**Navigating floristic networks: linking oceanic currents and littoral flora across oceanic archipelagos**

**Abstract**

Dispersal through marine currents (thalassochory) is predicted to play an important role in the distribution of plant biodiversity in oceanic archipelagos. Littoral plants, adapted to salt exposure, are hypothesized to disperse effectively via thalassochory. However, the extent and mechanisms remain largely unknown due to the lack of experimentation and the challenge of measuring complex marine current behaviors in diverse landscapes. Here, we integrate floristic data from the Galapagos, Canaries, and Azores with ocean current data spanning 26 years (1992-2018) to quantify the correlation between floristic and currents connectivity. Using Procrustes correlation analysis, we compared distance matrices of flora, ocean currents, and island factors (geographic distance, age, and area) for each archipelago. Network theory was applied to current connectivity data to identify island centrality roles as sinks (In-Degree), sources (Out-Degree), proximals (Closeness), and hubs (Betweenness) within each archipelago. We then assessed whether their centrality predicts its percentage of littoral species. Our results revealed a strong correlation (0.87) between current and floristic connectivity in the Canaries, moderate (0.55) in the Galapagos, and no significant in the Azores. These correlations were higher for littoral plants compared to non-littoral plants. Additionally, current connectivity was in all cases highly correlated with geographic connectivity and, for the Galapagos and Azores, moderately correlated with connectivity by island age. In the Canarian archipelago, the percent of littoral flora was predicted by the centrality of islands acting as sinks and hubs in the current network. In contrast, no effect was detected in the Galapagos and Azores. These findings underscore the varying influence of currents on littoral flora distributions across different archipelagos and demonstrate the utility of network theory in understanding ocean current connectivity. We suggest that the role of thalassochory in shaping plant biogeographic patterns depends on the spatial configuration of islands and the directionality of currents entering the archipelago.

Introduction

**[P1 - Role of oceanic currents in long-distance dispersal - oceanic archipelagos]**

**[P2 - LDD not reliable - need experimentation and quantify the dispersal vector. In traits such as zoochory is more straightforward. For thalassochory, too complex - infer from both experimentation and a combination of floristic and current patterns - but most analysis on one or few species, and very few at the community level]**

**[P3 - Littoral flora - potentially adapted to thalassochory]**

**[P4 - Hypothesis and objectives]**

We hypothesize that the connectivity of littoral flora shows a correlation with the currents connectivity, and that this correlation is higher than for non-littoral flora. We also predict that, because the spatial distribution of islands within an archipelago influences the ocean current network, archipelagos with similar island configurations, such as the Canaries and Azores, will exhibit similar connectivity patterns and distinct from those of Galapagos (Whittaker and Fernández-Palacios 2007). Finally, if thalassochory significantly drives littoral flora dispersal, islands with central positions in the current network should harbor greater diversity of littoral species due to enhanced connectivity.

To address this questions, our objectives are to (1) test for a relationship between the connectivity patterns of littoral flora and oceanic currents across archipelagos, and (2) identify whether islands with central roles in current connectivity networks contain a higher percentage of littoral plants.

Methods

**Oceanic currents data**

Oceanic current data were obtained from the Hybrid Coordinate Ocean Model (HYCOM) dataset ([www.hycom.org](http://www.hycom.org)), which provides spatially and temporally resolved information on ocean currents (see Chassignet et al. 2007). We used data covering 26 years (1992-2018) for the Galapagos (-1.8 to 0.9°N, -92.0 to -88.7°W), Canaries (26.7 to 29.9°N, -18.8 to -12.6°W), and Azores (36.5 to 40.1°N, -32.2 to -23.4°W) archipelagos. Using the "HMMoce" R package, we extracted eastward and northward current velocities at an 8km resolution. Using the extracted velocity components, sea direction (in degrees) and speed (in m/s) were computed. Direction was calculated using the “raster” package and converted from radians to the 0-360 degrees range. We extracted this information every two days along the 26 years, yielding 4770 (+-1) days with ocean currents data for the analysis in each archipelago.

**Oceanic currents connectivity**

We use the “rWind” package to compute a conductance matrix representing the ease of movement between geographic points due to ocean currents (See Fernández-López & Schliep 2018). The algorythm implemented in the package functions calculates the movement cost from any starting cell to one of its 8 adjacent cells (Moore neighborhood) accounting for the directional and speed characteristics of ocean currents (Muñoz et al. 2004, Felicísimo et al. 2008).

To assess connectivity between islands within each archipelago, cost matrices were derived from the conductance matrices. Using the costDistance function, we computed the minimum cost path (conductance) required to travel between pairs of islands. This process integrated the geographic coordinates (latitude and longitude) of the islands with the conductance values derived from oceanic current data. To cover all orientations (North, South, West, East), we selected a coordinate point on each side of the islands from which we calculated the current connectivity paths to the rest of the islands within the archipelago. For larger islands, we added one connection point every 40 km (5 pixels of 8 km) to increase our sampling of points and, consequently, potential shortest paths connecting with other islands. For example, Isabela Island in the Galápagos archipelago has a total of eight connection points: one in the North and South, and three each on the East and West sides. For small islands with an area occupying less than a pixel of the rasters (<8 km), a single connection point was assigned (Figure S1, S2).

Marine currents can vary over time due to climatological conditions, causing fluctuations in the potential for thalassochory. To account for this variability, we obtained the minimum 5% of cost distances (i.e., 5% of maximum connectivity) connecting each pair of geographic points within the temporal range of the data. This subset represents opportunity windows for thalassochory. Instead of relying on a single minimum cost value to conduct our analyses, which may reflect rare extreme climatic events, we calculated the median of these minimum costs, given its non-parametric distribution. This method captures the windows of opportunity for thalassochory while accounting for the inherent variability of current conditions.

**Floristic data**

Floristic data for species within lowland habitats (areas under 500m) were obtained from various databases for each archipelago: ref for Galapagos, ref for Canaries, ref for Azores. We then grouped them as those classified as littoral and those that don't, i.e. non-littoral: 25 and 429 in Galapagos, 111 and 1122 in Canaries, and 24 and 121 in Azores (Figure S3).

**Floristic connectivity**

We measured the Bray-Curtis Dissimilarity Index (Bray & Curtis, 1957) to quantify the relative separation (high dissimilarity) or closeness (low dissimilarity) of floristic composition between islands. This index ranges from zero, indicating high similarity among sites, to one, indicating no shared species among them. We chose this index because it accounts for double-zero attributes, or co-absences, where the absence of a species also informs the floristic composition of an island (Greenacre, 2017; Todeschini et al., 2012), and is widely used in comparing community distances on oceanic islands (e.g. Castro-Urgal & Traveset, 2014; Florencio et al., 2013, Thuesen et al., 2011). We then computed two floristic distance matrices between islands for each archipelago: one for littoral species and another for non-littoral species.

**Island factors connectivity**

To gain further insights from our measurements, we explored how the floristic connectivity of littoral floras relates to geographic distance, island age, and area. Geographic isolation often promotes diversification on isolated islands (ref), and therefore is expected to be correlated with floristic distances between islands. Additionally, we expect connectivity by currents to correlate with geographic distance, as increased distance typically raises the total travel cost between islands. Floristic connectivity may also align with island ages, since many terrestrial groups diversified in tandem with the geological formation of the islands (Parent et al., 2008, refs). Lastly, floristic diversity may also be affected by the size of islands as larger areas may support higher diversity by providing wider niche spaces, which enhance coexistence and ecological opportunity (Parent et al., 2020, refs).

To compute geographic distances (km), we downloaded shapefile maps of the archipelagos from NOAA ([www.noaa.gov](http://www.noaa.gov)) and obtained the geographic centroid of each island using QGIS software with the tool ‘geometry by expression’. This function calculates the geometric center of the polygon by averaging the x-coordinates and y-coordinates of all the vertices of the polygon. These maps also provided the measures for island area (km²). For island ages (Myr), we considered the mean between minimum and maximum emergence estimates for the Galapagos from Geist et al. 2014. For the Canaries, we obtained estimated ages from Carracedo et al. 1998 and Anguita & Hernán 2000, and considered the mean for islands with discrepancies between the two sources. For the Azores, we obtained the data from \_\_. For each archipelago, the pairwise geographic distances between island centroids formed a connectivity matrix. We computed Euclidean distances between island ages and areas using the daisy function from the “cluster” package to obtain the connectivity matrices for each.

**How does the structure of ocean currents connectivity networks within archipelagos correlate to that of the littoral flora? and to that of other island factors?**

To understand how the structure of ocean currents connectivity networks within archipelagos correlates with those of littoral flora and other island factors, we employed Procrustes analysis, a statistical method used to compare the shapes of datasets . It measures the degree of similarity between two matrices by finding an optimal superimposition through transformations such as translation, rotation, and scaling (Legendre & Legendre 2012). Its flexibility and interpretability have made it widely used in ecology to measure biogeographic patterns of floristic connectivity (Munoz et al. 2004, Legendre et al. 2012). The goal is to minimize the sum of squared differences between corresponding points in the matrices. After optimal superimposition, the Procrustes distance is calculated as the sum of squared distances between the corresponding points in the transformed configuration and the target configuration. This distance quantifies the degree of similarity between the two sets of points.

To explore how the structural pattern of ocean currents connectivity networks matches that of the littoral flora, we analyzed the correlation between the floristic distance and the current cost matrices. Additionally, we examined the correlation between the structure of the ocean current connectivity network and the networks formed by geographic, age, and area distances. We used the “vegan” package (Oksanen et al., 2007) to perform the Procrustes analysis on Principal Coordinates Analysis of the distance matrices. To test significance, a permutation procedure was applied by randomly permuting the points in one dataset 999 times and calculating Procrustes distances for each permutation (Peres-Neto & Jackson, 2001).

**Island centrality based on oceanic current connectivity**

The inverse of the current cost matrix represents the matrix of ocean current connectivity within an archipelago. Within networked systems, graph theory offers centrality measures that assess the importance or influence of nodes within a network (Scardoni & Laurdanna 2012, Chen et al. 2012). In landscape connectivity studies, centrality analysis helps identify critical ecological patches in terms of connectivity, information flow, or network influence (e.g. Estrada & Bodin 2008, Bodin & Saura 2010, Treml & Kool 2018, Cecino et al. 2021, Pereira et al. 2017). In our system, nodes correspond to specific islands (nodes) in the current network of the archipelago, with edge or link weights derived from current velocity and direction. To approximate the islands’ roles as critical connectors of the current network, we computed In-degree, Out-degree, Closeness, and Betweenness centrality measures (Freeman 2002, Opsahl et al. 2010). Starting with a cost matrix representing distances for ocean currents, we inverted the weights to obtain connectivity values (). In- and Out-degree centrality were calculated using these inverted weights to identify islands that act as major sinks and sources in the network, respectively. For Closeness and Betweenness centrality, we utilized the original distance-based weights. Higher Closeness centrality values indicate islands that are closer, on average, to other islands within the network. Higher Betweenness centrality values highlight islands frequently acting as bridges on shortest paths connecting other islands.

*Island In and Out Degree - sinks and sources of oceanic currents*

Degree centrality () is a straightforward measure that counts the total number of connections linked to a vertex. In ecological networks, the weighted In-Degree of a node sums the weights (or strengths) of all edges connected to that node, reflecting its overall importance or influence based on these weighted interactions. Conversely, the weighted Out-degree measures the sum of weights of all outgoing edges from a node, indicating the total contribution or output of resources or influence from the node to others in the network. We note them as and :

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For instance, in a mutualistic network where species exchange resources (e.g., pollination network), the weighted of a plant species represents the total amount of resources (e.g., pollen) it receives from its pollinator species (incoming edges), and the would be the total amount of resources (e.g., pollen) it provides to its plant partners (outgoing edges). In a network of current connectivity, where , of an island accounts for the sum of incoming currents with their associated strengths and represents the sum of outgoing currents from the island. We interpret islands with higher as “sinks” for oceanic currents in the archipelago, and those with higher as “sources”.

*Island Closeness - proximity based on oceanic currents*

A path is a series of steps that go from one node to another. Closeness centrality () of a node is the inverse of the sum of distances to all the other vertices in a graph. For a node in a network with nodes:

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where is the shortest path distance between nodes and . quantifies how central and accessible an island is within the current connectivity network of an archipelago. Islands with higher values are positioned closer to all other nodes in terms of oceanic current flow costs, enhancing their potential influence in facilitating efficient information dissemination or resource transfer.

*Island betweenness - hubs of oceanic currents*

For every pair of vertices in a connected graph, there exists at least one shortest path between the vertices such that the sum of the weights of the edges is minimized. Betweenness centrality () is defined as the number of shortest paths that pass through the node divided by the total number of shortest paths between all pairs of nodes. For a node in a network with nodes:

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where is the total number of shortest paths from node to node , and is the number of those paths that pass through node . A node with high acts as a bridge or bottleneck in the network, facilitating or controlling communication and interactions between other nodes. Within a network of ocean currents in an archipelago, islands with high may serve as ecological corridors or hubs for species dispersal.

Centrality metrics describe similar aspects and are usually correlated somehow (Oldham et al. 2019). We study the correlation of these central measures by computing their Pearson correlation between the islands of each archipelago.

**Does island centrality in the ocean connectivity network affect its percentage of littoral flora?**

To explore the relationship between the proportion of littoral plants and centrality measures across the Azores, Canaries, and Galapagos archipelagos, we employed the 'glmmTMB' package to fit a generalized linear model. The proportion of littoral plants was modeled using a beta distribution with a logit link function, chosen for its suitability in analyzing proportional data:

for which

Where is a given island, and “” refers to one of the predictor centrality variables: either , , or . was log-transformed and centered to address its large variance across archipelagos. In the three models, represents the baseline logit proportion of littoral plants for Azores. ​ and represent how the logit proportion of littoral plants changes for Canaries and Galapagos compared to Azores, respectively. ​ and ​ represent how the effect of on the logit proportion of littoral plants varies with Canaries and Galapagos, respectively. All models underwent diagnostic assessments for uniformity, dispersion, homoscedasticity, and identification of outliers, employing the “DHARMa” package (Hartig 2022).

Results

**Correlation between littoral flora and oceanic currents connectivity**

The correlation between the network structures of oceanic currents and littoral flora connectivity varied across the studied archipelagos. In the Galapagos, the correlation approached significance (ProcCor = 0.55, p = 0.057), while it was strong and significant in the Canaries (ProcCor = 0.87, p = 0.002). Conversely, in the Azores, this correlation was not significant (ProcCor = 0.15, p = 0.919). For non-littoral flora, a significant correlation was observed in the Canaries (ProcCor = 0.82, p = 0.008), while correlations in the Galapagos (ProcCor = 0.49, p = 0.122) and Azores (ProcCor = 0.38, p = 0.452) were not significant (Fig. 2A).

The network structure of littoral flora connectivity also showed a significant correlation with the connectivity by geographic distance in the Galapagos (ProcCor = 0.62, p = 0.015) and Canaries (ProcCor = 0.88, p = 0.002), but not in the Azores (ProcCor = 0.16, p = 0.918). For non-littoral flora, the correlation was significant only in the Canaries (ProcCor = 0.79, p = 0.015), with weaker correlations observed in the Galapagos (ProcCor = 0.54, p = 0.070) and Azores (ProcCor = 0.43, p = 0.337) (Fig. 2*A*).

A significant correlation between the connectivity pattern by littoral flora and island ages was only found in the Galapagos (ProcCor = 0.58, p = 0.018), with non-significant correlations in the Canaries (ProcCor = 0.28, p = 0.690) and Azores (ProcCor = 0.20, p = 0.733). No significant correlations were detected for non-littoral floras (ProcCor = 0.33, p = 0.301 in Galapagos; ProcCor = 0.23, p = 0.786 in Canaries; ProcCor = 0.20, p = 0.686 in Azores) (Fig. 2*A*).

Non-significant correlations were found between the connectivity pattern by both littoral and non-littoral floras and island areas in the three archipelagos (ProcCor = 0.38 and 0.44, p = 0.174 and 115 in Galapagos; ProcCor = 0.17 and 0.13, p = 0.876 and 0.907 in Canaries; ProcCor = 0.11 and 0.26, p = 0.924 and 0.566 in Azores) (Fig. 2*A*).

**Correlation between oceanic currents and island factors connectivity**

Strong and significant correlations were observed between the network structures of the ocean currents and geographic connectivity in all three archipelagos (ProcCor = 0.92, p = 0.001 in Galapagos; ProcCor = 0.98, p = 0.001 in Canaries; ProcCor = 0.98, p =0.001 in Azores). Significant correlations with island age connectivity were found in Galapagos (ProcCor = 0.62, p = 0.003) and Azores (ProcCor = 0.69, p = 0.039), but not in Canaries (ProcCor = 0.19, p = 0.671). No significant correlations were detected with connectivity patterns by island area (ProcCor = 0.18, p = 0.697 in Galapagos; ProcCor = 0.12, p = 0.847 in Canaries; ProcCor = 0.09, p =0.860 in Azores) (Fig. 2*B*).

**Island centrality and percentage of littoral species**

The mean percentage of littoral species was highest in the Azores at 16.51% (SD = 1.49), followed by the Canaries at 14.74% (SD = 6.59) and the Galapagos at 9.75% (SD = 2.51) (Table 1). The islands with the highest and lowest percentages were Graciosa (19 %) and Flores (15 %) in Azores, Fuerteventura (24 %) and La Palma (8 %) in Canaries, and Genovesa (16 %) and Isabela (8 %) in Galapagos (Table S1).

The Canaries exhibited a mean In-Degree centrality () of 0.56 (SD = 1.48), while values were markedly lower in Galapagos ( **=** 0.03, SD = 0.02) and Azores ( **=** 0.01, SD = 0.02). Similar results were observed for  in the three archipelagos. The mean Closeness centrality in the Galapagos was = 0.17 (SD = 0.04), twice as big as the Canaries (= 0.09, SD = 0.03) and Azores (= 0.06, SD = 0.02). Lastly, the mean Betweenness centrality was highest in Azores (= 13.56, SD = 11.20), followed by the Galapagos (= 10.17, SD = 10.18) and the Canaries (= 7.43, SD = 7.72).

Islands with the highest centrality measures included Santa Cruz ( and ) and Santa Fe ( and ) in Galapagos; Fuerteventura (), Lanzarote (), and Tenerife ( and ) in Canaries; and Pico ( and ), Faial ( and ), and Sao Jorge ( and ) in Azores (Table S1).

**Effect of island centrality on the percent of littoral species**

In all models, the archipelago significantly influenced the proportion of littoral plants (model : χ²(2) = 40.96, p < 0.001; model : χ²(2) = 26.17, p < 0.001 , model : χ²(2) = 21.76, p < 0.001) (Table 2 and S2).

*Island In-degree*

The ANOVA table indicated a significant joint effect of archipelago and on littoral plant proportions (χ² = 11.67, p = 0.001), indicating that the effect of island varies among archipelagos (Table S2). Analyzing the individual coefficients, the interaction with archipelago showed a trend towards significance for the Canaries (β = 0.144, p = 0.103), indicating a potential effect where a one-unit increase in centered log-transformed in-degree centrality could correspond to a 14.4% increase in the odds of having littoral plants. This was non-significant for the Galapagos (β = -0.21, p = 0.257) and Azores (β = -0.01, p = 0.864) (Table 2).

*Island Closeness*

The ANOVA table indicated that the interaction between island and archipelago was significant (χ²(2) = 16.41, p < 0.001) (Table S2), indicating that the effect of varies among archipelagos. For the Canaries, a one standard deviation increase in results in a logit change of 1.075, corresponding to a substantial increase in the proportion of littoral plants, with an odds ratio of approximately 2.929. This means there is a 192.9% increase in the odds of having littoral plants for each standard deviation increase in . For the Galapagos and Azores, the interaction term was not significant (β = -0.046, p = 0.862; β = 0.084, p = 0.729) (Table 2).

*Island Betweenness*

The ANOVA table indicated that neither the main effect of (χ² = 0.117, p = 0.733) nor its interaction with archipelago (χ² = 0.675, p = 0.714) were statistically significant (Table S2). Consistent with the ANOVA results, the model summary indicated that neither the effect of itself (β = -0.002, p = 0.842) nor the interaction with Galapagos (β = -0.01, p = 0.693) or Canaries (β = 0.01, p = 0.585) was significant (Table 2).

Discussion

The correlation between littoral flora and ocean currents connectivity varied significantly among the three archipelagos studied. The Canaries exhibited an exceptionally high correlation, followed by a moderate correlation in the Galapagos, and a lack of significant correlation in the Azores. As anticipated, current connectivity shows a strong correlation with geographic distances across all archipelagos, although there is a slight discrepancy observed in the Galapagos, potentially due to the islands being more evenly spaced compared to the Canaries and Azores. Consequently, it is challenging to speculate about the potential contribution of current connectivity to floristic patterns, as geographic distance potentially affects dispersal through other LDD mechanisms such as wind or bird transport. However, we found stronger correlation for littoral flora compared to non-littoral in the Canaries, and a significant correlation for littoral flora but not for non-littoral flora in the Galapagos. This suggests that alongside other potential dispersal modes influenced by geographic distance, current connectivity likely plays a more prominent role in shaping the distribution of littoral plants in these archipelagos.

The connectivity between littoral flora and island ages was significant for the Galapagos and Azores. A possible reason is the effect of community succession where species with opportunistic strategies are advantageous at colonizing new territories and are more prominent in younger islands, whereas in more mature communities in older islands, better competitive species take over (ref) and new lineages arise via diversification within islands (ref).

The pattern of current connectivities, however, showed to add new information on the potential thalassochory connectivity between islands beyond geographic distances, as these incorporate directionality. Therefore, two pairs of islands separated by the same geographic distances may show different connectivity through corrents depending on the direction of these. By computing the network of island connections and their directions, we could derive centrality metrics for islands and approximate their role as either sinks or sources, \_\_\_\_, or \_\_\_\_. There was substantial variation in correlations of centrality metrics between archipelagos, indicating distinct network configurations and roles of islands. The Canaries exhibit marked differences compared to the Galapagos and Azores, which show greater similarity.

The correlation between and , reflecting islands that act as sinks and sources of current flow, provides insights into the overall directionality of currents within an archipelago. In the Azores, this correlation was notably high, indicating a significant exchange of currents among the islands. Conversely, the Canaries displayed a remarkably low correlation, suggesting a stronger directionality in the overall current flow across the archipelago. The Galapagos exhibited a moderate correlation, falling between the Azores and Canaries, possibly reflecting a balance between complex currents and directional influences. Probably for the same reason, correlations were high between and in Azores and Galapagos, and not present in the Canaries. When testing the effect of centrality on the % of littoral species, we found no effect in the Galapagos and Azores, and an effect in the Canaries: Effect of on the % littoral flora, and while not statistically significant at the conventional threshold of 0.05, results for suggests a meaningful relationship.

We interpret that these patterns can be partly explained by the geographic arrangement of the islands and the converging dynamics of oceanic currents. Islands aligned in a chain-like formation, coupled with oceanic current convergence in a consistent direction, likely enhances the transport of plant propagules towards specific islands at either end of the chain promoting a stronger congruence between floristic and ocean current connectivity. This could be the case of the Canaries, which presents a linear spatial arrangement of the islands and are influenced by the Canary Current. This current moves parallel to the African coastline and begins to flow west under the influence of the Equatorial Countercurrent when reaches the area of 15°N (Batten et al. 2000). During winter, peak trade winds further intensify this flow, with core velocities exceeding 75 cm s-1 as the current traverses through the Canary archipelago (Fedoseev 1970). Fuerteventura the highest % littoral plants, followed by Lanzarote. Lanzarote the highest together with Tenerife, and the highest by a lot. Both are in the east, closer to the continent. A potential explanation is that continental littoral flora reaches first these islands through The Canarian Current that flows west from the continental coast, and therefore have higher diversity. These are also the oldest islands and the accumulation of biodiversity may be due to time for diversification.

Conversely, archipelagos with circular or complex spatial configurations and diverse incoming currents may obscure this pattern, as propagules are subjected to intricate and non-directional flow patterns. This complexity might partially elucidate why the Galapagos Islands exhibit a lower correlation between floristic and ocean current connectivity. The islands in the archipelago are arranged in a circular shape and three large and strong sea currents - namely, the Humboldt Current, Panama Flow, and South Equatorial Countercurrent (ref) - constantly enter the archipelago, creating a dynamic and probably less predictable environment for plant dispersal. Still, some islands show centrality measures and percentages of littoral species that may suggest a role of thalassochory. An example is Fernandina, which shows the second lowest percentage of littoral plants, the lowest , and low centrality for the rest of measures. This is probably because of a shield effect of Isabela that may isolate the island from the rest of the archipelago by blocking the currents and preventing propagules to disperse from and towards the island. Another possibility is that this is due to being the youngest of the islands, although littoral plants may be first colonizers and a large biodiversity of littoral plants would have had time enough to establish. However, other islands show the opposite expected relationship between centrality by currents and percentage of littoral species. This is the case for Genovesa, which shows the highest percentage of littoral plants, and still, it has the lowest and is among the islands with the lowest [...]. And some islands were identified potential important roles in the current connectivity network, such as Santa Fe, which is centrally located but east-wards, and show the highest and , and high . This may indicate that it acts as a bridge between the eastern islands and the rest of the archipelago.

In the Azores, we would expect a similar pattern than the Canaries due to its chain-like form. However, no effect of centrality by currents on the % littoral flora on each island. This lack of pattern we found could be due to the convergence of oceanographic processes that manifest in the archipelago in combination with the presence of a highly energetic eddy field, which is characterized by circular and constantly in motion currents (Caldeira & Reis 2017, Le Traon & De Mey 1994). Azores is considered a confluence zone between the west and the east North Atlantic (Caldeira & Reis 2017). This suggests that western currents flow east and eastern currents flow west, showing a pattern of convergence towards the middle islands. This may explain why Sao Jorge and Faial show the highest values of all three archipelagos, and together with Pico, also in the center, makes Azores the archipelago with the highest . This may also influence the marked homogeneous pattern of distribution of littoral flora across the islands, which differs from the more heterogeneous patterns in the Canaries, and probably also contributes to the fact that it is the archipelago with the highest % of littoral plants.

**Our analyses do not allow for exploring any causality of thalassochory on littoral flora biogeography, but rather describing patterns that could suggest that littoral flora communities are impacted by the current connectivity. We want to highlight important limitations shared with most studies addressing current connectivities, and it is mainly the temporal extent of the data, as we only have satellite data since several decades ago, and the current patterns can change with time. Floristic communities assemble from few years range to thousands and millions of years range. Within this period of time, oceanic islands could suffer major changes in the current connectivity landscape due to the emergence and submergence of islands (ref), sea level fluctuations driven by glacial cycles (ref), or changes in global currents (i.e. \_\_\_\_ due to the formation of the Panama itsmun; ref). Still, we think that it is possible that the current landscape we described may approximate that that happened in the archipelagos for long enough for influencing multiple colonization events among littoral flora between islands and therefore may be responsible for part of their biogeographic patterns, affecting others acting over longer timescales which include isolation and mixing due to geological events and speciation and extinction events. In addition, humans have been present in the archipelagos for hundres of years** (500 years in Galapagos (ref) 2100 in Canaries (ref), and 1300 in Azores (ref)) and **their movements across islands could have a strong homogenizing effect in the floras of archipelagos** (Castro et al. 2010). Although we did not observe higher % of littoral species in the most populated islands of archipelagos.

**[Future perspectives]**

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**Figures**

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| **Figure 1.** **Network representation of ocean current connectivity in each archipelago and the percent of littoral species in each island.** (A) Galapagos, (B) Canaries, and (C) Azores. Edge width and transparency corresponds to the connectivity weights ( between island pairs. These are log transformed for Canaries and square root transformed for Azores to facilitate readability. |

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| **Figure 2. Procrustes correlations between structures of connectivity networks within archipelagos.** (A) Procrustes correlations between island connectivity by floristic composition (Bray-Curtis DI) and by ocean currents and island factors. (B) Procrustes correlations between island connectivity by ocean currents and island factors. Black asterisks indicate the level of statistical significance. The solid point indicates marginally significant (p = 0.055 in this case). |

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| **Figure 3.** **Pearson correlation between island centrality measures for the ocean current connectivity network in each archipelago.** In and Out-degree are calculated from connectivity weights ( and approximate the role of islands as sinks or sources of currents. Closeness and Betweenness are calculated on the direct weights (distances) and approximate the role of islands as being more accessible and acting as hubs or bridges in the currents network, respectively. |
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| **Figure 4. Network representation and island centrality of the ocean current connectivity in each archipelago.** (A-B) Galapagos, (C-D) Canaries, and (E-F) Azores. In the network plots (A, C, E), the edge width and transparency corresponds to the connectivity weights ( between island pairs. These are log transformed for Canaries and square root transformed for Azores to facilitate readability. Panels B, D, and F show the results of a Generalized linear model (GLM) with a beta distribution fitted with the data for all archipelagos together, with the interaction between archipelago and centrality as predictor of the percent of littoral flora. Black and red trend lines indicate absence or presence of significance. In-degree was marginally significant. |

**Tables**

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| **Table 1.** Summary statistics for the percentage of littoral plants and centrality within the ocean currents network in each archipelago. | | | | | |
| Variable | Statistic | Galapagos |  | Canaries | Azores |
| % littoral plants | Mean | 9.75 |  | 14.74 | 16.51 |
|  | SD | 2.51 |  | 6.59 | 1.49 |
|  | Mean | 0.03 |  | 0.56 | 0.01 |
|  | SD | 0.02 |  | 1.48 | 0.02 |
|  | Mean | 0.03 |  | 0.56 | 0.01 |
|  | SD | 0.02 |  | 1.48 | 0.02 |
|  | Mean | 0.17 |  | 0.09 | 0.06 |
|  | SD | 0.04 |  | 0.03 | 0.02 |
|  | Mean | 10.17 |  | 7.43 | 13.56 |
|  | SD | 10.18 |  | 7.72 | 11.20 |

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| **Table 2.** Coefficients summary for the Generalized Linear Mixed Models with the interaction of the archipelago and the centrality measure in the ocean current network as predictor of the percent of littoral plants in islands. | | | | |
| Predictor | Estimate | SE | z value | p value |
| **In-Degree ()** | | | | |
| (Intercept) | -1.62 | 0.08 | -19.11 | **<0.001** |
| archipelago[Canaries] | -0.19 | 0.12 | -1.56 | 0.120 |
| archipelago[Galapagos] | -0.51 | 0.13 | -3.83 | **<0.001** |
|  | -0.01 | 0.08 | -0.17 | 0.864 |
| archipelago[Canaries]\* | 0.14 | 0.09 | 1.63 | 0.103 |
| archipelago[Galapagos]\* | -0.21 | 0.18 | -1.13 | 0.257 |
| **Closeness ()** | | | | |
| (Intercept) | -1.53 | 0.25 | -6.13 | **<0.001** |
| archipelago[Canaries] | 0.11 | 0.27 | 0.41 | **0.678** |
| archipelago[Galapagos] | -0.73 | 0.28 | -2.63 | **0.009** |
|  | 0.08 | 0.24 | 0.35 | 0.729 |
| archipelago[Canaries]\* | 1.07 | 0.35 | 3.05 | **0.002** |
| archipelago[Galapagos]\* | -0.05 | 0.27 | -0.17 | 0.862 |
| **Betweenness ()** |  |  |  |  |
| (Intercept) | -1.58 | 0.14 | -10.90 | **<0.001** |
| archipelago[Canaries] | -0.29 | 0.21 | -1.37 | 0.171 |
| archipelago[Galapagos] | -0.56 | 0.20 | -2.83 | **0.005** |
|  | -0.002 | 0.01 | -0.20 | 0.842 |
| archipelago[Canaries]\* | 0.01 | 0.02 | 0.55 | 0.585 |
| archipelago[Galapagos]\* | -0.01 | 0.01 | -0.40 | 0.693 |
| was transformed to logit scale.  was centered by subtracting the mean of the variable from each value, and scaled by dividing the centered values by the SD. | | | | |