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Plant dispersal profile of Indian tropical sub-continent on the basis of species commonality

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Abstract: Common species provide a basis to study plant species dispersal among any two landmasses. However, its utility and advantage to derive dispersal profile is hardly tested for Indian coastal and tropical archipelagos due to unavailability of comprehensive plant database. We analyzed an Indian national-level plant database to explore common species based dispersal profile at two spatial scales, regional (1–100 km) and biogeographical (>100 km). A total of 490 common species having 8 dispersal modes were analyzed to evaluate the relationship between geographic area/diversity to dispersed species, mean distance to dispersed species, and polychory with long distance dispersal (LDD). We found disparity in dispersal between the natural (hydrochory, anemochory) and biotic modes (anthropogenic), while effects of anthropochory and epizoochory are significant at two spatial scales (regional and biogeographical). In general, we observed that geographic area is directly proportional to species diversity and dispersal; while mean distance is inversely proportional to species dispersal. Western Ghats and Lakshadweep possess more number of polychory species in comparison to Eastern Coast and Andaman & Nicobar archipelagos. The number of monochory and dichory are proportionately high compared to polychory. This study supports the basis of species commonality in plant dispersal pattern.

Key words: Dispersal modes, geographic area, long distance dispersal (LDD), mean distance, polychory, spatial scale.

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Introduction

Dispersal is defined as the movement of species from a source to a sink through one or more mediating vectors. In plants, it is commonly unidirectional propagation from a parent plant that allows fruits, seeds and pollen grains to spread to sites, where the environment is favorable for growth (Cowie & Brenden 2006; Nathan 2006). Tolerance to environmental conditions, habitat specificity, dispersal limitation, establishment, recruitment, biotic interactions and evolutionary information are among the significant factors of dispersal in archipelagos (Bullock *et al.* 2002; Urban *et al.* 2013; Vikrant *et al.* 2016). Tropical archipelagos are of the prime interest for ecosystem conservation studies as they offer habitats to several species. However, dispersal studies in tropical archipelagos mainly suffer from (i) species data collection from isolated islands and (ii) insufficient information of the species dispersal.

The theory of 'island biogeography' and 'chance dispersal' infer that species common between two

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islands/or mainland may act as an indicator of dispersal (Carlquist 1981; MacArthur & Wilson 1967). The importance of common species and its application as indicator for species dispersal is increasing (Aravind *et al.* 2013). Firstly, as per chance dispersal concept, common species can be used as indicator of dispersal if any two landmass have occurrence of same species; and secondly, common species is a comprehensive information system to infer habitat suitability, recruitment and successful establishment of dispersed propagules. Species occurrence and distribution over the islands also rose by chance of dispersal from nearest mainland. Besides other factors, distance plays a major role to express the probability of getting species from a nearest land mass (mainland/ island). Theoretically, the chance dispersal is possible among archipelagos and the role of the nearest mainland. For example chance dispersal is possible in Bangladesh, Myanmar and Sri Lanka for Andaman and Nicobar; and Pakistan, Sri Lanka, United Arab Emirates for Lakshadweep archipelagos.

Species dispersal- vectors

Ability to disperse is a mutualistic relationship between a plant and the dispersers (Bascompte *et al.* 2006), and can be classified on the basis of the vectors, either as biotic or abiotic. The most common abiotic dispersal modes are hydrochory (by water), anemochory (by wind); while the biotic dispersal modes include endozoochory (by animal ingestion), epizoochory (by external body surface), anthropochory (by human), myrmecochory (by insects), ornithochory (by birds) and chiropterochory (by bats). Abiotic dispersal by wind and water are the predominant modes of dispersal in archipelagos (Cowie & Brenden 2006); and biotic modes of dispersal are increasing rapidly with increasing human activities. Studies have highlighted a few modes of dispersal (e.g., winds, birds and humans) responsible for long-distance dispersal (LDD), but these modes need support of other associated modes at local level for dispersal (David *et al.* 2015). For LDD, species considered more than one dispersal modes to avoid obstacle and reach safe habitat. When a species travel through single dispersal mode termed as monochory (e.g. hydrochory only or anemochory only); and accordingly, a species where two, three, four or five dispersal modes take part is termed as dichory, trichory, quadrichory or quintuchory respectively. The later three modes often termed as polychory. It has been reported that higher dispersal mode indicates higher diversity and *vice versa.*

Species dispersal- distance

Oceanic dispersal needs to be studied at different spatial scales (i.e., local, regional, biogeographical or global) to gain a better understanding of island species distribution (Karger *et al.* 2014; Virtanen 2013). Oceanic islands have acquired species across oceanic barriers, and the biota of an island is itself a collection of evidence in support of LDD of plants offering a living archive of dispersal events (Carlquist 1967). Species movement by short distance dispersal (SDD) can cover up to a few meters, whereas LDD can cover distances of kilometers. A single plant species may be dispersed by multiple dispersal vectors effective in LDD *e.g.*, winds, water, birds, bats and large mammals. Dispersal studies conducted in the tropical zone have focused on islands in the Pacific Ocean (Carlquist 1967; Grant & Leslie 2005; Keppel *et al.* 2009), and in the Indian Ocean region (Malik *et al.* 2006; Péchon *et al.* 2009; Venkataraman & Wafer 2005). LDD tend to receive support from polychory, where the species is free from any obstacle/ disturbance.

Indian archipelagos-geologic and human settlement

Andaman & Nicobar archipelago is the part of outer arc ridge of the northern segment of Sunda subduction zone (Rajendran *et al.* 2008); while Lakshadweep islands with <5000 years old, are believed to have formed from a large bank of continental shelf that was completely submerged in ancient past (Gardiner 1903). Andaman and Nicobar archipelagos have two tribal population origin *i.e.*, Andamans are of Negrito origin whereas Nicobar are of Mongolid origin and are inhabited since 2000 years. According to 2011 Census survey, the total population of Andaman & Nicobar archipelago is 38,0581 and that of Lakshadweep islands is 65,473.

Based on data availability, we analyzed the plant dispersal between the two Indian tropical archipelagos and the corresponding coastal regions of the mainland as a LDD phenomenon, assuming maximum species commonality in these archipelagos. We analyzed dispersal behavior of common species using (i) eight dispersal modes (i.e., hydrochory-H, anemochory-A, epizoochory-Ep, endozoochory-En, anthropochory-Ah, myrmecochory-M, ornithochory-O and chiropterochory-Ch)

Fig. 1. Showing the five spatial combinations broadly categorized under regional (1–100 km) and biogeographical scale (>100 km). The regional scale includes intra-Lakshadweep (31 km, Fig. 1a). The biogeographical scale includes intra-Andaman & Nicobar (234 km, Fig. 1b), Andaman & Nicobar-Lakshadweep (2291 km, Fig. 1c), Eastern Coast-Andaman & Nicobar (1441 km, Fig. 1d) and Western Ghats-Lakshadweep (335 km, Fig. 1e).

and (ii) mediating dispersal modes with five degrees of association (i.e., monochory, dichory, trichory, quadrichory and quintuchory). Further, we tried to analyze if (a) GA is proportional to dispersed plant species, (b) chance dispersal is related to distance, and (c) polychory supports LDD.

Study area

The Indian mainland is bracketed by two oceanic archipelagos, *i.e.*, the Andaman and Nicobar archipelago and the Lakshadweep archipelago on the eastern and western sides respectively (Fig. 1). The Andaman and Nicobar islands lie between 92° and 93° E longitudes and 7° and 13° N latitudes. The Lakshadweep islands lie between 72° and 73° E longitudes and 10° and 11° N latitudes (Table 1). The Andaman and Nicobar archipelago includes 105 small islands with 99 in the Andaman group and 6 in the Nicobar group. In the Andaman and Nicobar archipelago, North Andaman, Middle Andaman, South Andaman, Little Andaman, Car Nicobar, Great Nicobar, Katchall and Camorta are reported to be the highly populated areas (*Anonymous* 2003). The Lakshadweep archipelago consists of 36 coral islands, categorized in to 4-divisions with 11-inhabited, 16-uninhabited, 4-inset and 5-sub-merged islands (*Anonymous* 2011). The littoral forests are the only natural vegetation in the Lakshadweep archipelago, which are now filled with plantations of *Cocos nucifera* species and *Ipomoea pes-capre* as a ground runner (Champion & Seth 1968; Reddy *et al.* 2013; Roy *et al.* 2012a). Of late, a large number of crop plants (rice, vegetables, fruits, tubers, spices, sugar, *Areca* nut) were introduced from the Indian mainland, along with domestic live stocks.

Table 1. Description of study area and species characteristics: Seventeen islands from Andaman & Nicobar i.e., Camorta (A1), Car Nicobar (A2), Great Nicobar (A3), Havelock (A4), Henry (A5), John-Lawrence (A6), Katchall (A7), Labyrinth (A8), Little Andaman (A9), Middle Andaman (A10), Nancowry (A11), Neill (A12), North Andaman (A13), North island (A14), Sir-William Peel (A15), Smith (A16), South Andaman (A17); four from Lakshadweep *i.e.*, Agatti (L1), Bangaram (L2), Kalputhi (L3), Kavaratti (L4), & both the Eastern Coast (E) & Western Ghats (W) have been considered in the study (At least 0.1 ha considered or 4 nested quadrats laid).

Name of Islands	Longitude (E)	Latitude (N)	Geographic Area (km^2)	No. of Nested Quadrat	No. of Unique Species	No. of Family	No. of Genera
A1	93° 49.6'	8° 12.6'	124.522	7	132	59	110
A2	92° 77.9'	9° 16.5'	124.83	22	206	80	168
A3	93° 79.4'	7° 02.1'	969.296	35	263	87	195
A4	92° 99.3'	11° 96.6'	87.979	18	105	42	81
A5	93° 06.6'	12° 14.2'	48.255	4	46	28	38
A6	93° 02.4'	12° 09.8'	29.781	7	74	35	53
A7	93° 38.0'	7° 94.4'	158.07	14	168	68	130
A8	92° 64.1'	11° 40.9'	121.549	10	110	46	84
A9	92° 49.1'	10° 68.3'	652.577	46	188	75	147
A10	92° 80.2'	12° 20.0'	195.426	78	182	66	188
A11	93° 54.5'	7° 97.8'	48.473	6	93	44	82
A12	93° 04.6'	11° 82.2'	12.743	5	72	38	54
A13	92° 87.5'	12° 90.3'	2423.409	171	375	94	250
A14	92° 93.6'	12° 39.1'	14.059	4	44	25	38
A15	92° 98.1'	12° 07.5'	17.07	4	40	26	33
A16	93° 06.01'	13° 34.7'	16.938	4	58	29	47
A17	92° 66.7'	11° 84.2'	1159.42	87	233	47	70
L1	72° 32.2'	10° 94.8'	0.918	4	13	10	11
L2	72° 33.5'	10° 95.8'	0.579	4	24	16	21
L3	72° 28.9'	10° 94.1'	3.551	20	34	19	32
L4	72° 63.1'	10° 56.0'	10.239	20	72	38	67
E	76° 33'-86° 48'	10° 07'-22° 17′	265231.4	2621	1684	170	749
W	72° 46.3'-78° 26′	8° 14'-21° 52'	257949.2	1077	1478	171	705

Methodology

Spatial scale

The spatial scale was classified as per mean distance and accordingly, 1–100 km and >100 km was considered as regional and biogeographical scale respectively (Nathan *et al.* 2008). Hence, the dispersal combination was categorized under two scales for this study *i.e.*, (i) the regional scale: intra-Lakshadweep (LL) combination with a mean distance of 36 km; and (ii) the biogeographical scale: intra-Andaman & Nicobar (AA, 234 km), Andaman & Nicobar and Lakshadweep (AL, 2330 km), Eastern Coast–Andaman & Nicobar (1441 km) and Western Ghats–Lakshadweep combinations (335 km; Fig. 1; Table 2).

Collection and preparation of plant species data

The location data of the plant species was gathered through field sampling during a national project on *Biodiversity Characterization at Landscape Level* under the leadership of the senior author of this investigation. Following proportionate random sampling of vegetation, 15,565 nested-quadrats were laid in all through the length

Table 2. Contribution of principal dispersal mode in percentage (%) using mean distance separation at regional and biogeographical scales with respect to the dispersal modes: H (Hydrochory), A (Anemochory), Ep (Epizoochory), En (Endozoochory), Ah (Anthropochory), M (Myrmecochory), O (Ornithochory) and Ch (Chirepterochory). (Refer: A = Andaman & Nicobar, L-Lakshadweep, E = Eastern Coast, W = Western Ghats).

Spatial Scale		H	A	En	Ep	Ah	M	O	Ch	Mean Distance (Km)
Regional (SDD)	LL	17	9	0	8	6	2	13	2	31.55
Biogeographical (LDD)	AA	83	91	4	107	12	24	103	14	234.01
	AL	14	4	0	8	4	1	8	2	2291.5
	EA	42	34	3	56	11	9	45	6	335.38
	WL	15	14	0	15	7	2	13	3	1441.34

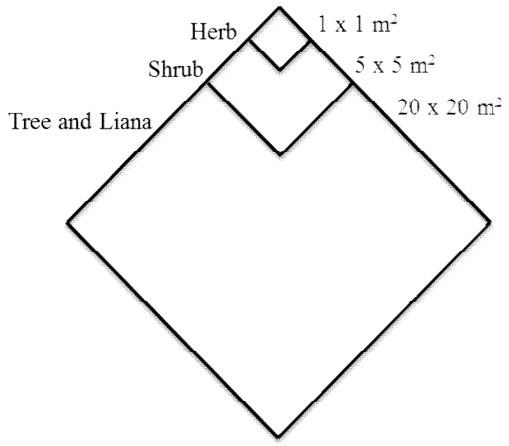

Fig. 2. Sampling methodology using nested quadrat method to measure different life-forms as tree, shrub, herb and liana (Roy et al., 2012).

and breadth of the country during 1997–2009, wherein all the phanerogams and some ferns were accounted under tree, shrub, herb and lianas (Roy *et al.* 2015; Fig. 2). The ramets were treated as two separate species or sub-species as warranted, while genets differentiation was not done. The nested quadrat represents 20 × 20 m^2 for the tree (>15 cm cbh) and lianas, two 5 × 5 m^2 plots for shrubs and sapling (>5 to <10 cm cbh), four 1 m^2 plots for herbs and seeding were recorded in designated forms with appropriate identification and site characteristics (Roy *et al.* 2012b; Behera *et al.* 2014). A nested quadrat accounts to 400 m^2 areas for tree and lianas, 50 m^2 sub-plot for shrubs and sapling, and 4 m^2 for herbs and seedling. So, a minimum of six sub-quadrats were laid under a principal quadrat in nested form.

We pooled location information of 4268 quadrats pertaining to the study site with 570 for Andaman & Nicobar and Lakshadweep islands, 2621 for the Eastern Coast (E), and 1077 for the Western Ghats (W) (Table 1). We selected 17 islands from Andaman & Nicobar and 4 islands from Lakshadweep archipelago for the study, where a minimum of 4 quadrats are laid.

Collection and analysis of dispersal data

The 4268 quadrats recorded a total of 2959 species. We found common species among the 5-spatial combinations of land mass and looked into their dispersal characteristics through various published/ unpublished literature and web sources (see supplementary references) and listed in Supplementary Table S1.

Hypothesis testing

We calculated the number of unique species and their geographic area for each geographic unit (Fig. 3). Further, we analyzed the mean distance between two geographic units and their corresponding number of common species (Fig. 4). Thirdly, we tested the distribution of polychory species; and comparison of dominant and frequent mediating modes in each spatial scale (Fig. 5).

Results

Taxonomical diversity and distribution of species

We found 2959 species distributed in 4268 nested quadrats over the study region. Eastern Coast accounted to 1684, while Western Ghats to 1478 unique species (Table 1). The ratio between numbers of families and genera is quite diverse *i.e.*, 170/ 749 in Eastern Coast and 171/ 705 in Western Ghats. Fabaceae and Rubiaceae emerged as the most dominant families in both Eastern Coast and Western Ghats, and *Terminalia* as the most dominant genera. *Ebenaceae and Arecaceae* were reported as the most commonly found family in Andaman & Nicobar and Lakshadweep archi-

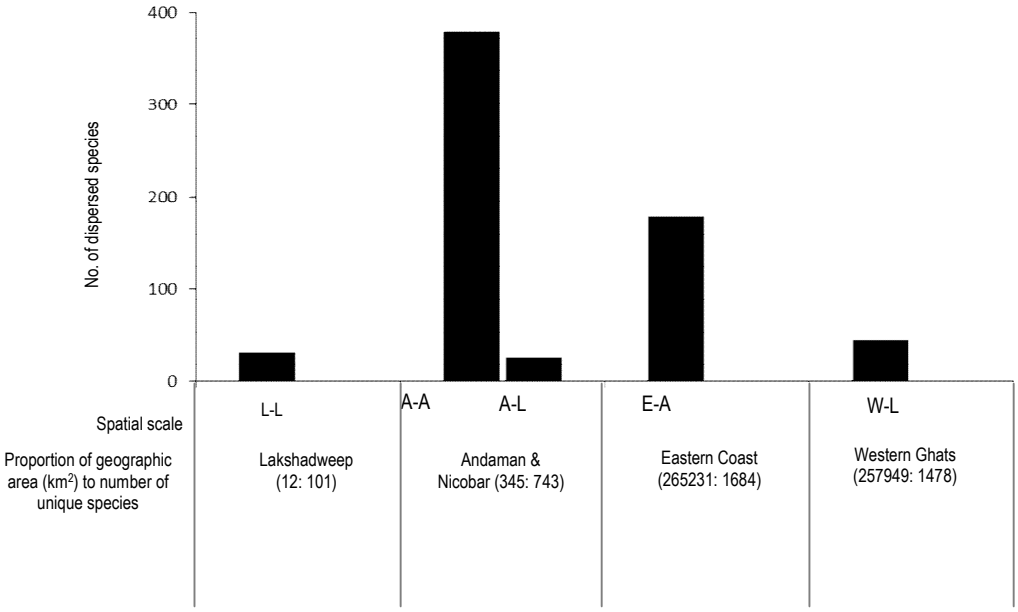

Fig. 3. Geographic area and species diversity of each landmass explaining the variation of common species along the five spatial scales (Where X–axis represents: Proportion of geographic area (km²) to number of unique species).

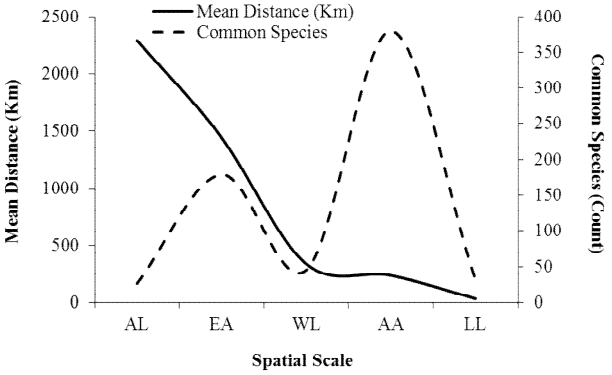

Fig. 4. Relationship between mean distances to common species is graphically represented and analyzed for each spatial scale.

pelagos, with *Ficus* and *Diospyrus* as the most dominant genera respectively (Table 1). North Andaman (2423.41 km²) and Kavaratti (10.24 km²) are the largest islands among Andaman & Nicobar and for Lakshadweep archipelago which also possess higher species abundance (Table 1).

Interpreting principal and mediating modes of the species

Out of 2959 unique species sampled from all four geographic units, 541 species were found common in 5 spatial scales. We gathered dispersal information for 490 out of 541 common species from different sources (Table S1). The dispersal modes of observed species were summarized as hydrochory, anemochory, endozoochory, epizoochory, anthropochory, myrmecochory, ornithochory and chirepterochory. Additionally, information on these dispersal modes was available in five degrees of association like, monochory, dichory, trichory, quadrichory and quintuchory (Table 3). Of 490, monochory alone accounted for 414 species followed by dichory (59), trichory (14), quadrichory (2) and quintuchory (1). It was evident that epizoochory, anemochory, and hydrochory are the most significant contributors to drive dispersal activity between mainland and archipelagos; while, monochory followed by dichory are the most frequent dispersal modes.

Monochory and dichory together accounted to share higher proportion of species dispersal through epizoochory, anemochory and hydrochory (Table 3). Among polychory, quadrichory species have least occurrence among spatial scale, as it was absent in the three out of five forms (Fig. 5). AL combinations have 26 common species; within that by means of hydrochory 14 species get dispersed. However, Ep and O contributed 8 species each, followed by Ah and A adopted dispersal mode by 4 species each. But, least species accounted by Ch (2) and M (1). We observed the

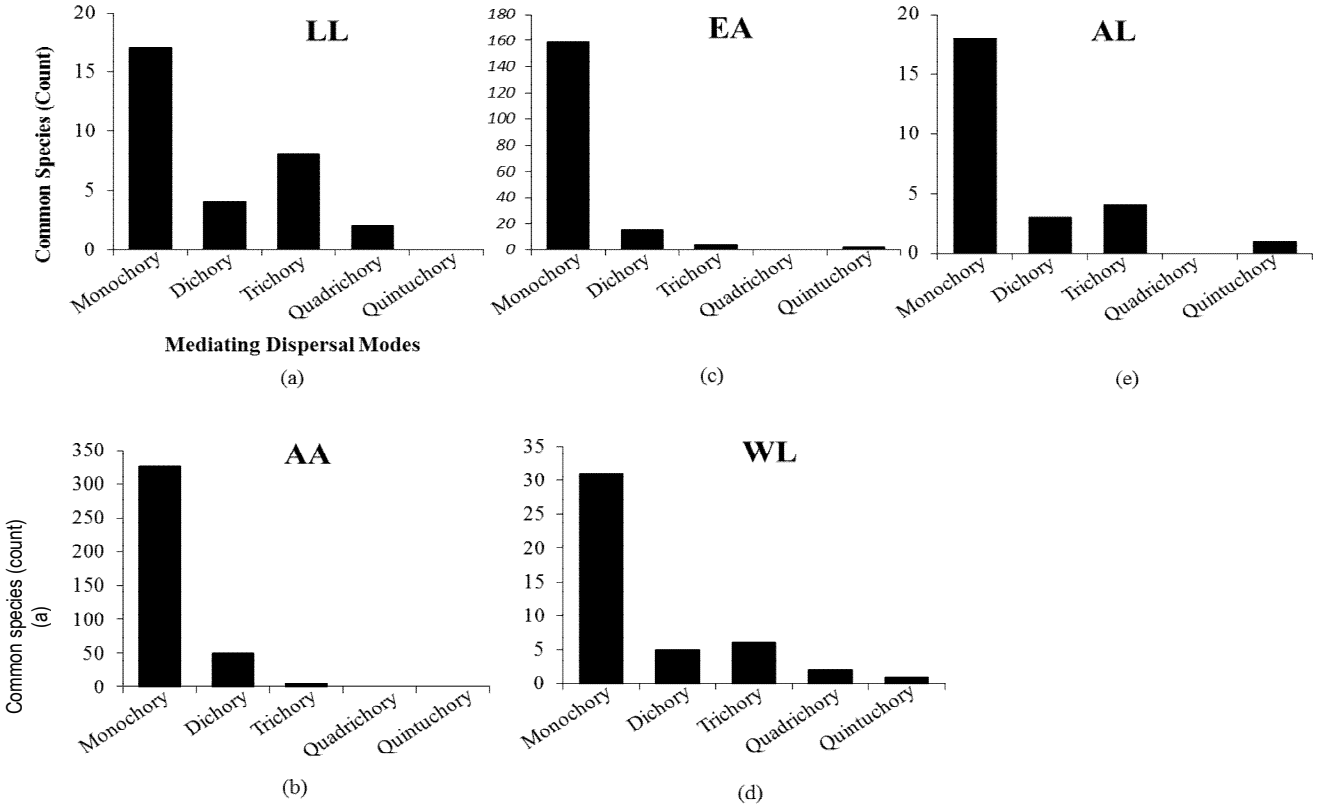

Fig. 5. Interpretation of common species dispersed through each mediating dispersal modes (monochory to polychory) is graphically represented for each spatial scales; where (a) Intra-Lakshadweep (LL), (b) Intra-Andaman & Nicobar (AA), (c) Andaman & Nicobar and Lakshadweep (AL), (d) Eastern Coast–Andaman & Nicobar (EA) and (e) Western Ghats–Lakshadweep (WL) combinations.

species associated to AL combination are having mainland origin; as 17 species are connected to Western Ghats and 19 with that of Eastern coast. Similarly, EA combination that have dominant number dispersed species are by means of Ep (56), O (45) followed by H (42), A (34). Importantly, observed that in EA combination role of human are playing significant role to affect species dispersal contributing 11 species through Ah modes. Subsequently, AA combination has 13 species dispersed through Ah modes. But, the Ah based species are less available in Lakshadweep and associated spatial scale. Besides, the human population density of Andaman & Nicobar is 47 inhabitants/ km^2 much lesser than the Lakshadweep where it was reported as 2013 inhabitants/ km^2. It might be inferred that for LDD, humans act as a significant career for species dispersal. In addition, endozoochory species are present only in Eastern Coast and Andaman & Nicobar, while these are absent in LL, AL and WL combinations (Table 2).

Geographic area vs unique and dispersed species

We found 101, 743, 1478 and 1684 number of unique species present in Lakshadweep, Andaman & Nicobar, Western Ghats and Eastern Coast with 12, 345, 257949 and 265231 km^2 geographic area (GA) respectively. This indicates that there is a proportional relationship between the amount of GA and the number of species content. Similarly, the subset of dispersed species also found the same trend with 31 and 380 numbers of dispersed species present in Lakshadweep, Andaman & Nicobar archipelagos (Fig. 3). The subset of dispersed species between increased between AL<WL<EA (Fig. 3).

The mean distance between two geographic units decreased from AL (2292 km^2) > EA (1441 km^2) > WL (335 km^2) > AA (234 km^2) > LL (32 km^2). Barring LL, we found that AA has maximum number of commonly dispersed species with minimum distance, and AL has minimum number

Table 3. Division of 490 common species into five dispersal modes derived in the study area scale (Abbreviations as provided in Table 2).

	Number of dispersal Modes				
Primary Dispersal Mode	Monochory 414/1=414	Dichory 118/2=59	Trichory 42/3=14	Quadrichory 8/4=2	Quintuchory 5/5=1
H	86	25	7	2	1
A	96	11	4	2	1
En	1	3	1	NA	NA
Ep	97	35	6	1	1
Ah	10	4	7	2	NA
M	21	3	3	NA	NA
O	93	32	12	1	1
Ch	10	5	2	NA	1
Observed Combinations	H, A, En, Ep, Ah, M, O, Ch	H-A, H-O, Ep-Ah, Ep-O, O-Ch, H-Ep, En-O, M-O, Ah-O, Ah-Ch, A-Ep, En-Ep, A-O, Ep-M	Ep-Ah-O, H-Ah-O, H-Ah-M, H-O-Ch, A-Ep-O, A-En-M, H-A-O, Ep-M-O, H-A-M, Ep-O-Ch	H-A-Ep-Ah, H-A-Ah-O	H-A-Ep-O-Ch

Table 4. Description of polychory species with their dispersal modes at different spatial scale (Abbreviations as provided in Table 2).

Spatial Scale	Species Name	Island/ Mainland		Dispersal Modes	Dispersal Combination
LL	*Digitaria ciliaris*	L3	L1	Four	H-A-Ah-O
	Leucas aspera	L4	L2	Four	H-A-Ep-Ah
AL	*Alysicarpus vaginalis*	A6	L4	Five	H-A-Ep-O-Ch
WL	*Digitaria ciliaris*	W	L1,L3	Four	H-A-Ah-O
	Leucas aspera	W	L2, L4	Four	H-A-Ep-Ah
	Alysicarpus vaginalis	W	L4	Five	H-A-Ep-O-Ch
EA	*Alysicarpus vaginalis*	E	A6	Five	H-A-Ep-O-Ch

of commonly dispersed species with maximum distance (Fig. 4). However, WL have less number of commonly dispersed species due to lower species diversity of Lakshadweep archipelagos.

Polychory and LDD

The distribution of *Alysicarpus vaginalis* (quintuchory species) observed only from Kavaratti island of Lakshadweep and John Lawrence island of Andaman & Nicobar archipelagos (Table 4; Fig. 5). So, the chance dispersal of *Alysicarpus vaginalis* derived for AL; while remains un-represented for LL and AA combination due to single island distribution (Fig. 5a, b & e). LL combination except quintuchory, all other four mediating modes are found; wherein, for AA combination multiple dispersal modes (quadri-chory and quintuchory) are absent. Relatively smoother decreasing trend was observed from monochory to trichory for AA combination (Fig. 5b). Species with Quadrichory is absent in EA combination; while species with all five dispersal modes are present in Western Ghats. All the five dispersal modes were reported in WL combination (Fig. 5d).

Western Ghats shared the highest number of polychory species. Among trichory, *Sida acuta* (Ep-Ah-O) have the highest number of species *and* also reported with highest occurrence in the LDD (AL combination, WL combination; Table 4). *Digitaria*

ciliaris (H-A-Ah-O) and *Leucas aspera* (H-A-Ep-Ah) were found preferring dispersed by quadrichory means of dispersal. Their dispersal activities reported from LL and WL combination. *Digitaria ciliaris* distribution was recorded from the Western Ghats and Lakshadweep archipelagos, but not from Andaman & Nicobar archipelago. *Leucas aspera* and *Alysicarpus vaginalis* are recorded from both the archipelagos and their respective facing coastal mainlands (Table 4). *Alysicarpus vaginalis* (H-A-Ep-O-Ch) dispersed through quintuchory modes among both spatial scales. It is the only quintuchory species reported.

Discussion

Geographic area vs unique and dispersed species

Theoretically, larger geographic area encompasses more resources to raise habitat diversity to attract wide range of dispersed species. As large geographic area facilitate more dispersed species that result in higher species richness. North Andaman Island from Andaman & Nicobar and Kavaratti from Lakshadweep archipelagos have highest occupancy of geographic area to diversity ratio, followed by maximum species individuals, genera and family (Table 1). The individual island with same geographic area from Andaman & Nicobar holds comparatively more diversity than islands of Lakshadweep archipelagos. Similarly, Eastern Coast proportionately quantified higher geographical area to species diversity than Western Ghats (Fig. 3). The enlisted unique species of mainland include 179 common species for spatial scale associated to Eastern Coast and 45 species from Western Ghats. Similarly, the higher geographic areas facilitate more number of common species in Andaman & Nicobar (380) than Lakshadweep (31) with their associated spatial scales. So, the common species are very often proportional to geographic area to diversity in Indian tropical sub-continent.

Role of mean distance for species dispersal

Higher geographic area gives species more land to get disperse. Conversely, island separated far from the nearest mainland, have very low probability of species dispersion. This inverse relationship between species dispersal and mean distance to the nearest mainland/ island is well elaborated by (McMaster 2005). The inverse relationship was also evident in the current study for five spatial scales. We also observed that with increasing mean distance from regional to biogeographical scale the commonly occurring dispersed species decreases (Fig. 4). The distance between Western Ghats to Lakshadweep is very low 335 km compared to Eastern coast and Andaman & Nicobar (1441 km); instead of that EA combination resulted in 179 common species compared to 45 species derived from WL combination.

Polychory and LDD

Cain *et al.* (2000) stated that multiple dispersal modes or polychory are important for LDD; and added species arriving on exceptionally long distance later on loss their dispersers that enhance island endemism. We found only one quintuchory and two quadrichory species while the number of trichory (14), dichory (59) and monochory (414) were more. Mostly, polychory species occupies an island environment, while later on turn to be monochory or dichory type. Probably, that reduces the number of polychory species, and effects their scanty distribution (Carlquist 1967). The dominant genera from our observation such as *Terminalia*, *Ficus* and *Diospyrus* reported to have monochory means of dispersal. The bulk of locally dispersed species shapes the dynamic activities of local population and communities in a spatial platform (Levin *et al.* 2003; Nathan *et al.* 2008). The maximum number of polychory species derived from LL combinations has least mean distance among the five spatial combinations, but the same is lacking with quintuchory species. Alternately, AA combination reported with least polychory (trichory) species. AL combination indicates the effective role of hydrochory and epizoochory which are efficient modes for LDD (Table 2; Sorenson 1986). The quintuchory species found in all the three high range LDD based spatial scale (AL, EA, and WL combination). This explains the hypothesis that the higher order polychory favors the LDD the most. The overall polychory species share is more from Lakshadweep than Andaman & Nicobar archipelagos (Fig. 5).

The most abundant polychory species among five spatial scale is a trichory species, i.e., *Sida acuta*. Both, quadrichory (*Digitaria ciliaris and Leucas aspera*) are restricted to Western Ghats and Lakshadweep region. However, the reduced LDD noted in the Andaman & Nicobar archipelago and the presence of a quintuchory species on John

Lawrence Island could be explained by wind and ocean current dispersal or dispersal from other nearest mainland. We have not considered dispersal from the mainland of Sri Lanka, Myanmar or Thailand because of the un-availability of required data. Further analysis including data from other surrounding mainland/ islands may provide more insights to the current study.

Conclusions

We found disparity in dispersal between the natural (hydrochory, anemochory) and biotic modes (anthropogenic) due to increasing human activities among mainland-islands. The effects of anthropochory and epizoochory are prominent to influence species dispersal at two spatial scales (regional and biogeographical). Especially, for Eastern Coast and Andaman & Nicobar, anthropochory and endozoochory species are comparatively dominant than Western Ghats and Lakshadweep landmass. Based on our observation, we could synthesize the positive correlation between geographic areas to diversity; and further with the dispersed species. The inverse relationship between mean distances with dispersed species is generally found. We noted increase contribution of polychory species among the spatial scale leading to LDD. Based on tested relationship WL combination observed to have an ideal dispersal environment with higher geographic area, low mean distance and importantly all available polychory species. As per theory of island biogeography and chance dispersal, the amount of dispersal activities among islands and the nearest mainland could be the most functional parameter of island diversity (MacArthur & Wilsons 1967). The western part of the Indian sub-continent and the associated archipelagos has more active polychory species compared with the eastern side. As the western side includes two quadrichory species (*Digitaria ciliaris* and *Leucas aspera*) and one quintuchory species (*Alysicarpus vaginalis*) while the eastern side has participation of quintuchory species. Future studies should aim to provide insights for 1) the role of other bio-climatic, physical and geographical factors towards dispersal, and 2) disturbance-LDD relationship. Our study reiterates the possibility that tropical archipelagos may be considered as a key factor to understand ecosystem conservation studies as they offer habitats to several species.

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Supporting Information

Additional Supporting information may be found in the online version of this article.

Table S1. List of 490 species for which plant dispersal mode and mediation have been mentioned as gathered from various literature ('√' indicate their presence). (Abbreviations used: A-Andaman & Nicobar, L-Lakshadweep, E-Eastern coast, W-Western Ghats).

Supplementary References

Web links