AQUATIC WEED FLORA ON THE SOUTHWEST LAKESIDE OF LAGUNA DE BAY

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Abstract: A weed floristic survey was conducted in the two barangays of the southwest lakeside of Laguna de Bay to determine the dominant weed species present *in situ*. Nine families and ten weed species were noted in the three sampling sites. The majority of the weed surveyed was aquatic, broadleaf weed species. Most of these are floating weeds and capable of sexual and asexual reproduction. The observed weeds can propagate through seeds, spores, offshoots, stolons, fronds, buds, runners and rhizomes. Three upland weeds, *Commelina diffusa*, *Cynodon dactylon* and *Rottboellia cochinchinensis*, were also observed. However, only *Eichhornia crassipes* dominated all the sampling sites followed by *Pistia stratiotes*. The invasiveness, competitive ability and vegetative reproduction of the weeds allowed survival and proliferation of water hyacinth and other aquatic weed species. The eutrophic condition of the lake aggravated the weed problem in the area. Most of the weeds noted were adapted to polluted waters characterized by high levels of nitrogen, phosphorus and heavy metals. Other environmental factors such as temperature and pH also affected the growth of weeds on the lake. Moreover, seeds and vegetative propagules of weeds dispersed by water current may block waterways. Some could also be potential weeds of irrigated rice such as *Salvinia molesta*, *Lemna minor* and *Cyperus imbricatus*. Knowledge on the ecology and biology of these weeds will aid in the development of effective weed management strategies.

Keywords: aquatic weeds, eutrophic, Laguna de Bay, water hyacinth, weed management

Introduction:

Laguna Lake is the largest lake in the Philippines (Oledan 2001). In Southeast Asia, it is considered to be the second largest inland body of water (Herrera et al. 2011). Since the early times, Laguna de Bay has been used chiefly for fisheries and as transport route. It also supplies water to nearby industrial plants and for irrigation (Guerrero 1996).

Over the years, the lake has encountered many problems. One of the major problems is eutrophication. Several studies on the causal factors were conducted in the past. The possible impact of nearby industries including its generated wastes was studied but no direct effect on the increase of nitrogen and phosphorus level in the lake was proven (Bergonia 1995). According to Delos Angeles (1999), the majority of the pollutants in the lake were from domestic

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wastes, others are from farms, industries, fisheries, poultry and livestock.

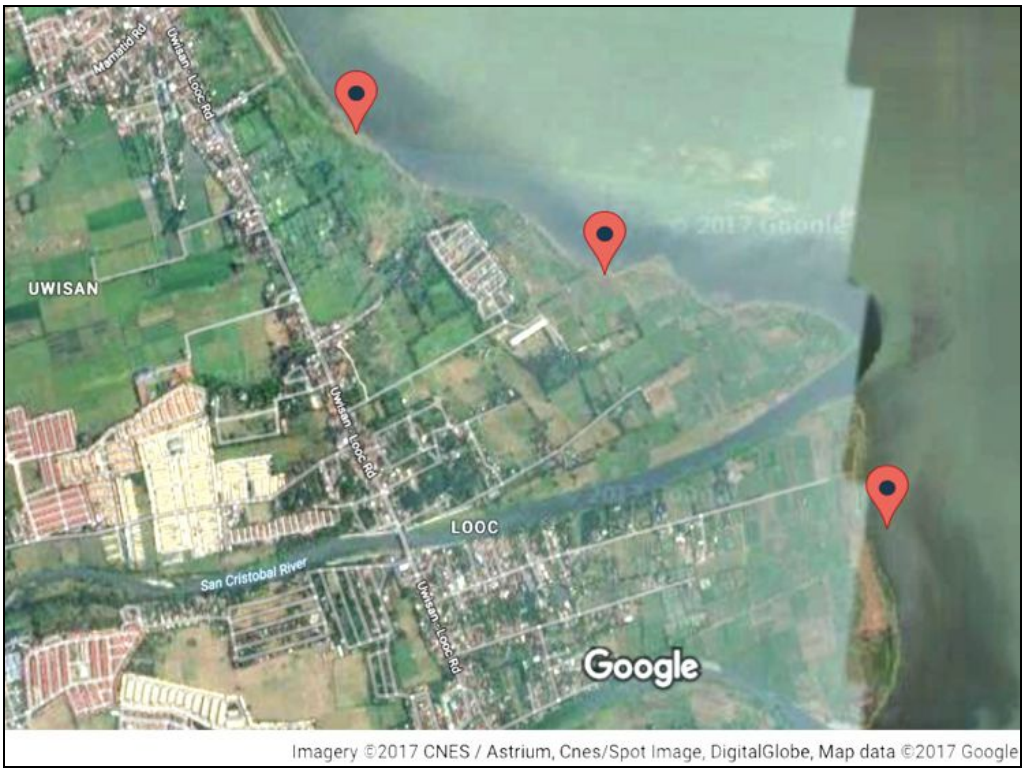
The problem on eutrophication led to mass fish kills that commonly occur from May through September. The cause of death was mainly due to low dissolved oxygen and pollution (Cuvin-Aralar et al. 2001). Other problems include invasion of dense blankets of water hyacinths and other weeds occupying large areas of the lake. It blocks tributaries and waterways such as irrigation canals, rivers and creeks. These weeds could be sources of weed seeds and propagules for the next season and serve as potential weeds of irrigated fields depending on the lake as source of irrigation water.

Weed survey is needed to determine the dominant weed species present in the lakeside and evaluate these weeds in terms of reproduction, response to eutrophication, life cycle and invasiveness. So that lake authorities can think of better options for weed management.

Materials and methods:

A weed floristic survey was conducted on southwest of Laguna de Bay from April to May 2017. Three sampling sites have been selected as shown in Figure 1. Locations 1 and 2 (LOOC1 and LOOC2) were situated at Barangay Looc, Calamba, Laguna with coordinates of 14.2294, 121.1892 and 14.2340, 121.1821, respectively. Location 3 (UWISAN) was positioned at 14.2374, 121.17620 in Barangay Uwisan, Calamba, Laguna.

Figure no. 1 Map of the three sampling sites located at Barangay Uwisan and Looc, Calamba, Laguna (modified Google Maps 2017)



The survey was conducted five meters from the lakeside with estimated water depth of 15 cm. Weed vegetation was observed using a 10-meter line intercept. The length of

intercept was determined based on the heterogeneity of vegetation. Weeds were identified and classified according to growth form, mode of reproduction and life cycle. Book on the Major Weeds of the Philippines (Moody et al. 2014) was used to identify the observed weeds. Separate evaluation was presented for each site.

Dominant weed species were determined using different parameters: frequency, relative frequency, cover, relative cover and mean height and relative height. These parameters were calculated using the equations (Utomo and Putranto 2014) as follows:

Frequency (F):

$$F = NI / TTI$$

where:

NI = number of intervals in which a species occurs in a transect

TTI = total number of transect intervals

Relative Frequency (RF):

$$RF = F / TF \times 100$$

where:

F = frequency value of a species

TF = total frequency values of all species

Cover (C):

$$C = TIL / TTL$$

where:

TIL = total intercept lengths of a species

TTL = total transect length

Relative Cover (RC):

$$RC = C / TC \times 100$$

where:

C = cover values of a species

TC = total cover values of all species

Mean Height (MH):

$$MH = TH / NIS$$

where:

TH = total height of a species

NIS = number of individuals per species

Relative Height (RH):

$$RH = MH / TMH$$

where:

MH = mean height of species

TMH = total mean height of all species

Summed Dominance Ratio (SDR):

$$SDR = RC + RH + RF / 3$$

Results and discussion:

Structure of the Aquatic Weed Flora

The weeds observed in the sampling sites were mostly floating aquatic weeds with more than one mode of reproduction as shown in Table 1 (Annexes). Weeds such as *Pistia stratiotes*, *Ipomoea aquatica* and *Eichhornia crassipes* can propagate both sexually and asexually. Others reproduce by fronds, buds and spores such as *Azolla pinnata* and *Salvinia molesta*. Also, the majority are perennials. The growth form, propagules, adaptability and invasiveness of weed may have affected the presence of these weeds in the three sampling sites. On the other hand, only water lettuce and water hyacinth were observed in all the surveyed locations.

Dominance Analysis of Aquatic Weed Flora in LOOC1 (Barangay Looc, Calamba, Laguna)

In LOOC1, nine families and nine weed species were observed. Among these, seven were broadleaves and two were grass and sedge. *Eichhornia crassipes* or water

hyacinth occurred in each transect followed by *Pistia stratiotes* which appeared in 8 out of 10 transects as presented in Table 2 (Annexes).

Water hyacinth and water lettuce were considered invasive (USDA 2017; Sinohin and Cuaterno 2003). The highest cover and relative cover were also observed in water hyacinth covering around 80% of LOOC1. Based on the Summed Dominance Ratio (SDR) in LOOC1, the dominant weed species was *Eichhornia crassipes* with SDR value of 45.225. The vegetative reproduction of water hyacinth and water lettuce allows fast spread in shallow waters. Offshoots provide aid in the survival and colonization of water hyacinth (Jayan and Sathyanathan 2012).

In terms of height, the highest value of 44 cm was obtained from *Cyperus imbricatus.* This sedge is native in the country and commonly found in wetland rice; it is capable of asexual and sexual reproduction (Kumar 2011; Moody et al. 2014). Despite its favorable characteristics for reproduction, it is sensitive to shading and may not tolerate dense blanket of water hyacinth. Hence, low cover and frequency values were observed for this species in LOOC1. However, when there is no competition, it can form dense groups of plants in the shallow water of the lake as shown in Figure 2.

Figure no. 2 Dense mat of *Cyperus imbricatus* plants observed in LOOC1, Brgy. Looc, Calamba, Laguna

On the other hand, the lowest frequency, cover and height were observed in *Commelina diffusa*, *Lemna minor*, *Azolla pinnata* and *Salvinia molesta*. The small size and easy fragmentation of the vegetative propagules of *L. minor* and *S. molesta* affected the dominance of these weeds in LOOC1. During summer, when pH and temperature increases, the mortality of *L. minor* increases as well (Keddy 1976). The

aerenchyma tissue and brittle rhizomes of *S. molesta* allows fast dispersal across bodies of water. This occurs when the water is fertile (McFarland et al. 2004), the same as the eutrophic condition of the lake. In the areas of the lake with gentle water current, many of these weeds were observed as shown in Figure 3.

Figure no. 3 Dense cover of *Pistia stratiotes*, *Salvinia molesta* and *Azolla pinnata* observed in LOOC1, Brgy. Looc, Calamba, Laguna

Meanwhile, *Commelina diffusa* is a dryland weed and cannot survive prolonged flooding or high water levels. The appearance of this weed in the sampling area may be due to the presence of *C. diffusa* in nearby upland farms and due to low water level in the lake during the summer season (Fig. 4).

Dominance Analysis of Aquatic Weed Flora in LOOC2 (Barangay Looc, Calamba, Laguna)

Less weed species were observed in LOOC2 than in LOOC1. Five families were observed with six weed species. The more prominent human activities such as recreation, upland farming and on-going government projects may have affected the weed composition. Still, the highest frequency and cover values were observed in *E. crassipes* as shown in Table 3 (Annexes). It covered almost 93% of the area surveyed indicating that despite disturbances, water hyacinth is capable of growing and reproducing well (Fig. 5).

Figure no. 4 *Commelina diffusa* observed along the transect line of LOOC1, Barangay Looc, Calamba, Laguna

Figure no. 5 Dense mat of *Eichhornia crassipes* covering the sampling area of LOOC1, Barangay Looc, Calamba, Laguna

Water hyacinth has the ability to reproduce through offshoots and seeds and resist unfavorable environmental conditions (Jayan and Sathyanathan 2012). The characteristic of a eutrophic lake, similar to Laguna Lake, such as high nitrogen, phosphorus and potassium level favors the growth of water hyacinth and may lead to height increase (Howard and Harley 1998).

Relatively lower values were obtained for water lettuce. The strong current in the area may have dispersed it easily. In LOOC2, more and taller *C. imbricatus* was observed. The less dense mat of water hyacinth allowed less light attenuation down the canopy. Thus, it permitted the germination and growth of this sedge. *Rottboellia cochinchinensis* and *Cynodon dactylon*, upland weeds, were also observed. The tallness of Itch grass was used by this weed to adapt to shading brought about by thick stands of water hyacinth. On the other hand, the low water level in the LOOC2 was tolerated by *C. dactylon*, which most probably came from upland farms of vegetables on the lakeside. The dominant weed species in LOOC2 was water hyacinth with SDR value of 55.994.

Dominance Analysis of Aquatic Weed Flora Barangay Uwisan, Calamba, Laguna

The least number of weed species was observed in UWISAN with only four families and four species. All of the noted plant species were aquatic weeds. Residential communities, both upland and lowland farms and fishponds, surround UWISAN. There was also a duck farm on the lakeside. Thus, it is mainly affected by recreational activities and uncontrolled waste disposal. In Table 4 (Annexes), the highest frequency, cover and height values were observed in *Eichhornia crassipes*, which indicates the dominance of this weed in UWISAN. About 98% of the area was covered by water hyacinth. Even though there is problem regarding waste and eutrophication in the lake, this weed can actually grow well even in 100% wastewater (Madan and Verma 2011).

In Figure 6, the second dominant weed, *Pistia stratiotes*, was presented. Water lettuce is less aggressive than water hyacinth but may be problematic in the tropics and subtropics. *Azolla pinnata* and *Lemna minor* have the lowest SDR value of 2.579. Both are small in size and can easily be displaced by water current or larger weeds (Keddy 1976).

General Observation

In the three adjacent locations in southwest part of Laguna de Bay, 10 weed species of nine families have been observed. The majority are broadleaves. Grass and sedge have only two and one representative species, respectively. In Table 5 (Annexes), the three major weeds (water hyacinth, water spinach, water lettuce) in the sampling sites were perennial weeds that reproduce by seeds and vegetative propagule such as stolons, stem-cuttings and offshoots.

Water hyacinth can flower throughout the year as source of seeds for the next generation (Balasubramanian et al. 2014). Even though it requires light and shallow water for germination to proceed (Center and Spencer 1981), reproduction is not a problem. In summer, the plants die but seeds germinate due to presence of favorable environmental conditions for germination. Water lettuce, despite being less aggressive than water hyacinth, can grow tremendously and form dense mats under high light intensity and nutrient levels. It can also produce highly viable and long-lived seeds (Dray and Center 1989; Howard and Harley 1998). In the three sampling locations, two cultivars were observed: violet and white-flowered water hyacinths (Figs. 7a and 7b).

On the other hand, smaller weeds such as *S. molesta*, *A. pinnata* and *L. minor* have the low SDR values due to small size. It can easily be fragmented and displaced. *Lemna minor* is a native, competitive weed species that can tolerate desiccation and rapidly

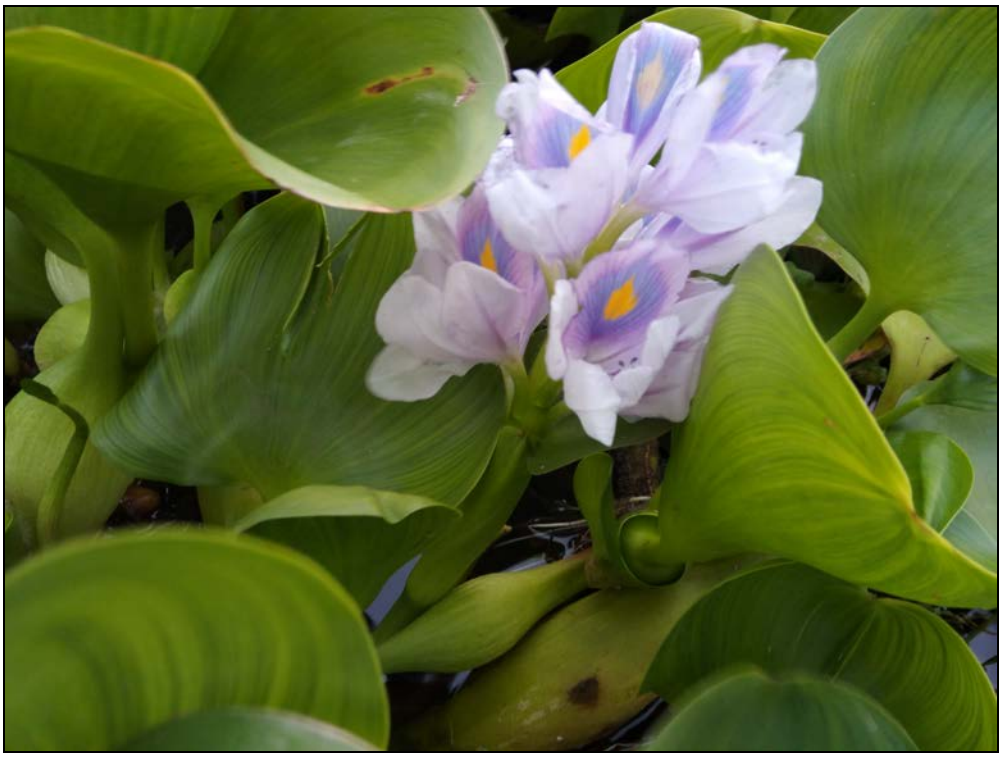
reproduce (Zhuang 2014; Keddy 1976). It grows well in fertile water and at temperatures up to 30 ºC (Jayan and Sathyanathan 2012). In fertile conditions, *Salvinia molesta* reproduces and fragments faster than in infertile waters (McFarland et al. 2004). Thus, the condition in the lake is conducive to its growth. *Azolla pinnat*a is native to the country (Gupta 1998) and currently not considered as an invasive aquatic weed (Fig. 8).

The upland weeds such as Itch grass and Bermuda grass are not much of a problem in the lake given its poor tolerance to submerged conditions. *Ipomoea aquatica* is also not a major problem because it has been consumed as food for the animals and humans in the nearby communities. It is commonly propagated on the lake for commercial uses. Hence, it can easily be found on the lake (Fig. 9). However, due to the eutrophic condition of the lake, health is a concern due to the bioaccumulation capability of this weed towards heavy metals (Milla et al. 2014).

The aquatic weeds surveyed within the two barangays are either invasive or potentially invasive. Without proper management of these weeds as well as of the waste management in the lake, proliferation and spread will be continuous. Weed problems may lead to aggravated weed cover engendered by rapid reproduction of weeds forming dense blankets. The dispersal of the aquatic weeds may eventually block waterways and tributaries. Water hyacinth, for example, can spread easily across bodies of water and irrigation canals impeding the water flow and reducing the available light and oxygen of the water systems. *Salvinia molesta* could also be a problem in the nearby future. The aerenchyma tissues of this weed provide buoyancy for ease of dispersal from the source to nearby bodies of water. It could also double its population in three days (McFarland et al. 2004).

Figure no. 6 *Pistia stratiotes* showing numerous offshoots

Figure no. 7 Flowers of Purple (a) and White (b) Cultivars of *Eichhornia crassipes* observed in the sampling sites



a

b

Figure no. 8 *Azolla pinnata* observed on the lakeside of Barangay Uwisan, Calamba, Laguna

Figure no. 9 *Ipomoea aquatica* growing alongside *Eichhornia crassipes*

The lake could be a source of weed seeds and vegetative propagule, which could be a threat to the rice production. The propagules and silt containing seeds may also be transferred from one place to another (Howard and Harley 1998). For example, giant salvinia can block irrigation canals and compete with rice. It could even outdo other weeds such as water hyacinth and water lettuce (Jayan and Sathyanathan 2012). Other weeds, including the upland ones, may serve as potential source of weed seeds, too. The dominant weeds are free-floating and can easily be carried away by current from lake to the irrigation canals and farms. The absence of filters or screens on the meeting point of lake and irrigation canals enables swift spread of these weeds throughout the rice farms. Prevention of entry of these weeds (including seeds and propagules) is necessary to prevent damage on the rice plant due to its invasiveness and high competitive ability.

Conclusions:

The weed species observed in the lakeside of Laguna de Bay were floating aquatic weeds that are capable of reproducing both sexually and asexually. The small size of the weeds, seeds and propagule as well as the free-floating nature of the aquatic weeds enable better transport from one place to another. Differences in the environmental conditions affected the present weed species and weed population in an area. The ability of *Eichhornia crassipes* to reproduce by seeds and stolons as well as adapt to adverse environmental conditions allowed its dominance in the southwest portion of the eutrophic lake. Potential weed species in the rice farms such as *Salvinia molesta*, *Cyperus imbricatus* and *Lemna minor* must be studied. Giant salvinia and water lettuce have already been noted in rice fields but further entry must be avoided.

Proliferation of aquatic weeds is an indication of mismanagement and due to nutrient enrichment of bodies of water. Policies on waste management must be strictly observed. Other possible sources of excessive nutrients such as upland farms must be monitored. Necessary actions must be performed to decrease the amount of nutrient loads down the lake.

Better knowledge on the ecology of these weeds will aid the development of suitable management strategies that may either prevent or control the weeds. Potential use of the weeds may likewise be studied as means of control.

Rezumat:

FLORA ACVATICĂ RUDERALĂ DE PE MALUL SUD-VESTIC AL LACULUI LAGUNA DE BAY

Un studiu al vegetației ruderale a fost realizat în două zone de pe malul sud-vestic al lacului Laguna de Bay, pentru a determina speciile dominante *in situ*. Zece specii ruderale aparținând la nouă familii au fost semnalate în trei puncte de studiu. Majoritatea speciilor studiate au fost acvatice, cu frunze late. Multe dintre acestea sunt natante, cu posibilități sexuate și asexuate de reproducere. Speciile observate se pot răspândi prin semințe, spori, tulpini, stoloni, frunze, muguri, ramuri târâtoare și rizomi. De asemenea, au fost observate și trei plante ruderale de pajiști umede: *Commelina diffusa*, *Cynodon dactylon* și *Rottboellia cochinchinensis*. Totuși, numai *Eichhornia crassipes* a fost dominantă în toate punctele de studiu, fiind urmată de *Pistia stratiotes*. Invazivitatea, capacitatea competitivă și reproducerea vegetativă au permis zambilei de apă, precum și altor specii ruderale, să supraviețuiască și să se răspândească. Condițiile eutrofice ale lacului au dus la agravarea problemei speciilor ruderale din zonă. Multe dintre speciile ruderale observate s-au adaptat în apele poluate caracterizate printr-un nivel ridicat al azotului, fosforului și metalelor grele. Alți

factori de mediu, precum temperatura și pH-ul afectează, de asemenea, dezvoltarea plantelor ruderale în lac. Mai mult, semințele și propagulele vegetative ale plantelor ruderale dispersate prin curentul apei pot bloca căile de navigație. Unele plante pot deveni potențiale specii ruderale, precum *Salvinia molesta*, *Lemna minor* și *Cyperus imbricatus*. Cunoașterea ecologiei și biologiei acestor specii ruderale va ajuta la dezvoltarea unor strategii manageriale eficiente.

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Annexes:

Table no. 1 General characteristics of the observed weeds at Barangay Looc and Uwisan, Calamba, Laguna

Family Botanical name	Common name	Propagules	Growth Form	Life Cycle	Location		
					1	2	3
Araceae *Pistia stratiotes* L.	Water lettuce	Seeds, Offshoots	F	P	+	+	+
Azollaceae *Azolla pinnata* R.Br.	Mosquito fern	Spores, Fronds	F	A	+	-	+
Commelinaceae *Commelina diffusa* Burm. f.	Spreading dayflower	Seeds	M	A/P	+	-	-
Convolvulaceae *Ipomoea aquatica* Forsk.	Water spinach	Seeds, stem cuttings	E	P	+	+	-
Cyperaceae *Cyperus imbricatus* Retz.	Shingle flatsedge	Rhizomes, seeds	M	P	+	+	-
Lemnaceae *Lemna minor* L.	Duckweed	Fronds	F	A/P	+	-	+
Poaceae *Cynodon dactylon* (L.) Pers.	Bermuda grass	Runners, rhizomes	M	P	+	+	-
Rottboellia cochinchinensis (Lour.) W.D. Clayton	Itch grass	Seeds	M	A	-	+	-
Pontederiaceae *Eichhornia crassipes* (Mart.) Solms	Water hyacinth	Stolons, seeds	F	A	+	+	+
Salviniaceae *Salvinia molesta* D.S. Mitchell	Giant salvinia	Spores, Buds	F	A/P	+	-	-

Note: E=Emergent, F=Floating, M=Marshy, A=Annual, P=Perennial

Table no. 2 Weed species observed in LOOC1 (Barangay Looc, Calamba, Laguna)

Family Botanical name	F	C	MH (cm)	RF (%)	RC (%)	RH (%)	SDR
Araceae							
Pistia stratiotes L.	0.8	0.086	3.06	25.806	4.592	1.989	10.796
Azollaceae							
Azolla pinnata R.Br.	0.3	0.007	0.3	9.677	0.374	0.195	3.415
Commelinaceae							
Commelina diffusa Burm. f.	0.1	0.01	17	3.226	0.534	11.051	4.937
Convolvulaceae							
Ipomoea aquatica Forsk.	0.3	0.088	21.25	9.677	4.698	13.814	9.397
Cyperaceae							
Cyperus imbricatus Retz.	0.1	0.01	44	3.226	0.534	28.603	10.788
Lemnaceae							
Lemna minor L.	0.1	0.001	0.1	3.226	0.027	0.065	1.106
Poaceae							
Cynodon dactylon (L.) Pers.	0.3	0.151	29.4	9.677	8.035	19.112	12.275
Pontederiaceae							
Eichhornia crassipes (Mart.) Solms	1	1.496	36.22	32.258	79.872	23.545	45.225
Salviniaceae							
Salvinia molesta D.S. Mitchell	0.1	0.025	2.5	3.226	1.335	1.625	2.062
Total	3.1	1.873	153.83	100	100	100	100

Table no. 3 Weed species observed in LOOC2 (Barangay Looc, Calamba, Laguna)

Family Botanical name	F	C	MH (cm)	RF (%)	RC (%)	RH (%)	SDR
Araceae							
Pistia stratiotes L.	0.1	0.012	2.33	5.556	0.563	1.25	2.456
Convolvulaceae							
Ipomoea aquatica Forsk.	0.1	0.028	56	5.556	1.315	30.035	12.302
Cyperaceae							
Cyperus imbricatus Retz.	0.4	0.033	8.8	22.222	1.549	4.72	9.497
Poaceae							
Cynodon dactylon (L.) Pers.	0.1	0.037	24.67	5.556	1.737	13.231	6.841
Rottboellia cochinchinensis (Lour.) W.D. Clayton	0.1	0.044	58	5.556	2.066	31.108	12.91
Pontederiaceae							
Eichhornia crassipes (Mart.) Solms	1	1.976	36.65	55.556	92.77	19.657	55.994
Total	1.8	2.13	186.45	100	100	100	100

Table no. 4 Weed species observed in UWISAN (Barangay Uwisan, Calamba, Laguna)

Family Botanical name	F	C	MH (cm)	RF (%)	RC (%)	RH (%)	SDR
Araceae							
Pistia stratiotes L.	0.4	0.034	5	25	1.739	14.372	13.704
Azollaceae							
Azolla pinnata R.Br.	0.1	0.001	0.5	6.25	0.051	1.437	2.579
Lemnaceae							
Lemna minor L.	0.1	0.001	0.5	6.25	0.051	1.437	2.579
Pontederiaceae							
Eichhornia crassipes (Mart.) Solms	1	1.919	28.79	62.5	98.159	82.754	81.137
Total	1.6	1.955	34.79	100	100	100	100

Table no. 5 Weed species observed in Barangay Looc and Uwisan, Calamba, Laguna

Family Botanical name	F	C	MH (cm)	RF (%)	RC (%)	RH (%)	SDR
Araceae							
Pistia stratiotes L.	1.3	0.132	10.39	20	2.216	2.77	8.329
Azollaceae							
Azolla pinnata R.Br.	0.4	0.008	0.8	6.154	0.134	0.213	2.167
Commelinaceae							
Commelina diffusa Burm. f.	0.1	0.01	17	1.538	0.168	4.532	2.08
Convolvulaceae							
Ipomoea aquatica Forsk.	0.4	0.116	77.25	6.154	1.947	20.596	9.566
Cyperaceae							
Cyperus imbricatus Retz.	0.5	0.043	52.8	7.692	0.722	14.077	7.497
Lemnaceae							
Lemna minor L.	0.2	0.002	0.6	3.077	0.025	0.16	1.087
Poaceae							
Cynodon dactylon (L.) Pers.	0.4	0.188	54.07	6.154	3.147	14.416	7.906
Rottboellia cochinchinensis (Lour.) W.D. Clayton	0.1	0.044	58	1.538	0.739	15.464	5.914
Pontederiaceae							
Eichhornia crassipes (Mart.) Solms	3	5.391	101.66	46.154	90.483	27.104	54.581
Salviniaceae							
Salvinia molesta D.S. Mitchell	0.1	0.025	2.5	1.538	0.42	0.667	0.875
Total	6.5	5.958	375.07	100	100	100	100