stream assessment, environmental monitoring, public participation, river water quality

1. Introduction

SVAP and its updated version SVAP2 were designed for conditions in the United States and in recognition of the influence of differences in stream conditions, the authors of these protocol highly encourage modifications and calibration to specific applications (USDA, 1998;USDA, 2009). Also, SVAP was designed for agricultural areas surrounding a river system. Moreover, it is intended to be conducted together with landowners and farmers living in the area so as to incorporate local knowledge in the assessment process. Sarno River has a wide range of land uses and involves a wider range of stakeholders. Hence, this affects possible data collection methods in the evaluation. A customization of the protocol to rivers in Italy was done and the resulting methodology was named Sarno River Visual Assessment Protocol (SRVAP). The design of the SRVAP was done in two (2) phases namely, (1) design of questionnaires and (2) development of assessment procedure.

1.1. Design of Questionnaires

Two types of evaluation were considered to cover technical and non-technical modes of evaluation. The former has the advantage of involving more scientific knowledge of environmental processes and interactions. Its drawback however is that it represents only instantaneous observations. To fill this gap, a non-technical evaluation was also considered to gain a more holistic understanding of river conditions.

1.2. Technical Evaluation

Fifteen elements were initially identified by the USDA (1998) as relevant elements in stream assessment. From the preliminary field evaluation of Sarno River, it was found that there are only eleven (11) applicable elements. Using SVAP as a guide, key visual observations were identified for each element and these were transformed into questions which can be answered using a multiple choice format.

1.3. Non-technical Evaluation

In order to incorporate public participation, a questionnaire was also prepared for non-technical evaluation. Local people have the advantage of a temporal and experiential knowledge of conditions in the river and so, questions enhancing such knowledge were formulated from the SVAP protocol. Considering the knowledge and availability of local people, SRVAP was limited to six (6) elements and the questions were condensed to 16. Pictures were also incorporated in order to facilitate ease and consistency of the answers. Table 1 presents the visual variables of the non-technical evaluation and its correspondence to the technical procedure.

Table 1: Visual Variables of SRVAP Elements for Technical and Non-technical evaluation based on SVAP*

SRVAP Element	VISUAL VARIABLES	
	TECHNICAL	**NON-TECHNICAL**
Channel Condition	Presence of structures	Channel alteration and Signs of Recovery
Hydrologic Alteration	Presence of Water withdrawal structures	Frequency of flooding
Bank Stability	Extent of erosion	Frequency of erosion
Water Appearance	Turbidity of water (instantaneous)	Turbidity of water (frequency)
Barriers to Fish Movement	Presence of Barriers	Abundance of biota in the river
Manure Presence	Presence of manure/human waste or sources	Presence of sources and Frequency of observed manure/human waste

*USDA, 1998 and USDA, 2009

2. Development of assessment procedure

Modifications in the derivation of the ecological condition were done in terms of (a) assignment of scores per element and (b) calculation of ecological condition score.

2.1. Assignment of Scores per element

Technical evaluation is based on the general consensus of the technical team while non-technical evaluation is based on the median scores of the answers of the respondents. Scores for each element were then assigned using a scale of 1 to 10, 1 representing the worst condition.

2.2. Calculation of Ecological Condition Score

The SVAP developed by USDA assumes equal importance among all elements in the derivation of the score for ecological condition. To adapt the procedure to local conditions, the weights were modified for Sarno River using the Paired Comparison Analysis (PCA) Method (Brown & Peterson, 2009; Ngo, 2014.; Pavey, 2014). PCA uses weights which are derived based on the pair-wise relative importance of the criteria using informed judgment.

The assignment of weights was done using the hierarchy tree shown in Figure 1. Ecological condition was determined using four (4) aspects and these were calculated from the different elements of SRVAP shown in Table 1. The aspects were based on the factors that influence the integrity of streams defined by Karr *et al*., (1986) as cited by USDA (1998) and USDA (2009).

The aspects and elements were categorized into levels 2 and 3 of analysis, respectively. For each aspect, comparison of importance for each pair of elements with an addition of a dummy variable was done and the weights for each element were calculated. Then, a pairwise analysis with a dummy variable was also done for the aspects with respect to their importance to ecological conditions. Weighted scores for level 3 were then used to calculate the scores for level 2 which in turn are weighted again to calculate the score for Ecological Condition. The resulting classification is then determined using the assigned scores for each element discussed in Section 2.1 above.

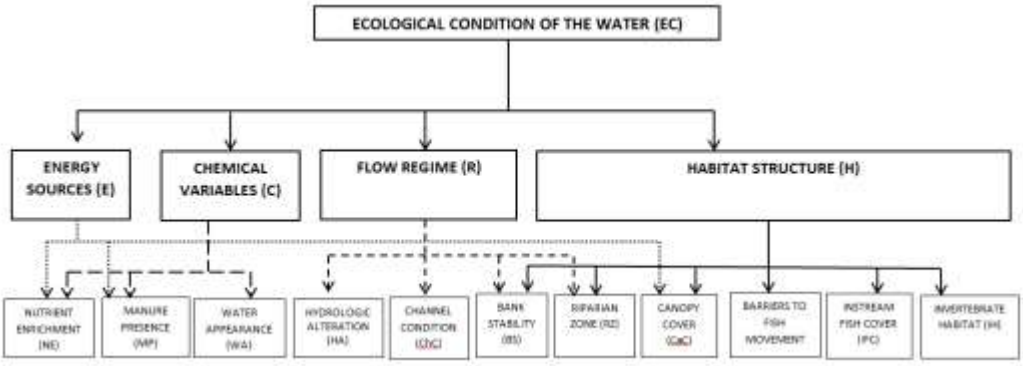

Figure 1: Hierarchy tree for the determination of Ecological Condition

3. Results and discussion

3.1. Visual Assessment of Sarno River

Based on SRVAP evaluation, various sections of Sarno River are classified as good to poor ecological condition. The upstream stations Site A and Site B generally exhibited higher quality than the downstream stations, Site C, Site D and Site E.

3.2. Technical Evaluation

The score for each element for the technical evaluation are shown in Table 2. Channel Condition in stations A, C and E were mainly defined by the presence of structures such as dikes, pathways since it affected the natural flow of the water while fish barriers in the Site A in the form of drop structures had impact on the biotic migration. There was no evident hydrologic alteration in Sarno River during spring but this changed during summer wherein a lowering of surface level was observed in Site A and Site C. There was a trend in the quality of the Riparian Zone in the river were the highest quality is seen in Site A and deteriorated downstream. Bank Stability was high in Site A, B and E while it is low in Site C and D. However, increased bank stability in Site C during summer was seen as more vegetation was observed growing in its riparian area. The results show that the flow conditions of the river are affected by seasonal variations.

Water Appearance and Nutrient Enrichment in the river were of the lowest quality except in Site A as manifested by dark green and turbid water in the area. In addition, the presence of manure and human waste were evident throughout Sarno River significantly affecting water quality as reflected by the organic content of the water.

SRVAP scores and the weights were used to calculate for the SRVAP scores of all stations and these are shown in Table 3. Scores ranged from 3.47 (poor) to 8.02 (good) for weighted SRVAP and ranged from 4.36 (poor) to 8.27 (good), with the quality deteriorating further downstream. Site A has high scores in all aspects which positively affected its water quality. A significant deterioration was noted in Site B on all aspects except Flow Regime, which resulted to its classification as fair. Site C and E both exhibited very low scores in ES, CV, FR and HS contributing to poor ecological condition. Site

D had high scores in FR which is attributed to the absence of structures and excellent channel condition in the area.

Table 2: SRVAP Scores for Technical Evaluation*

	SPRING (May 8 2013)						SUMMER (Aug 8 2013)				
SRVAP ELEMENT	Site A	Site B	Site C	Site D	Site E		Site A	Site B	Site C	Site D	Site E
Channel Condition	3	10	3	10	3		3	10	3	10	3
Barriers to Fish Movement	5	10	10	10	10		5	10	10	10	10
Hydrologic Alteration	10	10	10	10	10		**3**	10	**7**	10	10
Riparian Zone	10	6.5	1	1	2		10	6.5	**3**	1	2
Bank Stability	10	10	1	1	10		10	10	1	**10**	10
Water Appearance	10	1	1	1	1		10	1	1	1	1
Nutrient Enrichment	10	1	1	1	1		10	1	1	1	1
Canopy Cover	10	10	10	1	1		10	10	10	**10**	1
Manure Presence	5	3	1	3	1		5	3	1	3	1
Instream Fish Cover	8	5	3	5	3		**5**	5	**5**	5	3
Invertebrate Habitat	10	7	7	7	7		10	7	7	7	7

*Change in score during summer is shown in bold and underlined.

Table 3: SRVAP Scores using equal weights and weighted average methods

	SPRING (May 8 2013)					SUMMER (Aug 8 2013)				
	Site A	Site B	Site C	Site D	Site E	Site A	Site B	Site C	Site D	Site E
Energy Sources Score	8.33	3.17	2.50	1.67	1.00	8.33	3.17	2.50	3.17	1.00
Chemical Variables Score	7.50	2.00	1.00	2.00	1.00	7.50	2.00	1.00	2.00	1.00
Flow Regime Score	7.90	9.30	5.20	7.30	6.30	5.10	9.30	4.40	8.20	6.30
Habitat Structure Score	8.52	7.49	5.24	5.33	6.00	7.74	7.49	6.00	6.83	6.00
Weighted SRVAP Score	8.02	5.50	3.47	4.19	3.81	7.19	5.50	3.58	5.05	3.81
Classification	Good	Fair	Poor	Poor	Poor	Good	Fair	Poor	Fair	Poor
Equal Wgt SRVAP **Score**	8.27	6.68	4.36	4.55	4.45	7.36	6.68	4.45	6.18	4.45
Classification	Good	Fair	Poor	Poor	Poor	Good	Fair	Poor	Fair	Poor

Both SRVAP are consistent in its classification of the river but weighted SRVAP exhibited lower scores which is more reflective of actual conditions in the river. It is noted that there are similar scores using equal weights indicating that it is not able to discriminate between sites. This shows that it is more appropriate to use the weighted SRVAP procedure in evaluating the condition of Sarno River.

3.3. Non-technical Evaluation

The score for each element for the non-technical evaluation are shown in Table 4. Channel condition was deemed as in excellent condition by the local people for Sites A and B while C was deemed in good condition and Site E in poor condition. Water appearance was evaluated as poor quality in all sites except Site A while manure presence was consistently seen as fair condition in all stations. Fish

barriers and bank stability was generally given high scores except for the downstream stations. Hydrologic alteration was also given poor to bad rating.

Table 4: SRVAP Scores for Non-technical Evaluation

SRVAP Element	Site A	Site B	Site C	Site D	Site E
Channel Condition	10	10	7	4	10
Hydrologic Alteration	3	2	4.5	2	4
Fish Barriers	8	8	7	5	7
Bank Stability	7	7	7	5	3
Water Appearance	10	3	3	1	1
Manure Presence	6.5	6	6	6	6

Non-technical scores were combined with technical scores using weighted average and these were used for determining the ecological condition of the sampling stations. Based on the nature of the questions and the level of importance of the input of people living in the area, weights were assigned for each element by the technical team. These are shown in Table 5.

Table 5: Assignment of Weights for Technical and Non-technical evaluation

Element	Technical	Non-technical	Reason
Channel Condition	0.75	0.25	Knowledge of structures and their impacts on the river condition is the primary consideration and these are determined by technical evaluation
Hydrologic Alteration	0.75	0.25	The presence of water withdrawal structures compared to frequency of flooding is a better indicator of hydrologic alteration
Barriers to Fish Movement	0.75	0.25	Evaluation of this element needs technical knowledge of structures and its effect on the river system
Bank Stability	0.50	0.50	Temporal knowledge of erosion is important and this is seen in non-technical evaluation
Water Appearance	0.25	0.75	Experiential and temporal knowledge has greater weight and provides a more comprehensive evaluation of ecological condition
Manure Presence	0.25	0.75	Experiential and temporal knowledge has greater weight and provides a more comprehensive evaluation of ecological condition

SRVAP scores which incorporated non-technical evaluation ranged from 4.31 to 8.18, representing poor to good conditions (Table 6). Site A exhibited good conditions in all aspects of the evaluation while Site B exhibited good condition in terms of FR/HS. Its fair evaluation is mainly due to its low scores in ES/CV. The downstream stations were all classified as of poor quality, as it was evaluated to have low scores in ES/CV and fair condition in FR/HS. Contributing factors to low quality were identified as water appearance indicating that people tend to judge the quality of the river in terms of this visual cue.

Table 6: Results of combined technical with non-technical evaluation

	SPRING (May 8, 2013)					SUMMER (August 8, 2013)				
	Site A	Site B	Site C	Site D	Site E	Site A	Site B	Site C	Site D	Site E
Energy Sources Score	8.71	3.92	3.75	2.42	2.25	8.71	3.92	3.75	3.92	2.25
Chemical Variables Score	8.06	3.38	3.13	3.13	2.88	8.06	3.38	3.13	3.13	2.88
Flow Regime Score	7.58	8.35	5.25	6.25	5.88	5.48	8.35	4.75	6.70	5.88
Habitat Structure Score	8.49	7.21	5.45	5.33	5.44	7.70	7.21	6.21	6.30	5.44
Weighted SRVAP Score	8.18	5.77	4.43	4.45	4.31	7.48	5.77	4.59	5.03	4.31
Classification	Good	Fair	Poor	Poor	Poor	Good	Fair	Poor	Fair	Poor

4. Conclusion

The SRVAP using weighted-average technical evaluation is an effective tool in describing the general condition of Sarno River. Using this instrument, Sarno River was found to have good to poor conditions in the five sites studied. The condition of the river was also found to deteriorate as one travels downstream. The results showed the importance of incorporating public knowledge in the coming up with an accurate evaluation of the river's general condition.

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