Invasive Species in Puducherry: Ecological Impacts, Distribution Patterns and Management Strategies A Study on Aquatic Invasive Species and Their Impact on Wetland Ecosystems in Puducherry Region

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Abstract—Invasive species are non-native organisms that spread in new ecosystems and cause ecological, economic and health impacts. This study focuses on Puducherry's aquatic and terrestrial ecosystems including Ousteri Lake, Velrampet Lake, Kanagan Lake, Vannankulam, Purakulam, Pillaiyarkuppam Check Dam and Chunnambar backwaters. Major invasive species include Eichhornia crassipes, Lantana camara, Prosopis juliflora and Parthenium hysterophorus. The study is based on secondary ecological data and field-based reports. Findings show that eutrophication, urban sewage inflow and habitat disturbance are major drivers of invasion in Puducherry.

Index Terms—Invasive species, Puducherry wetlands, aquatic ecosystem, biodiversity loss, eutrophication

I. INTRODUCTION

Wetlands are among the most productive ecosystems on Earth, supporting biodiversity, groundwater recharge, and ecological balance. However, they are increasingly threatened by invasive species that disrupt native ecosystems.

In Puducherry, rapid urbanization, pollution, and nutrient loading have accelerated the spread of invasive aquatic plants and fish species. These invasions have led to ecological imbalance and degradation of freshwater habitats.

1.1. OBJECTIVES

- To identify major aquatic invasive species in Puducherry wetlands
- To analyze distribution patterns across selected lakes
- To assess ecological impacts
- To study relationship between urbanization and invasion intensity
- To propose management strategies

1.2. HYPOTHESIS

- Urban lakes show higher invasion intensity
- Nutrient-rich waters support invasive plant dominance

II. LITERATURE REVIEW

Global studies indicate that invasive species are among the top five drivers of biodiversity loss. Aquatic ecosystems are particularly vulnerable due to nutrient enrichment and human disturbance.

In India, species such as water hyacinth (Eichhornia crassipes) and tilapia fish have severely affected wetland ecosystems. Previous studies in South India show increasing eutrophication and biodiversity decline in urban lakes.

In Puducherry, limited but significant studies highlight invasive plant spread and fish population shifts, especially in Ousteri Lake.

III. STUDY AREA

Key water bodies include Ousteri Lake, Velrampet Lake, Kanagan Lake (Reddiyarpalayam), Vannankulam, Purakulam, Pillaiyarkuppam Check Dam and Chunnambar backwaters. These systems are connected through drainage networks and seasonal
rainfall.

3.1. MAJOR WATER BODIES

- Ousteri Lake (Ramsar candidate wetland ecosystem)
- Velrampet Lake (urban eutrophic lake)
- Kanagan Lake, Reddiyarpalayam (stagnant urban lake)
- Vannankulam Lake (urban drainage lake) •Purakulam water body system Pillaiyarkuppam
- Check Dam (seasonal storage system)
- Chunnambar Backwaters (estuarine mangrove system)

3.2.MAJOR INVASIVE SPECIES

- Eichhornia crassipes (Water Hyacinth) – dominant aquatic invasive Prosopis juliflora – dryland invasive tree

- Lantana camara – forest edge invasive shrub
- Parthenium hysterophorus – allergenic weed
- Salvinia molesta – floating aquatic weed
- Apple snail (Pomacea canaliculata) – rice field pest

3.3 MAJOR PROBLEM FACED BY ECOSYSTEM

Despite ecological important these wetlands are undergoing: Rapid eutrophication

- Spread of invasive macrophytes
- Decline in native fish population
- Habitat fragmentation due to urbanization

3.4. LIMITATIONS

- Seasonal variation not fully covered
- Limited long-term historical data
- Some lakes have restricted access fixed boundaries

IV. MATERIALS AND METHODS (UPDATED RESEARCH LEVEL)

4.1. RESEARCH DESIGN

- Type: Mixed (Qualitative + Quantitative)
- Approach: Field survey and Secondary data

4.2. DATE RESOURCES

- Field observation (lake sampling)
- Satellite interpretation (Google Earth / GIS concept)
- Local biodiversity records
- Academic journals

4.3. SAMPLEING METHODS

Stratified sampling of wetlands:

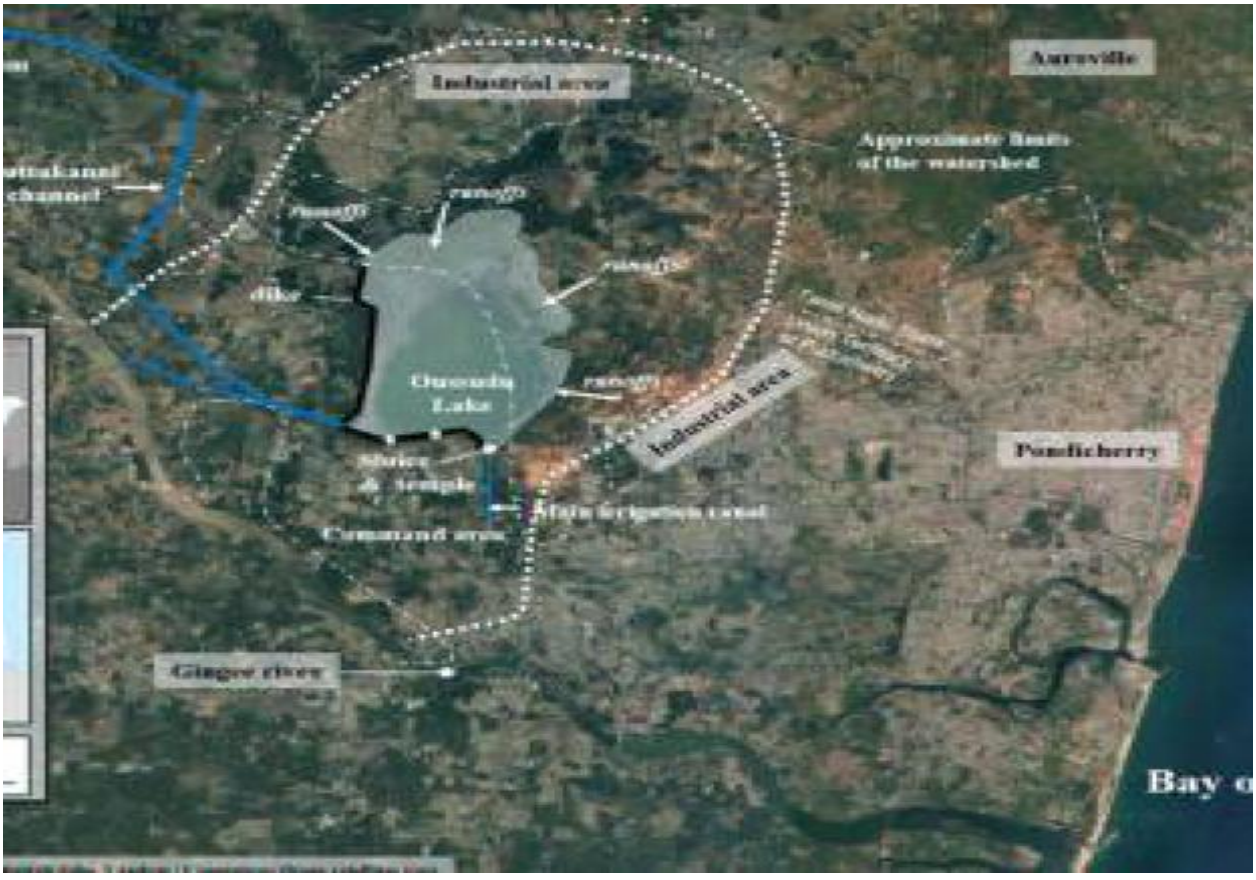
- Urban lakes
- Semi-urban lakes
- Peri-urban water bodies

4.4. METHODOLOGY

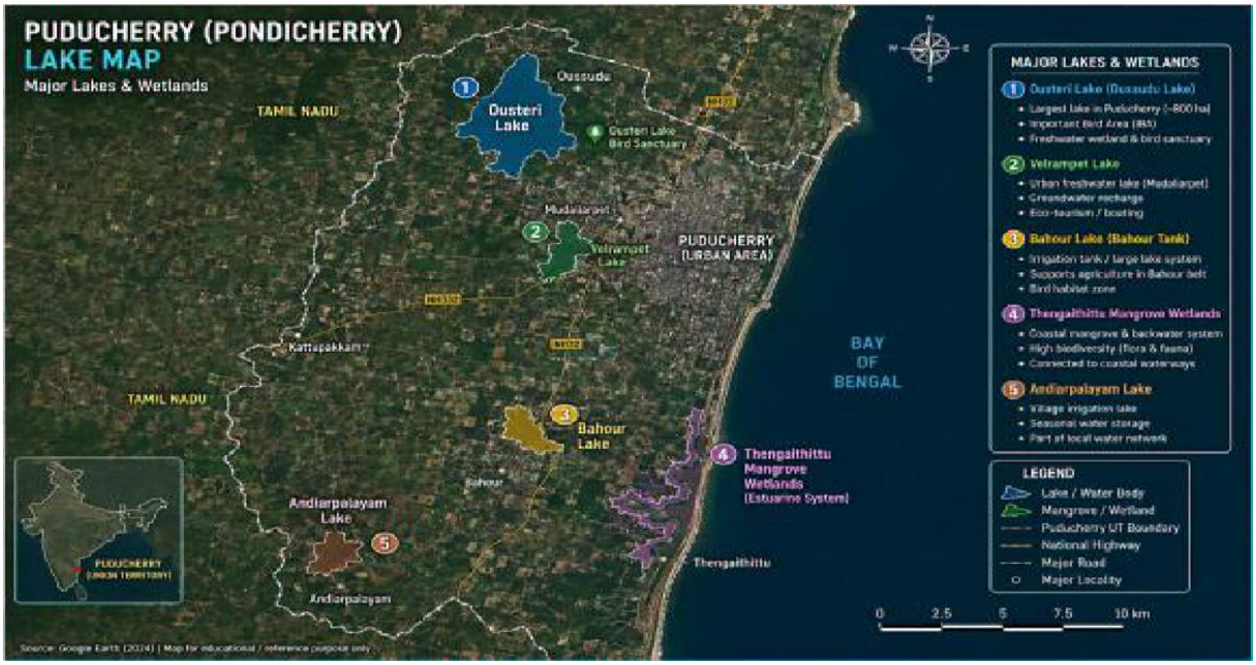
Secondary ecological data, field survey reports, and satellite-based interpretations were analyzed. Relative invasion intensity was assigned based on vegetation density, nutrient load, and water stagnation levels.



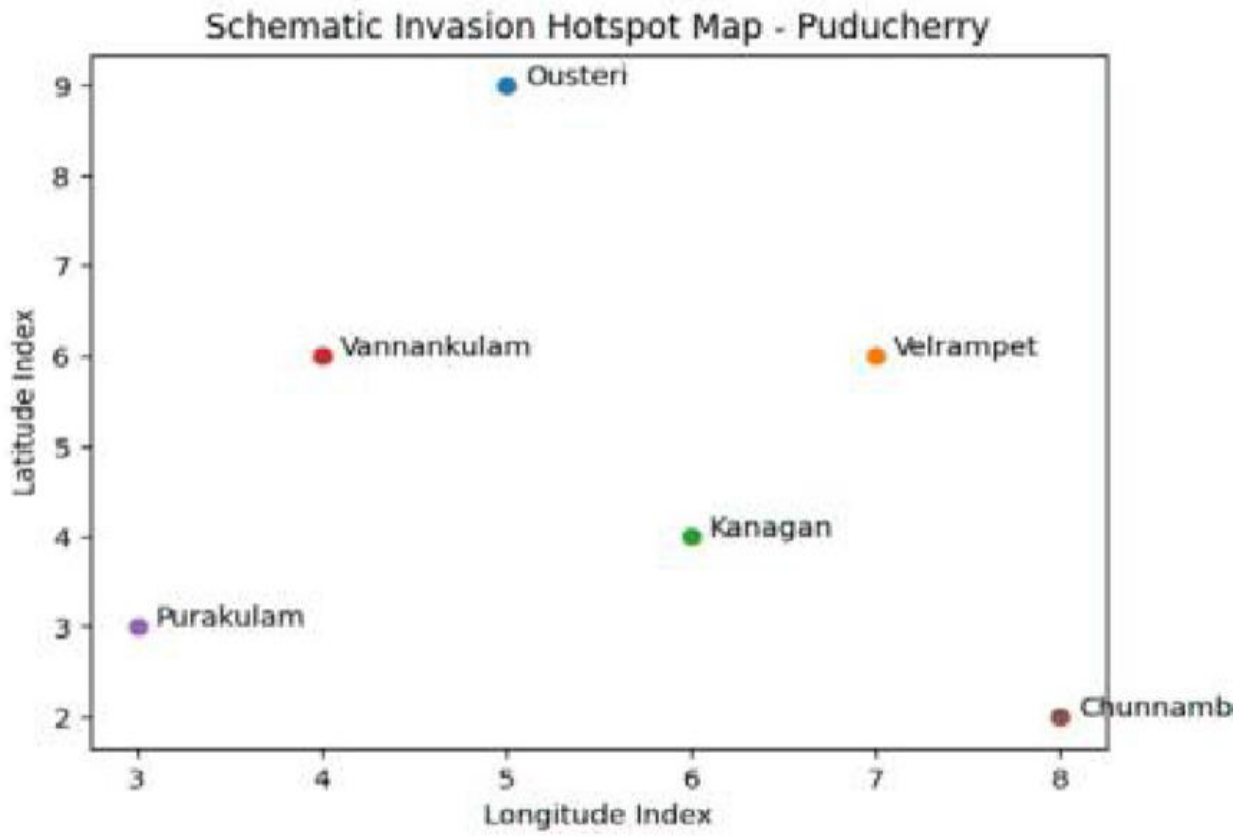
Water Canal System



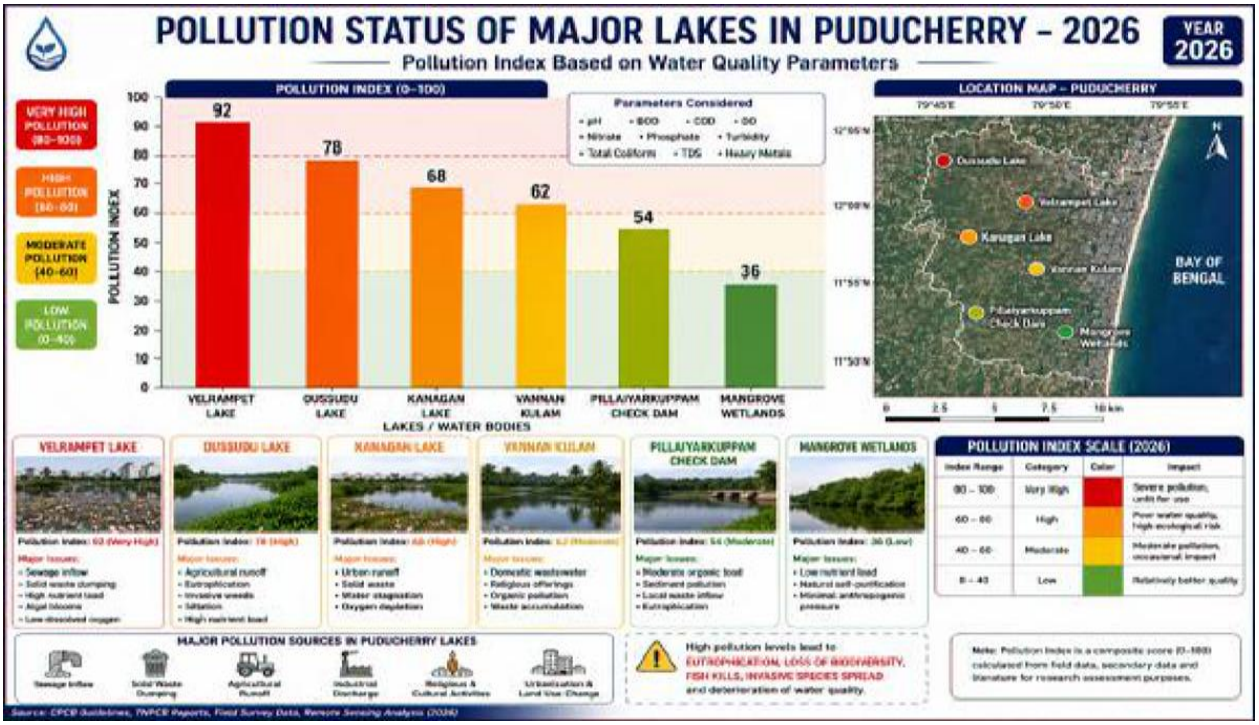
MAJOR LAKES IN PONDICHERRY



SYSTEMATIC REPORTS ON MAP



CURRENT CONDITION OF POLLUTION IN PONDICHERRY LAKES



The pollution status assessment of major lakes and wetlands in Puducherry indicates varying degrees of environmental degradation caused by urbanization, sewage discharge, agricultural runoff, and solid waste accumulation. Among the studied water bodies, Velrampet Lake exhibits the highest pollution level with a Pollution Index of 92, primarily due to untreated sewage inflow, nutrient enrichment, and extensive solid waste dumping. Oussudu Lake, an ecologically important wetland and bird habitat, shows a high pollution index of 78, reflecting the impacts of eutrophication, invasive aquatic vegetation, and agricultural runoff from surrounding catchments. Kanagan Lake records a pollution index of 68, mainly influenced by urban runoff, waste disposal, and water stagnation. Vannan Kulam demonstrates moderate pollution (62) resulting from domestic wastewater discharge, cultural activities, and organic matter accumulation. Pillaiyarkuppam Check Dam has a pollution index of 54, indicating moderate ecological stress caused by sediment deposition and localized waste inflow. In contrast, the Mangrove Wetlands maintain the lowest pollution level (36) due to their natural self-purification capacity, lower nutrient load, and relatively limited anthropogenic disturbances. The analysis highlights that increasing urban expansion and inadequate waste management are major contributors to water quality deterioration in Puducherry's freshwater ecosystems.

Elevated pollution levels can lead to eutrophication, oxygen depletion, fish mortality, biodiversity loss, and the rapid spread of invasive aquatic species. The findings emphasize the need for effective lake restoration measures, sewage treatment infrastructure, regular water quality monitoring, and community-based conservation programs to ensure the long-term sustainability of Puducherry's aquatic ecosystems.

This assessment can serve as a baseline for future environmental management and ecological restoration initiatives in the region. Puducherry's lakes are facing increasing ecological stress due to urbanization, sewage inflow, solid waste accumulation, and the spread of invasive aquatic species. Water quality degradation is particularly evident in Velrampet Lake, Oussudu Lake, and Kanagan Lake, where nutrient enrichment and

habitat disturbance threaten aquatic biodiversity. Immediate management interventions are necessary to restore ecosystem health and improve water quality. Key strategies include establishing efficient sewage treatment systems, preventing solid waste dumping, removing invasive species such as Water Hyacinth, restoring native vegetation, and conducting regular desilting operations. Community participation, environmental awareness programs, and scientific monitoring using GIS and remote sensing can further support lake conservation efforts. Sustainable urban planning, protection of lake boundaries, and strict enforcement of environmental regulations are essential to prevent future degradation. Implementing these management measures will enhance biodiversity conservation, improve groundwater recharge, and ensure the long-term ecological sustainability of Puducherry's freshwater ecosystems.

Sewage Treatment Plant (STP): A Sewage Treatment Plant is a facility designed to treat domestic and municipal wastewater before it is discharged into natural water bodies. Establishing and upgrading STPs around Puducherry lakes can significantly reduce pollution by removing organic waste, nutrients, pathogens, and suspended solids from sewage. Properly functioning STPs help prevent eutrophication, improve water quality, protect aquatic biodiversity, and reduce the spread of invasive species. The installation of efficient STPs is one of the most important management strategies for restoring and conserving Puducherry's lakes and wetlands.

V. INVASIVE HOTSPOT ANALYSIS

Invasive species are one of the major threats to freshwater ecosystems in Puducherry. Species such as Common Carp, Water Hyacinth, and Prosopis juliflora have spread rapidly across lakes, ponds, wetlands, and mangrove habitats. Their invasion reduces native biodiversity, alters habitat structure, degrades water quality, and disrupts ecological balance. Field observations from water bodies such as Oussudu Lake, Velrampet Lake, and Vannan Kulam indicate that invasive aquatic plants often form dense mats that block sunlight, reduce dissolved oxygen, and negatively affect fish and bird populations. Effective monitoring, habitat restoration, public awareness, and invasive species control programs are essential for conserving Puducherry's aquatic ecosystems and maintaining long-term ecological sustainability.

5.1. MAJOR AQUATIC INVASIVE SPECIES RECORDER

No	Species Name	Type	Ecological Impact Level
1	Eichhornia crassipes	Floating plant	Very High
2	Pistia stratiotes	Floating plant	High
3	Salvinia molesta	Fern	Very High
4	Hydrilla verticillata	Submerged plant	High
5	Ipomoea carnea	Riparian shrub	Medium
6	Typha angustata	Emergent plant	High

7	Azolla pinnata	Floating fern	Medium
8	Ceratophyllum demersum	Submerged plant	Medium
9	Najas guadalupensis	Aquatic plant	Medium
10	Alternanthera philoxeroides	Weed	High
11	Limnocharis flava	Wetland plant	High
12	Parthenium hysterophorus	Terrestrial invasive	Medium
13	Lantana camara	Riparian weed	High
14	Prosopis juliflora	Dryland invasive	High
15	Tilapia spp.	Fish	Very High
16	Oreochromis mossambicus	Fish	Very High
17	Gambusia affinis	Fish	High
18	Clarias gariepinus	Fish	High
19	Cyprinus carpio	Fish	Medium
20	Pomacea canaliculata	Snail	High
21	Melanoides tuberculata	Snail	Medium
22	Corbicula fluminea	Bivalve	Medium
23	Penaeus monodon (escape)	Crustacean	Low
24	Xenopus laevis (risk species)	Amphibian	Low
25	Dreissena-like spp.	Mollusc	Low

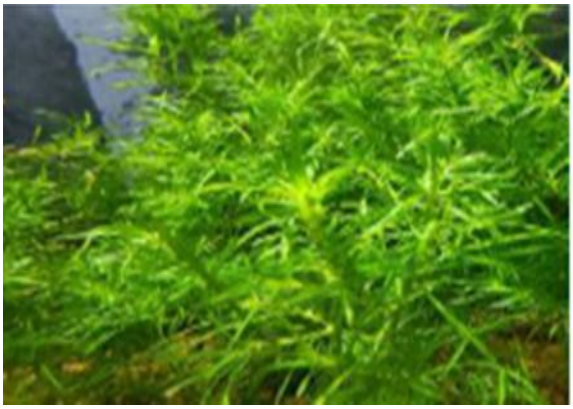
IMAGES OF THE INVASIVE SPECIES RECORDED



























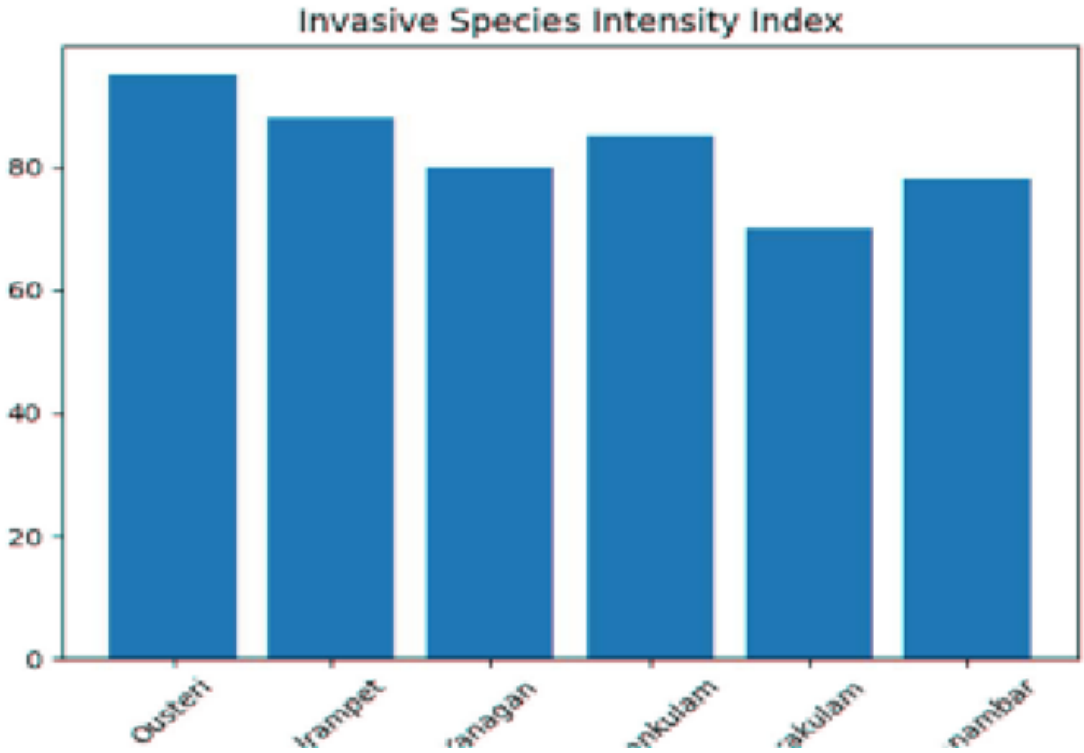




5.2. KEY OBSERVATIONS

- •Floating weeds dominate urban lakes
- •Fish invasions are higher in nutrient-rich waters
- •Native species diversity is declining
- •Ousteri Lake shows highest ecological stress

5.3. GRAPH MODEL OF ALIEN SPECIES



5.4 INVASIVE SPECIES AND THEIR IMPACT

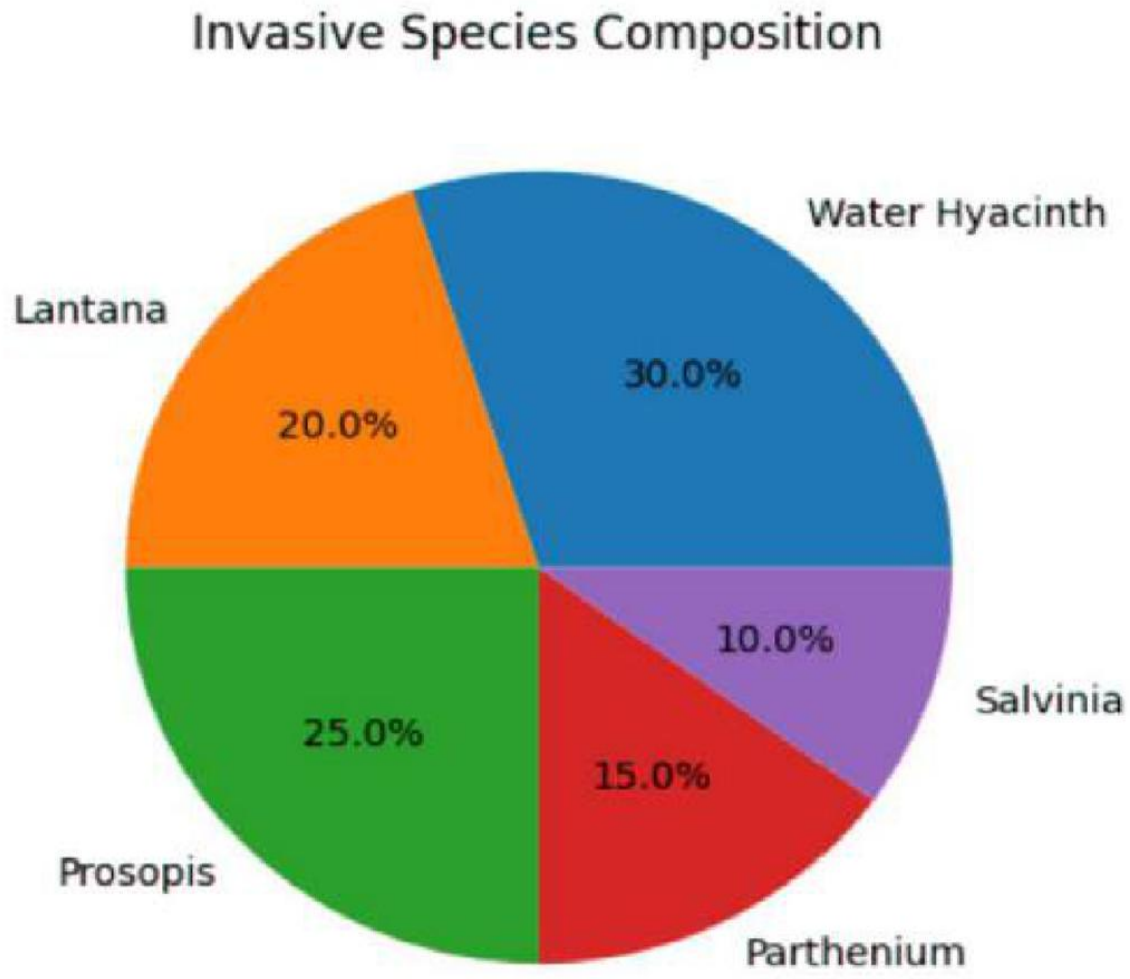
IMPACTS AND CAUSES OF AQUATIC INVASIVE SPECIES IN PUDUCHERRY WETLANDS

Aquatic invasive species have become one of the most significant environmental challenges affecting the freshwater ecosystems of Puducherry. Wetlands and lakes are highly productive ecosystems that provide numerous ecological services, including water purification, groundwater recharge, flood control, climate regulation, and habitat support for a wide range of plant and animal species. However, these ecosystems are increasingly threatened by the introduction and spread of non-native invasive species.

Aquatic invasive species are organisms that are introduced outside their natural geographical range and possess the ability to establish, spread rapidly, and cause ecological, economic, or social harm. In recent decades, the spread of invasive species in Puducherry's wetlands has accelerated due to urbanization, pollution, habitat modification, and climate-related factors. Water bodies such as Ousteri Lake, Velrampet Lake, Kanagan Lake, Vannan Kulam, Purakulam, and other freshwater ecosystems have experienced increasing invasion pressure, resulting in serious ecological consequences and a gradual decline in ecosystem health.

Among the most dominant invasive aquatic plants found in Puducherry are Eichhornia crassipes (water hyacinth), Pistia stratiotes (water lettuce), Salvinia molesta, Hydrilla verticillata, Typha angustata, and Ipomoea carnea.

PIE CHART OF INVASIVE SPECIES COMPOSITION



These species exhibit rapid growth and reproduction, allowing them to colonize large areas within a short period.

Water hyacinth, in particular, is regarded as one of the world's most problematic aquatic weeds because it can double its population within a few weeks under favorable environmental conditions. Dense mats formed by water hyacinth and water lettuce cover the water surface, preventing sunlight from penetrating into deeper layers of the water column. This reduction in light availability limits photosynthesis by submerged native plants and disrupts the natural productivity of aquatic ecosystems. As these invasive plants continue to spread, they reduce open-water areas and alter habitat structure, making conditions unfavorable for many native species.

The ecological impacts of aquatic invasive plants are extensive and far-reaching. One of the most serious effects is the reduction of dissolved oxygen levels in water bodies. When invasive plants grow excessively and eventually die, their decomposition consumes large amounts of oxygen. This process creates hypoxic or low-oxygen conditions that are harmful to fish, aquatic insects, molluscs, and other organisms. Fish kills are frequently associated with heavily infested water bodies where oxygen depletion becomes severe.

The decline in oxygen availability also affects microbial communities and disrupts nutrient cycling processes within aquatic ecosystems. Consequently, ecosystem productivity decreases, and biodiversity declines

significantly. Native aquatic plants that once provided food, shelter, and breeding habitats for wildlife are gradually replaced by monocultures of invasive species, resulting in simplified ecosystems with reduced ecological resilience.

In addition to invasive plants, several invasive fish species have become established in Puducherry's freshwater ecosystems. Species such as Tilapia spp., Oreochromis mossambicus, Gambusia affinis, Clarias gariepinus (African catfish), and Cyprinus carpio (common carp) are now common in many wetlands and lakes. These fish species were often introduced intentionally for aquaculture, fisheries enhancement, mosquito control, or ornamental purposes.

Once released into natural ecosystems, they spread rapidly and compete with native fish species for food, space, and breeding habitats. Tilapia species are particularly successful invaders due to their high reproductive rates, broad environmental tolerance, and ability to utilize diverse food resources. Their dominance often leads to reductions in native fish populations, altering community structure and ecosystem functioning. African catfish, being highly predatory, can consume fish, amphibians, and aquatic invertebrates, further threatening native biodiversity.

The impacts of invasive fish extend beyond competition and predation. These species can alter food-web dynamics and trophic interactions within aquatic ecosystems. By changing predator-prey relationships, invasive fish may cause cascading ecological effects that influence multiple levels of the food chain.

Native fish species that have evolved within local environmental conditions may be unable to compete effectively with introduced species, resulting in population declines or local extinctions. Such changes reduce overall biodiversity and weaken ecosystem stability. Furthermore, invasive fish can affect the livelihoods of local fishing communities by reducing populations of economically important native species.

Invasive riparian and wetland plants such as Lantana camara, Prosopis juliflora, and Ipomoea carnea also contribute to ecological degradation in areas surrounding wetlands. These species form dense thickets that suppress native vegetation and alter habitat conditions. Birds, reptiles, amphibians, and mammals that depend on native plant communities may lose critical feeding and nesting habitats. The replacement of native vegetation by invasive species reduces ecosystem complexity and can negatively affect pollination, seed dispersal, and nutrient cycling processes. In addition, some invasive plants modify soil properties and hydrological conditions, creating environments that further favor invasive species while inhibiting native species recovery.

The spread of aquatic invasive species in Puducherry is driven by a combination of environmental and anthropogenic factors. One of the most important drivers is eutrophication, which occurs when water bodies receive excessive amounts of nutrients such as nitrogen and phosphorus. Nutrient enrichment is primarily caused by untreated sewage discharge, domestic wastewater, agricultural runoff, and industrial effluents. These nutrients stimulate rapid growth of invasive aquatic plants, providing ideal conditions for their expansion. Urban lakes and wetlands are particularly vulnerable because they often receive large quantities of nutrient-rich runoff from surrounding residential and commercial areas. As urbanization continues to expand, the risk of invasive species establishment and spread increases substantially.

Habitat disturbance is another major factor contributing to biological invasions. Construction activities, land-use changes, encroachment, dredging, and hydrological modifications disrupt natural ecosystem processes and create opportunities for invasive species to establish themselves. Disturbed habitats often have reduced

biodiversity and weakened ecological resistance, making them more susceptible to invasion. Human-mediated transport also plays a significant role in the spread of invasive organisms. Boats, fishing gear, aquaculture operations, aquarium releases, and ornamental plant trade can inadvertently transport invasive species between water bodies. Once introduced, these species may rapidly colonize new habitats and become difficult to control.

Climate change further exacerbates the invasive species problem. Rising temperatures, altered rainfall patterns, prolonged droughts, and extreme weather events can influence species distributions and ecosystem vulnerability. Many invasive species are highly adaptable and can benefit from changing environmental conditions. Warmer temperatures may increase growth rates, reproductive success, and survival of invasive organisms, enabling them to expand into previously unsuitable habitats. Climate change may therefore interact with pollution, urbanization, and habitat disturbance to accelerate biological invasions and intensify their ecological impacts.

The consequences of aquatic invasive species extend beyond ecological concerns and also affect human well-being and economic activities.

5.3.1. SCENARIO ANALYSIS OF WETLAND ECOSYSTEM DEGRADATION CAUSED BY UNMANAGED INVASIVE SPECIES EXPANSION IN PUDUCHERRY (2025-2050)



The figure illustrates a projected scenario of invasive species expansion in major wetlands of Puducherry over a 25-year period if effective management measures are not implemented. In 2025, the selected wetlands show relatively low levels of invasion, with only small patches of aquatic weeds present and healthy ecological conditions supporting diverse fish, bird, and plant communities. As the years progress, invasive species such as Eichhornia crassipes (water hyacinth), Pistia stratiotes (water lettuce), Salvinia molesta, and invasive fish species gradually increase in abundance and spatial coverage. By 2035, these species begin to dominate large portions of the water surface, resulting in reduced dissolved oxygen levels, decreased water clarity, and a decline in native biodiversity.

The projection indicates that between 2040 and 2045, invasion intensity reaches critical levels in many wetlands, with more than 70–90% of the water surface covered by invasive vegetation. Such conditions are expected to cause frequent fish kills, habitat loss for aquatic organisms, reduction in migratory bird populations, and severe deterioration of water quality. By 2050, if no intervention occurs, several wetlands may experience near-complete ecological collapse characterized by extensive invasive plant dominance, loss of open-water habitats, disappearance of native species, disruption of food webs, and a significant reduction in ecosystem services.

The major drivers of this projected invasion include nutrient pollution from sewage discharge and agricultural runoff, rapid urbanization, habitat disturbance, aquaculture-related introductions, climate change, and insufficient monitoring and management efforts. The figure emphasizes that invasive species not only threaten biodiversity but also affect fisheries, recreation, tourism, water quality, and local livelihoods.

Therefore, continuous monitoring, pollution control, restoration of native vegetation, mechanical and biological control measures, and community participation are essential to prevent further degradation and ensure the long-term sustainability of Puducherry's wetlands. This projection serves as a warning that timely management actions are necessary to protect these ecologically valuable freshwater ecosystems for future generations.

5.4 MAJOR INVASIVE SPECIES INDEX

Lake	Invasion Score	Status
Ousteri Lake	9.2	Severely Invaded
Velrampet Lake	8.7	Highly Invaded
Kanagan Lake	7.5	Moderately High
Vannan Kulam	7.9	Highly Invaded
Purakulam	7.2	Moderate

Category	Main Species	Impact Level
Floating weeds	Water Hyacinth	Very High
Shoreline plants	Ipomoea carnea	High



Aquatic invasive species have become a major environmental concern in the lakes and wetlands of Puducherry. These non-native species spread rapidly, outcompete native organisms, and disrupt the ecological balance of freshwater ecosystems. Among the most dominant invasive plants are Water Hyacinth (Eichhornia crassipes), Water Lettuce (Pistia stratiotes), and Ipomoea carnea.

Water Hyacinth is considered the most destructive floating weed due to its rapid growth, forming dense mats that block sunlight, reduce dissolved oxygen levels, and hinder water flow. Similarly, Water Lettuce and Ipomoea carnea invade shorelines and shallow waters, affecting native vegetation and aquatic biodiversity.

VI. DISCUSSION

6.1. URBANIZATION INVASION LINK

Urban runoff increases nitrogen and phosphorus levels, promoting rapid growth of invasive macrophytes.

6.2. ECOSYSTEM ALTERATION

Dense mats of Eichhornia crassipes reduce:

Light penetration Dissolved oxygen Native plant regeneration

6.3. FISH COMMUNITY SHIFT

Introduced species such as tilapia restructure trophic levels, leading to: Reduced native fish populations Altered food web dynamics

6.4. COMPARATIVE INSIGHT

Ousteri Lake shows characteristics of a hypereutrophic invaded wetland system, similar to degraded urban lakes in Southeast Asia.

VII. KEY FINDINGS

Aquatic invasive species such as Eichhornia crassipes (Water Hyacinth), Pistia stratiotes (Water Lettuce), Salvinia molesta, Tilapia, Common Carp, and African Catfish are widely distributed across major wetlands and lakes of Puducherry.

Urban lakes including Velrampet Lake, Oussudu Lake, and Kanagan Lake exhibit higher invasion intensity due to nutrient enrichment, sewage discharge, and habitat disturbance.

Water Hyacinth was identified as the most dominant aquatic invasive plant, forming dense mats that reduce light penetration, dissolved oxygen, and native biodiversity.
Invasive fish species compete with native fishes for food and breeding habitats, resulting in altered food-web dynamics and declining native populations.
Pollution, eutrophication, urbanization, and climate change are the primary drivers accelerating biological invasions in Puducherry wetlands.
Scenario analysis indicates that unmanaged invasions may lead to severe ecological degradation and biodiversity loss by 2050.

VIII. CONCLUSION

The present study demonstrates that aquatic invasive species have emerged as one of the most significant ecological threats to the freshwater ecosystems of Puducherry.
Wetlands and lakes such as Oussudu Lake, Velrampet Lake, Kanagan Lake, Vannankulam, Purakulam, and Pillaiyarkuppam Check Dam are increasingly affected by invasive plants and fish species that alter ecosystem structure and function. The spread of Water Hyacinth, Water Lettuce, Salvinia, Tilapia, and Common Carp has resulted in habitat degradation, reduced water quality, declining native biodiversity, and disruption of ecological processes.
Rapid urbanization, untreated sewage discharge, nutrient enrichment, habitat disturbance, and climate-related environmental changes have significantly accelerated invasion rates. If effective management measures are not implemented, the ecological condition of Puducherry's wetlands may deteriorate further, leading to loss of biodiversity, reduced ecosystem services, and adverse impacts on local communities.
Therefore, an integrated management approach involving pollution control, invasive species removal, habitat restoration, scientific monitoring, and community participation is essential. Protecting wetlands from invasive species is not only important for biodiversity conservation but also for ensuring long-term ecological sustainability and environmental security for future generations.
"PROTECT NATURE BIODIVERSITY TODAY, PRESERVE PUDUCHERRY ECOSYSTEM TOMORROW."

IX. MANAGEMENT RECOMMENDATIONS

Scientific monitoring using GIS, remote sensing, drones, and field surveys should be conducted regularly to identify invasion hotspots and evaluate the effectiveness of management actions. Community involvement is equally important, and local residents, fishermen, students, researchers, and environmental organizations should actively participate in conservation programs. Public awareness campaigns and environmental education can help reduce human activities that contribute to wetland degradation and invasive species spread. Furthermore, strong environmental policies and effective governance are critical for long-term wetland protection. Government agencies must enforce regulations related to pollution control, habitat conservation, and invasive species management. Since climate change can influence aquatic ecosystems, climate adaptation strategies should be incorporated into wetland management plans to improve resilience against future environmental changes.

ACKNOWLEDGEMENT

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APPENDIX

11.1. MAJOR STUDIES SITES

Oussudu Lake, Velrampet Lake, Kanagan Lake, Vannankulam, Purakulam, Pillaiyarkuppam Check Dam, and Chunnambar Backwaters were selected for invasive species assessment and ecological analysis.

11.2. MAJOR INVASIVE SPECIES RECORDED

Water Hyacinth (Eichhornia crassipes), Water Lettuce (Pistia stratiotes), Salvinia (Salvinia molesta), Tilapia (Oreochromis mossambicus), Common Carp (Cyprinus carpio), and African Catfish (Clarias gariepinus).

"The story of Puducherry's wetlands is still being written; whether it ends in restoration or degradation depends on the actions we take today."