Report of the **risk assessment** of **invasive alien plants in Shendurney** wildlife sanctuary

Report Submitted to the Shendurney Wildlife Sanctuary

KSCSTE – Kerala Forest Research Institute
An Institution of Kerala State Council for Science, Technology and Environment
Peechi 680653 Thrissur, Kerala | August-2021

REPORT OF THE RISK ASSESSMENT OF INVASIVE ALIEN PLANTS IN SHENDURNEY WILDLIFE SANCTUARY

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1. Introduction

Invasive alien species (IAS) are species introduced into places out of their natural range of distribution, where they become established and disperse, causing a negative impact on the local ecosystem and species (IUCN). The spread of IAS is one of the major global threats to ecosystem services and biodiversity. Biological invasion causes irretrievable environmental changes affecting all ecosystems and their services (IUCN). Invasive alien plant species potentially threaten biodiversity of Kerala; however such invasions are not well investigated especially in protected areas of the state. Surveillance and monitoring of invasive alien species in the protected areas of Kerala need to be carried out periodically to identify new incursions and to develop protocols to eradicate or manage the spread of the species. In this context, KFRI conducted a rapid survey at Shendurney Wildlife Sanctuary to identify and map occurrence, spread and distribution of invasive alien plants of the sanctuary.

1.1Study Area

Shendurney Wildlife Sanctuary is located in Pathanapuram Taluk, Kollam district (8°44' - 9°14' N, 76°59'.30'' - 77°16'.30''E), and encompass tributaries of Kallada River, upstream of Parappar Dam and its reservoir (13.72 sq.km) and forests in the catchment zone. The sanctuary was established in the year 1984 and earmarked with an area of 100.32 sq.km. Later a map developed using geo-coordinates recorded sanctuary area as 172.403sq.km. Newly recorded area has been verified and confirmed by KFRI using Planimeter. Also, an area of 1.233sq.km was received from Punaloor Forest Division making a total of 173.636sq.km as the final area of the Sanctuary including 422.2513 Ha Vested forests and 35.439 ha of EFL (Ecologically Fragile Land) area. The sanctuary owes its name to an endemic tree species *Gluta travancorica* ('Chenkurinji' in Malayalam) which is categorized as a near threatened species in the IUCN Red List. Lies south of Aryankavu valley and stretches to a length of about 25km east-west, the sanctuary border coincides with the watershed boundary of Kallada reservoir in North, East and South. The dam built across Shendurney River joins with Kulathupuzha and Kazhuthurutti rivers which meet the irrigation needs of Kollam and Pathanamthitta districts in Kerala. Being the only sanctuary occurring in Kollam district, conservation of its forests and catchment area is vital in keeping up the constant supply of water.

1.2 Geology& Vegetation

The terrain of the sanctuary varies from gentle to steep slopes and irregular high hills laced with ravines, where the elevation ranges within 100-1550m ASL. Metamorphic rocks like Charnockite and different gneisses produced by high-temperature and high-pressure metamorphic processes form the underlying rocks. Intrusions of huge masses of granite-like rocks observed in rugged form along the major edges and slopes, and crumbling granite gneisses structure a fine soil with a combination of humus which varies as shallow and stony along the ridges, and deep and fine in the valley. Laterites occur in the sanctuary in varying compositions from hard rock to fine gravel and alluvial deposits along the streams and river banks.

Towards interior locations such as Mankuthu, OnnamMile, Choodal, Pappamkuzhy and Vilakkumaram in the sanctuary, a typical edaphic pattern is visible owing to alluvium and humidified sand brought from the surrounding slopes in a huge proportion. They are exposed to flooding for six months every year between July-December; generally known as 'Myristica Swamp'(Champion and Seth 1968). These localized swamps occur below 300m ASL along forest fringes where drainage is poor. Sand deposition in the reservoir in multilayers was observed when the water level dwindles below MWL. The sand heaps near the reservoir due to landslides were also observed close to anti-poaching camps at Umayar, which in turn changed the landscape with an increase in the ground level because of silt and sand deposition. The vegetation types along the boundaries include West coast semi- evergreen, West coast evergreen, Southern secondary moist mosaic deciduous, and Hilltop evergreen/Subtropical hill forests. The northern boundary of the sanctuary is lined with West- coast semi-evergreen forests shifted into West coast evergreen forest and Southern secondary moist mosaic deciduous forests and hill top evergreen towards the east side. The southern boundary is covered with West coast evergreen forests and Southern secondary moist deciduous forests modified into West coast semi-evergreen followed by Southern secondary moist deciduous forests and Hilltop evergreen forests towards the west side.

1.3 Formation

The sanctuary is located on the north of Kulathupuzha valley on either side of Shendurney River; well demarcated from reserve forests of Thenmala in the north, Tirunelveli in the east,

Thiruvananthapuram in the south, Punalur and a portion of Thenmala in the west. The sanctuary has been divided into three sections; Eetapadappu, Kalamkunnu,and Kalluvarambu. The Kalamkunnu section-west is considered as the most frequented tourism zone followed by Kalamkunnu section-east. Rosemala under Ettapadappu Section-east belongs to the buffer zone and is also a major tourist attraction in the region. The section also encloses a private estate in Rosemala which is demarcated with solar fencing. The Rockwood camp located deep inside the forest comes under the Kalluvarambu section is another major tourist attraction that has trekking sites through major forest types in the sanctuary. Also, two major private estates, Kallar and Rockwood, lie under this section.

1.4 Forest Types

According to Champion and Seth classification (1968), Shendurney harbour the following major and subtypes of vegetation: Southern hilltop tropical evergreen forest (1A/C3), West coast tropical evergreen forest (1A/C4), Cane brakes (1A/E1), Wet bamboo brakes (1A/E2), West coast semi- evergreen forest (2A/C2), Southern moist mixed deciduous forest (3B/C2), Myristica swamp forest (1C/FS1), Sub-montane hill valley swamp forest (4C/FS2), Riparian fringing forests (4E/RS1), Reed brakes (8A/E1), South Indian sub-tropical hill savannah woodland (8A/DS1), Southern montane wet temperate forest (11A/C1) and Southern montane wet grassland (11A/DS2).Of which we could observe only six forest types: West coast tropical evergreen forest in Pandimotta and Rockwood; Wet bamboo brakes in Pandimotta and Kattilappara; West coast semi-evergreen forest in Pandimotta, Rosemala, Umayar, Katilappara, Rockwood, Kallar and Idimuzhanganppara; Southern moist mixed deciduous forest in Rosemala, Kattilappara, Umayar and Idimuzhanganppara.

Even though sanctuary marked with zero tribal settlements; two human habitations are present in Rosemala and Kattilappara comprising of about hundred families in each of the locations. A relocation programme has commenced in these locations as a part of ‘Rebuild Kerala Relocation Plan’ where procedures have just initiated in Rosemala and at final stage in Kattilappara. In addition to the settlements, three private estates, namely Rosemala, Kallar (including Thengumthoppu Estate) and a part of Rockwood estate encompassing a total area of 877ha which are mostly covered by rubber plantations. Based on the zone classification, the sanctuary

has been divided into Tourism, Buffer and Core Zones. The tourism zone falls on the western side of the sanctuary comprising an area of about 28.20% (48.35sq.km). This zone makes the doorway to the sanctuary with a major part of the reservoir allotted for regulated tourism activities. Major attraction of this zone include boating facilities and services at Kalamkunnu and Idimuzhaganppara situated on the banks of Parappar dam which also host two camping sites for tourists.

Buffer zone sandwiched between the Core and Tourism zones covers an area of 27.6% of the sanctuary (47.13sq.km) including a part of the reservoir area. Rosemala, an offbeat place for bike trips, belongs to this zone. It encloses the Rockwood estate in the south by crossing the reservoir and Idimuzhangan para and touches the northern boundary at Thirthakara Mala (780m). The sanctuary offers limited tourism services within this zone such as trekking and stay at the Rockwood estate and Pallivasal, near Rosemala. The presence of private estates (Kallar and Rosemala) and human settlements in the zone interfere with management and conservation of the sancturary. An anti-poaching camp staffed by forest guards has been set up at Dharbhakulam near Rosemala. Core Zone, where no human interventions are permitted, is situated to the eastern side of the sanctuary which encompasses about 44% (75.5sq.km) of the total area. The zone boundary starts from the south at Ambakallumottai (1169m) and passes to the north through Umayar by crossing the northern boundary of the reservoir and ends at Kannampallimedu. The highest peak Alwarkurichi (1550m), Pandimotta, Umayar, Aruliyar, Narathar and Dharbhakulam lies in this zone with two anti-poaching camps at Umayar and Pandimotta.

Shendurney Wildlife Sanctuary holds 951 species of native flora, of which 32% are Western Endemic species representing 24% endemic plant species of Kerala. Tourism activities including trekking, boating and camping facilities in the forest interiors, presence of three private estates, human inhabited areas and the Parappar reservoir lake have caused the introduction of invasive alien plants into the sanctuary, harming the native plants including the endemic ones. Those alien plants which have landed on the forest fringes advertently or inadvertently can get into the sanctuary via different pathways with the help of tourism and travel within the area. They may be able to replace the native flora and can establish a mass population in the sanctuary. The sanctuary located on either side of the reservoir portrays an aquatic-terrestrial ecotone;

considered as a dynamic zone for interaction between different ecological communities which also acts as a buffer zone that offers protection to the bordering ecosystems from possible damages.

2. Methods

The entire area was surveyed either by a Jeep or by walks. The state boundaries adjoining the sanctuary were excluded from the surveys due to presence of heavily closed canopy which doesn't favour the growth and establishment of invasive alien species. The survey was done by alighting and recording the invasive alien plants at every 500m interval. All invasive species at each site were recorded within an observational range of 250m which were indexed based on visual accuracy on a scale of ten. Geo-coordinates, habitat, elevation, percentage of canopy, presence of drainage and native plants were also noted (Figure 1, 2).Location sketches indicating the sampling area were also made. Apart from the survey method that followed, presence of any new invasive alien plants observed outside the sampled locations was noted separately. The survey was completed in two phases by taking a total of seven days, covering the extreme west of the sanctuary during the first phase and the remaining locations in the later phase. Additionally, a boat survey was carried out along the reservoir banks to check further invasions.

Of the total 215 geo-coordinates surveyed; 91 coordinates represent the drainage, 24 coordinates represent the reservoir and the rest includes the data from trek paths, tourist camps, Core Zone, forest fringes and anti-poaching camps which covers the major locations- Kalamkunnu, Earth dam, Thottapura, Mannanthara, Idimuzhanganpara, Eetapadappu, Rosemala, Pallivasal, Umayar, Rockwood estate, Kattilappara, Pandimotta, Kallar estate and the Parappar reservoir. Risk Impact Assessment of the recorded invasive plant was done using the Generic Impact Scoring System (GISS).

Figure 1 & 2. Survey of Invasive alien plants conducted in Shendurney Wildlife Sanctuary

3. Results

A total of 25 invasive alien plants were recorded from the survey conducted in Shendurney Wildlife Sanctuary and are listed in Table 1. Risk Impact Assessment done using the Generic Impact Scoring System (GISS) yielded eight high risk species and seventeen medium risk species. The high risk species recognised include *Mikania micrantha, Mucuna bracteata, Lantana camara, Tithonia diversifolia, Chromolaena odorata, Clidemia hirta, Senna siamea* and *Tridax procumbens.* The medium risk species recognised include *Mimosa diplotricha, Pueraria phaseoloides, Ipomoea cairica, Alternanthera bettzickiana, Alternanthera brasiliana, Pennisetum polystachion, Synedrella nodiflora, Senna alata, Merremia vitifolia, Ageratum conyzoides, Acacia auriculiformis, Pennisetum pedicellatum, Centrosema molle, Sphagneticola trilobata, Ricinus communis, Pteridium aquilinum* and *Ipomoea hederifolia*. The distribution of invasive alien plants in Sanctuary is plotted in Fig.3.

Table 1. List of Invasive Alien Plants recorded from Shendurney Wildlife Sanctuary

#	**Plant Species**
1.	*Acacia auriculiformis*
2.	*Ageratum conyzoides*
3.	*Alternanthera bettzickiana*
4.	*Alternanthera brasiliana*
5.	*Centrosema molle*
6.	*Chromolaena odorata*
7.	*Clidemia hirta*
8.	*Ipomoea cairica*
9.	*Ipomoea hederifolia*
10.	*Lantana camara*
11.	*Merremia vitifolia*
12.	*Mikania micrantha*
13.	*Mimosa diplotricha*
14.	*Mucuna bracteata*

15.	*Pennisetum pedicellatum*
16.	*Pennisetum polystachion*
17.	*Pteridium aquilinum*
18.	*Pueraria phaseoloides*
19.	*Ricinus communis*
20.	*Senna alata*
21.	*Senna siamea*
22.	*Sphagneticola trilobata*
23.	*Synedrella nodiflora*
24.	*Tithonia diversifolia*
25.	*Tridax procumbens*

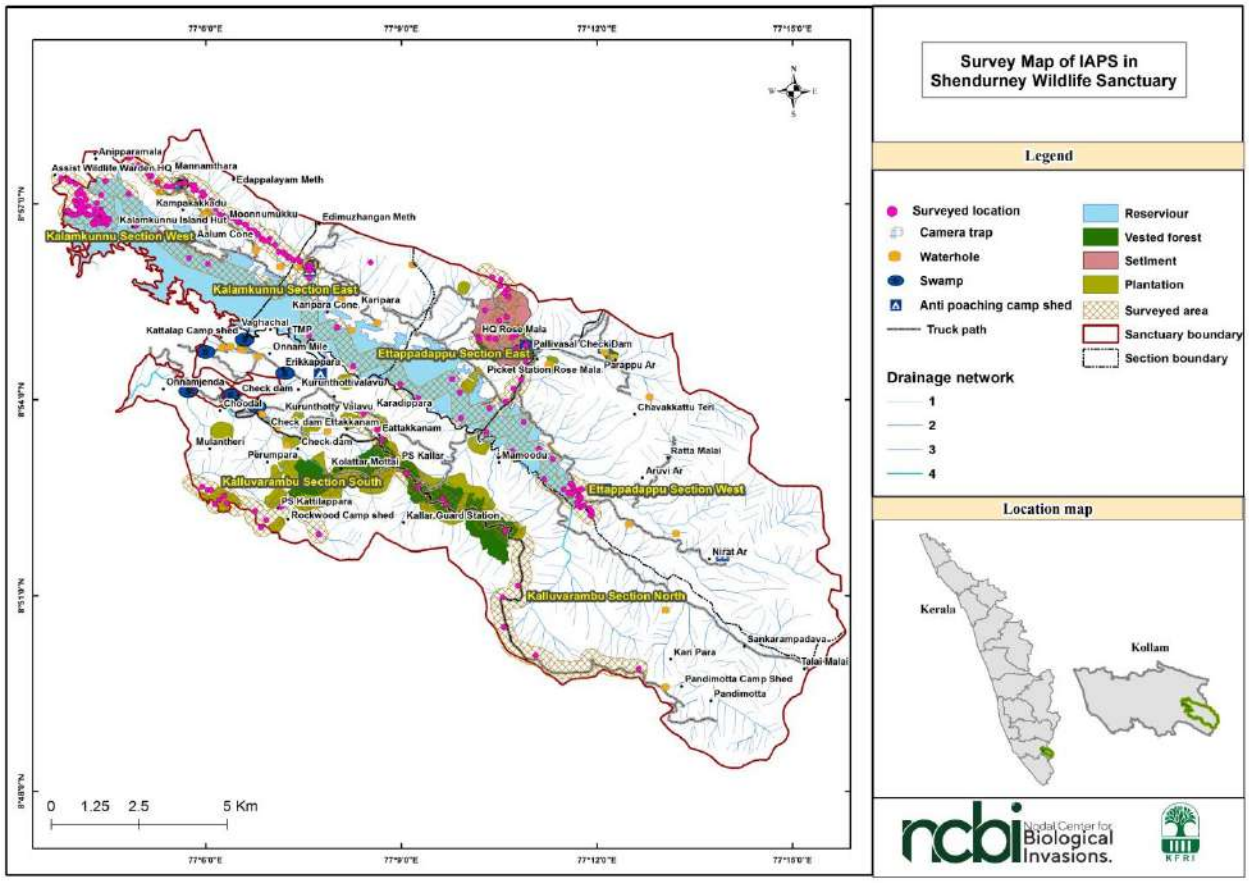


Figure 3. Map showing the presence of invasive alien plants in the surveyed locations.

3a. Distribution of Invasive Alien Plants in the Sanctuary

The survey covered the sanctuary excluding a portion in the Core Zone with heavy canopy cover. The invasive alien plants along the roads, major trek paths, tourist and anti-poaching camps were noted separately by keeping a field observation range of 250m. The distribution of invasive alien plants recorded in the sanctuary is listed below:

1. ***Acacia auriculiformis*** **Benth.**

A few trees of the species were located in the sandbanks near to the Kalamkunnu Island Hut, where most of them were debarked and dried. Saplings of the species were also spotted in the same location. The risk impacts of this species were found to be very low due its isolated occurrence in habitats with no human intrusions.

2. ***Ageratum conyzoides*** **L.**

This herb was recorded enroute Rosemala viewpoint, on roadsides adjacent to rubber plantations. Level of infestation was low. The location is highly prone to invasive alien plants because of tourists and thus may be able to spread once favorable conditions arrive.

3. ***Alternanthera bettzickiana*** **(Regel) G. Nicholson**

This thickly branched herb has a wide spread of distribution along road sides and rubber plantations of Rosemala and Kallar with moderate infestation on roadsides and low in rubber plantations.

4. ***Alternanthera brasiliana*****(L.) Kuntze**

Found nearby the ticket counter, in rubber plantations and on roadsides towards Rosemala Viewpoint with moderately low infestation, while at Rockwood Estate Entrance gate has recorded moderate infestation. These locations are the major pathways of tourism in the sanctuary.

5. ***Centrosema molle*** **Benth.**

Invaded even in the Core Zone; trek paths of Umayar and river banks of Shenduney Aar and Unakkathodu, road sides enroute Pandimotta and near the ‘Layam’ area of Kallar Estate.

They were also sighted in Rosemala Road near Ambalamukku and Rockwood Estate Road. Major trek paths, roads and tourism pathways have been invaded by this species with moderately low and moderate levels of infestation.

6. ***Chromolaena odorata*(L.) R.M.King & H.Rob.**

The species is one of the worst invasive alien plants, located in 46 surveyed locations in the sanctuary. Recorded in Core areas of Umayar camps and trekpaths, river banks of Shendurney Aar, Unakkathodu, and roadsides towards Pandimotta Camp including Thengumthoppu, Kallar Estate and 'Layam' premises. Also sighted in Eetapadappu-Vilakkumaram, road towards Rosemala Viewpoint and at the hilltop, along the trekpaths and reservoir banks near Pallivasal Camp, at the Rockwood Estate Entrance and on either side of Estate roads. The species had widespread distribution in Tourism Zone.

7. ***Clidemia hirta*(L.) D. Don**

The spread of *Clidemia* was recorded towards the left extremes of Kalamkunnu Section, Umayar and Pandimotta with medium distribution while its wide distribution was sighted along the trek paths and roadsides of Rockwood Camp and Estate respectively. This species could potentially be the second most invasive alien plant which could spread and establish throughout the sanctuary.

8. ***Ipomoea cairica*(L.) Sweet**

Ipomoea was not very well established in sanctuary except in Thottapura, Kallar Estate, Layam Premises of Kallar Estate, road sides of Kallar- Pandimotta and Kavungod. Major population was recorded along roadsides and estate boundaries with high level of human interventions. The species did not occur in forested landscapes of the sanctuary even in areas with moderate canopy covers.

9. ***Ipomoea hederifolia* L.**

Recorded from human settlements enroute Rosemala Viewpoint and in plantation premises nearby Rockwood Camp. Since it is used as an ornamental plant, the species presence was

noted only in human inhabited areas. The species is absent in forested areas except in Rosemala and near Rock Wood Estate.

10. *Lantana camara* L.

Lantana was widespread in the sanctuary; recorded from Idimuzhanganppara, Rosemala Road, near Rosemala Viewpoint ticket counter, Thengumthoppu-Pandimotta Road, Umayar Camp, Unakkathodu, Thoppippara, Rockwood Estate, Pandimotta, Kallar Estate and near Layam premises of Kallar Estate. High infestation of *Lantana* was noted along the banks of Shendurney Aar located in the Core Zone of the Sanctuary. Lantana is a high risk invasive alien plant which is widespread in Core Zone, and need to be controlled soon.

11. *Merremia vitifolia* (Burm. fil.) Hall. fil.

The species was sparsely distributed and was sighted only at Idimuzhanganppara Camp and Ambalamukku enroute Rosemala Viewpoint. This is a medium risk species with moderately low level of infestation.

12. *Mikania micrantha* Kunth.

Invasion of *Mikania* was very high and the species was recorded from Kalamkunnu Trek path, Rosemala, Rockwood Estate, Thoppippara, Kallar Estate, Thengumthoppu, Kavungod and Pandimotta. Major spread was located in Umayar including trekpaths, Unakkathodu, camps premises and along the banks of Shendurney Aar. This high risk invasive alien plant causes severe ecological and economic impacts in the sanctuary.

13. *Mimosa diplotricha* Sauvalle

Mimosa diplotricha was less widespread species; recorded from Kalamkunnu, Idimuzhanganppara Camp, roadside towards Rosemala, Umayar trek paths and on banks of Shendurney Aar.

14. *Mucuna bracteata* DC.

Located near to Rubber plantations, heavy infestation was noted in Rosemala near ticket counter and at the hilltop near Viewpoint, trekpaths of Umayar including Shendurney Aar, at

the Rockwood Estate Entrance and along roadsides of Rockwood Estate, Thoppippara and Layam premises of Kallar Estate. The species has invaded the major tourist locations from the plantations nearby and negatively affect the ecology of the sanctuary.

15. *Pennisetum pedicellatum*Trin.

Recorded only from Idimuzhanganppara Camp with moderately low infestation. Immediate control can be done since the species has not established anywhere else in the sanctuary.

16. *Pennisetum polystachion*(L.) J.A. Schultes

Rosemala Viewpoint, Store Junction, Thoppippara, Thengumthoppu, Kavungod and Rockwood Estate are under threat of this plant species. Core Zone near Umayar Camp is also infested by them. Levels of infestation are moderately low in these locations where they can be controlled locally.

17. *Pteridium aquilinum*(L.) Kuhn

Infestation of *Pteridium* has noted near Kalamkunnu Earth Dam Section with moderately less population. They co-exist with other medium risk invasive alien plants on trek paths towards Kalamkunnu IB.

18. *Pueraria phaseoloides* (Roxb.)Benth

Noticed the presence only at Rosemala region, near to the plantations. They co-exist with Mucuna on either side of the road towards Rosemala Viewpoint. Infestation was noted as moderately low when compared with Mucuna invasion.

19. *Ricinus communis* L.

Recorded only from Idimuzhanganppara Camp with moderately low infestation. They can be controlled locally by physical methods.

20. *Senna alata*(L.)Roxb.

Recorded mostly along the roadside of Kallar Estate with medium level of infestation. The species was found in a patch in a specific location which can be controlled before getting established to adjacent areas.

21. *Senna siamea*(Lam.)H.S.Irwin & Barneby

Heavy infestation of *Senna* was recorded in regions between Earth Dam and Kalmkunnu IB, where the population of the species found to be quite large, and showed high coppice rate. No native plant species were noticed nearby their population. Since they are seen on the fringes of the forest adjoining the reservoir areas, the invasion of *Senna* can be a major threat to other native plant species in the sanctuary.

22. *Sphagneticola trilobata*(L.) Pruski

These ornamental invasive plants were observed in Kalmakunnu Island Hut, where tourists frequent *via* boat. Few Acacia trees occur on the island where the invasion can be controlled.

23. *Synedrella nodiflora*(L.) Gaertn.

This can be an emerging potential invasive alien plant in Shendurney where the presence noted in areas like Kallar, Thengumthoppu-Kavungod, near Thengumthoppu Janda, trekpaths of Kalmakunnu, Thottapura, roadsides towards Rosemala and on trekpaths of Umayar.

24. *Tithonia diversifolia*(Hemsl.) A.Gray

Huge patches of *Tithonia* were observed in 'Layam' premises of Kallar Estate, Kavungod road and along roadsides towards Pandimotta Camp. A small patch was also recorded nearby the Rosemala Ticket Counter.

25. *Tridax procumbens*L.

High infestation was noted in Kalamkunnu IB Entrance along the roadsides, Idimuzhanganppara Camp, Store Junction near Rosemala and at Rosemala hill top. The species has established the population in the sanctuary replacing the native species especially near tourist locations.

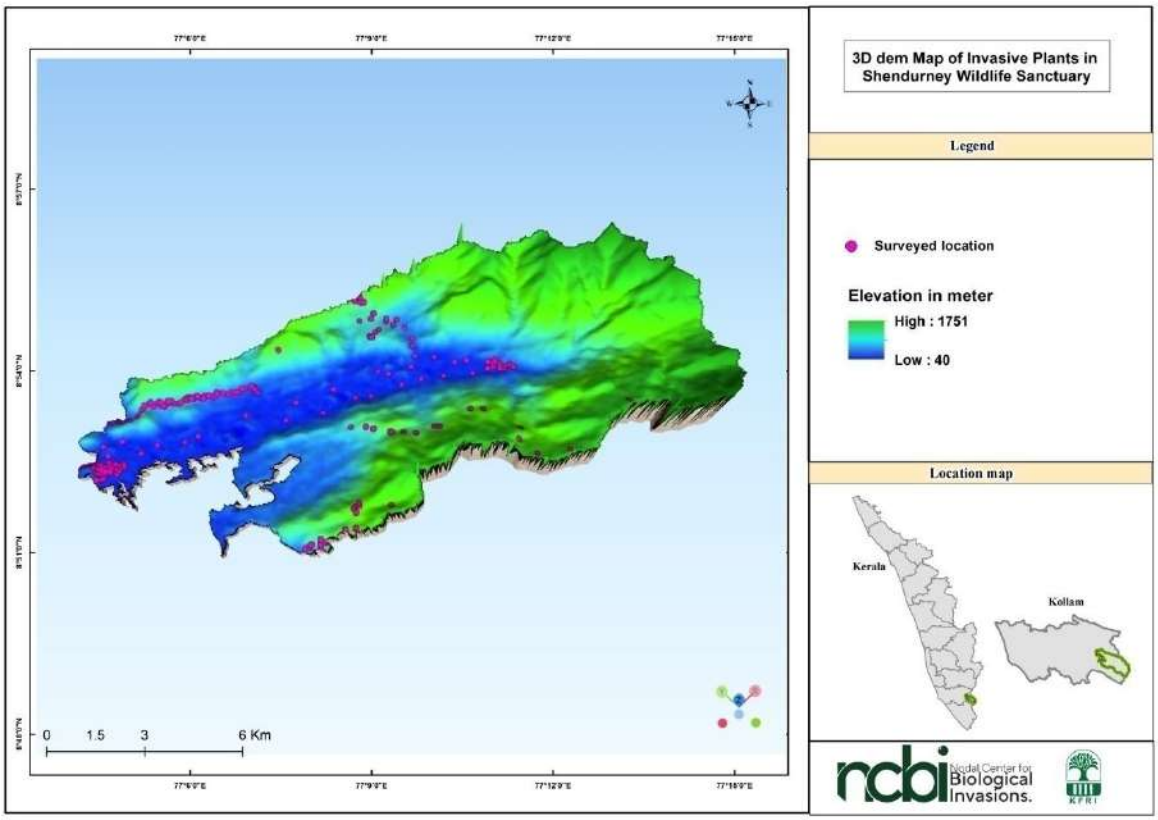


Figure 4. Map showing 3D DEM map of invasive alien plants recorded in Shendurney WLS

A comparison of invasive alien plants surveys conducted inside & periphery of Shendurney Wildlife Sanctuary

During state-wide road survey of invasive alien plants conducted by KFRI in 2011, a total of 17 invasive plants were recorded in the peripheral region of the Shendurney Wildlife Sanctuary. *Amaranthus spinosus*, *Centrosema molle*, *Chromolaena odorata*, *Hyptis capitata*, *Hyptis suaveolens*, *Lantana camara*, *Merremia vitifolia*, *Mikania micrantha*, *Mimosa diplotricha*, *Mimosa diplotricha* var.*inermis*, *Parthenium hysterophorous*, *Pennisetum polysatchyon*, *Prosopis juliflora*, *Ricinus communis*, *Senna occidentalis*, *Tithonia diversifolia* and *Tridax procumbens* were the plants identified in the periphery of sanctuary. Eight years later, three transect surveys (Kattilappara- Choodal Road, Idimuzhanganpara trekpath and Rockwood Estate) were conducted in 2019 and has recorded 18 invasive plants such as *Chromolaena odorata*, *Lantana camara*, *Merremia vitifolia*, *Mikania micrantha*, *Mimosa diplotricha*, *Mucuna bracteata*, *Pennisetum polystachyon*, *Pteridium aquilinum*, *Sphagneticola trilobata*,

Calopogonium muconoides, Tithonia diversifolia, *Ageratum conyzoides*, *Centrosema molle*, *Clidemia hirta, Alternanthera bettzickiana, Alternanthera brasiliana, Asclepias curassavica* and *Synedrella nodiflora*. The present survey has covered all the jeep-able and walk-able paths (2021) and identified 25 invasives. The presence and absence of invasive alien plants in these three surveys have listed in Table 2.

Table 2. Invasive alien plants recorded during surveys conducted in 2011, 2019 and 2021

IAP	2011(Peripheral survey)	2019 (Sanctuary-only 3 transects)	2021 (SWLS-complete)
Ageratum conyzoides	-	+	+
Alternanthera bettzeckiana	-	+	+
Alternanthera brasiliana	-	+	+
Amaranthus spinosus	+	-	-
Asclepias curassavica	-	+	-
Calopogonium mucunoides	-	+	-
Centrosema molle	+	+	+
Chromolaena odorata	+	+	+
Clidemia hirta	-	+	+
Hyptis capitata	+	-	-
Hyptis suaveolens	+	-	-
Lantana camara	+	+	+
Merremia vitifolia	+	+	+
Mikania micrantha	+	+	+
Mimosa diplotricha	+	+	+
Mimosa diplotricha var.*inermis*	+	-	-
Mucuna bracteata	-	+	+
Parthenium hysterophorus	+	-	-
Pennisetum polystachion	+	+	+
Prosopis juliflora	+	-	-
Pteridium aquilinum	-	+	+
Ricinus communis	+	-	+
Senna occidentalis	+	-	-
Sphagneticola trilobata	-	+	+
Synedrella nodiflora	-	+	+
Tithonia diversifolia	+	+	+
Tridax procumbens	+	-	+
Acacia auriculiformis	-	-	+
Ipomoea cairica	-	-	+

Ipomoea hederifolia	-	-	+
Pennisetum pedicellatum	-	-	+
Pueraria phaseoloides	-	-	+
Senna alata	-	-	+
Senna siamea	-	-	+

Invasive alien plants; *Centrosema molle, Chromolaena odorata, Lantana camara, Merremia vitifolia, Mikania micrantha, Mimosa diplotricha, Pennisetum polysatchyon* and *Tithonia diversifolia* were reported in all three surveys. There are invasive plant species that have only recorded in the periphery and not yet reported inside the sanctuary till date. The list includes *Amaranthus spinosus, Hyptis capitata, Hyptis suaveolens, Mimosa diplotricha* var *inermis, Parthenium hysterophorous, Prosopis juliflora* and *Senna occidentalis* where *Asclepias curassavica* and *Calopogonium muconoides* have recorded only during the 2019 survey. Also, invasive plants like *Ageratum conyzoides, Alternanthera bettzickiana, Alternanthera brasiliana, Clidemia hirta, Mucuna bracteata, Pteridium aquilinum, Sphagneticola trilobata* and *Synedrella nodiflora* have identified inside the sanctuary during 2019 and 2021 surveys, but haven't reported in 2011 survey.

Some of the notable observations were the shift on range of invasive alien plants in new locations as in the case of *Tithonia diversifolia*, which had been highly abundant along the forest fringes of Mannamthara enroute Idimuzhanganppara as indicated in the 2019 survey. However, the species was found absent in the same location in the present survey and noted in new locations with higher anthropogenic activities.

The 2021 survey yielded new records of *Pennisetum pedicellatum, Pueraria phaseolodies, Ipomoea cairica, Ipomoea hederifolia, Senna siamea* and *Senna alata* which weren't reported either in the periphery or during the 2019 survey. Invasives like *Tridax procumbens* and *Ricinus communis* reported in periphery during 2011 survey was absent in the 2019 survey, have now been observed in the sanctuary with wide and moderately wide distribution, under the risk category of high and medium respectively.

3b. Distribution of invasive alien plants in different forest sections

The distribution of invasive alien plants in each forest sections are given as follows.

3b.1Kalamkunnu Section West

High and medium risk invasive plants have been observed at Kalamkunnu IB, Thottappura, Earth Dam and Mannamthara (Fig. 5).

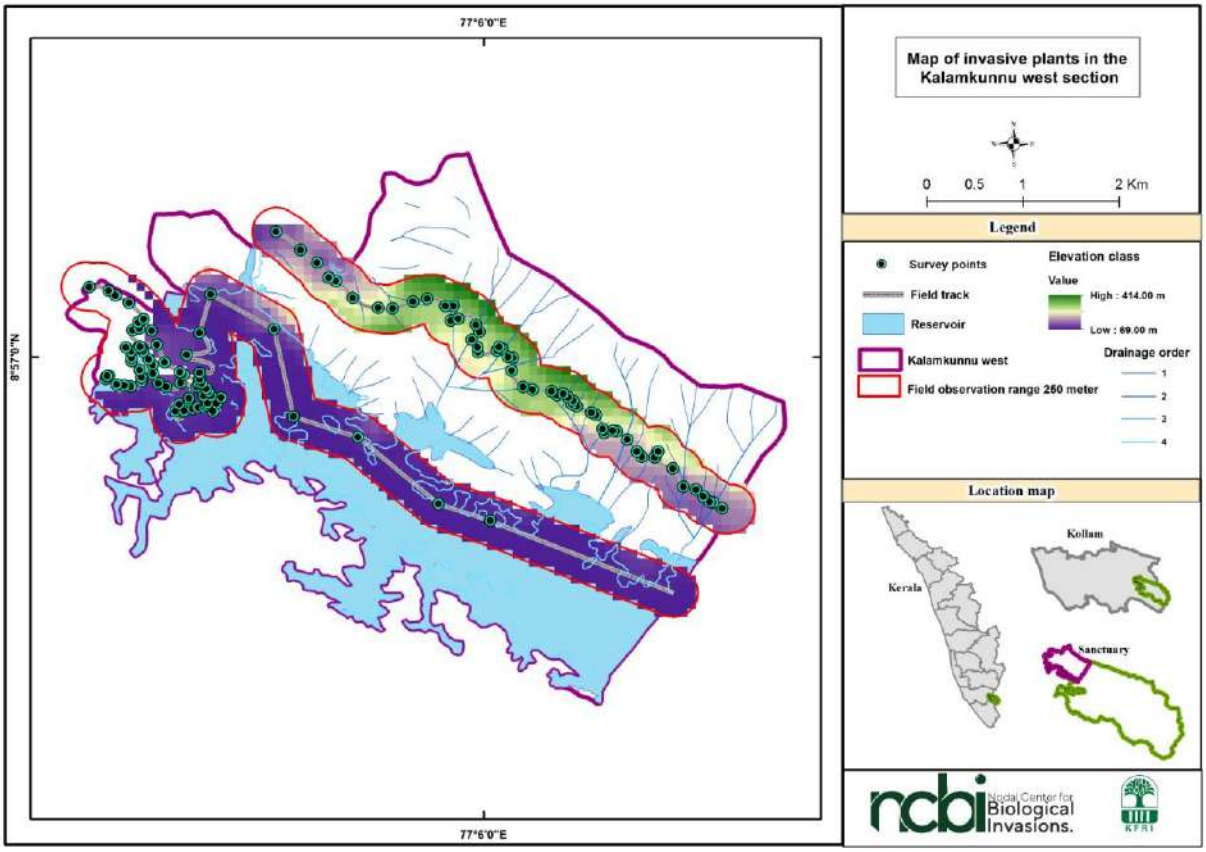


Figure 5.Map showing invasive alien plants recorded in Kalamkunnu West Section

Of the total 12 species recorded in this forest section, *Acacia auriculiformis*, *Ipomoea cairica*, *Mimosa diplotricha*, *Sphagneticola trilobata*, *Synedrella nodiflora*, and *Pteridium aquilinum* belong to medium risk while *Chromolaena odorata*, *Clidemia hirta*, *Lantana camara*, *Mikania micrantha*, *Senna siamea* and *Tridax procumbens* belong to high risk category. The spread of *Tridax procumbens* and *Chromolaena odorata* were very high especially along the roadsides and trek paths of this forest section. Presence of *Acacia auriculiformis* was only noted from an island located in the Parappar Reservoir. Most of the invasive plants were observed near the tourist

spots with high human footfall. A prominent invasion of *Senna siamea* was observed along the reservoir banks, located near the Earth Dam. The coppicing rate of *Senna* was found to be very high throughout its distribution.

3b.2 Kalamkunnu Section East

The section has a tourist camp at Idimuzhanganppara near the reservoir which can be accessed either by trekking or boating. The location is very much prone to invasive alien plants since this site is open for public for eco-tourism.

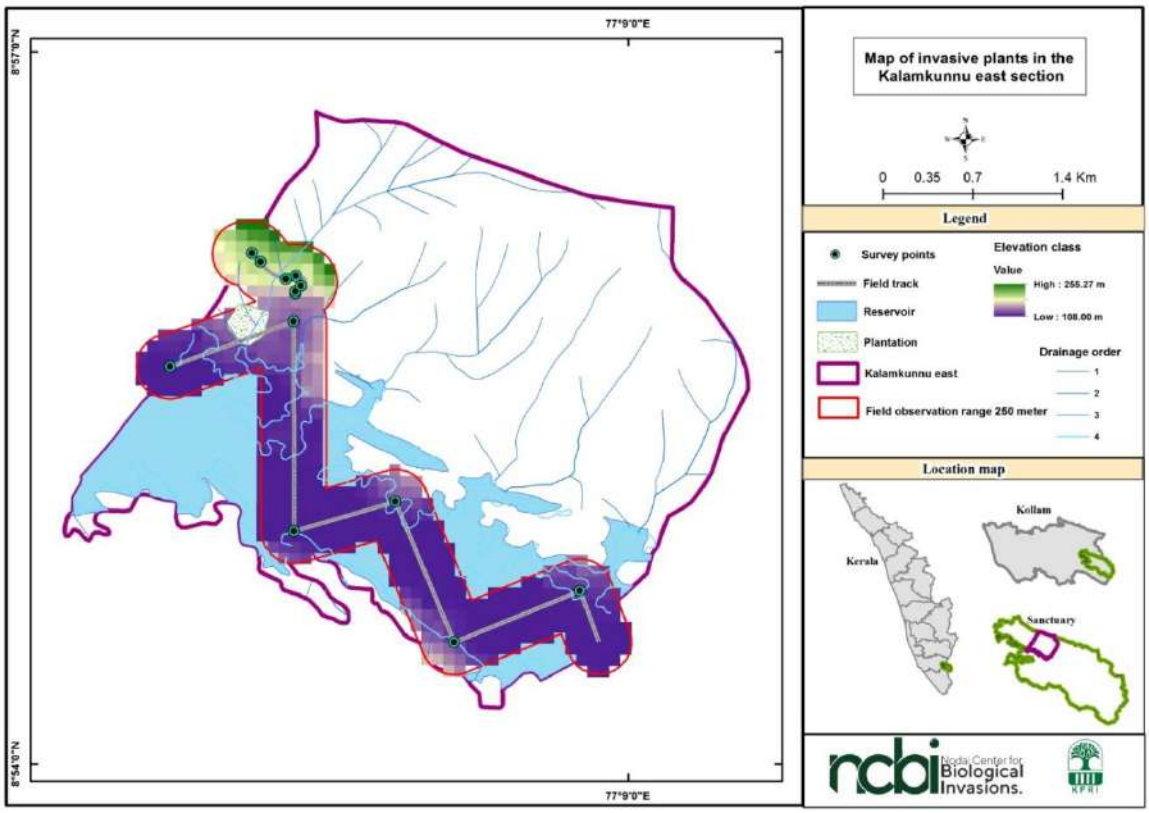


Figure 6.Map showing invasive alien plants recorded in Kalamkunnu East Section

Seven invasive plants have been recorded from this section which include *Chromolaena odorata*, *Lantana camara*, *Tridax procumbens*(higher risk species), and *Mimosa diplotricha*, *Pennisetum pedicellatum*, *Merremia vitifolia* and *Ricinus communis*(medium risk species). The spread of invasive plants are widespread along the trek path towards the camp from the boat- drop off point.

3b.3 Eetapadappu Section East

The section covers the major tourist attractions-Rosemala and a tourist camp at Pallivasal. Sixteen invasive plants which have been recorded from the section include *Alternanthera bettzickiana*, *Alternanthera brasiliana*, *Ipomoea hederifolia*, *Mimosa diplotricha*, *Pennisetumpolystachyon*, *Synedrella nodiflora*, *Merremia vitifolia*, *Centrosema molle*, *Pueraria phaseoloides* and *Ageratum conyzoides* under medium risk category and *Chromolaena odorata*, *Lantana camara*, *Mikania micrantha*, *Mucuna bracteata*, *Tridax procumbens*, and *Tithonia diversifolia* as high risk plants.

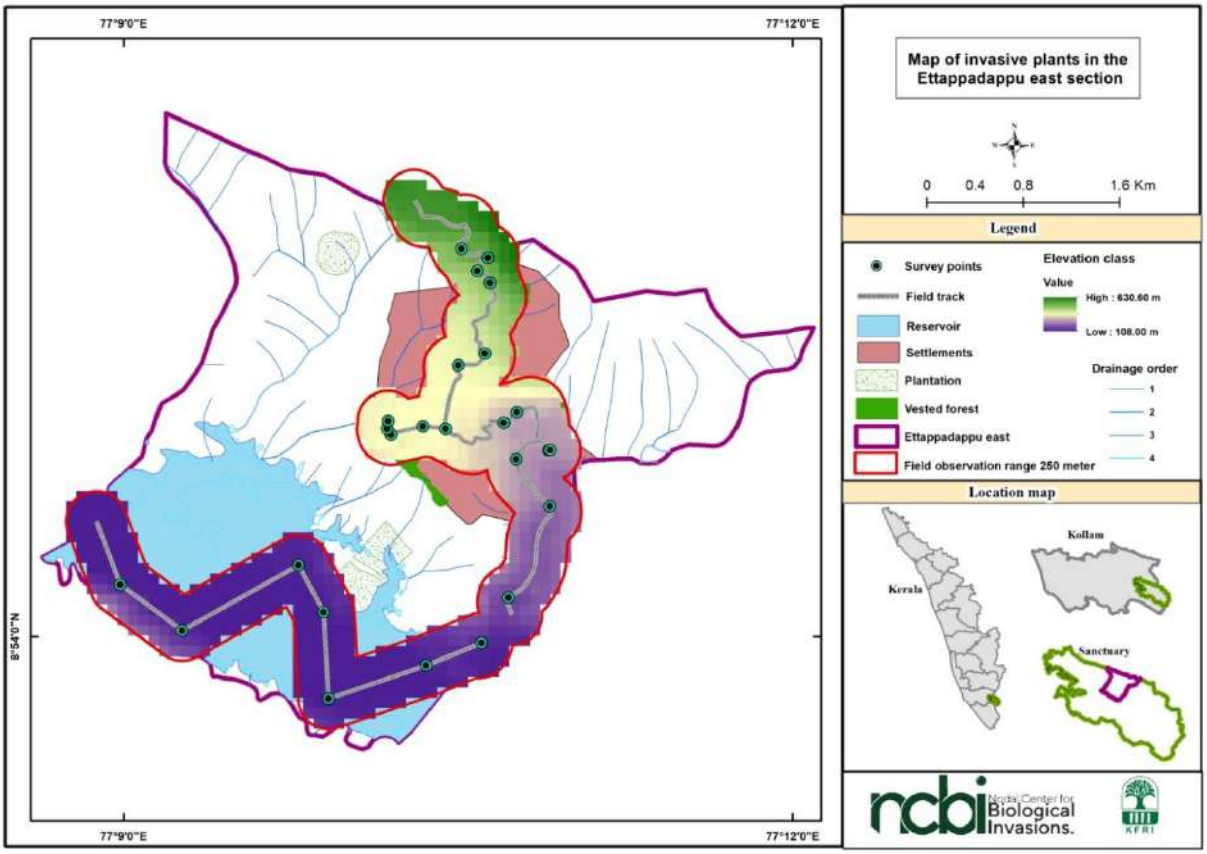


Figure 7.Map showing invasive alien plants recorded in Ettapadappu East Section

Mucuna bracteata was abundant near Rosemala Viewpoint where the species shifted its spread towards uphill from the plantations nearby. The species co-exited with another invasive plant, *Pennisetum polystachyon* on the hill top. Towards the Pallivasal Camp and the trek paths enroute reservoir, *Chromolaena odorata* and *Mikania micrantha* were widely distributed. The road towards the viewpoint that lie across human settlements, public transport may have accelerated

the spread of other invasive plants like *Alternanthera bettzickiana*, *Alternanthera brasiliana* and *Tridax procumbens* on the roadsides of Ambalamukku and Store Junction. Tourism could be a major pathway for the plant invasions in this forest section.

3b.4 Eetapadappu Section West

This forest section, located in the Core Zone of Shendurney, is threatened by the spread of 9 invasive plants:*Chromolaena odorata*, *Clidemia hirta*, *Lantana camara*, *Mikania micrantha*, *Mucunabracteata* (high risk species), and *Mimosa diplotricha*, *Pennisetum polystachyon*, *Synedrella nodiflora* and *Centrosema molle* (medium risk species).

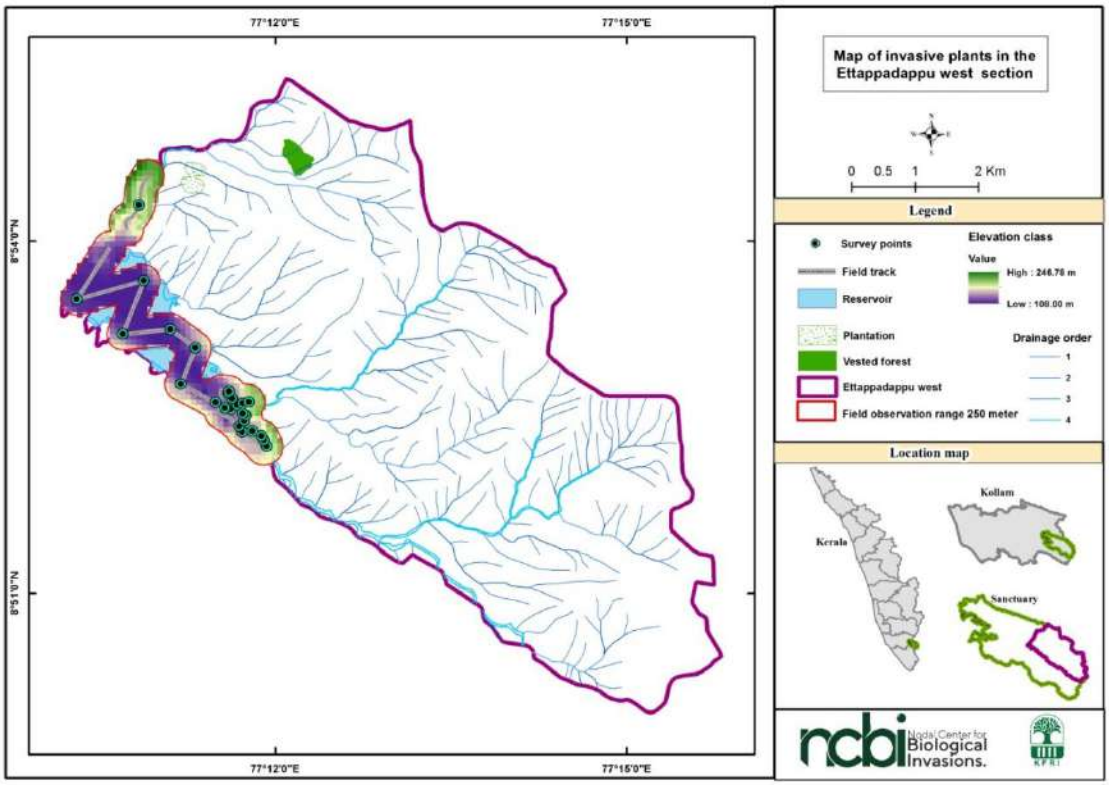


Figure 8.Map showing invasive alien plants recorded in Ettapadappu West Section.

Umayar, an anti-poaching camp situated under this section has marked with zero tourism activities. The trek paths in the area are only used by the Forest Department staff for regular patrolling and researchers. High risk plants were noticed on trek paths and in and around the camp where invasiveness ranged from low to high. Huge patches of *Lantana camara* occurred along the open banks of Shendurney Aar. Similarly, *Clidemia hirta* and *Mikania micrantha* were

also widely distributed near the Aar. High infestation of plants on the river bank noticed with less canopy cover is a major concern in the Core Zone.

3b.5 Kalluvarambu Section South

The section covers Rockwood Estate and Rockwood Camp- another major tourist spot in Shendurney Wildlife Sanctuary. Eleven invasive plants sighted in the section are *Chromolaena odorata*, *Clidemia hirta*, *Lantana camara*, *Mikania micrantha* and *Mucuna bracteata* (high risk species) and *Alternanthera bettzickiana*, *Alternanthera brasiliana*, *Ipomoea hederifolia*, *Pennisetum polystachyon*, *Synedrella nodiflora* and *Centrosema molle* (medium risk species).

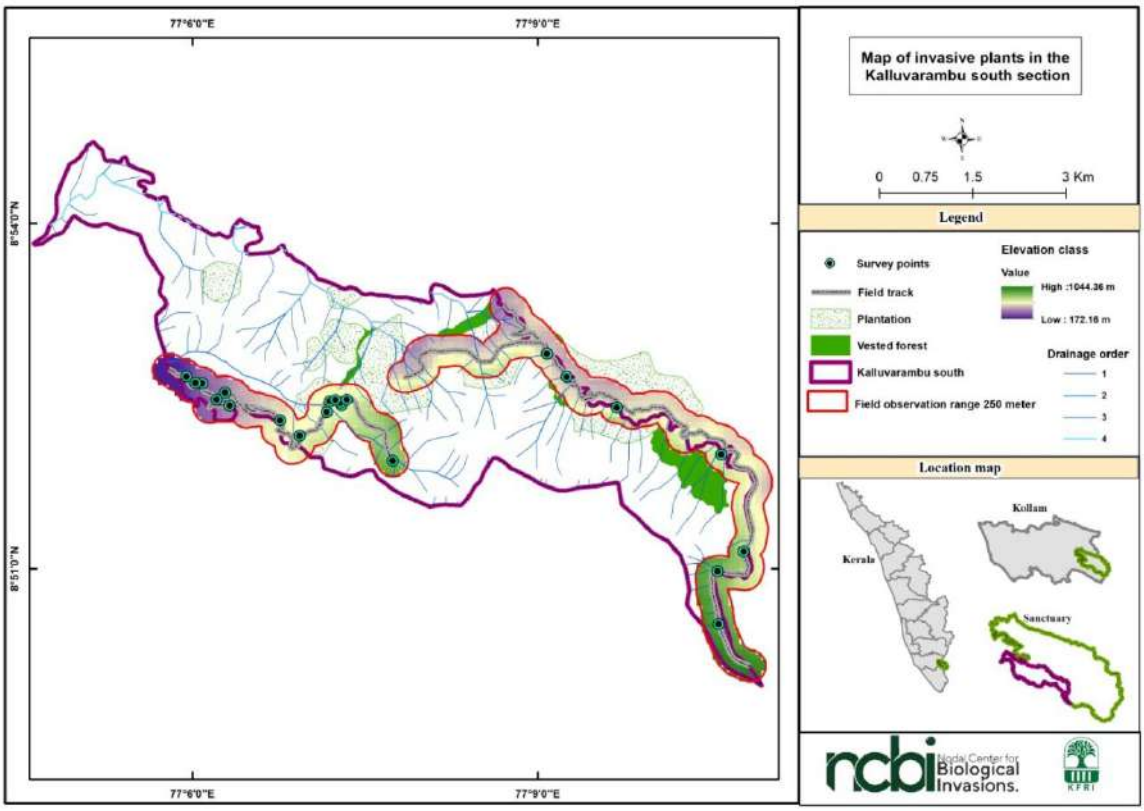


Figure 9.Map showing invasive alien plants recorded in Kalluvarambu South Section

High rate of invasion of *Mucuna bracteata*, *Lantana camara*, *Clidemia hirta* and *Mikania micrantha* was noted along the road sides of Rockwood Estate. Premises of Rockwood Camp along the trek paths which are frequented by tourists are also under threat of *Clidemia hirta* invasion.

3b.6 Kalluvarambu Section North

Six high risk and five medium risk species were recorded: *Chromolaena odorata*, *Clidemia hirta*, *Lantana camara*, *Mikania micrantha*, *Mucuna bracteata* and *Tithonia diversifolia* (high risk species) *and Ipomoea cairica, Pennisetum polystachyon, Synedrella nodiflora, Centrosema molle* and *Senna alata* (medium risk species). Of which, high spread of *Mucuna bracteata* was very evident on plantations and roadsides. Heavy spread of *Tithonia diversifolia* and moderately low spread of *Ipomoea cairica* was noted at 'Layam' premises in Kallar Estate. Similar kind of invasion was observed enroute Pandimotta Anti-poaching camp. Roadsides towards Pandimotta were also invaded by *Clidemia hirta*, *Lantana camara* and *Mikania micrantha*. Moderate spread of *Senna alata* in a small patch was observed on roadsides. Very few invasive plants (few saplings of *Clidemia hirta*) have been recorded in the Anti-poaching camp.

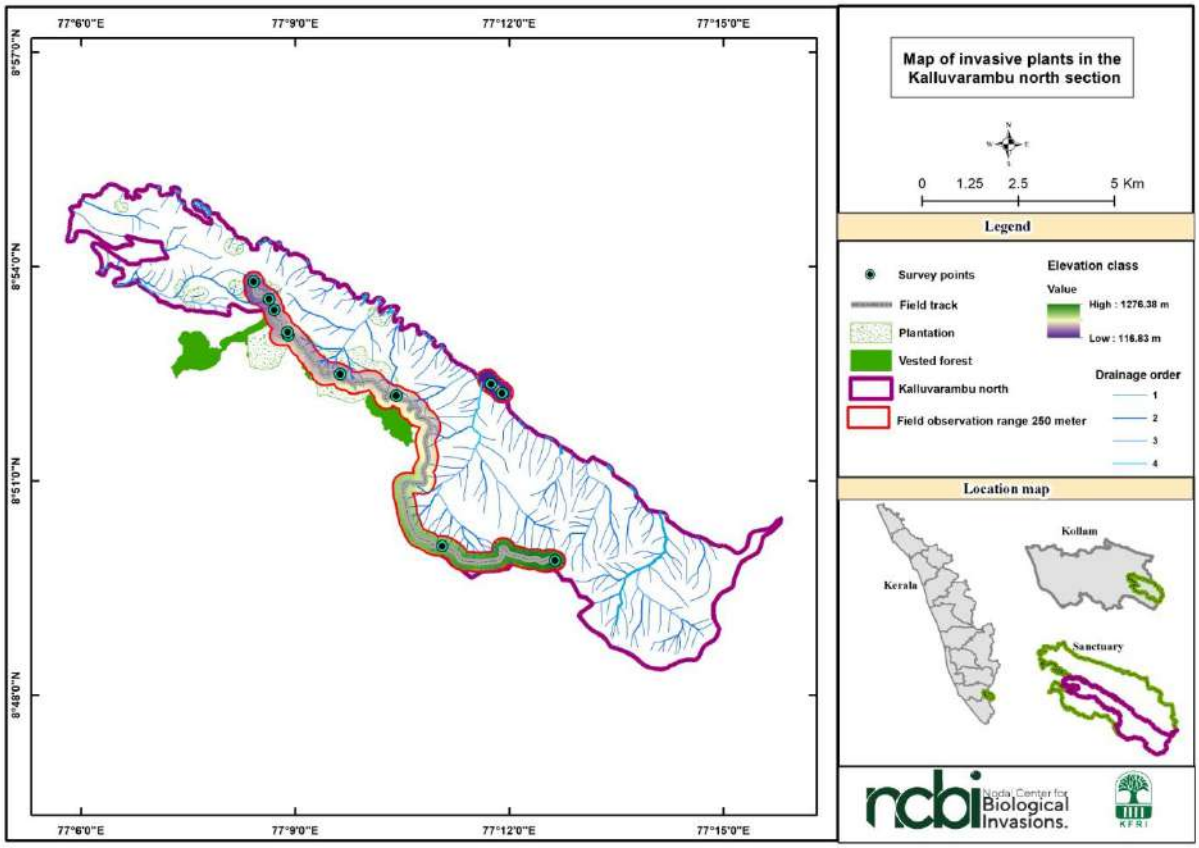


Figure 10. Map showing invasive alien plants recorded in Kalluvarambu North Section.

3c. Distribution of Invasive Alien Plants based on Forest Zonation

The Tourism Zone includes the Earth Dam, Kalmkunnu IB, Kalamkunnu Island Hut, Mannamthara and Idimuzhanganppara Camp. The tourist route to Parappar Dam joining with Kalamkunnu IB is under threat of invasion by plants such as *Tridax procumbens*, *Clidemia hirta* and *Ipomoea cairica*. A total of 20 invasive plants (13 medium risk and 7 high risk species) were recorded from the Tourism Zone that spread along the roadsides of Kalamkunnu IB and Rock wood Estate, forest fringes of Mannamthara and the trek paths towards Idimuzhanganppara. The observed invasive plants were *Acacia auriculiformis*, *Alternanthera brasiliana*, *Chromolaena odorata*, *Clidemia h*irta, *Ipomoea cairica*, *Ipomoea hederifolia*, *Lantana camara*, *Mikania micrantha*, *Mimosa diplotricha*, *Mucuna bracteata*, *Pennisetum pedicellatum*, *Pennisetum polystachyon*, *Senna siamea*, *Sphagneticola trilobata*, *Synedrella nodiflora*, *Tridax procumbens*, *Merremia vitifoli*a, *Centrosema molle*, *Pteridium aquilinum* and *Ricinus communis*. Intense spread of *Mucuna bracteata* was noted in plantations of Rockwood Estate. It was also noted that species have started to spread outside the plantations into new habitats. Another high risk species, *Chromolaena odorata* has widely spread in the Tourism Zone especially near to Kalamkunnu IB, Mannamthara and Rockwood Estate. Likewise, heavy invasion by *Senna siamea* with high coppicing rate was noted near Earth Dam. The species may be able to establish their population to new habitats of the sanctuary very soon. The major high risk species in the Tourism Zone such as *Chromolaena odorata*, *Lantana camara*, *Clidemia hirta*, *Mucuna bracteata* and *Tridax procumbens* needs urgent monitoring and management.

In Buffer Zone, 19 invasive alien plants including 12 medium and 7 high risk species were recorded. Major tourist attractions like Rosemala Viewpoint, Pallivasal Camp and Rockwood Camp are located in this zone. Also, the two major estates- Kallar and Rockwood fall under this zone. The threat of spread of invasive plants is comparatively high in tourist locations and nearby human settlements. Roadsides near Ambalamukku and Store Junction were dominated by the spread of species such as *Alternanthera bettzickiana*, *Alternanthera brasiliana* and *Chromolaena odorata*. These species have extensively established their population in Kallar, Rosemala and Rockwood. Similarly, *Clidemia hirta* invaded the landscapes of Rockwood and Kallar. *Ipomoea cairica* and *Tithonia diversifolia* was observed near 'Layam' premises in Kallar Estate (medium risk invasive), *Ipomoea hederifolia*- an ornamental plant was sighted in human settlements of

Rosemala. *Lantana camara*, another high risk invasive alien plant was noted in Kallar Estate enroute Pandimotta and Rosemala. Infestation of *Mucuna bracteata* and *Pennisetum polystachyon* was noted near Rosemala Viewpoint, ticket counter and roadsides.

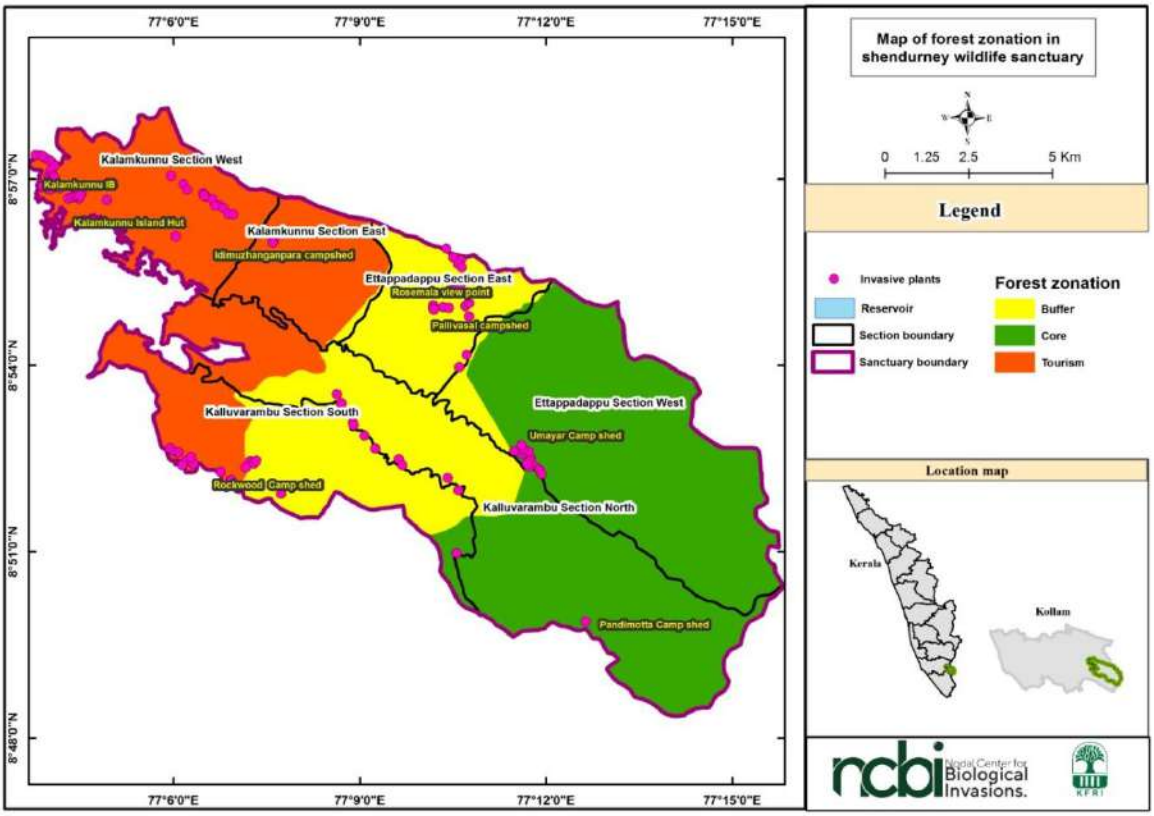


Figure 11. Map showing presence of invasive alien plants based on forest zonation

The Core Zone covers Umayar and Pandimotta Anti-poaching camps with minimum human interference as this zone is frequented only by staff of the Forest Department. Umayar Camp is accessible via boat or by trekking from Pandimotta. Nine invasive alien plants (5 high risk and 4 medium risk species) recorded in Umayar are *Chromolaena odorata*, *Clidemia hirta*, *Lantana camara*, *Mikania micrantha*, *Mimosa diplotricha*, *Mucuna bracteata*, *Pennisetum polystachyon*, *Synedrella nodiflora* and *Centrosema molle*. High invasion of *Lantana camara* and moderate invasion of *Clidemia hirta* and *Mikania micrantha* as small patches were noted along the banks of Shendurney Aar. Unlike Umayar, trek paths of Pandimotta are under moderate risk of invasion of a single species- *Clidemia hirta*. Most of the invasive species have identified on trek paths and areas without a canopy cover. The seeds of invasive plants stuck or trapped in forest

personnel's shoe or clothing could potentially be a cause for the invasion in Core Zone. A few invasions have also been observed in the trench made around the Anti-poaching Camp.

3d. Relationship of distribution and spread of invasive alien species to the site Characteristics:

i. Canopy cover

The relationship between extend of canopy cover and occurrence of invasive alien plants was explored. The percentage of canopy cover observed in the surveyed locations (covering a total of 382 sites or coordinates) of the sanctuary ranges from 0-71.34%. The presence of invasive alien plants were noted and visually assessed along with the canopy cover. Ecologists have hypothesised a negative relationship between the canopy cover and incidence of invasive alien plants. Thus, an increase in canopy cover is expected to reduce invasion rate of alien plant species in an area. Open habitats and high sun exposure are prerequisites for the dispersal, germination and establishment of invasive species.

However, in Shendurney, we couldn't find a definite negative relationship between canopy cover and incidence of invasive alien species. As per the hypothesis, there were no invasives recorded in areas with high canopy percentage (50% and 70%). On contrary, areas with canopy percentage ranges between 0% -71.34% have also shown varying incidence of invasives. This trend with no definite relationship between canopy cover and invasive species occurrence indicates that other ecological factors might be at play in determining the dispersal and establishment of the invasive species.

ii. Tourism

Shendurney provides ample opportunities for tourists to experience the scenic beauty and wilderness.Trekking to Kattilappara and Neduvannukadavu, Enippara and Mannamthara, Rosemala and Pallivasal, and jungle camps at Idimuzhanganppara, Rockwood and Island hut, and boat ride in the Parappar dam reservoir are major attractions of the sanctuary. The tourism in the sanctuary is one of the major pathways for unintentional introductions and spread of invasive alien plants into these vulnerable ecosystems. Activities such as trekking, camping and boat riding can act as pathways for the dispersal of seeds of invasive alien species. The seeds stuck to clothes, footwear, vehicles of tourist or forest personals could be

major cause of alien species invasions. The results shows that the abundance of certain invasive alien plants are considerably higher in sites where major tourist activities take place. Invasive plants such as *Chromolaena odorata* and *Mimosa diplotricha* have been recorded near Earth Dam, where tourists abound. Kalamkunnu Island Hut, located in the Parappar Reservoir and accessed by tourists via boat, is under risk of spread of invasive species, *Acacia auriculiformis* and *Sphagneticola triobata*. It is remarkable that these two species have notbeen recordedelsewhere in Shendurney and the island could act as potential source pool for further inadvertent introductions to other areas of the sanctuary. *Clidemia hirta* was widespread and abundant at Rockwood camp which is a favourite among the eco-tourists. Rosemala and Pallivasal are usually frequented by teenagers and biker's clubs for off-road experience where vehicles can be potential vectors of introductions. These observations highlight the need for biosecurity interventions to prevent the unintentional introductions of invasive alien species.

iii. Drainage

Soil drainage is known to negatively affect occurrence of invasive plant species in an area. Overall results show a moderate kind of invasion near drainage pathways because invasive plants have been identified in locations with very low, low, moderate, and high drainage conditions. Invasives occurred at Kalamkunnu, Earth Dam, Rosemala and Pandimotta where drainage was moderate, low or very low. At Mannamthara, most of the invasive plants occurred where drainage was moderate, while at Kallar Estate they occurred in moderate and low drainage conditions. Invasive plants occurred in low or very low drainage soils at Rockwood (Fig. 12). The invasive plant species are highly adapted to grow in extreme conditions which are typical of many hardy plant species. Nevertheless, high risk invasive species were recorded in high drainage locations along the banks of Shendurney Aar at Umayar which lie in core zone of the sanctuary.

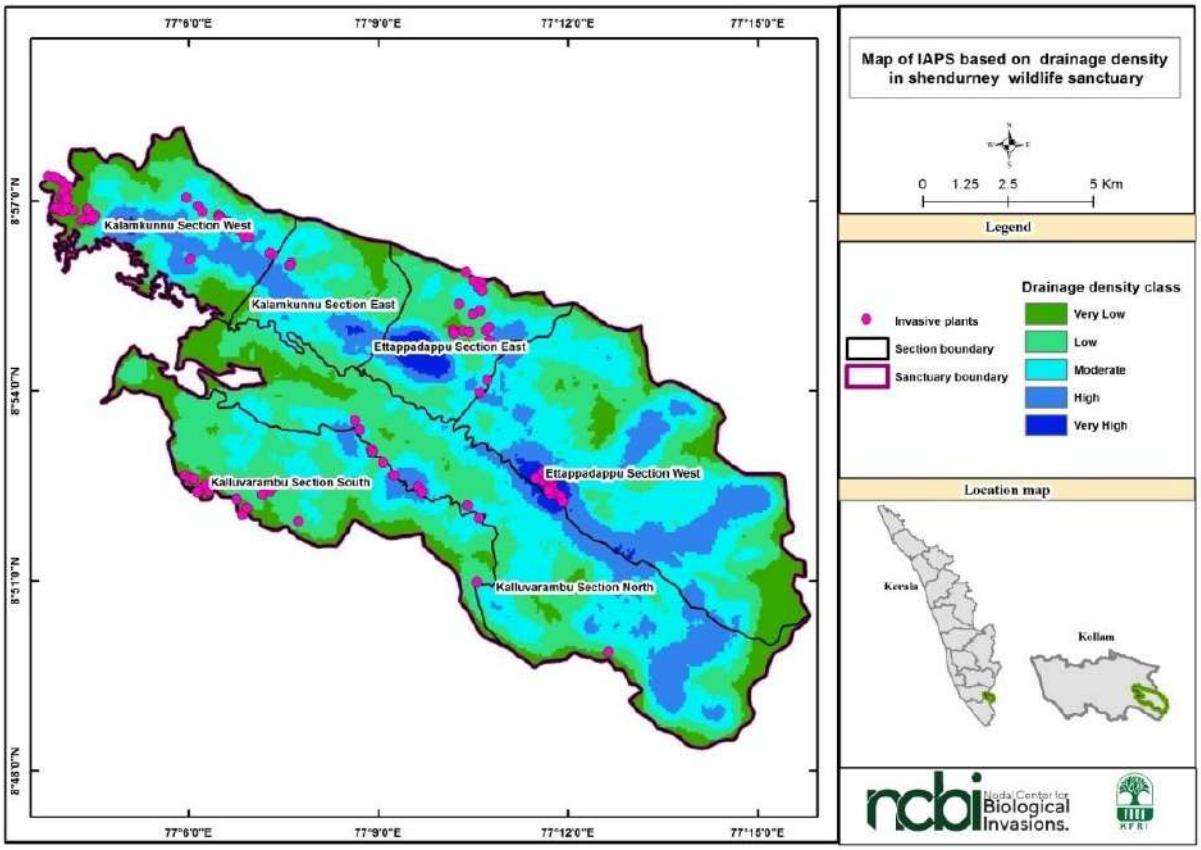


Figure 12. Map showing the presence of invasive alien plants based on drainage density.

iv. Boundary habitats

A map of habitats outside the boundary of the sanctuary was prepared by drawing a buffer of one kilometre. The boundary habitat map allows visualising and assessing the type and extending of edge habitats outside the boundary that could potentially be source pool for new introductions of invasive plants into the sanctuary.

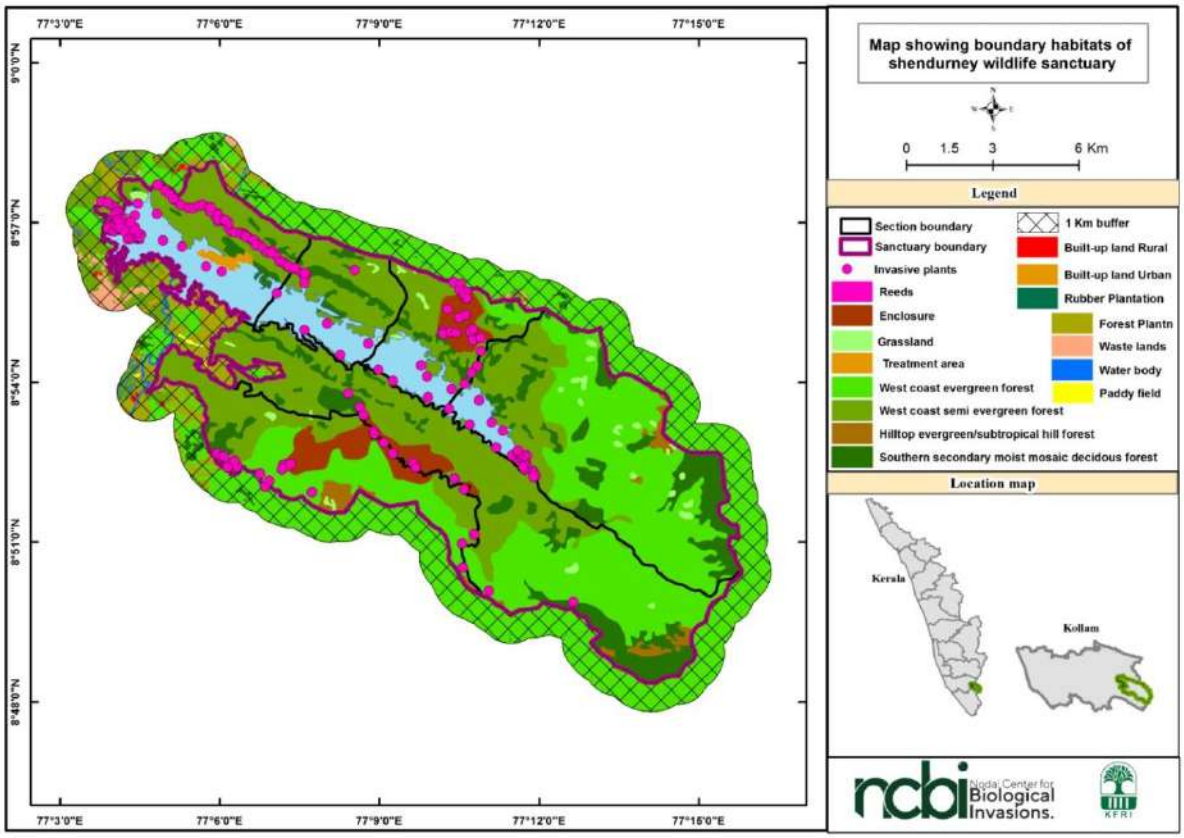


Figure 13. Map showing the presence of invasive alien plants recorded and the boundary habitats.

The West Coast Semi-evergreen forests border most of the sanctuary perimeter, except along the western side (Fig. 13). The western border of the sanctuary adjoining the Tourism Zone is covered by wastelands, hill top evergreen forests, rubber plantations, paddy fields and rural built-ups. A short stretch of similar habitats and plantations was also found outside the sanctuary adjacent to Rosemala Viewpoint. The plantations could potentially be a source of heavy invasion of *Mucuna* sp. into the sanctuary. Presence of wastelands outside sanctuary is another possible route for spreading of invasives. Likewise, presence of paddy fields, which are prone to Sphagneticola invasion, is also a concern. Though the invasion of Sphagneticola has only been noted from Kalamkunnu Island Hut within the sanctuary, the species occurs elsewhere outside the sanctuary. The map of boundary habitats makes it very evident that the areas within the Tourism Zone especially that border with disturbed habitats outside the sanctuary can be the critical entry points for invasive into the sanctuary than any

other areas. Moreover, it is remarkable that a disturbance along the periphery of the sanctuary will in turn increases the invasion rate of alien species inside the sanctuary.

v. Forest Zonation

The Tourism Zone especially that border with disturbed habitats outside the sanctuary can be the critical entry points for invasive into the sanctuary. In the Buffer Zone, the tourist activities and anthropogenic disturbances are prominent causes for spread of invasive alien plant species. The Core Zone, which is only frequented and patrolled forest personals, also found to harbour certain high risk invasive plants.

3e.Risk Assessment

i. Priority list of Invasive Alien Plants after risk assessment

Based on the survey conducted, a total of 25 invasive plant species have been recorded from the sanctuary and later the risk assessment of each plant observed has been done separately using the Generic Impact Scoring System (GISS). Based on the GISS score calculated for each invasive plant species, their impact risks were assessed and classified as High risk and Medium risk species. The system consists of 12 impact categories including the ecological and socio-economic impacts that an invasive alien species can exert. The intensity of each species was quantified in a scale ranging from zero to five showing no impact and the highest impact respectively. Each impact category was assigned a maximum of score 5 which makes a total of 60 to account for both ecological and socio economic impacts. The score finally calculated out of sixty were categorized as High risk and Medium risk species; those with GISS score more than twenty and less than twenty correspondingly.

Table 3. List of risk assessed invasive alien plants with their impact category

#	Plant Species	Risk Category
1.	*Acacia auriculiformis*	Medium
2.	*Ageratum conyzoides*	Medium
3.	*Alternanthera bettzickiana*	Medium
4.	*Alternanthera brasiliana*	Medium
5.	*Centrosema molle*	Medium

6.	*Chromolaena odorata*	High
7.	*Clidemia hirta*	High
8.	*Ipomoea cairica*	Medium
9.	*Ipomoea hederifolia*	Medium
10.	*Lantana camara*	High
11.	*Merremia vitifolia*	Medium
12.	*Mikania micrantha*	High
13.	*Mimosa diplotricha*	Medium
14.	*Mucuna bracteata*	High
15.	*Pennisetum pedicellatum*	Medium
16.	*Pennisetum polystachion*	Medium
17.	*Pteridium aquilinum*	Medium
18.	*Pueraria phaseoloides*	Medium
19.	*Ricinus communis*	Medium
20.	*Senna alata*	Medium
21.	*Senna siamea*	High
22.	*Sphagneticola trilobata*	Medium
23.	*Synedrella nodiflora*	Medium
24.	*Tithonia diversifolia*	High
25.	*Tridax procumbens*	High

ii. Distribution of Invasive Alien Plants based on risk impact

Based on the GISS score, the invasive plants have been classified into High risk and Medium risk plants (Table 4). From the survey conducted, high risk plants of Shendurney include the *Chromolaena odorata*, *Clidemia hirta*, *Lantana camara*, *Mikania micrantha*, *Mucuna bracteata*, *Senna siamea*, *Tridax procumbens* and *Tithonia diversifolia* and medium risk plants are *Acacia auriculiformis*, *Alternanthera bettzickiana*, *Alternanthera brasiliana*, *Ipomoea cairica*, *Ipomoea hederifolia*, *Mimosa diplotricha*, *Pennisetum pedicellatum*, *Pennisetum polystachyon*, *Sphagneticola trilobata*, *Synedrella nodiflora*, *Merremia vitifolia*,

Centrosema molle, Pueraria phaseoloides, Ageratum conyzoides, Senna alata, Pteridiumaquilinum and Ricinus communis.

Table 4. List of invasive alien plants categorized based on GISS Score.

#	Plant Species	GISS Score	Risk Category
1.	*Ipomoea hederifolia*	4	Medium
2.	*Pteridium aquilinum*	4	Medium
3.	*Ricinus communis*	4	Medium
4.	*Sphagneticola trilobata*	4	Medium
5.	*Centrosema molle*	5	Medium
6.	*Pennisetum pedicellatum*	5	High
7.	*Acacia auriculiformis*	7	High
8.	*Ageratum conyzoides*	7	Medium
9.	*Merremia vitifolia*	7	Medium
10.	*Senna alata*	9	High
11.	*Synedrella nodiflora*	9	Medium
12.	*Pennisetum polystachion*	11	High
13.	*Alternanthera brasiliana*	12	Medium
14.	*Alternanthera bettzickiana*	13	High
15.	*Ipomoea cairica*	14	Medium
16.	*Pueraria phaseoloides*	16	Medium
17.	*Mimosa diplotricha*	17	Medium
18.	*Tridax procumbens*	21	Medium
19.	*Senna siamea*	22	Medium
20.	*Clidemia hirta*	25	Medium
21.	*Chromolaena odorata*	27	High
22.	*Tithonia diversifolia*	27	Medium
23.	*Lantana camara*	28	Medium
24.	*Mucuna bracteata*	32	High
25.	*Mikania micrantha*	34	High

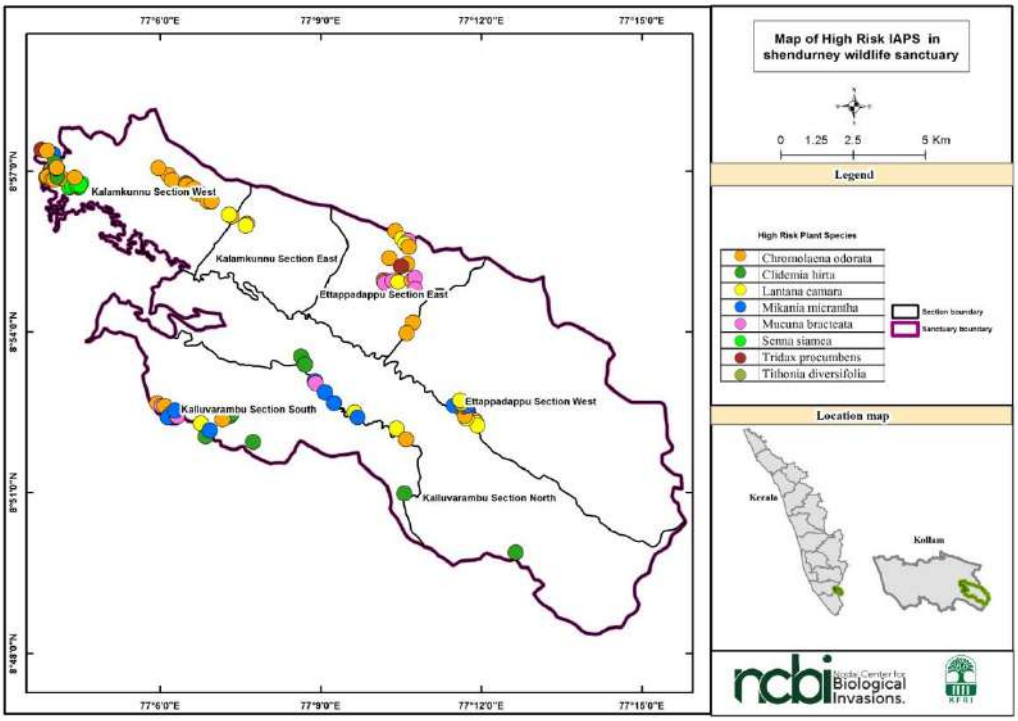


Figure 14. Map showing high risk invasive alien plants of Shendurney

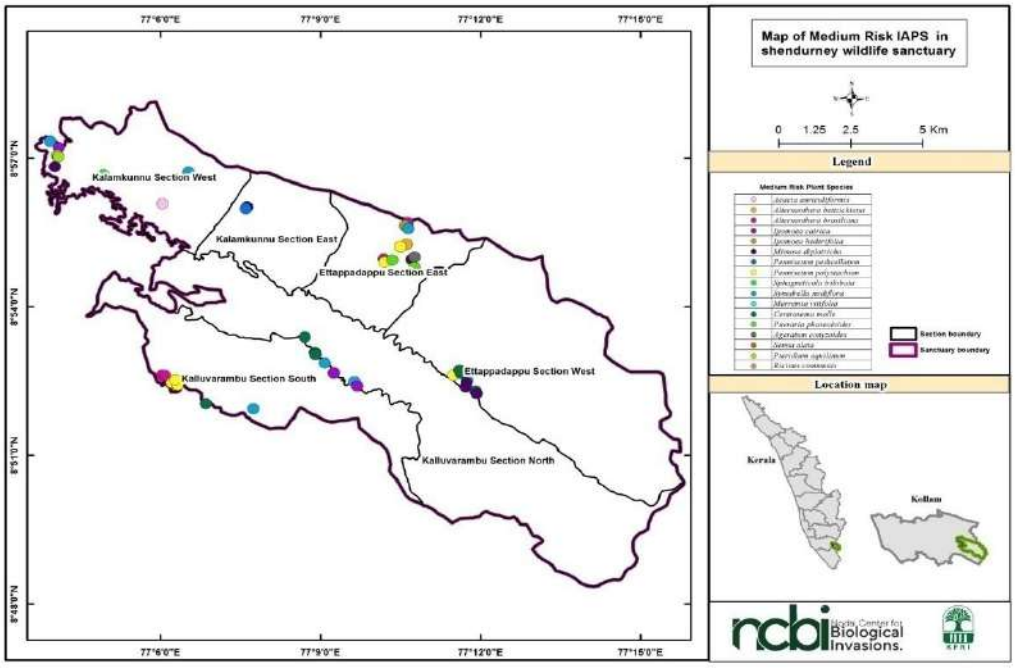


Figure 15. Map showing Medium risk invasive alien plants of Shendurney

3f. Site prioritization map for urgent management

Control and management of invasive alien species should depend on the degree of invasion, based on which the probable management can be suggested. In an area where a recent invasion has occurred, the best possible management strategy to contain the species is its Early Detection and Rapid Response (EDRR) followed by physical methods. If the invasive have already established their range by reproducing populations, then 'slow the spread' methods can be tried which arrests their reproduction. For species which have established in a larger landscape for a period of time, the above mentioned strategies would not provide better results. So for those kinds of invasions, habitat restoration methods can be followed by combining physical removal procedures. But it is more important to restore the cleared landscapes with the native species once the invasive species get removed.

Site prioritization maps were prepared based on forest sections, where sites that need urgent action to manage the invasive are illustrated. The Earth Dam premises enroute Kalamkunnu IB, where *Senna siamea* infestation was observed need an urgent action under the forest Section- Kalamkunnu West. In the Kalamkunnu East section, regions adjacent to Idimuzhanganppara Camp are under threat of invasive species, which needs immediate action to control them. Under the section, Eetapadappu West- the roadsides near Ambalamukku and store junction and the Rosemala Viewpoint are under threat of invasive plants which have to be managed soon. Towards the core zone in Umayar, the invasion along river banks has to be controlled otherwise they can harm other native plant species. Towards the Kalluvarambu Section North, the area near to Umayar Camp has shown high invasive density which should be controlled immediately. Under Kalluvarambu Section South, roadsides along Rockwood plantation have to give priority while managing invasive species.

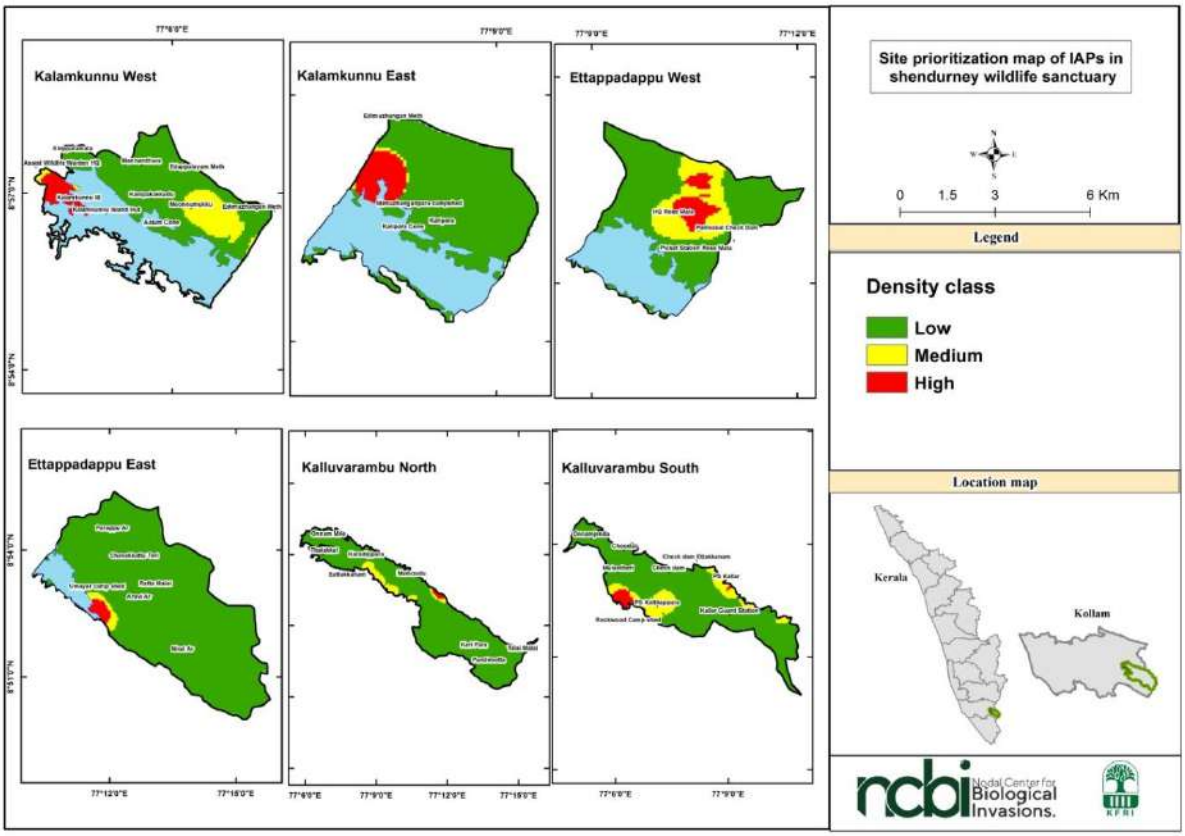


Figure 16. Site prioritization maps for each forest section for urgent weed management.

3g. *Mahogany* as a potential IAS

i.The problem

During the survey conducted in 2019, the forest department officials have reported that the *Mahogany* tree species were showing an invasive nature in the forest area of Choodal. We have visited the area and observed a large number of regenerating saplings of the species. We were told that the mahogany was planted in that area during 1999-2000 with around 20 to 25 saplings. We had revisited the site during the survey conducted in 2021 and observed a wide range of *Mahogany* tree distribution near Choodal with saplings, adults and matured ones. We had observed plenty of mahogany trees amidst the low elevation evergreen forest.

ii. Current status

Distribution of *Mahogan*y trees has expanded to a wider region covering a larger area with regenerating saplings. The area will be entirely under the threat of *Mahogany*, if not managed well. Number of samplings is found to be very high compared with that of adult *Mahogany* trees. Seed pods were also observed in the plot premises which can produce around 40-50 seeds. To understand the nature and extentof invasiveness of the *Mahogany* in Shendurney Wildlife Sanctuary, we have laid three experimental plots on different elevations with two replicates each. Elevation and geo-coordinates of each plot were marked separately. From each plot and its replicates; number of saplings, adult trees and matured ones were recorded along with the number of seeds observed.

iii. Observations from the Experimental Plot

Three experimental plots have been marked as 1,2 and 3 with replicates as 1a,1b,1c,2a,2b,2c,3a,3b and 3c. Number of saplings and adult trees observed was higher than the number of seeds per plot. Total number of saplings recorded from the first plot including the replicates is 119 followed by 230 in second and 331 in third while adult trees are higher in first plot (167) followed by second (100) and least recorded in third(51). Seeds have only been observed from Plot 1 with a total of 13 in number.

Table 5. Table showing observations from experimental plots to study the potential invasiveness of *Mahogany*

Plot #	Elevation(m) (Avg.)	No. of Saplings	No. of Adult trees	No. of matured trees	No. of Seeds
1a	176	48	43	0	5
1b		47	75	0	4
1c		24	49	0	4
2a	172	107	33	0	0
2b		72	27	1	0
2c		51	40	0	0
3a	170	88	19	3	0
3b		160	18	3	0
3c		83	14	9	0

iv. What can we do?

Restoration methods like debarking and uprooting of saplings can be tried in experimental plots to determine the best possible method of control. The cleared landscape should be restored immediately with native plants found nearby the plot.

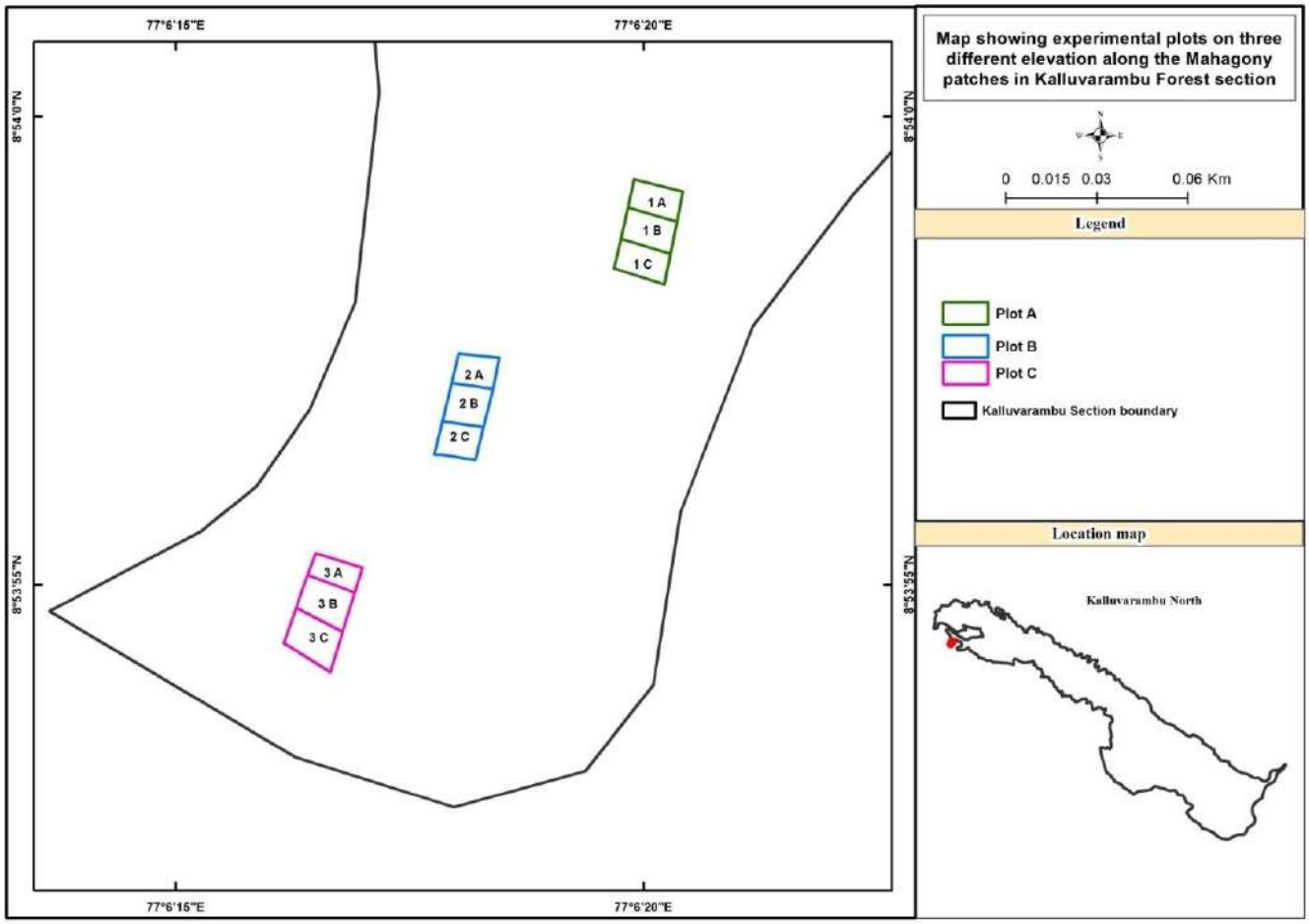


Figure 17. Map showing experimental plots along the *Mahogany* patches in Choodal area

Figure 18. Site inspection by the officials and research team in *Mahogany* plot

Figure 19. Setting experimental plots at three different elevations in *Mahogany* invaded locations.

v. List of native plants observed nearby the invaded plot

Eighteen native plants have been identified from the locations nearby Mahogany trees which can be used for restoring the invaded landscapes.

Table 6. List of native plants observed nearby *Mahogany* plot

#	**Native plant species**	**Local Name**
1.	*Aporosa cardiosperma*	Vetti
2.	*Cinnamomum malabatrum*	Vayana
3.	*Mesua ferrea*	Nangk
4.	*Kingiodendron pinnatum*	Kulav
5.	*Vitex altissima*	Maila
6.	*Aporosa acuminata*	Neerotti
7.	*Aegle marmelos*	Koovalam
8.	*Polyalthia fragrans*	Nedunari
9.	*Terminalia paniculate*	Maruth
10.	*Syzygium cumini*	Njaval
11.	*Macaranga peltate*	Vatta
12.	*Hydnocarpus pentandra*	Maravetti
13.	*Bischofia javanica*	Chorakaali
14.	*Dalbergia latifoloia*	Veetti
15.	*Hopea parviflora*	Kambakam
16.	*Butea monosperma*	Plash
17.	*Calophyllum polyanthum*	Punnamaram
18.	*Cullenia exarillata*	Vediplav

3h. Management strategies to be taken after bamboo flowering

Patches of flowered Bamboo have been observed enroute Choodal via Kattilappara which can provide a suitable platform for invading species to establish inside the Sanctuary. The invasive plant saplings growth will be doubled in the first year when the solar radiations hit the forest floor after the bamboo flowering. The understory invasive will rapidly establish their population since the canopy is open. So management methods have to be adopted specifically according to the location to contain the population of invaded populations.

3i. Species on the wings

Based on the survey results, some of the medium risk plants recorded in the sanctuary have a potential to shift their impact into high risk. Plants like *Mimosa diplotricha*, *Pennisetum polystachyon*, *Synedrella nodiflora* and *Alternanthera bettzickiana* have a potential to be a high risk plant in the near future. Presence of *Mimosa diplotricha* has been noticed nearby Earth Dam has recorded high tourist footfall. Being a tourist destination, invasion of this plant species could have been occurred at much more pace than other invasives. Similarly, *Pennisetum polystachyon* observed in Rosemala Viewpoint is another tourist location with moderate tourist footfall. *Synedrella nodiflora*- an invasive plant mostly found along roadsides and trek paths of Shendurney can be a potential high risk species very soon. Spread of *Alternanthera bettzickiana* noticed enroute Rosemala- a place where human interference is very high, will be shifted into heavy infestation in a little while.

3j. Tourism guidelines

Shendurney being an eco-tourism centre, the chances for new invasive introductions are plenty. So guidelines have to be published for tourists visiting the sanctuary. Sterilization, disinfection and cleaning of clothing, shoes, hands and legs of tourists are necessary before and after the sanctuary visit. Department staff jeeps -especially the wheels, used for eco-tourism activities have to be disinfected pre and post travel. Awareness can be done on invasive alien species by distributing pamphlets or brochures, and the guide who accompanies the team can provide information regarding invasion and invasive species.

4. Conclusions

The survey of invasive alien plants conducted in Shendurney has recorded a total of 25 invasive alien plant species. Risk Impact Assessment conducted for the identified invasive plants have categorized eight High and seventeen Medium risk classes based on the Generic Impact Score. Of which, most of the invasion originates from the tourism zone. Eighteen invasive alien plants were identified during the 2019 survey where eight of them were already identified from the periphery of the sanctuary in 2011.Similarly, of the total 25 identified invasive plant species, 15 of them were recorded during 2019 survey. Relationship analysis has been done between invasive alien plant incidence with various factors like tourism, drainage density, forest zonation, boundary habitats and canopy cover. Tourism activities are directly connected with introduction of invasive plants since the results shows abundant invasives in locations marked with high tourism activities. Even though presence of invasives were noted nearby drainage paths with very low, low, moderate and high drainage pathways, drainage density seems to be negatively correlated with invasive introduction in Shendurney with low or moderately low levels of infestation. The analysis based on forest zonation indicates tourism zone with the highest tourist foot fall and recorded heavy infestation of invasive plants followed by buffer and core zone. In the Buffer zone, the tourist activities and anthropogenic interferences are prominent causes for the spread of invasive plants while in Core Zone, only frequented and patrolled by forest department staff is also found to be under threat of high risk invasive plants especially along the fringes of deep forests. Invasion which we see inside the sanctuary has its origin from the periphery habitats where the boundary habitats ranges from paddy fields, wastelands, rubber plantations, built-ups and forest plantations towards the west side of the sanctuary which borders the tourism zone of Shendurney. Comparing the plant invasions, mostly invaded spaces are from the tourism zone of Shendurney which denotes a positive relationship between invasive introduction and boundary habitats. Comparison of canopy cover and invasive incidence haven’t shown any stable relation as indicated by the incidence of invasive plants at sites even with 70% of forest cover. These invasive have to be managed accordingly (mechanically; since the population is small) rather than setting plans to apply it to the whole sanctuary. Therefore, site prioritization maps were generated and red zones where urgent management is needed have been identified under each forest section.

Location specific management protocols will provide better results in large invaded landscapes. Besides, we also examined the potential invasive nature of Mahogany located in Choodal area by setting three experimental plots in different elevations by studying the density of Mahogany saplings, matured and adult trees along with numbering of seeds per plot. A list of native plant species nearby Mahogany plot was identified and the landscape can be restored at the earliest with the native ones.

5. Recommendations

1. Continuous inspection of the belongings of the tourists such as clothes, shoes and sterilization of hands and legs of the tourists at the time of both entry and exit in the sanctuary.
2. Constant checking of the department staff jeeps and other private vehicles- especially the wheels, used for ecotourism activities have to be disinfected pre and post travel.
3. Execute site specific protocols in the locations that need urgent management and continuous surveillance and monitoring have to be conducted in trek paths, drainage paths forest zones, forest fringes etc.
4. Inspect and clear the trek paths towards campsites located inside the sanctuary to check the spread of invasive alien plants to newer locations.
5. Establish early detection of invasives in new locations of the sanctuary so that rapid response (EDRR) can be deployed for the newly invaded ones.
6. Raising awareness of biological invasion among tourists by placing boards and hoardings in the sanctuary premises especially in tourist assembling points and distribution if pamphlets.
7. Establish mutual co-operation with land owners of the adjacent properties to minimize the invasion beyond the boundaries of sanctuary.

6. Acknowledgement

The completion of this undertaking could not have been possible without the involvement and support of so many people whose names may not all be enumerated. Their contributions are sincerely appreciated and thankfully acknowledged. However, the research team would like to express their deep gratitude and indebtedness particularly to ;

Sri.Sajeev Kumar B, Wildlife Warden of Shendurney Wildlife Sanctuary for granting permission and overall assistance to conduct the survey.

Sri.Saju T S, Assistant Wildlife Warden who laid down the framework within which the work was possible.

Sri. Shiju B, Wildlife Assistant for sharing the sanctuary maps for the study.

Department Staff - Anil, Binoj, Vishnu, Sreerajand Pushpa and other field staff for their support in and out of the work.

Special thanks to **Mr.Jose**- Chauffeur, for his great support and help rendered even in harsh terrains.

We express our extreme gratitude, privilege and great sense of honor to IB Staff, cook and all others of the sanctuary who expressed their empathy, support and friendship for their endless kind efforts.

7. References

Sajeev, T V., Suganthasakthivel, R., Karthika M Nair, Praveen P Raj, Sumi M S and Thushar Naduvalloor. 2019. A preliminary report of the rapid assessment of invasive alien species in Shendurney Wildlife Sanctuary.

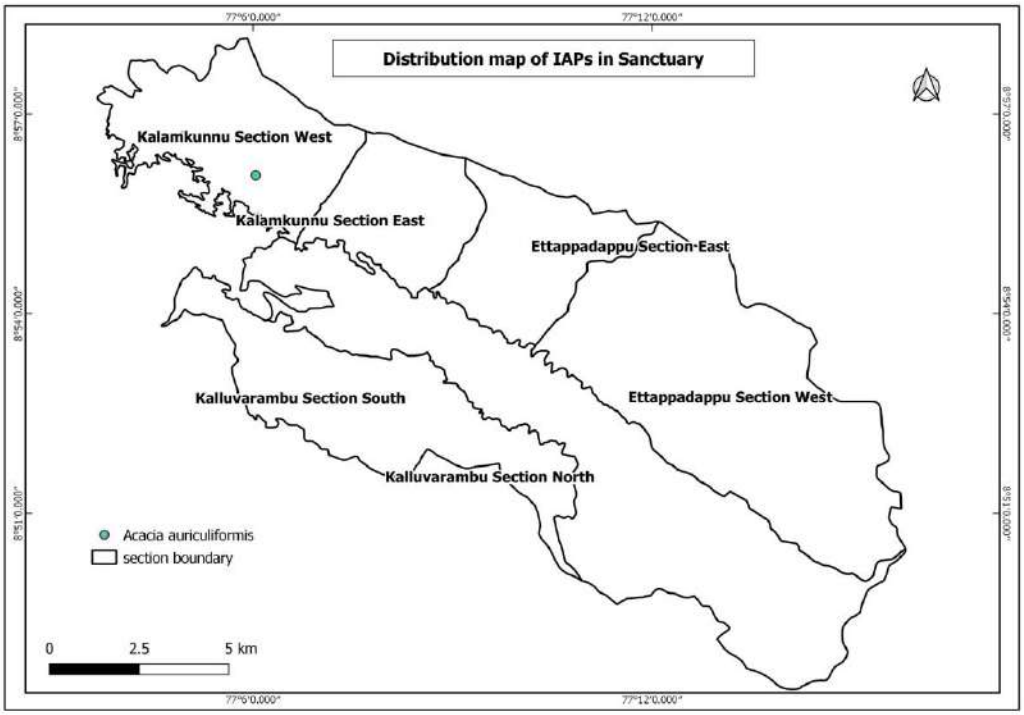
Champion, H.G. and Seth, S.K.1968. A Revised Forest Types of India. Manager of Publications, Government of India, Delhi.

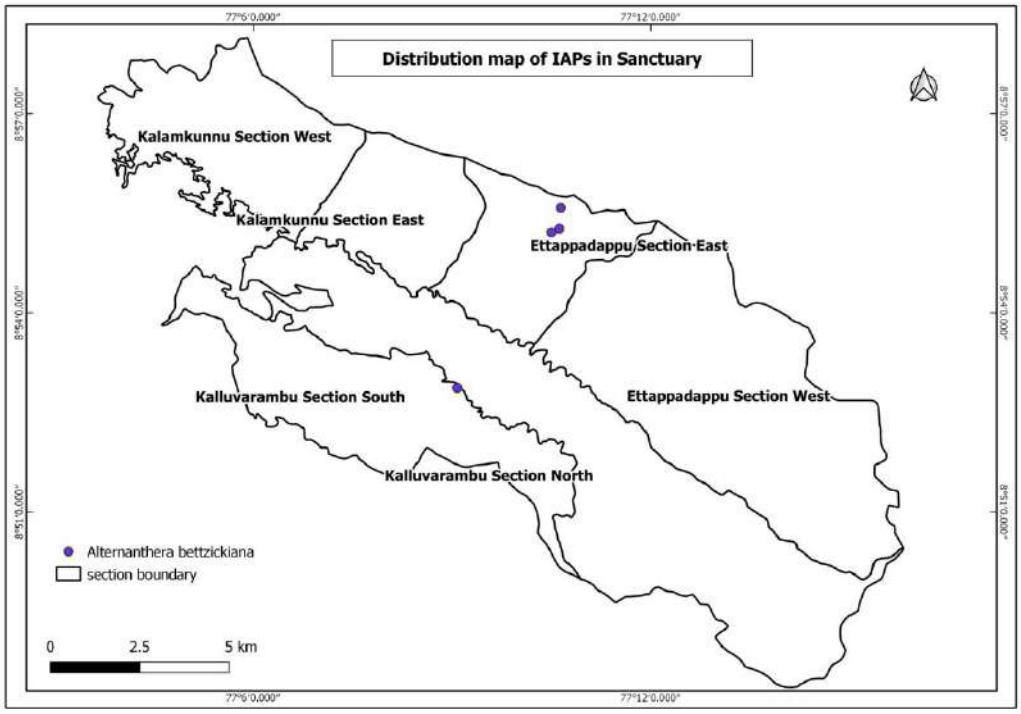
Management Plan of Shendurney Wildlife Sanctuary 2012-13 to 2021-2022.

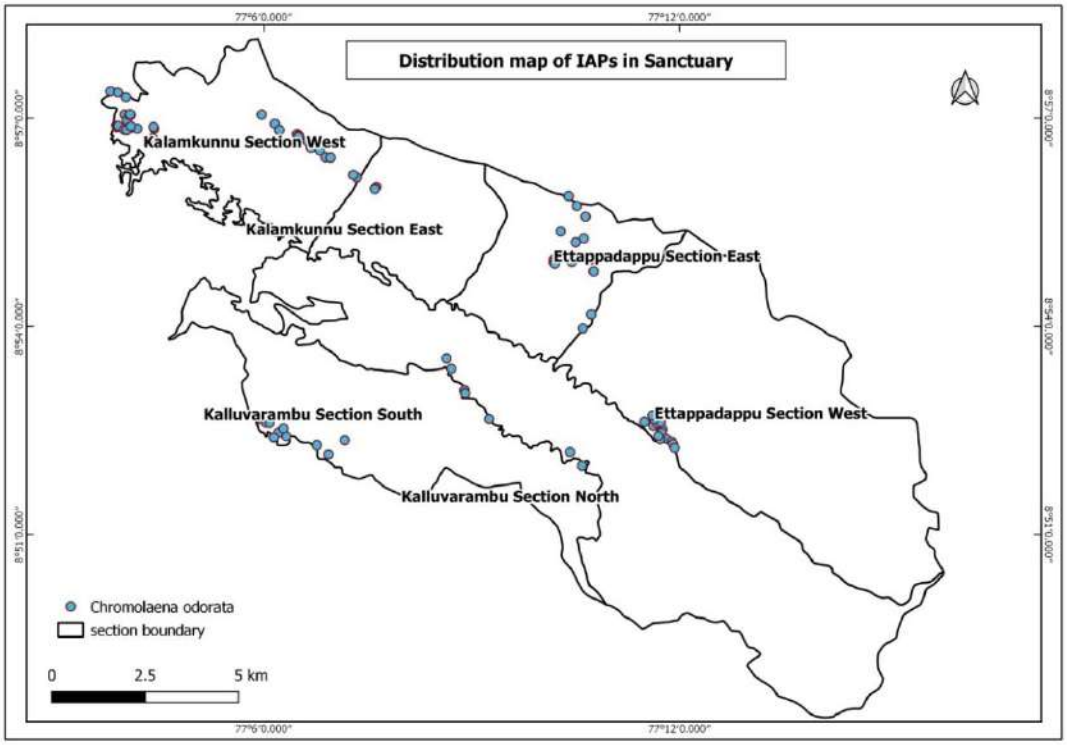
IUCN's Policy brief on invasive and alien species, biodiversity, human health and food security.

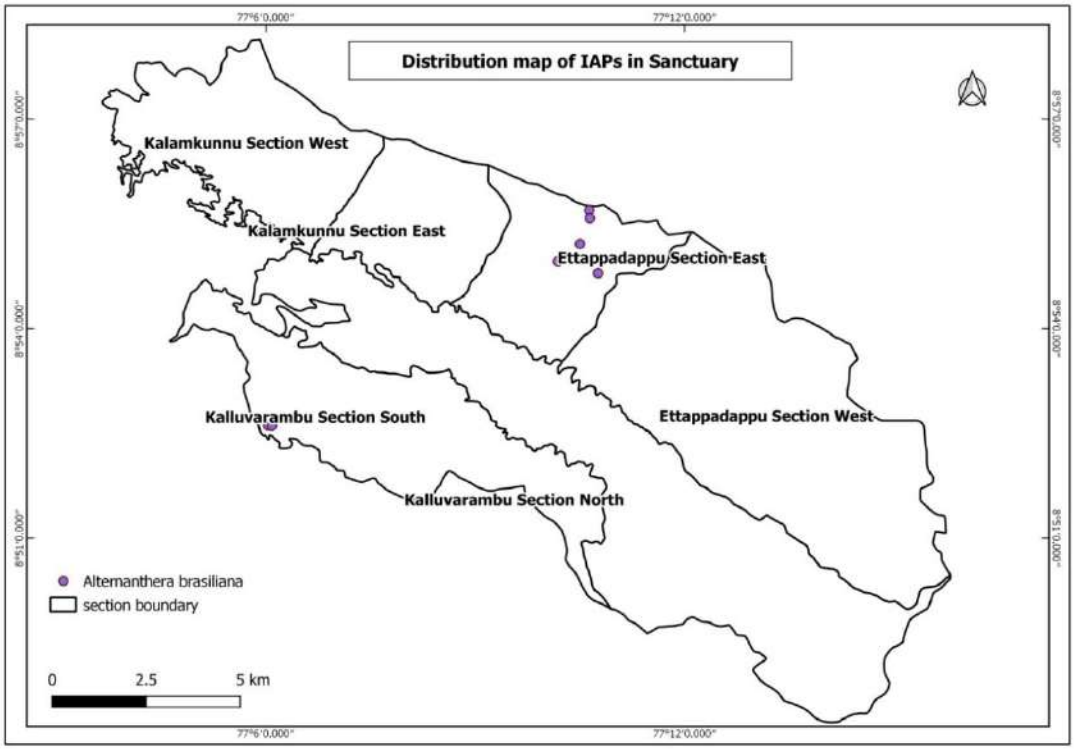
Appendix-I

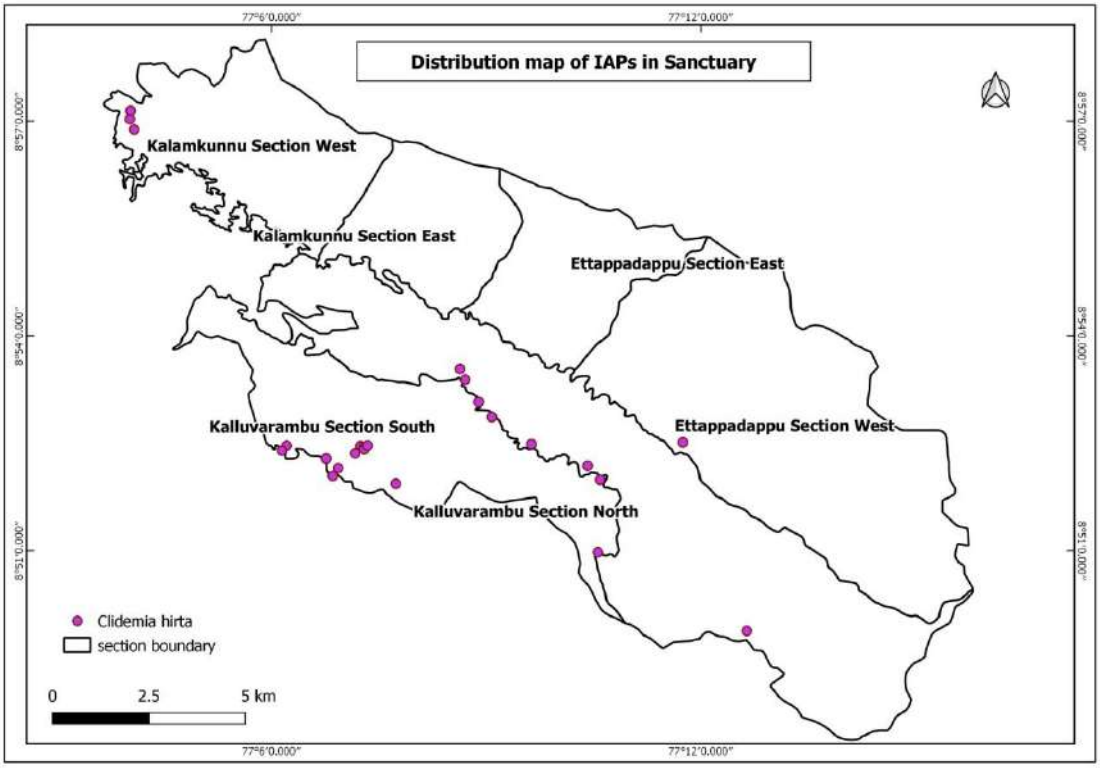
Distribution maps of invasive alien plants recorded in Shendurney Wildlife Sanctuary






Distribution map of IAPs in Sanctuary
Kalamkunnu Section West
Kalamkunnu Section East
Ettappadappu Section East
Kalluvarambu Section South
Ettappadappu Section West
Kalluvarambu Section North
Chromolaena odorata
section boundary
0
2.5
5 km


Distribution map of IAPs in Sanctuary
Kalamkunnu Section West
Kalamkunnu Section East
Ettappadappu Section East
Kalluvarambu Section South
Ettappadappu Section West
Kalluvarambu Section North
Alternanthera brasiliana
section boundary
0
2.5
5 km


Distribution map of IAPs in Sanctuary
Kalamkunnu Section West
Kalamkunnu Section East
Ettappadappu Section East
Kalluvarambu Section South
Ettappadappu Section West
Kalluvarambu Section North
Clidemia hirta
section boundary
0
2.5
5 km
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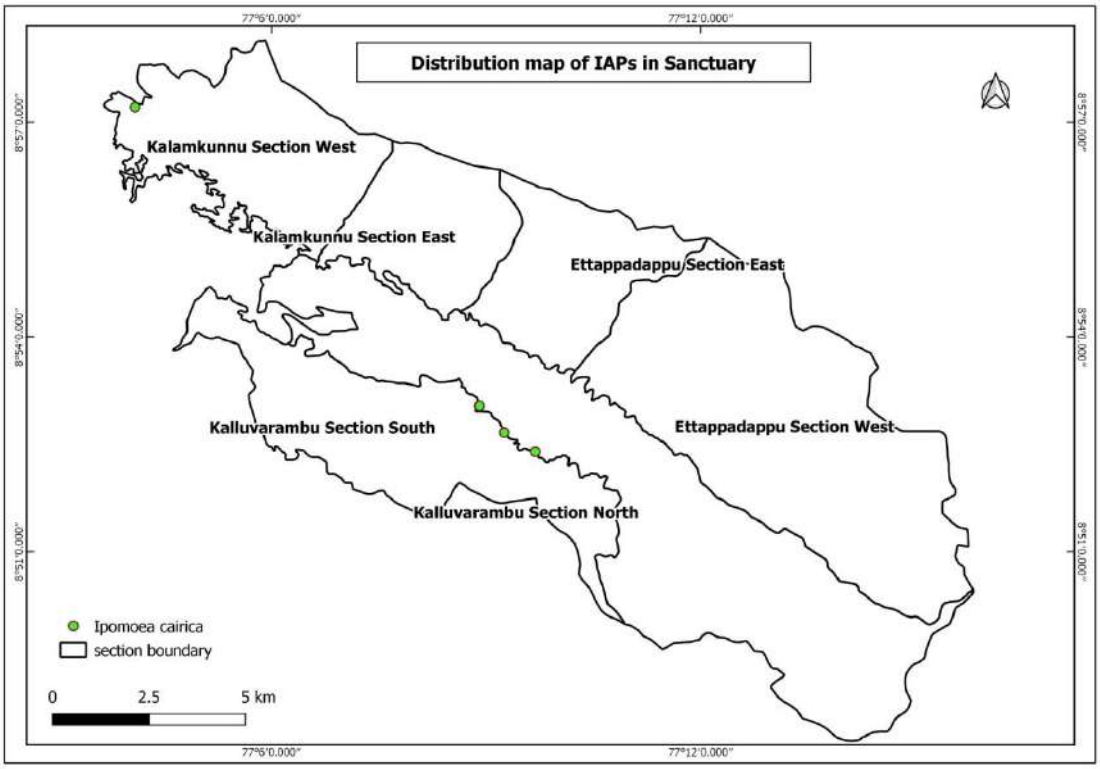
8°57'0.000"
8°54'0.000"
8°51'0.000"


Distribution map of IAPs in Sanctuary
Kalamkunnu Section West
Kalamkunnu Section East
Ettappadappu Section East
Kalluvarambu Section South
Ettappadappu Section West
Kalluvarambu Section North
Ipomoea cairica
section boundary
0
2.5
5 km
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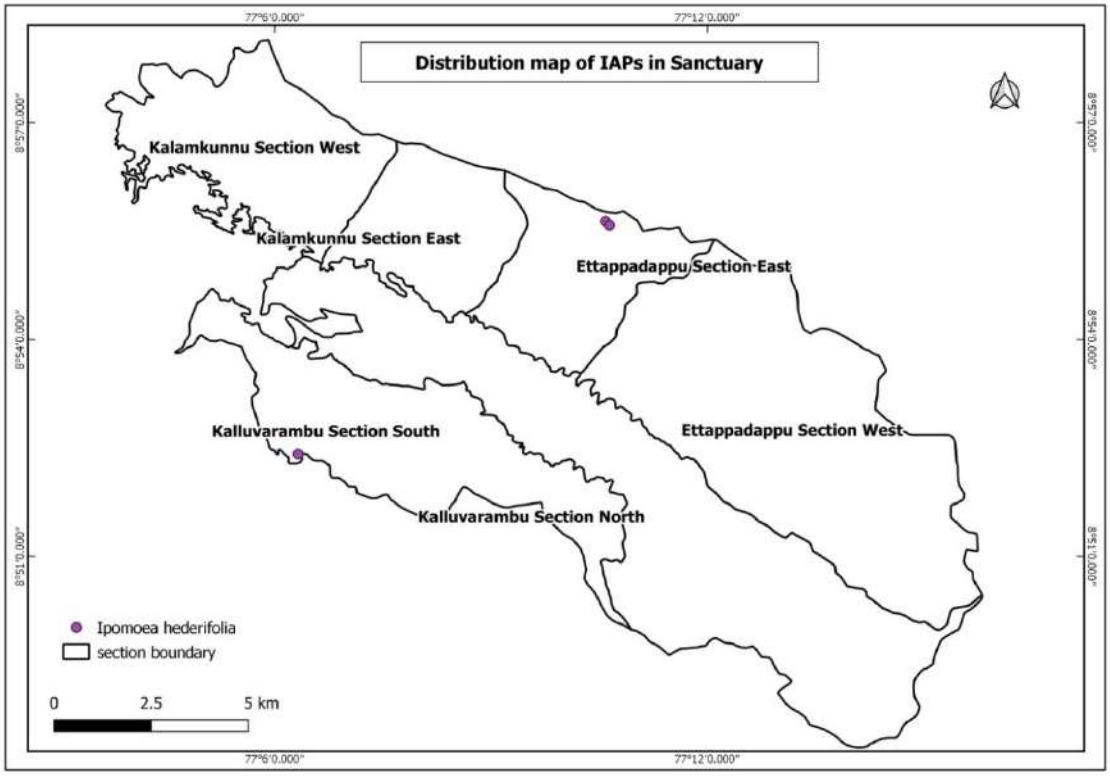
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Kalamkunnu Section West
Kalamkunnu Section East
Ettappadappu Section East
Kalluvarambu Section South
Ettappadappu Section West
Kalluvarambu Section North
Ipomoea hederifolia
section boundary
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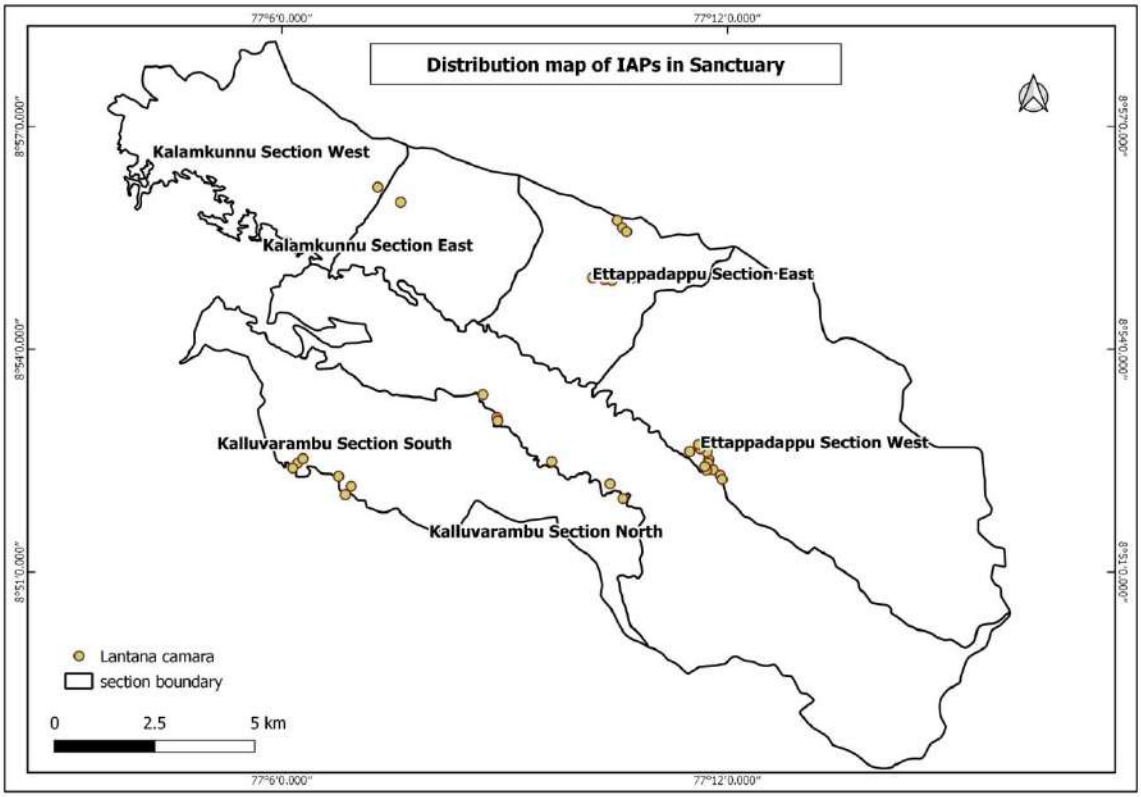
5 km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Kalamkunnu Section West
Kalamkunnu Section East
Ettappadappu Section East
Kalluvarambu Section South
Ettappadappu Section West
Kalluvarambu Section North
Lantana camara
section boundary
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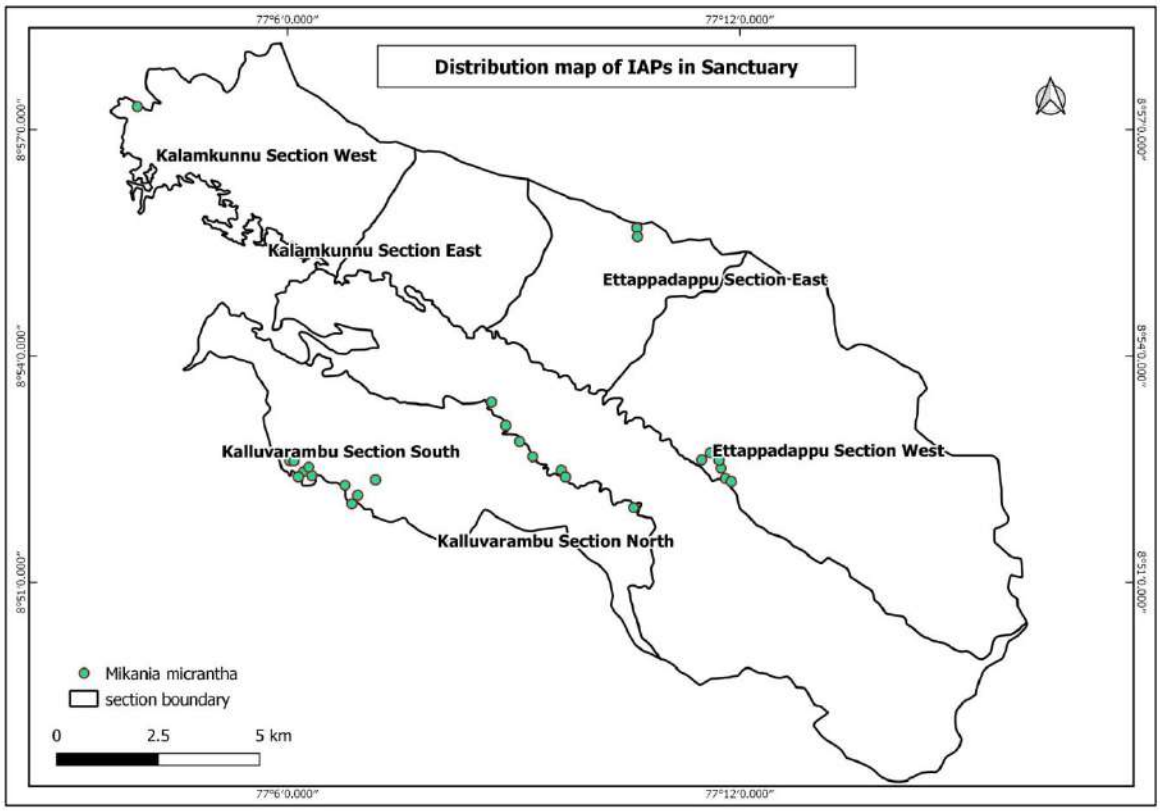
2.5
5 km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Kalamkunnu Section East
Ettappadappu Section-East
Kalluvarambu Section South
Ettappadappu Section West
Kalluvarambu Section North
Mikania micrantha
section boundary
0
2.5
5 km
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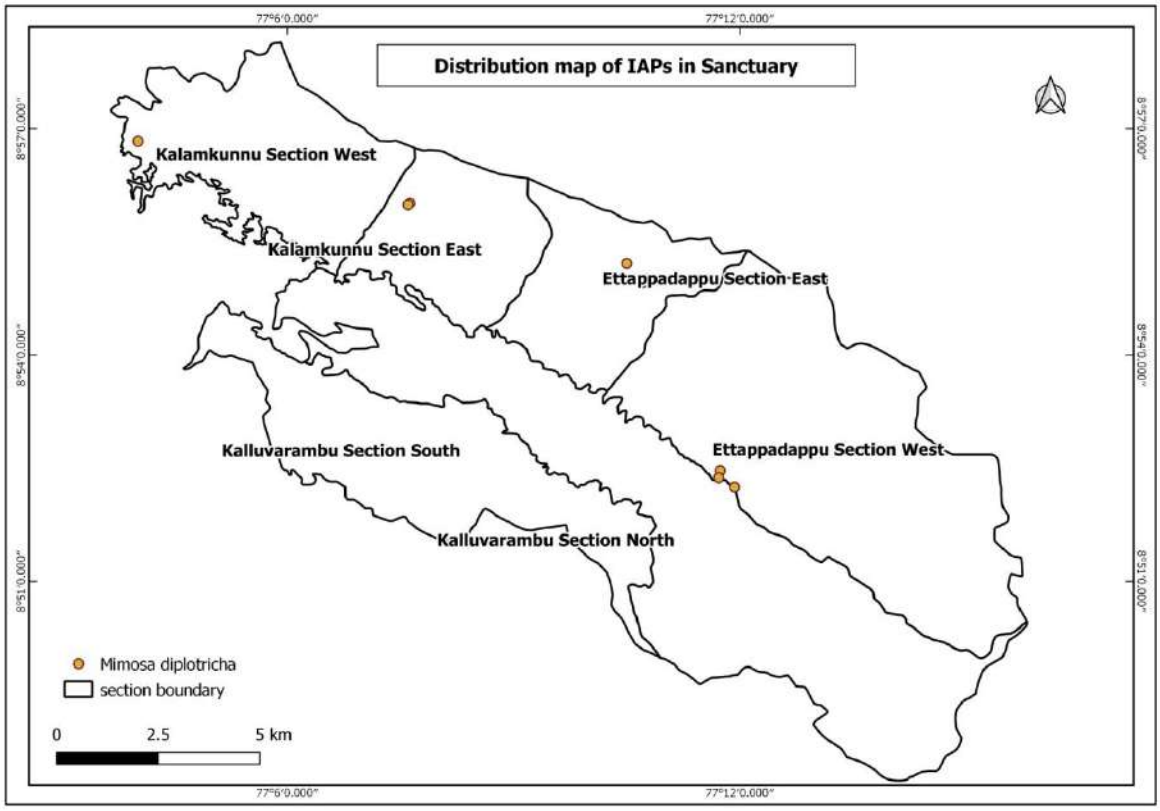
Distribution map of IAPs in Sanctuary
Kalamkunnu Section West
Kalamkunnu Section East
Ettappadappu Section-East
Kalluvarambu Section South
Ettappadappu Section West
Kalluvarambu Section North
Mimosa diplotricha
section boundary
0
2.5
5 km
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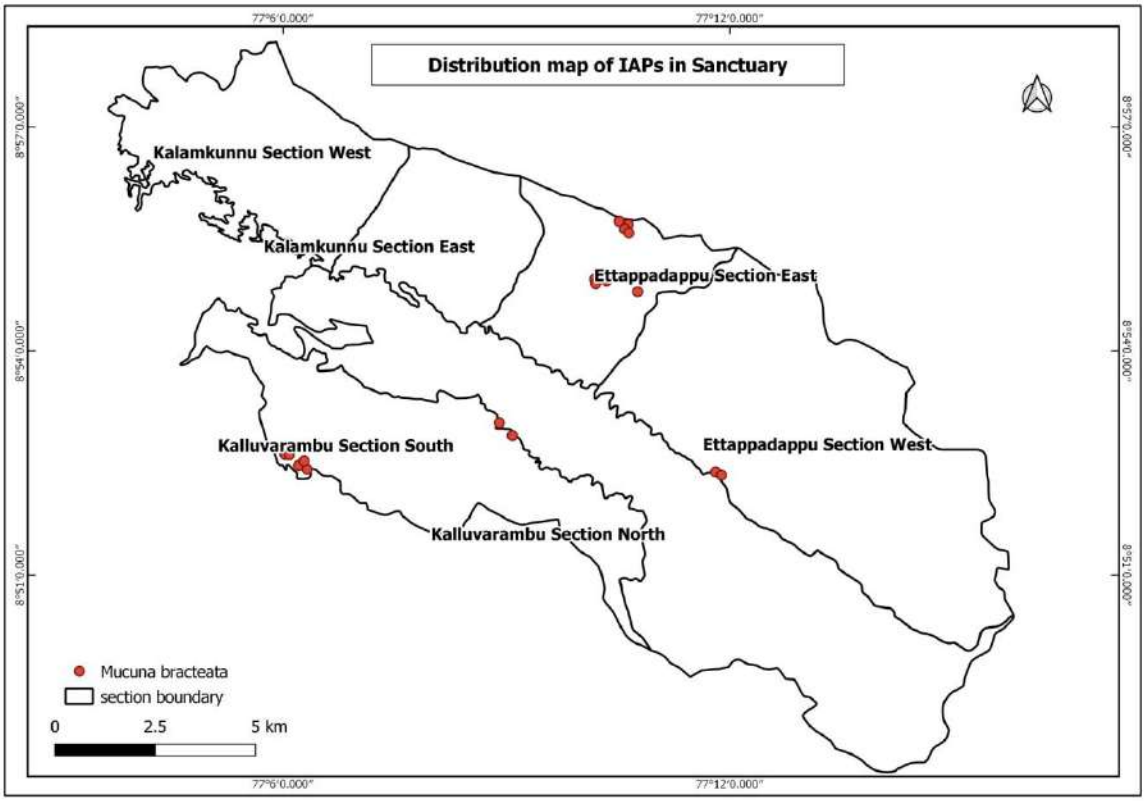
Distribution map of IAPs in Sanctuary
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Kalamkunnu Section East
Ettappadappu Section East
Kalluvarambu Section South
Ettappadappu Section West
Kalluvarambu Section North
Mucuna bracteata
section boundary
0
2.5
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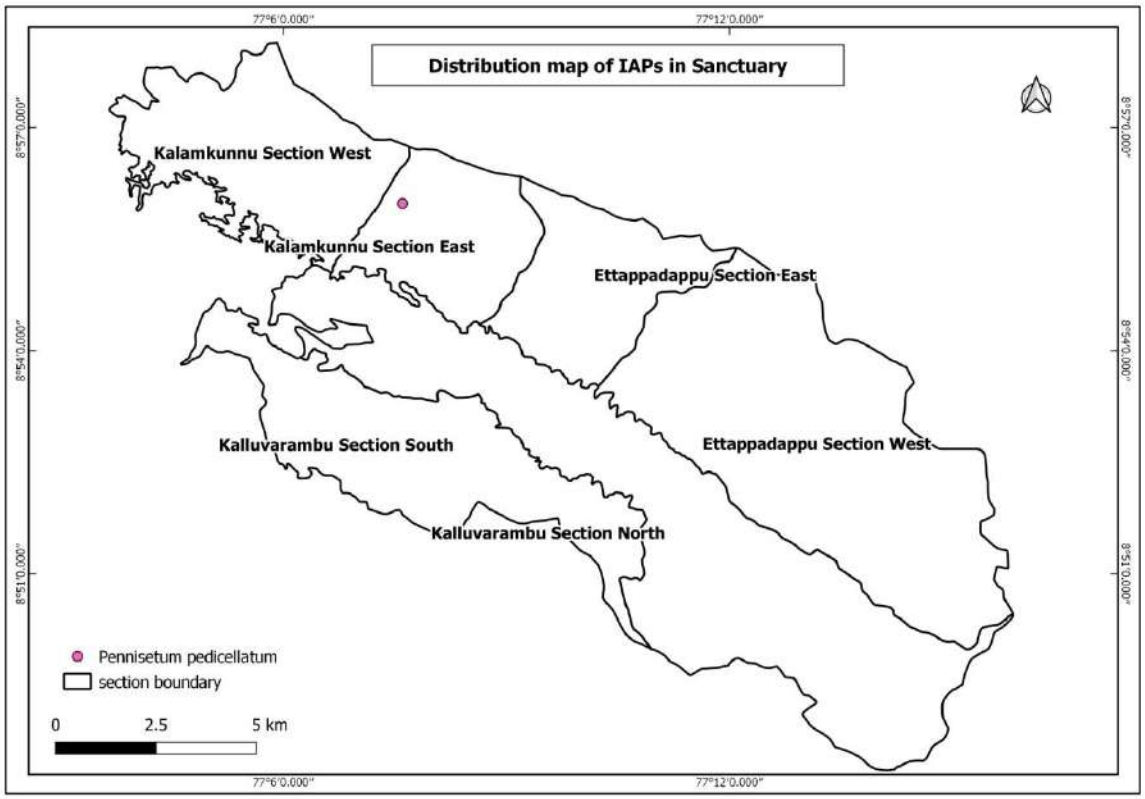
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Kalamkunnu Section East
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Ettappadappu Section West
Kalluvarambu Section North
Pennisetum pedicellatum
section boundary
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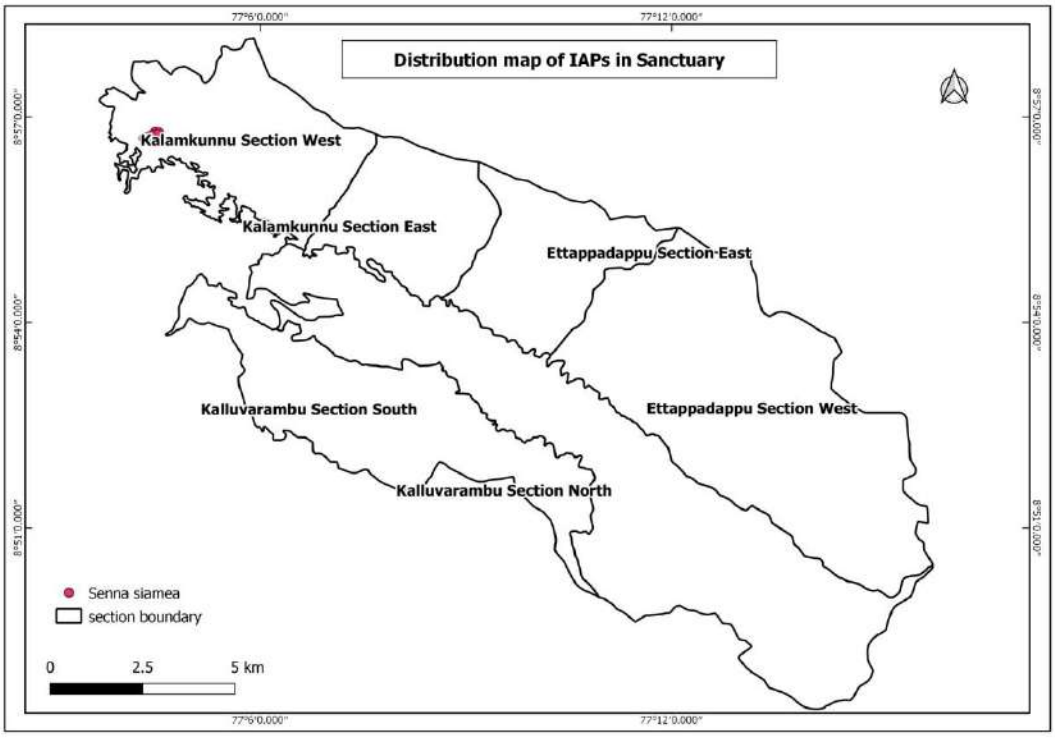
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Kalamkunnu Section East
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Kalluvarambu Section North
Senna siamea
section boundary
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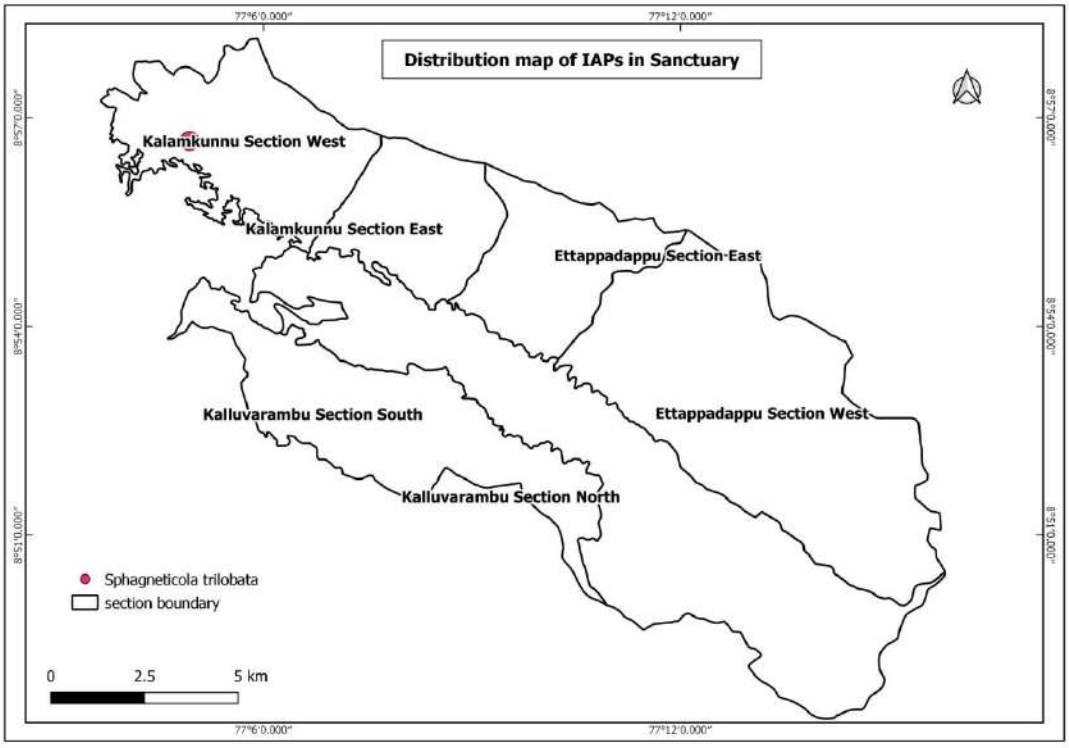
2.5
5 km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Ettappadappu Section West
Kalluvarambu Section North
Sphagneticola trilobata
section boundary
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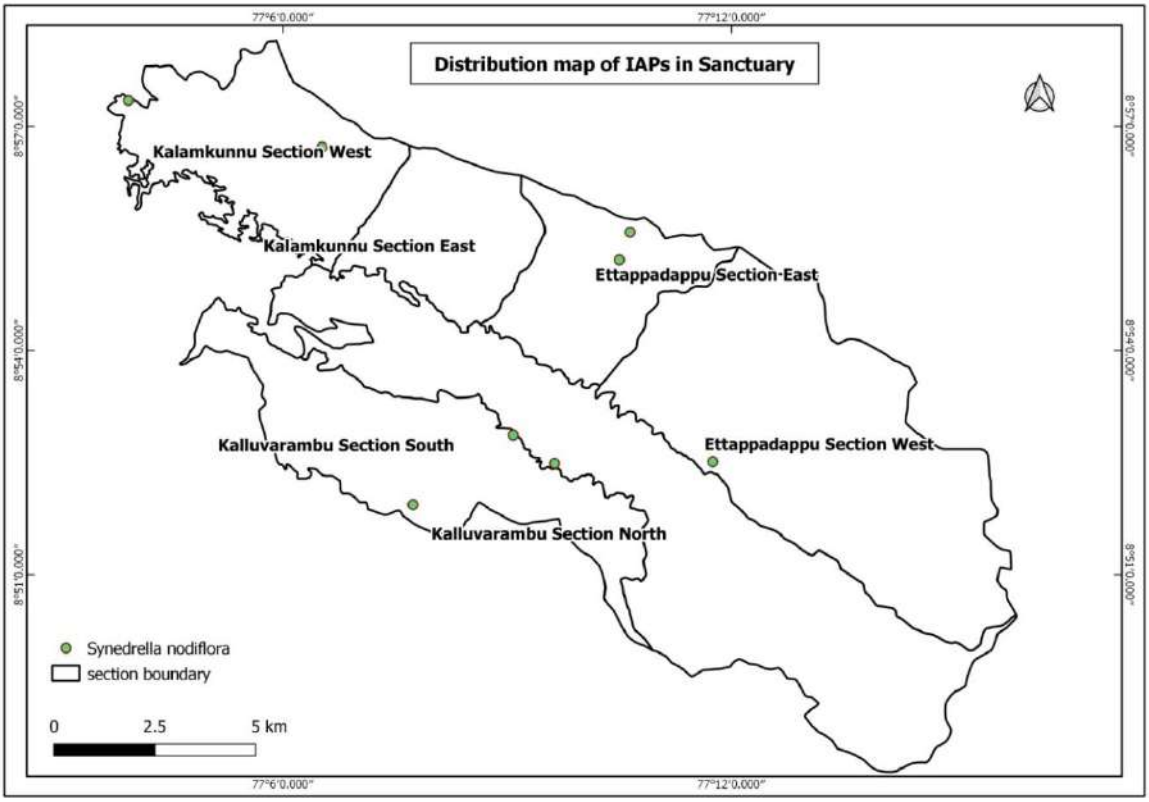
2.5
5 km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Kalamkunnu Section East
Ettappadappu Section East
Kalluvarambu Section South
Ettappadappu Section West
Kalluvarambu Section North
Synedrella nodiflora
section boundary
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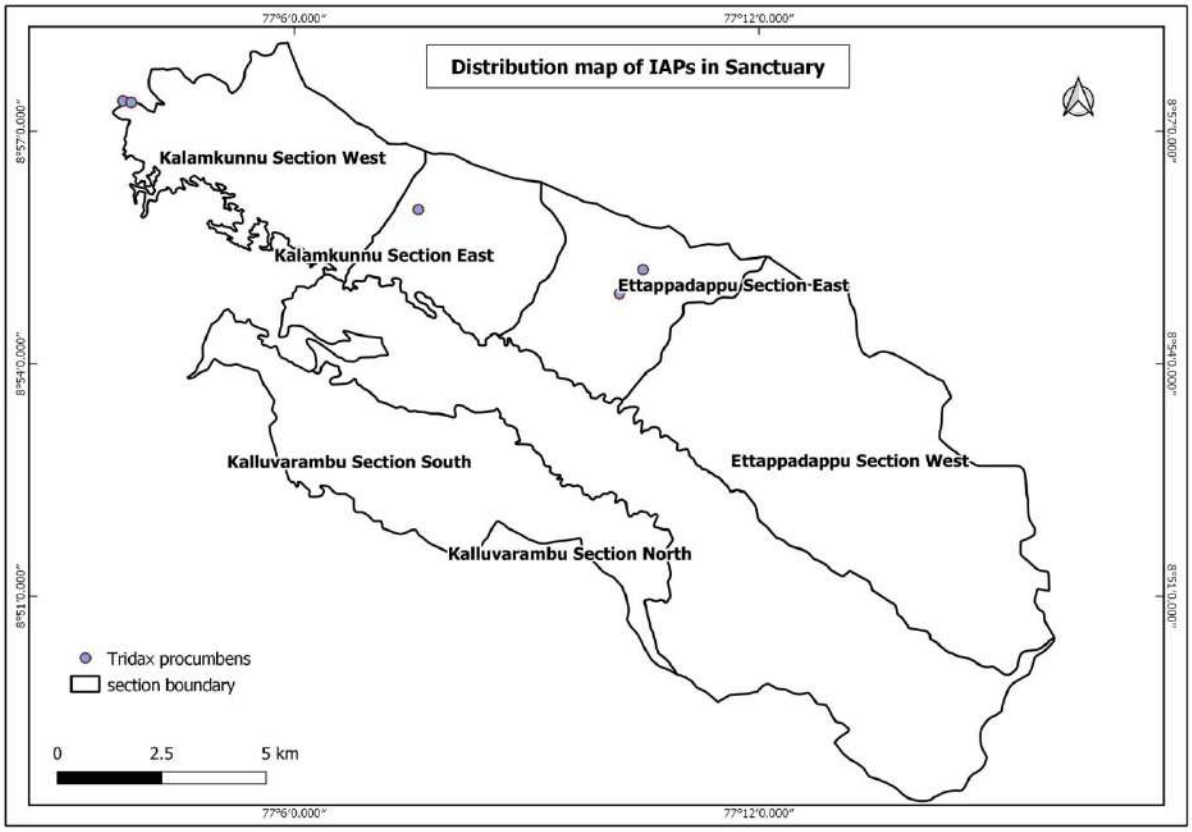
5 km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Kalamkunnu Section East
Ettappadappu Section East
Kalluvarambu Section South
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Kalluvarambu Section North
Tridax procumbens
section boundary
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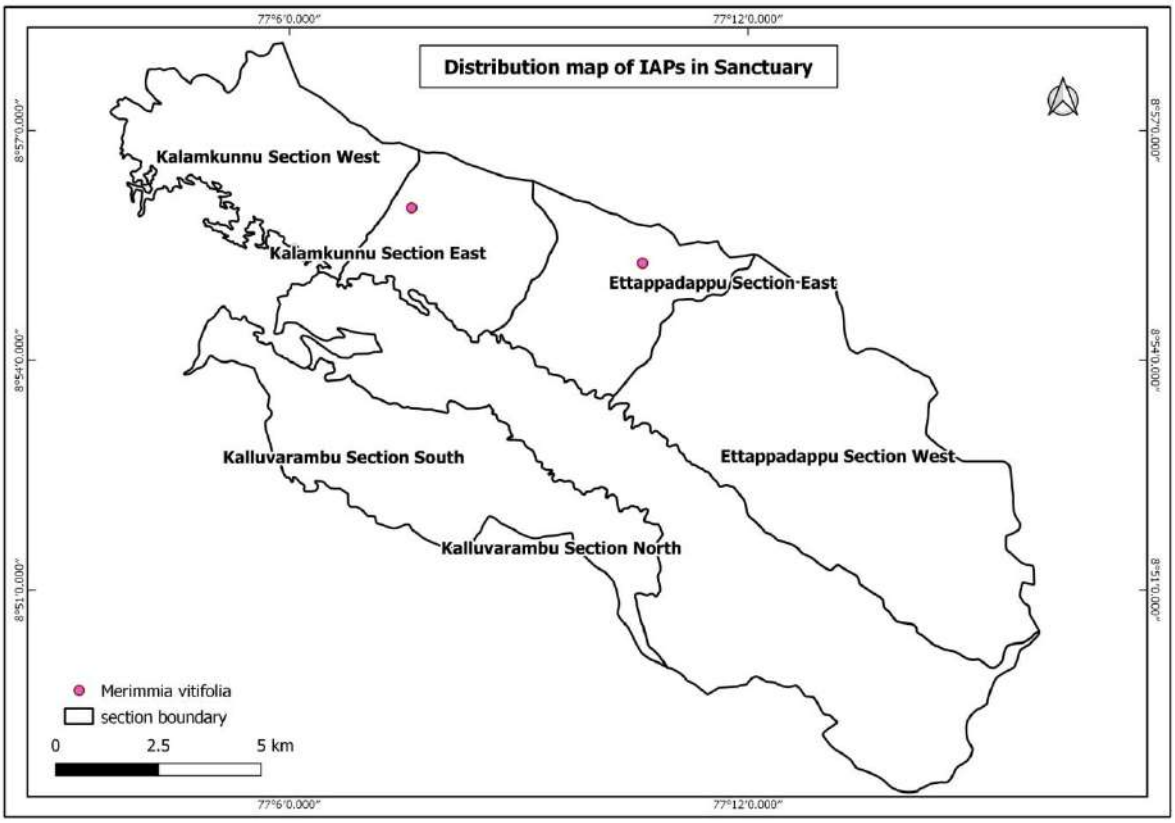
5 km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8°51'0.000"
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Kalamkunnu Section East
Ettappadappu Section-East
Kalluvarambu Section South
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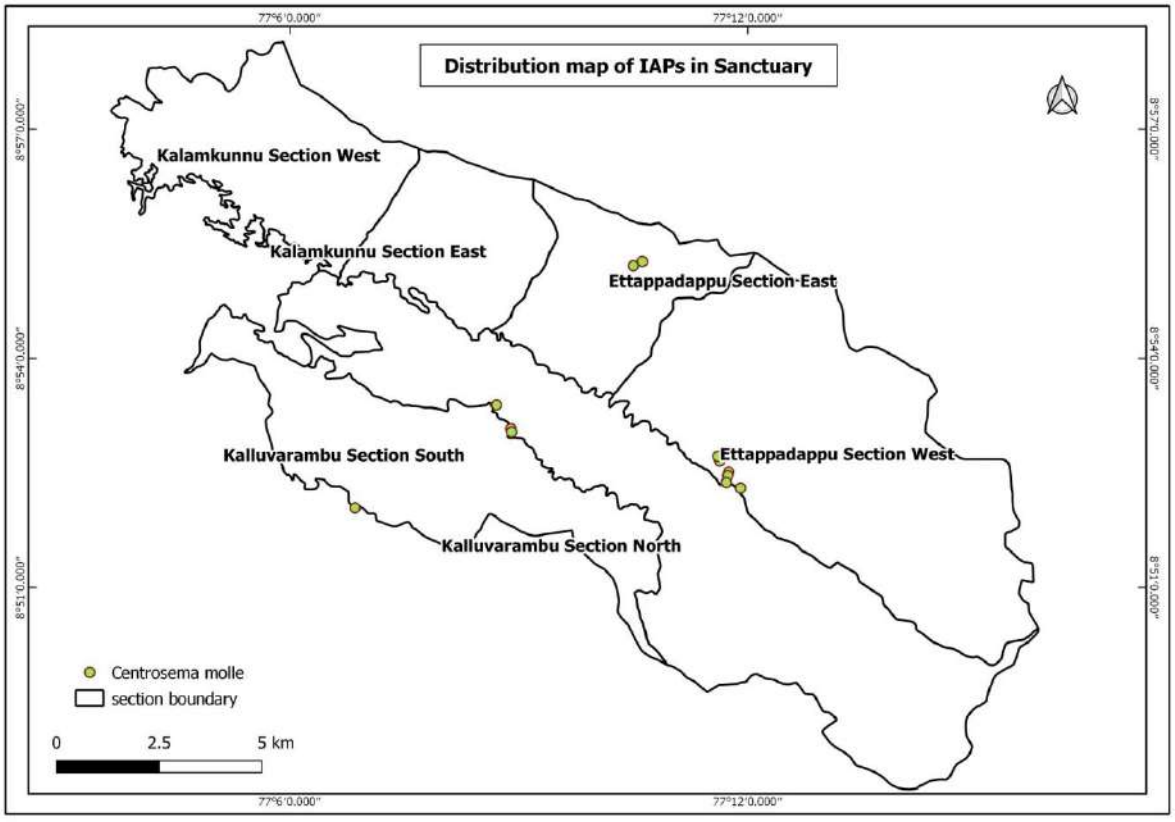
Kalluvarambu Section North
Merimmia vitifolia
section boundary
0
2.5
5 km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Kalamkunnu Section East
Ettappadappu Section-East
Kalluvarambu Section South
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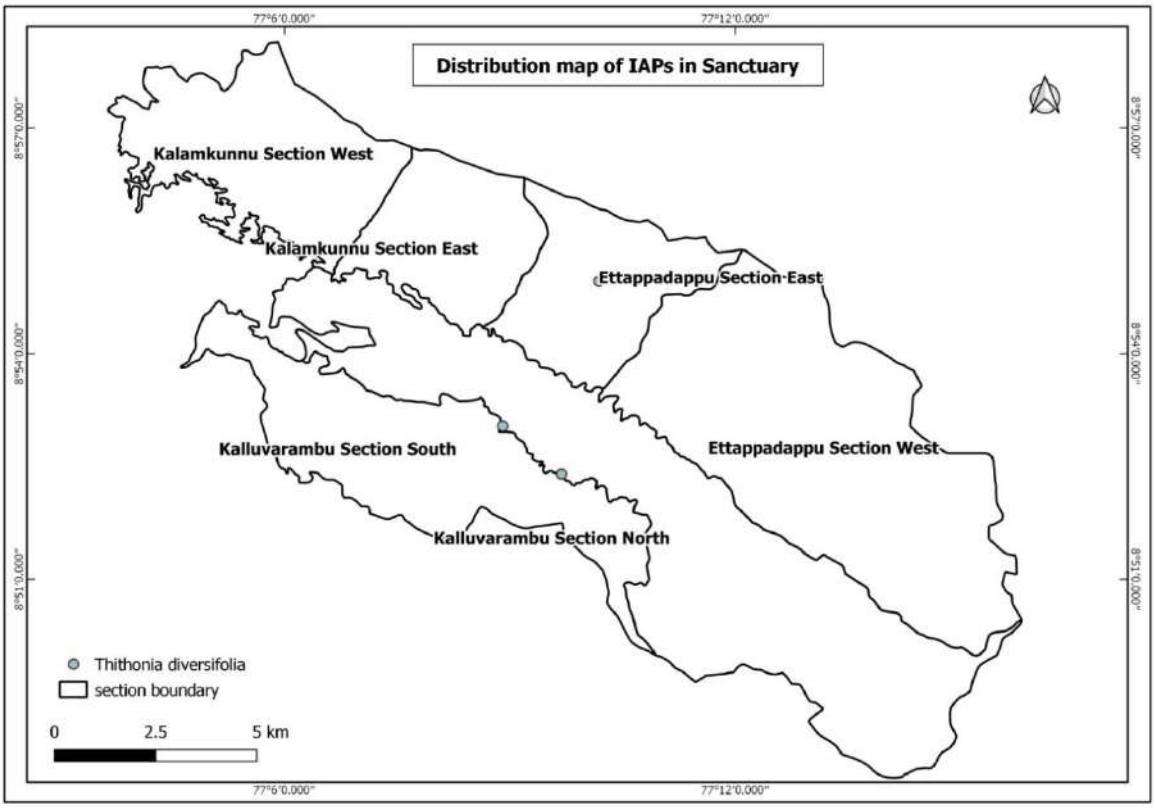
Kalluvarambu Section North
Centrosema molle
section boundary
0
2.5
5 km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Kalamkunnu Section West
Kalamkunnu Section East
Ettappadappu Section East
Kalluvarambu Section South
Ettappadappu Section West
Kalluvarambu Section North
Thithonia diversifolia
section boundary
0
2.5
5 km
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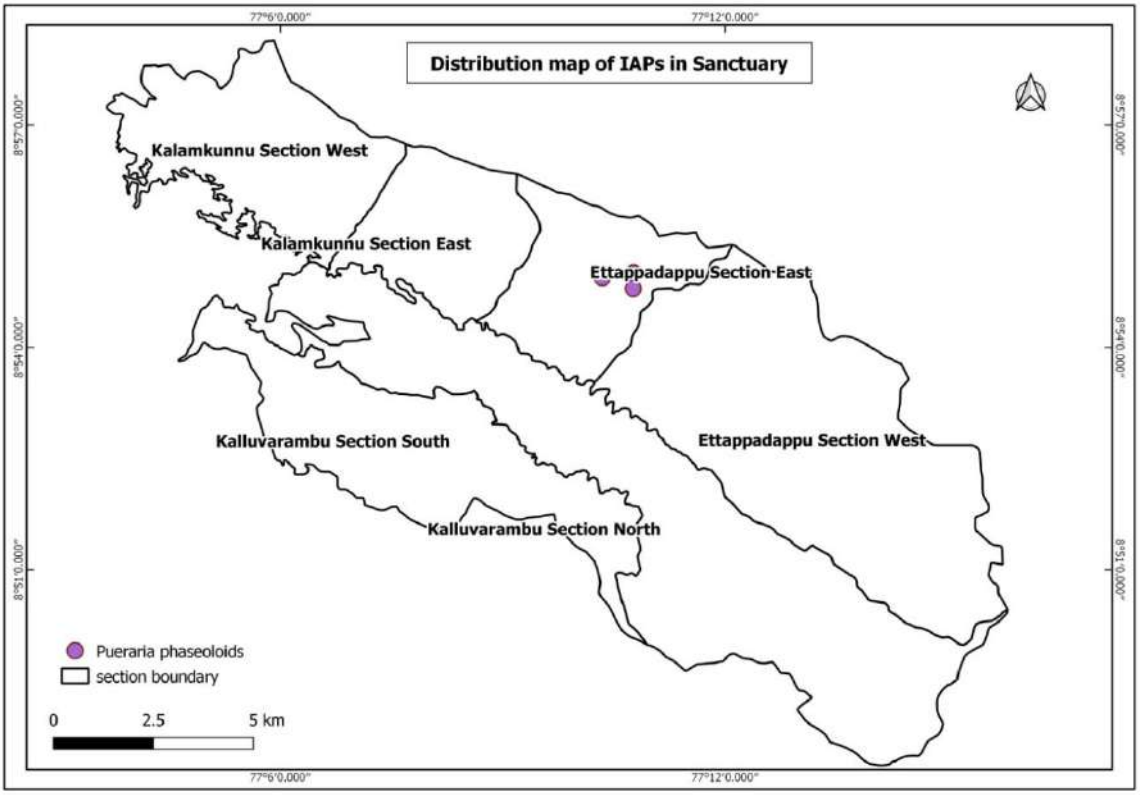
Distribution map of IAPs in Sanctuary
Kalamkunnu Section West
Kalamkunnu Section East
Ettappadappu Section East
Kalluvarambu Section South
Ettappadappu Section West
Kalluvarambu Section North
Pueraria phaseoloids
section boundary
0
2.5
5 km
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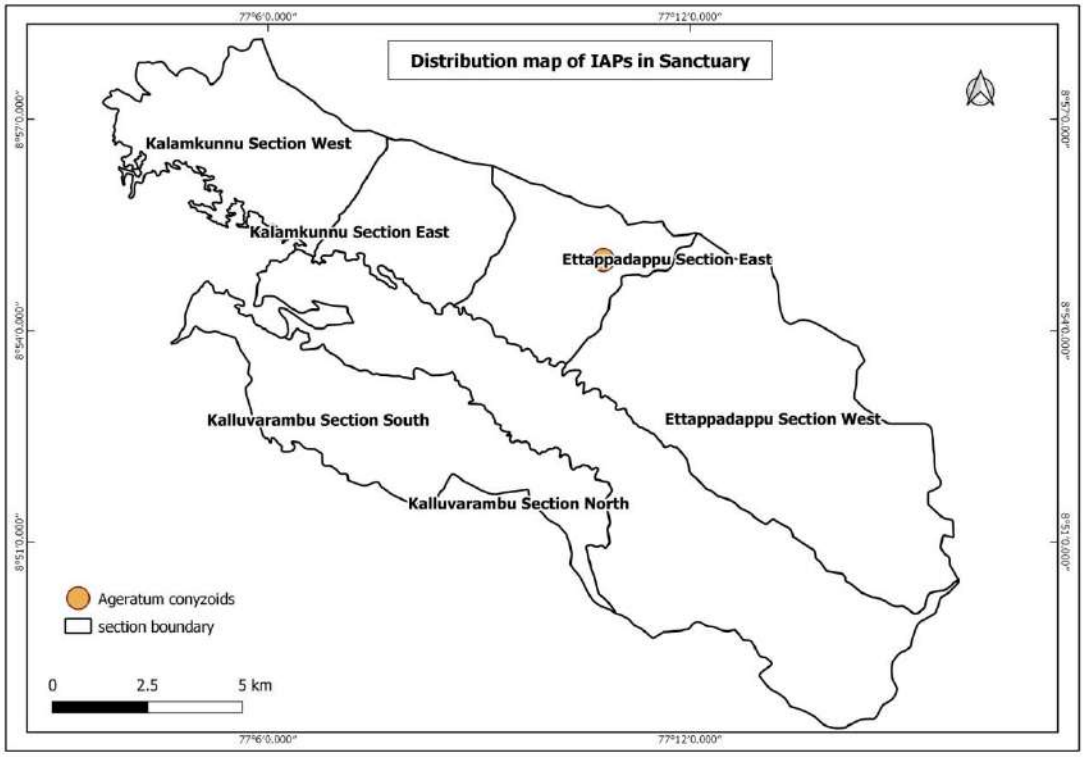
Distribution map of IAPs in Sanctuary
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Kalamkunnu Section East
Ettappadappu Section-East
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Ageratum conyzoids
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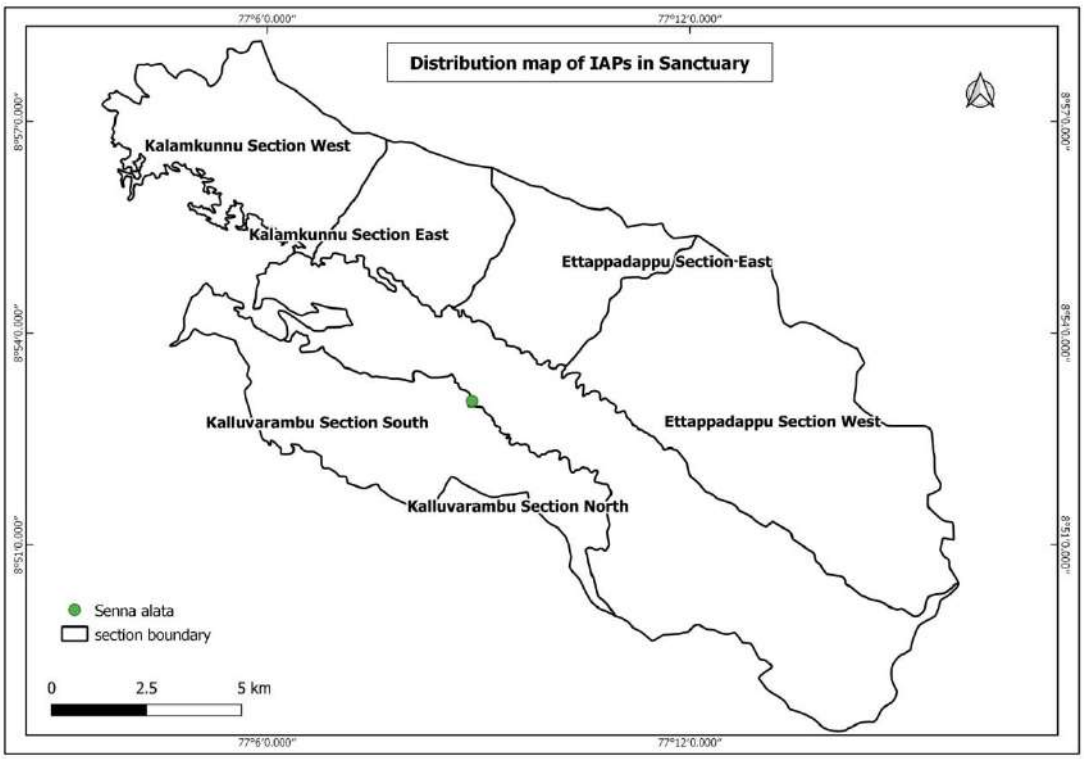
2.5
5 km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Kalamkunnu Section East
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Kalluvarambu Section South
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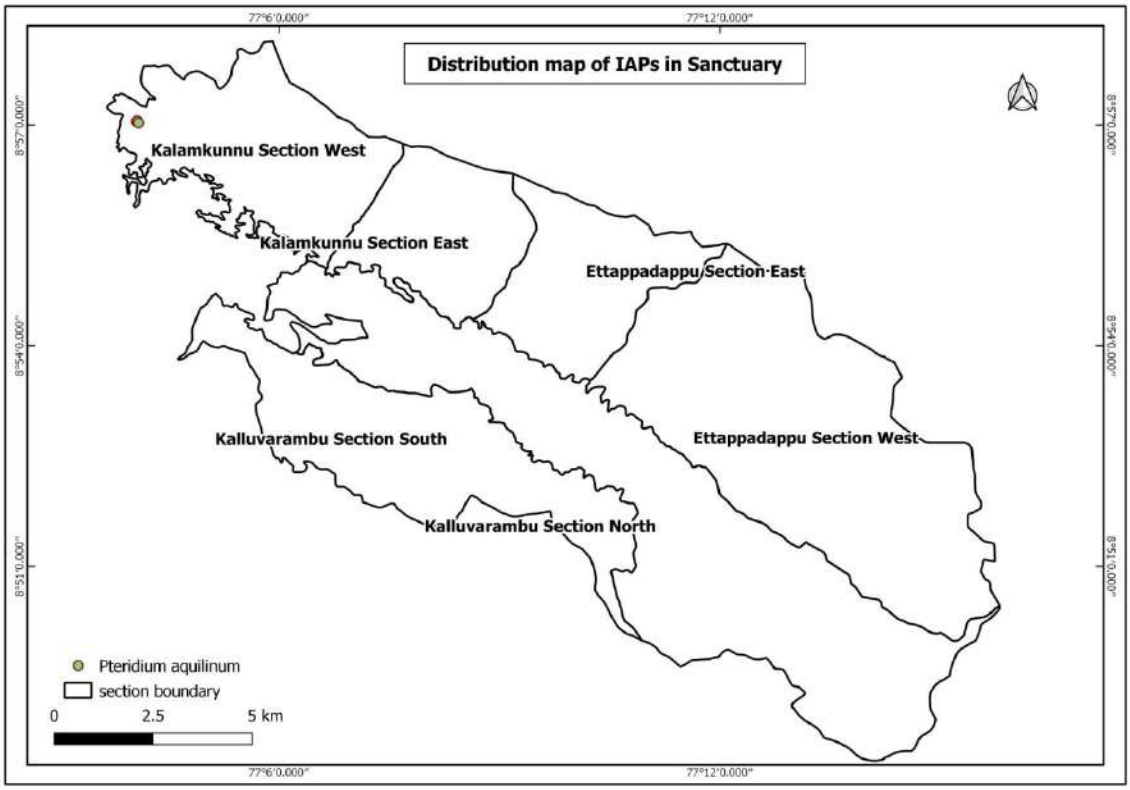
Kalluvarambu Section North
Senna alata
section boundary
0
2.5
5 km


Distribution map of IAPs in Sanctuary
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77°12'0.000"
8°57'0.000"
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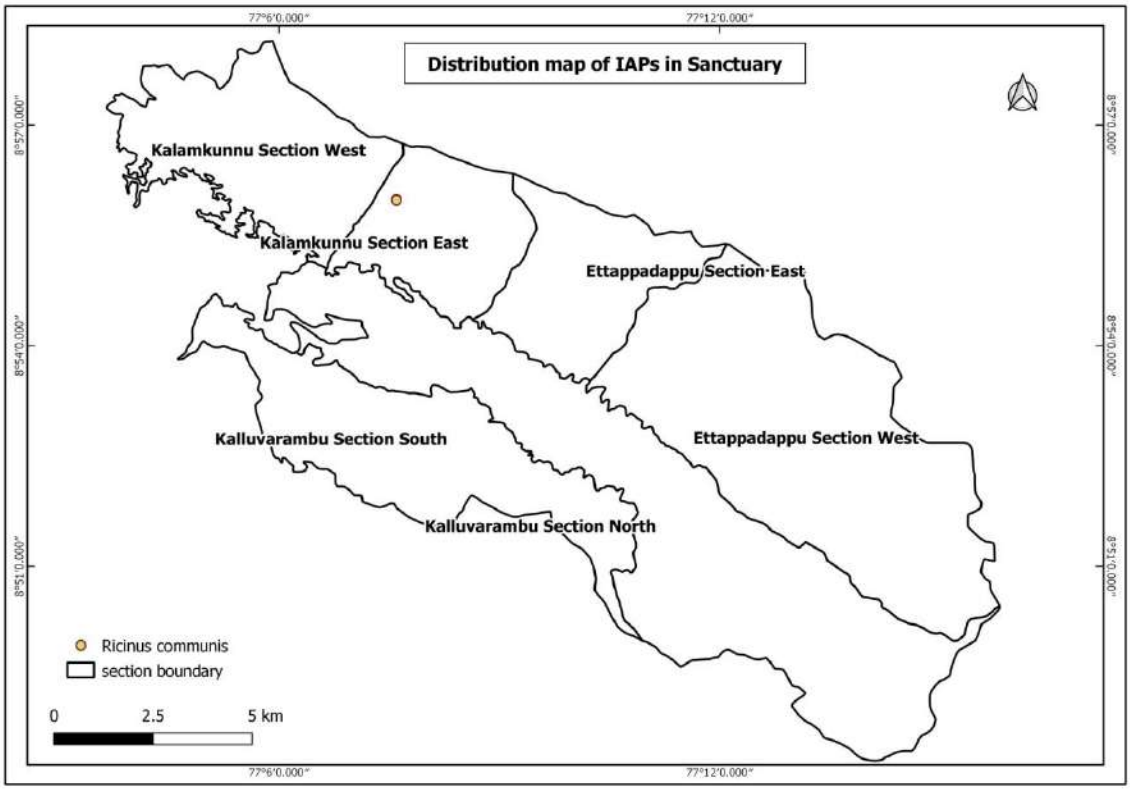
Kalamkunnu Section West
Kalamkunnu Section East
Ettappadappu Section East
Kalluvarambu Section South
Ettappadappu Section West
Kalluvarambu Section North
Pteridium aquilinum
section boundary
0
2.5
5 km


Distribution map of IAPs in Sanctuary
77°6'0.000"
77°12'0.000"
8°57'0.000"
8°54'0.000"
8°51'0.000"
Kalamkunnu Section West
Kalamkunnu Section East
Ettappadappu Section East
Kalluvarambu Section South
Ettappadappu Section West
Kalluvarambu Section North
Ricinus communis
section boundary
0
2.5
5 km

Appendix-II
Invasive Alien Plants observed in Shendurney Wildlife Sanctuary

Acacia auriculiformis

Alternantherabettzickiana

Centrosemamole

Alternanthera brasiliana

Clidemia hirta

Ipomoea cairica

Lantana camara

Merremiavitifolia

Mikania micrantha

Mucuna bracteata

Pteridium aquilinum

Ricinus communis

Senna alata

Senna siamea

Sphagneticola trilobata

Synedrella nodiflora

Tithonia diversifolia

Tridax procumbens

Ageratum conyzoides

Chromolaena odorata

Ipomoea hederifolia

Mimosa diplotricha

Pennisetum pedicellatum

Pueraria phaseoloides

Pennisetum polystachyon

Nodal Center for Biological Invasions.
Kerala Forest Research Institute

Report Submitted to the Shendurney Wildlife Sanctuary

Report of the **risk assessment** of **invasive alien plants in Shendurney** wildlife sanctuary

KSCSTE – Kerala Forest Research Institute
An Institution of Kerala State Council for Science, Technology and Environment
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