Wetlands are known as the *kidneys* of nature and the macrophytic vegetation in wetlands play a significant role in maintaining the resilience of the system. Kuttanad wetland ecosystem supports high growth of aquatic macrophytes and it is a menace to the local people. Very few studies have so far been done and limited knowledge exists on the ecology of these macrophytes in Kuttanad. Hence the present study was undertaken to assess the diversity, distribution, biomass production and heavy metal accumulation of the dominant macrophytes of this wetland ecosystem. The environmental variables like physico-chemical parameters of water and sediment quality were analyzed to correlate the distribution of macrophytes.

The present study recorded a total of 130 aquatic macrophytes including 7 pteridophytes. A total of 9 exotic (non-native) macrophytes were recorded and among them *Eichhornia crassipes*, *Cabombo caroliniana*, *Salvinia molesta* and *Limnocharis flava* are found invading in the productive paddy fields of Kuttanad. *C. caroliniana*, *L. flava* and *Alternanthera philoxeroides*, the recently introduced exotics, have shown gregarious growth which replaces local plants. *E. crassipes* showed high percentage cover during premonsoon season in the canal systems of Kuttanad and comparatively low during monsoon season. *Ischaemum travancorense*, an endemic grass species, mainly growing in the abandoned fields, formed sudd communities. Most of the aquatic plants have shown comparatively high production values in Kuttanad compared to the other tropical wetlands of the world. *E. crassipes* registered nearly 4 kg/m² of biomass during season’s maximum growth and 124 g/m² of per day production.

The most distinct aspect of Kuttanad wetlands is the high acidity all over the area, declining during monsoon and peaking during summer which highly varied between the rivers, canals, cultivated fields and abandoned fields. The water temperature showed a significant increase in the cultivated fields and exceeded 35°C (mostly 33-35°C), the maximum reported from the entire Kuttanad region and this points towards a climatic shift to higher water temperature which directly impact the biota. From very low values (29 ppm), the TDS increased 600 times (1864 ppm) in different systems of Kuttanad and the maximum from abandoned fields. High turbidity was recorded from this wetland due to the release of organic matter which renders a black colour to the water especially in the Vaikom and Purakkad kari lands. The significant seasonal variation of pH between Kari lands and Karappadoms were noted during study. The acidity varied 80 times between the canal systems from 4 mgCaCO₃/L to 320 mgCaCO₃/L with lowest in AC canal and highest in Vaikom kari (VA1) sites respectively. The
mean alkalinity was <30 mg/L which indicated the deficiency of carbonates and bicarbonates in this system. Saline water intrusion resulted in the increase of chloride in Kayal lands and Kari lands. The hardness also recorded a similar fluctuating pattern with chloride. High DO levels were correlated to low BOD and vice versa at sites receiving sewage especially at river Kodurar at Kodimatha, canal site at Pallom (P6) and ACC1 site at AC canal. The COD recorded significant variation between canals and exceeded 31 times in comparison to other systems due to the impact of sewage and organic decomposition. Nitrate, phosphate and potassium recorded higher values in the canal systems. The sulphate levels in water varied 40–53 times between the different canal systems during premonsoon and postmonsoon seasons. The FC, FS and VCLO load was higher during monsoon season in both river and canal systems due to the land run off. VPLO counts were higher during premonsoon and Pseudomonas counts exhibited higher values in monsoon. The influence of Sabarimala pilgrimage during postmonsoon season exhibited high FC values in Pampa river system. FC/FS ratio showed that the human faecal contamination was the major factor behind the bacteriological pollution in Kuttanad especially during the premonsoon and postmonsoon season. During monsoon, other sources like land run off and sewage were the factors contributing to the pollution load.

Generally Kuttanad soils are acidic in nature and the pH is <4. The high acidic values (<2.3) were recorded from kari (acid sulphate) lands viz., Vaikom and Purakkad. Spatial and temporal variations of pH, organic carbon and nutrients were observed in the present study. Seasonal flooding and macrophytic vegetation growth have significant role in the distribution of nutrients in sediments. Canal systems showed high accumulation of organic carbon and nutrients resulted due to the runoff from the rice fields and decay of organic materials. Due to continuous flow of water in the river systems, organic carbon and nutrients showed the least values compared to other systems. The organic carbon content showed significant correlation with nutrients and negatively correlated with pH. Cultivated rice fields recorded comparatively higher concentration of available nitrogen than other systems which indicated the accumulation of nitrogenous fertilizers in the sediment system.

Among different seasons, monsoon recorded comparatively high heavy metal concentration in water samples but in sediment samples, postmonsoon recorded highest values. Heavy metal concentration in sediment was 100 times greater than the concentration in water. River systems recorded high heavy metals than other systems. Among the river systems studied, Kodurar at Kodimatha recorded the highest concentration of heavy metals both in water and sediment. This site receives the municipal sewage and wastes from the vehicle workshops, hotels and also the motor boat transportation using kerosene and diesel. In cultivated fields, the excess application of synthetic chemical fertilizers, fungicides, herbicides and weedicides have caused
the highest accumulation of heavy metals especially copper and zinc in water and sediment. Copper concentration in water showed three to five times increase than the permissible limit as per BIS drinking water standard in all the systems during monsoon season. \textit{E. crassipes} exhibited comparatively high accumulation of heavy metals while high Cu accumulation was noted in \textit{N. hydrophylla}. The mean concentration values of the heavy metals in different compartments of the Kuttanad ecosystem exhibited the order Sediment $>$ Macrophytes $>$ Water.

As per the results of Principal Component analysis, the inflow from the river systems i.e. the hydrology formed the major principal factor for the maintenance of the Kuttanad wetland ecosystem. Dissolved oxygen, pH and nutrients act as the major factor loadings which contributed 28.73\% variance. The second factor loading, bacteriological parameters, accounted for 19.4\% variance. The seasonal salinity intrusion was the third principal factor that exhibited 14.16\% variance. During premonsoon season, the salinity intrusion from Vembanad lake reaches up to lower reaches of Kuttanad. The salinity does not affect the areas like Upper Kuttanad and eastern parts of North Kuttanad due to the influence of Thaneermukkom bund across the lake on its northern part.

The Hierarchical Cluster analysis distinctly separated the macrophytes based on their habitat and the growth form. The results of the TWINSPLAN identified 6 meaningful ecological vegetation groups: (1) Paddy field-off season inundated community, (2) paddy field - during cultivation dominated with LF-MV-C-C-F assemblage (3) paddy field levee/bund vegetation (4) abandoned field dominated with I-C-C-E assemblage, (5) flowing systems like canal and river dominated with \textit{N. hydrophylla} and (6) slow flowing or stagnated water body dominated by \textit{E. crassipes} and \textit{N. pubescence}. Among these, the \textit{E. crassipes} and \textit{N. pubescence} were found in different systems of Kuttanad. Among the macrophytes studied, the assemblage of \textit{I. travancorense} - \textit{C. platystylis} - \textit{C. interruptus} - \textit{E. crassipes} (I-C-C-E) have shown the significant value followed by \textit{E. crassipes} and \textit{N. hydrophylla}. The I-C-C-E assemblage was the major macrophytic group in the abandoned fields and floating islands of Kuttanad.

The macrophyte growth supports the growth of bacterial population in Kuttanad. Faecal coliform have shown affinity towards the cultivated field macrophyte communities like \textit{S. molesta}, \textit{L. flava}, \textit{M. vaginalis} and \textit{N. pubescence}. The VCLO, VPLO have shown close relation with the abandoned field macrophyte assemblage, I-C-C-E. The \textit{Pseudomonas spp.} has no specific relation with the macrophyte distribution. Macrophytes like \textit{E. crassipes}, \textit{A. philoxeroides}, and \textit{I. aquatic} - \textit{L. adscendens} - \textit{P. distichum} assemblage have no specific relation with the bacterial population.
The growth of aquatic macrophytes reduced the nutrient level in Kuttanad and the system remediates the pollution load. As per the CCA ordination analysis, all the macrophytes have shown negative correlation with the salinity and hardness which clearly indicated that the salinity intrusion into Kuttanad will reduce the growth of nuisance macrophytes especially the exotics like *E. crassipes*, *C. caroliniana*, *S. molesta*, *L. flava* and *A. philoxeroides*. It can be concluded that the seasonal salinity intrusion from the Vembanad lake is essential for controlling the aquatic macrophyte growth. The decay of aquatic macrophytes, decaying of rice straw after cultivation and the discharge of organic pollutants by the river systems are the significant factors for the organic pollution in Kuttanad. The silting and ‘bottle necked’ bridge construction over the canals and river courses reduced the flow of water which also promoted the weed growth. Consequent effects of thick growth of macrophytes also influenced the water level changes in the Kuttanad. The increase of abandoned fields and the filling of paddy fields and canal systems have greatly influenced the ecology of Kuttanad. Organic decay in abandoned fields releases water with high BOD, COD, TDS and conductivity into the surrounding canal systems. In Kuttanad, the aquatic macrophytes are efficient in purifying the polluted waters, and periodic harvest and removal of these macrophytes during cultivation time enable the system for restoration to a great extent. These macrophytes are a boon in disguise to the maintenance of the Kuttanad wetland ecosystem from further deterioration.