Impacts of Fragmentation on Vegetation and Conservation of Myristica Swamps of Western Ghats, India: Special Emphasis to Flagship Species *Myristica magnifica* Bedd.

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Abstract: ***The Western Ghats, one of the biodiversity hotspots in India is endowed with a variety of ecosystems. The edaphically formed freshwater swamps in the low laying valleys are one amongst them. The vegetation of swamp is dominated by the members of the family Myristicaceae and is termed the Myristica swamp, unique with Myristica magnifica, an evergreen dioecious swampy Indian endemic and endangered tree. The specialist species, M. magnifica, is structurally and functionally adapted to grow in inundated condition with stilt roots, pneumatophores, recalcitrant seeds, etiolate initial growth of seedlings etc. and are restricted in distribution. It is proved that no other ecosystems of Western Ghats supporting the germination, recruitment and establishment of this tree; hence M. magnifica can be considered as flagship species of Myristica swamp. This unique and vital forests and flag ship species are in the verge of extinction due to natural and manmade reasons, especially due to isolation and fragmentation. The anthropogenic pressure has lead to disruption and discontinuation of flora and fauna with selective recruitment, which in turn interrupts the structural and functional dynamism of the swamp, followed by the vegetational succession. This can be typified into three zones viz. core, transition and edge based on the degree of succession and community status of the flagship species. The present study focuses on the percentage of seeding and germination, viability pattern, seedling vigour, survival rate, and subsequent selective recruitment of flagship species in natural and nursery conditions to assess the effect of fragmentation on acclimatization of flagship species to the swamp. This information is most crucial in elucidating the lifecycle of this tree, an Indian endemic and endangered species which is struggle for existence due to habitat loss. The information about vegetational dynamics of swamp and ecological functioning of flagship species are helpful in management of species and ecosystem.***

Keywords: Fragmentation, *Myristica magnifica*, Myristica Swamps, Flagship species, Western Ghats

1. Introduction

Myristica swamps of the Western Ghats are unique and fragile forested ecosystems with complex association of flora and fauna, which is renowned for unique and characteristic floristic wealth and diversity. The members are mostly adapted to survive in marshy conditions. These rare fresh water ecosystems of Kerala region are furthermore specific with the distribution, community and conservation status of arborescent species *Myristica magnifica* Bedd., nevertheless the species has not been reported from any other forest types. The swamps are also co-dominated with other amphibian Myristicaceae tree species like *Gymnacranthera canarica*, *Myristica malabarica*, *M. beddomei* and *Knema attenuata*. The other common non-Myristicaceae members are *Syzygium travancoricum*, *Lophopetalum wightianum*, *Lagerstroemia speciosa* etc., the members from other life forms like geophytes, lianas and epiphytes are well contributed to floristic and structural components. The floristic wealth and its conservation status were documented by different authors [3], [36], [31], [6] some of them are entered in the Red Data Book of Indian plants [26], [27]. Presently, like any other ecosystems, this pristine vegetation is also heading towards extinction due to fragmentation and isolation by altering the structural and functional dynamism. The initial changes in general ecology and physical edaphology will create a wedge in water flow, resulting in silting and leading to the destruction of micro niche by checking matter and energy flow. This gets reflected in the seed dispersal, germination and seedling establishment of members, most critical and sensitive stages in the life cycle of plants, and subsequently these virgin ecosystems are in the transformed condition with different degree of ecological successions. This ecological and floristic shift is initiated with seed germination, recruitment and early establishment of flagship species *M. magnifica* and hence regenerative capacity and aggressive capacity of the *M. magnifica* can be taken as the beginning benchmark for the floristic transformation. Being a specialist species the life cycle of this plant is related to swamp conditions. The abiotic and biotic factors of swamp play a major role in determining initial establishment and subsequent existence, especially with positive water regime. The fluctuating water regime due to fragmentation will alter the general ecology and physical edaphology, which changes the floristic component of the ecosystem in general and the community status of specialist species in particular. Under this circumstance this investigation focuses on the seed germination, survival rate and growth performance calendar of *M. magnifica* in different conditions, and its relative community status in natural habitat in relation with changes in the functional dynamism, ecological successions, which will summarise future conservation status and functional dynamism of these ecosystems together with flagship species.

2. Literary Survey

The freshwater swamps ecosystems conserving unique pristine biotic associations by harbouring many threatened adaptive life forms especially of dominant distribution of Myristicaceae members and can considered to be the home of Angiosperms [7], [8]. [38] finds many archaic and primitive features in the family Myristicaceae, the terms it as one of ‘living fossils’, which due to some favourable circumstances escaped from extinction. The present day geographic distribution of this family is an enough evidence of its origin before the breakup of Gondwanaland [32], Thorner, 1974; [40], [9], [23]. Whenever the members of Myristicaceae distributed in world today, in Amazon, Africa, New Guinea, Madagascar, Malaysia or India, despite their separation by thousands of kilometres of oceans, they have striking similarity such as tree habit, evergreen nature, reddish exudation, unisexual flowers, beetle pollination, and fleshy fruits with a single large seed envelop in a brightly coloured aril. The taxonomists considered Myristicaceae as an archaic family in Magnolias, the most primitive of the flowering plants. The fresh water swamps of Western Ghats are being threatened habitats, the population of flagship species is also declining [30]. The major threat to the Myristica swamp of Western Ghats was their conversion into rice field [22], [5]. Many have been also converted Areca nut, Oil palm and Teak plantations. In 1970s, during the peak period of commercial extraction of timbers from forests, the *Myristica* spp. was leased out to the plywood industry, especially the light wood of *M. magnifica* and *Gymnacranthera canarica* considered useful for packing cases, matches box, plywood industries [13]. This scenario with additional impacts of fragmentation and isolation many taxa are being disappearing from these fragile ecosystems [30]. Habitat loss largely has, consistent negative impacts on biodiversity, so the researchers who conceptualize and measure fragmentation as equivalent to habitat loss typically concluded that fragmentation has large negative effects. The negative effects of habitat loss apply not only to direct measures of biodiversity such as species richness [12], [15], [37], [10] population abundance and distribution [16], [17], [18], [20], [25], [34], [42] and genetic diversity [14], but also to indirect measures of biodiversity and factors affecting biodiversity. A model by [1] predicts a negative effect of habitat loss on population growth rate. This is supported by [11], who found that species showing declining trends in global abundance are more likely to occur in areas with high habitat loss than are species with increasing or stable trends. Habitat loss has been shown to reduce trophic chain length [21], to alter species interactions [45], and to reduce the number of specialists, large-bodied species [14]. Habitat loss also negatively affects breeding success [24], dispersal success [2], [29], [43] predation rate [46], [19], and aspects of animal behaviour that affect foraging success rate [44].

3. Materials and Methods

3.1 Study Site

Myristica swamps with different degrees of vegetational and ecological succession due to fragmentation and isolation under Shankhili section, Kulathupuzha Forest Range, Trivandrum Forest Division in Kerala State was selected as the study area. 10-15 quadrates (size-10 x 10 m.) were laid in each site and enumeration were carried out and the numbers were converted into percentage of occurrence. Here, the swampy ecosystem is fragmented and isolated by the construction of road. Each swamp was identified and classified into three vegetational zones viz. core zone, transition zone and edge zone based on degree of succession, the occurrence and community status of specialist species and rate of invasion of the generalist species. The region with minimum invasion and maximum swampy condition (including the edaphic conditions) is selected as core zone. The edge zone is identified with maximum invasion of generalist species and minimum occurrence of specialist species and absence of flag ship species. The region with intermediate condition is selected as transition zone. The natural germination percentage, seedling establishment and casualty rate at different stages were calculated by counting method.

	Geo coordinates	Description
1	Sasthanada 77.0524^{o}N, 8.81886^{o}E	This patch is located in the right side of Venkolla- Sankhili road, an area 3.22 ha is located opposite to Sasthanada temple.
2	Karinkurinji 77.0472^{o}N, 8.80027^{o}E	It is also situated on the right side of Venkolla - Sankhili road 500 m before reaching the Sasthanada temple, occupying an area of 7.00 ha
3	Uthiranchira 77.0401^{o}N, 8.80073^{o}E	The typical swamp in the Sasthanada region, situated on the far left of Venkolla- Uthiranchira road, of an area 5 ha. The swamp is inundated throughout the year.
4	Muppatadi 77.0665^{o}N, 8.81139^{o}E	The swamp is situating 1 km interior to the Poovar-Muppatadi range. It covers an area of 1.37 ha.

3.2 Methodology

The germination studies were conducted in both *in-situ* and *ex-situ* conditions. The germination medium in the laboratory was standard potting mixture and swampy soil in 18 x 30 cm tray with 8 cm depth with negative and positive water regime in room temperature. The germinated seeds and early establishments were counted every 5 days for 10 weeks in core, transition, edge zones, as well as in different nursery conditions. The growth performance were measured and plotted against time. 50 seeds were collected and allowed to germinate in potting mixture and swampy soil in laboratory condition to study the effects of edaphic condition along with negative and positive water regime. The seeding percentage was assessed by counting methods. The seed viability was determined by examining whether the endosperm was decayed or not. Viability percentage was determined by counting number of viable seed from total number of tested seeds. The seed vigour index is calculated by multiplying germination percentage with seedling length (m). The casualty rate due to other reasons was also calculated by counting method.

$$\textbf{Viability percentage} = \frac{\text{Number of viable seeds}}{\text{Total number of seeds}} \text{X100}$$

$$\textbf{Germination percentage} = \frac{\text{Total number of germinated seeds}}{\text{Total number of seeds}} \text{X100}$$

Seed vigour index = Germination percentage X Seedling length at the end

4. Results and Discussion

The study shows that, in the core zone the rate of non-viable seeds were 9.05%, in the transition it was 13.5% and in the edge zone it was 26.5% after the seeding. The secondary dispersal rate was 15.6% of the total seeds in the core, 19.9% seeds in the transition and 38.04% on edge. The germination percentage was also noticed, out of 131 viable seeds, 76.8% germinated in the core region, while 66.5% in transition and only 35% in edge zone. The respective values of casualty rate of seedlings in core, transition and edge was 73.1%, 80.8% and 91.6% (Table1). In the swampy soil with positive water regime, 94% of seeds germinated and the survival rate is 72%. In the medium of swampy soil with negative water regime; 52% seeds germinated and 14% survived. The normal potting mixture (sand, soil, cow dung in 1:1:1 ratio) with positive water regime shows a germination percentage of 86 and 67% survival rate. The other experimental medium of potting mixture with negative water regime shows a 64% germination rate and 09 % survival rates. (Table.2). The growth performance of *M. magnifica* in both media with positive water regime is high, while in the situation of negative water regime, the growth performance is low. Water regime is the main factor in germination (Fig. 1). The Seedling Vigour Index in core zone is 52.22, transition zone 39.9, and edge zone is 15.4. In nursery condition, the swampy soil with positive water regime shows the highest value (75.2) followed by potting mixture with positive water regime (64.5). The respective values for swampy soil and potting mixture with negative water regime are 26.0 and 18.0 (Table. 3, Plate. 1).

Table 1: Regeneration and initial recruitment status of the *Myristica magnifica* in natural habitat

S. No	Parameters	Core zone	Transition zone	Edge zone
1	Total no of viable seeds	131	101	061
2	Secondary dispersal (%)	15.60	19.90	38.40
3	Non-viable seeds (%)	09.05	13.50	26.50
4	Germination rate (%)	76.80	66.50	35.00
5	Casualty rate (%)	73.10	80.80	91.60
6	Survival rate (%)	26.80	19.10	08.30

Table 2: Regeneration and initial recruitment status of the *Myristica magnifica* in nursery condition

Growth medium	Positive water regime					Negative water regime				
	Total no seeds	Non-viable seeds (%)	Germination rate (%)	Casualty rate (%)	Survival rate (%)	Total no of seeds	Non-viable seeds (%)	Germination rate (%)	Casualty rate (%)	Survival rate (%)
Swampy soil	50	06	94	28	72	50	58	52	86	14
Potting mixture	50	14	86	33	67	50	64	36	91	09

Table 3: Seed vigour index in different zones and growing medium

Sl no	Germination in natural condition and nursery	Germination (%)	Seedling length in m	Seedling Vigour Index
1	Core zone	76.80	0.68	52.22
2	Transition zone	66.50	0.60	39.90
3	Edge zone	35.00	0.44	15.40
4	Swampy soil with + ve water regime	94.00	0.80	75.20
5	Swampy soil with - ve water regime	52.00	0.50	26.00
6	Potting mixture with + ve water regime	86.00	0.75	64.50
7	Potting mixture with - ve water regime	36.00	0.50	18.00

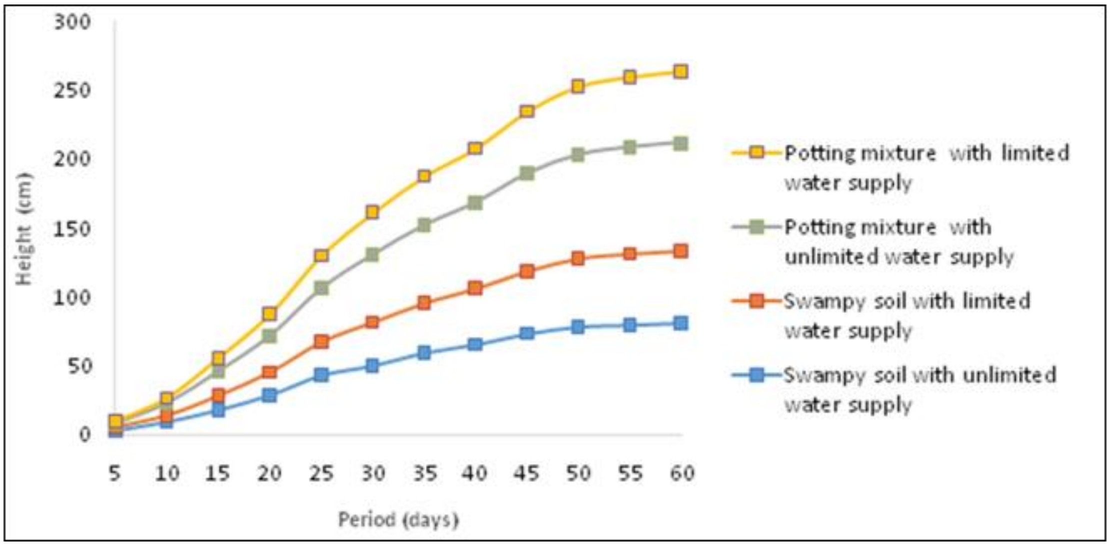

Figure 1: Comparative growth rate of *Myristica magnifica* in swampy soil and potting mixture in different water regime.

Plate 1: Physiognomy and Ecology of Myristica swamp and reproductive capacity of *Myristica magnifica*
A. Typical Myristica swamp with M.magnifica; **B.** Stilt roots; **C.** Knee roots; **D.** Male flower; **E.** Fruit, seed & aril; **F,G,H,I,J.** Different stages of growth (*in vivo* & *in vitro*); **K.** Etiolated seedling with scale leaves; **L.** Etiolated seedling with leaves; **M,N.** Hardening of seedlings; **O.** Primary seed dispersing agent (*Ocyceros griseus*); **P.** Secondary dispersing agent (*Barytelphusa guerini*)

The growth rate of seedlings up to 60 days in 3 zones viz. core, transition and edge shows vigorous growth rate with an average of 1 cm per day from the first day of germination were observed. The growth performance in edge zone is slightly less when compared to the core and transition zones. This may be due to the edaphic condition which does not satisfy the requirement of swampy species. After 60 days of etiolating growth of seedlings the relative growth rate retarded or arrested due to apical bud abortion, and is followed by the development of leaves and stem hardening. At next stage in natural conditions, seedlings have high percentage of casualty, succumbing to either pest attack or unfavourable environmental or edaphic conditions. In this regard, also a considerable variability is reflected in different successional areas, in the core zone the value is 97.5%, in the transition zone the value is 98.5%, while in the edge zone 100% casualty has been observed (fig 2, plate 2). It is observed that, except edge zone the age class curve of flagship species is 'L' shaped, indication of sustained growth and development in both core and transition zone. More number of large trees (>200 cm) is seen in the edge zone, benchmark of earlier swampy condition of zone.

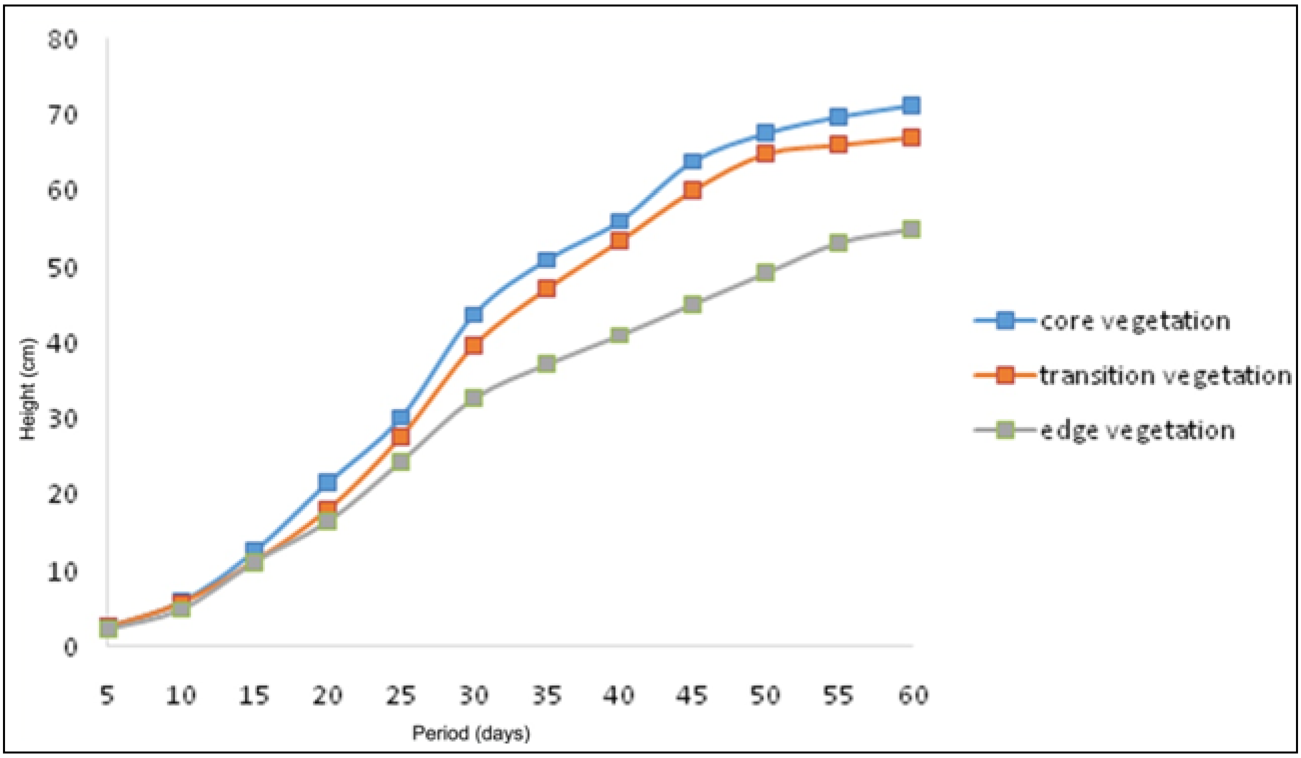

Figure 2: Relative Growth Rate of *Myristica magnifica* seedlings

Plate 2: *In vivo* Seedling causalities of *Myristica magnifica*
a. Sprouting after apical bud abortion; **b.** Pest attack; **c.** Damage due to flood; **d.** Wilting; **e.** Debarking by wild animals; **f.** Anthropogenic activities

The Western Ghats is well known for being endowed with a variety of ecosystems. The freshwater ecosystems are distributed in the low lying valleys of this hill tract. These ecosystems are critically important in floristic, ecologic and edaphic conditions. Swamps and marshes are physio-geographic features of low lying areas resulting from hydrologic and geomorphic peculiarities [39]. They support characteristic vegetation types subjected to seasonal flooding. In tropical countries such vegetation are frequently seen in midst of natural forests and along the flood plains of rivers. They form an integral part of wetland ecosystems, serving as habitats, breeding chests, and food sources for many life forms [4]. In India, fresh water swamps (4C/FSI forest category by [5] occurs mainly in valleys of southern Western Ghats [22], [28], [33], [13], [35], [6], [41]. The existing swamps are heading towards extinction due to the transformation through ecological succession generated with fragmentation and isolation of these ecosystems, with various manmade and natural reasons. A number of critical ecological factors and environment or edaphic interactive issues are related to *in vivo* species conservation, affected by fragmentation, degradation and depletion of vegetation, due to selective recruitment. One amongst that is the fall in the recruitment rate of important specialist species, *M. magnifica*, the red listed Indian endemic is an evergreen dioecious 25-30 m tall tree. It is characterised by straight trunk, horizontal branching, conical canopy and large leaves. The taproot is rudimentary or absent in adult condition and are modified as highly branched stilt roots to anchor in marshy condition, the special adaptive feature of the tree. The fruits are drupes with a single large seed covered with red aril. The tree shows ecologic and edaphic specificity in distribution, dominant members in core and transition zone, while subdominant or co-dominant in transition zone and in edge zone it is represented with mature plants having the community well below the generalist species (Table. 4).

Table 4: The community Status of important tree species of Myristica swamps in three succession zone

Sl No.	Name	Core Area	Transition Zone	Edge Area
1.	*Aporosa lindleyana*		05.12	16.75
2.	*Chilocarpus denudatus*	13.92	08.53	06.82
3.	*Gymnacranthera canarica*	52.56	49.37	19.89
4.	*Holigarna arnottiana*	16.10	24.15	36.38
5.	*Hopea parviflora*		16.73	14.58
6.	*Hydnocarpus pentandra*	11.74	13.85	10.00
7.	*Knema attunetta*	10.34	18.24	33.47
8.	*Lagerstroemia speciosa*	23.50	08.90	30.90
9.	*Lophopetalum wightianum*	09.48	19.85	33.75
10.	*Myristica bedommii*	05.67	21.84	23.90
11.	*Myristica magnifica*	86.43	59.81	22.34
12.	*Myristica malabarica*	26.17	28,43	30.17
13.	*Neolamarckia cadamba*	06.74	16.60	18.90
14.	*Syzygium travancoricum*	20.41	10.50	06.30
15.	*Vateria indica*		20.49	28.00
16.	*Xanthophyllum arnottianum*		04.85	11.20

The mammalian and avian fauna aid primary dispersal, and biotic agents like rodents (*Mus musculus*) and freshwater crabs (*Barytelphusa guerini*) and abiotic agents like water current are actively involved in secondary dispersal, resulting in the high percentage of seed removal from the system. The high activity of the dispersing agents both through the pre and post seed shedding predation results in high mortality of the swampy species even in the dispersing stage. This is because of the seeds' specific requirements of germination. The seeds dispersed from the systems also failed to germinate due to unfavourable edaphic and environmental condition created mostly due to the negative water regime. Even though the germination rate is promising within the system the rate of casualty of the seeds and seedlings increase at the time of etiolating, due to attack by pests, wild fauna and water currents. Seedlings which were monitored for 60 days show a different state of casualty in different stages. The primary cause was the flooding and silting of the soil. If the water is excess the plumule decays and in dry condition the plumule wilts and causes the death of the seedlings. Again, those which survive these conditions were attacked by the pests and wild fauna; this can be taken as the second stage of casualty. The rate of casualty in different strata from core to edge is increasing. The seedlings are adapted to survive in marshy condition with high relative growth rate in the initial stage followed by hardening. In the latter stage, grown up seedlings also die due to changes in ecology and edaphology indicating the involvement of environmental and floristic association required for the species. The germination and establishment rate is high in the core area and shows decreasing trends towards the advancement of ecological and vegetation successions. The seed germination and initial seedling establishment of generalist species shows the reverse order values, high in edge followed by transition and core zones. This information is indicative and relevant to the different required micro-niches of specialist species. This will reveal generalities about species composition and their community status (Plate.2).

It is observed that both the media with positive water regime shows relatively high germination rate. The negative water regime shows low germination rate and further establishment, may be the reason for the decline in the recruitment in the transition and edge zones. The changes created with fragmentation and isolation leads to swampy edaphic condition to terrestrial soil condition. The unfavourable micro-niche retards the seed germination and seedling establishment of specialist species and favoured the growth and establishment of generalist species. This selective recruitment for a period leads to the formation of terrestrial ecosystems from swampy ecosystems and the natural erosion of species *M. magnifica*. The fluctuations in the community status of specialist species in terms of different age class frequency in different successional stages of vegetation indicate the specific edaphic requirement for its establishment. The high occurrence of mature and large trees of *M. magnifica* in edge zone is the relic of once sustained population of this ecologically sensitive species.

The study also discussed about some casualty causing biotic and abiotic agents which are responsible for the high mortality rate after the initial establishment. The apical bud abortion and wilting due to low light intensity or by predation of insects is the factor in the third stage of mortality. In the field, in the core and transition zones, pests attack in the meristematic region and the tender leaves of the seedlings and suck out the juice from the seedling, and the latter causes wilting and death. In the edge zone water scarcity leads to the death of the seedlings. In the advanced stage, wild animal feeding and anthropogenic activities are the major threats. The human beings also create special stress in sustained germination of the species through collection of seeds and aril as Non-Wood Forest Products. The large scale collection and removal leads to decline in the population strength.

The Myristica swamp of the Western Ghats, India is endowed with a wealth of diverse and unique adaptive life forms embedded in a unique set of ecological and edaphological conditions. The specialist species *M. magnifica* is an Indian endemic species surviving only in the virgin swamp forest, hitherto known only from Southern Western Ghats, hence considered as flagship species. The swamps are water inundated and flagship species have stilt and breathing roots as morphological characters and large fruits, recalcitrant seeds and etiolate seedlings as reproductive advantage, and have biotic association with adaptive other life forms together formulating a different and unique ecosystem. The fragmentation and isolation results in the three stages of ecosystems, ecological function and conservation status, initially the amphibian swamp becomes seasonal one and finally terrestrial through the transformation of vegetation succession with the core region characterized with sustained regeneration and recruitment of *M. magnifica* and middle level tolerance in transitional zone and least adaptive in edge zone. The ecological, edaphological conditions of edge zone no way supporting the seed germination and seedling establishment of flagship species, whereas the sustained community status is gradually eroding, likely support the germination and growth performance of generalist species. The edge zone still supports mature trees indicating the past luxurious growth of this swampy tree. This summarise that, ecological and edaphological degradation and destruction due to fragmentation and isolation leads to the shift of vegetation and conservation status of swamp through gene pool erosion of specialist species, especially of the flagship species *Myristica magnifica*. Finally the cumulative effect further increases the probability of species extinction and ecosystem replacement.

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Reference

[1] J. Bascompte, Hugh Possingham, Joan Roughgarden, Associate Editor: Lenore Fahrig, "Patchy Populations in Stochastic Environments: Critical Number of Patches for Persistence", The American Naturalist, CLIX (2), 2002.
[2] M. Bélisle, André Desrochers, Marie-Josée Fortin, "Influence of forest cover on the movements of forest birds: a homing experiment", Ecology, LXXXII (7), pp. 1893-1904, 2001.
[3] T.F. Bourdillion, The forest trees of Travancore, Govt. Press, Trivandrum, xxxii+456pp,1908.
[4] S.L. Brown, M.M. Brinson & A.E. Lugo, "Structure and function of riparian wetlands", In: Strategies for Protection and Management of Flood Plain Wet Lands and Other Riparian Ecosystems. US Forest Survey General Technical Report, R.R. Johnson & J.E. Cormick (eds.), W. O. 12. Washington DC, U.S.A., pp. 17-31, 1979.
[5] H.G. Champion, S.K. Seth., A revised survey of the forest type of India, Government of India. xxiii+404pp, 1968.
[6] M.D.S. Chandran, D.K. Mesta, "On the conservation of the Myristica swamps of the Western Ghats", In: Forest Genetic Resources: Status, Threats, and Conservation Strategies. Uma Shanker, R., Ganeshaih, K.N., and Bawa, K.S. (eds.), Oxford and IBH, New Delhi: 1-19, 2001.
[7] E.J.H. Corner, "The Durian theory and origin of the modern tree", Annals of Botany (NS), XIII, pp.367-414, 1949.
[8] E.J.H. Corner, The life of plants, Wiedenfeild and Nicholson, London, 1964.
[9] C.B. Cox & P.D. Moore, Biogeography; an ecological and evolutionary approach (5th edn), Oxford; Blackwell Scientific Publications,1993.
[10] I.S. Dewenter, Ute Münzenberg, Christof Bürger Carsten Thies, Teja Tscharntke, "Scale-dependent effects of landscape context on three pollinator guilds", Ecology, LXXXIII (5), pp. 1421-1432, 2002.
[11] T. M. Donovan, Curtis, H. Flather, "Relationships Among North American Songbird Trends, Habitat Fragmentation and Landscape Occupancy", Ecological applications,XII (2), pp. 364-374, 2002.
[12] C.S. Findlay, J. Houlahan, "Anthropogenic Correlates of Species Richness in South-eastern Ontario Wetland", Conservation Biology, XI (4), pp. 1000-1009, 1997.
[13] M. Gadgil, M.D.S. Chandran, Environmental impact of forest based industries on the evergreen forests of Uttara Kannada district, a case study (Final Report), Department of Ecology and Environment, Government of Karnataka, Bangalore, 1989.
[14] J. P. Gibbs, Edward J. Stanton, "Habitat Fragmentation and Arthropod Community Change: Carrion Beetles, Phoretic Mites and Flies", Ecological Applications, XI (1), pp. 79-85, 2001.
[15] D.B. Gurd, T.D Nudds, D.H Rivard, "Conservation of mammals in eastern North American wildlife reserves: how small is too small", Conservation Biology, Vol. XV (5), pp. 1355, 2001.
[16] F.S. Guthery, Charels L. Land and Brent W. Hall, "Heat Loads on Reproducing Bobwhites in the Semiarid Subtropics", The Journal of Wildlife Management, LXV (1), pp. 111-117, 2001.
[17] Hanski, Atte Moilanen, Mats Gyllenberg, "Minimum viable Meta population size", The American Naturalist, CXLVII (4), 1996.
[18] Hargis et al., "The behaviour of landscape metrics commonly used in the study of habitat fragmentation", Landscape Ecology XIII, pp. 167-186, 1998.
[19] M. J. Hartley, Malcolm L. Hunter, Jr., "A Meta-Analysis of Forest Cover, Edge Effects, and Artificial Nest Predation Rates", Conservation Biology, XII (2), pp. 465-469, 1998.
[20] S.A. Hinsley, P.E. Bellamy, I. Newton and T.H. Sparks, "Habitat and landscape factors influencing the presence of individual breeding bird species in woodland fragments", Journal of avian biology, XXVI, pp.94-104, 1995.
[21] A. Komonen, Reijo Penttilä, Mariko Lindgren, Ilkka Hanski, "Forest fragmentation truncates a food chain based on an old-growth forest bracket fungus", OIKOS, Vol. XC (1), pp. 119-126, 2000.
[22] K. Krishnamoorthi, "Myristica swamps in the evergreen forests of Travancore", Indian forester, LXXXVI (5), pp. 314-15, 1960.
[23] K. Kubitzki, J.G. Rohwer, V. Bittrich, (Eds.), The Families and Genera of Vascular Plants, Vol. II, Flowering Plants. Dicotyledons, Springer, 1993.
[24] S. Kurki, Ari Nikula, Pekka Helle, Harto Lindén, "Landscape fragmentation and forest composition effects on grouse breeding success in boreal forests", Ecology, LXXXI (7), pp. 1985-1997, 2000.

[25] R. Lande, "A Quantitative Genetic Theory of Life History Evolution", Ecology, LXIII (3), pp. 607-615, 1982.
[26] M.P. Nayar, A. Sastry, Red Data Books of Indian Plants. Vol. III, Botanical Survey of India, Calcutta, 1990.
[27] M.P. Nayar, A. Sastry, Red Data Books of Indian Plants. Vol I, Botanical Survey of India, Calcutta, pp. 147-159. 1987.
[28] J.P. Pascal, Les forêtsdenses humidess empervirentes des Ghâts occidentaux. Ecologie, structure, floristique ET succession. Inst. Fr. Pondicherry, Trav. Sec. Sci. Tech. 20. (English Version: 1988. Wet Evergreen Forests of the Western Ghats of India.), 1984.
[29] Pither, J., Philip D Taylor, "An experimental assessment of landscape connectivity", OIKOS, LXXXIII, pp. 166-174, 1998.
[30] M. Rajendraprasad, "Ecology and Conservation of Freshwater Swamp Ecosystems of Western Ghats-Kerala Region", DBT-JNTBGRI Fourth Year Project Progress Report, pp. 1-33, 2019.
[31] Ramesh & Pascal, Atlas of Endemics of the Western Ghats (India); Distribution of Tree species in the Evergreen and Semi-evergreen Forests, French Institute, Pondichery, 403, 1997.
[32] Raven & Axelrod, "Angiosperm Biogeography and Past Continental Movements", Annals of the Missouri Botanical Garden, LXI (3), 1974.
[33] C.J. Saldanha, Flora of Karnataka, Vol. I, Oxford and IBH Publishing co, New Delhi. 1984.
[34] Sanchez-Zapata, J.A., Jose F Calvo, "Raptor distribution in relation to landscape composition in semi-arid Mediterranean habitats", Journal of Applied Ecology, XXXVI (2), pp. 254-262,1999.
[35] L.N. Santhakumaran, A. Singh, V.T. Thomas, "Description of a sacred grove in Goa (India), with notes on the unusual aerial roots produced by its vegetation", Wood, Oct. Dec: 24-28, 1995.
[36] N. Sasidharan, V.V. Sivarajan, Flowering Plants of Trissur Forests, Scientific Publishers, Jodhpur, 1996.
[37] Schmiegelow, Monkkonen, "Habitat loss and fragmentation in dynamic landscapes: Avian perspectives from the boreal forest", Ecological Application, XII (2), pp. 375-389, 2002.
[38] A. Takhtajan, Flowering Plants, Origin and Dispersal, Tr. Jeffery, Edinburgh. 1969.
[39] J.R. Taylor, M.A. Cardamone, W.J. Mitsch., "Bottomland hardwood forests: their functional values", In: Ecological Processes and Cumulative Impacts, J.G. Gosselink, L.C. Lee & T.A. Muir (eds.), Lewis Publishers, Inc., Chelesia, pp. 13-86, 1990.
[40] J. Terborgh, Diversity and the tropical rain forest. Scientific American Library, W.H. Freeman, New York,1992.
[41] R. Vasudeva, R. Raghu, H.B. Dasappa, R. Umasankar, N. Ganesh, Population structure, reproductive biology and conservation of *Semicarpus kathalekunensis*: a critically endangered freshwater swamp tree species of the Western Ghats In: Forest Genetic resources: Status, Threat and Conservation strategies, Umasankar, R., Ganeshaih, K.N., and Bawa, K.S., (eds.), Oxford and IBH publications, New Delhi, pp. 211-233, 2001.
[42] L.A. Venier, L. Fahrig, "Habitat availability causes the species abundance-distribution relationship", OIKOS, LXXVI, pp. 564 - 570, 1996.
[43] K.A. With, Thomas O. Crist, "Critical Thresholds in Species' Responses to Landscape Structure", Ecology, Vol. LXXVI (8), PP. 2446-2459, 1995.
[44] R.H. Yahner, Carolyn G. Mahan, "Potential for Predator Learning of Artificial Arboreal Nest Locations", The Wilson Bulletin, CXI (4), pp. 536-540, 1999.
[45] P.D. Taylor, G.Merriam, "Habitat fragmentation and parasitism of a forest Damselfly", Landscape Ecology, XI, pp. 181-89, 1995.
[46] T. M. Bergin, L.B. Best, K.E. Freemark, K.J. Koehler, "Effects of landscape structure on nest predation in road side of mid western agro-ecosystem: a multi scale analysis, Landscape Ecology, XV, pp. 131-143, 2000.

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