International Journal of Ecology and Environmental Sciences 49: 473-484, 2023
ISSN: 2320-5199 (Online); https://doi.org/10.55863/ijees.2023.2838

Status and Distribution of *Mallotus nudiflorus* (L.) Kulju & Welzen a Disturbance Indicator Species in Riparian Forest Ecosystem of a North Bank Tributary of River Brahmaputra in Northeast India

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ABSTRACT
The present study was carried out with the intent to assess the types of disturbances present in the riparian forests and also to assess the effect of different disturbances on the status and distribution of *Mallotus nudiflorus* (L.) Kulju & Welzen in the riparian forests of Pagladia river, a major north bank tributary of river Brahmaputra. Representative forest stands were selected for assessing the disturbance scores, disturbance indicator value and quantitative parameters of tree species across different zones. Fourteen key disturbance types were recorded in the area which differed in their characteristics across the four zones and among them, bank erosion, sand mining, channel diversion, vegetation clearing, weed infestation and waste deposition were the most severe ones. Fourty six tree species were recorded in the riparian zones that belonged to 39 genera and 23 families. In-depth analysis of vegetation data, disturbance scores and indicator value revealed that *M. nudiflorus* was the most dominant species that occurred mostly in close proximity to the water edges. A positive correlation was also observed between the disturbance types, scores and indicator value with the density of *M. nudiflorus.*

Key words: Disturbance score, Pioneer, Density, Forest, Erosion, Pagladia

INTRODUCTION

Riparian forests are critical ecosystems that are transition zones between terrestrial and aquatic systems characterized by frequent natural disturbance that leads to the formation of a mosaic of different micro-topographical and micro-environmental conditions due to the presence of active channels, abandoned channels, floodplains, terraces and alluvial fans (Gregory et al. 1991, Sakio 1997). The diversity of microsites and disturbance regimes helps in promoting the coexistence of diverse vegetation exhibiting a high degree of structural and compositional diversity promoting diverse ecological function and colonization of successional sites in this unique ecosystem (Chazdon 2014). The various agents of natural and anthropogenic disturbances coupled with the hydrological processes interact with the earliest stages of plant succession and has significant impact on pioneer vegetation (Stella et al. 2011). Disturbance primarily shapes plant communities in riparian areas. The riparian forest of Pagladia river, a major north bank tributary of Brahmaputra River in Assam experiences severe annual floods, sand mining, human settlement, cultivation, weed infestation, vegetation clearing, fire etc. *Mallotus* species are characteristic of secondary forests in Southeast Asia (Whitmore 1969, Primack and Lee 1991, Davies 1998, Davies et al. 1998). *Mallotus nudiflorus* (L.) Kulju &Welzen, is a species under the genus *Mallotus* Lour. and family Euphorbiaceae is an important component of the forest vegetation and exhibits wide life-history strategies, ranging from early successional pioneers to climax species (Primack and Lee 1991, Davies et al. 1998, Slik and Van Welzen 2000). They occur in diverse habitats such as the understory of primary forest, disturbed secondary forest, or open places like river banks, forest edges, and cleared areas (Pax and Hoffmann 1914, Airy Shaw 1975, Whitmore 1975, Slik and Van Welzen 2000). Few studies are available that was carried out to understand the disturbance and quantitative ecology of riparian forests (Knopf and Cannon 1982, Nilson and Johnson 1995, Sakio 1997, Griscom et al. 2009) and in India (Reshi et al. 2008, Deb et al. 2009, Sunil et al. 2011). The tree species richness and density of riparian forest and particularly *M. nudiflorus,* is perceived to be

dependent on the type and severity of disturbances encountered in a habitat. The present study was carried out to study the type of disturbances present in the riparian forests of Pagladia river and also to assess the effect of different disturbances on the status and distribution of *M. nudiflorus* in the riparian forests.

MATERIALS AND METHODS

Study area

The study was conducted in the riparian forests of Pagladia river, a major tributary of river Brahmaputra, Assam, Northeast India (Fig. 1). Pagladia (locally known as Mad River) originates in the southern slope of foothills of Bhutan Himalaya (26°59' N Latitude and 91°27' E Longitude). After flowing through the southern boundary, it enters India into Baksa district of Assam near Bhutan Chowki and then flows through Nalbari district of Assam. The river flows in a north-south direction up to Bijulighat and then flows in a south-west direction up to its confluence with Brahmaputra River at Laopara village of Nalbari district, Assam (Das et al. 2015).

Methods

The riparian forests found along the entire course of Pagladia river were categorized into different zones on the basis of its distance from water edge viz. Riparian Zone I (Riparian patches from water edge to 30 m distance were categorized as RZ- I), Riparian Zone II (Riparian patches from 31-60 m from water edge were designated as RZ-II), Riparian Zone III (Riparian patches from 61-90 m from water edge were categorized as RZ-III) and Riparian zone IV (Riparian forest areas which were found beyond 90 m from water edge were designated as RZ-IV). It may be worth mentioning that the farthest zone (RZ-IV) were encountered in few areas only mostly in the middle and lower reaches and in extremely few cases extended up to 110 m in some areas. From each

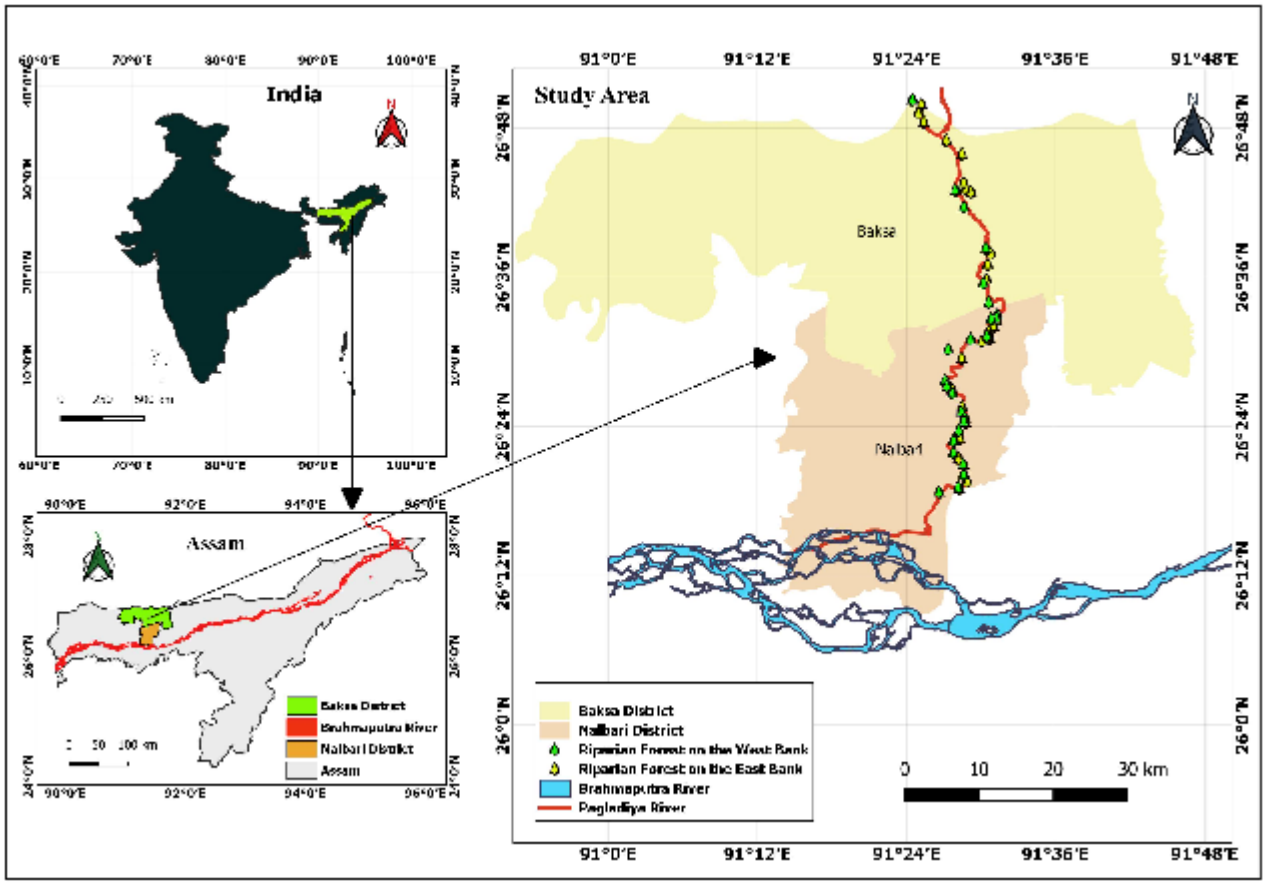

Figure 1. Location map of Pagladia river, Assam, India showing riparian forest patches

such zone, three locations were selected along the river course following random systematic approach (minimum of 2 km apart) for quantitative data collection thereby maintaining habitat heterogeneity (Barbour et al. 1999).

Disturbance types

Line transect of 100 m were laid at 12 locations for assessing the disturbance factors present. Disturbance scores were assigned to each location by qualitatively assessing various disturbances and were ranked as 0 = absent, 1 = rare, 2 = occasional and 3 = frequent levels of disturbances (Mani and Parthasarathy 2009). The sum of all these scores showing higher rank were considered as high disturbance zone, low ranks as low disturbance zone and intermediate ranks between high and low as moderate disturbance zone.

Disturbance indicator value

Disturbance indicator values for dominant species of each zone were calculated following Dufrene and Legendre (1997):

$$IV_{ij} = RA_{ij} \times RF_{ij} \times 100$$

Where, for each species i in each site group j, the relative abundance RA_{ij}, and the relative frequency RF_{ij}. Indicator value ranged from 0 (no indication) to 100 (perfect indication).

$$RA_{ij} = A_{ij}/A_i$$

Where, A_{ij} = the mean abundance of species i across sites of the group j, A_i = the sum of the mean abundance of species i over all groups.

$$RF_{ij} = S_{ij}/S_j$$

Where, S_{ij} = the number of sites in group j where species i is present, S_j = the total number of sites in that group.

Vegetation analysis

Reconnaissance surveys were undertaken to identify riparian forest patches along the entire course of river Pagladia in Assam. The extent of the riparian forest along the Pagladia river were categorized into four riparian zones based on their distance from the river bank (water edge) for comparison of various quantitative ecological parameters. Quadrats of 10 x 10 m were laid to assess the tree species diversity of the area (Sagwal 1995). A total of 68 quadrats were laid for sampling trees. Shrubs and herbs were enumerated by using nested quadrat of 5 × 5m (n= 68) and 1 × 1m (n=136), respectively. Standard taxonomic methods were followed for collection and drying of the plant specimens (Bridson and Forman 1998). Specimens were identified by using relevant taxonomic literature (Hooker 1897, Bor 1960). Macro-morphological characters for field identification of *Mallotus* species were studied through recent taxonomic revisions (Bollendorff et al. 2000, Slik and Van Welzen 2001, Sierra et al. 2005, 2007).

Data analysis

Kruskal-Wallis test (Kruskal and Wallis 1952) was carried out to check for significant differences in the intensity of the recorded disturbance types with the change in different riparian zones. Variation in the total tree species richness and density and the density of *M. nudiflorus* across the studied riparian zones were checked through the Kruskal-Wallis test (Kruskal and Wallis 1952). Further, the population size (seedling, sapling and tree individual) of *M. nudiflorus* was estimated in the studied zones and their relationships with two independent variables i.e. the different riparian zones and the disturbance scores were observed through Spearman Rank Correlation.

RESULTS

Type of disturbances in the riparian forest

A total of 14 prominent disturbance types were identified that supposedly affected the distribution of riparian forest species in the study area. However, the occurrence of all these 14 type of disturbances were not uniform across the riparian zones (RZ) (Fig. 2). It was observed during the survey that bank erosion, sand mining, channel diversion, vegetation clearing, weed infestation and waste deposition were the most frequent disturbance types encountered in the different riparian zones (Table 1). However, except for sand mining, weed infestation and fire, the other disturbance types were rare in the forested areas, which were at some distance from the water edge of the river (>91 m). On the contrary, disturbance factors like settlements or built-up area,

Table 1. Distribution of disturbance types in different zones of riparian forest of Pagladia river

Disturbance types	RZ-I(0-30 m)	RZ-II(31-60 m)	RZ-III(61-90 m)	RZ-IV(>90 m)
Sand mining	+	+	+	+
Embankment	+	+	+	-
Cultivation	+	+	+	-
Weed infestation	+	+	+	+
Vegetation clearing	+	+	+	+
Bank erosion	+	+	+	+
Waste deposition	+	+	+	+
Settlements	+	+	+	-
Grazing	+	+	+	-
Channel diversion	+	+	+	+
Road	+	+	+	-
Bridge	+	+	+	-
Fire	-	+	+	+
Dam	-	-	+	+

*RZ = Riparian Zone

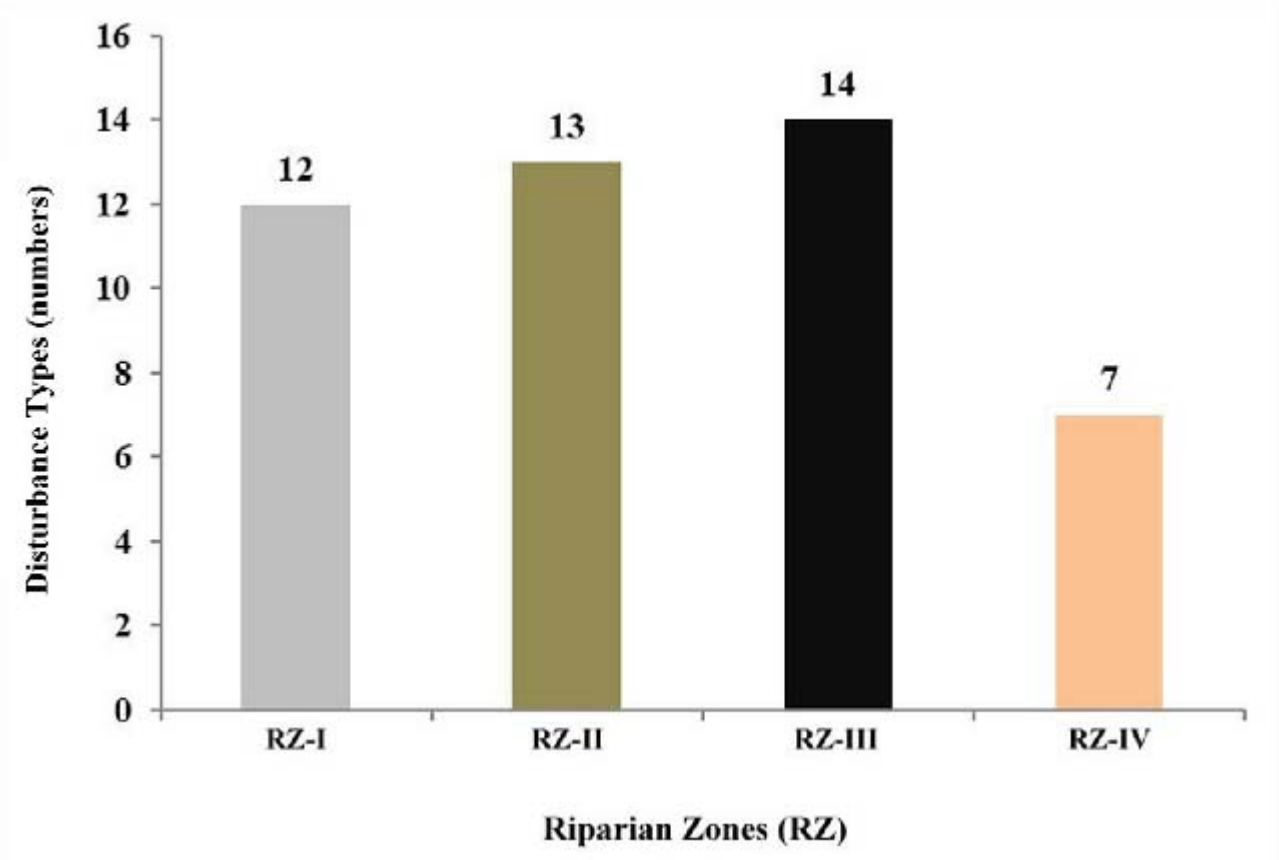

Figure 2. Type of disturbances in the different riparian zones of Pagladia river, Assam

agriculture, grazing, roadways, bridge and embankment occurred mostly in riparian zones situated close to the river (within 90m from water edge). The intensity of each disturbance type with respect to different riparian zones (RZ) were analysed using the Kruskal-Wallis test and it was observed that the incidence of sand mining was significantly different (H= 10.527, df= 3, p= 0.015) in both RZ-III and RZ—IV (61-90 m and > 91 m distance from water edge) with that of RZ-I (0-30 m distance from water edge) (Table 2). The intensity of agriculture or cultivation was significantly different (H= 9.604, df= 3, p= 0.022) between RZ-II and RZ-IV, while the frequency of weed infestation was found to be significantly different among all the studied riparian zones (H= 8.316, df= 3, p= 0.039). Similarly bank erosion (H= 8.418, df= 3, p= 0.038), waste deposition (H= 9.519, df= 3, p= 0.023), settlements (H= 9.519, df= 3, p= 0.023), and grazing (H= 9.316, df= 3, p= 0.025) intensities differed significantly between RZ-II and RZ-IV, and the presence of roads too differed significantly (H= 9.517, df= 3, p= 0.023) among all the riparian zones (Table 2).

Status of tree species in the riparian forest

A total of 46 tree species were recorded in the riparian forests that belonged to 39 genera and 23 families. *Mallotus nudiflorus* (IVI 39.40) was the most dominant species in the riparian forest area, followed by *Albizia lucidior* (Steud.) I.C. Nielsen (IVI 25.21), and *Bombax ceiba* L. (IVI 22.41) (Fig. 3). However, variation in tree species composition was observed along the different riparian zones (RZ) with the variation in the type and intensity of disturbance (Table 3). At RZ-I, the disturbance status was moderate and the area was dominated by tree species such as *M. nudiflorus, Albizia procera* (Roxb.) Benth., *B. ceiba*, and *Albizia lucidior* (Steud.) I.C. Nielsen. *M. nudiflorus* was the most important species (IVI 65.14) and frequent species (frequency 35%) in this zone. At RZ-II, disturbance status was high (Table 2) and here also the dominant tree species were *M. nudiflorus*, *Ficus auriculata* Lour., *Garuga pinnata* Roxb., *Ficus religiosa* L., *A. lucidior* and

Table 2. Relationship among different zones with the type of disturbances along riparian forest of Pagladia river

Disturbance types	Chi square (H)	Significance (P=)	Pair wise remarks
Sand mining	10.527	0.015	Both RZ-III and RZ- IV were significantly different with RZ-I (at P= 0.045)
Embankment	7.512	0.057	N/A
Cultivation	9.604	0.022	Significant difference observed between RZ-II and RZ-IV (at P= 0.038)
Weed infestation	8.316	0.039	Not observed
Vegetation clearing	6.389	0.094	N/A
Bank erosion	8.418	0.038	Significant difference observed between RZ-II and RZ-IV (at P= 0.025)
Waste deposition	9.519	0.023	Significant difference observed between RZ-II and RZ-IV (at P= 0.032)
Settlements	9.519	0.023	Significant difference observed between RZ-II and RZ-IV (at P= 0.032)
Grazing	9.316	0.025	Significant difference observed between RZ-II and RZ-IV (at P= 0.017)
Channel diversion	5.439	0.142	N/A
Road	9.517	0.023	Not observed
Bridge	7.403	0.060	N/A
Fire	7.464	0.058	N/A
Dam	2.200	0.532	N/A

(The significance level is 0.05) RZ = Riparian zone

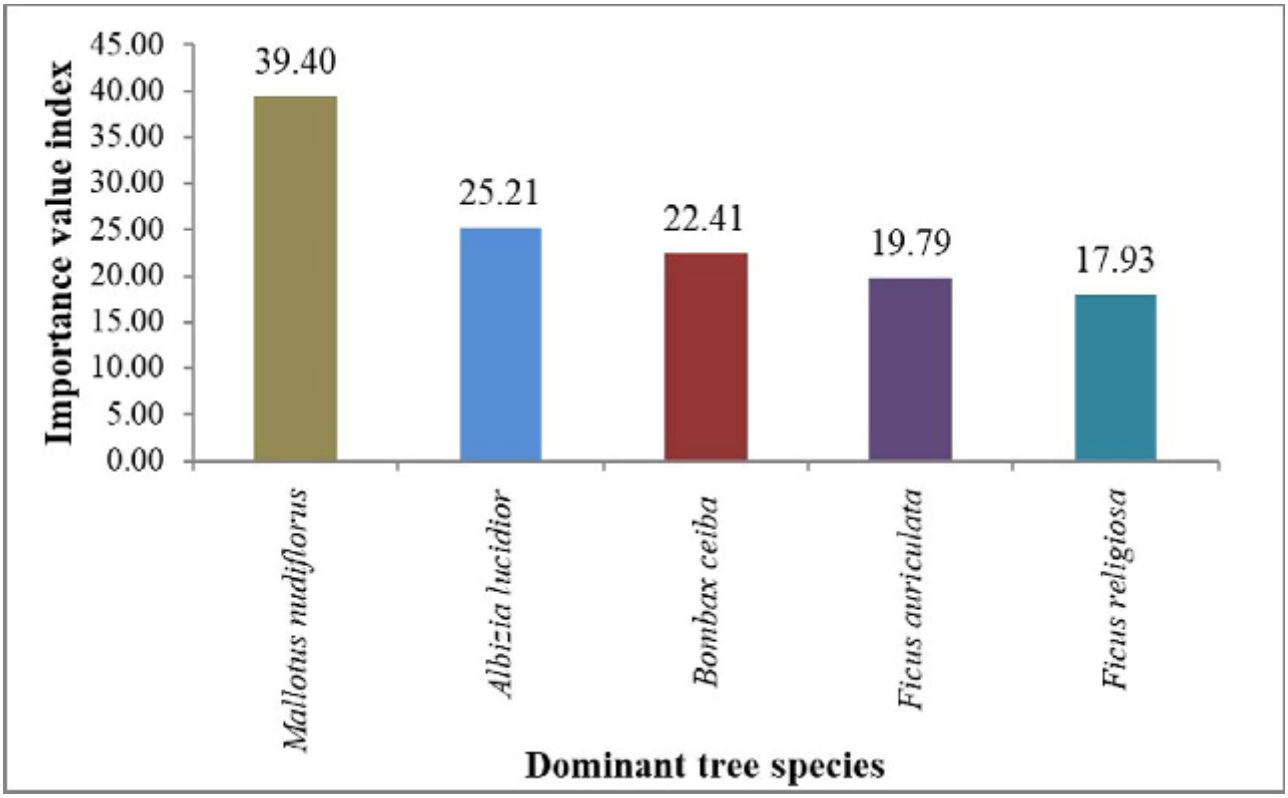

Figure 3. Status of five dominant tree species in the riparian forest of Pagladia river, Assam

M. nudiflorus. Here also *M. nudiflorus* was the most important species (IVI 41.10). However, *A. lucidor* was the most frequent species with 40% occurrence. At RZ-III, disturbance status was moderate and the dominant tree species were *M. nudiflorus*, *Lagerstroemia speciosa* (L.) Pers., *F. auriculata*, *A. lucidior* and *B. ceiba*. Among them *B. ceiba* was the most important and frequent species with an IVI of 68.19 and frequency of 55.56%. The disturbance status was recorded low for RZ-IV, where the dominant tree species were *Dysoxylum mollissimum* Blume, *Cassia fistula* L., *Phyllanthus emblica* L., *Ziziphus jujuba* Mill., and *Lagerstroemia speciosa* (L.) Pers. *Dysoxylum mollissimum* Blume was the most frequent species (frequency 57.14%) and also contributed to the highest importance value index (IVI= 54.55) for this zone. The basal area was dominated by *M. nudiflorus*, *F. religiosa*, *B. ceiba*, and *D. mollissimum* for the different zones viz. RZ-I, RZ-II, RZ-III and RZ-IV, respectively (Table 3).

The present study revealed that pioneers were confined to the heavily disturbed habitats (confined mostly nearer to the water edges), viz. *M. nudiflorus*, *A. lucidior*, *F. religiosa*, *G. pinnata* and *F. auriculata* (Table 3). Among the five dominant tree species found in the riparian zones studied, *M. nudiflorus* was the most dominant species of high (RZ-II) and moderately disturbed riparian zones RZ-I and RZ-III. However, *Mallotus* species was not recorded in the comparatively low disturbed habitat RZ-IV (>90 m distance from water edge). These forest patches were dominated by *D. mollissimum*, followed by *L. speciosa* and *Z. jujuba*.

Mallotus nudiflorus as a disturbance indicator species in the riparian forests

Analysis of disturbance indicator values for tree, sapling and seedling of *M. nudiflorus* for each riparian zone revealed that tree species had a positive correlation with the disturbance scores of the riparian forest of Pagladia river, Assam. The high values of disturbance scores were recorded for riparian zones (RZ-II: 29 and RZ-I: 22) close to the water edge and exhibited high disturbance indicator value for *M. nudiflorus* (Fig. 4). This species showed strong affinity for disturbed zone with comparatively high disturbance indicator value in RZ-II (14.75%) and RZ-I (10.66%). However, disturbance indicator value

Table 3. Account of ecological parameters of five dominant tree species across the studied riparian forest zones (RZ) of Pagladia river, Assam

Most dominant tree species	Frequency (%)	Density (Individuals/ha)	Basal area (m^2/ha)	IVI
RZ-I (Disturbance status: Moderate, Disturbance score: 22)				
Albizia procera (Roxb.) Benth.	15.00	40.00	3.20	17.29
Bombax ceiba L.	20.00	45.00	2.75	18.48
Albizia lucidior (Steud.) I.C.Nielsen	25.00	45.00	2.45	19.28
Ficus auriculata Lour.	35.00	55.00	2.05	22.77
Mallotus nudiflorus (L.) Kulju & Welzen	25.00	130.00	17.55	65.14
RZ-II (Disturbance status: High, Disturbance score: 29)				
Ficus auriculata Lour.	20.00	44.00	6.56	21.54
Garuga pinnata Roxb.	28.00	76.00	4.20	22.63
Ficus religiosa L.	20.00	104.00	9.12	32.16
Albizia lucidior (Steud.) I.C. Nielsen	40.00	176.00	4.64	36.65
Mallotus nudiflorus (L.) Kulju & Welzen	36.00	180.00	7.48	41.10
RZ-III (Disturbance status: Moderate, Disturbance score: 19)				
Mallotus nudiflorus (L.) Kulju &Welzen	22.22	44.44	2.11	18.84
Lagerstroemia speciosa (L.) Pers.	33.33	55.56	0.89	20.24
Ficus auriculata Lour.	33.33	44.44	3.11	24.88
Albizia lucidior (Steud.) I.C.Nielsen	22.22	77.78	4.44	30.24
Bombax ceiba L.	55.56	111.11	12.78	68.19
RZ-IV (Disturbance status: Low, Disturbance score: 8)				
Cassia fistula L.	21.43	57.14	1.93	24.07
Phyllanthus emblica L.	21.43	64.29	1.86	24.79
Ziziphus jujuba Mill.	21.43	78.57	2.71	30.40
Lagerstroemia speciosa (L.) Pers.	28.57	107.14	1.57	32.36
Dysoxylum mollissimum Blume	57.14	128.57	3.64	54.55

gradually decreased (3.64%) for the moderately disturbed riparian zone RZ-III (3.64) and with no indication in the RZ-IV as the distance from the water edge increased. The regenerating saplings were positively correlated to the moderate zones as compared to the highly disturbed zone (Fig. 4). A very low disturbance indicator value (1.74) was recorded for saplings, when the distance of riparian forest extended beyond 90 m in the low disturbed riparian forest patches (Disturbance Score 8). While, *M. nudiflorus* seedlings were recorded only in the riparian zones closest to the water edge viz. RZ-I and RZ-II with a disturbance indicator value of 3.86% and 2.76%, respectively. The seedlings for this species were not found beyond 60 meters from water edge (Fig. 4).

Quadrat wise analysis revealed that tree species richness was recorded highest for RZ-II (3.91) followed by RZ-III (3.89) (Table 4). Similarly, tree density varied from 630 to 1037.50 individuals ha^{-1} for the different riparian zones (Table 4). Whereas, the density of *M. nudiflorus* varied from 185.71 individuals ha^{-1}, 187.50 individuals ha^{-1} and 50 individuals ha^{-1} at RZ-I, RZ-II and RZ-III, respectively, but in RZ-IV, it was completely absent (Table 4).

There was no significant difference in tree species richness in the different riparian forest zones studied (Kruskal-Wallis test, H= 4.285, df= 3, p= 0.232). However, significant difference in tree density (Kruskal-Wallis test, H= 9.638, df= 3, p= 0.022) for the riparian forests and density of *M. nudiflorus* (Kruskal-Wallis test, H= 9.703, df= 3, p= 0.021) were observed among the riparian zones. The post hoc test revealed that both tree density and *M. nudiflorus* density significantly varied for RZ-II and RZ-IV at

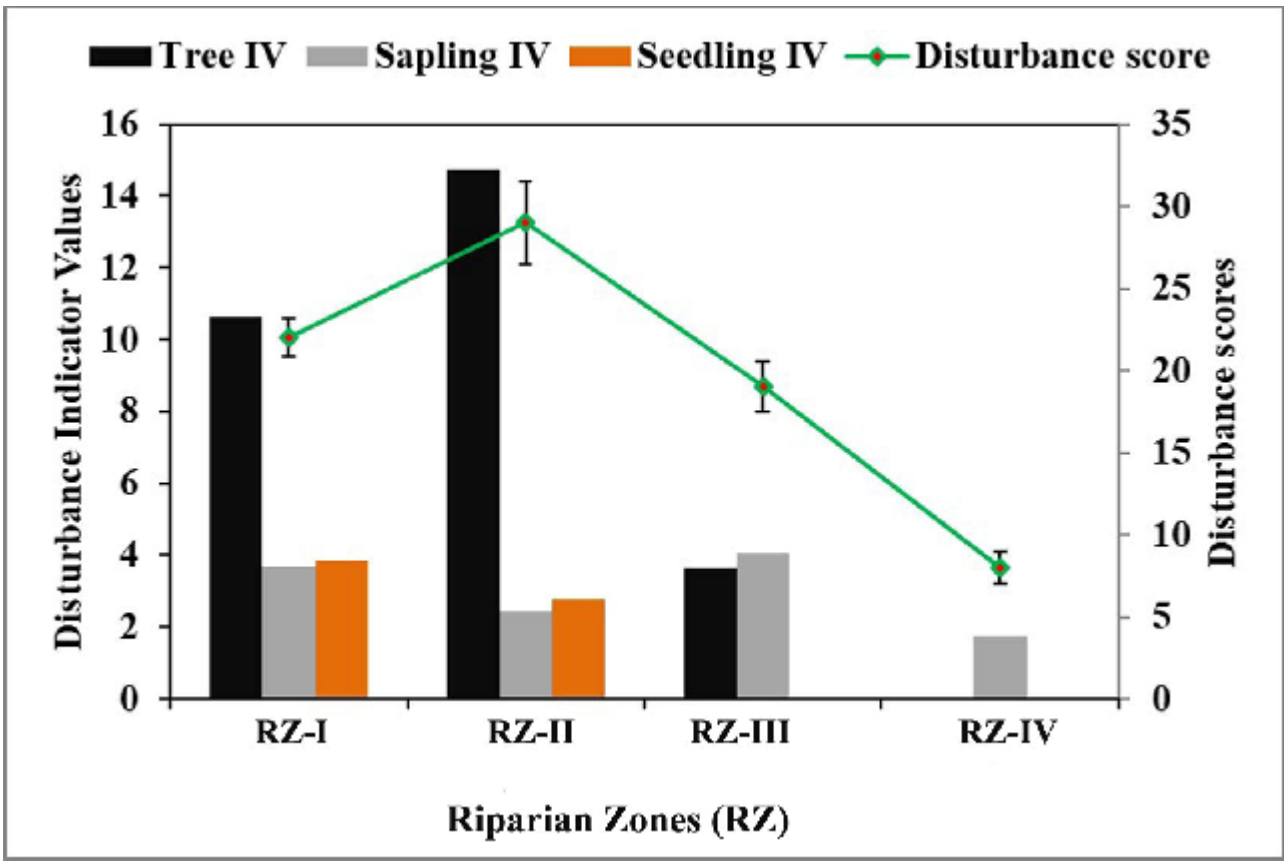

Figure 4. Relationship between disturbance indicator values of *Mallotus nudiflorus* and disturbance scores in the different riparian forest zones of Pagladia river, Assam

Table 4. Status of total tree species richness and density and *M. nudiflorus* density in the riparian zones

Riparian zones	Tree species richness Mean ± SD (Range)	Tree density (Individuals ha^{-1}) Mean ± SD	Density of *Mallotus nudiflorus* (Individuals ha^{-1}) Mean ± SD
RZ-I	3.64 ± 2.13 (1-7)	792.86 ± 349.65	185.71 ± 300.91
RZ-II	3.91 ± 1.95 (1-8)	1037.50 ± 463.27	187.50 ± 354.24
RZ-III	3.89 ± 2.17 (1-8)	775 ± 608.86	50 ± 106.90
RZ-IV	2.75 ± 1.29 (1-5)	630 ± 392.16	0

Table 5. Comparative account of disturbance scores and density (Individual ha^{-1}) of trees, saplings and seedlings of *Mallotus nudiflorus* in different zones of riparian forest of Pagladia river, Assam

Parameters	**Riparian zones**	**Disturbance score**
Tree density	-0.206	**0.295***
Sapling density	0.002	**-0.530****
Seedling density	-0.098	0.208
Riparian zones	-	**0.530****

*Correlation is significant at the 0.05 level (2-tailed)

p= 0.017 and p= 0.028, respectively (Table 5).

Spearman Rank Correlation revealed that disturbance scores were positively correlated with the different riparian zones (r_s=0.530 at 0.01 significant level) (Table 5). Similarly, a significant positive correlation was also found between *M. nudiflorus* tree density and disturbance scores (rs=0.295, p=0.05). However, a strong negative correlation was observed between *M. nudiflorus* sapling density and the disturbance scores (rs= 0.530, p= 0.01) (Table 5).

DISCUSSION

Pagladia (locally known as the Mad river) being a major North bank tributary of the river Brahmaputra originates in the Bhutan foothills and flows through the Baksa and Nalbari districts of Assam, Northeast India. The Pagladia river forms one of the major watersheds in the North Bank of Brahmaputra River. The Pagladia as the name implies, has been a chronic source of disturbance triggering annual flood and thereby inflicting severe bank erosion leading to frequent changes in its flow course. The river has been creating devastations in the entire sub-basin inundating large areas, damaging standing crops, washing away homestead lands, and snapping road and railway communications. The flood can be attributed to high discharge in the river that results in frequent breaching of the embankments. The extent of riparian forest along the river is not continuous throughout its course and the forest patches were found to vary with the altering of the river course. Pagladia seems like a small channel near the foothills of Bhutan Himalaya and comprised of comparatively less disturbed riparian forest patches as this zone is almost free from bank erosion and human habitations. However, bank erosion is a typical disturbance factor of the river and evident mostly in the riparian zones RZ-I and RZ-II, which were comparatively closer to the water edge. It was evident that, when the river flows downstream in the valley areas, it gradually increases its river bed width and the maximum distance of riparian zones from water edge kept on changing depending on factors like severe bank erosion due to the effect of heavy rain induced flash floods during monsoon, as well as the confluence zone created by several other seasonal and perennial streams joining the Pagladia river.

Mani and Parthasarathy (2009) found that tree species richness and abundance exhibited a considerable change due to the effect of various disturbance factors and associated it with cultural tradition of the local communities, grazing, resource removal and land use changes. Riparian zone is a highly productive and preferred area for human settlements, as it has a great impact on socio-economic activities. In the present study also, except for the foot hills of Bhutan Himalaya, the maximum stretch of the river was occupied by human settlements with activities like agricultural practices, riparian vegetation clearing as well as livestock grazing, construction of embankment, roadways, bridges and sand mining, which might have altered this otherwise unique and highly productive ecotone zone. The riparian ecosystem of major river basins such as the Amazon and Mediterranean landscapes have already lost much of their structure due to the severe anthropogenic activities (Nilsson and Jansson 1995).

During the present survey, it was observed that the riparian forest patches were severely infested by invasive alien species viz. *Chromolaena odorata* (L.) R.M. King & H. Rob., *Lantana camara* L., *Mikania micrantha* Kunth, *Ageratum houstonianum* Mill. etc. Alien invaders can alter the structure and functioning of the natural ecosystems (Khuroo et al. 2007, Reshi et al. 2008). Riparian ecosystems provide the dispersal networks for different landscapes and are very vulnerable to plant invasion due to the high frequency of open ground for colonization resulting due to the continuous occurrence of natural disturbances (Forman and Godron 1986, Malanson 1993, Planty-Tabacchi et al. 1996, Sunil et al. 2011). Although, building dams on the river Pagladia was evident mostly in the distant areas such as in RZ-III and RZ-IV only, where other disturbances were observed rare, but due to habitat alterations, this zone also facilitated the proliferation and establishment of weedy plants to the previously non-invaded areas.

In the present survey, it was observed that *Mallotus nudiflorus* preferred the highly disturbed riparian zones in the lower reaches of the river; than the comparatively lesser disturbed foot hill zones of the Bhutan Himalaya. Previous works indicated that *Mallotus* species are characteristic of secondary forest types and establishes only after an event of

disturbance (Airy Shaw 1975, Whitmore 1975, Davies 2001, Slik et al. 2003). All the dominant species of the study area were observed to have the elements of secondary forest as compared to the primary forest. *Mallotus* species are mostly pioneer species that preferred high to moderately disturbed habitats for their successful establishment in a site (Primack and Lee 1991, Davies et al. 1998, Slik et al. 2002). *M. nudiflorus* in the present study area was confined mostly to the highly disturbed habitats that might have been created either due to natural disturbances or anthropogenic activities. The foot hills of Bhutan Himalaya in the upper reaches of the river were characterized by natural and comparatively less disturbed forest patches and were dominated by shade tolerant plant groups representing primary forest. These forest patches were found to be dominated by tree species such as *Dysoxylum mollissimum* Blume, followed by *Lagerstroemia speciosa* (L.) Pers., *Ziziphus jujuba* Mill., *Phyllanthus emblica* L. and *Cassia fistula* L. *D. mollissimum* a shade tolerant element of undisturbed habitats that regenerates in the shades and is a late successional species in mature forests (Kariuki and Kooyman 2005).

Tree density of *M. nudiflorus* was found to vary significantly among the different riparian zones depicting different disturbance intensity and was positively correlated with the disturbance scores indicating that this species preferred open disturbed habitats like a typical riparian forest species. It has been reported that the occurrence of pioneer species like *Mallotus* was closely related to the level of disturbances in a forest (Slik et al. 2003). However, the regenerating saplings of *M. nudiflorus* were found to be negatively correlated with the disturbance scores, which might be due to the effect of some other prominent disturbances like recurrent flooding and sedimentation, grazing, fire and vegetation clearance in the studied zone. The seedlings of the *Mallotus* species kept on declining with the increase in distance from water edge clearly indicating its preference for disturbed habitat.

CONCLUSION

Riparian landscapes are important ecosystems that portrays the ecological system of stream side and flood plain areas from the perspective of landscape ecology and hence it becomes important to understand its ecology. The occurrence of *Mallotus* species was related to the type and level of forest disturbance in the riparian forests of Pagladia river, a major tributary of river Brahmaputra in Northeastern India. *M. nudiflorus* can be ranked according to its preference for certain types of disturbance like open disturbed habitat, severe weed infestation, bank erosion, fire, continuous flood and grazing. Disturbance adapted species such as *M. nudiflorus* can be used as forest disturbance indicator species which can be instrumental in predicting the level of forest disturbance.

ACKNOWLEDGEMENT

The authors are grateful to Head of the Department of Ecology and Environmental Science, Assam University, Silchar, Assam, India for extending his support during the research work. We would also like to thank Mr. Sibam Sarkar for helping with the statistical analysis which improved the work greatly. The first author (RS) would like to extend his heartfelt gratitude to Late Bipul Das for his assistance during the entire field survey and dedicate this article to him.

Author's contributions: Rupam Sarmah (RS) carried out the field works, collected the field data, tabulated and analysed the data and drafted the manuscript. Panna Deb (PD) designed, supervised, monitored and analysed the research work. Both the authors read and approved the final manuscript before submission. The study is a part of the Ph.D. work of Rupam Sarmah.

Conflict of Interest: The authors declare no conflict of interest.

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Received:23rd March 2023
Accepted:12th July 2023