LAKE GREGORY, ALIEN FLORA AND URBAN AQUA-ENVIRONMENTS IN A MISTY CITY OF SRI LANKA

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Abstract: Lake Gregory in the uppermost hill capital of Sri Lanka is a man made water-body built to enhance the site esthetic beauty. Now it has to act as a waste sinker, having lost its ability to supply bathing/ recreational/agricultural water. A series of short studies on its floral composition and water quality parameters were done from 2007 to 2009 through direct visual observations and the APHA standard methods to quantify its current ecological conditions and future sustainability. Floral composition of the lake was found to dominate by Alien Plant Species (APS) demonstrating rapid spatial changes from time to time. *Myriophyllum* sp., *Polygonium* sp, *Salvinia molesta*, *Eichhornia crassipes*, *Ceratophyllum demersum* and *Pistia stratiotes* were the dominant APS of which *E. crassipes* was found to occupy nearly 1/3 of the lake. Others were in localized patches. There was a reduction of native water Lilly plant cover and amplification of extensive mat forming of APS *Polygonium* sp., *Ludwigia* sp. and *Altermanthera philoxeroides* in water edge areas. *Wedelia trilobota, Ulex europaeus* and *Colocasia esculenta* were found to form thickets in peripheral areas displacing the grass land gradually while modifying the structure and function of the lake. APS in water edge areas was found to facilitate sediment accumulation in greater amounts while converting lake into a semi-terrestrial area and choking in flow channels. Now its open water area estimated was <0.5 Km^2. Lake water quality was found to deplete rapidly, where most parameters exceeded permitted levels i. e. pH 7.8, EC 103.5 μS/cm, ammonia 0.38 mg/l, nitrate 3.7 mg/l and phosphate 1.04 mg/l. The condition was attributed to dense APS patches. It is clear now that the lake is persisting in a meso to eutrophic condition. Comparably less similar conditions were recorded in down stream at Meepilinama (*Nanu Oya;* BOD 8.14 mg/l, pH 7.10, DO 7.00 mg/l, EC 99.72 μS/cm, ammonia 0.14 mg/l, nitrate 2.34 mg/l and phosphate 1.54mg/l) in spite of receiving high quality water from a natural forest stretch. It appears that water quality depletion is so severe at the lake that it enables its down stream to self purification at this extension. Heavy use of agrochemicals and fertilizers in riparian areas and high silation were found as main pollution causes. The additional contribution of APS colonies blocking the air-water interface resulted low oxygen levels (DO <5.2 mg/l). Dumping huge quantities of waste as well as outflows from neighboring hotels, houses, etc. were other known threats which contributed to make the lake sometimes unpleasant. Discarding unwanted vegetable parts into the lake areas was another big problem as it adds on to the organic pollution. Altered floral composition in Lake Gregory is mainly due to heavy loading of nutrients and sedimentation from crop/tea farming and ecotourism based activities. Therefore, control/mitigation of such activities and removal of APS from time to time are highly recommended in addition to dragging as the lake is now rapidly loosing its ecological sustainability.

Key words: Gregory Lake, water pollution, alien plant, ecological risk.

1 Introduction

1.1 Alien flora in freshwater ecosystems

Of the world, nearly almost all natural ecosystems are under stress particularly freshwaters may be the most endangered of all as they have lost a greater propotion of their speices and habitats compare to other ecosystems on land or in the oceans (www.wri.org). Industrial discharges as well as agricultural and urban run off are pervasive strees on frehswater ecosystems since they alter the physical (water temperature, water flow and light availability), chemical (nutrients, oxygen consuming materials and toxins) and biological environmets in freshwaters (exotic species) (www.towards-sustainability.co.uk/issues/built). The biological alternation in freshwaters are largely supported by alternations of their physical and chemical factors mainly due to siltation and organic pollution which facilitates some alien species to colonize and pose significant threats causing an ultimate effect on their sustainability (www.iucn.org).

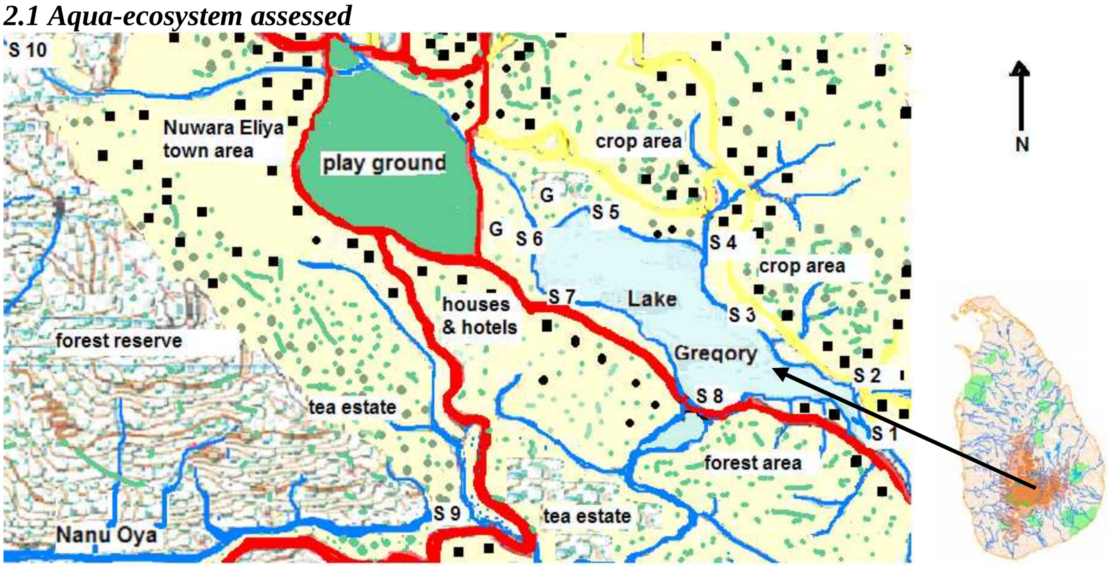
Alien species *i.e. non- native/non-indigenous/foreign/exotic* can be a species, sub species or lower taxon occurring out side of its natural range. Alien Plant Species (APS) in freshwaters are concern; there are several instances that they have invaded and possess threats to functions and structures of natural, semi natural and irrigational ecosystems of the world causing terrific damage to some of them (www.iucn.org). However, APS are important as indicators in disturbed waters since most of them are tend to colonize certain places where elevated levels of nutrients, heavy metals and etc. are encountered due to obvious point causes of pollution (Bambaradeniya et al. 2002). Hence APS colonization depends on site quality and detection of their colonization in a freshwater body is very significant to get an exact idea on existing quality depletion or pollution trends.

1.2 Rational for the study

Sri Lanka harbours a thousands of man made water bodies of which the Lake Gregory in the uppermost hill capital Nuwara Eliya is a major tourist destination in South East Asia and it is a monument of the British rule in Sri Lanka (*www.jetwinghotels.com)*. The potato cultivation introduce in the early 1970s and vegetable farming caused extensive environmental damage to the Nuwara Eliya urban area as well as to the lake Gregory causing massive erosion of surface soil and up loading of nutrient rich run off into the lake (www.encyclopedea.com). The alienation of surrounding lands of the lake went by political favour regardless of the environment and the natural beauty of the Nuwara Eliya town. As a result the lake Gregory became a waste sinker as well as a sufferer due to stress condition built by agricultural base activities as well as due to rapid urbanization. Now it is likely to deviate from all levels of standards for its sustainability proving ideal place to colonize for some destructive alien aquatic plants. In recent past several projects have been implemented to maintain Lake Gregory but no avail (www.jetwinghotels.com*)*. The reason may be due to lack of thorough understanding on causes and effect on its eco-quality depletion. Since it is reasonable to carry out an eco-monitoring assessment in the lake to identify causes and effects on eco-quality depletion, the present study was carried out with an objective of recommending suitable management strategies to bring the lake into a manageable level.

2. Material and methods

2.1 Aqua-ecosystem assessed



Scale 1: 50 000

Figure 2.1 Map of Sri Lanka showing the location of the Nuwara Eliya and water sources of the Gregory Lake (■ houses & hotels, G – grass land and **S** sampling point).

Lake Gregory is a man made water-body in a most superficial sight in 06°53'.816N and 080°52'.536E in the uppermost hill capital *Nuwara Eliya* (1200 m Mean Sea Level) in Sri Lanka (Figure 2.1). It was built in 1874 by then British Governor by crossing the Thalagala Oya which is one of the uppermost streams of the Nanu Oya that empties into the Kotmale Oya; a tributary of the River Mahaweli of Sri Lanka (*www.encyclopedia.freedictionary.com).* In the past the lake was used to feed a mini-hydropower plant at Black Pool area. Since the hydro-power plant was closed later, enhancing the sight esthetic beauty and use as a sport fishing ground become main target functions of the lake. The Gregory lake is of an area of 30 hectares and its catchment is of several natural streams that originate from the Piduruthalagala mountain range in North-western, Kandapola area in North-eastern and Magatota area in South-eastern. In addition to these the lake gets water from several inflow culverts from Nuwara Eliya municipal area. From South-western side the lake connects to the Nanu Oya which encounters several other perennial streams flow through natural forest stretches as well as from plantation areas (figure 2.1).

2.2 Study sites selected

A total of eight sampling points covering al most all significant inflow channels into the lake *i. e. including natural streams and culverts that are of obvious point source pollution* were selected for the study (figure 2.1). The site 1 is a 3rd order perennial upstream originates in Magastota area where intensive vegetable farms are found. The site 2 is a 2nd order perennial stream flows through Magastota tea estate as well as vegetable crop areas. The site 3 is a small inflow channel. The site 4 is 3rd order stream flows through Hawa Eliya crop area. The site 5 is a stream at the army camp site. The site 6 is a 3rd order perennial relatively large stream (Thalagala Oya) originates in the Piduruthalagala mountain peak. The site 7 is a culvert from Nuwara Eliya town side. These sites (6 and 7) are encountering obvious point sources of pollution due to agricultural and urban run off. The site 8 is a reservoir site close to the main road. The site 9 is a riverine site at the Nanu Oya at Black Pool junction. At this point the Nanu Oya receives water from neighbouring annual crop lands and tea plantation areas as well as from a natural forest stretch at Kelegama.

2.3 Monitoring of Alien Plant Species

The study sites were visited at least in three monthly intervals from April 2007 to March 2009 and the floristic composition at the sampling points selected was studied through *in situ* direct observation. Their spatial distributions were stretched out on a schematic diagram of the lake. Later temporal variation in occupancy area of APS during the entire study period was roughly assessed.

2.4 Monitoring of some physio-chemical parameters

At each study occasion some water quality measurements; dissolved Oxygen (*Orion 830A* DO meter), pH (*Orion 260A* pH meter), temperature (thermometer incorporated in DO meter), electrical conductivity (*HANNA HI 8733t* conductivity meter) and alkalinity (tritration method) were made *in situ.* In the laboratory nitrate, phosphorus and ammonia level were analyzed following the standards methods given in APHA (APHA, 1998). Bio-Chemical Oxygen Demand (BOD) was measured using Aqua Lytic BOD sensors.

2.5 Assessment of site condition

Finally assessment of trophic status of the reservoir sites was evaluated referring to the eutrophication survey guideline values given for water quality parameters for lakes and reservoirs (table 2.1).

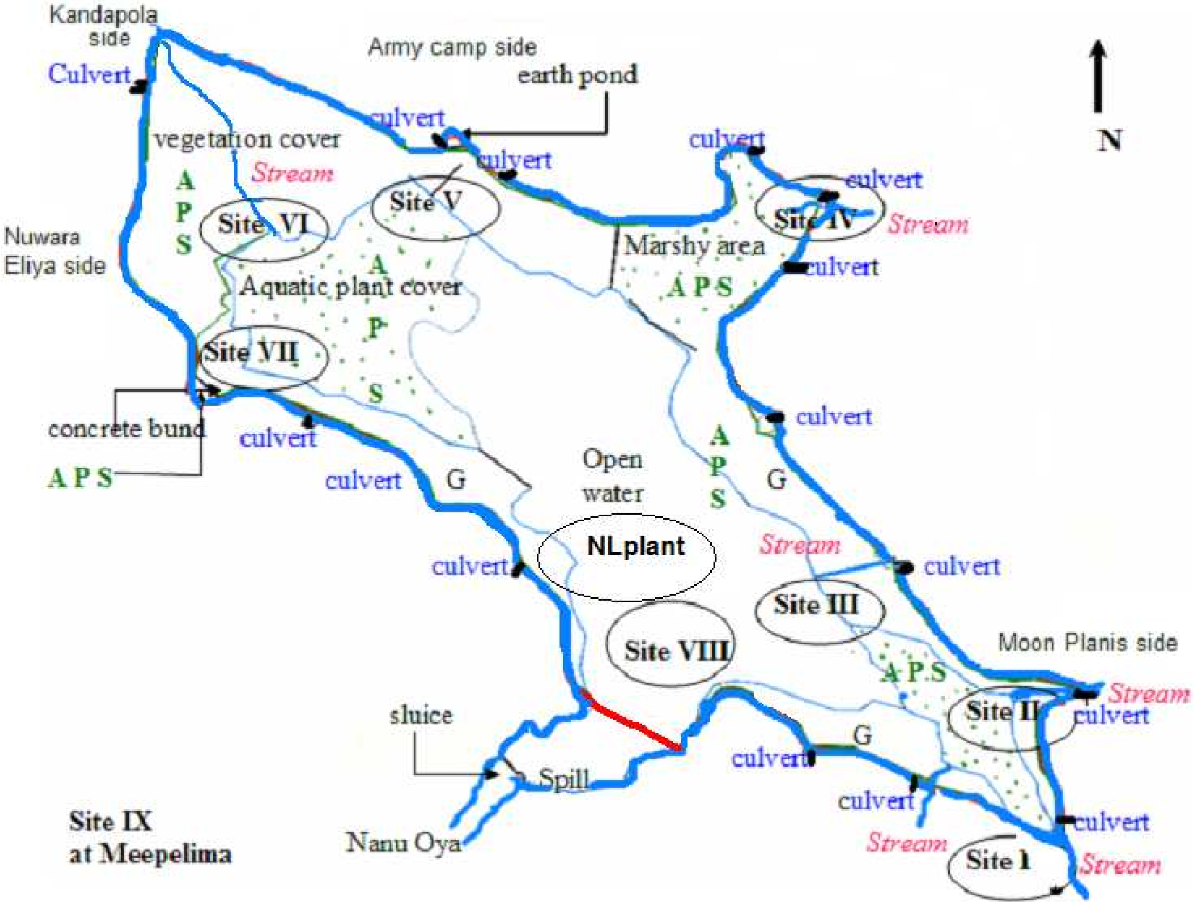
Table 2.1 Eutrophication survey guidelines for lakes and reservoirs (source: Mason 1996)

	Oligotrophic	**Mesotrophic**	**Eutrophic**
Total phosphorous (mg/l)	< 0.01	0.01- 0.02	> 0.20
Total nitrogen (mg/l)	< 0.20	0.20 - 0. 50	> 0.50
Secchi depth (m)	> 3.7	3.7 – 2.0	< 2.0
Hypolimnetic dissolved oxygen (% saturation)	> 80	10 – 80	< 10
Chlorophyll-a (mg/l)	< 4	4 – 10	> 10
Phytoplankton production (g Cm^{-2} d^{-1})	7 -25	75 - 250	350 - 700

3. Results

3.1 Floristic composition of the lake

During the entire study period a total of 14 APS were recorded from the Lake and their site vise abundances are given in table 3.1. The potential impacts of those APS are also given in the table 3.1. The variation in spatial distribution of APS patches in the lake at the beginning of the study (in 2007) and at the end of the study (in 2009) is respectively shown in figure 3.1 and 3.2. Majority of APS were noxious aquatic weeds of which *Eichhornia crassipes* and *Altermanthera philoxeroides* were found to colonize in all the study sites. However, they were found to form dense thickets in certain sites i. e. in site 1, 2, 3, 7 and 8 which were found to on a point source of pollution mostly due to nutrient rich run off. *Myriophyllum* sp. was found to colonize largely in the sites 1 and 7 though it was firstly recorded in early 2008.



Scale 1: 2500

Figure 3.1 Map of Gregory lake showing the sampling points and distribution of Alien Plant Species (APS) and Native Lilly plant (NLplant) in 2007 (G – grass land).

Salvinia molesta was found in site 5 and site 6 only. However, there was a considerable reduction of native water Lilly plant cover and amplification in APS cover due to extensive mat forming of *Polygonium* sp., *Ludwigia* sp. and *Altermanthera philoxeroides* in water edge areas along the lake. *Ulex europaeus* and *Wedelia trilobota* were found in water edge areas forming dense thickets and found to invade grass land very rapidly in peripheral area of the lake. Relatively small patches of unidentified small weeds were recently (in late 2009) found in site 2 and site 3. Densely grown patches of *Colocasia esculenta*, unidentified shrub and *Cyprus* grass species were found to facilitate sedimentation leading to clog the inflow channels of the lakes. They were found in water edge areas as well as semi aquatic peripheral areas where grazing cattle and horse/pony are often found.

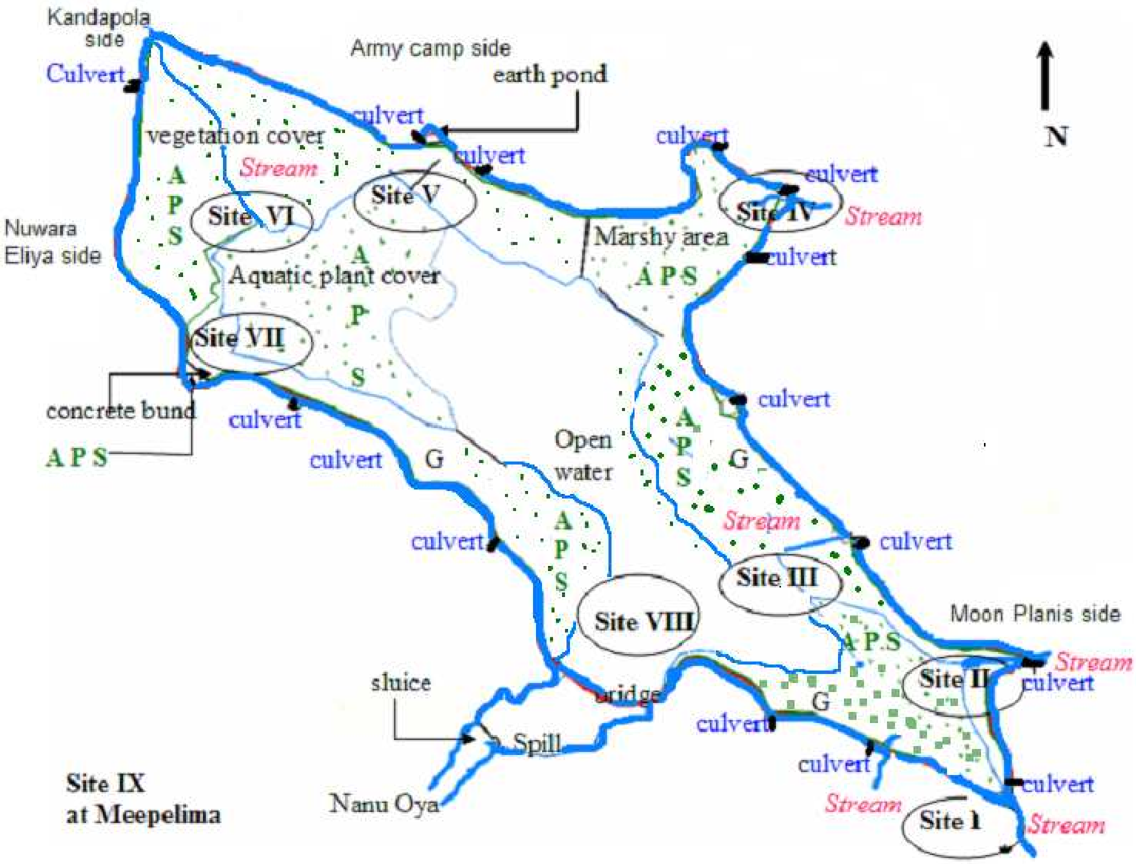


Figure 3.2 Map of Gregory lake showing the sampling points and distribution of Alien Plant Species (APS) in 2009.

Table 3.1 Floristic composition; Alien Plant Species (APS) and native plant species (NPS) (abundance: + small fragmented patch, ++ large patch, +++ forming thicket/mat, – not recorded) at each study site in the Gregory Lake in Nuwara Eliya during the study period and their potential impacts (FT- form thickets, FM - form mats, IG – invade grass land, FSA - facilitate *sediment accumulation, CFC - choking in flow channels and CWS - cover water surface and ● NLI listed as national invasive plant (Source: Marambe 2001),*

Plant species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Possible impacts	NLI
Altermanthera philoxeroides	+++	-	+	+	-	++	+++	+++	FT, IG, FSA, CFC, CWS	●
Ceratophyllum demersum	+	-	-	+	-	+	+	+	FT, FSA, CFC	●
Colocasia esculenta	+++	+++	+	++	+	+++	+	++	FT, IG, FSA, CFC	●
Eichhornia crassipes	+++	++	+++	+++	+	++	++	+++	FM, FSA, CFC, CWS	●
Mayaca sp.	+	-	-	-	-	+	+	-	FT, CFC	-
Myriophyllum sp.	++	-	+	++	-	+	+++	++	FT, FSA, CFC, CWS	-
Ludwigia sp.	+	+	+	+	+	++	+++	+	FM, CWS	-
Pistia stratiotes	+	-	-	+	-	+	+	+	FM, FSA, CFC, CWS	●

Table 2.1 cont.

Plant species	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**	**Site 8**	**Possible impacts**	**NLI**
Polygonium sp,	-	+	++	++	+	++	++	++	FT, IG, FSA, CFC, CWS	-
Salvinia molesta,	+	-	-	++	-	++	+	++	FM, FSA, CFC, CWS	●
Ulex europaeus	+	-	+++	++	+	+	-	++	FT, IG,	●
Wedelia trilobota	-	-	+	+	+	++	++	++	FT, IG, CFC FSA,	●
Unidentified sp. 1	+	-	++	+	+	++	+	+	FT, IG, FSA,	-
Unidentified sp. 2	+	-	++	++	-	+	-	-	FT, CFC	-
Cyprus sp.	-	+	++	++	++	+++	++	++		-
Nymphea sp. (native Lilly)	-	-	-	-	+	-	++	+		
Total APS	**11**	**04**	**10**	**13**	**07**	**14**	**12**	**12**		**08**

3.2 Results of chemical monitoring

Table 3.2 some physio-chemical parameters of water at the sampling sites selected average for the entire study period (LA: average for lake sites and site 9; Nanu oya site).

					Lake site					**Stream site**
Water quality parameter	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**	**Site 8**	**LA**	**Site 9**
Water temperature (ºC)	19.70	20.70	18.6	18.90	17.5	20.0	17.6	17.2	18.76	19.4
pH	7.85	7.57	7.8	7.91	7.98	7.55	7.82	7.53	7.75	7.10
DO (mg/l)	3.39	4.46	6.77	5.05	4.47	4.43	6.50	6.35	5.20	7.00
BOD (mg/l)	9.20	10.5	7.21	12.5	12.42	10.25	8.20	7.58	9.72	8.14
Alkalinity ($CaCO_3$ mg/l)	32.8	31.60	36.4	14.0	18.40	92.60	19.60	21.05	33.31	-
Nitrate (mg/l)	05.3	06.90	7.20	3.2	3.0	2.02	1.4	1.03	3.7	2.34
Phosphate (mg/l)	1.10	1.75	0.98	2.03	2.31	3.15	0.49	4.48	1.04	1.54
Ammonia (mg/l)	0.35	0.33	0.31	0.18	0.26	0.17	0.8	0.56	0.38	0.14
EC (µS/cm)	94.5	108.8	126.6	128.2	85.57	85.3	105	95.2	103.38	99.72

The values for some water quality parameters average for the entire study period for the lake sites and for the Nanu Oya site assessed are given in table 3.2. The lowest DO value (3.39 mg/l) was recorded at the lake site 1 whereas the highest DO value (6.77 mg/l) was recorded at the lake site 3. All the lake sites assessed were recorded relatively higher value for BOD <7.0 mg/l indicating an organic pollution condition in the lake. The nutrient concentrations were considerably high in all the lake inflow channels assessed except in site 7 that flows through Nuwara Eliya municipal area. Though there was a significant variation in the water quality parameters in lake sites assessed, the lake was found of poor quality water since most parameters (average for entire lake) exceeded the permitted levels for ambient water quality i. e. pH 7.8, EC 103.5 µS/cm, ammonia 0.38 mg/l, nitrate 3.7 mg/l and phosphate 1.04 mg/l. Less similar results were recorded in the more down stream site assessed (site 9); BOD was 8.14 mg/l, pH was 7.10, DO was 7.00 mg/l, EC was 99.72 µS/cm, ammonia 0.14 mg/l, nitrate 2.34 mg/l and phosphate 1.54 mg/l.

3.3 Identified causes for low down of ecological integrity of the sites assessed

The identified causes for deterioration of water quality of the lake sites assessed as well as in riverine site assessed are given in table 3.3. It is clear from the table 3.3 that reservoir sites are encountering more impacts that lead to rapid water quality depletion due to agricultural and urban run off.

Table 3.3 identified causes for water quality depletion in the lake site assessed and Nanu Oya site at Meepilimana (possible effects are given parentheses).

	Lake sites								Stream site
Identified causes	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Colonization of APS (*modifying the structure and function of the lake*)	+++	++	++	+++	+	++	++	+	-
Converting riparian tea/forest area into annual crops (*soil erosion and high siltation*)	+	+	+	+	+	+	+	+	++
Excessive use of agrochemicals and fertilizer (*loading of organic pollutants, heavy metals and other toxic compound*)	++	+	+	+	+	+	+	+	++
Dumping of unwanted vegetables (*loading of organic substances and harmful microbs/pathogen*)	++	++	+	+	+	+	+	+	+
Dumping waste due to eco-tourism (*loading bio and non bio degradable substances*)	+	+	++	+	+	+	++	++	+
Mixing of urban/hotel sewage/drainage channels (*loading of organic/inorganic substances and harmful microbs/pathogen*)	+	+	+	+	++	++	++	++	+
Graze by cattle/horse (*loading of organic/inorganic substances and harmful microbs/pathogen*)	-	+	++	+++	+	++	++	-	-
Boat riding *(mixing of oil and grease)*	-	-	+	-	-	+	++	++	-

(Severity: + low, ++ moderate and +++ high)

4. Discussion

Plants are an important part of healthy diverse aquatic ecosystems as they play a major role in maintaining the integrity of lakes, ponds, streams and etc (Dash 2001). However, t*here are several instances in many parts of the world that the natural balance between vegetation and other aquatic organisms is disrupted when exotic plants are introduced and they become noxious weeds particularly in lakes and urban drainage channels* (www.*aquanic.org). S*pread of alien aquatic plants such as *Eichhornia crassipes*, *Salvinia molesta*, *Hydrilla verticillata*, *Najas marina* into many places in Madu Ganga estuary due to accumulation of nutrients through agricultural runoff and discharge of organic wastes into south-western costal area in Sri Lanka was discussed by Bambaradeniya et. al (2002). They have shown that alien plants species sometimes can be invader particularly that form thickets and shade out native vegetation, and thereby displacing the natives gradually. The reason they have given for that kind of invasiveness is a heavy load of excess nutrient run off that comes through nearby cinnamon cultivation and waste run off. More or less severe scenario was observed in the Lake Gregory as it was found as eutrophic (tables 2.1 and 3.2) water body since some of parameters assessed from the lake sites have exceeded their meso trophic levels. Signifying a hypo-eutrophic condition, an extra elevated level of nutrients (nitrate and phosphate) was recorded at some lake sites assessed particularly in sites 1, 2, 4 and 5 which were observed to under dense APS colonies. All these sites are having point sources of organic/chemical pollution due to agricultural based activities. Since the riparian area is under intensive potato, horticulture and vegetable cultivation, farmers apply fertilizer and agrochemicals at least once in two days, hence the excess amount or all if it is raining washed off into the lake subsequently leading to surface water to become a nutrient rich. In addition to this the existing APS colonies probably disturb water circulation process within the lake. Due to relative small area, the lake it-self is having a poor water mixing ability (Silva 1996). The integrated condition is largely favoured by floating root APS forming dense mats and thickets in preferred areas. Due to functional and structural adaptation of these APS leads to gradual convert of water edge area into a land area as well as leads to further depletion in lake eco-quality.

Adding of non-agricultural based organic run off and waste onto the lake water is another critical impact identified. The eco-tourism based activities are among the major sources of them. The neighbouring hotels, guest houses and hose-hold drainage channels were found as contributories in urban run off that bring a considerable amount of waste into the lake daily. Decomposition of them due to microbs activities results significantly elevated level of BOD and reduced level of DO. At the same time it would release high amount of nutrients (Mason 1996) that consequent for dense mat forming of existing APS. This probably be faster leading to drastic fluctuation of dissolved oxygen due to reduction of air water interface which less facilitate to Oxygen to dissolve in water. The large APS covers especially made with well-known troublesome aquatic noxious weeds like *Ludwigia peploides*, *Myriophyllum* and *Eichhornia* (www.aquanic.org/management) may possibly attributed to the comparatively low levels of DO values in sites 1, 2, 4 and 6. During the study period the above perennial herbs were found to grow in moist to wet riparian areas in the lake, spread to form mats on the sediment, or floats ascending in the water edge areas. However, comparatively higher concentration of dissolved Oxygen (6.67 mg/l) was recorded at site 3. The reason may be due to more open water area with small patches APS. For that reason, too it clear that occupancy area of APS and their spread is extremely couple with lake nutrient profile that significant on lake quality.

Certain APS were found to choke waterways totally especially at sites 1, 2, 4 and 6 facilitating sedimentation and clog waste excluding light penetration into the lake. Especially *Ludwigia* predominately colonizing in these sites was found to entrap plastic bottles and other containers due to blanket in water surface, sometimes making the lake-site unpleasant. This has profound effects on communities of native plants and animals in the water. They also interfere with animal access for drinking water, human access for swimming and boating. The condition was critical in site 7 as dense APS patches have already converted the water edge area into a semi terrestrial land where *Cyprus* grass was observed to colonize rapidly. It has already extended onto the native Lilly plants cover. In initial stages of the study it was found in relatively deep areas of the lake very close to the site 7 (figure 3.1 and 3.2) . Due to high siltation, the particular area became a very shallow within a very short period, and rapidly invaded by few APS namely *Eichhornia crassipes*, *Ludwigia*, *Cyprus* and *Altermanthera philoxeroides.* Now few of native Lilley plants can be seen among *Cyprus* sp. that confined to a very little area. It is clear that the APS at the extreme levels have entirely modified the structure ad function of the lake ecosystem in many ways. Sometimes APS can produce substances that are toxic (www.nps.gov/plants/alien) i. e. allopathic to others thereby make the soil unsuitable for original native species. So that it might be one of reasons for APS thrives into a native Lilly plant area. However, further studies need to be carried out to come a definite conclusion regards.

The cattle/horse feeding in marshy areas in the lake might facilitate adding of organic and inorganic load through their dung and urine that adds onto the pollution load. The reason for relatively high ammonia level (≤0.3 mg/l) at sites 2 and 3 possibly attributed by cattle forage. Decaying unwanted vegetable stumps which was observed to be intensified in harvesting period, is significant as it adds extra organic pollution load into the lake. The condition was found to severe in site 2 where the elevated level of BOD (10.5 mg/l) was recorded probably due to additional organic inputs brought by vegetable stump releasing an increased amount of nutrients (nitrates 6.9 mg/l and phosphates 1.75 mg/l). This possibly stimulates massive growth of APS in lake peripherals thereby becoming a deal cattle feeding ground.

The water edge area at town side was largely colonized by *Cyprus* sp. and *Eichhornia* that facilitate fast sediment deposit. Not only but some floating species such as *Salvinia*, *Pistia* were found to accumulate greater amount of sediments. Since most of them possess physiological and structural adaptations to grow in organically polluted muddy conditions (www.nps.gov/plants/alien) the area is now having a plentiful cover of APS. More recently *Myriophyllum* sp. thrives in the area. *The condition could be severe in near future as it is among world worst invasive plant species (*www.nps.gov/plants/alien). It *was found to dense in site 1 where Magastota river empties in to the lake with high nutrient load i. e. 5.3 mg/l nitrate, 1.10 mg/l phosphate and 0.35 mg/l ammonia. This condition possibly attributes to rapid colonization of Myriophyllum*.

Present result also showed that deviation in some other water quality parameter such as pH and conductivity from the ambient standards might be directly couple with organic pollution. The heavy metal levels in the lake can possibly be high though it was not assessed during the present study, as the lake is routinely subjected loading of them through agrochemicals as well as combustion of fossil fuel. The eco-quality depletion scenario originated at the Gregory lake site seems to be forwarding to its down stream stretch since more or less comparable water quality depletion trend observed at the Nanu Oya though water gets diluted at this run there is no sufficient enough purification process to bring river water into a good quality as the river encounter addition threats at this stretch. Further more the landscape changes due to encroachment, illegal cultivation of tea and annual crops and coverting of tea plantation into annual crop are attributing to elevated levels BOD was 8.14 mg/l, pH

was 7.10, DO was 7.00 mg/l, EC was 99.72 μS/cm, ammonia 0.14 mg/l, nitrate 2.34 mg/l and phosphate 1.54 mg/l. Since this riverine area is very steep having fast flowing waters, APS are unable to colonize very rapidly but river bankers may be affected.
The APS have already interfered with recreational activities such as fishing, boating and swimming and with enjoyment of the natural beauty of this unique water resource. According to the www.nps.gov/plants/alien web site most APS are tolerant of many water pollutants thereby they tends to invade disturbed areas where native plants cannot adapt to the alteration. Further APS does not spread rapidly into undisturbed areas where native plants are well established. It is well understood from the present study we have already altered the chemical, physical as well as biological environments in the Gregory Lake and we have created a new and unnatural niches where APS thrives. The ornamental plant industry has been identified as source of APS into the lake. Yet no prompt action has been taken in the near past to mitigate routinely up loadings of pollutants into the lake and we further alter the environments that are ideal for more APS. The activities in related to the growing human population pressure are fundamentally threatening the lake giving considerable stress on its ecology. Once it has being a sustainable built aqua environment though it is now being threatened. It is a big challenge to the city as it has reduced a potential to develop the city as a sustainable built eco-tourism site.

5. Conclusions

The colonization of APS in eutrophic Gregory Lake in uppermost reaches of the Mahaweli river is due to agricultural based activities and urban run off. Since further colonization of APS can possibly be a great threat actions should immediately be taken to bring the lake environments into manageable levels as it seems to be losing its sustainability very rapidly.

6. Recommendation for future of the lake:

The Gregory Lake was once a famous tourist attraction site in Sri Lanka where visitors truly feel a refreshing sense of peace with additionally magnificent reverse views of the surrounding area (www.jetwinghotels.com). Since the lake has been recognized as a priority wetland of the uppermost hill country of the island several conservation/reclamation management plans being developed during the last decade by the central government and the Nuwara Eliya urban council. Under the circumstances, several projects were implemented to maintain Lake Gregory from 1978 to 2001, but to no avail yet the lake is covered with destructive aquatic plants. Since the Lake Gregory, adorns Nuwara Eliya city, it should be given a facelift to improve tourist potentials. According to the results of present monitoring study there is a severe depletion in sustainability of the lake mainly due to destitute quality in lake water largely attributed by heavy load of nutrient pollutants. The condition attribute to intensified growth in steady populations of APS. According to the cause and effect studies (table 3.3), nearby crop lands and hotels are critical problem to the lake as they bring plenty of nutrient and organic waste through their drainage canal systems. Therefore, it is recommended to initiate comprehensive monitoring study to document the physio-chemical, hydrological and biological status of the lake at least in two month intervals. The local administrators and government conservation agencies should take immediate steps to mitigate harmful practices that degrade the lake. A work should be initiated to control loading of silt into lake. It can be achieved by constructing long term persist effective silt traps (concrete ones) at all in-flows for significant entrapping of sediment. Appropriate control/mitigation actions should be taken on agriculture based activities and to avoid further colonization of new APS. The Nuwara Eliya Municipal Council should initiate awareness programs on proper waste removing and management. In addition to these it is highly recommended to remove APS from time to time for effective removal of excess nutrient through bio-remediation process. Since the dragging of the lake sediment in an appropriate manner could help to remove load of heavy metals and other pollutants too it also highly recommended. The local administrative should regulate the number of boats operation in the lake as it could leads to oil/geese contamination.

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