FLORAL DIVERSITY ASSESSMENT OF BALILI RIVER AS POTENTIAL PHYTOREMEDIATORS

Jones T. Napaldet and Inocencio E. Buot Jr.

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Abstract: Local floras of Balili River were inventoried to determine plants with phytoremediation potential using line intercept method. Common weeds namely *Alternanthera sessilis*, *Pennisetum purpureum*, *Eleusine indica*, *Cyperus distans*, *Amaranthus spinosus* dominated the littoral zones of Balili River. Only nine species were documented in the area and thus, expectantly, registered low values in diversity indices such as Shannon-Wiener's, Margalef's and Simpson's index. The upstream, midstream and downstream sampling stations in the littoral zone have high index of similarity but differ significantly with the nearby upper riparian zone in terms of diversity and species composition. This could be attributed to the prevailing environmental conditions in the two zones – the littoral zone has waterlogged sandy soil while clayey loam and mesophytic condition prevail in the upper riparian zone. Literature reviews showed that these local flora have phytoremediation potential, albeit mostly in soil conditions, and thus worthy to be explored for the clean-up of the river's pollutants.

Keywords: *Alternanthera sessilis, Amaranthus spinosus, Cyperus distans,* diversity indices, *Eleusine indica, Pennisetum purpureum,* phytoremediation

Introduction:

Several water bodies around the globe are the main receiving end of water pollutants, discharged as sewage, wastewater and untreated or poorly treated effluents from industries. Total global water use has steadily increased thought-out human history. The wastewater generated in different activities enters water bodies either in untreated or partially treated conditions with heavy loads of pollutants containing pathogens, oxygen depleting organic matters, non-biodegradable organic chemicals, heavy metals, crude oil, hydrocarbons etc. that cause large scale pollution of these water bodies (Chavan and Dhulap 2012).

Such was the case of Balili River, an important water resource of Baguio City and La Trinidad. With a total length of 9,760 meters, the upper Balili River basin starts upstream from Baguio City with its tributary Sagudin River and flows into La Trinidad valley draining 74 of the 128 barangays of Baguio and 7 of the 13 barangays of La Trinidad. Due to various human activities, Balili River is highly polluted. It was

Jones T. Napaldet:
Biology Department
Benguet State University
La Trinidad, Benguet 2601
and Institute of Biological Sciences
University of the Philippines Los Baños
Laguna, Philippines
e-mail: jtnapaldet@up.edu.ph

Inocencio E. Buot Jr.:
Institute of Biological Sciences
University of the Philippines Los Baños
and Faculty of Management and Development Studies
University of the Philippines Open University
Los Baños, Laguna, Philippines 4031
e-mail: iebuotjr@upou.edu.ph

originally classified as Class A but its current water quality only qualifies for Class D water particularly during summer months. This had been established in several studies conducted from 1990s to 2010, and from the regular monitoring of EMB-CAR and the Baguio City Environment and Parks Management. Amidst these, the river still remains as an important source of irrigation for La Trinidad farmers. Strawberry and salad crops are primarily being grown in the valley thus use of contaminated water from the river poses a direct threat to the food safety of these crops. Also, being an eyesore, the clean-up of Balili River is seen to boost the tourism industry in the area.

Amidst the polluted state of the river, some plants are seen growing, or even vigorously thriving, on its littoral zones. These plants may have phytoremediation potentials. Aside from being high tolerant to pollution, these plants may also have the ability to extract or degrade contaminants. Also, these plants are naturally adapted to the local condition thus easing the need for maintenance, a common challenge in phytoremediation. However, these plants need first to be botanically identified and inventoried.

The study aimed to inventory the floral diversity of Balili River which can be potentially used for its remediation and restoration. Specifically, it aimed to:

- inventory the species richness and dominant plants in the river particularly in the littoral zones;
- compare the floral diversity in the littoral zone along the upper, middle and downstream stretch of the river and with the adjacent areas;
- determine the phytoremediation potential of the river's dominant plants from available published articles and other related literatures.

Materials and methods:

The floral diversity assessment was conducted on the main tributary of Balili River along the La Trinidad valley particularly the Km 5 to Km 6 stretch (see Fig. 1).

A reconnaissance survey was first conducted to determine parts of the river which were relatively undisturbed and were near the aquatic portion of the river or the littoral zones. Several portions of the river had or are currently undergoing riverbank stabilization, thus the floral populations therein were disturbed. Also, only the littoral zones were considered where plants were most exposed to water pollutants and were evidently hydrophytic or tolerant to waterlogging. Three sampling stations were established along the river, designated as upstream, midstream and downstream stations in the map. The sampling stations were approximately 500 meters apart.

Line intercept method was selected and employed in the study. This method is advantageous in fast inventory of plants within an area / community. It primarily aims to determine the dominant plants but it is considered more of a qualitative tool. This method is also worthwhile in littoral zones where quadrats are relatively hard to be established. For small herbs, 1 meter is the standard transect length. However, in the sampling stations, tall grasses and herbs predominate so the transect lines were doubled into 2 meters. Three transect lines per sampling station were laid-out for a total of 9 transect lines. Plants traversed by the line including those under and over the line were inventoried using density, frequency and intercepted length as the major parameters (see Figs. 2, 3 and 4).

Plants inventoried were documented and taxonomically identified (see Annex Plates). An additional sampling station was also laid out on the upper river bank on the edge of the river's flood plain parallel to midstream station (Fig. 5). This served as a comparison with the littoral zone. The upper river banks parallel to other stations were not considered because these were already converted to farms together with the flood plains. Diversity indices such as Shannon–Wiener's, Margalef's and Simpson's were computed and compared among the sampling stations.

Figure no. 1 Google Map of Balili River in La Trinidad valley showing the sampling areas (2016)

Figure no. 2 Upstream sampling station

Figure no. 3 Midstream sampling station

Figure no. 4 Downstream sampling station

Shannon-Wiener diversity index takes into account species richness and the proportion of each species within the local community. It also takes into account evenness or the distribution of individuals among the species. It was calculated as follows:

$$H = \sum_{i=1}^{S} pi\ (\ln pi)$$

where:

H = Shannon-Wiener diversity index

p*i* = Number of individuals of species *i*/ total number of samples

S = Number of species or species richness

$$E = H/H_{max}$$

where:

E = evenness

H_{max} (maximum diversity possible) = ln (N)

Simpson's index is the complimentary of evenness. It is the common measure of dominance and was computed as follows:

$$D = \sum ni\ (ni - 1) / N\ (N-1)$$

where:

n*i* = total individual of species *i*

N = total number of individual of all species

On the other hand, Margalef's index is simpler. It was computed as:

$$R = (S - 1) / \ln (N)$$

where:

R = richness

S = # of species

N = # of individuals (of all species)

To compare the diversity between sampling stations, Jaccard index of similarity was used. It was simply computed as:

$$J = (S_c) / (S_a + S_b + S_c) \times 100$$

where:

S_c - number of species common to the two samples

S_a - number of species unique to station a

S_b - number of species unique to station b

Figure no. 5 Upper riparian sampling station

Results and discussion:

Population counts

Only nine plant species were documented in the three littoral sampling stations. Of these, six were considered dominant namely *Alternanthera sessilis*, *Pennisetum* *purpureum*, *Eleusine indica*, *Cyperus distans*, *Amaranthus spinosus* and *Cynodon dactylon* with importance values of 22.85, 17.33, 14.51, 14.03, 13.48 and 11.82, respectively (see Tab. 1, Annexes). It can be readily gleaned in the table that the diversity in the littoral zone is low. This was expected given the high amount of pollutants in the river that most plants cannot tolerate. Also, the high disturbance experienced by the area made it highly unstable thus contributing to its low biodiversity. During summer, the water level recedes into low levels allowing the growth of plants but during rainy season and typhoons, the river turns into a roaring rapid. This was consistent with Intermediate Disturbance Theory by Connell (1978) which stated that highly disturbed ecosystems have low diversity.

The dominant plants in the littoral zone were noxious weeds. In fact, these plants were commonly included in several weed manuals (Pancho 1983; Pancho and Obien 1983, 1995) and *Eleusine indica*, *Pennisetum purpureum* and *C. distans* were named among the world's worst weeds (Holm et al. 1977). These plants were fast growing and have high tolerance to different environmental conditions including pollution. It could be generalized that these plants were not simply surviving in the littoral zone but seem to be thriving as they were observably robust. The success of *A. sessilis*, *P. purpureum* and *C. dactylon* in the area could be attributed to their stolon which enables them to colonize exposed area rapidly. Also, the moist condition and occasional flooding favor rooting at their nodes thus hastening their reproduction asexually.

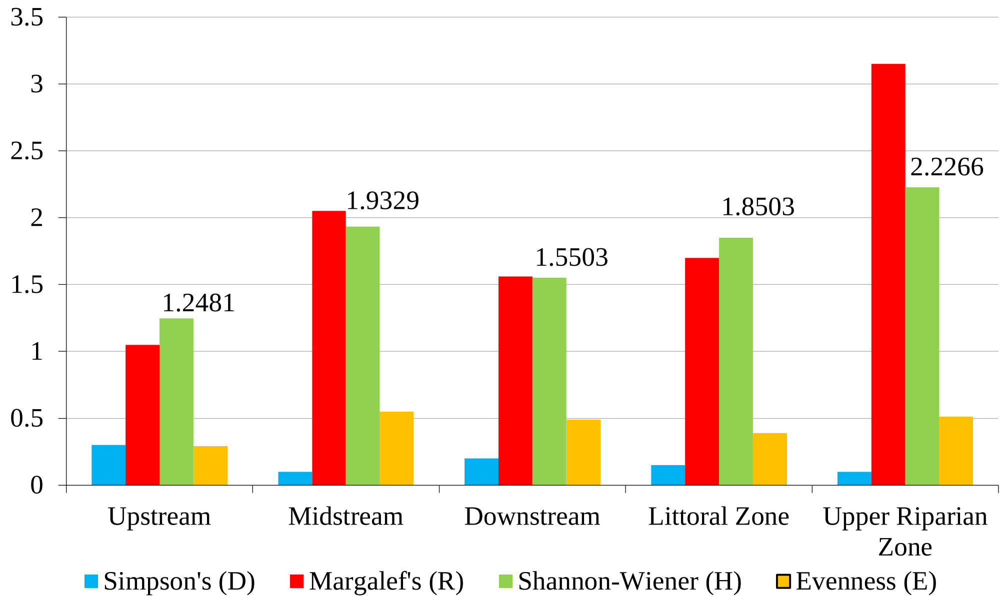
Of the six dominant plants, two belong to family Amaranthaceae (*A. sessilis* and *A. spinosus*), three under Poaceae (*P. purpureum*, *E. indica* and *C. dactylon*) and one Cyperaceae (*C. distans*). The most likely source of these weeds was run-off from erosion or from nearby farm since it was commonly observed that farmers simply dumped uprooted weeds from their farm to the river. *Pennisetum purpureum* and *C. dactylon* were usually being gathered from the river for food of ruminants.

Table 2 (Annexes) presents the species richness in the upper riparian zone. *Cynodon dactylon*, *Phyllanthus tenellus*, *Tithonia diversifolia*, *Mikania cordata* and *Ipomoea purpurea* predominated with important values of 20.91, 15.85, 13.28, 9.08, and 7.67, respectively. Species richness was observably higher than in the littoral zone with 14 species documented. Also, species composition in the upper riparian differed from the littoral zone. Only three species were found common to the two zones, namely *A. sessilis*, *C. dactylon*, *M. cordata*, amidst their proximity.

Diversity indices

Diversity indices such as Simpson's, Margalef's and Shannon-Wiener's were computed in the three littoral stations for comparison purposes (refer to Fig. 6). As expected, Margalef's and Shannon-Wiener's index were low with values ranging from 1.0389 to 2.0384 and 1.2481 to 1.9329, respectively. Shannon-Wiener's index is generally between 1.5 and 3.5 in most ecological studies with higher number indicating greater species richness and evenness. These low index values clearly illustrated the low floral diversity of the littoral zone. On the other hand, Simpson's index ranges from 0 to 1 with higher values indicating presence of dominant species. Upstream and downstream stations registered relatively higher values of 0.3423 and 0.2167 than other stations. *Alternanthera sessilis* dominated the upstream while *C. dactylon* in downstream station. Simpson's index is said to be opposite of evenness and the values gathered supported this. Midstream station registered lower Simpson's but higher evenness.

Figure no. 6 Diversity indices of the sampling stations (littoral zone as the summary of the upstream, midstream and downstream station)



In general, the diversity indices of the three littoral sampling stations did not differ significantly from each other. Moreover, Jaccard's index of similarity (Tab. 3) showed high values ranging from 44% to 75% between the three littoral stations. In fact, the five most dominant plants were present in all the littoral stations. From this, it could be inferred that the environmental conditions prevailing in the littoral sampling stations were comparable which allowed the thriving of similar species.

Table no. 3 Jaccard's index of similarity (%) among stations

	Upstream	Midstream	Upper riparian zone
Midstream	44		
Downstream	57	75	
Littoral zone			15

The indices of the three littoral stations were summarized into littoral zone to make a direct comparison with the upper riparian zone. As expected, the upper riparian zone registered higher values in Margalef's, Shannon-Wiener's and evenness but lower Simpson's index. This clearly illustrated the higher species richness and evenness or overall diversity of the upper riparian zone than the littoral zone. The higher diversity of the upper riparian zone could be attributed to the lesser amount of disturbance experienced by the area as compared to the littoral zone (Connell 1978).

On the other hand, Jaccard's index registered only 15% similarity between the upper riparian zone and littoral zone. Only three species were found common in the two zones namely *A. sessilis*, *C. dactylon*, *M. cordata*. Among the three, only *C. dactylon* was found dominant in both zones. From this result, it could be inferred that the two zones offer different environmental conditions which favored one group of plants but not the other group and vice versa. The littoral zone has waterlogged sandy soil while clayey loam and mesophytic condition prevail in the upper riparian zone.

Phytoremediation potentials of the dominant local plants

Alternanthera sessilis was found to be a good phytoremediator of heavy metals such as Pb, Zn, Fe and Mg in the study of Mazundar and Das (2015) for effluent and Li et al. (2008) for contaminated soils. The plant registered a transcription factor (TF) >1 which indicates a good metal hyperaccumulator. It also means that the plant is capable of translocating the absorbion metal from the root to its shoot. In another study by Tahira (2008), this plant was found to be Na and Cr accumulator but not the best among other plants tested in the study. Earlier, Sinha et al. (2002) determined that *A. sessilis* was not a good accumulator of Cr.

Pennisetum purpureum was also cited to be good phytoremediator of soils contaminated by Cd, Zn, Cs, petroleum hydrocarbon and P. In the study of Zhang et. al. (2010), this plant was tolerant to high Cd polluted soils and registered accumulation and transloction potential for Cd and Zn. In latter study by same authors (Zhang et. al. 2014), only the leaf shape of the plant was affected by high Cd soil pollution but not the biomass. Another study by Ayotamuno et al. (2006) found the plant capable of degrading petroleum hydrocarbon in contaminated soils but less efficient than *Zea mays*. This plant also performed admirably in accumulating Cs with greater accumulation in the shoot than in the roots. Moreover, *P. purpureum* was an excellent P remover due to its high biomass production (Silveira et al. 2013).

From literature review, *Eleusine indica* was documented only as phytostabilizer or good metal excluder at best. Studies of Merkl et al. (2005) found this plant to be tolerant to petroleum hydrocarbon but its accumulation was not significant due to low biomass production. No translocation of the pollutant was also observed. Visoottiviseth et al. (2002), on the other hand, investigated the potential of this plant in As soil remediation but found it inefficient. However, EDTA-assisted accumulation of Cu, Cd, Cr, Co and Pb was observed by Garba et al. (2012) but with low translocation suggesting the plant to be a good metal excluder. This is supported by Lum et al. (2014) which found the plant a good phytostabilizer for Cu.

Only one study was cited on the phytoremediation potential of *Amaranthus spinosus*. Chinmayee et al. (2012) investigated and found the plant suitable for heavy metal (Cu, Zn, Cr, Pb, Cd) accumulation and translocation. More studies were conducted for its related species, *Amaranthus viridis*, which found it also to be highly suitable for phytoremediation.

Literature review showed that several *Cyperus* species were potential phytoremdiators particularly for As and petroleum hydrocarbon but no studies were cited dealing specifically with *C. distans*. Lastly, *Cynodon dactylon* was documented to be a hyperaccumulator of Cr but with low translocation (Abou-Shanab et al. 2007). It was investigated by Wang and Oyaizu (2009) for dibenzofuran remediation but found it inefficient. Shu et al. (2002), on the other hand, determined that *C. dactylon* can develop co-tolerant ecotypes upon exposure to elevated Cd and Zn soil conditions.

Conclusions:

Nine species of aquatic macrophytes were inventoried on the littoral zones of Balili River, La Trinidad, Benguet, Philippines. Dominant were common weeds namely *Alternanthera sessilis*, *Pennisetum purpureum*, *Eleusine indica*, *Cyperus distans* and *Amaranthus spinosus*. Expectantly, the littoral zone registered low values in diversity indices such as Shannon-Wiener's, Margalef's and Simpson's index. The three sampling stations in the littoral zone, namely upstream, midstream and downstream have high index of similarity but differ significantly with the nearby upper riparian zone in terms of diversity and species composition. This is expected since the prevailing environmental conditions in the two zones differ significantly – the littoral zone has waterlogged sandy soil while clayey loam and mesophytic condition prevails in the upper riparian zone. These dominant local plants have been shown in literature reviews to be potential phytoremediators, albeit mostly in soil conditions, and thus timely to be explored for freshwater application.

Rezumat:

EVALUAREA DIVERSITĂȚII FLORALE A RÂULUI BALILI CU POTENȚIAL FITOREMEDIATOR

Flora râului Balili a fost inventariată pentru a determina plantele cu potențial fitoremediator, utilizând metoda transectelor. Plante precum *Alternanthera sessilis*, *Pennisetum purpureum*, *Eleusine indica*, *Cyperus distans*, *Amaranthus spinosus* sunt dominante în zona litorală a râului Balili. Doar nouă specii au fost identificate in areal și, așa cum era de așteptat, au prezentat valori scăzute ale indicilor de diversitate Shannon-Wiener, Margalef și Simpson. Stațiile de colectare situate în zona litorală din amonte, mijloc și aval au prezentat un indice de similaritate mare, dar semnificativ diferit față de zona de mal superioară din apropiere, în ceea ce privește diversitatea și compoziția speciilor. Acest lucru poate fi ca o consecință a condițiilor de mediu din cele două zone de colectare, respectiv, în zona litorală solul este predominant nisipos umed, în timp ce în zona de mal superioară domină un sol argilos cu condiții mezofitice. Literatura de specialitate indică faptul că flora locală prezintă un potențial fitoremediator, mai ales în condițiile solului existent, și astfel se recomandă utilizarea lor pentru curățarea poluanților din râu.

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Annexes:

Table no. 1 Floral species diversity in the three littoral sampling stations

Species name	ni	Ii	Ji	Di	Ci	Fi	RDi	RCi	RFi	IV
Alternanthera sessilis (L.) R.Br. ex DC.	33	830	6	1.83	46.11	66.67	31.73	22.86	13.95	22.85 [I]
Amaranthus spinosus L.	14	304	8	0.78	16.89	88.89	13.46	8.37	18.60	13.48 [V]
Cucurbita maxima Duchesne	1	35	1	0.06	1.94	11.11	0.96	0.96	2.33	1.42
Cynodon dactylon (L.) Pers.	8	670	4	0.44	37.22	44.44	7.69	18.45	9.30	11.82 [VI]
Cyperus distans L.f.	13	483	7	0.72	26.83	77.78	12.50	13.30	16.28	14.03 [IV]
Eleusine indica (L.) Gaertn.	16	515	6	0.89	28.61	66.67	15.38	14.18	13.95	14.51[III]
Mikania cordata (Burm.f.) B.L.Rob.	1	30	1	0.06	1.67	11.11	0.96	0.83	2.33	1.37
Pennisetum purpureum Schumach.	15	689	8	0.83	38.28	88.89	14.42	18.98	18.60	17.33 [II]
Polygonum cf. *barbatum*	3	75	2	0.17	4.17	22.22	2.88	2.07	4.65	3.20

Notes: ni- number of individuals; Ii – intercepted length; Ji – number of station where the species occur; Di – density; Ci – coverage; Fi – frequency; RDi – relative density; RCi – relative coverage; RFi – relative frequency; IV – importance value.

Table no. 2 Floral species diversity in the upper riparian sampling stations

Species name	ni	Ii	Ji	Di	Ci	Fi	RDi	RCi	RFi	IV
Alternanthera sessilis (L.) R.Br. ex DC.	2	25	2	0.33	4.17	66.67	3.33	1.43	6.90	3.89
Phyllanthus tenellus Roxb.	11	330	3	1.83	55.00	100.00	18.33	18.86	10.34	15.85 [II]
Bidens pilosa L.	1	5	1	0.17	0.83	33.33	1.67	0.29	3.45	1.80
Commelina diffusa Burm.f.	5	36	3	0.83	6.00	100.00	8.33	2.06	10.34	6.91
Crassocephalum crepidioides (Benth.) S.Moore	1	11	1	0.17	1.83	33.33	1.67	0.63	3.45	1.91
Cynodon dactylon (L.) Pers.	16	450	3	2.67	75.00	100.00	26.67	25.71	10.34	20.91 [I]
Desmodium procumbens (Mill.) Hitchc.	1	25	1	0.17	4.17	33.33	1.67	1.43	3.45	2.18
Ipomoea cairica (L.) Sweet	4	105	3	0.67	17.50	100.00	6.67	6.00	10.34	7.67 [V]
Lantana camara L.	2	145	2	0.33	24.17	66.67	3.33	8.29	6.90	6.17
Leucaena leucocephala (Lam.) de Wit	3	53	3	0.50	8.83	100.00	5.00	3.03	10.34	6.12
Mikania cordata (Burm.f.) B.L.Rob.	5	210	2	0.83	35.00	66.67	8.33	12.00	6.90	9.08 [IV]
Paspalum conjugatum P.J.Bergius	1	30	1	0.17	5.00	33.33	1.67	1.71	3.45	2.28
Rumex obtusifolius L.	1	13	1	0.17	2.17	33.33	1.67	0.74	3.45	1.95
Tithonia diversifolia (Hemsl.) A.Gray	7	312	3	1.17	52.00	100.00	11.67	17.83	10.34	13.28 [III]

Notes: ni- number of individuals; Ii – intercepted length; Ji – number of station where the species occur; Di – density; Ci – coverage; Fi – frequency; RDi – relative density; RCi – relative coverage; RFi – relative frequency; IV – importance value.