

Role of Hydrological Parameters and Environmental Disturbances in Steering Bioinvasion and Biohomogenization of *Eichhornia crassipes* in Cochin Backwaters - A Mini Review

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ABSTRACT

The preliminary study provides an account of the influence of various hydrological parameters of the water body and other environmental issues in the bioinvasion and biohomogenization of *Eichhornia crassipes* in Cochin backwaters located in the southwest coast of Kerala, India. The study of invasion gateway is significant considering the means of control and eradication of such noxious weeds. The situation of bioinvasion could get further worsened by its interactions with existing environmental disturbances and frequently changing hydrological parameters due to adverse human interventions. Water hyacinth has been listed among the top 100 most destructive invasive species of the world by the International Union for the Conservation of Nature (IUCN). The weed devoured for its aesthetically pleasing appearance has a great history of invasiveness in a large number of countries around the globe and harnessing them of its resources. The recent few years have witnessed a tremendous increase in the studies relating phytoremediation aspects of *Eichhornia crassipes* and harvesting bio-energy out of weed. This forms a preliminary data for further investigations with respect to water hyacinth in Cochin backwaters.

Keywords: Water Hyacinth, Physico-chemical Parameters, Aquatic Environment, Backwater Pollution, Aquatic Weed, Biological Invasion.

INTRODUCTION

Aquatic weeds refer to plants that thrive in water or moist soils and are usually found to occupy the riparian zones of regions like dams, lakes, and river mouths. The adaptability of aquatic macrophytes to highly diverse environmental conditions imparts a profound impact on the original habitat causing severe ecological and economic losses. However, they constitute a free crop of high productivity requiring no amount of neither tillage nor fertilization along with their enormous potential to be used as a low-cost source of animal feed, human foods, oil additives, fuel production, wastewater treatment and habitat to a number of organisms (Ojeifo et al. 2002).

Eichhornia crassipes, also known as water hyacinth in the family Pontederiaceae is native to the Amazon in South America and has been introduced to various regions of the globe. The global concern over the issue of infestation of water bodies by this noxious aquatic weed, water hyacinth has provided the momentum for researchers and other concerned authorities to find ways to monitor, control and curb the damage induced by its exponential rate of spread (Narayanan et al. 2007). This invasive weed creates severe menace which includes endangering biodiversity, sheltering pests, causing eutrophication, clogging waterways, affecting agriculture and aquaculture, hampering shipping and recreational activities. The aesthetically pleasing appearance of

its purplish and blue-tinged inflorescence has been responsible for their spread to various tropical and sub-tropical countries by humans during the 1800s and 1900s (Onyango and Ondeng 2015). Alien invasive species are alien species that establishes itself in ecosystems that are natural or semi-natural imparting changes, and threatening indigenous biological diversity, according to the International Union for Conservation of Nature and Natural Resources (IUCN). Ecology of invasion requires information on the rate and mechanism of transport and movement of the organism, the characteristics that permit the species to turn out to be a successful invader, and indeed the attributes of the ecosystems that make them more susceptible to other invaders naturally present in the region (Lodge 1993). Especially in view of globalization, lack of awareness and non-compliance to pivotal ecological values for environmental management, introduction and proliferation of invasive species has experienced a dramatic increase over the past few decades, causing environmental changes, such as loss of biodiversity and breakdown of the ecosystem (Kolar and Lodge 2001, Chakraborty 2019). Multifaceted substantial outcomes of bio invasion directing towards serious issues like genetic extinction due to the chance of hybridization with native species cannot be ignored. Further chance of their interaction with existing environmental perturbations could still worsen up the state of the respective ecosystem (Kohli et al. 2012). The capability to outcompete and outnumber the native species for space, food and shelter resulting in changes of food chain and emanation of numerous harmful pathogenic effects disrupting aquatic lives, public health by the introduction of several water borne illnesses, annoyance by fouling of fishing equipments, ships and boats forms the characteristics defining a non-indigenous species as invasive (Chakraborty 2019). Biotic homogenization is now known to cause major economic, developmental and social implications thus leading to a broader biodiversity crisis (Shanab et al. 2010). The process is expected to increase over the years in response to the anthropogenic actions related to human populations. The capacity for resilience and restoration will be at stake due to the ecological disruption which in effect, will minimize heterogeneity within communities. Several

ecological implications could be foreseen by the outcomes of biotic homogenization. The genetic similarity of gene pools that evolved over time results from the inter specific and intra specific hybridization operating at the molecular levels (Olden et al. 2004). The genetic homogenization could be recognized by analysis of the frequencies of a set of loci or allelic composition. The restraints on the species variability concerning composition and diversity threaten the potential for future speciation by altering the evolutionary trajectories through the reduction in the number of interactions and thus relieving selection pressures in such homogenized communities (Rahel and Olden 2008). The coastal region which is an area convergence of terrestrial and aquatic habitats display different patterns of succession, distribution and eco-dynamics in compliance with rising ecological gradients (Varma et al. 2002). The stability of coastal habitats to cope up with increasing environmental stress is challenged by contamination and over-exploitation of resources that have not only increased environmental stress but also intensified the pace of bioinvasion (Cohen and Carlton 1998). Introduced species turn invasive only if has the potential to traverse many natural barriers. Transport, introduction, colonization (establishment), and naturalization constitute the stages of the invasion process. If an environment is disrupted by environmental or anthropogenic causes, it allows for the creation, an invasion gateway to the alien species. The alien species slowly overcome the barriers to the climate, reproduction and dispersal and expands its population to become invasive species that outnumber and outcompete the native species (Chakraborty, 2019).

ECOLOGY, HABITAT AND CONTROL

Water hyacinth is categorized under the heliophyte group which grows best in tropical, macronutrient-rich waters (Cock 2004). As *E. crassipes* is a vigorous growth exhibiting perennial plant with high reproductive potential, the production of water hyacinth depends greatly on solar energy efficiency, water nutrient composition, cultural techniques and other environmental factors (USEPA 1988). The habitat extends from tropical deserts to subtropical to warm arid deserts to rainforests. The tolerable pH

value ranges from 4 to 10 although optimal water pH for growth of this aquatic plant lies in the neutral range (Center et al. 2002). The plant finds significant use in different kinds of wastewater treatments. Optimal growth temperature in the water is 28 to 30°C (Chu et al. 2006). Study by Gopal (1987) also state that the temperatures ranging 22.5 to 35°C with high humidity are suitable for maximum fruiting of plant. Optimal air temperature for growth is 21 to 30°C (U.S.EPA 1988). *E. crassipes* resist near drought conditions due to its ability to survive in moist sediments for several months (Herfjord et al. 1994, Center et al. 2002). Water hyacinths do not grow where salinity on an average exceeds 15 percent that of seawater. The leaves exhibit epinasty and chlorosis in brackishwater, and ultimately die. The seasonal changes in the rainfall cause a dramatic fluctuation in lake water levels in its native origin, Amazon basin and in the extensive lakes and marshes of the western Brazilian Pantanal region and thus the river will rise and fall 10 meters per year allowing for the vigorous growth of the plant during the high water periods (Piedade et al. 2010). Water hyacinth production in the wet season is higher than in the dry season and the knowledge of temporal water hyacinth distribution is poor (Thamaga and Dube 2019). Flowering period of *E. crassipes* is from August to September. Sensitivity to temperatures below 6.5°C retards the plant from flowering during the cold season. Also under natural conditions, water hyacinth can cover the water surface at relatively low plant density (10 kg/m² wet weight), and can achieve a maximum density of 50 kg/m² wet weight before growth ceases (Truijen and Heijden 2013). This aquatic macrophyte has the ability to completely clog aquatic ecosystems outside its native range by achieving a density of 60 kg/m² of wet weight (Julien and Orapa 1999). As water hyacinth is made up of 95 percent water, the rate of evapotranspiration is high. As such, small wetlands filled with the plant will dry out and leave populations without a sufficient supply of water or food. They can tolerate extreme fluctuations in water level and seasonal variations in the velocity of water flow, and variations in nutrient availability, pH, temperature and toxic substances (Nang'alelwa 2008). Minerals like nitrogen, potassium and phosphorus present in the nutrient rich waters intensified the growth of water

hyacinth (Koutika and Rainey 2015). Such nutrients play an important role in augmenting the plant biomass production when present abundantly or restrict production when available in small amounts (Mugidde and Wanda 2002). During the recent years, there has been a tremendous increase in the studies relating to the mechanism of control and phytoremediation aspects of *E. crassipes*. The most eco-friendly measure for eradicating this noxious weed is biological control mostly involving two weevil species belonging to the genus *Nechetina* (Center et al. 2002). Choosing the right species that can perform biological control is very necessary to eradicate the proliferative species. Species often introduced for biological control exhibit poor performance in its new habitat as they prefer to destroy aquatic macrophyte other than water hyacinth populations that become their new hosts. Another issue might be related to their acclimatization, especially if they are introduced to colder climates (Nesic and Jovanovic 1996). Mechanical regulation of the invasive plant species is often limited to cutting, and burning (Babu et al. 2003). The major problem that arises while using cutting as a control measure is that machines get filled up quickly when dense mats are present and thus the whole process becomes very slow and costly.

***Eichhornia crassipes* in Cochin Backwaters**

The presence of estuaries termed backwaters is a remarkable aspect of the coastal region of Kerala. An enthralling landscape and profuse greenery add to the beauty of backwaters. The highly diverse and biologically productive Cochin backwaters extend between 9°40'2" and 10°12'2" N and 76°10'2" and 76°30'2" E bounded by Azheekode at its northern end and Thannirmukkam bund at its southern end. This tropical positive estuarine system occupying an area of 157 km² with Periyar and Muvattupuzha constituting the two major rivers that flows into this estuary. The adjoining Thannirmukkam bund maintains the flow of the rivers Achankovil, Pamba, Manimala and Meenachillar. The major variable in the backwaters of Cochin is salinity, exhibiting a gradual downfall from 30 ppt at the entrance of the estuary to 0.2 ppt at the point of entry of the rivers. Manifold species of flora and fauna based on their ability to tolerate oligohaline, mesohaline or marine

conditions is attributed by the salinity gradient as the region exhibits a gradual downfall of salinity over the transition of its area (Menon et al. 2000). The area extremely suitable for aquaculture promotes artisanal, seasonal and perennial fishery. The estuary undertakes the role of nursery ground for many marine finfishes, shellfishes, crustaceans and mollusc species. Swamps and tidal creeks with the sparse distribution of mangroves provide shelter to larval and juvenile forms of many culturally important species. Fine sediments and rich organic matter at the bottom support the enormous and diverse benthic fauna. While the whole area of Cochin is well known for its backwaters, the region is encountering troubles of eutrophication, clogged water bodies, obstructed transport ways due to the unchecked growth of water hyacinth favored by its high reproductive potential (Fig. 1). *Eichhornia crassipes*, *Limnocharis flava*, *Salvinia molesta*, *Pistia stratiotes*, are the major aquatic plants identified as invasive in the inventory

of invasive species in Kerala (Lancar and Krake 2002). Locations like Nayarambalam, Puthuvypin, Pallipuram, Edavanakadu, Bolgatty have turned eutrophic due to *E. crassipes*. The longest lake of the country, Vembanad is densely infested by water hyacinth mats which shade native underwater plant species and uproot new emerging plants and dissolved oxygen content gets decreased dramatically causing shifts in habitats of plant and animal populations such as native fish populations comparatively high in upstream regions after construction of Thannirmukkam bund (Walmiki 2016). Reduction of water flow in drainage channels, impeding discharge and clogging pump intakes in irrigation channels, interfering with vessel navigation includes some of the damages caused by the plant species. An annual variation is visible in the growth pattern of macrophytes present in Cochin backwaters between monsoon and dry spells (Imchen et al. 2020). Monsoon season experience the proliferative



Figure 1. A view of *Eichhornia crassipes* in Cochin back waters

growth of the weed followed by decomposition in huge amounts due to ingress of saline waters during post monsoon which can be related to the addition of nutrient loads to backwaters. This could also adversely affect the fisheries in Cochin backwaters (Asha et al. 2016, Imchen et al. 2020). Water hyacinth mats are found to alter the speed of water flow, causing precipitation of suspended particles and thus leading to siltation within water body. If infested, the effective water capacity in reservoirs gets reduced causing dropping water levels in reservoirs during dry seasons. This imparts harm to hydroelectric schemes due to displacement, siltation and fouling of water bodies (Patel 2012). Fouling of boat propellers by water hyacinth mats are a major cause of concern for fishermen. Additionally, infestations make access to fishing grounds increasingly time consuming and interference with nets imposes more difficulty in fishing.

Interpretation of the causes of invasion

According to invasive plant theory, a successful invasion occurs when environmental limitations are lifted as a consequence of altered hydrological conditions. (Galatowitsch et al. 1999, Toft 2000) which implies that disrupted or changed human-altered habitats pave the way for the establishment of invasive species. The major factors leading to biohomogenization of *E. crassipes* is as follows:

Hydrological Parameters

The temporospatial differences in biodiversity, management of their distribution, succession and regulation of biological productivity are all decided by different physico-chemical parameters (Chakraborty 2019). The availability of optimum sunlight is a characteristic feature of Cochin backwaters owing to its tropical conditions (Barrett 1980, Rajeswari et al. 2018). The production of the seeds of *E. crassipes* is found to double in a tropical climate when compared to temperate conditions. The surface temperature recorded in the year 2000 from the Cochin backwaters exhibited a range from 25 to 33°C whereas surface water temperature varied from 25 to 34 °C according to a research study on water quality status of Cochin estuary (Thomson 2002, Thasneem et al. 2018). This seasonal variability in figures obtained over years though minimal and

relatively stable indicates the palatability of invasive species like *E. crassipes* to occupy the region and flourish in their new habitat. Also studies state that water hyacinth cannot tolerate higher ranges of salinity and its growth is favored at lowered salinity. It was also found that the effective salinity for *E. crassipes* transfoliar spraying is 24 g/l (De Laet et al. 2019). Comparison of the salinity profile of the estuary before and after construction of Thannirmukkam bund has found that salinity has exhibited a decrease on the southern side of the bund and remains as freshwater for a long time. The hydroelectric project in Idukki additionally has contributed to a reduction in the salinity of Vembanad lake (Batcha and Damodaran 1982). Well-marked seasonal salinity fluctuations were observed in the entire ecosystem with pre monsoon months exhibiting high salinity while monsoon and post monsoon months experiencing the lowest salinity (Thomson 2002). The climate change variability coupled with growing urbanization has been a significant contributor of heavy precipitation and increased flooding leading to the decrease in salinity that aids in proliferative growth of *E. crassipes* in the backwaters of Kerala (Le Maitre et al. 2004, Mishra and Shah 2018, Boyaj et al. 2020). The average pH of the Cochin estuary was observed as 7.25 ± 0.25 and maximum pH was observed during post monsoon period followed by pre monsoon period (Thasneem et al. 2018, Bhuyan et al. 2020). Monsoon periods were marked by abundant rain and runoff from land together resulting in falling pH. Slight acidity and basicity observed by researchers indicated the addition of chemical pollutants from agricultural waste. The ability to survive and flourish in neutral pH helps *E. crassipes* to form dense mats. Increased amounts of nitrate, nitrogen and BOD values ($>5\text{mg/l}$) indicated the highly nutrient-enriched status of Cochin backwaters especially during monsoon months (Gopalan et al. 1983, Thasneem et al. 2018). Studies of (Thomson 2002) also reveal higher values of nitrates and phosphates during monsoon months stimulate the overgrowth of different aquatic weeds.

Aquaculture in Backwaters

Inappropriate care and management in aquaculture has lead to the unwanted introduction of several fish,

invertebrates, parasites, plants and pathogen species. Western Ghats and north eastern parts of India rich in biodiversity are flaunted with country's major proportion of endemic and indigenous varieties. The Convention on Biological Diversity (CBD) holds signatory members responsible for performing scientific risk evaluations for introductions and promotes the use of native species in aquaculture. In certain cases, the aquaculture industry manifests a financial attitude towards the prevention of exotic species introductions which damage their products. Comprehensive recommendations are suggested by IUCN and ICES (International Council for Exploration of the Sea) for the reduction of invasive species introductions (Shine 2003). Backwaters have been continuously exposed to reclamations to perform agriculture, aquaculture activities, harbour growth and industrialization. Reclamations for paddy-cum-shrimp aquaculture, freshwater prawn fisheries, and shellfish fisheries have significantly contributed to improvements in the backwater environment since the 1960s. Until the 1970s, a total of 5,100 hectare had been converted into 80 paddy cum shrimp culture systems and further on an area of around 800 hectare for paddy cum shrimp culture and other aquaculture purposes towards the end of the nineties (Thomson 2002). Mangroves in and around Cochin backwaters are heavily destroyed thereby releasing the sediment adding turbidity to water. The remaining scattered patches of mangroves are now found in Vypin, Vallarpadam, Malippuram, and Mangalavanam in the north zone and Kumbalam, Panangad, Chellanam and Kumbalangi in the south (Sunilkumar 1981). The past two to three decades have witnessed tremendous growth in the sector causing remarkable variation to the hydrobiology of backwater system.

Industrial Pollution and Eutrophication in Backwaters

Backwater receives effluents from industries such as food processing, drug manufacturing, paper, textiles, rubber, plywood manufacturing industries and chemical engineering. Backwaters also gathers waste including domestic sewages and urban wastes, organic fertilizers and agricultural land residues, oil spillage and other hydro-carbon products from Cochin Refineries, Cochin Port and Caprolactum

plant of FACT, effluents from other small industries, chemical wastes from fertilizer plants, residues from fish landing centre and dockyards, fishing harbour waste, metal, oil, paints and paint scrapings from Cochin shipyard and other sediments from dredging. Nutrients primarily phosphorus and nitrogen from such discharge waters if added an enormous amount to backwaters is found to cause proliferative production of water hyacinth (Mugidde and Wanda 2002). The increased availability of one or more restricting growth factors necessary for photosynthesis such as sunlight, carbon dioxide and nutrient fertilizers have resulted in this greater havoc called eutrophication characterized by excessive plant and algal growth producing numerous algal blooms (Schindler 2006). The resilience and resistance to survive the adverse environmental disruptions have paved the way for the invasive species not only to intrude but to outstrip the native species which is aided mainly by anthropogenic activities, eventually making the marine ecosystem challenging and hostile for the native species (Makowski and Finkl 2018). The low Dissolved Oxygen (DO) content influences the changes in the water body's biotic community composition inducing variability in species richness of the ecosystem. Production of toxins by the blooming algal species makes the water unsuitable leading to the extinction of indigenous species and threatening the food web dynamics (Chakraborty 2019). Eutrophication related high photosynthesis rates will deplete dissolved inorganic carbon and increase the pH during the day to drastic levels.

Global Climate Change

The conclusion of the Intergovernmental Panel on Climate Change (IPCC 2007) depicts that the climate caused extinctions and other alterations in biodiversity leads to invasion of invasive species from warmer regions. Besides factor like temperature elevation, habitat fragmentation has resulted in the aggravation of the problem worsened along with changing patterns of land uses making the region non-compatible for the native species to get adapted (Rejmánek 1989). Once moved to a landfill ground after its clearance, the water hyacinth decomposes, releasing carbon dioxide, methane and nitrous oxides which will both have a detrimental effect on the air

quality and even lead to global warming. Global climate change is likely to lead to more frequent and prolonged occurrences of events such as droughts and floods, which can cause severe disruptions in the affected areas. Floods threaten the state of river banks, reroute water courses and thus create recruitment sites for plants to colonize. Floods contribute to the proliferation of phytoplankton and marine macrophytes with the addition of significant quantities of total dissolved and suspended solids and debris (Neif et al. 2001). Earlier studies by Le Maitre et al. (2004) reveals siltation and flooding act as means of transportation of seeds or whole plants to a new colonizing territory.

Ecotourism in Backwaters

Unplanned and unstructured ecotourism seemed to contribute towards ecodegradation in Cochin backwaters. Tourism in turn is also negatively affected as mats of the plant species clog waterways making the movement through water bodies difficult. The enormous amount of waste discharged into water bodies can be related to the tourism sector aggravating the pollution status of backwaters (Zacharias and Manalel 2008). Tourism advancement in regions such as Vembanad backwaters, Vypin, Puthuvypin makes a significant contribution to the state economy. While the influx of tourists was initially small due to lack of connectivity and transportation, but in recent years road links have improved and a fleet of transportation operations resulted in a substantial influx of tourists into all places.

CONCLUSIONS

Environmental perturbations and hydrobiological factors have triggered the process of bioinvasion caused by the dense mats of *Eichhornia crassipes* bringing about deteriorated water quality in Cochin backwaters. These factors have aggravated the condition of biohomogenization that can generate a severe biodiversity crisis. Adequate care shall be taken while introducing exotic species with better performance for improving aquaculture production which intensifies the distress brought to the environment. Excessive amounts of fertilizers flushed and drained off into water bodies make them

highly eutrophic. Environmental degradations on the account of ecotourism and urbanization in backwaters disposing of huge amounts of waste along with increased flood frequencies and changes in salinity owing to the perspectives of climate change exacerbate the strain imparted on the ecosystem allowing an invasive plant to establish in its new habitat. Ideal growth conditions provided by the Cochin backwaters with optimum availability of sunlight, temperature, pH, salinity and abundance of nutrients favor the unchecked growth of plant species. The preliminary study and its review made an understanding about the status of a vast expanse of water body invaded by the plant species in Cochin backwaters. Unlike some attempts to convert the menace into a worthy resource as researches conducted by National Institute of Advanced Studies (NIAS) to harvest bio-energy out of the species, more researches conducted in Kerala focused mainly on the Kuttanad regions of Alappuzha and the majority of innovations devised so far have not found its way to commercial daily basis nor industrialized. Focus on control of the driving factors that intensify the bioinvasions is an area of concern as the study area is an urban conglomeration subjected to surging anthropogenic disturbances day by day. Finally, it can be concluded that despite the measures taken to control the havoc, the research area is of at most importance looking upon the highly diverse ecosystem and its biotic components being disrupted by biohomogenization of *Eichhornia* species.

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