BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL
(SOUTHERN ZONE BENCH, CHENNAI)

ORIGINAL APPLICATION NO.162 OF 2023 (SZ)

Tribunal on its own motion - SUO MOTU based on the News item in The Hindu Epaper, web edition dated 24.09.2023, "Kole wetlands of Kerala face threat of alien plants".

And

The Principal Secretary to Govt of Kerala, Dept. of Environment, Thiruvanthapuram and Ors. ...Respondent(s)

ACTION TAKEN REPORT FILED BY SECRETARY, ENVIRONMENT DEPARTMENT/1ST RESPONDENT

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Dated at Chennai on this the 13th day of March,2025.

for. G. Yoh 13/3/25

M/s. E.K.KUMARESAN

Standing Counsel for State Government of Kerala - NGT(SZ) Chennai Bench

Action taken report

- On May 22, 2024, the Kerala State Biodiversity Board (KSBB) conducted a state-level workshop at KTDC Grand Chaithram, Thiruvananthapuram to observe the International Day for Biological Diversity, focusing on Bioinvasion Regulatory Framework – in line with Target 6 of the Kunming-Montreal Global Biodiversity Framework. The workshop was attended by 80 participants, including experts, policymakers, stakeholders from 28 line departments (Virtual Biodiversity Cadres), distinguished guests, KSBB staff, and representatives from Biodiversity Management Committees (BMCs). The event addressed the pressing issue of invasive alien species and their impact on biodiversity. During the event, KSBB presented the draft policy on bioinvasion, initiating discussions and inviting specific comments and suggestions from the attendees. Furthermore, the participants were divided into three sectoral groups—Agrobiodiversity, Aquatic, and Forest—to identify key indicators, implementation methods, and policy recommendations aligned with Kunming-Montreal Global Biodiversity Framework (KMGBF's) Target 6. Each group proposed key indicators for assessing bioinvasions and discussed strategies for regulation within their sectors in Kerala. The workshop concluded with panel discussions where group chairmen presented the identified indicators, implementation methods, and policy recommendations. KSBB is in the process of incorporating these into the draft policy and submitting the final policy to the government.
- KSBB has initiated a project for the preparation of the Local Biodiversity Strategy and Action Plan (LBSAP). As part of the action plan, one of the activities envisaged is the management of invasive species. In this regard, last year, KSBB provided financial assistance to 25 BMCs for the preparation of the Local Biodiversity Strategy and Action Plan (LBSAP) (Annexure).
- A project was implemented on stock enhancement of native inland fishes in major rivers in Kerala through the management of monsoon floodplain fisheries in 7 BMCs viz., Mallappuzhasseri, Mannar, Koruthodu, Ramamangalam, Valakam, Elavally and Annamanada Grama Panchayat BMCs. By increasing native species, the project indirectly aims to resist bio invasion in these areas.

ENVIRONMENT DEPARTMENT
GOVT. SECRETARIAT

Dr. Rathan U Kelkar IAS
Secretary
Environment Department
Govt Secretariat
Thiruvananthapuram

Annexure

Financial assistance to 25 BMCs for the preparation of the Local Biodiversity Strategy and Action Plan (LBSAP)

Sl. No.	District	Selected BMCs for the preparation of LBSAP	Amount given (in rupees)
1	Thiruvananthapuram	1. Chirayinkeezhu Grama Panchayat	2,00,000/-
		2. Vembayam Grama Panchayat	2,00,000/-
2	Kollam	3. Kareepra Grama Panchayat	2,00,000/-
		4. Kadakkal Grama Panchayat	2,00,000/-
3	Pathanamthitta	5. Mallppuzhasseri Grama Panchayat	2,00,000/-
		6. Mezhuveli Grama Panchayat	2,00,000/-
4	Alappuzha	7. Devikulangara Grama Panchayat	2,00,000/-
5	Kottayam	8. Veliyannur Grama Panchayat	2,00,000/-
		9. Kallara (Vaikkom) Grama Panchayat	2,00,000/-
6	Idukki	10. Peruvanthanam Grama Panchayat	2,00,000/-
7	Ernakulam	11. Karumaloor Grama Panchayat	2,00,000/-
		12. Marady Grama Panchayat	2,00,000/-
8	Thrissur	13. Sreenarayanapuram Grama Panchayat	2,00,000/-
		14. Elavally Grama Panchayat	2,00,000/-
9	Palakkad	15. Muthuthala Grama Panchayat	2,00,000/-
		16. Thirumittacode Grama Panchayat	2,00,000/-
10	Malappuram	17. Marancherry Grama Panchayat	2,00,000/-
		18. Vettom Grama Panchayat	2,00,000/-
11	Kozhikode	19. Kadalundi Grama Panchayat	2,00,000/-

Dr. [illegible] Kelkar IAS
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[illegible]ment Department
Govt Secretariat
[illegible]vananthapuram

		20. Kayanna Grama Panchayat	2,00,000/-
12	Wayanad	21. Thodernadu Grama Panchayat	2,00,000/-
		22. Vythiri Grama Panchayat	2,00,000/-
13	Kannur	23. Karivellur Peralam Grama Panchayat	2,00,000/-
14	Kasaragod	24. Valiyaparamba Grama Panchayat	2,00,000/-
		25. Udma Grama Panchayat	2,00,000/-
		Total	**50,00,000/-**

ENVIRONMENT DEPARTMENT
TH RUVANANTHAPURAM
GOVT. SECRETARIAT

Dr Rathan U Kelkar IAS
Secretary
Environment
Thiruvananthapuram

Biological Invasions

Status and Strategies for Management in Kerala

Contents

Preamble

Invasive species have been identified as one of the significant causes of biodiversity loss in boterrestrial and aquatic ecosystems in Kerala. In order to address this issue, a national conference on National Conference on "Bioinvasions- Trends, Threats, and Management" was organised by the Kerala State Biodiversity Board and constituted a commitee consisting of renowned for formulating strategies and action plan for managing the threat of invasion. This document was drafted after several deliberations. The main aim is prevention of unintentional or deliberate introduction of invasive alien plant and animal species and the identification, prevention of spread, appropriate control, and eradication of invasive alien species in terrestrial and aquatic ecosystems.

1. Introduction and Defenitions

As approved by the Convention of Biodiversity (Decision VI/23 of COP 6) , an alien species is a species, sub-species, or lower taxon, introduced outside its natural past or present distribution, which includes any part, gametes, seeds, eggs or propagules of such species that might survive and subsequently reproduce (CBD, 2002). According to the Global Invasive Species Programme (GISP), invasive species have the potential to affect the ecosystems in several ways including changing the density, diversity, and distribution pattern of the native species. As reported by Early et al. (2016), 17 percent of the global land area is highly prone to invasion (except Antarctica and glaciated Greenland).

Invasive alien species are one of the five major direct drivers of biodiversity loss globally, alongwith land and sea-use change, direct exploitation of organisms, climate change, and pollution. Among the various reasons of biodiversity loss, 16.2 percent is exclusively IAS and 40.5 percent of extinctions are driven by invasive alien species plus other threats. These affect the growth and distribution of native plant species by hindering the light availability, altering the microclimates, and modifying the pattern of plant succession, causing eutrophication through high rate of decomposition and depleting dissolved oxygen. A decline of local diversity is the most often reported impact of plant invasions. Other factors like global climate change will affect the distribution and impacts of invasive freshwater species and in many cases will make those impacts more severe.

The Target 6 of the recently adopted Kunming-Montreal Global Biodiversity Framework in COP 15 is to " Manage pathways for the introduction of invasive alien species, preventing, or reducing their rate of introduction and establishment by at least 50 per cent, and control or eradicate invasive alien species to eliminate or reduce their impacts, focusing on priority species and priority sites" According to the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) Assessment Report on Invasive Alien Species and their Control (known as the "Invasive Alien Species Report"), more than 37,000 alien species have been introduced by many human activities to regions and biomes around the world. The global economic cost of invasive alien species exceeded $423 billion annually in 2019, with costs having at least quadrupled every decade since 1970 (IPBES, 2023).

Globally, 6075 plant species are known to be invasive in different parts of the world (Wills 2017). Studies in India indicate that about 8.5 percent of the plant species in India are alien to the country (Khuroo et al. 2012), which includes, at least 756 cultivated aliens, 1388 other alien species, and 25 cryptogenic species (Pant et al. 2021). The 1388 alien species include 220 invasive aliens, 237 naturalized aliens (Inderjit et al. 2018; GloNAF database), and 931 casual aliens. The World Register of Introduced Marine Species estimates that globally there are

1711 introduced marine species, although not all these species may become invasive. Th International Union of Conservation of Nature (IUCN) has developed two knowledge platforms namely, the Global Invasive Species Database (GISD), and the The Global Register of Introduced and Invasive Species (GRIIS) for dealing with invasive species.

1.1. Scope and vision

Vision

Identification of invasive alien species in terrestrial and aquatic ecosystems, regulate pathways of introduction, prioritize areas requiring intervention, and manage them through mechanical, chemical, biological means, or through the development of value added products.

Geographical scope

The document is applicable to whole of Kerala (includes all terrestrial, marine and freshwater ecosystems)

Stakeholders

The control and management of invasive alien plant species require participatory efforts of diverse stakeholders such as academic institutions, research organizations, line departments, local self-governments, biodiversity management committee, non-governmental organisaionas, and local communities.

1.2. Objectives

The following are the objectives in preparing this document

- To develop a framework for the identification and management of invasive alien species (IAS) in Kerala
- To identify knowledge gaps and research priorities for impact assessment and eradication of IAS
- To develop processing techniques for the development of value added products from IAS and translation of research results for livelihood promotion of local people
- To identify the best practices for eradication of priority invasive alien plant species at local level

1.3. Some definitions related to Invasive Alien species

Some key definitions within the biological invasion process have been defined here as given in IPBES (2023). Some additional terms are also defined based on popular uasage.

Biological invasion: A process that transports (moves) and introduces a species outside of its natural range, intentionally or unintentionally by human activities to new regions where it may become established and spread.

The biological invasion process is comprised of the following stages— *transport, introduction, establishment,* and *spread* (or dispersal).

Transport: Human activities move a species, intentionally or unintentionally, through introduction pathways beyond barriers that define its natural range

Introduction: Arrival at a new location outside of its natural range through human activities

Establishment: Production of a viable, self-sustaining population

Spread: Dispersal and/or movement in a new region or range

Native species: A species (animal, plant, or other organism) within its natural range, including shifting its range, without human involvement

Alien species: A species whose presence in a region is attributable to human activities that have enabled it to overcome the barriers that define its natural range

Established alien species: A subset of alien species that have produced a viable, self-sustaining population and may have spread

Invasive alien species: A subset of established alien species that spread and have a negative impact on biodiversity, local ecosystems, and species. Many invasive alien species also have impacts on nature's contributions to people (embodying different concepts, such as ecosystem goods and services and nature's gifts) and good quality of life.

Introduction pathways: The many ways in which species are moved from one location to another by human activities that give rise to an intentional or unintentional introduction

Drivers: Factors that directly or indirectly cause changes to nature and may facilitate biological invasion

Negative impacts: Negative changes to nature, nature's contribution to people and/or good quality of life caused by invasive alien species

Some additional defenitions

Introduced species: A species that is brought to a new geographical area by humans, either intentionally or unintentionally

Foreign species: A species belonging to one country brought to another country by humans, either intentionally or unintentionally

Exotic species: Non-native species that do not belong to the area in which they occur

Naturalized species: Species, taxon, or population of exotic origin that integrates into a given ecosystem, becoming capable of reproducing and growing in it, and proceeds to disseminate spontaneously and is through an ecological phenomenon

Immigrant species: A non-native species naturally arrived and become permanent residents.

Acclimatized species: Non-native species got introduced and adapted to new environment for survival

Invasive species: Invasive species are those introduced species that spread widely or quickly and cause harm, be that to the environment, human health, other valued resources, or the economy

Vagrant species: Species that appear from time to time beyond their normal range and are often confused with exotic species

Traded-alien: An alien species after getting acclimatized become economically important together with negative impacts

Fugitive–alien: A non-native species escaped from captivity and threaten to naturalize in a new environment (mostly aquarium organisms)

Facultative-alien: An alien species after getting acclimatized become a non-influencing candidate (can be synonym of naturalized alien)

2. Impact of Invasive Aliens on Biodiversity

Invasive alien species are major threats to nature, biodiversity, ecosystem services, livelihoods of people, and quality of life. Alien species are being introduced by human activities to all regions and biomes of the world at unprecedented rates. Some become invasive, causing negative and in some cases irreversible impacts on nature, including loss of uniqueness of biological communities, contributing to the incomparable degree of deterioration of the biosphere upon which humanity depends.

2.1. Impact of invasive aliens on biodiversity

Invasive alien species cause striking and in some cases, irreversible changes to biodiversity and ecosystems, resulting in adverse and complex outcomes across all regions of earth, including local and global species extinctions

Invasive alien species have invaded and affected native biota in almost every ecosystems of the wold, and affected all major taxonomic groups of organisms. In economic terms, the costs of invasive alien species are stupendous. Total annual costs, including losses to crops, pastures and forests, as well as environmental damages and control costs, have been conservatively estimated to be in hundreds of billions of dollars and possibly more than one trillion. This does not include valuation of species extinctions, losses in biodiversity, ecosystem services, and aesthetics. The impacts from invasive aliens can be compounded by climate change , which can facilitate the spread and establishment of alien species. For instance, climatic events such as floods can bring invasive species into new areas. The resilience of natural habitats can also be reduced by these species making them more vulnerable to the impacts of climate change. Introduced grasses and trees may alter fire regimes, putting habitats and human life at risk.

The non-native vegetation disrupts movement of water and sediment and may have impact on water quality. The water-logged soils in aquatic ecosystems formed by high degree of eutrophication emit high concentration of methane to the atmosphere. Dense mats of floating and submersed plants restrict navigation and impede water movement important for flood control and irrigation. This may also affect ecotourism.

It is estimated that more than 37,000 established alien species have been introduced by human activities across all regions and biomes of earth, with new alien species presently being recorded at an unprecedented rate of approximately 200 annually (IPBES, 2023). **Among these, evidence of negative impacts exists for more than 3,500 of these species, which are categorized as invasive alien species.** The proportion of established alien species known to be invasive varies among taxonomic groups, ranging from 6 per cent of all alien plants to 22 per cent of all alien invertebrates. About 20 per cent of all impacts are reported from islands. About 25 percent of documented negative impacts have been reported

from aquatic realms, especially from inland surface waters/waterbodies and shelf ecosystems. In addition to their impacts on nature, about 16 per cent of invasive alien species have negative impacts on nature's contributions to people, and about 7 per cent on good quality of life

2.2. Factors affecting the spread of invasive species

Invasion process is accelerated by deforestation, changes in land use and land cover, urbanization, habitat fragmentation, and edge effect. Fragmented land and barren uncultivated land act as corridors for the spread of invasive species. Other factors include:

- Prevailing environmental conditions and climate change
- Ecological conditions (food, accessibility, etc.)
- Behavior of native species (predation)
- Nature of introduction (time, population, etc.)
- Reproductive rate and physiological tolerance
- Purpose of introduction (livelihood, economic development, food, etc)
- Protection available for non-native organisms
- Sturdiness of introduced organisms
- Strength of out-competence

2.3. Criteria for identifying a species as invasive

The National Biodiversity Authority (NBA) realised the need to avoid ambiguity and developed the following a criteria for designating a species as IAS (Sandilyan et al., 2018): The invasive species should have been:

1. Introduced from outside the political boundary of India;
2. Established as a reproductive population within the political boundary of India;
3. Reported as IAS in scientific studies conducted in India; and
4. Well-recognised for its negative impacts on biodiversity/ecosystem functions and services/economy, health, social, and cultural system.

The main attributes used for designating 'species' as invasive alien species are

- *invasiveness* (invasive elsewhere, rapid multiplication and spread in different ecosystems, multiple modes of reproduction and multiple modes of dispersion),
- *impacts* (affecting ecosystem functions and services, biodiversity loss and economic loss and health hazard) and
- *invasion areas* (continued spread - range extension). The following criteria has been developed by NBA for declaring a species as invasive

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3. Existing Regulatory Mechanism. Quarantine Systems

The Ministry of Environment, Forests, and Climate Change (MoEFCC) is the nodal agency to deal with invasive alien spices for negotiations with CBD and the Ministry of Agriculture and Farmers Welfare deals with the quarantine survey and control India government has framed certain legislative measures to cope with the invasive spices. Plant Quarantine Regulatory Measures (PQRM) in India operate on the basis of :

1) The Destructive Insects & Pests Act, 1914 promulgated to prevent introduction and spread of destructive pests affecting crops (Rules Promulgated for regulating import of live insects in 1941 ; of fungi in 1943, and of cotton in 1972)

2) New Seed Policy,1988, formulated in 1988 to provide access to the best available seeds and planting material to Indian farmers, Domestic and imported.

3) The Plants, Fruits & Seeds (Regulation of import into India) Order 1989, notified for prohibiting and regulating the import to India of Plants / Plant material and the like, based on Post-entry Quarantine checks, and

4) The new Plant Quarantine Order 2003 (84 amendments until date, the last being S.O.2390 (E) dated 20th July, 2020) to replace the PFS Order 1989. The directive encourages an earlier Pest Risk Analysis(PRA) to determine the Phytosanitary safeguards needed to guard Plant resources against the invasive Pest.

In India, there are general and specific conditions for the import of Plants (including bulbs, tubers, rhizomes, corms,cuttings, buildings, grafts, layers, suckers, roots and flowers) and plant material (including plant products such as ginned cotton, unmanufactured tobacco etc.).

General Conditions are:

1) Import permits are essential
2) All plants should be accompanied by phytosanitary certificate from the country of origin **Fig.1. Criteria developed by NBA for declaring a species as invasive**
3) All Plants on arrival at port, shall be inspected and if necessary fumigated, disinfested or disinfected by a Plant Protection Adviser to the Govt. of India or any other officer authorized by him on his behalf
4) Plants and seeds, which require post-entry quarantine inspection, shall be grown in post-entry quarantine facilities approved by the Plant Protection Adviser to the Govt. of India
5) Import of hay or straw or any material of plant origin used for packing is prohibited.
6) Import of soil, earth, compost, sand, plant debris along with plants. Fruits, and seeds is prohibited.

3. Existing Regulatory Mechanism: Quarantine Systems

The Ministry of Environment, Forests, and Climate Change (MoEFCC) is the nodal agency to deal with invasive alien species for negotiations with CBD and the Ministry of Agriculture and Farmers Welfare deals with their quarantine, survey, and control. India government has framed certain legislative measures to cope with the invasive species. Plant Quarantine Regulatory Measures (PQRM) in India operate on the basis of :

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6. Import of soil, earth, compost, sand, plant debris along with plants, fruits, and seeds is prohibited.

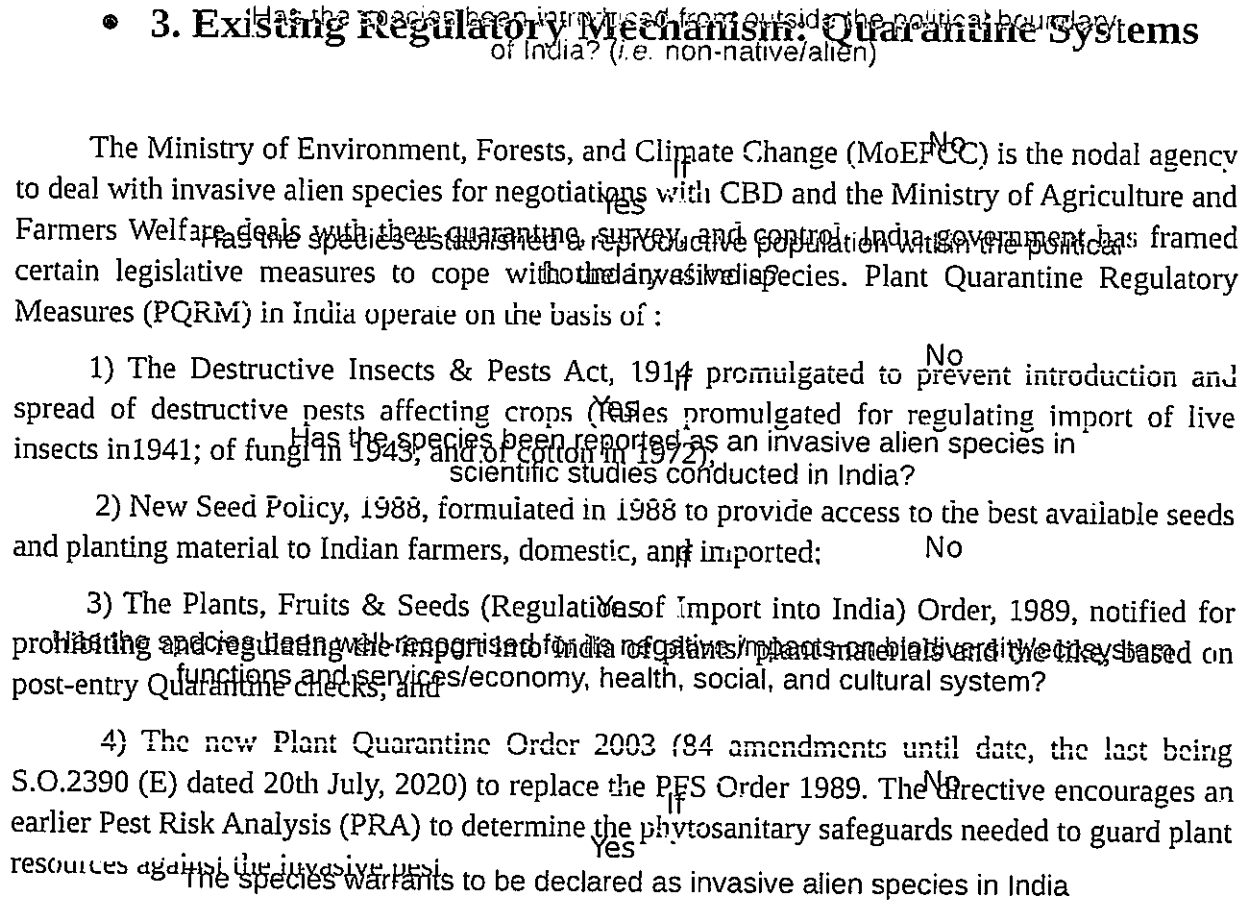

Fig. 1. Criteria developed by NBA for declaring a species as invasive

There are 71 plant quarantine stations across the major and minor ports (34 seaports, 12 airports, 14 land frontiers, and 11 foreign post offices) in India, which deals exclusively on restricting the import of any foreign contaminants. The consignments of plants/plant material for consumption shall be permitted import through the entry points notified vide Schedule-I, Schedule-II and Schedule-III of Plant Quarantine (Regulation of Import into India) Order, 2003. The points of entry Kerala for the import of plants/ plant materials and other articles notified under Plant Quarantine (Regulation of Import into India) Order, 2003 include seaports at Alapuzha, Kozhikode, Kochi, Beypore, Thiruvananthapuram, Vizhinjam, and the airport at Thiruvananthapuram.

The import of seeds, plants, cuttings, bulbs, and other planting materials for propagation purpose are permitted to import only through Regional Plant Quarantine Stations of Amritsar, Chennai, Kolkata, Mumbai and National Plant Quarantine Station, New Delhi. The port of entry through Alapuzha (Kerala), is permitted only for import of consignments of food grains by Food Corporation of India. All the regulated articles such as live insects, microbial cultures, bio-control agents and soil, earth, clay and similar material for microbiological, soil mechanics or mineralogical investigations and peat for horticultural purposes shall only be imported into India through Regional Plant Quarantine Stations at Amritsar, Chennai, Kolkata, Mumbai and New Delhi as per the provisions under Clause 3(14) of PQ Order, 2003. Import of germplaam/transgenic/ Genetically Modified Organisms shall be permitted only through New Delhi Airport as per the provisions under Clause 3(14) of PQ Order, 2003.

The Plant Quarantine Order 2003 of Govt. of India notified 152 insects, 67 fungi, 5 bacteria, 3 viruses, 1 nematode, 1 pest of unknown etiology (Mundulla yellows- Mundulla yellows dieback), and 1 parasitic plant (Arceuthobium pusillum Peck—eastern dwarf mistletoe) as regulated pests associated with various forest species and associated material including wood being imported into India. In all, 57 plant species (not specific to forests) are also notified as regulated pests. These have been identified based on pest risk assessments carried out by the National Plant Protection Organization Government of India (GOI, 2003). Agricultural imports have been classified as:

1) Prohibited plant species (Schedule IV);
2) Restricted species where import permitted only by authorized institutions (Schedule V);
3) Restricted species permitted only with additional declarations of freedoms from quarantine/ regulated pests and subject to specified treatment certifications (Schedule VI)
4) Plant material imported for consumption/ industrial processing permitted with normal Phytosanitary Certificate (Schedule VII).

Additional declarations are specified in the Order for the import of 700 agricultural commodities with specific lists of more than 1200 quarantine pests and 57 weed species.

4. Pathways of Introduction

Alien or exotic species may arrive and enter a new region through three broad mechanisms: (1). importation, (2) arrival, and (3) natural spread from the initial place of its presence where the species is itself alien. These three mechanisms result in six principal pathways: release, escape, contaminant, stowaway, corridor, and unaided. Exotic species transported as commodities may be introduced as a deliberate release or as an escape from captivity. Many species are not intentionally transported but arrive as a contaminant of a commodity, for example, pests and pathogens. Construction of dams and river linking projects also pave way for the introduction of invasive species. For example, *Badis badis* (Blue perch or Badis), *Pethia gelius* (Golden barb), *Osteobrama cotio* (Cotio) and *Lepidocephalus guntea* (Gutum) invaded in to Chennai lakes only after the river-linking project (SBSTTA, 2003; Daniel *et al.*, 2004; Knight and Balasubramanian, 2015).

Throughout India, more than 30 exotic species, which were introduced for different purpose (*e.g.* food, game, larvicidal) were reported in the wild. However, the ornamental trade has been identified as the vital pathway for the entry of invasive species, particularly fish and plant species. As reported by Soundararajan *et al.*(2015), 65 genera of freshwater fishes and 66 genera of marine fishes are available in on-line shopping websites of India. So far, more than 10 ornamental fish species established a good breeding population in Indian inland aquatic systems (Sandilyan, 2016).

Analysing the possible pathways for invasive species, a working group of the National Invasive Species Council (NISC) and the Aquatic Nuisance Species (ANS) Task Force in the USA differentiated three major pathway categories:

1) Transportation related pathways;
2) Lliving industry pathways; and
3) Miscellaneous pathways (NISC, 2006).

The pathways of marine introduction can be classified into two major groups: (a) intentional introduction (aquaculture) and (b) unintentional introduction through ballast water discharge and fouling of ship hulls.

The major invasion pathways have been worked out and identified as inadvertent or deliberate releases, escapes, contaminant from hatcheries where multispecies fish are bred in the same facility and river corridors (Singh, 2021). Besides, natural calamities such as tsunami, cyclone, and flood also play a crucial role on marine invasion. The major pathway for coastal invasion is through ballast water (e.g. *Karenia brevis*), natural calamity (e.g. Lion fish - *Pterois volitans*) accidental introduction/escape during unscientific coastal aquaculture (e.g. *Litopenaeus*

vannamei) and seaweed culture (e.g. *Kappaphycus alvarezii*)) (Anil *et al.*, 2002; Brigg *et al.*, 2004).

Annually, 1 2 billion tonnes of ballast water is being exchanged throughout the world. A single bulk cargo ship of 200,000 tonnes can carry up to 60,000 tonnes of ballast water (Ibrahim and Manal, 2012; Raghunathan *et al.*, 2013). Every day, nearly 7,000 marine and coastal species travel across the world's oceans by cargo ships, which silently carry more than 4,500+ different species including microbes, plants, and small animals in their ballast water tanks. For instance, studies highlighted that death of a large number of fishes, sea turtle, sea birds and marine mammals was reported due to harmful algal blooms (HABs) as a result of untreated ballast water discharge (Pierce and Henry, 2008). The HABs, commonly known as 'Red Tides', have been identified as a major health hazard. More than 300 algal species, which cause red tides, have been identified so far, and most of the species produce toxins that are harmful to marine organisms and human. The major pathways of introduction of IAS includes:

- Ballast waters
- Food related releases aquaculture
- Game or bait organisms
- Aquarium & ornamental releases
- Bio-control organisms
- Plant nurseries/ Ornamental/ Horticulture/ Plantations etc
- Scientific or conservation releases
- Bio-prospecting or as part of global economy
- R & D

5. Alien Invasive Species in Aquatic Ecosystem

5.1. Invasive aquatic plants

Invasive plants are found across a wide variety of aquatic habitats, including lakes, ponds, rivers, streams, estuaries, paddy fields, and marshy lands. There are three main growth forms of aquatic invasive plants present in the water bodies of Kerala,

- Free floating (Eg. *Pontederia crassipes*, *Pistia stratiotes*),
- Rrooted underwater but potentially floating on water surface (Eg. *Cabomba caroliniana*) and
- Emergent plants with erect stems above or on the surface of the water/saturated soils (Eg. *Limnocharis flava*).

Aquatic invasive alien plant species (IAPS) have adapted to living in, on, or next to water, and that can grow either submerged or partially submerged in water. Among the aquatic plants, the most commonly distributed species is Kariba weed (*Salvinia molesta*) occurring in all the 44 rivers, 4 reservoirs, and 3 freshwater lakes in Kerala, followed by water hyacinth (*Pontederia crassipes*) reported from 38 rivers and one freshwater lake. The red cabomba (*Cabomba furcata*), a native of South America, is a recent entrant to the aquatic water bodies in SWG, recorded from 7 rivers and 2 lakes (BijuKumar, 2022). Invasive macrophytes form thick mats and reduce light to submerged plants, often outcompeting rooted and submerged native plants and reducing vascular plant diversity.

The aquatic invasive species can also be classified based on the risks involved (Sankeran et.al., 2012). Accordingly, 7 species are included in the high-risk category (A), 4 under medium risk (B), 6 in low risk (C) and 1 species in insignificant (D) category. However, there is a need for more studies with respect to the categorization of plants. Among plants, 18 truly aquatic IAPS (16 Angiosperms and 2 Pteridophytes) belonging to 16 families has been identified. All the aquatic IAPS listed except *Ipomoea carnea* subsp. *fistulosa*, are herbaceous plants, 6 out of the 18 species are floating plants and others are rooted plants found in marshy/wet areas and shallow waters. Most of these plants are distributed all over Kerala but some are restricted to coastal areas only.

Ipomoea aquatica is included in the IAPS list of Kerala (Sankeran et. al, 2012), the native distribution range of these plants include India (POWO, 2022; Sasidharan, 2022), and needs further examination for including the plants in truly IAPS category. In the case of *Pistia stratiotes* also, most of the literature shows India in the native geographic range (eg., POWO, 2022). The 17th century botanical treatise, *Hortus Malabaricus* by Hendrik van Rheede also described this plant from India (*Kodapayil*, Vol. XI). Hence, including this plant in the IAPS list also need a re-check. *Hanguana anthelminthica* is one exotic plant

now widely spreading in the margins of the backwater areas of Alappuzha and Kottayam district, which needs more study to include in the aquatic IAPS list of Kerala. Some species like *Cyperus prolifer, Ludwigia sedoides*, and *Myriophyllum aquaticum*, which are widely grown in gardens and aquarium in Kerala may become a future threat to the aquatic habitats when released into the natural systems.

5.2. Riparian flora

It has been reported from all over the world that riparian zones are among the natural habitats exhibiting a higher proportion of invasive plants. The plants growing in riparian areas are very much linked with aquatic fauna and flora and the effects of invaders may propagate across the food webs. In Kerala, many terrestrial IAPS grow luxuriously in the riparian zones of almost all rivers in Kerala. There are 40 riparian IAPS, all Angiosperms, belonging to 12 families found in the riparian areas of Kerala. Majority of the species belong to Fabaceae (12), Asteraceae (10), and Amaranthaceae (5). Here also majority are herbaceous plants. Most of the plants are distributed all over Kerala. Among them, 10 species are in the high-risk category (A), 13 under medium risk (B), 10 in low risk (C), and 7 species in insignificant (D) category. Presence of good number of plants in the high-risk category is a matter of concern. *Lantana camara* is also found growing in some riparian areas but growth is not so vigorous as seen in the open forest areas.

Established invasive aquarium plants

Alternanthera reineckii
Echinodorus grisebachii
Echinodorus cordiforlius
Cabomba califonria
Cabomba furcata
Vallisneria spp.
Hygrophila corymbosa
Hygrophila difformis
Taxiphyllum sp.
Egeria sp.

Table1. Invasive alien plants found in th truly aquatic ecossttems in Kerala

Sl. No	Bot. Name	Common Name	Family	Habitat	Distributio n-Kerala	Native Country	Cate gory *	Reference
1	*Alternanthera philoxeroides* (Mart.) Griseb	Vellamkanni - Alligator weed	Amarant haceae	Wet/Marshy areas and paddy fields	Coastal Districts from ALP to KNR	Trinidad to N. Argentina.	D	Sandilyan, 2019; Sankaran et.al, 2012; CABI, 2022, GISD, 2022
2	*Azolla pinnata* R.Br.	Mosquito fern	Salviniac eae	Coastal water bodies and paddy fields -Free floating		Tropical & Subtropica l Old World.	C	CABI, 2022; GISD, 2022
3	*Cabomba caroliniana* A.Gray	Mullenpayal - Carolina fanwort	Cabombac eae	Fresh water canals, ponds and rivers - rooted/ floating	All Districts	Central & E. U.S.A. to NE. Mexico, Brazil to Central Argentina	A	Sandilyan, 2019; CABI, 2022; GISD, 2022
4	*Cyperus aromaticus* (Ridl.) Mattf. & Kük.	Navua sedge	Cyperace ae	Wet/Marshy areas and paddy fields	ALP, EKM	Tropical Africa	C	CABI, 2022
5	*Dactyloctenium aegyptium* (L.) Willd.	Kavarapullu - Crow foot Grass	Poaceae	Wet/Marshy areas and paddy fields	All Districts	South America	C	CABI, 2022

6	*Ipomoea aquatica* Forssk.	Kozhuppa – Swamp	Convolvulaceae	Ponds, streams and lakes	All Districts	Pantropics	B	Sankaran et.al, 2012, CABI, 2022, GISD, 2022
7	*Ipomoea carnea subsp. fistulosa* (Mart. ex Choisy) D.F.Austin	Neyveli katta - Bush Morning Glory	Convolvulaceae	Wet/Marshy areas and River/stream sides	All Districts	Mexico to S. Tropical America	A	Sandilyan, 2019; Sankaran et.al, 2012, CABI, 2022
8	*Lemna perpusilla* Torr.	Duckweed	Araceae	Stagnant waters-Free floating	All Districts	E. Canada to Central & E. U.S.A	B	Sandilyan, 2019; CABI, 2022
9	*Limnocharis flava* (L.) Buchenau	Nagapola - Water cabbage	Alismataceae	Wet/Marshy areas, paddy fields and streams	All Coastal Districts	Mexico to Tropical America	A	CABI, 2022, GISD, 2022
10	*Ludwigia peruviana* (L.) H.Hara	Clavo	Onagraceae	Wet/Marshy areas and paddy fields	ALP to KNR	Mexico to Tropical America	B	Sankaran et.al, 2012, CABI, 2022, GISD, 2022
11	*Marsilea quadrifolia* L	Water clover	Marsileaceae	Wet/Marshy areas and paddy fields	All Coastal Districts	Canary Islands, Europe to Japan and Iran	C	Sandilyan, 2019
12	*Pistia stratiotes* L.	Water lettuce	Araceae	Ponds and tanks-Free floating	All Districts	Tropics & Subtropics	A	CABI, 2022, GISD, 2022
13	*Pontederia crassipes* Mart. (Syn. Eichhornia crassipes (Mart.) Solms.)	Kulavazh a-Water hyacinth	Pontederiaceae	Backwaters, ponds, lakes, rivers and rice paddy fields-Free floating	All Districts	Tropical America	A	Sandilyan, 2019: CABI, 2022

14	*Salvinia molesta* D.Mitch	African Payal - Kariba weed,	Salviniaceae	Coastal/Near coastal water bodies-Free Floating	All Districts	S. & SE. Brazil to Argentina	A	Sandilyan, 2019: CABI, 2022; GISD, 2022
15	*Sesbania bispinosa* (Jacq.) W.Wight	Prickly sesban, Dhaincha	Fabaceae	Marshy/paddy fields	ALP, EKM, TSR, PKD, MPM	Pantropics	A	Sankaran et.al, 2012, CABI, 2022
16	*Spermacoce remota* Lam.	Button weed	Rubiaceae	Wet/Marshy areas and paddy fields	ALP, EKM, KKD, WYD	Tropical & Subtropical America	C	Narasimhan eta. al. 2011
17	*Struchium sparganophorum* (L.) Kuntze	Oreille-mouton	Asteraceae	Wet/Marshy areas and paddy fields	TVM to TSR	SE. Mexico to Tropical America	C	Suhara Beevy nd Kamarudheen kunju, 2019
18	*Urochloa mutica* (Forssk.) T.Q.Nguyen (Syn. *Brachiaria mutica* (Forssk.) Stapf)	Para grass	Poaceae	Shallow water, banks of stream, backwaters and rivers	TVM, KLM, ALP, KKD	Sahara to Angola, N. Africa to Syria, SW. Arabian Peninsula	B	CABI, 2022, GISD, 2022

*A-High Risk, B-Medium Risk, C-Low Risk and D-Insignificant

Table2: IAPS found in the riparian ecosystems in Kerala

S. No	Bot. Name	Common Name	Family	Habitat	Distribution-Kerala	Native Country	Category*	Reference
1	*Acacia auriculiformis* A.Cunn. ex Benth.	Acasia - Ear Pod Wattle	Fabaceae	Banks of streams, Paddy fields	All Districts	SE. Maluku to New Guinea and Australia	B	Sandilyan, 2019; Sankaran et.al, 2012; CABI, 2022
2	*Ageratina adenophora* (Spreng.) King & Robins	Crofton weed	Asteraceae	Banks of Streams	KLM, PTA, IDK, TSR to KNR	Mexico	B	Sandilyan, 2019; Sankaran et.al, 2012, CABI, 2022, GISD, 2022
3	*Ageratum conyzoides* (L.) L.	Kummini pacha - Marrubio	Asteraceae	Banks of streams	All Districts	Mexico	C	Sankaran et.al, 2012, CABI, 2022, GISD, 2022
4	*Ageratum houstonianum* Mill.	Neelappa -Goat weed	Asterace ae	Banks of streams	All Districts	Mexico to Central America	D	Sankaran et.al, 2012, CABI, 2022
5	*Alternanthera brasiliana* (L.) Kuntze	Joy weed	Amaranthaceae	Banks of streams	All Districts	Mexico to Central America	C	Sandilyan, 2019; Sankaran et.al, 2012

6	*Amaranthus spinosus* L.	Mullanch era - Spiny pigweed	Amarant haceae	Banks of streams	All Districts	Mexico to Tropical America	C	Sankaran et.al, 2012, CABI, 2022
7	*Antigonon leptopus* Hook. & Arn.	Thenpoo valli- Coral vine	Polygona ceae	Banks of streams	All Districts	Mexico to Central America	A	Sandilyan, 2019; Sankaran et.al, 2012; CABI, 2022; GISD, 2022
8	*Asclepias curassavica* L.	Kammalc hedi- Blood flower	Apocyna ceae	Banks of streams	All Districts	Mexico to Tropical America	D	Sankaran et.al, 2012
9	*Bambusa vulgaris* Schrad. ex J.C.Wendl.	Seema mula - Yello bamboo	Poaceae	Banks of streams	All Districts	China (Yunnan) to Indo-China		CABI, 2022, GISD, 2022
10	*Calopogonium mucunoides* Desv.	Wild ground nut	Fabaceae	Banks of streams	All Districts	Mexico to Tropical America	B	Sankaran et.al, 2012, CABI, 2022
11	*Camonea vitifolia* (Burm.f.) A.R.Simões & Staples *(Merremia vitifolia* (Burm. f.) Hall. f.)	Manja vayaraval li-Grape- leaf Wood Rose	Convolv ulaceae	Banks of streams	All Districts	Indo-China and China	A	Sankaran et.al, 2012
12	*Cenchrus purpureus* (Schumach.) Morrone *(Pennisetum purpureum Schumach.)*	Elephant grass	Poaceae	Banks of streams and backwaters	ALP, KTM, KNR, KSD	Sahara to Tropical Africa, Aldabra, Arabian Peninsula	B	CABI, 2022

13	*Centrosema molle* Benth.	Kattupay ar - Spurred Butterfly Pea	Fabaceae	Banks of streams	All Districts	Mexico to Tropical America	C	Sankaran et.al, 2012
14	*Chromolaena odorata* (L.) R.M.King &H.Rob.	Commun istpacha - Siam weed, Bitter Bush	Asterace ae	Banks of streams	All Districts	Tropical & Subtropica l America	A	Sankaran et.al, 2012, CABI, 2022, GISD, 2022
15	*Combretum indicum* (L.) DeFilipps *(Quisqualis indica* L.)	Thookuc hethi - Rangoon creeper	Combret aceae	Banks of streams	All Districts	Myanmar	A	Sankaran et.al, 2012; CABI, 2022
16	*Croton bonplandianus* Baill.	Ban Tulsi - Riverside Weed	Euphorbi aceae	Banks of streams	TSR, PKD	S. Bolivia to Uruguay.	D	Sankaran et.al, 2012
17	*Gomphrena celosioides* Mart.	Neervada malli - Water globehea D	Amarant haceae	Banks of streams	All Districts	Ecuador to N. Argentina	D	Sankaran et.al, 2012
18	*Hyptis capitata* Jacq.	Knobwee d	Lamiace ae	Banks of streams	All Districts	Florida, Mexico to Tropical America	B	Sankaran et.al, 2012
19	*Ipomoea cairica* (L.) Sweet	Railway creeper	Convolv ulaceae	Banks of streams	All Districts	Paleotropic s	A	Sankaran et.al, 2012, CABI, 2022, GISD, 2022
20	*Leucaena leucocephala* (Lam.) de Wit	Ippilippil - Subaul	Fabaceae	Banks of streams	All Districts	Mexico to Central America	C	Sankaran et.al, 2012, CABI, 2022, GISD, 2022

21	*Mesosphaerum suaveolens* (L.) Kuntze *(Hyptis suaveolens* (L.) Poit.)	Nattapoo chedi - Pignut, Wild Spikenar D	Lamiace ae	Banks of streams	All Districts	Mexico to Tropical America	B	Sankaran et.al, 2012, CABI, 2022
22	*Miconia crenata* (Vahl) Michelang. *(Clidemia hirta* (L.) D. Don)	Soap bush	Melasto mataceae	Banks of streams	TVM to PKD	Mexico to Tropical America	C	Sankaran et.al, 2012, CABI, 2022, GISD, 2022
23	*Mikania micrantha* Kunth	Vayara - Bitter vine	Asterace ae	Banks of streams	All Districts	Tropical & Subtropica l America	A	Sankaran et.al, 2012, CABI, 2022, GISD, 2022
24	*Mimosa diplotricha* C.Wright ex Sauvalle	Anathott avadi - Giant sensitive plant	Fabaceae	Banks of streams	All Districts	Tropical & Subtropica l America	A	Sankaran et.al, 2012, CABI, 2022,
25	*Mimosa pudica* L.	Thottava di - Touch me not	Fabaceae	Banks of streams	All Districts	Mexico to Tropical America	C	Sankaran et.al, 2012, CABI, 2022, GISD, 2022
26	*Neustanthus phaseoloides* (Roxb.) Benth. *(Pueraria phaseoloides* (Roxb.) Benth)	Thotta- payar - Tropical kudzu	Fabaceae	Banks of streams	All Districts	Tropical & Subtropica l Asia	A	Sankaran et.al, 2012, CABI, 2022
27	*Parthenium hysterophorus* L.	Congress pacha - Carrot Grass	Asterace ae	Banks of streams	All Districts	Tropical & Subtropica l America	B	Sankaran et.al, 2012, CABI, 2022, GISD, 2022

28	*Passiflora foetida* L.	Poodapaz ham - Stinking passion flower	Passiflor aceae	Banks of streams	All Districts	Tropical & Subtropica l America	B	Sankaran et.al, 2012, CABI, 2022, GISD, 2022
29	*Ricinus communis* L.	Aavanak ku - Castor oil plant	Euphorbi aceae	Banks of streams	All Districts	NE. Tropical Africa.	B	Sankaran et.al, 2012, CABI, 2022, GISD, 2022
30	*Senna alata* (L.) Roxb.	Puzhukk adithakar a - Golden Candle sticks	Fabaceae	Banks of streams	All Districts	SW. Mexico to Tropical America	A	Sankaran et.al, 2012, CABI, 2022
31	*Senna hirsuta* (L.) Irwin & Barneby	Woolly Cassia	Fabaceae	Banks of streams	All Districts	Tropical & Subtropica l America.	B	Sankaran et.al, 2012, CABI, 2022
32	*Senna occidentalis* (L.) Link	Ponniont hakara - Coffee- senna, Negro coffee	Fabaceae	Banks of streams	All Districts	Tropical & Subtropica l America	C	Sankaran et.al, 2012, CABI, 2022
33	*Senna tora* (L.) Roxb.	Ponthaka ra - Sickle Senna	Fabaceae	Banks of streams	All Districts	Central America	B	Sankaran et.al, 2012
34	*Sphagneticola trilobata* (L.) Pruski	Singapor e daisy	Asterace ae	Banks of streams	All Districts	S. Tropical America and Trinidad	A	Sankaran et.al, 2012, CABI, 2022, GISD, 2022
35	*Synedrella nodiflora* (L.) Gaertn.	Mudianp acha - Synedrell A	Asterace ae	Banks of streams	All Districts	Tropical & Subtropica l America.	D	Sankaran et.al, 2012, CABI, 2022

36	*Tithonia diversifolia* (Hemsl.) A. Gray	Velisoor yakanthi Mexican Sunflowe r	Asterace ae	Banks of streams	All Districts	Mexico to Central America.	B	Sankaran et.al, 2012, CABI, 2022, GISD, 2022
37	*Aeschynomene americana* L.	America n Joint Vetch	Fabaceae	Banks of streams	KLM, PTA, EKM, TSR, MPM, KKD, KNR	Tropical & Subtropica l America	C	Sankaran et.al, 2012, CABI, 2022
38	*Alternanthera ficoidea (L.) P.Beauv.*	Rabit meat	Amarant haceae	Banks of streams	PTA to MPM	Tropical America	C	Sandilyan, 2019; CABI, 2022
39	*Alternanthera paronychioides* A.St.-Hil	Pampera - Smooth joyweed.	Amarant haceae	Banks of streams	KLM, IDK, TSR, PKD, WYD	Tropical & Subtropica l America	D	Sandilyan, 2019; CABI, 2022
40	*Tridax procumbens* L.	Kummini pacha - Tridax daisy	Asterace ae	Banks of streams	All Districts	Mexico to Tropical America	D	Sankaran et.al, 2012, CABI, 2022

*A-High Risk, B-Medium Risk, C-Low Risk and D-Insignificant

5.3. Invasive fauna in Inland aquatic ecosystem

A total of 32 alien species, including 4 species of plants (macrophytes) and 28 species of fish, were recorded from the SWG (Bijukumar). Of the 28 fish species, 7 were identified as invasive, represented by 2 species within Cichlidae (*Oreochromis mossambicus* and *O. niloticus*) and Poeciliidae (*Poecilia reticulata* and *Gambusia affinis*), and 1 species within Loricariidae (*Pterygoplichthys pardalis*), Cyprinidae (*Cyprinus carpio*) and Clariidae (*Clarias gariepinus*) mainly in highland and midland zones (Bijukumar).

Among fishes, the most widely distributed species is the Mozambique tilapia (*O. mossambicus*), occurring in all 44 rivers, 18 reservoirs and 2 lakes and having established abundant populations in most habitats. Common carp (*C. carpio*) was the second most common invasive species, recorded from 17 rivers, 29 reservoirs, and 1 lake. On the other hand, guppy (*P. reticulata*) was distributed in 14 rivers and 22 reservoirs, with highly stable populations in high-altitude streams (800-1200m MSL). The study also showed that invasive species such as *C. carpio*, *P. reticulata*, *O. mossambicus*, and *C. gariepinus* had established good populations in the reservoirs, including those within the protected areas.

Table 3 : Details of major species of fishes introduced to India (excluding aquarium fishes)

Name of species	Native place/ imported from	year	Introduced to	Purpose of introduction
Salmo trutta fario Linnaeus, 1758	U.K	1863	Nilgiris (T.N.)	Sport, not established
Carassius carrasius (Linnaeus, 1758)	U.K	1870	Ooty lake (T.N)	Commercial Aquaculture
Osphronemus goramy Lacépède, 1801	South East Asia	1870-	India	Aquarium
Tinca tinca (Linnaeus, 1758)	U.K	1876	Ooty lake (T.N.)	Commercial Aquaculture
Salmo trutta fario Linnaeus, 1758	U.K	1899	Harwan (Kashmir)	Sport & Aquaculture, established well
Onchorhynchus mykiss (Walbaum, 1792) Former name : *Salmo gairdneri* Richardson, 1836	Sri Lanka, U.K	1904, 1912	Harwan (Kashmir)	Sport & Aquaculture
Poecilia reticulates (W. Peters, 1859)	England	1908	India	Mosquito control
Osphronemus goramy Lacépède, 1801	Southern China	1900s	India	Weed control
Salmo gairdneri Richardson, 1836 (*Onchorhynchus mykiss* (Walbaum, 1792))	Sri Lanka, Germany, New Zealand	1909-1910	Nilgiris (T.N)	Sport and Aquaculture
Salmo trutta Linnaeus, 1758	U.K	1909-1938	Munnar High Range	Sport and Aquaculture

Gambusia holbrooki Girard, 1859 (formerly *Gambussia affinis holobrooki* Girard, 1859)	Italy	1928	Cuttack (Orissa)	Larvicidal, spread throughout India
Salmo gairdneri Richardson, 1836 (*Onchorhynchus mykiss* (Walbaum, 1792))	U.K, Sri Lanka	1938-1940	Munnar High Range	Sport and Aquaculture
Salmo gairdneri Shasta (*Onchorhynchus mykiss* (Walbaum, 1792))	U.K	1941	Munnar High Region	Sport and Aquaculture
Cyprinus carpio Linnaeus, 1758	Sri Lanka	1939	Nilgiris (T.N.)	Commercial Aquaculture
Oreochromis mossambicus (W. K. H. Peters, 1852)	Africa	1952	Yamuna River	Aquaculture
Hypophthalmichthys molitrix (Valenciennes, 1844)	Hongkong, Japan	1959	Cuttack	Commercial Aquaculture (Orissa)
Ctenopharyngodon idella (Valenciennes in Cuvier & Valenciennes, 1844)	Hongkong	1959	Cuttack (Orissa)	Commercial Aquaculture
Salmo salar Linnaeus, 1758	Canada	1960-1970	Harwan/Lariba l (Kashmir)	Aquaculture
Salvelinus fontinalis (Mitchill, 1814)	U.S.A	1963	Harwan (Kashmir)	Aquaculture
Onchorhynchus nerka (Walbaum, 1792)	Japan	1968	Nilgiris (T.N)	Aquaculture
Salmo trutta Linnaeus, 1758	Japan	1968	Nilgiris (T.N)	Sport & Aquaculture
Japanese Rainbow Trout	Japan	1968	Nilgiris (T.N)	Sport & Aquaculture
Tiger Trout (Hybrid : Brown Trout X Eastern Brook Trout)	Japan	1968	Nilgiris (T.N)	Sport & Aquaculture
Albino Rainbow *Epalzeorhynchos frenatum* (Fowler, 1934)	Japan	1968	Nilgiris (T.N)	Aquaculture
Lake trout (Hybrid: Lake Trout X Brown Trout)	Canada	1968	Harwan/Lariba l (Kashmir)	Aquaculture
Rainbow trout Onchorhynchus mykiss (Walbaum, 1792)	Isle of (U.K)	1984	Kokernag (Kashmir)	Aquaculture Growing variety, Established
Coptodon zillii (Gervais, 1848)	Africa	1986	Northern states	Aquaculture
Oreochromis niloticus (Linnaeus, 1 758)	Africa	1987	All states of India	Aquaculture
Orecochromis urolepis (Norman, 1922)	Tanzania	Not known	North Inida	Aquaculture
Pangasianodon hypophthalmus (S auvage, 1878)	Bangladesh	1994-95	India	Aquaculture Under captive

				conditions
Pangasianodon gigas Chevey,1931	Thailand	1997	India	Aquaculture
Barbonymus gonionotus (Bleeker, 1850)	Java	-	West Bengal	Weed control/ Aquaculture
Mylopharyngodon piceus (Richardon, 1849)	China	1990s	India	Controlling molluscks in aquaculture ponds
Piaractus mesopotamicus (Holmberg, 1887)	Bangladesh	2004	Indian states	Aquaculture
Clarias gariepinus Burchell, 1822	Africa	1990s	Indian States	Aquaculture – banned
Kappaphycus alvarezii (Doty) Doty ex Silva, 1988	Japan	1990 1995-97	Okha coast Tamil Nadu	Cultivation

Of the 32 alien species, 15 were introduced into the natural water bodies of the SWG through the aquarium hobby and trade. While 6 species were introduced solely for promoting aquaculture, 3 species were introduced for mosquito control, and 3 species for either aquarium keeping or promotion of aquaculture. The rainbow trout, *Oncorhynchus mykiss*, was introduced during the colonial period to promote sport fishing, the only species introduced for this purpose.

Three IAPS, *S. molesta, Pistia stratiotes* and *E. crassipes* were introduced to the region as garden plants or for promotion of research, and their entry into natural systems is believed to be accidental. *Cabomba furcata* is a common aquarium plant, and this might have entered natural waterbodies either from home aquaria or from aquarium ponds adjoining the river basins, which are also used for rearing aquarium plants. While the release of most alien species may be accidental, species such as *C. gariepinus* has been illegally introduced for aquaculture. Of the 32 alien species, 11 were native to South East Asia, ten to South America, seven to Central or North America, and four to Africa. (Bijukumar)

Five exotic ornamental fishes *viz., Gambusia affinis, Oreochromis mossambicus, Osphronemus goramy, Poecilia reticulata, Xiphophorus maculatus* were reported from Chalakudy River in the Western Ghats, a biodiversity hotspot which harbours 16 endangered and 4 critically endangered species. Further, the study highlighted that *Poecilia reticulate* species established a breeding population in this hotspot (Raghavan *et al.*, 2008).

Lissachatina fulica is a snail , which feeds voraciously and is vector for plant pathogens, causing severe damage to agricultural crops and native plants. It competes with native snail taxa, is a nuisance pest of urban areas, and spreads human disease. This snail is listed as one of the top 100 invasive species in the world

Table 4: List of aquatic invasive species (AIS) in Inland freshwaters, India (Modified after Singh, 2021a).

Sl No	Name of fish species	NP+RE	AI

1.	African catfish *Clarias gariepinus*	√	√
2.	Bighead *Hypoththalmichthys nobilis*	√	√
3.	Silver carp *Hypophthalmichthys molitrix*	√	√
4.	Common carp *Cyprinus carpio* Communis.	√	√
5.	Leather carp, *Cyprinus carpio* Nudus.	√	√
6.	Mirror carp *Cyprinus carpio* Specularis.	√	√
7.	Black carp *Mylopharyngodon piceus*	√	√
8.	Mozambique tilapia *Oreochromis mossambicus*	√	√
9.	Nile tilapia *Oreochromis niloticus*	√	√
10.	Western Mosquito fish/ Topminnow *Gambusia affinis*	√	√
11.	Eastern Mosquito fish *Gambusia holbrooki*	√	√
12.	Guppy *Poecillia reticulate*	√	√
13.	Vermiculated sailfin catfish *Pterygoplichthys disjunctivus*	√	√
14.	Amazon sailfin catfish *Pterygoplichthys pardalis*	√	√
15.	Sucker mouth armoured catfish *Pterygoplichthys multiradiatus*	√	√
16.	Parana sailfin catfish *Pterygoplichthys anisitsi*	√	√
17.	Red Piranha *Pygocentrus nattereri*	√	√
18.	Three spot cichlid *Cichlasoma trimaculatum*	√	√
19.	Giant gaurami *Osphronemus goramy*	√	√
20.	Three-spot gourami *Trichogaster trichopterus*	√	√
21.	Green swordtail *Xiphophorus helleri*	√	√
22.	Platy *Xiphophorus maculatus*	√	√
23.	Gutum *Lepidocephalus guntea*	√	√
24.	Golden Apple snail *Pomacea canaliculata*	√	√
25.	Charru mussel *Mytella strigata*	√	√

Note: NP-Naturalised population; RE-Range Extension; Adverse Impacts (AI)-Included Biodiversity loss, Habitat alterations, Human health hazards and Impaired Ecosystem Services.

The rapid expansion of culture of exotic species was found to facilitate the escape of the exotic fishes into natural water bodies. There has been an alarming increase in the number of exotic fish species being captured in the rivers, lakes and reservoirs in recent years. Some of the introduced fish species were widely distributed across several states/union territories e.g. common crap *Cyprinus carpio*, Chinese carps *Ctenopharyngodon idella, Hypohthalmichthys molitrix*, koi carp *Cyprinus carpio*, African catfish *C. gariepinus*, while others were localized in specific regions e.g. Nile tilapia *Oreochromis niloticus*, sutchi catfish *Pangasianodon hypophthalamus*, Pacu *Piaractus brachypomus*, piranha *Pygocentrys nattereri, Pterygoplichthys spp and* many ther ornamental fishes. While aquaculture promises economic and social benefits for potential exotic species, escape of exotic fishes especially those becoming invasive have seriously posed ecological risks to the receiving aquatic environments. An assessment of culture production of exotic fishes which included mainly *Pangasianodon hypophthalmus, Clarias*

gariepinus, *Hypophthalmichthys nobilis*, *Litopenaeus vannamei*, *Piaractus brachypomus* and others was over 40% of total fish production of the country. Out of several fish species screened, a list of 25 potential aquatic invasive species has been prepared (Table). These identified and listed invasive fish species were found to develop naturalized population in inland waters and they displayed a range expansion besides causing array of adverse ecological impacts. Several hybrids of catfish, pacu, tilapia, bighead, ornamental fish arrived and invaded have not been assessed and there are scientific evidences that they will behave insidiously if no action is taken to contain them. The poorly regulated international pet trade will give entry to future invasive ornamental fishes.

Table:5. Spread and status of exotic fish species in Indian open-waters (Modified after Singh, 2014)

Name of Exotic fish species	Reasons of their introduction	Occurrences in natural water bodies			
		Rivers	Reservoirs	Lakes	Wetlands
Cyprinus carpio (C. carpio communis, C. carpio specularis, C. carpio nudus)	Introduced for broadening the species spectrum in aquaculture	Ganga, Yamuna, Godavari, Gomti Damodar, Ghaghra, Rapti, Panba, Tons	Most of the reservoirs	Most of the freshwater lakes	Bihar, West Bengal, Assam, Uttar Pradesh
Hypophthalm-ichthys moltrix	Do	Yamuna, Sutlej, Mahanadi, Pumba, Gomti, Tons, Ganga	Some reservoirs in Himachal Pradesh, Madhya Pradesh, Kearala, Uttar Pradesh	Some freshwater lakes in Himachal Pradesh, Madhya Pradesh, Uttar Pradesh, Uttarakhand	Wetlands of Bihar, West Bengal, Assam, Uttar Pradesh
Ctenopharyn-godon idella	Do	Pumba, Gomti, Yamuna, Ganga	Some reservoirs	Some freshwater lakes in north India	Wetlands of Bihar, West Bengal, Assam, Uttar Pradesh
Hypophthalm-ichthys nobilis	Illegally introduced but widely cultivated. It is a banned species	Yamuna, Ghaghra, Rapti, Gomti, Ganga, Sarayu	Uttar Pradesh	Some freshwater lakes in Uttar Pradesh, Madhya Pradesh, Karnataka	Wetlands of Bihar, West Bengal, Assam, Uttar Pradesh
Clarias gariepinus	Illegally introduced but widely cultivated. It is a banned species	Yamuna, Gomti, Godavari, Pamba, Ganga	Karnataka, Uttar Pradesh, Andhra Pradesh	Some lakes in Andhra Pradesh, Karnataka Kerala, Meghalaya,	West Bengal, Bihar, Andhra Pradesh, Uttar Pradesh

				Uttar Pradesh	
Oreochromis massambicus	A nuisance species widely distributed	Yamuna, Subarnarekha, Kavery, Damodar, Periyar, Ken and Betwa	Most of the reservoirs in Tamil Nadu and some reservoirs Karnataka and Kerala, Jaisamundsagar (Rajasthan), Getalsud reservoir (Jharkhan)	Some lakes in West Bengal, Assam and Madhya Pradesh	West Bengal and Assam
O. niloticus	Introduced for aquaculture. Popular in sewage fed fisheries.	Yamuna, Ganga Subarnarekha, Kavery, Damodar, Periyar, Ken and Betwa	Many reservoirs in West Bengal, Bihar, Madhya Pradesh and Uttar Pradesh	Some lakes in West Bengal, Assam and Madhya Pradesh	West Bengal, Biharand Assam
Pangasianod-on hypophthalm-us	Considered potential species for aquaculture promotion	Churni river, Godavari, Krishna	No report	Some lakes in Andhra Pradesh and Kerala	West Bengal
Oncorhynchus mykiss	A good candidate species of aquaculture in hills	Pamba, Periyar, Bharathapuzha, Bhilangana, Asi Ganga	No information	Some river strems and lakes in upland waters	Himalayan region
Salmo trutta	A very good candidate species for aquaculture in hills	Beas Sutlej, Asi Ganga		Some river streams and lakes in upland waters	Himalayan region
Piaractus brachypomus	Unauthorised culture and distributed in many states including coastal areas	Periyar river Kearala and some Other states	Maharashtra, Andhra Pradesh and Tamil Nadu	-	West Bengal and Andhra Pradesh
Pterygoplichthys spp. (*P. perdalis, P. disjuntivus*)	Unauthorised culture and distributed widely	Ganga and Gomti rivers	-	-	West Bengal and Andhra Pradesh
Pygocentrus naterreri	Unauthorised culture and a banned species	Periyar	Maharashtra	Kerala	-

Table 6. **List of alien/invasive flora and fauna recorded from the waterbodies along southern Western Ghats, India**

Sl. No.	Common name	Species	Native Range	Pathway of introduction	Alien/ Invasive	Presence in number of water bodies		
						Rivers	Reservoirs	Freshwater lakes
FLORA (Macrophytes)								
1	Kariba Weed	*Salvinia molesta*	South eastern Brazil	GP	Invasive	44	4	3
2	Water Lettuce	*Pistia stratiotes*	Pantropical	GP	Invasive	20	2	2
3	Water Hyacinth	*Eichhornia crassipes*	South America	GP	Invasive	38	0	1
4	Red Cabomba	*Cabombafurcata*	South America	AQ	Invasive	7	0	2
FAUNA (Fish)								
5	Mozambique Tilapia	*Oreochromis mossambicus*	Tropical and subtropical Africa	AS	Invasive	44	18	2
6	Nile Tilapia	*Oreochromis niloticus*	Africa	AS	Invasive	4	0	0
7	Sailfin Catfish	*Pterygoplichthys pardalis*	South America	AQ	Invasive	5	0	1
8	Common Carp	*Cyprinus carpio*	Europe to Asia	AS	Invasive	17	29	1
9	North African Catfish	*Clarias gariepinus*	Pan Africa	AS	Invasive	7	10	0
10	Guppy	*Poecilia reticulata*	South America	MC	Invasive	14	22	0
11	Mosquito Fish	*Gambusia affinis*	North and Central America	MC	Invasive	2	5	0
12	Green Swordtail	*Xiphophorus hellerii*	Central America	AQ	Alien	1	0	0
13	Southern Platyfish	*Xiphophorus maculatus*	North America	AQ	Alien	1	0	0
14	Giant Gourami	*Osphronemus goramy*	South east Asia	MC	Alien	2	0	0
15	Three Spot Gourami	*Trichopodustrichopterus*	South east Asia	AQ	Alien	1	0	0
16	Moonlight Gourami	*Trichopodusmicrolepis*	South east Asia	AQ	Alien	1	0	0
17	Shortfin Molly	*Poecilia mexicana*	North and Central America	AQ	Alien	1	0	0
18	Pacu	*Piaractus mesopotamicus*	South America	AS/AQ	Alien	2	0	0
19	Pirapitinga	*Piaractus*	South	AS/AQ	Alien	9	0	1

		brachypomus	America					
20	Striped Catfish	*Pangasianodon hypophthalmus*	Asia	AS/AQ	Alien	8	0	0
21	Arawana	*Osteoglossumbi cirrhosum*	South America	AQ	Alien	1	0	0
22	Rainbow Trout	*Oncorhynchus mykiss*	Asia and North America	SF	Alien	1	0	0
23	Silver Carp	*Hypophthalmic hthys molitrix*	East Asia	AS	Alien	2	0	0
24	Kissing Gourami	*Helostomatemm inckii*	Asia (Thailand to Indonesia)	AQ	Alien	1	0	0
25	Grass Carp	*Ctenopharyngo don idella*	Asia (Eastern China and Russia)	AS	Alien	5	0	0
26	Forest Snakehead	*Channalucius*	Asia (Thailand to Indonesia)	AQ	Alien	1	0	0
27	Red Tailed Tinfoil	*Barbonymus altus*	Asia	AQ	Alien	2	0	0
28	Alligator Gar	*Atractosteus spatula*	North America	AQ	Alien	3	0	0
29	Oscar	*Astronotus ocellatus*	South America	AQ	Alien	1	0	0
30	Arapaima	*Arapaima gigas*	South America	AQ	Alien	3	1	0
31	Gold fish	*Carassius auratus*	Central Asia and China	AQ	Alien	1	0	0
32	Mexican mojarra	*Mayaherosurop hthalmus*	Central America	AQ	Alien	1	0	0

GP: Garden Pond; AS: Aquaculture Systems; AQ: Aquarium System and Ornamental fish trade fish trade; MC: Mosquito larvae control; SF: Sport Fisheries

5.4 Marine Alien/Invasive species

Ten species of marine alien species have been recorded from Kerala coast, which include five molluscs, one byozoan, one jellyfish, one shrimp, one ascidian and one seaweed. Of this, the invasive mussel *Mytella strigata* is the most widespread species, causing several ecosystem damages. The green mussel *Perna perna* also as an invasive species, though it has been established and exploited commercially and a traded commodity in southern Kerala.

Table 7. Marine invasive species of Kerala

No.	Species name	References	Native Range
Phylum: Mollusca			
1.	*Mytella strigata* (d'Orbigny, 1842)	Biju Kumar et al., 2019 and Jayachandran et al., 2019.	Atlantic coast of South America
2.	*Mytiloposis sallei* (Recluz, 1849)	Jayachandran et al., 2018; Sandilyan 2018.	Caribbean islands and the Bay of Mexico
3.	*Perna perna* (Linnaeus, 1758)	Appukuttan & Alagarswami. 1980; Kuriakose 1980; Ramachandran et al., 1998; Kripa 2005; Ramakrishna & Dey 2010; Bijukumar 2012; Gardner et al., 2016; Sandilyan 2018.	Western Indian Ocean and the west coast of Africa.
4.	*Tenellia adspersa* (Nordmann, 1845)	Dhanya et al., 2017.	Native to the Eastern Atlantic and Western Mediterranean
5.	*Thecacera pennigera* (Montagu, 1813)	Ravinesh et al., 2017.	South and west of the British Isles, extending up the English Channel
Bryozoa			
6.	*Bugula neritina* (Linnaeus, 1758)	Menon & Nair1971; Ravinesh & Biju Kumar 2013.	Mediterranean Sea
Cnidaria (Jellyfish)			
7.	*Pelagia noctiluca* (Forsskål, 1775)	Nair, 1941, 1951; and Sandilyan 2018.	Atlantic ocean.
Crustacea (Shrimp)			
8.	*Penaeus vannamei* Boone, 1931	Radhakrishnan et al., 2012 and Sandilyan 2018.	Pacific ocean.
Ascidia			
9.	*Didemnum candidum* Savigny, 1816	Abdul & Sivakumar 2007.	North America
Sea Weed			

10.	*Hypnea musciformis* (Wulfen) J.V.Lamouroux, 1813	Baby Usha Kiran et al., 2017.	Eastern and western Atlantic

Mytella strigata, the newly introduced marine invasive species was recorded from various places in Kerala such as Vembanad Lake (Jayachandran et al., 2019), Kadinamkulam, Paravur, Edava-Nadayar, Ashtamudi Lake, Kayamkulam, Chettuva and Ponnani (Biju Kumar et al., 2019). Due to the floods in 2019 to 2020, during the incessant south west monsoon it was transported and established in major estuaries along Kerala and other States. *M. strigata* competes with other filter-feeding organisms, including other bivalves such as clams, oysters and other natives leading to a decline of native clams and oysters in the estuaries of Kerala, promotion of human consumption and manual removal may be the options to reduce or manage population size. Along north Kerala, the invasive species *M strigata* occurred in Beeyam kayal, Kadalundi, Mampuzha and Puthiyappa. It was also found in the Kavvayii estuary in Ori, Padanna and Punchakkad areas .It was observed in the green mussel farms (*Perna viridis*) as well as the finfish cages.

In Vembanad Lake, *M strigata* was found in the northern parts where the salinity is higher. The invasive species were found along Njarakkal, Keethedom, Moothakunnan, Cherai, Pullut, Kadanakudi, Gothuruthu, Chendamangalam, Perumbalan, Panavally and Aratupuzha. It was not found in the southern part where freshwater conditions prevailed, not conducive for the invasive species.

In Chettuva estuary, it was extensively distributed. In Ashtamudi Lake the invasive species was distributed wide across the Ashtamudi kayal and Kayamkulam kayal, affecting the green mussel and oyster farming activities causing economic loss and affecting livelihood. In southern Kerala, the invasive species was recorded in Kadinamkulam kayal, Achenthengu kayal, Edava Nadayara and and Paravur backwaters. In Ashtamudi Lake, it was found extensively along with the oyster *Crassostrea madrasensis*.

In Chettuva estuary the invasive mussel was found along with the green mussel *Perna viridis*. In Ashtamudi Lake. *M Strigata* was picked by the mussel pickers and sold in the market in place of the green mussel with *M strigata comprising nearly 39% of* the mussel fishery and sold at Rs. 80-120/120-65 numbers shell-on. Nearly 852 t of *M strigata* was sold during 2019 in Kerala.

Impact on farming:

The impact of the invasive mussel *M strigata* on farming activities was very high not only disrupting the farming but also affecting the livelihood of the farmers. In bivalve faming oyster and mussel farms were severely infested by the mussel. The bamboo poles, the oyster ren and the nylon ropes were infested by the mussel. The profuse settlement of the invasive mussel resulted in reduced settlement of oyster spat and also affected growth of oysters to market size. This in turn affected the returns in terms of increased labour charges for cleaning the oyster rens to remove the *M strigata* attached along with the oysters. In the mussel ropes also, the settlement of *M strigata* was very high impacting growth and causing economic loss. The settlement of the invasive mussel on finfish cages was so severe that the cleaning of the

nets, both outer and inner was labour intensive. Bio fouling of the inner and outer nets required frequent cleaning, thereby increasing expenditure on labour charges. The manual cleaning of the nets and discarding the mussels back into the water body again facilitated rapid spread of the invasive species and additional expenditure. Frequent cleaning of nets also led to damage of nets, and additional expenditure to replace nets. Cleaning of nets by sun drying caused foul smell, raising environmental social issues in the vicinity. Ignoring the bio fouling caused by the invasive species on the nets increased the weight of the nets, clogging, reduced water circulation, net damage there by resulting in poor growth of the fin fish reared in the cages and economic loss. During 2019-2022, farming activities were reduced due to the economic loss caused by the invasive mussel along with the Covid- 19 pandemic issues.

Oreochromis mossambicus, the most common invasive species in SWG, is naturalised in most waterbodies of Kerala, where they are found to compete with indigenous cichlid *Etroplus suratensis*, both for food and breeding habitats. In areas heavily invaded by *P. pardalis*, they have destabilised bank structure by breeding in pits along the stream banks, competing with native species, and damaging fishing gears. In Thiruvananthapuram, this species has invaded all natural streams, out-competing native species due to their ability to survive in polluted waters with the help of accessory respiratory organs.

The Common carp, *C. carpio* introduced into Kerala for aquaculture, and primarily stocked in the reservoirs, has escaped into the natural waterbodies establishing good populations. In many ecosystems, particularly in reservoirs, they compete with indigenous cyprinids, and particularly in Kallada river they have stronger competition with the native *Tor* sp. which is considered sacred. Another dominant species in reservoirs of the SWG is *C. gariepinus* where they pose a serious threat to native species because of their predatory habits. In the Mattupetty reservoir of the Idukki district, they are the most dominant species, displacing all native species. *Poecilia reticulata*, though not regarded as a severe pest in India, have now established strong populations even inside protected areas at higher elevations. It is recorded this species in many second-order streams of WG overlapping with many endemic and threatened species. *Gambusia affinis*, a remarkably hardy species introduced in Kerala for mosquito control, was observed to survive in low-oxygen waters, in high salinities and temperatures. Adult fishes were observed as too aggressive and attacking other young fish and particularly competing with indigenous killifish, *Aplocheilus* spp.

While *C. carpio* competes with native species for food and space, *C. gariepinus* feeds on many smaller cyprinids and other endemic species in the freshwater ecosystems. Though this species is banned by the fisheries department of the Kerala Government (and Government of India), they continue to represent the dominant biomass in most reservoirs of the WG. An emerging threat is the Amazonian Sailfin Catfish *P. pardalis* and probable hybrids of *Pterygoplichthys* spp. (Biju Kumar et al., 2015), an aquarium-associated species that has quickly established in many natural habitats since their first record in 2009 (Krishnakumar et al., 2009; Smrithy et al., 2019).

Among these, aquarium fish trade has been identified as the major global vector for freshwater fish invasions (Chan et al., 2019). Illegal transport of species such as *C. gariepinus* across the borders have also led to their proliferation in aquaculture systems and

their subsequent release and escape into the water bodies (Singh and Lakra, 2006; Lakra et al., 2008; Singh et al., 2013, 2015). In addition, alien species like *P. reticulata* and *G. affinis* have been introduced for controlling mosquito larvae, despite the fact that the rich diversity of indigenous larvicidal fish in India can be effectively used for the purpose (Das et al., 2018).

Studies by Smrithy et al. (2019) and Roshni et al. (2020) have shown that two invasive species *P. pardalis* and *C. gariepinus,* which have established healthy populations in the water bodies of the SWG can be managed only by targeting smaller-sized individuals rather than large adult fish; rapid growth rate, low fishing mortality and continuous recruitment contributing to the invasion success of the two species. The impact of *P. reticulata,* which has established even in many second-order streams of SWG, can be revealed only through detailed studies on invasion biology, as previous research indicate their strong invasion potential and impact on aquatic biodiversity (Sievers et al., 2012; El-Sabaawi Rana et al., 2016).

5.5. Management Measures for Some Priority Species

Management measures for some priority species are given below (NBA)

Mozambique Tilapia (*Oreochromis mossambicus* (Peters, 1852) Particularly hardy, resistant to wide varieties of water salinity oxygen and pollution levels, and can migrate long distances. They occupy a wide range of habitats, and reproduce rapidly and successfully. Removal from natural water resources where they have established may be impossible. The most effective management is complete isolation of individuals from natural waters to prevent introductions. Established populations may require intensive fishing to prevent overpopulations from affecting native populations. Promotion of culture of indigenous food fish and risk assessment of tilapia invasion are recommended.

Nile Tilapia (*Oreochromis niloticus* (Linnaeus, 1758) Particularly hardy, resistant to wide varieties of water salinity oxygen and pollution levels. They occupy a wide range of habitats, and reproduce rapidly and successfully. Removal from natural water resources where they have established may be impossible. The most effective management is complete isolation of individuals from natural waters to prevent introductions. Established populations may require intensive fishing to prevent overpopulations from affecting native populations.

Sucker Fish/Sailfin Armoured Catfish (*Pterygoplichthys* spp): Removal of larger fish by intensive fishing may be effective in smaller habitats and this could be used to support commercial fish market. They can also be removed in large numbers and used for large scale production of fish manures or fish meal. Intense egg collection from the breeding burrows could reduce their abundance in such habitats. There should also be restrictions and ban on import. Educating the public, to avoid releasing their unwanted fishes into open waters may reduce their introductions.

Common Carp (*Cyprinus carpio* (Linnaeus, 1758) The use of potentially invasive alien species for aquaculture and their accidental release/or escape can have negative impacts on native biodiversity and ecosystems should be prevented. Potential carp control techniques practiced in the west include harvesting, barriers, biomanipulation, exclusion with screens or

barriers, poisoning, biological control, bioacoustics, bubble barriers, immunocontraception and genetic manipulation. Research is needed to realise the full environmental implications of this species in India.

North African Catfish (*Clarias gariepinus* (Burchell, 1822): Various factors make this species very difficult to control: omnivorous diet, direct air-breathing, ability to crawl on land, burrowing capabilities and ability to hide in vegetation. Now common in many larger water bodies of India. Since the introduction of this fish is illegal, their culture should not be promoted. Extensive populations should be removed mechanically from the critical ecosystems such as Periyar lake in Kerala. Report illegal culture and presence on natural water bodies. Make the people aware of the negative impacts of this species.

Guppy (*Poecilia reticulata* (Peters, 1859 Introductions may have resulted from escapes or releases from aquaria or outdoor breeding ponds. Educating the public, especially aquarists, to avoid releasing their unwanted fishes into open waters may reduce their introductions. More risk assessment studies are required in India to find out the full environmental implications of this species.

Mosquito Fish (*Gambusia affinis* (Baird & Girard, 1853) : Rather difficult to control because of their small size and fast reproduction rates. The poison Rotenone, which works by inducing hypoxia in fish, may be used to eliminate mosquito fish from small areas of permanent water, without much native indigenous species. More risk assessment studies are required in India to find out the full environmental implications of this species

Species such as *M. strigata* should not be used for farming, as it will promote further spreading. Strict monitoring should be done by the Department of Fisheries to ensure that this species is not used for any farming activity. If found attached to cages/nets or any other materials they should be removed and kept out of the water body to ensure its eradication. It can also be utilized as ingredient in fish /animal feed. Boat hull fouling by *M. strigata* is a major concern. Periodic scrapping of bio foulers from boat should be undertaken outside the water body

Table 8: List of alien crustaceans recorded from Indian water and their threat status

Sl. No.	Group and Species	Family	Native/ Exotic/ Cryptogenic	Threat Status	Source
	Decapoda				
1	*Litopenaeus vannamei* (Boone, 1931)	Penaeidae	Exotic, Introduced	Not suspected	Dev Roy, 2007
	Isopoda				
2	*Cirolana hardfordi* (Lockington, 1877)	Cirolanidae	Exotic	Not suspected	Anil et al., 2003
3	*Cilicaea latreillei* Leach Limnoriidae, 1818	Cirolanidae	Exotic	Not suspected	Anil et al., 2002
4	*Paradella dianae* (Menzies, 1962)	Sphaeromatidae	Exotic	Not suspected	Anil et al., 2003
5	*Sphaeroma serratum*(Fabricius, 1787)	Sphaeromatidae	Exotic	Not suspected	Anil et al., 2003
6	*Synidotea*	Idoteidae	Exotic	Not	Anil et al.. 2003

	laevidorsalis(Benedict, 1897)			suspected	
	Amphipoda				
7	*Monocorophium acherusicum*(Costa, 1853) as *Corophium acherusicum*Costa, 1853	Corophiidae	Exotic	Not yet assessed	Shyamasudari, 1997
8	*Jassa falcata*(Montague, 1808)	Ischyrocerid e	Exotic	Not yet assessed	Shyamasundari, 1997
9	*Jassa marmorata Holmes*, 1905	Ischyrocerid e	Exotic	Not suspected	Anil et al., 2003
10	*Elasmopus rapax* Costa, 1853	Maeridae	Exotic	Not yet assessed	Shyamasundari, 1997
11	*Quadrimaera pacifica* (Schellenberg, 1938) as *Maera pacifica* Schellenberg, 1938	Maeridae	Exotic		Anil et al., 2002
12	*Paracaprella pusilla* Mayr, 1890	Caprellidae	Exotic	Not yet assessed	Guerra-García,2010
13	*Stenothoe gallensis* Walker, 1904	Stenothoidae	Exotic	-	Anil et al., 2003
14	*Stenothoe valida* Dana, 1852	Stenothoidae	Exotic	Not yet assessed	Shyamasundari, 1997
15	*Podocerus brasiliensis*(Dana, 1853)	Podoceridae	Exotic		Anil et al., 2003 Shyamasundari, 1997
	Cirripedia				
16	*Amphibalanus eburneus*(Gould, 1841) as *Balanus amphitrite eburneus*	Archaebalan e	Cryptogenic	Not suspected	Anil et al., 2003
16	*Amphibalanu sreticulatus* (Utinomi, 1967) as *Balanus reticulatus* Utinomi, 1967 and *Balanus amphitrite hawaiiensis* Broch	Archaebalan e	Exotic	Not suspected	Anil et al 2002,2003
17	*Fistulobalanus pallidus*(Darwin, 1854)= *Balanus amphitrite stutsburi*(Darwin)	Balanidae	Exotic	-	Wagh, 1974, Anil et al. , 2003
18	*Megabalanus tintinnabulum*(Linnaeus, 1758)	Balanidae	Exotic	Known harmful species	Anil et al., 2003
19	*Megabalanus zebra* (Darwin, 1854)	Balanidae	Cryptogenic	Not suspected	Anil et al., 2003
	Copepoda				
20	*Nannocalanus minor* (Claus, 1863)	Calanidae	Exotic	-	Gaonkar et al., 2010
21	*Cosmocalanus* sp.	Calanidae	-	-	Gaonkar et al., 2010
22	*Paracalanus* sp.	Calanidae	-	-	Gaonkar et al., 2010
23	*Tortanus* sp.	Tortanidae	-	-	Gaonkar et al., 2010
25	*Euterpina acutifrons* (Dana, 1847)	Euterpinidae	Exotic	-	Gaonkar et al., 2010

6. Alien and Invasive Species in Forest Ecosystem

Forest invasive species can be further categorized as floral (weeds and plants having national and regional distribution), entomological (insects), and pathogenic (fungi). Approximately, 111 FIS have been identified in India. The FIS affects the productivity of forests and also cause heavy losses to production, blocking of water bodies, water transport ways, affecting wildlife habitat in the forests and wetlands and commercial activities such as cultivation of medicinal plants etc FRI, Dehradun and Institute of Forest Genetics and Tree Breeding, Coimbatore under the ICFRE are authorized institutions to issue phytosanitary certificates for exporting any products or produce of forest origin. The regional offices for wildlife preservation of the GOI under the Ministry of Environment and Forests (MoEF) established at New Delhi, Mumbai, Chennai and Kolkata with their sub-regional offices at Amritsar, Kochi and Guwahati check and regulate the import and export of wildlife species at airports and sea ports. The introduction of invasives can be intentional or unintentional.

Insects are major determinants of forests productivity. Periodic outbreaks of insects occur in the natural forests that causes heavy losses. In monocultures, the outbreaks of insect pests are frequent which reduces the productivity of the plantations besides causing mortality in extreme cases. Studies funded by KSBB post 2018 floods has pointed out that 45 species of known invasive nature are establishing in landslide affected areas in Wayanad. The landslides resulted in gap formation, which causes changes in microenvironment and community dynamics. Larger gaps raise the probability of taking over of shade-intolerant species and the spread of invasive species. Landslide will change the microhabitat condition to such an extent that it mostly suites the spread of invasive species. The changing climatic regime favours invasive species which survives with comparatively less nutrient requirements and will invade first in these open areas affecting the forest composition and survival and establishment of other specialized species.

Intentional

- Introduced as ornamental plants, but became invasive – *Senna spectabilis, Lantana camara, Sphagneticola trilobata, Hypoestes phyllostachya*
- Shade plants- *Maesopsis eminii*
- Cover crops- *Mucuna bracteata*
- Farming- *Acacia mianci*

Unintentional introductions

- *Mikania micrantha, Parthenium hysterophorus,* African sanil,

Unknown mode

- *Clidemia hirata*

India State of Forests report has estimated the total extent of forests of Kerala with invasive species (Table)

Table 9: Major invasive species inside the RFA/Green Wash in Kerala (sq km)

1. *Chromolaena odorata*	773
2. *Lantana camara*	185
3. *Ageratum conyzoides*	62
4. *Ageratina adenophora*	21
5. *Mikania micrantha*	8

Vast plantations of eucalyptus, wattle and pine have been established in forest areas. *Prosopis juliflora, Parthenium hysterophorus* and *Chroloena odorata,* can be seen on the lower slopes. Although Kerala Forest Department is removing eucalyptus and wattle in a phased manner, intensive planting of the indigenous floral species should also be conducted after removing the alien species. Attempts are being made to eradicate the *Prosopis juliflora* and Lantana camara as well since they compete to establish the natural regeneration of the native species. Moist Deciduous Forest are hot spot of IAS compared to other habitats such as evergreen, semi-evergreen and shola they are highly susceptible to introduction and spread of IAS. Seasonal variation in the canopy, shedding of leaves during summer, paved way for the introduction of invasive species. Forest clearings and gaps are other areas of invasions whether for hydroelectric projects or power. Invasive species gradually intrudes the cleared area. Banks of the reservoir and monoculture plantations also act as a potential centre of introduction. Immediately after the first rain when the indigenous flora is in a quiescent stage, IAPS with high regeneration potential establishes fast. *Emilia sonchifolia, Vernonia cinerea, Evolvulus alsinoides,* and *Rubia cordifolia* are examples. Major species in shady as well as in open areas of forest includes *Lantana camara, Chromolaena odorata, Mikania micrantha Hyptis capitata, Caesalpinia mimosoides,* and *Mimosa diplotricha*

Studies by Sajeevan and Suresh 2013 has prioritized 38 invasive plants in Moist Deciduous Forest (MDF) of Southern Western Ghats (SWG) with High risk – 10, Medium risk – 12, and Low risk – 10. There are 5 trees, 11 shrubs, 4 subshrubs, 12 herbs and 6. climbers among the AIS found in the forests of Kerala . The land of origin of the AIPS happens to be central and south America.

Most of the introductions into the forests of Kerala were intentional (31 species). Six species were accidentally introduced. There are 12 AIPS in Kerala, which fall under the medium risk category. These include shrubs like *Cestrum aurantiacum, Hyptis capitata, Senna hirsuta* and *Tithonia diversifolia* which were intentionally introduced for ornamental purposes. While *C. aurantiacum* and *T. diversifolia* are seen invading medium to high altitudes, others are limited to lowland forests. The medium risk species which are subshrubs include *Ageratina adenophora, Hyptis suaveolens* and *Senna tora* which all intentionally introduced. The former is seen only in the high altitudes where it is showing aggressive invading behavior. *Ipomoea purpurea* is a medium risk climber, again introduced intentionally for its ornamental appeal and currently invading forest fringes. *Parthenium hysterophorus* and *Pennisetum polystachyon* are other medium risk AIPS in Kerala, the former accidentally introduced and the latter intentionally introduced. *Measopsis eminii* and *Senna spectabilis* are two medium risk tree invasives, which were intentionally introduced.

Low risk AIS are significant but are relatively of low risk to the forest ecosystems of State, now. Ten species belong to this category of which 4 are herbs, 3 shrubs, and one each a subshrub, a climber and a tree. The tree *Leucaena leucocephala* is seen in open lands outside forests and is seen within the forests at Thattekkadu and Muthanga. The climber *Centrosema molle* has been introduced as a cover crop and has invaded forest fringes. *Alternanthera brasiliana* is an ornamental plant which spreads fast on the ground vegetatively. The herbs include naturalized species like *Mimosa pudica, Ageratum conyzoides, Amaranthus spinosus* and *Erigeron karvinskianus* which have caused little or no impact on native flora. It can be seen that there are two groups of plants which come under low risk species. Most of the species have been naturalized and should not pose serious threat to the habitats

Senna spectabilis is a major tree Invasive species in MDF – introduced as an avenue plant . It is a light demanding species with high rate of regeneration including coppice growth. Difficulty in eradication mainly due to high regeneration capacity and peculiarity of infested habitats

In *Pteridium aquilinum*, regeneration occurs in open areas with subterranean rhizome. Establishs in open areas due to fire lines, fire affected areas, rocky areas, and grasslands. It is a light demanding species but grow well in shades also

Mucuna bracteata is a light demanding species, common in forest clearings, especially in lower altitudes. It survive in shade also. It has high rate of regeneration with gregarious growth, and smother all the vegetation including trees. It was introduced as a cover crop in rubber plantations, and from there, escaped into forest areas.

Medium Risk Plants

Ageratina adenophora Hyptis capitata Hyptis suaveolens Leucaena leucocephala Merremia vitifolia Parthenium hysterophorus Passiflora foetida Pennisetum pedicellatum Racosperma auriculiforme Ricinus communis Senna hirsuta Senna tora

Low Risk Plants

Ageratum conyzoides Alternanthera brasiliana Amaranthus spinosus Centrosema molle Mimosa pudica Senna occidentalis Senna siamea Sesbania grandiflora Stylosanthes fruticosa Alternanther bettzickiana Asclepias curassavica Croton bonplandianus Syndrella nodiflora Tridax procumbens

Invasive species viz. *Grevillea robusta, Erythrina subumbrans and Spathodea companulata* are common features in the CHR area.

Table 10. The list of invasive plant species in Kerala with high-risk category

Sl. No.	Common name	Local name	Scientific name	Country of origin	Regions in Kerala
1	Black wattle	*Karuva*	*Acacia mearnsii*	South East Australia	Idukki
2	Calopo	*Manja Payar*	*Calopogonium mucunoides*	Troical Asia	Alapuzha, Idukki, Kollam, Kozhikode, Kasaragod, Malapuram, Pathanamthitta, Thiruvananthapuram, Thrissr
3	Siam weed	*Assam Pacha,Communist pacha*	*Chromolaena odorata*	Tropical America	Throughout Kerala
4	Knob weed	*nill*	*Hyptis Capitata*	Central America	Alapuzha, Eranakulam, Idukki, Kollam, Kozhikode, Malapuram, Thiruvananthapuram, Thrissr
5	Bush Morning glory	*Neyvelikatta*	*Ipomoea Carnea*	Tropical America	Eranakulam, Malapuram, Thiruvananthapuram, Thrissr
6	Lantana	*Arippu.Kongini, poochedi, Unnichedi*	*Lantana Camara*	Central and South America	Throughout Kerala
7	Mile-minute weed	*American vally, dhritharashtra pacha, Mayakkuvally*	*Mikania micrantha*	North,Central and South America	Throughout Kerala
8	Giant sensitive plant	*Anathottawadi*	*Mimosa diplotricha*	Tropical America	Throughout Kerala
9	Congress grass	*Congress pacha*	*Parthenium hysterophorus*	North and South America	Idukki, Kollam, Kasaragod, Wayanad, Thiruvananthapuram, Thrissr, Palakkad
10	Mission grass	*Kothappullu*	*Pennisetum polystrachyon*	Tropical Africa	All district in the state except Kasargod and Pathanamthitta
11	Velvet mesquite	*Varuni*	*Prosopis juliflora*	North, South Central and America	Idukki, Palakkad
12	Tropical Kudzu	*Thotta payar*	*Pueraria phaseoloides*	Troical Asia	All district in the state except Wayanad
13	Prickly sesban	*Kedangu,Killannu*	*Sesbania bispinosa*	Asia and Africa	Eranakulam, Kannur, Pathanamthitta, Palakkad and Thrissr
14	Singapore daisy	*Veriappacha*	*Sphagneticola trilobata*	Tropical America	Throughout Kerala

7. Alien and Invasive Species in Agriculture Ecosystem

Sustainable management of agroecosystems are essential for attaining food and nutritional security. Weeds have been one of the major biotic constraints in achieving optimum production of crops. Different weed management practices are used for controlling these weeds both in cropped and non-cropped situations. Among these options, none is enough to completely control weeds. Therefore, integration of all the possible weed management tools is needed to manage weeds including IAPS. In crop production, a weed is an undesirable, injurious, and troublesome plant, which interferes with cultivated crops and affects human affairs. Noxious weeds are plant species that tend to be injurious to public health, crops, livestock, or other properties. Invasive weeds are plant species that have the potential to spread rapidly and become noxious.

7.1. What makes a plant an invasive weed?

Major plant introductions to India can be traced back to the establishment of a Botanical Garden by East India Company during 1786 at Culcutta. The spread of invasive alien weeds like *Mikania micrantha*, *Lantana camara* and *Chromolaena odorata* in India are examples of such introductions (Table 1). However, weeds like *Parthenium hysterophorus* was accidentally introduced along with the wheat import in 1950s.

Table 11. Invasion pathway of some agriculturally important alien weeds

Plant	Country of origin	Pathway of invasion
Parthenium hysterophorus	Central and South America	Import of wheat from Australia
Lantana camara		Introduced as ornamental
Mikania micrantha		Brought for camouflaging army during World War II
Eichhornia crassipes		Introduced as ornamental
Salvinia molesta		Accidental/ornamental

For a new plant to establish itself successfully and to become a weed in a disturbed area, it has to overcome several barriers (USDA, 2006).

1). *Large-scale geographical barriers*: These can be geographical boundaries like mountains, sea, or any physical obstacles for the movement of seeds or any reproductive plant parts.

2). *Survival barriers*: Germination and survival barriers such as moisture availability, physico-chemical properties of soil, nutrient availability, and competition ability.

3). *Establishment barriers*: The barriers to establishing itself successfully to form a population that is self-sustaining and does not need re-introduction to maintain a population base such that it continues to survive and thrive in its new environment. Once the non-native plant survives this barrier, its population is considered established.

4). *Dispersal and spread barriers*: Not only the species has to overcome the establishment barriers but also ensure its succession by seed dispersal and progeny

production. Additionally, the rate of spread must be relatively fast. However, this movement or spread alone does not necessarily make the non-native plant an invasive weed.

5). *Harm and impact*: Finally, a plant is deemed to be an invasive weed, if it causes negative environmental, economic, or human health effects, which outweigh any beneficial effects. For example, *Mikania micarantha* is a source of nectar for bees. Nevertheless, the displacement of native and other desirable plant species caused by this weed leads to biodiversity loss. Further, it is reported that nectar and pollen availability from this plant is indirectly affecting the pollination and seed set in native plants. As the negative effects greatly overshadow the positive effects, it is considered an invasive alien weed.

The success of invasive weeds depends on factors like prolific seed production, efficient dispersal mechanisms, higher germination rate, rapid growth rate, rampant vegetative spread with special organs such as offsets (*Pontederia crassipes*), turions (*Hydrilla verticillata*), root suckers or bulbs, wide adaptability and tolerance to changing environments and higher competitive ability. Invasive weeds like lantana and siam weed have allelopathic effect on agricultural crops making them more competitive (Sahid and Sugau, 1993).The absence of natural enemies in the new environment also provides favourable conditions for invasive species.

Often, invasive species are grouped as *driver species*, *passenger species*, and *back seat drivers* (Barua and Deka, 2016). Weeds that can establish themselves easily in undisturbed habitats and bear the capacity to alter the community structure within a short period in an irreversible direction can be termed as driver species. *Mikania micrantha* is an example for a driver species. Weeds that are abundant in disturbed areas where population of a primary floral community is in a declining phase can be classified as passenger species (Didham *et al.*, 2005), for example, lantana and siam weed. The third type, back seat drivers can establish in disturbed areas but they further deteriorate the native community over a period of time (Bauer, 2012). Carrot grass (*Parthenium hysterophorus)* is a back seat driver, invading cropped areas, which in its pure stand eliminates majority of resident plant populations.

In Kerala, maritime trade also paved way for introduction of large number of invasive weeds. In addition to terrestrial invasive plants, aquatic invasive plants are also posing great challenges, especially to water resources of Kerala. It is believed that the floods in August, 2018, hastened invasive weed growth by the transport of propagules through water thus encroaching new areas. Weeds like water hyacinth and Kariba weed (*Salvinia molesta*), earlier noticed mainly in the backwaters of Kuttanad, have spread to several low-lying paddy fields. Some weeds such as *Hydrilla, Vallisneria* and *Utricularia,* introduced as aquarium plants are now attaining the status of major weeds in rice fields. Many invasive plants continue to be adored by people who may not be aware of their weedy nature. For example, Singapore daisy (*Sphagneticola trilobata*), a problematic invasive weed, is still being used as an ornamental plant due to its attractive bright yellow flowers. Several species are exploited by people for various purposes, but eventually develop invasive traits and harm other plants. For example, the leguminous cover crop, *Mucuna bracteata* used in rubber plantations to manage soil erosion has attained the status of a noxious weed, spreading fast and inhibiting the growth of native plants and trees.

7.2. Major invasive weeds of Kerala

Out of the 225 invasive plant species reported from India, 11 species were included in the list of the 100 worst invasive species categorized by the International Union for Conservation of Nature (Lowe *et al.*, 2000). These 11 species comprise of *Acacia mearnsii, Arundo donax, Chromolaena odorata, Clindemia hirta, Imperata cylindrica, Lantana camara, Leucaena latisiliqua, Mikania micrantha, Opuntia stricta, Ulex europaeus* and *Sphagneticola trilobata.*

The names of 50 major invasive weeds in Kerala selected based on various studies and observations (Prameela, 2022) are listed in Table 12 .

Table 12. Major invasive weeds of Kerala

Sl. No.	Scientific name	Common name in Engish	Malayalam Name	
1.	*Actinoscirpus grossus*	Greater club rush	പോട്ടപുല്ല്	SE Asia
2.	*Ageratina adenophora (Eupatorium adenophorum)*	Mexican devil Crofton weed	ക്രോഫൺ പച്ച	Central America
3.	*Alternanthera philoxeroides*	Alligator weed	വെള്ളാം കണ്ണി	Tropical America
4.	*Alternanthera betzickiana*	Calico plant	കാട്ട പൊന്നാംകണ്ണി	Tropical America
5.	*Alternanthera brasiliana*	Purple joy weed	ക്രോട്ടൺ ചിര	Central and S. America
6.	*Ageratum conyzoides*	Goat weed	അപ്പ	Tropical America
7.	*Ageratum houstonianum*	Floss flower	നീല അപ്പ	Central America
8.	*Amaranthus spinosus*	Prickly amaranth	മുള്ളഞ്ചീര	Central and S. America
9.	*Antigonon leptopus*	Coral vine	പവിഴ വള്ളി	Mexico
10.	*Cabomba furcata*	Red cabomba	കബോംബാ	South America
11.	*Caladium bicolour*	Heart of jesus	ചെടിച്ചേമ്പ്	South America
12.	*Calapagonium mucunoides*	Calopo	കലപ്പോ	Tropical Asia
13.	*Cenchrus pedicellatus (Pennisetum pedicellatum)*	Deenanath grass	ദീനനാഥ് പുല്ല്	Africa and Asia
14.	*(Cenchrus polystachios) Pennisetum polystachyon*	Mission grass	പുച്ച വാലൻ പുല്ല്	Tropical Africa
15.	*Chromolaena odorata*	Siam weed	കമ്മ്യൂണിസ്റ്റ് പച്ച	Tropical America
16.	*Clindemia hirta*	Koster's curse	വെള്ളക്കടലി	South America
17.	*Cuscuta* spp.	Dodder plant	മുടില്ലാതാളി	North America
18.	*Dolichandra unguis-cati*	Cat's claw	ഡോളി	South America
19.	*Euphorbia heterophylla*	Milkweed	പാൽക്കള	Central America

20.	*Hydrilla verticillata*	Water thyme	ഹൈഡ്രില്ല	Asia and North Australia
21.	*Imperata cylindrica*	Cogon grass	ദർഭ പുല്ല്	Asia/ Africa
22.	*Ipomoea aquatic*	Water spinach	തോട്ട ചീര	China
23.	*Ipomoea cairica*	Railway creeper	റെയിൽവള്ളി	Tropical Africa to Asia
24.	*Ipomoea carnea*	Bush morning glory	ഗ്രാമഫോൺ ചെടി	Tropical America
25.	*Lantana camara*	Common lantana	കൊങ്ങിണി	Tropical America
26.	*Limnocharis flava*	Yellow velvetleaf	മലങ്കവളം	South America
27.	*Melochia corchorifolia*	Chocolate weed	ചെറു ഊരം	Tropical America
28.	*Mesosphaerum suaveolens (Hyptis suaveolens)*	Pignut	നാറ്റ പൂച്ചെടി	South America
29.	*Merremia vitifolia*	Grape vine weed	വേലിക്കോളാമ്പി	Indo-Malasia and China
30.	*Mikania micrantha*	Mile-a-minute weed	മൈക്കേനിയ	Central and S. America
31.	*Mimosa diplotricha*	Giant sensitive plant	ആനത്തൊട്ടാവാടി	South America
32.	*Mimosa pudica*	Sensitive plant	തൊട്ടാവാടി	South America
33.	*Mucuna bracteata*	Mucuna	മുക്കണ	Asia
34.	*Muntingia calabura*	Jamaican cherry	ജമൈക്കൻ ചെറി	South America
35.	*Najas guadalupensis*	Guppy grass	ഗപ്പി പുല്ല്	North and S. America
36.	*Parthenium hysterophorus*	Carrot grass	പാർത്തിനിയം	Tropical America
37.	*Passiflora foetida*	Stinking passion flower	പുച്ചപ്പഴം	North America
38.	*Pistia stratiotes*	Tropical duckweed	മുട്ടപ്പായൽ	South America
39.	Pontederia crassipes *(Eichhornia crassipes)*	Water hyacinth	കുളവാഴ	South America
40.	*Pteridium aquilinum*	Bracken fern	കഴുകൻ പച്ച	Tropical America
41.	*Quisqualis indica*	Rangoon creeper	റങ്കൂൺ വള്ളി	Tropical Africa and S. E. Asia
42.	*Rottboellia cochinchinensis*	Itch grass	മുറിയൻ പുല്ല്	Tropical Africa and Asia
43.	*Sacciolepis interrupta*	Interrupted cupscale grass	പൊള്ളക്കള	Tropical Africa and Asia
44.	*Salvinia molesta*	Water fern	ആഫ്രിക്കൻ പായൽ	South America
45.	*Senna spectabilis*	American cassia	രാക്ഷസ കൊന്ന	Tropical America
46.	*Sphagneticola trilobata*	Singapore daisy	സിങ്കപ്പൂർ	Central America

			ഡയിസി	
47.	*Synedrella nodiflora*	Synedrella	വേനപ്പച്ച	West Indies
48.	*Tithonia diversifolia*	Mexican sunflower	തിത്തോണിയ	Mexico to Central America
49.	*Utricularia* spp.	Bladderworts	യുടിക്കുലേറിയ	America
50.	*Vallisneria spiralis*	Tape grass/ Eel grass	വാലിസ്നേരിയ	S. Europe, N. Africa, and Southw

7.4. Management of invasive weeds

Prevention is the most important measure for managing invasive weeds, and requires utmost attention, as prevention is always better than cure. Proper surveillance, monitoring, strict quarantine laws, and treatment of imported goods that might include invasive species in the entry points are the preventive measures that should be taken care of immediately to avoid future introductions. International organizations like International Union for Conservation of Nature and Natural Resources (IUCN) and Convention on Biological Diversity (CBD) are concerned with the prevention and management of this problem. At a global level, IUCN through a group of specialists (Invasive Species Specialist Group, ISSG) elaborated a list of the invasive species and established a set of rules for the prevention of biodiversity loss caused by invasive species.

Management practices can be followed in two different ways to deal with weeds, which have already established and those possessing the potential to become invasive. The potential invasive species can be managed through environment impact assessment, collecting information regarding pathways of invasion to prevent further spread, strict post quarantine measures to eradicate the potential invasive weeds, and conducting awareness programmes to the public.

Once an alien plant is introduced and become invasive, manual, mechanical, cultural, biological, or chemical control measures can be adopted, but in an integrated manner as no single method has been found effective for a long term and sustainable management. Understanding the weed ecology and biology can help in devising proper management practices. Manual collection and removal is largely followed in managing weeds in fragile ecosystems. Manual hand pulling or mechanical weeding is possible only if the extent of spread is less. Mechanical methods include mowing, slashing and digging with various implements. After the removal of plants, they should be properly burnt or buried. Cultural control includes mulching, cover cropping, crop rotation or frequent soil disturbances, and stale seedbed.

Biological control involves classical, augmentative, or conservative approaches. Classical biological control includes searching for the efficient natural enemies (insects, mites, and pathogens) from the native place of the weed, and introduction, multiplication, and release to reestablish the equilibrium between pests and natural enemies (Table 3).

Table 13. Classical biological control agents introduced to manage weeds in India

Weed	Biological control agent

Parthenium hysterophorus	*Zygogram mabicolorata, Smicronyx lutulentus* and *Epiblema strenuana*
Eichhornia crassipes	*Neochetina eichhorniae, N. bruchi* and *Orthogalumna terebrantis*
Salvinia molesta	*Cyrtobagous salviniae, Phoma glomerata* and *Nigrospora sphaerica*
Opuntia spp.	*Dactylopius tomentosus*
Lantana camara	*Ophiomyia lantanae, Ortheziain signis, Diastema igris, Salbia (Syngamia) haemorrhoidalis, Uroplata girardi, Teleonemia scrupulosa,Octotoma scabripennis* and *Epinotia lantanae*
Alternanthera philoxeroides	*Agasicles hygrophila*
Eupatorium adenophorum	*Procecidochares utilis*
Chromolaena odorata	*Pareuchaetes pseudoinsulata, Apion brunneonigrum* and *Cecidochares connexa*
Mikania micrantha	*Puccinia spegazzinii*
Submerged aquatic weeds (eg: Hydrilla, Vallisneria)	*Ctenopharyngodon idella, Puntius javanicus, Pulchellus pulchellus, Tilapia mossambica, T. melanopleura,* and *Ophronemus gorami.*

Source : Kumar, 2015

Although classical biological control is highly effective and environment friendly, it is time-consuming and useful in non-cropped situations only. Sometimes, natural enemies may not establish well as that of the native place or may give only partial control of weeds. About 30 exotic biological control agents have been introduced to control invasive weeds in India (Kumar, 2015). Until now, 21 of these were recovered and established, while three could not be recovered after being released. Of the 30 biological agents, 6 could not be released in the field. Among these, 7 well-established bioagents gave excellent control, 4 gave significant control, and 9 resulted in partial control (Kumar, 2015). Singh (2004) reported that 56 per cent control was noticed in aquatic weeds and 24 per cent in terrestrial weeds by classical biological control in India. Efforts to increase the population of natural enemies either by

propagation and release or by environmental manipulation and conservation are followed in augmentative and conservative approaches.

Weed management practices

Hand weeding

- Most effective method of weed control for most of the weeds. The other weed control methods are usually compared with hand weeding for their effectiveness
- Not effective against perennial weeds

Stale seed bed technique (SSB)

- Renu *et al.* (2000) found that SSB with one or two weed flushes destroyed before the main crop being planted is the most effective method for managing mimicry weed i.e., *Sacciolepis interrupta* under semi dry rice conditions.
- Preparation of stale seed bed method by ploughing land at 25-30 days interval before sowing in between two germinations of rice, helped in germination of most of the weed seeds. Comparatively wet ploughing was more efficient over dry ploughing to control weedy rice (Jose *et al.*, 2012)

Concurrent growing

- Dual cropping of cowpea and incorporation of cowpea using 2,4-D at 45 DAS helped in reducing weeds under semi-dry rice (Anitha *et al.*, 2009).
- Soil solarization using polythene of 100 microns transparent sheets for 30-45 days in summer led to nearly 90% of weedy rice control (Jose *et al.*, 2012)
- Soil solarization for 2-6 weeks during summer increased the temperature of about 8-10°C in upper layers, destroyed all weed seeds and helped in reducing weed growth for next season (Sainudheen and Abraham, 2001)

Mulching for weed suppression

- Black plastic mulching is a worldwide practice in pineapple cultivation for weed control. Polythene sheet (black) recorded higher weed control efficiency (WCE) of about 95.21 per cent and higher yield
- Silver-black polythene mulch was noted to be best for weed control in cabbage (Akshata *et al.*, 2018).
- Straw mulch recorded reduction in weed dry matter and increased yield of chilli (Fasna *et al.*, 2021)

Azolla for weed control in rice

- Dual culture of azolla with rice lowered weed dry weight at azolla inoculation level of 0.5 kg m^{-2}

Mechanical weeding

- Self propelled cono-weeder had a field capacity of 0.1 ha /hr at an operating speed of 2.0–3.0 km/hr. The weeding efficiency of the unit in rice was at par with that of the manual cono-weeder operated twice at 15 and 30 days after transplanting
- Wheel hoe weeding at 15, 30 and 45 DAS, recorded lowest weed biomass in Okra (Chacko *et al.*, 2022)

Biological weed control

- *Cyrtobagous salviniae* dispersed quickly and devoured the weed within two years of its first release, clearing over 1,000 square km of water bodies (Joy *et al.*, 1986)
- Praveena and Naseema (2004) identified *Myrothecium advena* and *Fusarium pallidoroseum* (Cooke) Sacc. as promising biocontrol agents of water hyacinth as they caused more than 50 per cent infection of the weed.
- Nymphs and adults of *Aphis fabae* and *A. spiraecola* fed on tender leaves and shoots of *Chromolaena odorata* causing severe leaf crinkling (Lyla et al.,1995)
- Recently, re-occurrence of *Pareuchaetes pseudoinsulata* larvae was reported in Thiruvananthapuram which feeds voraciously on auxiliary and terminal buds of Chromolaena odorata. It has to be further investigated for its further spread for this weed control (Arjun et al., 2016).

Table 14.. New generation herbicides based on target weed flora

Grass herbicides				
Chemical Name	**Trade Name**	**Dose**	**Time of application**	**Colour code**
Cyhalofop butyl 10 EC	Clincher	80 g ha^{-1}	15 DAS	Green
Fenoxaprop-p-ethy7.5 EC	Rice star, Whip super	56 g ha^{-1}	15 DAS	Blue
Metamifop	Critel	100 g ha^{-1}	15-20 DAS	
Quizalofop-ethyl	-	37.5 g ha^{-1}	15-20 DAS	Blue
Haloxyfop R Methyl 10.5% w/w EC	Gallant	108-135 g ha^{-1}	20 DAS	Green
Sedges and broad-leaved weeds				
Chorimuron ethyl + metsulfuron methyl	Almix	4 g ha^{-1}	20-25 DAS	Blue
Carfentrazone ethyl	Affinity	20-25 g ha^{-1}	20-25 DAS	Green
Ethoxysulfurom	Sunrice	12.5-18 g ha^{-1}	20-25 DAS	Blue
Diclosulam	Strongarm	12.5 g ha^{-1}	0-3 DAS	Green
Halosulfuron methyl	Sempra	67.5 g ha^{-1}	3-4 leaf stage of weed	Green
Pyrazosulfuron ethyl	Saathi	20 g ha^{-1}	3-6 DAS	Blue
Broad spectrum herbicides				
Bispyribac sodium 10 % SC	Nominee gold, Tarak, Adora	25 -30 g ha^{-1}	15- 18 DAS	Blue
Penoxsulam 24 SC	Granite	22.5- 25 g ha^{-1}	15-18 DAS	Green
Imazethapyr, Imamox	Pursuit	30 g ha^{-1}	10 DAS	Green
Flucetosulfuron	-	15-30 g ha^{-1}	10-12 DAS	-
Herbicide mixtures				
Bensulfuron methyl 0.6%+Pretilachlor 6% GR	Londax power	60 + 600 gm	0-6 DAS	Green
Metsulfuron methyl 10% + Chlorimuron ethyl 10% WP	Almix	4 g ha^{-1}	15-20 DAS	Blue
Penoxsulam+ cyhalofop butyl	Vivaya	135 g ha^{-1}	15-20 DAS	Blue

7.5.

Invasive Insect pests in Agroecosystem

Agriculture and fisheries are particularly vulnerable to the effects of invasive insect species, threatening food security and livelihoods. The packaging, transport containers, and ship cargo are held to contribute in introducing IAS into the ecosystem. One of the most lucrative industries is thought to be the trade in logs. Although it generates a significant amount of foreign exchange, it also has the side effect of introducing Invasive Alien Species.

The logs are responsible for the introduction of insect species due to breeding grounds for numerous insects and viruses due to their extended time of untreated storage in godowns. Some invasive alien insects are excellent flyers at 100km/per night, there is a rumour that fall armyworms have travelled from Africa continent to India. The invasive species must first move from its current habitat or arrange to be moved to settle in a new area outside of its normal range. Passive transport is the movement of invasive alien insect species caused by vectors. Humans or human consignments are currently the most prevalent vectors. These invasive species are frequently transported passively, which makes them challenging to control. It is challenging to find the cryptic early stages of the insect that might be brought in by tourists, even after rigorous quarantine examinations. The invasive alien insects are very resilient, adaptable to new environments very easily, reproduce quickly with high fecundity, and can attack numerous hosts. They are voracious feeders, have high dispersal abilities, and benefit from mutualist interaction. 24 insect pests wreak havoc in India. The chronological order of invasive insects in India is given in Table. Some of the invasive alien insects with the incurred cost are given in Table.

Table 15. Chronology of invasive insects reported in India

S. No	Common Name	Scientific name	Origin	Entry to India	Hosts	Highlights	Reference
1.	Woolly aphid	*Eriosoma lanigerum* (Comstock) (Hemiptera: Diaspididae)	China	1889, Kashmir	Apple, Pear	The average production loss per tree was 2.4 kg (13 apples), which translates to a gross loss per hectare of $465.18.	Thakur and Dogra, 1980 and Brown *et al.* 1995
2.	San Jose scale	*Quadraspidiotus perniciosus* (Hausmann) (Hemiptera: Aphididae)	China	1911, Coonoor/Tamil Nadu	*Populus* spp.; *Betula* spp.; *Celtis* spp.; *Fagus* spp.; *Morus* spp., *Salix* spp.; *Aesculus* spp.; *Alnus* spp.;	This pest can destroy entire trees shortly after being introduced to a new area. The trees age more quickly and lose their vigour.	Fotedar, 1941
3.	Diamondback moth	*Plutella xylostella* Linnaeus (Lepidoptera: Plutellidae)	Italy	1914	Cruciferous vegetables	The control costs for *P. xylostella* in China are estimated at US$100/ha for each crop for the peak periods of April/May and September/October. If no sprays were applied, the crop losses of the summer crop of cabbage there were 99% in 1992 and 80% in 1994, compared with the plots treated with insecticides.	Fletcher, 1914 and www.cabi.org
4.	Lantana bug	*Teleonemia scrupulosa* Stal (Hemiptera: Tingidae)	Sri Lanka/West indies	1915	*Lantana*, coffee, *Jacaranda*, *Citrus*, sweet potato, gumwood, brinjal, rose	-	Muniappan and Viraktamath, 1985
5.	Cottony cushion scale	*Icerya purchase* Maskell (Hemiptera: Margarodidae)	Australia	1921, Tamil Nadu	*Acacia decurrens*, *Acacia dealbata*, and also a wide range of forest trees and agriculture are affected by this insect	The pest attacks a wide range of plants, including some of the endemic flora, and could endanger the native flora and the fauna dependent on it.	Rao, 1951 and

6.	Potato tuber moth	*Phthorimaea operculella* Zeller (Lepidoptera: Gelechiidae)	Italy	1937, East Bengal (Now in Bangladesh)	Potato, Tobacco, tomato, brinjal, beet and stored potato	The range of damage is from 3.3% in deep-planted tubers to 16% in shallow-planted tubers. It is also a significant post-harvest pest on potatoes in the same regions.	Singh, 2004
7.	Pine woolly aphid	*Pineus pini* (Macquart) (Hemiptera; Adelgidae)	Western and Central Europe	1970, Nilgiris, Tamil Nadu	*Pinus* spp. *Pinus patula*	*Pineus boerneri* infestation reduces productivity and results in up to a 50% loss of growth increment and up to 20% tree death by causing premature needle shedding and shortening of infected needles.	McAvoy *et al.* 2007
8.	Subabul psyllid	*Heteropsylla cubana* Crawford (Hemiptera: Psyllidae)	Central America	1988, Tamil Nadu & Bangalore	*Leucaena* sp.	Leucaena was first cultivated in 1972, and it is grown on 10,000 acres of land in Karnataka State alone. Only six months after *H. Cubana* arrived in India, Leucaena cultivation decreased drastically throughout the entire region.	Veeresh, 1990
9.	Coffee berry borer	*Hypothenemus hamperi* Ferrari (Coleoptera: Curculionidae)	Northeast Africa	1990, Gudalur, Tamilnadu	Arabica and robusta types of coffee	Crop losses caused by this pest can be severe, ranging from 50-100% of berries attacked if no control measures are applied	Kumar *et al.* 1990
10.	Serpentine leaf miner	*Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae)	USA	1990, Hyderabad, Telangana	Polyphagous pest	There is no significant impact of serpentine leaf miners on the yield.	Viraktamath *et al.* 1993
11.	Spiralling whitefly	*Aleurodicus disperses* Russell (Hemiptera: Aleyrodidae)	Caribbean region, Central America	1993, Kerala	Wide range of plants (481 hosts)	The pest could lower crop yield, and crop value (including increasing crop production costs) and trigger the loss of markets.	Palaniswami *et al.* 1995
12.	Coconut eriophyid mite	*Aceria guerreronis* Keifer (Arachnida: Eriophyidae)	Mexico	1997, Enakulam, Kerala	Coconut	The accurate crop loss due to this pest ranges from 7.5% and 30% to 60%	Sathiamma *et al.* 1998 Julia and Mariau, 1979

13.	Silver leaf whitefly	*Bemisia argentifolii* Gennadius (Hemiptera: Aleyrodidae)	-	1999	Tomato, Squash, Poinsettia, Cucumber, Eggplants, Okra, Beans, and Cotton	Polyphagous pest	Singh, 2004
14.	Blue gum chalcid	*Leptocybe invasa* Fisher & La Salle (Hymenoptera: Eulophidae)	Australia	2001, Karnataka/ Tamil Nadu	Eucalyptus	-	Jacob *et al.* 2007
15.	Erythrina gall wasp	*Quadrastichus erythrinae* Kim (Hymenoptera: Eulophidae)	Tanzania, East Africa	2006, Kerala	*Erythrina* sp., black pepper vanilla	-	Faizal *et al.* 2006
16.	Cotton mealybug	*Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae)	USA	2005, Gujarat	Cotton, brinjal, okra, tomato, sesame, sunflower, rose	In India 2008, the cotton crop severely destructed by this pest and yield losses up to 50-60%	Tanwar *et al.* 2005 Nagarare *et al.* 2009
17.	Papaya mealybug	*Paracoccus marginatus* Williams and Granara de Willink (Hemiptera: Pseudococcidae)	Central America	2007, Coimbatore, Tamil Nadu	Mulberry, tapioca, *Jatropha*, cotton and several fruits, flowers and plantation crops	This papaya mealybug, severely impacted the low marginal farmers and resulted in 100% losses	Tanwar *et al.* 2010
18.	South American tomato leaf miner	*Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae)	South America	2014, Pune, Maharashtra	Tomato, potato, pepper, brinjal	The pin hole sized holes on the fruit reduces the market value of the crop and unable to detect the pest. The pest causes 100% yield losses without control measures	Shashank *et al.* 2015
19	Invasive thrips	*Thrips parvispinus* (Karny) (Thysanoptera: Thripidae)	Thailand	2015, Karnataka	Chilli, fruit crops and vegetables	In recent years, it became a big problem in chilli and mango cultivation	Tyagi *et al.* 2015; NPPO 2019
20.	Rugose spiralling whitefly	*Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae)	Central America	2016, Tamil Nadu	Coconut, guava, banana, mango, drumstick, jackfruit	It can cause 38% - 50% nut yield loss	Srinivasan *et al.* 2016
21.	Fall armyworm	*Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae)	America to Africa, Africa to	2018, Karnataka	Polyphagous pest	FAW cause 21-53% loss in annual maize production It attacks 353 plant species belonging to 76 families	Sharanabasappa 2018 Montezano *et al.* 2018 Suby *et al.* 2020

			India				
22.	Woolly whitefly	*Aleurothrixus floccosus* (Maskell) (Hemiptera: Aleyrodidae)	Neotropical	2019, Kerala	Guava, Citrus species	The woolly whitefly becoming serious threat to fruit and plantation crops. This whitefly species dominates the remaining species	Sundararaj *et al.* 2020
23.	Neotropical whitefly	*Aleurotrachelus atratus* Hempel (Hemiptera: Aleyrodidae)	Neotropical	2019, Mandya/ Bangalore	*Cocos nucifera* and *Dypsis lutescens*	Distributed widely in the tropics and subtropics and colonize more than 110 plant species	Selvaraj *et al.* 2019
24.	Cassava mealybug (CMB)	*Phenacoccus manihoti* Matile-Ferrero (Hemiptera: Pseudococcidae)	Africa	2020, Kerala	Cassava	CMB damages 50-60% of cassava and reduction in crop acreage from 9300ha to less than 2000ha in Tamil Nadu due to the severity of CMB	Joshi *et al.* 2020 Sampathkumar *et al.* 2021 Farmers training cum awareness program- SPAC, Erode_0.pdf (nbair.res.in)

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Table 17 . Invasive insect species with reported costs in India, geographical origin, introduction pathways, reasons for introduction and year of the first record

Invasive insect species	US$ billion	Pathway	Reason	First record in India
Paracoccus marginatus	0.14	Contaminant	Trade; Live plant material	2008
Spodoptera frugiperda	0.04	Contaminant	Tourism/Trade	2018
Hypothenemus hampei	3.81 E−03	Contaminant	Trade; Plant material	1990
Aleurodicus rugioperculatus	0.13 E−06	Contaminant	Trade; Live plant material	2016

8. Future Policies and Strategies

A concerted effort is needed to keep the invasive aliens at bay. Based on the discussions with the experts and review of literature (eg., Jayachandran, 2024), the following strategies are proposed for the integrated management consisiting of prevention, control, and eradication of alien species from various ecosystems of the state. The 40 startegies are grouped under 9 heads.

1. Introduction of species

1. Introduction of any alien spevies shall not be allowed without proper authorization from the relevant competent national/state authority. The authority shall make sure that the new introduction is unlikely to cause undesirable harms to the environment, habitat, humans, and other species.
2. Authorization of an introduction (species/breed/cultivar) shall be accompanied by conditions, such as preparation of a mitigation plan, monitoring procedures and/or containment requirements.
3. Common pathways leading to unintentional introductions need to be identified and appropriate provisions to minimize such introductions shall be in place. Possible pathways shall be identified for each species for regulating prevention and management.
4. Unintentional introductions shall be managed with proper statutory and regulatory measures, institutions, and agencies with appropriate responsibilities and with the operational resources required for rapid and effective action
5. Sector wise data on invasive species have to be developed for agriculture, forestry, fisheries, shipping (including the discharge of ballast waters), ground and air transportation, construction projects, landscaping, ornamental aquaculture, tourism and game-farming.
6. The role of nurseries and plant dealers in introducing new species and cultiavrs of plants can not be ignored. Therefore, proper documentation is needed of the plants available with them. This is important during the recent times as several different types of planting materials are available for purchase through Iinternet with-out following plant quarantine rules.
7. Restrict movement of soil and plant parts from infested areas to uninfested areas. All plant and soil which move into the forests (for civil works, saplings from central nurseries, etc) need to be thoroughly monitored for the presence of invasive species as seedlings, plant parts, or propagules.
8. Tourist destinations inside the forests should be under constant surveillance to avoid unintentional transportation of IAS through baggage, vehicles, etc. Tourist and pilgrimage routes and spots within forests should be put under regular surveillance todetect and eradicate new AIS.

9. Separate strategies are to be formulated for microbial introductions

2. Identification and taxonomic validity of alien species

10. Strict scientific approach shall be adopted to reconfirm the status of reported alien species. Taxonomic validation is essential.

11. Many alien species have been reported to be invasive. Scientific data to prove these species as invasive is often lacking and hence measures are to be taken to establish the status of reported species. Methods shall be developed to address an alien species as invasive.

12. It is observed that many introduced as ornamental plants have become invasive noxious invasive weeds. Therefore, develop a systematic reporting mechanism of non-native plants spotted in an area. On a regular basis, agricultural department shall take the lead to document and report newer plants introduced to a region through regular channels following the rules and regulations, and those brought in by agriculturists and nursery owners.

3. Need of strict quarantine measures

13. Strict quarantine measures are needed to ensure that legitimate introductions shall not pause any threat to the environment. Regulations shall be imposed at airports and seaports and at other entry points. Quarantine measures shall be based on risk assessment posed by alien species and their potential pathways of entry. For this government departments and agencies should be strengthened and technically equipped. Regional co-ordination is highly essential.

14. Quarantine measures shall be in place for the introduction of any alien species or cultivars of agricultural crops whether possible environmental, social, health, and economic risks posed by a potential alien species or by a potential pathway are known or not.

4. Capacity building

15. For the control or eradication of certain noxious alien species, co-operation of governments of different countries may be required, and in such situations, appropriate policies must be developed to suit and tackle the issue.

16. The counties of origin and receiving species shall exchange information about alien species. Agreements to that effect may be developed.

17. The state shall support capacity-building programmes to assess the introduction of alien species and their subsequent effects.

5. Public awareness

18. Most common people are unaware of the rules and regulations pertaining to the import of plants from other countries and from different parts of the country. They must aware of the risks involved in the introduction of alien species. When mitigation measures are required, public-awareness-oriented programmes shall be set in motion

to inform local communities and appropriate sector groups on how to support such measures. Media shall also be involved in the process.

6. **Risk assessment studies**

19. Alien species threaten habitats, ecosystems, and species. Risk assessments due to alien species have not been precisely investigated, and hence such studies are required.

20. Information on the performance of the alien species in its native place has to be collected and compared with it behavier in the new environment.

7. **Research and development**

21. For creating an appropriate knowledge base enabling to address the problem, adequate emphasis on research and development and monitoring of alien species shall be undertaken by various agencies.

22. Research should concentrate on surveys, history of invasions (origin, pathways, and time), characteristics of aliens, associated ecological and economic impacts, and how they change over time.

23. Formulate integrated pest management (IPM) strategies for the management or eradication of the invasive species..

24. Mode of suppression of native species by the aliens shall be studied in detail.

25. Allelochemicals are interestingly identified as novel weapons, which suppress the native species and pave the way for the aliens in colonisation in the new habitat. Studies on allelochemicals shal be ebcouraged.

26. Climate change together with other anthropogenic disturbances are expected to cause the upward movement of invasive plant species from plains to mountain regions especially in the protected forested areas and this upward movement is projected to happen at a rapid rate. Studies are to be undertaken on these lines.

27. In addition to public health, alien plant species also affect health of plants. It acts as alternate and collateral hosts of several microbial pathogens thereby increasing the crop loss. The quantification of economic loss in mitigating the alien species induced disease is also important for their threat and risk assessment.

28. Wherever feasible, develop strategies for using the invasive species economically as a stategy of management..

8. **Traded invasive and fugitive alien species**

29. Alien species under trade are to be brought under investigation for its retention or eradication. Reasons of retention, if any, shall be consolidated.

30. Several species have been introduced for agriculture, ornamental gardening, food processing, and other purposes. The performance of fugitive alien species shall also be assessed periodically. .

9. **Management**

31. Prevention is generally far more cost effective and environmentally desirable than the control measures after introduction and establishement of an alien species. All possible measures shall be taken for prevention as a management strategy.

32. For certain noxious established invasives, eradication shall be planned. If it is not feasible or cost-effective, long-term management measures shall be adopted with the final intention of eradication. Hence, early detection of new introduction of alien species is of utmost importance.

33. If eradication is planned, the best opportunity for eradicating alien invasive species is in the early stages of invasion when populations are small and localized; hence, early detection systems focused on high-risk entry points can be critically useful. Community support built through comprehensive consultation shall be an integral part of eradication projects.

34. Involve fishermen/farmers/ BMC members/ Haritha karma sena/ Suchitwa mission, local people, etc in a suitable way in management and eradication so that it is cost-effective. Field staff shall be trained in the identification of restricted and noxious invasive plants. The extension machinery of different departments under the Government can play a pivotal role in this aspect.

35. To limit the potential establishment of invasive plants on disturbed ground, re-vegetate the area with approved species through a time bound plan. If the area has a known invasive plant population, it may be better to control the plants prior to re-vegetation

36. When herbides are used for the control of invasive plants, ensure that they are non-persisitant and safe to the environment.

37. Control IAPS in infested areas before flowering and fruiting. Management of weed infested area during the reproductive phase of the AIPS is crucial so as to prevent the dispersal of seeds to un-infested areas.

38. Regular monitoring outside the management boundaries is essential with quick action to conatin any new outbreaks. Focus the management measures on reducing the damage caused rather than on merely reducing the numbers of alien invasive species.

39. Use the best management practices following an integrated approach in all activities associated with invasive species.

40. Considering the high impacts on environment and multiple ways of utilization of the alien species, go for integrated planning. When planning for various activities consider the risks involved and provide for alternatives to the extent possible to reduce the risks associated with the introduction, establishment, and spread of invasive species.

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Annexure I

The main policy measures or actions that will be taken to achieve national target 6: Invasive Alien Species

- Inventorying, assessment of distribution and status, preparation of an illustrative atlas of invasive and alien species in terrestrial, inland waters, and marine ecosystems, and wider dissemination of information are urgently needed. Concerned ministries/ departments need to create general awareness in a mission mode.
- Encourage and support researches to identify and manage pathways of introduction of alien species thereby preventing the introduction, establishment and proliferation of priority invasive alien species.
- Initiate field/ experimental researches on biological control of invasive alien species.
- Eliminate, control, minimize, and reduce invasive and alien species and mitigate their impact on biodiversity, productivity and ecosystem services.
- Control/ eradicate invasive and alien species in priority conservation sites of biodiversity importance e.g., PAs, managed forests, wetlands, coastal and marine ecosystems, wildlife corridors, and islands.

Indicators to be used to monitor the national target 6: Invasive Alien Species

1. Rate of invasive alien species establishment.
2. Rate of invasive species establishment and rate of impact.
3. Rate of invasive alien species spread.
4. Number of invasive alien species introduction events.
5. Number of invasive alien species in national lists as per the Central Regulation of Introduced and Invasive Species.
6. Trends in abundance, temporal occurrence and spatial distribution of non indigenous species, particularly invasive notably in risk areas (in relation to the main vectors and pathways of spreading of such species).
7. Redlist Index (Impact of Invasive species).

8. Number and coverage of management plans developed for prioritised invasive species and integration with PA management plans and wetland management plan.

9. Change in area affected by invasive species.

Means of implementation and barriers to implementation of Target 6

- State departments dealing with forest, wildlife, environment, agriculture, fisheries, animal husbandry are primary agencies in managing invasive alien species.
- Current capacity, and support in terms of manpower, infrastructure, technology and finances are grossly inadequate to tackle the gigantic task of managing invasive alien species.
- Committed support at all levels for research, capacity enhancement, management, law enforcement, monitoring and finances is the need of the hour.

ENVIRONMENT GOVT. SECRETARIAT

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BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL (SOUTHERN ZONE BENCH, CHENNAI)

ORIGINAL APPLICATION NO.162 OF 2023 (SZ)

Tribunal on its own motion - SUO MOTU based on the News item in The Hindu Epaper, web edition dated 24.09.2023, "Kole wetlands of Kerala face threat of alien plants".

And

The Principal Secretary to Govt of Kerala, Dept. of Environment, Thiruvanthapuram and Ors.

...Respondent(s)

ACTION TAKEN REPORT FILED BY SECRETARY, ENVIRONMENT DEPARTMENT/1ST RESPONDENT

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