Santa Barbara Botanic Garden

Gap Analysis of the California Channel Islands: Vascular Plants

Final Report

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Cover photo: Northern Channel Islands endemic soft-leaved paintbrush, *Castilleja mollis* (Orobanchaceae), on Carrington Point, Santa Rosa Island. Photo by Matt Guilliams.

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Introduction

Describing the composition, distribution, and abundance of Earth's biodiversity has been one of the fundamental pursuits of biologists for centuries. Understanding these aspects of biodiversity has attained critical, new relevance as humans grapple with the combined effects of habitat destruction, invasive species, and global climate change on the Earth's biota. Although great strides have been made in improving our knowledge of living systems, existing biodiversity data is unevenly distributed in space, time, and across the tree of life. Here we seek to characterize these spatial, temporal, and taxonomic data gaps for the vascular plants of the California Channel Islands.

Early botanical exploration of the Channel Islands

Early botanical surveys on the Channel Islands began in mid-1800s, and were largely exploratory in nature. Early voyages include W. Gambel on Santa Catalina Island in 1847 (Millspaugh & Nuttall, 1923); J.G. Cooper on Santa Barbara Island in 1863 (Junak et al., 1993); Kellogg and Harford on Santa Cruz Island in 1874 (Eastwood, 1941); W.S. Lyon and J.C. Nevin on San Clemente Island in 1885 (Lyon, 1886); E.L. Greene on San Miguel Island in 1886 (Greene, 1889); T.S. Brandegee on Santa Rosa Island in 1887/1888 (Brandegee, 1888), L.G. Yates on Anacapa Island in the early 1890s (Junak & Philbrick, 2018), and B. Trask on San Nicolas Island in 1897 (Eastwood, 1898). The results of these surveys were sometimes published as prose-based accounts of the voyage, and often were not explicitly voucher-based, even if a species list was included. In some cases, it has not been possible to later locate living plants or specimens of certain taxa mentioned in these early accounts (Wallace, 1985).

Voucher-based floristics of the Channel Islands

Published works

The era of explicitly voucher-based study of the flora of the Channel Islands began in 1923, with the publication of the Flora of Santa Catalina Island (Millspaugh & Nuttall, 1923). Since that time, there have been a number of voucher-based studies of the vascular plants of individual islands in the Channel Islands archipelago, discussed here from the northwest to the south east. No individual, voucher-based checklists or floras exist for San Miguel or Santa Rosa islands at the present time, but all of the northern Channel Islands were included in the geographic domain of the Santa Barbara Region flora (Smith, 1998). The preparation of the Santa Barbara Region flora did not include field work on the Channel Islands, however. A book-length flora of Santa Cruz Island was written by Junak et al. in 1995. A voucher-based checklist of Anacapa Island was written by Junak and Philbrick 2018. A voucher-based checklist of Santa Barbara Island was written by Philbrick in 1972, and later revised by Junak et al. in 1993. A book-length flora of San Nicolas Island was published by Junak in 2008. A voucher-based checklist of San Clemente Island was published by Raven in 1963. An annotated, voucher-based checklist of the island was later published by Thorne in 1967, with updates pertaining to both Santa Catalina and San Clemente islands published in 1969.

There are two, comprehensive, voucher-based checklists of vascular plants of the Channel Islands. Wallace provided the first voucher-based checklist inclusive of all of the Channel Islands (Wallace, 1985). This list is primarily based on those plants that have been documented with a specimen deposited in an accredited herbarium. The list also cites the published literature for cases where a taxon was included in a published account but for which a voucher has not been observed. A second voucher-based checklist for the Channel Islands was published in 2014 by Ratay et al. (Ratay et al., 2014). This checklist built upon Wallace's 1985 checklist, including new records to the archipelago and to individual islands. While nearly all of the new additions were based on specimens deposited in herbaria, some were included on the basis of personal communications with island botanists.

Works in progress

A number of voucher-based studies of the Channel Islands flora are in progress. Online checklists for each individual island have been published or are in preparation. These working checklists have been published online on the California Consortium of California 2 website (cch2.org), where they will be updated regularly and made freely available in perpetuity. At this time, online checklists are publicly available for San Miguel (K. E. Hasenstab-Lehman & Guilliams, 2021a), Santa Rosa (K. E. Hasenstab-Lehman & Guilliams, 2021b), Anacapa (K. Hasenstab-Lehman et al., 2021), Santa Barbara (Guilliams & Hasenstab-Lehman, 2021), San Nicolas (Guilliams & Hasenstab-Lehman, 2020a), and Santa Catalina islands (Guilliams & Hasenstab-Lehman, 2020b). Online checklists are in preparation for Santa Cruz Island and for the Channel Islands archipelago as a whole. Traditional, printed, voucher-based checklists are in preparation for San Miguel Island (Junak et al., in preparation), San Nicolas Island (Guilliams and Hasenstab-Lehman, in preparation), and San Clemente Island (Rebman and Vanderplank, in preparation). Two book-length, voucher-based floras are in preparation. A book-length flora for Santa Catalina Island is in the late publication phase (Guilliams et al., unpublished). A book-length flora for the Channel Islands is in the botanical editing phase (Guilliams et al., unpublished).

Gap analysis goal and objectives

The goal of this project is to use the existing pool of digitized, georeferenced plant specimen and observation records from the Channel Islands to reveal historical collection patterns and assist in prioritizing future island plant biodiversity exploration and documentation. Historical collection patterns will be evaluated through the following three objectives:

- **Objective 1.** Describe spatial patterns in existing collections and observations at the archipelago scale and on each individual island.
- **Objective 2.** Describe annual and seasonal temporal patterns in existing collections at the archipelago scale and on each individual island.
- **Objective 3.** Describe taxonomic patterns in existing collections and observations at the archipelago scale and on each individual island.

Methods

Focal taxa

The analyses presented here focus on the vascular plants of the Channel Islands. Vascular plants, also known as Tracheophytes, are the most taxon-rich, conspicuous, and ecologically important group of land plants. The other three groups of land plants, often collectively referred to as the bryophytes, include the hornworts, liverworts, and mosses. These non-vascular land plants are treated in a separate report (B. Carter, 2021).

Vascular plants as a group can be defined by a suite of derived features. These features include an independent, long-lived, branched sporophyte; secondary cell walls with lignin; development of specialized support tissues (sclerenchyma); specialized vascular tissue cells for conducting water (tracheary elements in xylem) and sugars (sieve elements in phloem); an endodermis; and roots (Simpson, 2019b).

Vascular plants have long been recognized as a natural group comprising the lycophytes, ferns, and seed plants (Simpson, 2019b). The lycophytes (Lycopodiophyta) include two main groups of plants, the Lycopodiales and the Isoetales. Both of these lycophyte orders are relatively taxon-poor, and only the Isoetales have members on the Channel Islands (*Isoetes* and *Selaginella*). Lycophytes are sister to the remaining vascular plants, which resolve in two main clades, the ferns and seed plants. The ferns, also known as Monilophytes, are relatively taxon-poor on the Channel Islands, but are nevertheless common in some ecological settings such as shaded north-facing slopes and along canyon walls and bottoms (Junak et al., 1995). The seed plants, also known as the Spermatophyta, are the most taxon-rich and ecologically important members of the vascular plants. Comprising two main groups, the gymnosperms and the angiosperms, the seed plants are the dominant plant group across all vegetation communities on the Channel Islands.

Dataset assembly

Digital specimen records from the Consortium of California Herbaria (CCH2), the Global Biodiversity Information Facility (GBIF), and SEINet were retrieved from the Islands of the Californias Biodiversity Information System (Cal-IBIS) symbiota portal at www.cal-ibis.org as a comma separated values (CSV) file. This all-taxa portal was created to consolidate California Islands biodiversity data for ready use by land managers, scientists, and others, and to facilitate the assessment and management of the islands as a whole archipelago. It is one of only a few all-taxa portals created for defined geographic areas in existence. To maintain this portal, data from other sources are periodically searched and data "snapshots" are imported. Other data sets are unique to this portal. Records from other sources are searched via a series of name and spatial searches. Because data coming from different sources can be redundant, a series of operations are then performed to remove duplicates and clean the data prior to posting on the Cal-IBIS portal. Island records that do not contain either geographic coordinates or key island names may not be recovered through this process. Furthermore, occasional non-Channel Islands specimens may be retrieved when location names contain our keywords, including University of California *Santa Barbara* Lagoon *Island*.

Records were cleaned to exclude non-Channel Islands specimens. Georeferenced specimens were assigned to islands using the geolocations provided. For non-georeferenced specimens, island was determined manually based on various text entries to the locality field. A series of data cleaning steps was then performed to further refine the dataset. First, specimens of non-vascular plants (i.e., non-Tracheophyta) and specimens not identified to species rank were removed. Specimens of horticultural plants in anthropogenic landscapes were also removed from the dataset. In some cases, and only for the purposes of this study, selected taxa not determined to minimum rank (species, subspecies, or variety) were assigned a minimum-rank designation when it could be done unambiguously. For example, specimens of *Lyonothamnus floribundus* from Santa Cruz Island determined only to species rank were assigned to subsp. *aspleniifolius*. The distribution of this iconic plant has been well-studied and only subsp. *aspleniifolius* occurs on Santa Cruz Island. In all cases, our taxon-by-island designations for the specimen dataset were compared against the unpublished Channel Islands Flora checklist, which includes a taxon-by-island matrix. Specimens assigned to particular islands that had current determinations in conflict with the unpublished Channel Islands Flora checklist were evaluated on a case-by-case basis. Specimens bearing minimum-rank names not currently in use (synonyms) were assigned to accepted names using current floras and studies in the published literature. Specimens assigned to older, higher-rank taxa (e.g., families) were updated with new, higher-taxon names. For example, the genus *Eriodictyon* has been historically placed in both the Hydrophyllaceae and Boraginaceae, and some specimens in Cal-IBIS are still assigned to these older names. We updated all *Eriodictyon* to the currently recognized family name, Namaceae. A second, reduced dataset comprising only those filtered, cleaned records with latitude and longitude records was assembled for use in analyses examining within-island spatial patterns.

Observation data from the digital community science platform iNaturalist (www.iNaturalist.org) were downloaded separately. Although iNaturalist records are a component of the GBIF data included in Cal-IBIS, it was discovered that not all records were being retrieved (likely an issue with the process to remove duplicates). Here only "research grade" iNaturalist observations were included in analyses. To be research grade, an observation must have a photographic voucher, a community-supported identification, and date and locality data. All iNaturalist observations are from prior to October 25, 2021.

For iNaturalist data, some observations were "obscured" meaning that available locality data are intentionally offset from the actual observation location. This can occur if the user intentionally changes settings from "open" to "obscured." The iNaturalist platform also automatically obscures all locality data for species of conservation concern. To get access to the unobscured locality data for these observations, researchers would need to contact the individual observers and/or get them to contribute their observations to a project for which the user gives permission to project staff to see unobscured locality data. As a result, getting access to the unobscured locality data is a significant time investment and beyond the scope of the current study.

Statistical analyses

All statistical analyses were performed in the program R version 4.1.1 (R Development Core Team, 2021) using custom scripts developed by Ben Carter and Josie Lesage. The complete dataset was used to tabulate taxa and associated specimens by island. Species accumulation curves for each island were calculated by performing 100 iterations of reshuffling all specimens from each island and then finding the mean species accumulation across increasing numbers of collections.

The reduced dataset of specimens with latitude and longitude coordinates was used in within-island analyses. Each island was divided into a grid of 1 km^2 grid cells. Specimens were assigned to individual grid cells using their latitude and longitude coordinates. The R package 'raster' (Hijmans, 2021) was used for all spatial analyses.

Results

Evaluating spatial patterns

Island-scale spatial patterns

Comparative taxonomic richness by island is reported in **Table 1**. This table summarizes taxonomic richness from six sources: 1) the draft, unpublished checklist from the Channel Islands Flora (Guilliams

Table 1. Comparative taxonomic richness by island from six different sources.

Data Source	Vascular plant taxonomic richness by island							
	San Miguel Island	Santa Rosa Island	Santa Cruz Island	Anacapa Island	Santa Barbara Island	San Nicolas Island	San Clemente Island	Santa Catalina Island
Channel Islands Flora checklist	295	535	684	279	144	300	451	715
Ratay et al. checklist	296	519	662	271	150	279	436	633
Flora of Santa Cruz Island	267	485	650	265	132	270	382	604
Gap Analysis all specimen data post quality-filtering	268	491	651	239	129	274	413	662
Gap Analysis all specimen data with latitude and longitude coordinates	266	482	643	235	127	272	403	650
Gap Analysis iNaturalist all observations post-quality filter	73	265	347	50	60	95	322	398

et al. unpublished data), 2) the checklist of Ratay et al. (2014), 3) the Flora of Santa Cruz Island (Junak et al., 1995), 4) the Gap Analysis dataset inclusive of all specimen records that passed quality filters (79,777 unique gatherings), 5) the Gap Analysis dataset reduced to only those specimens with latitude and longitude coordinates (56,528 unique gatherings), and 6) iNaturalist community scientist observations.

Taxonomic richness values by island vary strongly among these five sources, with the general trend among the published sources being an increase in richness through time. The taxonomic richness values presented in the Channel Islands Flora checklist are higher than those reported in other sources for all islands except for San Miguel and Santa Barbara islands. The Ratay et al. (2014) checklist reports the highest levels of taxonomic richness for San Miguel and Santa Barbara islands, and the next highest levels of taxonomic richness for all other islands. The Flora of Santa Cruz Island and the Gap Analysis dataset inclusive of all specimen records present intermediate values for taxonomic richness. The specimen dataset reduced to only those specimens with latitude and longitude coordinates had the lowest reported levels of taxonomic richness by island of the specimen data. iNaturalist observation data had the lowest richness of all data sets; these numbers were highest for Santa Cruz, San Clemente, and Santa Catalina. Underlying differences among these sources as well as other potential explanations for these patterns are given in the discussion.

The number of specimens per island was roughly proportional to island size in most cases (**Table 2**, **Figure 1**). Island sizes range from 2.6 km^2 for Santa Barbara Island to 249 km^2 for Santa Cruz Island. The number of specimens per island ranged from 1,341 on Santa Barbara Island to 18,609 on Santa Cruz Island. In general, the smallest islands have the fewest specimens collected (e.g., Santa Barbara Island = 1,341 specimens, Anacapa Island = 3,123 specimens) and the largest islands have the greatest number of specimens collected (e.g., Santa Cruz Island = 18,609 specimens, Santa Catalina Island = 14,029 specimens). There are exceptions to the trend, however, with the clearest being the relative lack of specimens collected from Santa Rosa Island. Santa Rosa Island is the second largest island in the archipelago (217 km^2), but has only 5,551 specimens collected. This is well-below the regression line (Figure 1), and is roughly similar to the number of specimens collected on the much smaller, 58 km^2 San Nicolas Island (4,760 specimens).

Within-island spatial patterns: collection intensity

Within-island spatial patterns were evaluated by partitioning each island into a system of 1km^2 grid cells and examining a variety of collections-oriented statistics within each grid cell. Within-island summary spatial statistics for specimens with latitude and longitude coordinates are presented in **Table 2**. Statistics reported by island include island size (km^2), total number of specimens, taxonomic richness, number of 1km^2 grid cells, number of empty 1km^2 grid cells, percent empty 1km^2 grid cells, mean number of specimens per cell, mean taxonomic richness per cell, and mean redundancy per cell. Note that at this time, calculations for mean number of specimens per cell, mean taxonomic richness per cell, and mean redundancy per cell include some specimens with "place holder" latitude and longitude coordinates at the island centroid. The georeferences for these specimens will be improved on a case-by-case basis when possible. Those specimens with coordinates at the island centroid that cannot be further refined will be removed prior to analyses in the final draft of the report.

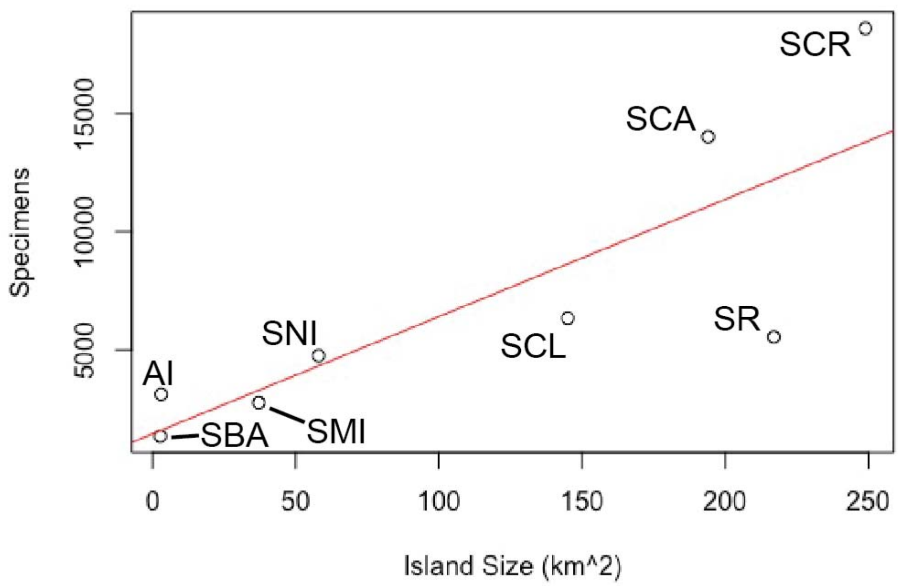
Table 2. Summary spatial statistics for specimens with latitude and longitude coordinates.

*At this time calculations for specimens/cell, taxonomic richness/cell, and mean redundancy include some specimens with "place holder" latitude and longitude coordinates at the island centroid; the georeferences for these specimens will be improved on a case-by-case basis when possible.

Island	Island size (km^2)	Total Specimens	Taxonomic Richness	1 km^2 cells	Empty 1 km^2 cells	% Empty Cells	Mean specimens /cell*	Mean taxonomic richness/cell*	Mean redundancy*
San Miguel Island	37	2,768	266	61	10	16.4	54.2	25.6	0.340
Santa Rosa Island	217	5,551	482	263	76	28.9	29.7	18.4	0.184
Santa Cruz Island	249	18,609	643	313	40	12.8	68.2	33.5	0.306
Anacapa Island	2.9	3,123	235	14	2	14.3	260.2	76.1	0.555
Santa Barbara Island	2.6	1,341	127	11	3	27.3	167.6	42.6	0.486
San Nicolas Island	58	4,760	272	81	7	8.6	64.3	31.5	0.408
San Clemente Island	145	6,347	403	198	28	14.1	37.3	21.5	0.309
Santa Catalina Island	194	14,029	650	250	36	14.4	65.6	34.6	0.334

Figure 1. Scatterplot of specimens collected versus island size (km^2)

Island abbreviations: AI = Anacapa Island, SBA = Santa Barbara Island, SCA = Santa Catalina Island, SCL = San Clemente Island, SCR = Santa Cruz Island, SMI = San Miguel Island, SNI = San Nicolas Island, SR = Santa Rosa Island.



The number of 1km^2 grid cells per island follows directly from island size and varied accordingly from 11 on Santa Barbara Island to 313 on Santa Cruz Island. The number of empty 1km^2 grid cells ranged from 2 on Anacapa Island to 76 on Santa Rosa Island. The percent empty 1km^2 grid cells ranged from 8.6% on San Nicolas Island to 28.9% on Santa Rosa Island. Specimens per 1km^2 grid cell ranged from 29.7 on Santa Rosa Island to 260.2 on Anacapa Island.

Figure 2A-D shows within-island collection intensity for the northern Channel Islands of San Miguel, Santa Rosa, Santa Cruz, and Anacapa. Not surprisingly, within-island collection intensity on each of the northern Channel Islands is unevenly distributed. Predictably, the greatest numbers of specimens occur in grid cells nearest to areas of heavy human activity, such as roads, field stations, and regularly used boat landings (e.g., piers). The grid cells with the lowest levels of collection intensity occur in seldom-traveled areas. Each of the northern Channel Islands has grid cells within which no specimens have been collected.

Collection intensity and associated spatial statistics vary between the northern Channel Islands. For relatively small San Miguel Island (37 km^2), 10 of 61 grid cells (16.4%) are empty. Mean specimens per cell is 54.2. Santa Rosa Island is the second largest of the Channel Islands (217 km^2), but is poorly collected. A total of 76 of 263 grid cells have zero collections, which is well over a quarter of the island (28.9%). Mean specimens per cell is the lowest of any island in the archipelago, at 29.7. Although the largest island in the archipelago, Santa Cruz Island (249 km^2) is relatively well-collected. Only 40 of the 313 grid cells have zero collections. This is 12.8%, the lowest percent empty cells in the archipelago. Mean specimens per cell is 68.2. Anacapa Island is the second smallest island in the archipelago (2.9 km^2), with only 14 grid cells. Only 2 of 14 grid cells are empty (14.3%), but the 2 empty grid cells are mostly ocean and contain very little land. Anacapa Island has the highest mean specimens per cell, at 260.2.

Figure 3A-D shows within-island collection intensity for the southern Channel Islands of Santa Barbara, San Nicolas, San Clemente, and Santa Catalina. As with the northern Channel Islands, within-island collection intensity on each of the southern Channel Islands is unevenly distributed. The greatest numbers of specimens occur in grid cells nearest to areas of heavy human activity, such as roads, field stations, and regularly used boat landings (e.g., piers). The grid cells with the lowest levels of collection intensity occur in seldom-traveled areas. Each of the southern Channel Islands has grid cells within which no specimens have been collected.

Collection intensity and associated spatial statistics also vary between the southern Channel Islands. The smallest island in the archipelago, Santa Barbara Island (2.6 km^2) is relatively well-collected. Three of the 11 total grid cells have zero collections (27.3%), but these cells are essentially landless. Mean specimens per cell is the second highest in the archipelago at 167.6. Although San Nicolas Island is a small-to-medium sized island (58 km^2), it is also relatively well-collected. Of the 81 grid cells on the island, only 7 are empty, yielding the lowest percent empty grid cells of the archipelago (8.6%). A medium-to-large island, San Clemente Island (145 km^2) has 28 of 198 grid cells empty (14.1%). Despite a somewhat low percent empty cells, the mean specimens per cell is the second lowest in the archipelago (37.3). The largest of the southern Channel Islands and the third largest of the archipelago, Santa Catalina Island (194 km^2) is relatively well-collected. Only 36 of 250 grid cells are empty (14.4%), and mean specimens per cell is relatively high for a larger island (65.6).

Figure 4 shows the distribution of iNaturalist observations across A) the northern islands, B) Anacapa Island, and C) the southern islands. Although the large number of obscured data points obscures the true

Figure 2A-D. Within-island specimen collection intensity for the northern Channel Islands.

A. San Miguel Island; **B.** Santa Rosa Island; **C.** Santa Cruz Island; **D.** Anacapa Island. Red dots show individual specimen collection locations. Collection intensity within grid cells is indicated by a color ramp from white to dark blue. Individual grid cells are 1 km^2.

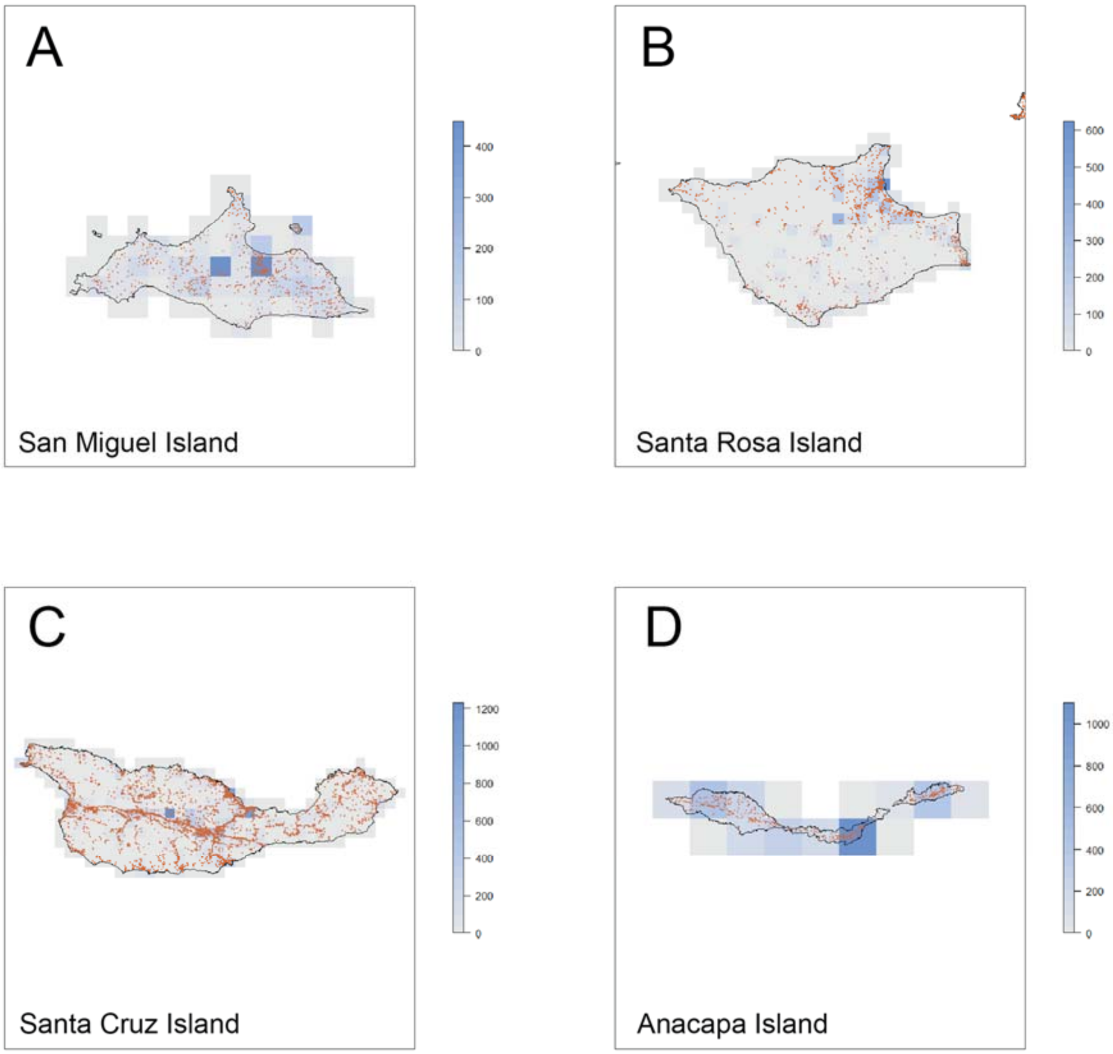


Figure 3A-D. Within-island specimen collection intensity for the southern Channel Islands.

A. Santa Barbara Island; **B.** San Nicolas Island; **C.** San Clemente Island; **D.** Santa Catalina Island. Red dots show individual specimen collection locations. Collection intensity within grid cells is indicated by a color ramp from white to dark blue. Individual grid cells are 1 km^2.

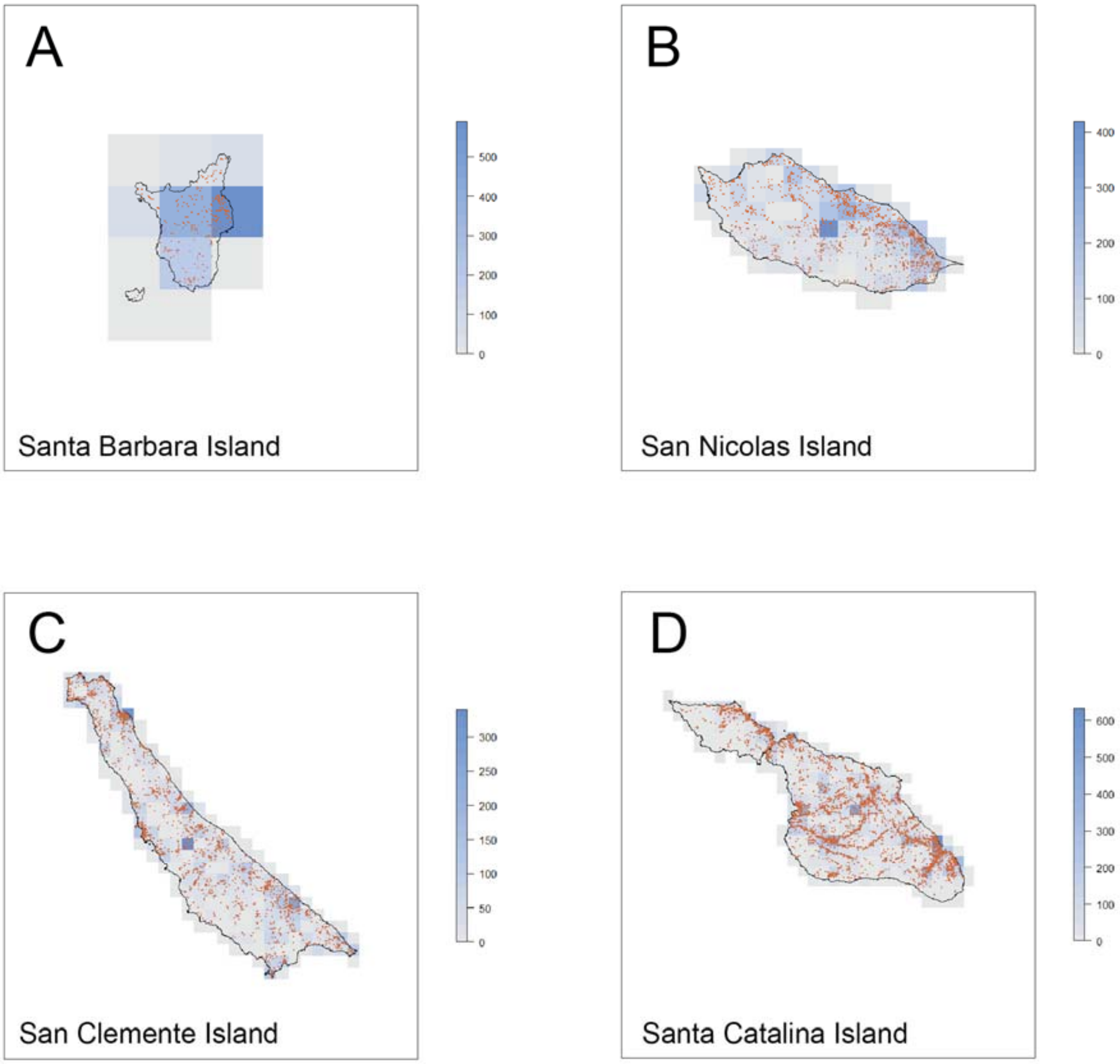
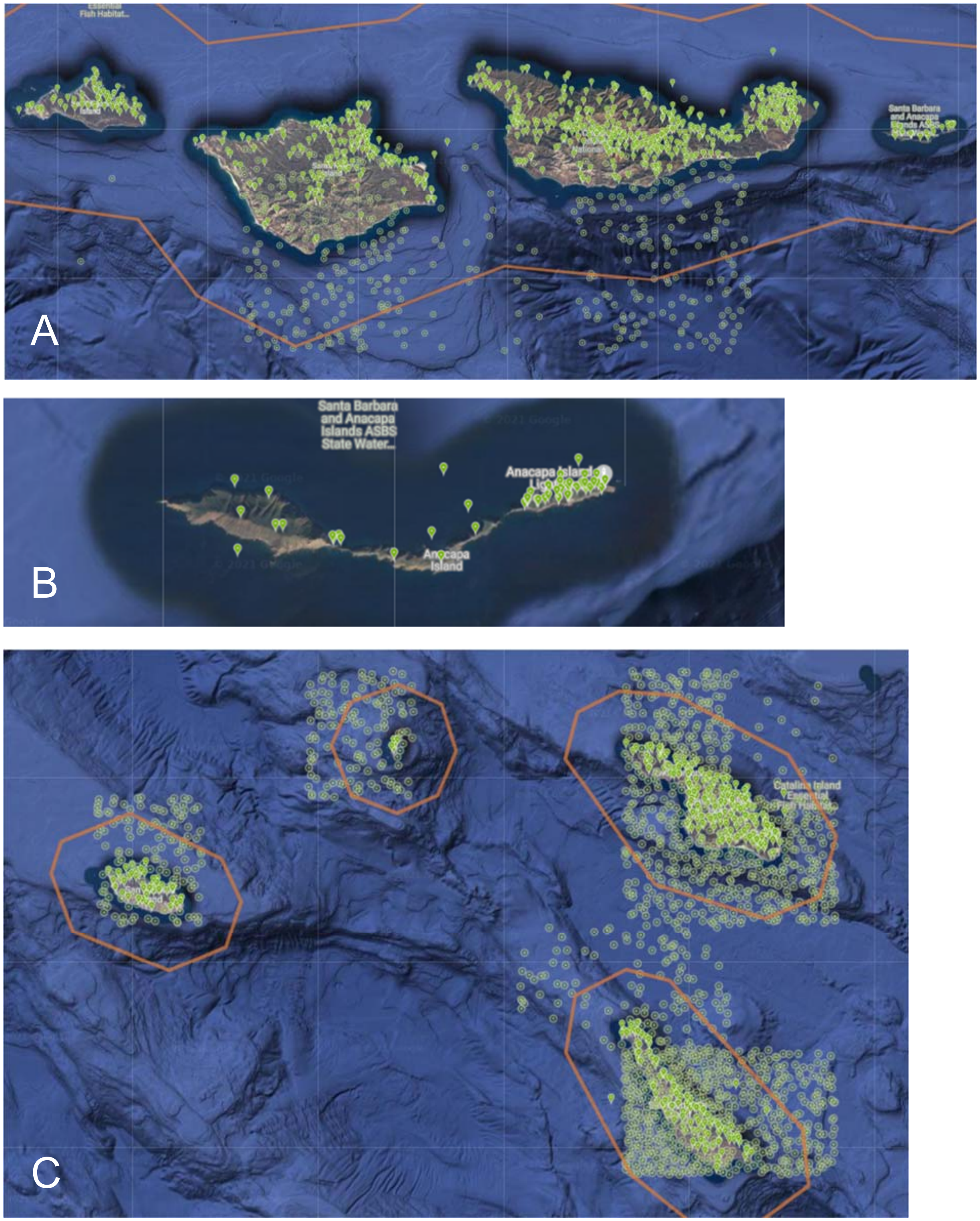


Figure 4A-C. Distribution of iNaturalist plant observations on the Channel Islands.

A. plant observations on the northern Channel Islands; **B.** Anacapa Island; **C**. the southern Channel Islands. Drops represent "open" observations for which the plotted location is the actual observation location; circles are "obscured" observations for which the plotted location is offset from the actual observation location.



distributions, these maps show that the islands vary in how thoroughly they have been covered. Eastern Anacapa Islet, Santa Catalina, San Clemente, and San Nicolas islands appear to be the most well-traveled. For the former two, this can be explained by the ease of access by visitors. For the latter two, both Navy islands, this can be explained by the presence of staff and contract biologists active on this platform. Western and Middle Anacapa Islets have been particularly under-sampled, as well as the more remote portions of Santa Rosa and Santa Cruz.

Within-island spatial patterns: taxonomic richness and redundancy

Within-island taxonomic richness for each of the northern Channel Islands is shown in **Figure 5A-D**. Mean taxonomic richness per $1km^2$ grid cell varied strongly across the northern Channel Islands, appearing to interact with island size, the correlated overall island taxonomic richness, and collection intensity. San Miguel Island had a relatively low mean taxonomic richness of 25.6 per grid cell. Santa Rosa Island had the lowest mean taxonomic richness per grid cell of any island in the archipelago of 18.4. Although with the largest overall number of specimens collected of any island, Santa Cruz Island has a moderate taxonomic richness per grid cell of 33.5. Anacapa Island is the second smallest island in the archipelago, but has the largest value of mean taxonomic richness per grid cell of 76.1. Mean redundancy on the northern Channel Islands ranged from 0.184 for Santa Rosa Island to 0.555 for Anacapa Island.

Within-island taxonomic richness for each of the southern Channel Islands is shown in **Figure 6A-D**. Mean taxonomic richness per $1km^2$ grid cell also varied across the southern Channel Islands, but to a lesser extent than on the northern islands. At 42.6, Santa Barbara Island had the highest mean taxonomic richness of the southern Channel Islands and the second highest in the archipelago. San Nicolas Island had relatively moderate levels of mean taxonomic richness at 31.5, while the much larger San Clemente Island had the second lowest value of 21.5. Santa Catalina Island had a moderate value of mean taxonomic richness per cell of 34.6. Mean redundancy on the southern Channel Islands ranged from 0.309 on San Clemente Island to 0.486 on Santa Barbara Island.

Evaluating temporal patterns

Annual temporal patterns

The raw number of vascular plant specimens collected through time by island is presented in **Figure 7A-B**. Figure 7A shows raw samples collected through time, *with y-axes independently scaled by island*. In the current dataset, specimen collections through time appear highly-irregular, coming in a series of major waves. The collection history of each island begins in the mid- to late-1800s with the collection of a relatively modest number of specimens. On most islands, a large pulse of collection activity occurs in the late 1920s through the1930s, corresponding to separate floristic work of Meryl B. Dunkle and F. Ray Fosberg. The next major collection wave occurs on most islands in the 1960s, corresponding to the work of Ralph Philbrick on the northern Channel Islands and with the collections of Peter Raven and Bob Thorne on San Clemente Island and Santa Catalina Island, respectively, on the southern Channel Islands. The most recent wave of collections on most islands corresponds in large part to the floristic work of Steve Junak between ca. 1980 and the present.

Figure 5A-D. Within-island specimen taxonomic richness for the northern Channel Islands.

A. San Miguel Island; **B.** Santa Rosa Island; **C.** Santa Cruz Island; **D.** Anacapa Island. Red dots show individual specimen collection locations. Taxonomic richness within grid cells is indicated by a color ramp from white to dark blue. Individual grid cells are 1 km^2.

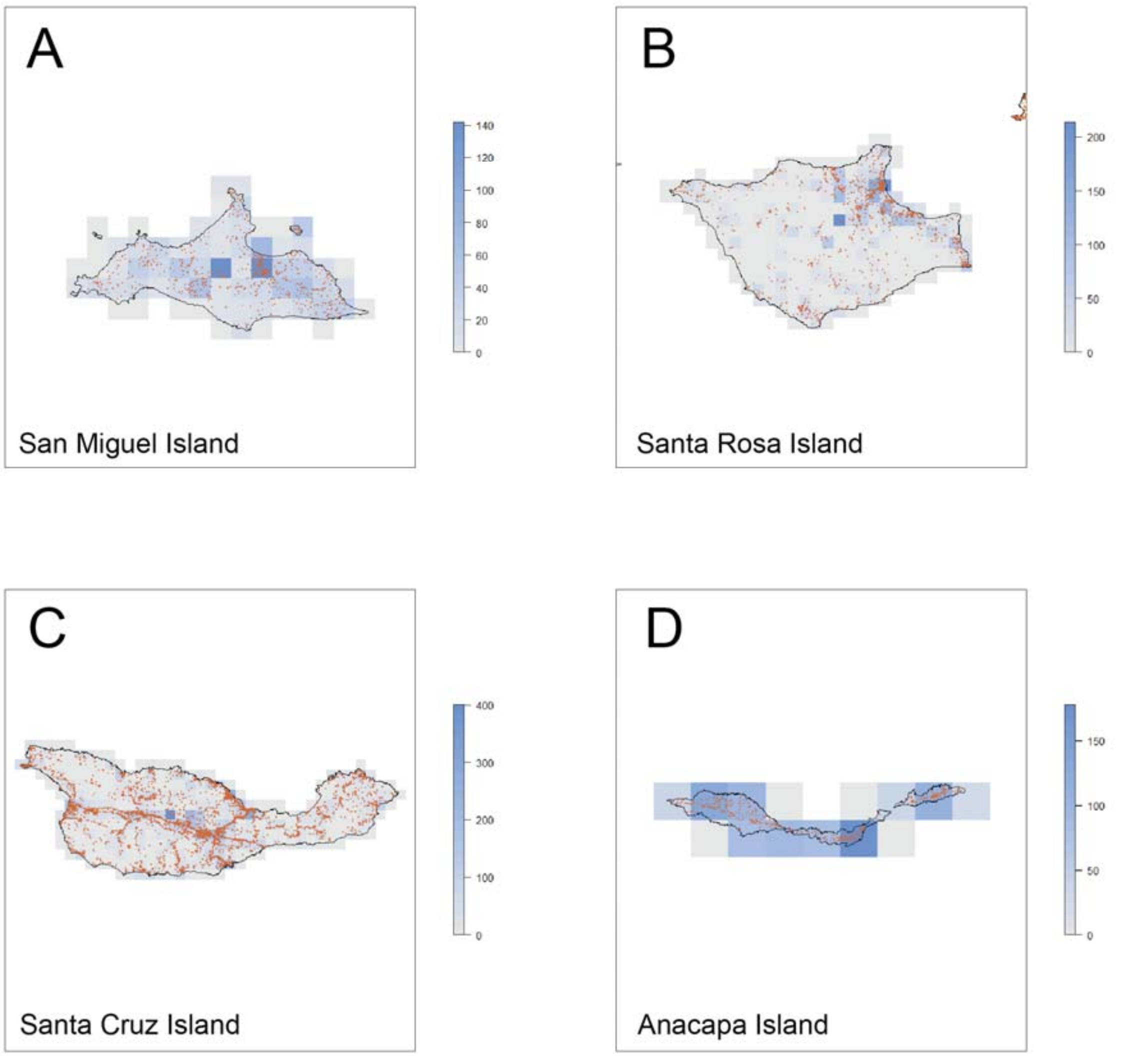


Figure 6A-D. Within-island specimen taxonomic richness for the southern Channel Islands.

A. Santa Barbara Island; **B.** San Nicolas Island; **C.** San Clemente Island; **D.** Santa Catalina Island. Red dots show individual specimen collection locations. Taxonomic richness within grid cells is indicated by a color ramp from white to dark blue. Individual grid cells are 1 km^2.

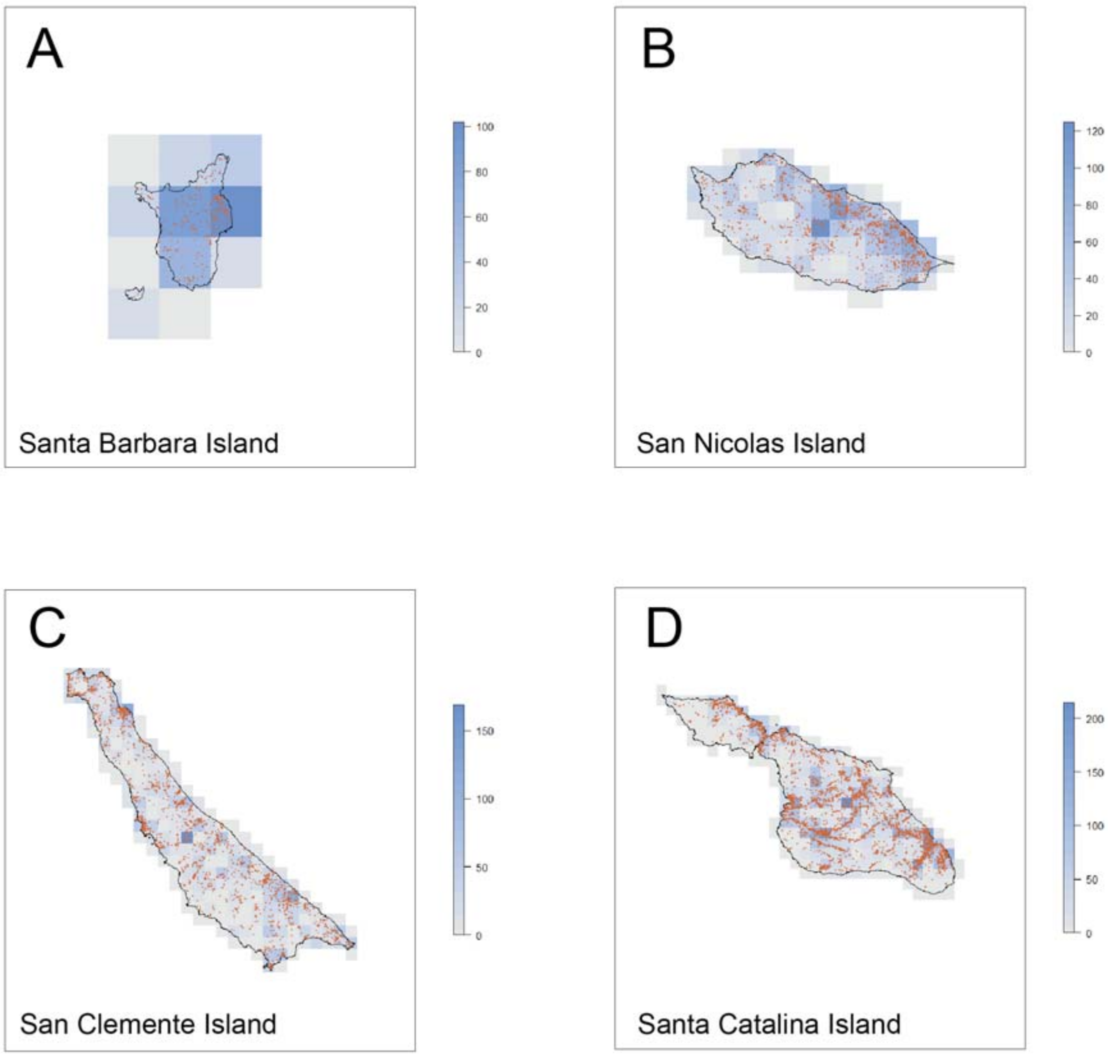
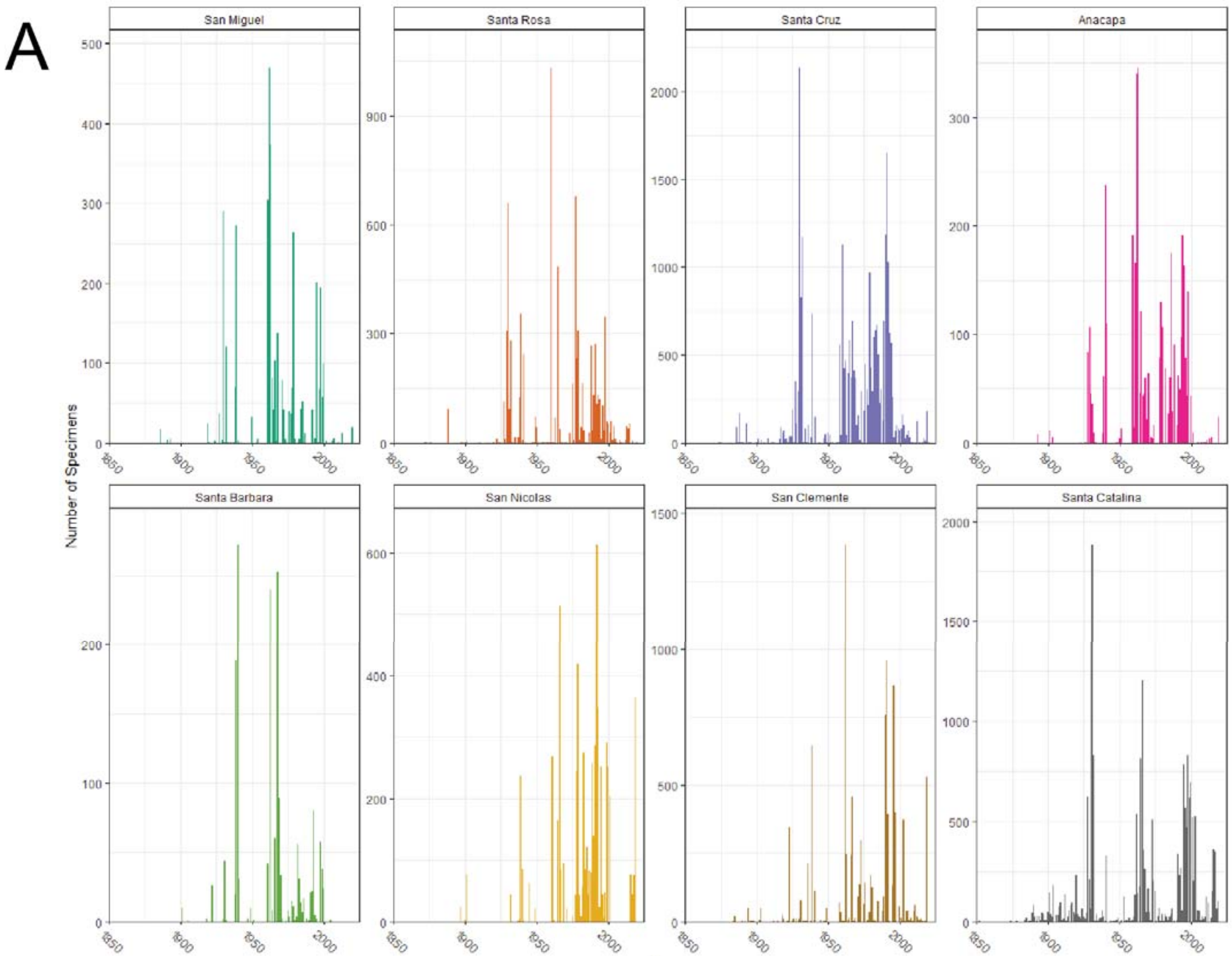
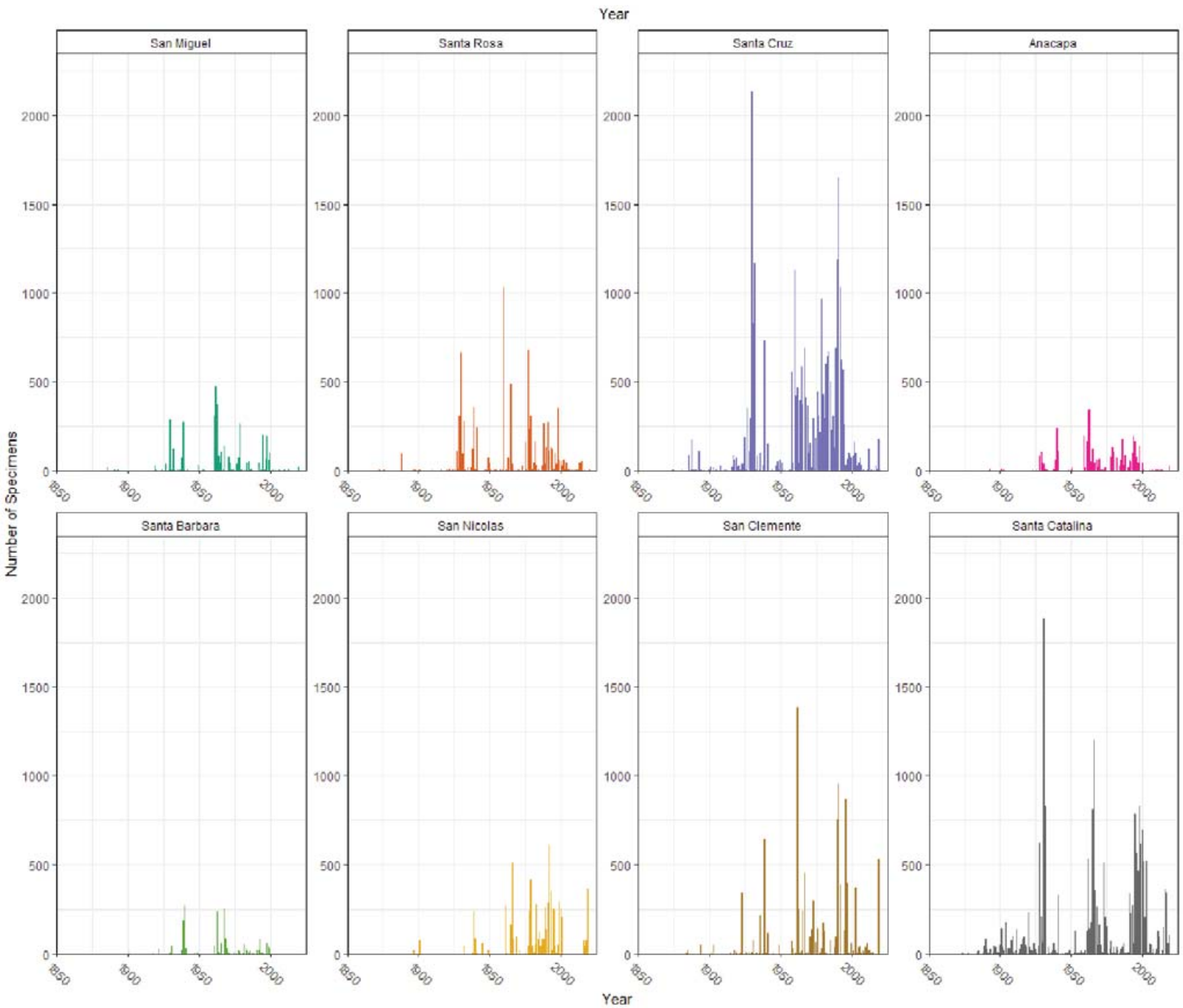


Figure 7A-B. Raw number of specimens collected through time by island.

A. Raw number of specimens collected through time, with y-axes independently scaled by island; **B.** raw number of specimens collected through time, with identical y-axes across islands.



B



Year
San Miguel
Santa Rosa
Santa Cruz
Anacapa
Santa Barbara
San Nicolas
San Clemente
Santa Catalina
Number of Specimens
0
500
1000
1500
2000
1850
1900
1950
2000
Year

Figure 7B shows raw samples collected through time, *with identical y-axes across islands*. While the through-time collection history of the islands appears episodic as in **Figure 7A**, these plots also reveal the uneven collection intensity by island through time. In most cases, lower overall collection intensities through time tend to exist for smaller islands, e.g., Santa Barbara and Anacapa islands. However, Figure 7B reveals lower overall collection intensity for San Miguel and Santa Rosa islands, the latter of which is the second largest island in the archipelago.

The number of specimens collected through time by island, standardized by island area (/km^2) is presented in **Figure 8A-B**. Figure 8A shows samples collected through time, standardized by island area, *with y-axes independently scaled by island*. Patterns by island in Figure 8A are similar to those in Figure 7A. Figure 8B shows samples collected through time, standardized by island area, *with identical y-axes across islands*. Here the imbalanced collection intensity per unit area is evident for the two smallest islands in the archipelago, Anacapa and Santa Barbara islands, relative to the other six islands.

Monthly temporal patterns

The number of vascular plant specimens collected per month is presented by island in **Figure 9A-B.** Figure 9A shows samples collected by month, *with y-axes independently scaled by island*. Not surprisingly, the number of samples collected by month is strongly skewed toward Spring months. The month with the greatest number of specimens collected was April for most islands. The month with the greatest number of specimens for Santa Catalina Island was May. Collections in the Fall and Winter months are negligible for most islands other than Santa Cruz and Santa Catalina islands. Similar patterns are showing in Figure 9B, which shows samples collected by month, *with identical y-axes across islands*.

Figure 10A shows samples collected by month, standardized by island area, *with y-axes independently scaled by island*. **Figure 10B** shows samples collected by month, standardized by island area, *with identical y-axes across islands*. Both show patterns similar to Figure 9A-B, with a strong skew toward the Spring months and minimal collections in Fall and Winter months.

Evaluating taxonomic patterns

Figure 11 shows a plot with species accumulation curves for the vascular plants of the Channel Islands. Theses curves indicate that there are likely considerable numbers of species yet to discover or document on each of the Channel Islands. Only Santa Cruz Island appears to have a curve that is approaching an asymptote; the remainder of the islands have curves that have only slightly begun to flatten. In particular, San Miguel, Santa Rosa, and Santa Barbara islands would have the greatest number of undiscovered taxa based on the shapes of the curves in Figure 11.

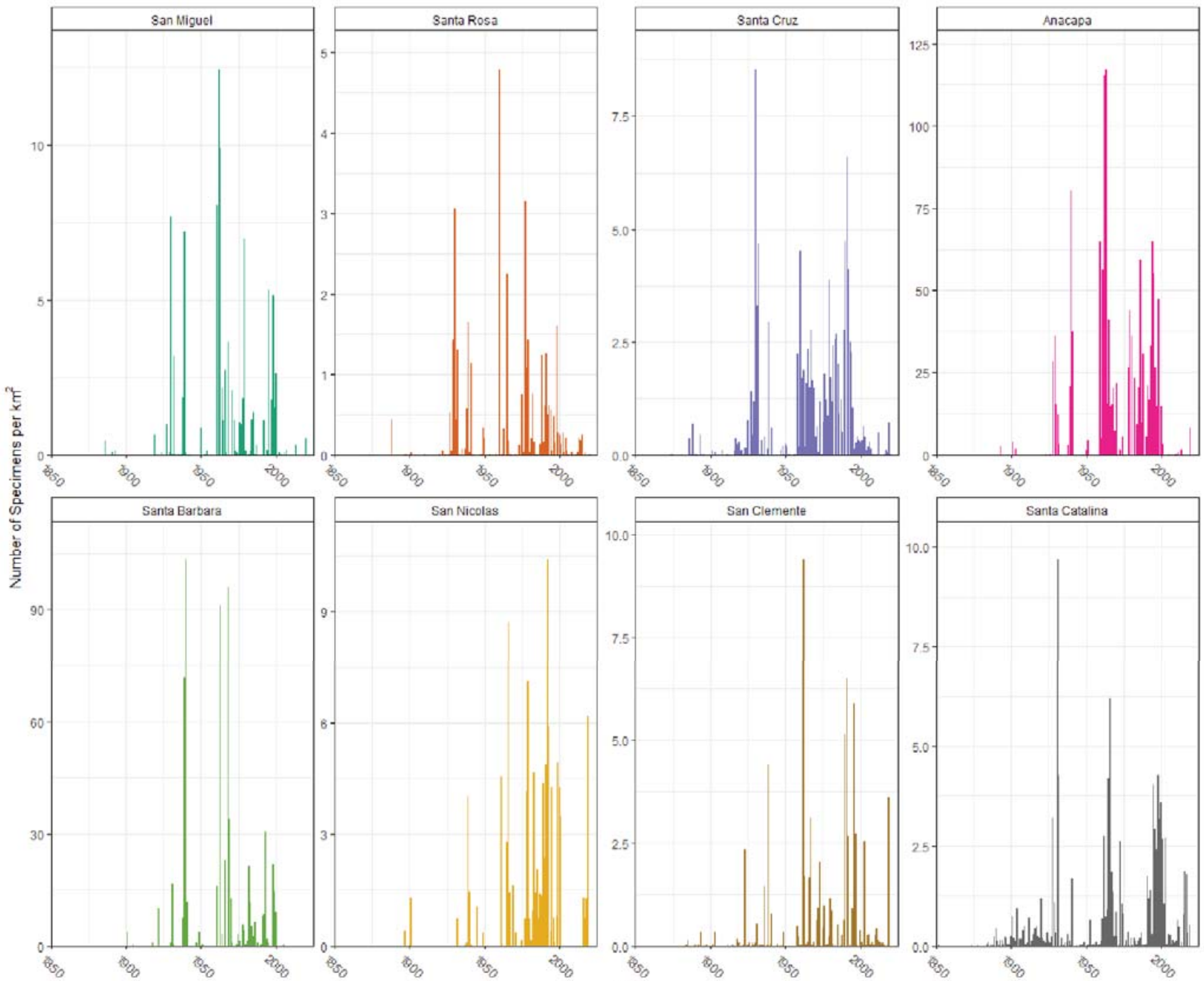
Table 3 shows the number of specimens collected by family for the Channel Islands archipelago and for each island. The number of specimens by family ranges from very few (e.g., 1 in Arecaceae, 2 in Bataceae) to 14,167 in Asteraceae. The five families with the greatest number of specimens collected across the archipelago are (in descending order): Asteraceae (14,167 specimens), Poaceae (9,706 specimens), Fabaceae (7,714 specimens), Brassicaceae (3,273 specimens), and Chenopodiaceae (3,011 specimens).

Table 4 shows the number of iNaturalist observations by family for the archipelago and each island. Most plant families on the islands are much better represented by specimens, and six (somewhat obscure and

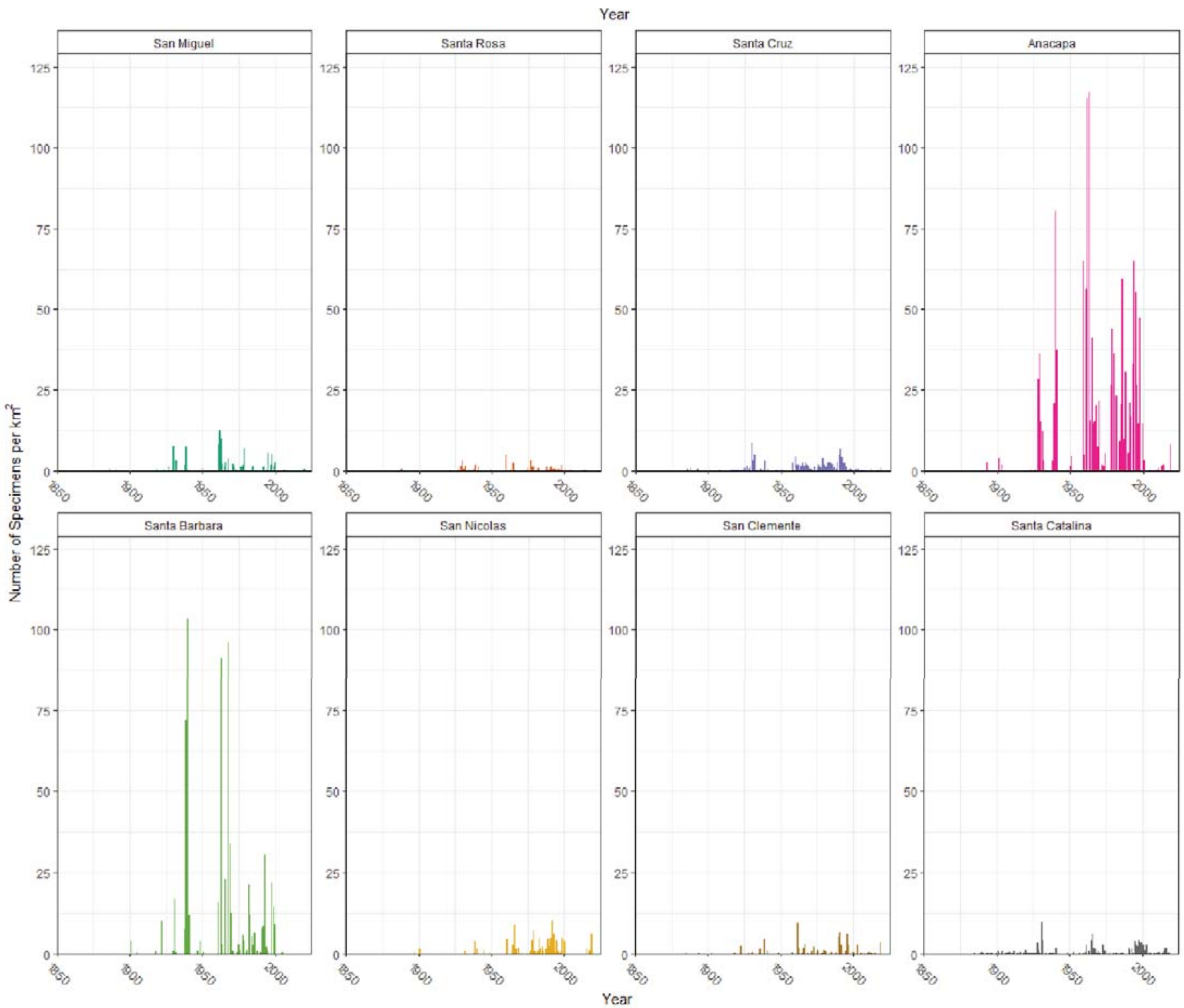
Figure 8A-B. Number of specimens collected through time by island, standardized by area (/km^2).

A. Number of specimens collected through time, standardized by area (/km^2), with y-axes independently scaled by island;
B. number of specimens collected through time, standardized by area (/km^2), with identical y-axes across islands.

A



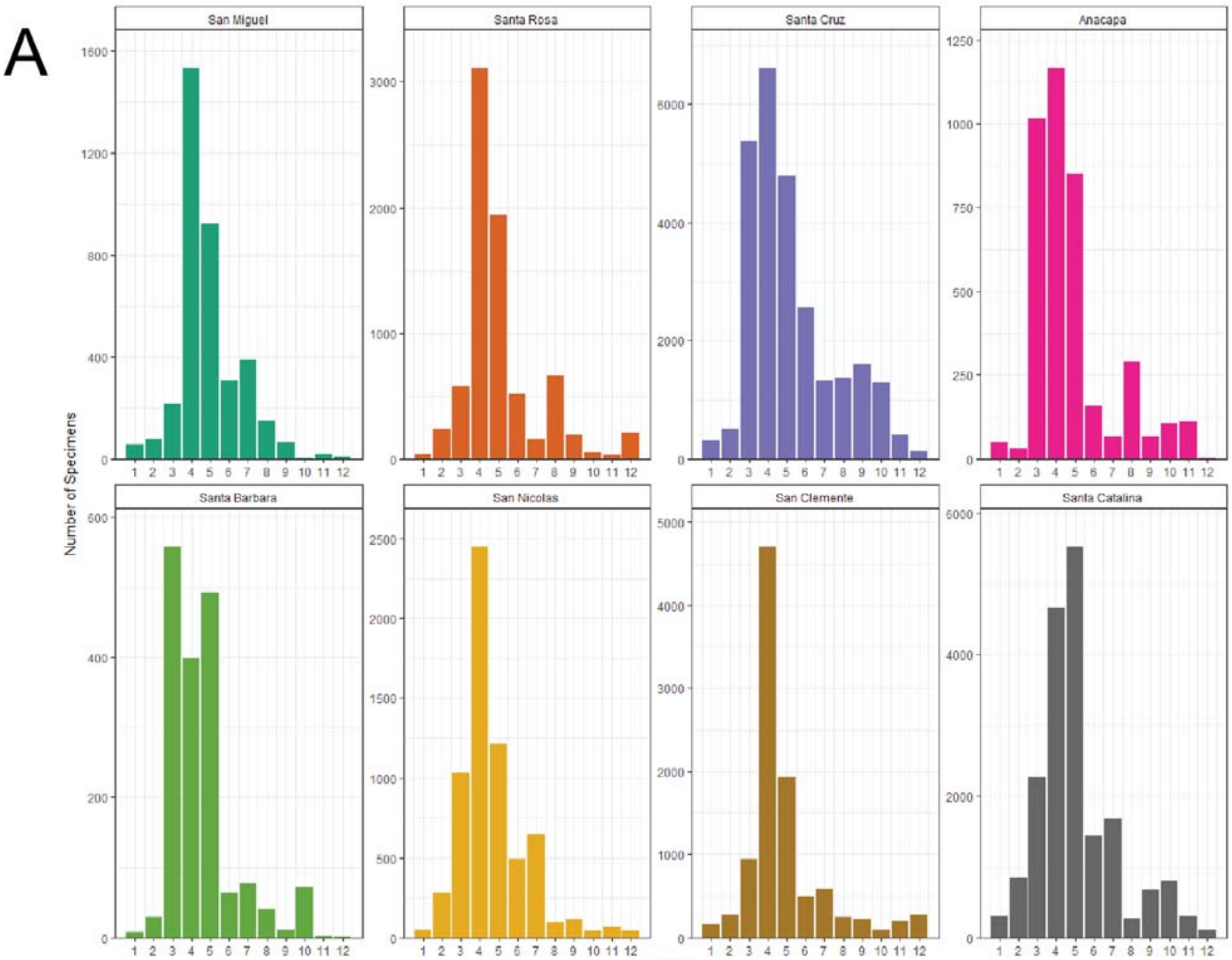
B



Year
San Miguel
Santa Rosa
Santa Cruz
Anacapa
Santa Barbara
San Nicolas
San Clemente
Santa Catalina
Number of Specimens per km²
0
25
50
75
100
125
1850
1900
1950
2000
Year

Figure 9A-B. Raw number of specimens collected by month, by island (continued on next page)

A. Raw number of specimens collected by month, with y-axes independently scaled by island; **B.** raw number of specimens collected by month, with identical y-axes across islands.



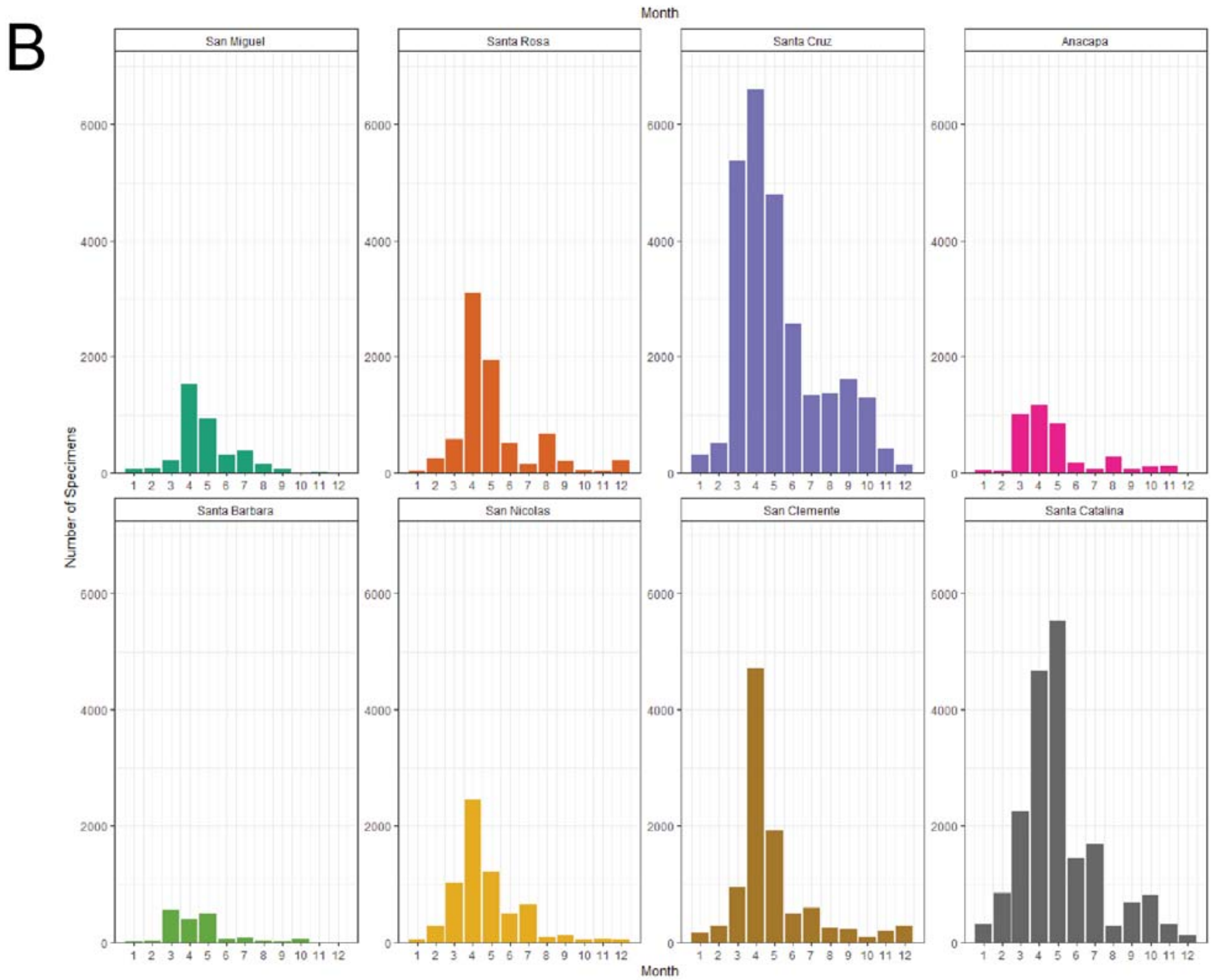
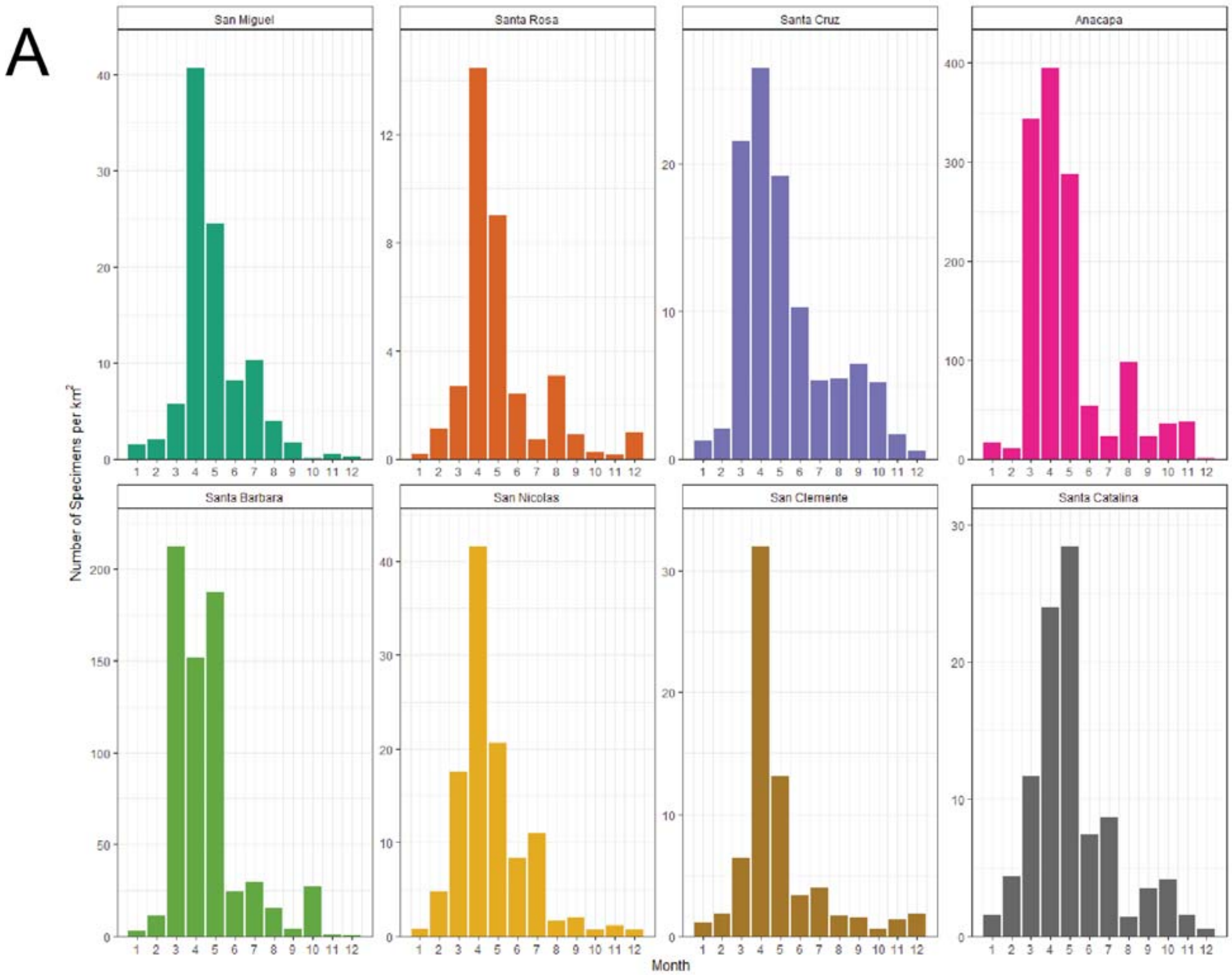

B
Month
San Miguel
Santa Rosa
Santa Cruz
Anacapa
Santa Barbara
San Nicolas
San Clemente
Santa Catalina
Number of Specimens
Month

Figure 10A-B. Number of specimens collected by month by island, standardized by area (/km^2; continued on next page).

A. Number of specimens collected by month, standardized by area (/km^2), with y-axes independently scaled by island; **B.** number of specimens collected by month, standardized by area (/km^2), with identical y-axes across islands.



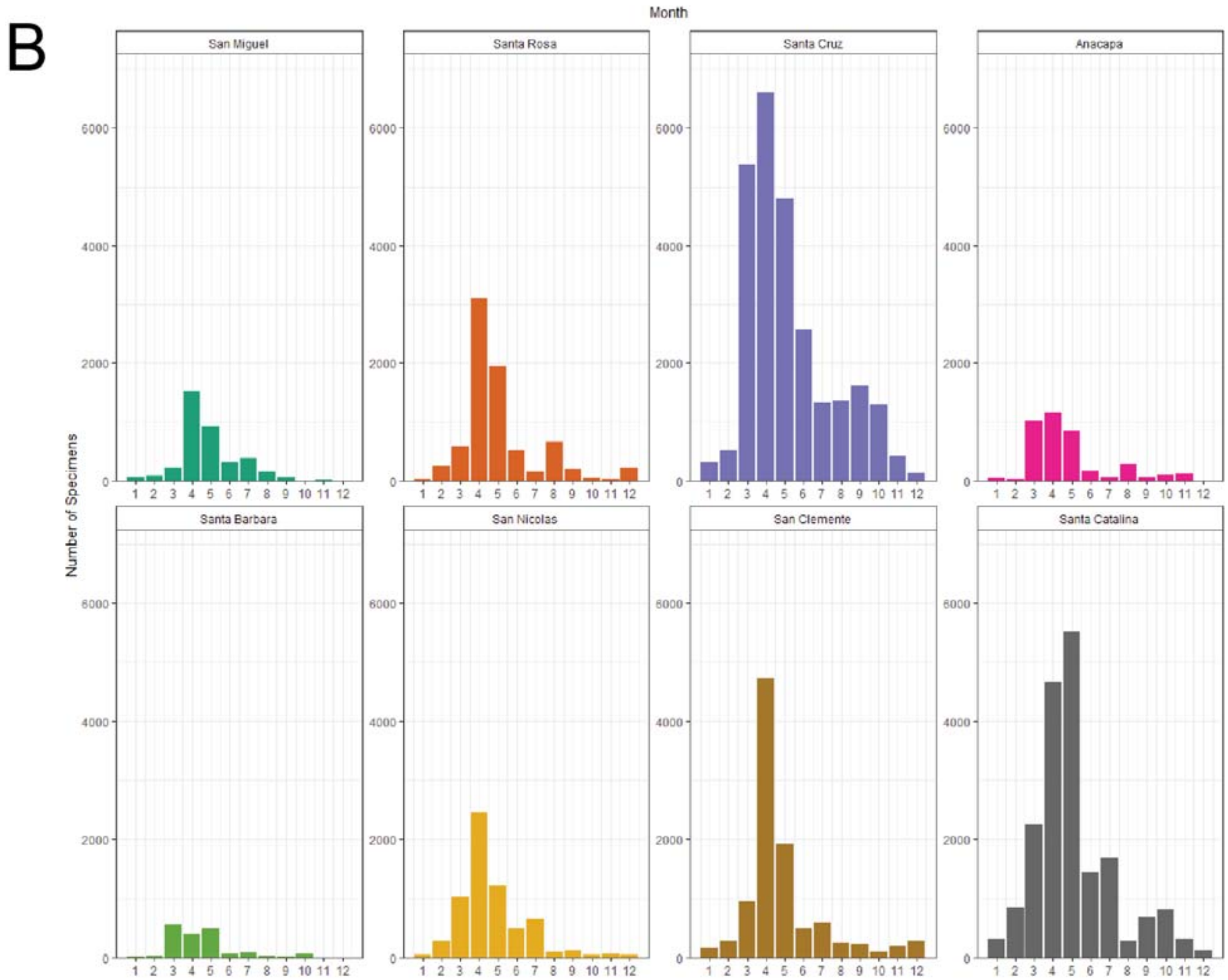

B
Month
San Miguel
Santa Rosa
Santa Cruz
Anacapa
Santa Barbara
San Nicolas
San Clemente
Santa Catalina
Number of Specimens
0
2000
4000
6000
1 2 3 4 5 6 7 8 9 10 11 12

Figure 11. Plot of species accumulation curves for the vascular plants of the Channel Islands.

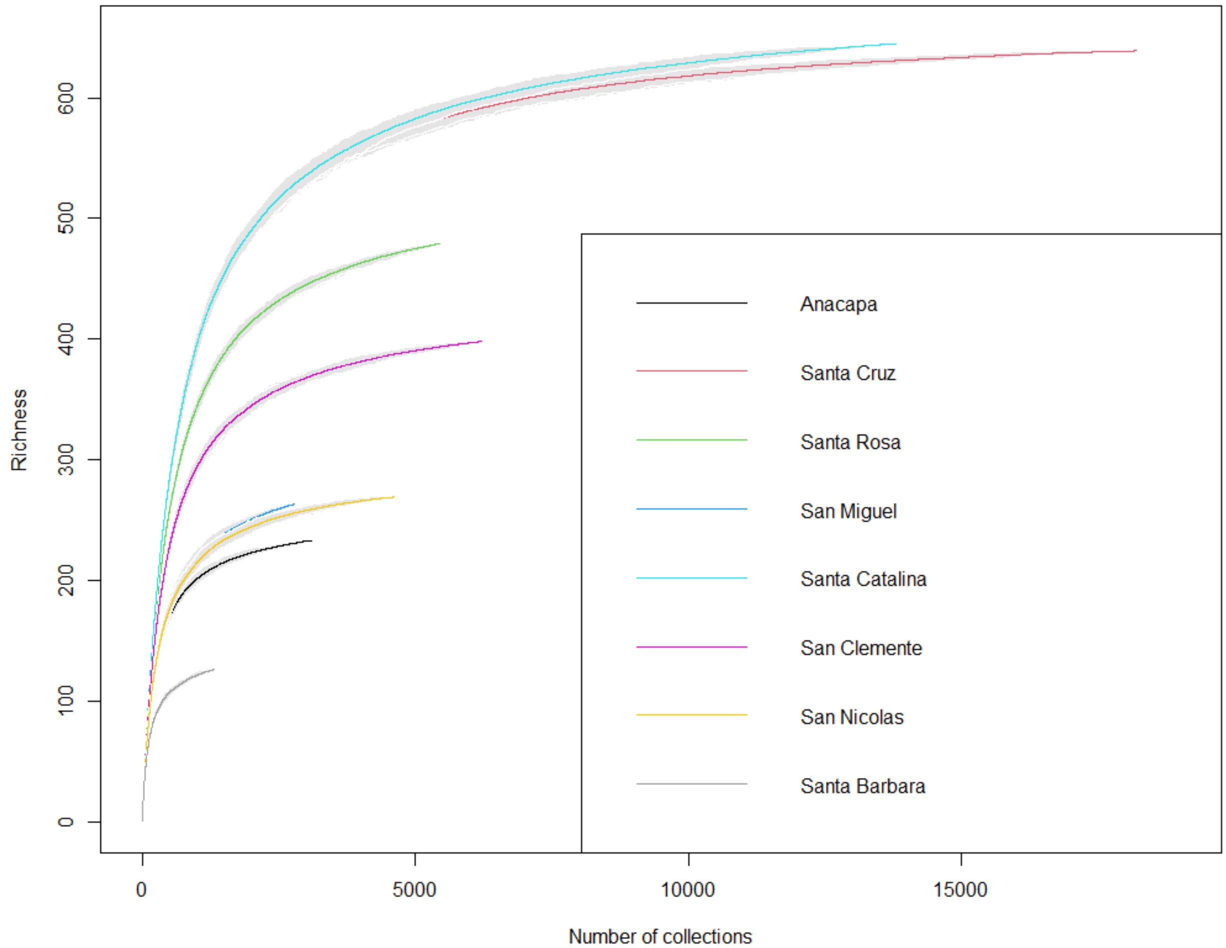


Table 3. Plant specimens collected by family across the Channel Islands

Family	All Islands	Northern Channel Islands				Southern Channel Islands			
		San Miguel	Santa Rosa	Santa Cruz	Anacapa	Santa Barbara	San Nicolas	San Clemente	Santa Catalina
Adoxaceae	143	NA	13	60	NA	NA	NA	19	51
Agavaceae	12	NA	6	2	NA	NA	NA	NA	4
Aizoaceae	467	60	27	73	39	33	77	67	91
Alliaceae	224	25	25	78	NA	NA	NA	52	44
Amaranthaceae	90	NA	2	55	1	NA	NA	NA	32
Anacardiaceae	590	32	26	171	29	NA	4	84	244
Apiaceae	1707	114	147	474	55	8	307	202	400
Apocynaceae	96	NA	9	57	1	NA	NA	NA	29
Arecaceae	1	NA	NA	NA	NA	NA	NA	NA	1
Asparagaceae	35	NA	NA	NA	NA	NA	NA	NA	35
Asphodelaceae	18	NA	NA	NA	NA	NA	NA	18	NA
Asteraceae	14167	809	1422	4249	834	406	1349	2113	2985
Athyriaceae	45	NA	NA	45	NA	NA	NA	NA	NA
Azollaceae	32	NA	NA	NA	NA	NA	NA	NA	32
Bataceae	2	NA	NA	NA	NA	NA	NA	1	1
Berberidaceae	69	NA	2	58	9	NA	NA	NA	NA
Blechnaceae	112	NA	3	102	NA	NA	NA	NA	7
Boraginaceae	1987	114	155	507	89	101	250	320	451
Brassicaceae	3273	228	251	1108	176	50	493	381	586
Cactaceae	170	4	7	33	8	11	28	43	36
Campanulaceae	80	NA	3	46	NA	NA	NA	2	29
Caprifoliaceae	299	NA	8	115	NA	NA	NA	15	161
Caryophyllaceae	1988	126	213	619	122	39	167	326	376
Chenopodiaceae	3011	153	263	561	205	161	394	637	637
Cistaceae	233	1	31	140	NA	NA	NA	2	59
Cleomaceae	182	NA	58	NA	NA	NA	NA	16	108
Convolvulaceae	728	58	56	190	42	9	74	112	187
Cornaceae	32	NA	NA	NA	NA	NA	NA	1	31
Crassulaceae	496	59	83	166	30	41	34	42	41
Crossosomataceae	263	NA	NA	NA	NA	NA	NA	22	241
Cucurbitaceae	438	33	22	172	35	20	24	61	71
Cupressaceae	8	NA	3	4	1	NA	NA	NA	NA
Cyatheaceae	7	NA	NA	NA	NA	NA	NA	NA	7
Cyperaceae	602	18	117	217	NA	NA	54	44	152
Dennstaedtiaceae	88	NA	15	48	NA	NA	NA	NA	25
Dryopteridaceae	239	2	41	127	5	NA	NA	20	44
Elatinaceae	4	NA	NA	NA	NA	NA	NA	NA	4
Equisetaceae	162	NA	10	73	NA	NA	NA	NA	79
Ericaceae	1396	NA	153	1028	3	NA	NA	NA	212

Family	All Islands	Northern Channel Islands				Southern Channel Islands			
		San Miguel	Santa Rosa	Santa Cruz	Anacapa	Santa Barbara	San Nicolas	San Clemente	Santa Catalina
Euphorbiaceae	315	NA	17	73	NA	NA	3	78	144
Fabaceae	7714	383	764	2424	424	147	604	1186	1782
Fagaceae	1645	NA	168	925	26	NA	NA	128	398
Frankeniaceae	264	15	27	41	33	NA	60	29	59
Garryaceae	47	NA	NA	47	NA	NA	NA	NA	NA
Gentianaceae	105	NA	1	32	NA	NA	15	8	49
Geraniaceae	537	23	42	112	39	30	80	66	145
Grossulariaceae	310	NA	1	152	16	NA	NA	23	118
Heliotropaceae	165	13	18	37	8	NA	20	3	66
Hydrophyllaceae	1419	112	146	389	77	68	14	256	357
Iridaceae	99	33	25	27	NA	NA	NA	NA	14
Isoetaceae	3	NA	NA	NA	NA	NA	NA	3	NA
Juglandaceae	6	NA	NA	NA	NA	NA	NA	NA	6
Juncaceae	615	40	107	176	5	NA	23	55	209
Lamiaceae	927	26	174	370	19	NA	23	44	271
Liliaceae	343	NA	44	180	1	NA	NA	NA	118
Linaceae	13	NA	NA	NA	NA	NA	NA	NA	13
Loasaceae	109	NA	1	18	NA	NA	17	25	48
Lythraceae	67	NA	9	35	NA	NA	13	NA	10
Malvaceae	427	57	76	87	29	9	21	115	33
Melanthiaceae	82	6	23	35	18	NA	NA	NA	NA
Montiaceae	743	32	59	193	72	53	66	133	135
Moraceae	23	3	NA	5	NA	NA	NA	6	9
Myrsinaceae	120	6	12	28	3	5	12	14	40
Myrtaceae	98	NA	8	48	5	NA	9	8	20
Namaceae	43	NA	NA	NA	NA	NA	NA	1	42
Nyctaginaceae	837	86	86	185	35	16	140	171	118
Oleaceae	24	NA	NA	14	NA	NA	NA	NA	10
Onagraceae	994	38	143	436	29	NA	NA	85	263
Ophioglossaceae	1	NA	NA	NA	NA	NA	NA	NA	1
Orchidaceae	95	NA	12	49	NA	NA	NA	1	33
Orobanchaceae	1253	97	239	436	106	NA	112	54	209
Oxalidaceae	115	1	1	45	NA	NA	17	12	39
Papaveraceae	1253	93	154	541	16	34	73	100	242
Phrymaceae	733	1	73	406	28	NA	NA	69	156
Pinaceae	366	NA	111	235	NA	NA	NA	NA	20
Pittosporaceae	13	NA	NA	NA	NA	NA	NA	NA	13
Plantaginaceae	1708	26	179	523	52	14	96	308	510
Platanaceae	23	NA	NA	17	NA	NA	NA	NA	6

Family	All Islands	Northern Channel Islands				Southern Channel Islands			
		San Miguel	Santa Rosa	Santa Cruz	Anacapa	Santa Barbara	San Nicolas	San Clemente	Santa Catalina
Plumbaginaceae	31	NA	21	NA	NA	NA	NA	3	7
Poaceae	9706	515	826	2553	744	372	1330	1085	2281
Polemoniaceae	1000	12	105	315	48	14	2	200	304
Polygalaceae	30	NA	NA	30	NA	NA	NA	NA	NA
Polygonaceae	1376	49	166	602	85	13	106	112	243
Polypodiaceae	322	NA	25	103	22	13	7	66	86
Portulacaceae	12	NA	NA	7	NA	NA	NA	NA	5
Potamogetonaceae	46	NA	2	15	NA	NA	NA	1	28
Primulaceae	130	NA	15	36	24	NA	6	4	45
Pteridaceae	1385	24	124	609	54	NA	72	176	326
Ranunculaceae	292	14	26	115	NA	NA	NA	64	73
Resedaceae	161	23	9	17	12	15	44	19	22
Rhamnaceae	1060	NA	49	506	14	NA	NA	54	437
Rosaceae	1871	19	129	833	57	NA	3	173	657
Rubiaceae	807	65	89	352	24	18	28	55	176
Salicaceae	498	20	44	233	1	NA	38	4	158
Sapindaceae	45	NA	NA	45	NA	NA	NA	NA	NA
Saururaceae	65	NA	NA	32	NA	NA	3	1	29
Saxifragaceae	448	NA	70	235	24	NA	21	47	51
Scrophulariaceae	188	NA	5	33	NA	NA	12	30	108
Selaginellaceae	181	NA	15	71	5	NA	NA	43	47
Solanaceae	1143	38	110	339	52	22	101	142	339
Tamaricaceae	73	NA	2	33	1	NA	13	5	19
Themidaceae	470	12	21	83	20	17	42	157	118
Theophrastaceae	9	NA	NA	9	NA	NA	NA	NA	NA
Tropaeolaceae	15	NA	NA	NA	NA	1	NA	5	9
Typhaceae	161	14	6	35	NA	NA	24	19	63
Urticaceae	331	17	33	124	11	8	15	44	79
Valerianaceae	50	NA	NA	24	NA	NA	NA	NA	26
Verbenaceae	218	1	16	53	NA	NA	1	42	105
Violaceae	200	NA	20	71	NA	NA	NA	55	54
Vitaceae	53	NA	NA	NA	NA	NA	NA	NA	53
Woodsiaceae	11	NA	NA	11	NA	NA	NA	NA	NA
Zannichelliaceae	6	NA	NA	3	NA	NA	NA	NA	3
Zosteraceae	214	18	6	59	3	20	31	15	62
Zygophyllaceae	19	NA	NA	NA	NA	NA	NA	NA	19

Table 4. iNaturalist plant observations summarized by family across the Channel Islands.

Abbreviations: AI = Anacapa Island, SBA = Santa Barbara Island, SCA = Santa Catalina Island, SCL = San Clemente, SCR = Santa Cruz Island, SMI = San Miguel Island, SNI = San Nicolas Island, SR = Santa Rosa.

Family	All 8	Northern Channel Islands				Southern Channel Islands			
		SMI	SR	SCR	AI	SBA	SNI	SCL	SCA
Adoxaceae	38	NA	7	5	NA	NA	NA	7	19
Agavaceae	33	NA	NA	10	NA	NA	NA	3	20
Aizoaceae	496	7	57	83	44	26	13	89	177
Alliaceae	41	1	2	3	NA	NA	NA	24	11
Amaranthaceae	2	NA	NA	1	NA	NA	NA	1	NA
Anacardiaceae	586	3	24	211	8	NA	NA	82	260
Apiaceae	340	2	21	100	1	NA	20	80	116
Apocynaceae	86	NA	NA	51	NA	NA	NA	NA	35
Arecaceae	26	NA	NA	NA	NA	NA	NA	2	24
Asparagaceae	36	NA	NA	NA	NA	NA	NA	NA	36
Asphodelaceae	3	NA	NA	1	NA	NA	NA	2	NA
Asteraceae	3922	114	384	968	102	104	133	1183	939
Athyriaceae	2	NA	NA	2	NA	NA	NA	NA	NA
Azollaceae	1	NA	NA	NA	NA	NA	NA	NA	1
Bataceae	1	NA	NA	1	NA	NA	NA	NA	NA
Blechnaceae	19	NA	3	10	NA	NA	NA	NA	6
Boraginaceae	108	2	5	13	1	2	15	33	37
Brassicaceae	374	5	26	107	1	4	16	104	111
Cactaceae	501	2	10	66	22	15	13	218	155
Campanulaceae	3	NA	NA	1	NA	NA	NA	1	1
Caprifoliaceae	24	NA	NA	3	NA	NA	NA	1	20
Caryophyllaceae	270	5	67	64	5	4	9	82	34
Chenopodiaceae	306	2	20	67	7	18	8	109	75
Cistaceae	21	NA	6	6	NA	NA	NA	2	7
Cleomaceae	84	NA	9	NA	NA	NA	NA	21	54
Convolvulaceae	206	4	13	71	7	NA	10	82	19
Crassulaceae	327	NA	30	16	6	12	28	107	128
Crossosomataceae	64	NA	NA	NA	NA	NA	NA	18	46
Cucurbitaceae	104	1	2	39	1	NA	4	13	44
Cupressaceae	15	NA	5	8	NA	NA	NA	NA	2
Cyperaceae	16	NA	NA	2	NA	NA	NA	10	4
Dennstaedtiaceae	5	NA	1	4	NA	NA	NA	NA	NA
Dryopteridaceae	15	NA	3	10	NA	NA	NA	1	1
Equisetaceae	12	NA	4	5	NA	NA	NA	NA	3
Ericaceae	174	NA	18	93	NA	NA	NA	NA	63
Euphorbiaceae	104	NA	3	12	NA	NA	NA	26	63

Fabaceae	1257	12	90	229	3	9	59	495	360
Fagaceae	172	NA	38	45	NA	NA	NA	31	58
Frankeniaceae	51	1	8	5	9	NA	3	14	11
Garryaceae	4	NA	NA	4	NA	NA	NA	NA	NA
Gentianaceae	27	NA	1	3	NA	NA	NA	8	15
Geraniaceae	71	NA	10	12	NA	NA	1	28	20
Grossulariaceae	34	NA	NA	1	NA	NA	NA	8	25
Heliotropaceae	46	NA	15	11	NA	NA	NA	2	18
Hydrophyllaceae	211	6	14	41	6	7	2	99	36
Iridaceae	58	10	22	11	NA	NA	NA	NA	15
Isoetaceae	3	NA	NA	NA	NA	NA	NA	3	NA
Juncaceae	26	NA	1	1	NA	NA	NA	5	19
Lamiaceae	369	3	41	117	NA	NA	1	30	177
Liliaceae	171	NA	27	55	NA	NA	NA	NA	89
Linaceae	2	NA	NA	NA	NA	NA	NA	NA	2
Loasaceae	4	NA	NA	NA	NA	NA	NA	1	3
Lythraceae	10	NA	2	6	NA	NA	NA	2	NA
Malvaceae	369	10	12	12	44	9	4	161	117
Melanthiaceae	14	NA	4	10	NA	NA	NA	NA	NA
Montiaceae	151	1	8	30	NA	8	4	70	30
Moraceae	33	NA	NA	3	NA	NA	NA	1	29
Myrsinaceae	73	1	12	6	NA	NA	NA	3	51
Myrtaceae	18	NA	NA	9	NA	NA	NA	NA	9
Namaceae	34	NA	NA	NA	NA	NA	NA	3	31
Nyctaginaceae	245	4	30	33	NA	NA	17	94	67
Oleaceae	9	NA	NA	6	NA	NA	NA	NA	3
Onagraceae	266	8	27	86	NA	NA	7	84	54
Orchidaceae	13	NA	2	2	NA	NA	NA	1	8
Orobanchaceae	393	18	94	60	3	NA	15	141	62
Oxalidaceae	47	NA	1	2	1	NA	1	5	37
Papaveraceae	348	12	50	96	NA	1	4	76	109
Phrymaceae	247	NA	36	64	NA	NA	NA	56	91
Pinaceae	149	NA	79	62	NA	NA	NA	NA	8
Plantaginaceae	341	NA	14	75	NA	3	5	128	116
Platanaceae	16	NA	NA	3	NA	NA	NA	NA	13
Plumbaginaceae	20	NA	8	NA	NA	NA	NA	2	10
Poaceae	454	3	38	70	3	8	7	156	169
Polemoniaceae	119	NA	6	7	NA	4	NA	70	32
Polygonaceae	635	2	98	260	25	18	14	139	79
Polypodiaceae	57	NA	3	15	NA	5	NA	16	18
Portulacaceae	1	NA	NA	NA	NA	NA	NA	NA	1

Primulaceae	119	NA	7	27	NA	NA	2	26	57
Pteridaceae	246	1	24	80	NA	NA	3	99	39
Ranunculaceae	89	4	10	23	NA	NA	NA	47	5
Resedaceae	10	1	NA	NA	NA	4	2	1	2
Rhamnaceae	246	NA	4	149	NA	NA	NA	29	64
Rosaceae	716	1	67	211	NA	NA	NA	165	272
Rubiaceae	133	NA	5	24	NA	1	1	81	21
Salicaceae	60	NA	10	27	NA	NA	3	3	17
Saururaceae	9	NA	NA	5	NA	NA	NA	NA	4
Saxifragaceae	84	NA	3	16	NA	NA	1	59	5
Scrophulariaceae	46	NA	NA	16	NA	NA	3	18	9
Selaginellaceae	60	NA	1	26	NA	NA	NA	21	12
Solanaceae	359	1	11	54	1	7	12	70	203
Tamaricaceae	5	1	2	1	NA	NA	NA	NA	1
Themidaceae	482	4	37	126	3	11	12	181	108
Tropaeolaceae	13	NA	NA	NA	NA	NA	NA	2	11
Typhaceae	10	1	2	1	NA	NA	1	4	1
Urticaceae	9	NA	NA	1	1	4	NA	1	2
Valerianaceae	40	NA	NA	1	NA	NA	NA	NA	39
Verbenaceae	20	NA	NA	NA	NA	NA	NA	17	3
Violaceae	120	NA	12	39	NA	NA	NA	44	25
Vitaceae	3	NA	NA	NA	NA	NA	NA	NA	3
Zosteraceae	6	NA	NA	2	1	NA	NA	2	1
Zygophyllaceae	2	NA	NA	NA	NA	NA	NA	NA	2

uncommon) families are not represented by observations at all (Cyathaceae, Pittosporaceae, Potamogetonaceae, Sapindaceae, Woodsiaceae, and Zannichelliaceae). A few families (all succulents and trees) have more observations than specimens, however: Agavaceae, Arecaceae, Cactaceae, Cupressaceae, and Moraceae. Furthermore, a dozen families have similar numbers of specimens and observations: the Aizoaceae, Anacardiaceae, Apocynaceae, Asparagaceae, Bataceae, Crassulaceae, Isoetaceae, Malvaceae, Namaceae, Primulaceae, Themidaceae, and Tropaeolaceae.

Taxonomic patterns: island size

Island size may be indicative of where future efforts might result in the documentation of additional taxonomic diversity on the Channel Islands. Island size is considered to be a major predictor of taxonomic richness (MacArthur & Wilson, 1967), with larger islands expected to support a greater number of taxa relative to smaller islands. In general, this is because larger islands often have higher immigration rates along with lower extinction rates. Distance from the mainland is also a major predictor of taxonomic richness in oceanic island systems (MacArthur & Wilson, 1967). Given that the Channel Islands is a fringing, continental archipelago (Carlquist, 1974), however, it may be the case that distance from the mainland plays only a minor role in shaping overall levels of taxonomic richness (Carter & Guilliams, 2018).

If island size is strongly predictive of taxonomic richness while at the same time dispersal from the mainland is not a limiting factor in island colonization, then the largest Channel Islands may be expected to have many taxa in common. Therefore, when a taxon is found on three of the largest four Channel Islands, it is possible that it is present on the fourth island but has gone undetected. **Table 5** provides lists for each of the largest Channel Islands – Santa Cruz Island (249 km^2), Santa Rosa Island (217 km^2), Santa Catalina Island (194 km^2), and San Clemente Island (145 km^2) – that indicate absence of a taxon on a given island when it has been collected on the other three. San Clemente Island has the largest number of missing taxa by this tabulation at 106. Santa Rosa Island has a moderately large number of absent taxa at 64. Santa Catalina Island has 12 absent taxa. Santa Cruz Island has the fewest number of absent taxa, at 9.

Taxonomic patterns: geography

Table 6 provides lists for the four northern Channel Islands, indicating for each when a given taxon is absent from an island but present on the other three. In this tabulation, San Miguel Island has the largest number of missing taxa, at 68. Anacapa Island has the next largest value, at 59. Santa Rosa and Santa Cruz islands have low numbers of missing taxa, at 3 and 2, respectively.

Table 7 provides lists for the four southern Channel Islands, indicating for each when a given taxon is absent from an island but present on the other three. In this tabulation, Santa Barbara Island has the largest number of plants absent at 106. San Nicolas has 21 absent plants. San Clemente and Santa Catalina islands each have very few missing taxa, at 3 each.

Taxonomic patterns: historically documented taxa not recently collected

Taxonomic and temporal patterns intersect on that class of plant taxa that have been documented historically on an island but not recently collected. **Table 8** provides a taxon-by-island matrix showing taxa for which the most recent collection on at least one island is greater than 60 years old. These results

Table 5. Lists for the four largest Channel Islands indicating for each when a given taxon is absent from an island but present on the other three.

Total numbers by island are given in parentheses.

Absent from Santa Rosa Island (64)	Absent from Santa Cruz Island (9)
Amsinckia menziesii	*Acmispon argophyllus* var. *argenteus*
Anemopsis californica	*Eleocharis macrostachya*
Aristida adscensionis	*Erythranthe floribunda*
Athysanus pusillus	*Herniaria hirsuta var. cinerea*
Atriplex lentiformis	*Malva pseudolavatera*
Brachypodium distachyon	*Malvella leprosa*
Brassica rapa	*Peritoma arborea*
Bromus catharticus	*Phalaris lemmonii*
Camissoniopsis robusta	*Verbena bracteata*
Ceanothus megacarpus var. *megacarpus*	
Convolvulus simulans	
Dactylis glomerata	
Deinandra clementina	
Emmenanthe penduliflora var. *penduliflora*	
Encelia californica	
Epilobium brachycarpum	
Eremalche exilis	
Eriastrum filifolium	
Erigeron bonariensis	
Erodium brachycarpum	
Euphorbia maculata	
Euphorbia misera	
Euphorbia spathulata	
Ficus carica	
Glebionis coronaria	
Gnaphalium palustre	
Helianthus annuus	
Hesperocnide tenella	
Hordeum murinum subsp. *glaucum*	
Lepidium latipes	
Lepidium virginicum subsp. *menziesii*	
Logfia arizonica	
Marah fabacea	
Melilotus albus	
Mentzelia affinis	
Navarretia hamata subsp. *leptantha*	
Nicotiana glauca	
Opuntia ficus-indica	
Opuntia oricola	
Oxalis corniculata	
Oxalis pes-caprae	
Pelargonium x*hortorum*	
Phalaris caroliniana	
Phalaris paradoxa	
Pholistoma auritum var. *auritum*	
Pholistoma racemosum	
Phyla nodiflora	
Phyllospadix scouleri	
Plagiobothrys collinus var. *gracilis*	
Polycarpon depressum	
Polygonum argyrocoleon	
Quercus chrysolepis	
Rumex conglomeratus	

Salsola australis
Schismus arabicus
Schismus barbatus
Sibara filifolia
Stellaria pallida
Stephanomeria diegensis
Tamarix ramosissima
Thysanocarpus curvipes
Tragopogon porrifolius
Typha latifolia
Yabea microcarpa

Absent from San Clemente Island (106)

Acmispon grandiflorus var. *grandiflorus*
Acmispon wrangelianus
Acourtia microcephala
Adiantum capillus-veneris
Agrostis pallens
Amaranthus albus
Aphyllon parishii subsp. *brachylobum*
Aphyllon tuberosum
Artemisia douglasiana
Arundo donax
Asclepias fascicularis
Astragalus trichopodus var. *lonchus*
Baccharis glutinosa
Bloomeria crocea var. *crocea*
Brodiaea jolonensis
Bromus pseudolaevipes
Calochortus albus
Calochortus catalinae
Calystegia macrostegia subsp. *macrostegia*
Cardamine californica
Carduus pycnocephalus subsp. *pycnocephalus*
Carex globosa
Castilleja affinis subsp. *affinis*
Castilleja exserta subsp. *exserta*
Ceanothus arboreus
Centaurea solstitialis
Cercocarpus betuloides var. *blancheae*
Chenopodium berlandieri
Cirsium vulgare
Clarkia purpurea subsp. *quadrivulnera*
Clematis ligusticifolia
Clinopodium douglasii
Comarostaphylis diversifolia subsp. *planifolia*
Convolvulus arvensis
Corethrogyne filaginifolia
Cortaderia selloana
Cotula coronopifolia
Crocanthemum greenei
Cryptantha micromeres
Dendromecon harfordii
Dichondra occidentalis
Dudleya greenei
Elymus glaucus subsp. *glaucus*
Elymus triticoides
Equisetum laevigatum
Erigeron foliosus var. *foliosus*
Eucalyptus camaldulensis

Absent from Santa Catalina Island (12)

Apium graveolens
Astragalus miguelensis
Calystegia soldanella
Cardionema ramosissimum
Carex tumulicola
Diplacus parviflorus
Hornungia procumbens
Juncus patens
Monolepis nuttalliana
Ribes malvaceum var. *malvaceum*
Trifolium fucatum
Zeltnera davyi

Eulobus californicus
Euphorbia peplus
Galium nuttallii subsp. *insulare*
Gamochaeta ustulata
Geranium carolinianum
Gilia clivorum
Hazardia squarrosa var. *grindelioides*
Hordeum brachyantherum subsp. *californicum*
Jaumea carnosa
Juncus mexicanus
Lactuca saligna
Lastarriaea coriacea
Lepechinia fragrans
Leptosiphon parviflorus
Lupinus albifrons var. *albifrons*
Lupinus albifrons var. *douglasii*
Lythrum hyssopifolia
Matricaria discoidea
Micropus californicus var. *californicus*
Navarretia atractyloides
Papaver californicum
Pennisetum clandestinum
Phacelia grandiflora
Phacelia viscida
Pinus muricata var. *muricata*
Piperia elongata
Platystemon californicus
Pluchea odorata var. *odorata*
Populus trichocarpa
Pseudognaphalium beneolens
Pteridium aquilinum var. *pubescens*
Quercus pacifica
Quercus x macdonaldii
Rosa californica
Rubus ursinus
Sagina apetala
Sagina decumbens subsp. *occidentalis*
Salix exigua
Schoenoplectus pungens var. *longispicatus*
Senecio aphanactis
Silybum marianum
Sisymbrium officinale
Sisyrinchium bellum
Solanum elaeagnifolium
Solanum wallacei
Solidago velutina subsp. *californica*
Stellaria nitens
Stuckenia pectinata
Symphoricarpos mollis
Taraxacum officinale
Tetragonia tetragonioides
Torilis nodosa
Trifolium albopurpureum
Trifolium ciliolatum
Trifolium macraei
Urtica urens
Verbena lasiostachys var. *scabrida*
Woodwardia fimbriata
Xanthium spinosum

Table 6. Lists for the four northern Channel Islands indicating for each when a given taxon is absent from an island but present on the other three.

Total numbers by island are given in parentheses.

San Miguel Island (68)	Santa Rosa Island (3)
Acmispon micranthus	*Erigeron bonariensis*
Acmispon strigosus	*Hordeum murinum* subsp. *glaucum*
Adiantum capillus-veneris	*Opuntia oricola*
Amaranthus albus	
Aphanisma blitoides	
Asclepias fascicularis	
Atriplex pacifica	
Baccharis salicifolia	
Berberis pinnata subsp. *insularis*	
Brassica nigra	
Brickellia californica	
Bromus arizonicus	
Bromus berteroanus	
Carpobrotus edulis	
Ceanothus megacarpus var. *insularis*	
Chenopodium berlandieri	
Cistanthe maritima	
Clarkia epilobioides	
Comarostaphylis diversifolia subsp. *planifolia*	
Cylindropuntia prolifera	
Cynodon dactylon	
Deinandra fasciculata	
Descurainia pinnata	
Eriogonum arborescens	
Eschscholzia ramosa	
Eucalyptus globulus	
Gilia nevinii	
Hazardia detonsa	
Hesperocyparis macrocarpa	
Heuchera maxima	
Keckiella cordifolia	
Lathyrus vestitus	
Lathyrus vestitus var. *vestitus*	
Lilium humboldtii subsp. *ocellatum*	
Lupinus hirsutissimus	
Lupinus truncatus	
Lycopersicon esculentum	
Matricaria discoidea	
Mirabilis laevis var. *crassifolia*	
Muhlenbergia microsperma	
Pectocarya linearis subsp. *ferocula*	
Pentagramma viscosa	
Perityle emoryi	
Phacelia cicutaria var. *hispida*	
Phacelia viscida	
Plagiobothrys canescens var. *catalinensis*	
Plantago erecta	
Plantago ovata var. *insularis*	
Poa secunda subsp. *secunda*	
Polygonum aviculare	
Polypodium californicum	
Polypogon viridis	
Primula clevelandii var. *insularis*	

Prunus ilicifolia subsp. *lyonii*
Pseudognaphalium beneolens
Pseudognaphalium microcephalum
Quercus tomentella
Rafinesquia californica
Ribes malvaceum var. *malvaceum*
Selaginella bigelovii
Silybum marianum
Spergularia marina
Stachys bullata
Stebbinsoseris heterocarpa
Uropappus lindleyi
Vicia hassei
Vicia ludoviciana subsp. *ludoviciana*
Vicia sativa

Santa Cruz Island (2)

Cryptantha hispidissima
Malva pseudolavatera

Anacapa Island (59)

Abronia umbellata var. *umbellata*
Agoseris grandiflora var. *grandiflora*
Allium praecox
Ambrosia psilostachya
Aphyllon parishii subsp. *brachylobum*
Arthrocnemum subterminale
Atriplex leucophylla
Baccharis glutinosa
Brodiaea jolonensis
Calystegia soldanella
Capsella bursa-pastoris
Cardionema ramosissimum
Carduus pycnocephalus subsp. *pycnocephalus*
Castilleja densiflora
Castilleja exserta subsp. *exserta*
Cirsium occidentale
Cirsium vulgare
Clinopodium douglasii
Cortaderia selloana
Crocanthemum greenei
Dichondra occidentalis
Dudleya candelabrum
Dudleya greenei
Eschscholzia californica
Festuca arundinacea
Foeniculum vulgare
Galium buxifolium
Galium californicum
Hainardia cylindrica
Hirschfeldia incana
Jaumea carnosa
Juncus mexicanus
Koeleria macrantha
Leptosiphon parviflorus
Lomatium caruifolium var. *caruifolium*
Lomatium utriculatum
Lupinus arboreus
Malacothrix indecora
Marrubium vulgare
Microseris douglasii subsp. *tenella*
Monolepis nuttalliana
Nemophila pedunculata
Phacelia ramosissima

Polypogon interruptus
Ranunculus californicus var. *cuneatus*
Raphanus sativus
Rubus ursinus
Rumex salicifolius
Sagina apetala
Sagina decumbens subsp. *occidentalis*
Senecio glomeratus
Sidalcea malviflora subsp. *malviflora*
Silene antirrhina
Sisyrinchium bellum
Stephanomeria exigua subsp. *coronaria*
Torilis nodosa
Typha domingensis
Vicia americana subsp. *americana*
Xanthium spinosum

Table 7. Lists for the four southern Channel Islands indicating for each when a given taxon is absent from an island but present on the other three.

Total numbers by island are given in parentheses.

Santa Barbara Island (106)	San Nicolas Island (21)
Abronia maritima	*Baccharis salicina*
Abronia umbellata var. *umbellata*	*Bromus berteroanus*
Acmispon maritimus var. *maritimus*	*Caulanthus lasiophyllus*
Acmispon strigosus	*Constancea nevinii*
Adiantum jordanii	*Cotula australis*
Ambrosia chamissonis	*Cryptantha clevelandii*
Ambrosia psilostachya	*Deinandra fasciculata*
Anemopsis californica	*Hesperocnide tenella*
Atriplex argentea var. *expansa*	*Laennecia coulteri*
Atriplex lentiformis	*Logfia arizonica*
Atriplex leucophylla	*Mirabilis laevis* var. *crassifolia*
Atriplex watsonii	*Papaver heterophyllum*
Baccharis salicifolia	*Perityle emoryi*
Bassia hyssopifolia	*Pholistoma auritum* var. *auritum*
Brachypodium distachyon	*Pholistoma racemosum*
Bromus catharticus	*Polycarpon tetraphyllum*
Bromus sitchensis var. *carinatus*	*Pseudognaphalium microcephalum*
Cakile maritima subsp. *maritima*	*Rafinesquia californica*
Carpobrotus chilensis	*Schismus barbatus*
Carpobrotus edulis	*Tropaeolum majus*
Chenopodium macrospermum	*Uropappus lindleyi*
Cirsium occidentale	
Cressa truxillensis	
Distichlis spicata	
Dysphania ambrosioides	
Eleocharis macrostachya	
Elymus condensatus	
Erodium botrys	
Eschscholzia californica	
Eucalyptus globulus	
Festuca arundinacea	
Foeniculum vulgare	
Frankenia salina	
Glebionis coronaria	
Gnaphalium palustre	
Helianthus annuus	
Heliotropium curassavicum var. *oculatum*	
Heteromeles arbutifolia	
Heterotheca grandiflora	
Hirschfeldia incana	
Hordeum marinum subsp. *gussoneanum*	
Hordeum vulgare	
Hypochaeris radicata	
Isocoma menziesii	
Jepsonia malvifolia	
Juncus bufonius var. *bufonius*	
Lactuca serriola	
Lepidium lasiocarpum subsp. *lasiocarpum*	
Lepidium oblongum	
Lobularia maritima	
Logfia filaginoides	
Lupinus bicolor subsp. *bicolor*	

Lupinus succulentus
Lycium brevipes var. *hassei*
Lycopersicon esculentum
Malacothrix saxatilis var. *tenuifolia*
Malva pseudolavatera
Marah fabacea
Marrubium vulgare
Medicago sativa
Melilotus albus
Mentzelia affinis
Microseris douglasii
Nicotiana glauca
Opuntia ficus-indica
Oxalis corniculata
Oxalis pes-caprae
Pectocarya linearis subsp. *ferocula*
Pellaea andromedifolia
Pentagramma triangularis
Phalaris paradoxa
Plantago coronopus
Plantago erecta
Poa secunda subsp. *secunda*
Polygonum argyrocoleon
Polygonum aviculare
Primula clevelandii var. *insularis*
Pseudognaphalium stramineum
Raphanus sativus
Ricinus communis
Rumex crispus
Rumex salicifolius
Salicornia pacifica
Salix lasiolepis
Salsola australis
Sanicula arguta
Schinus molle
Senecio vulgaris
Sisymbrium irio
Sisymbrium orientale
Solanum douglasii
Sonchus asper subsp. *asper*
Spergularia villosa
Stebbinsoseris heterocarpa
Stipa cernua
Stipa miliacea var. *miliacea*
Tamarix ramosissima
Toxicodendron diversilobum
Tragopogon porrifolius
Trifolium depauperatum
Trifolium microcephalum
Typha domingensis
Typha latifolia
Verbena lasiostachys var. *lasiostachys*
Vicia hassei
Xanthium strumarium

San Clemente Island (3)

Claytonia parviflora subsp. *parviflora*
Platystemon californicus
Silybum marianum

Santa Catalina Island (3)

Artemisia nesiotica
Calystegia macrostegia subsp. *amplissima*
Hornungia procumbens

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Table 8. Taxon-by-island matrix showing taxa for which the most recent collection on at least one island is greater than 60 years old.

*Non-native taxon names are in bold, non-italics. NA indicates that no specimen in this dataset corresponds to a given island. A blue color ramp is applied to cells in the taxon-by-island matrix with values greater than or equal to 60 years old. The lightest blue value corresponds to islands on which the taxon has not been collected in between 60 and 80 years. The intermediate blue value corresponds to islands on which the taxon has not been collected in between 80 and 100 years. The darkest blue value corresponds to islands on which the taxon has not been collected in over 100 years. The last three columns tabulate island endemic taxa that occur on more than one island, single island endemic taxa, and non-island endemic taxa that are rare on the Channel Islands.

Family	Scientific Name*	Northern Channel Islands				Southern Channel Islands				Multi-Island Endemic	Single Island Endemic	Rare non-Island Endemic
		San Miguel	Santa Rosa	Santa Cruz	Anacapa	Santa Barbara	San Nicolas	San Clemente	Santa Catalina			
Dennstaedtiaceae	*Pteridium aquilinum* var. *pubescens*	NA	1960	1995	NA	NA	NA	NA	2006			
Pteridaceae	*Pellaea mucronata* var. *mucronata*	NA	1930	1983	NA	NA	NA	1997	NA			
Pteridaceae	*Pentagramma viscosa*	NA	1979	1994	1963	NA	NA	1903	1997			
Cupressaceae	**Hesperocyparis macrocarpa**	NA	1988	1990	1959	NA	NA	NA	NA			
Amaranthaceae	**Amaranthus albus**	NA	1930	1991	1978	NA	NA	NA	1998			
Amaranthaceae	*Amaranthus blitoides*	NA	1930	1990	NA	NA	NA	NA	NA			
Anacardiaceae	*Toxicodendron diversilobum*	1961	1977	1976	1967	NA	1990	1967	2016			
Apiaceae	*Lomatium insulare*	NA	NA	NA	NA	NA	2019	1918	NA	1		
Asteraceae	*Agoseris apargioides*	NA	1939	NA	NA	NA	NA	NA	NA			1
Asteraceae	*Ambrosia acanthicarpa*	NA	NA	NA	NA	NA	NA	NA	1932			
Asteraceae	*Artemisia dracunculus*	NA	NA	NA	NA	NA	NA	NA	1931			
Asteraceae	*Eurybia radulina*	NA	1929	1996	NA	NA	NA	NA	NA			1
Asteraceae	**Glebionis coronaria**	NA	NA	1939	NA	NA	1991	1997	1970			
Asteraceae	*Hazardia squarrosa* var. *grindelioides*	1930	1998	1993	1978	NA	NA	NA	2012			
Asteraceae	*Malacothrix coulteri*	NA	1981	1932	NA	NA	NA	NA	NA			1
Asteraceae	*Malacothrix saxatilis* var. *implicata*	1998	NA	2019	2019	1932	NA	NA	NA	1		
Asteraceae	*Malacothrix similis*	NA	NA	1888	NA	NA	NA	NA	NA			1
Asteraceae	*Microseris elegans*	1931	NA	1991	NA	NA	1998	2019	NA			
Asteraceae	*Senecio aphanactis*	NA	1929	1991	NA	NA	NA	NA	1901			1
Asteraceae	*douglasii*	NA	NA	1999	NA	NA	NA	1939	NA			
Asteraceae	*Stephanomeria cichoriacea*	NA	1932	2012	NA	NA	NA	NA	NA			
Asteraceae	*Stephanomeria exigua* subsp. *coronaria*	1886	2003	2005	NA	NA	NA	NA	NA			
Asteraceae	*Xanthium spinosum*	1978	1988	1995	NA	1931	NA	NA	2017			
Bataceae	*Batis maritima*	NA	NA	NA	NA	NA	NA	1885	1899			1

Family	Scientific Name*	Northern Channel Islands				Southern Channel Islands				Multi-Island Endemic	Single Island Endemic	Rare non-Island Endemic
		San Miguel	Santa Rosa	Santa Cruz	Anacapa	Santa Barbara	San Nicolas	San Clemente	Santa Catalina			
Berberidaceae	*Berberis pinnata* subsp. *insularis*	NA	1930	2017	1990	NA	NA	NA	NA	1		
Boraginaceae	*Amsinckia spectabilis* var. *spectabilis*	2020	1999	2019	1986	1982	2019	2019	1931			
Boraginaceae	*Cryptantha micromeres*	NA	1932	1986	NA	NA	NA	NA	1967			
Boraginaceae	*Cryptantha microstachys*	NA	NA	NA	NA	NA	NA	NA	**1920**			1
Boraginaceae	*Pectocarya heterocarpa*	NA	NA	1932	NA	NA	NA	NA	NA			1
Boraginaceae	*Pectocarya penicillata*	NA	NA	1960	NA	NA	NA	NA	1971			1
Boraginaceae	*Plagiobothrys collinus* var. *gracilis*	1932	NA	2019	NA	NA	NA	2019	2015			
Brassicaceae	*Boechera hoffmannii*	NA	1930	2004	NA	NA	NA	NA	NA	1		
Brassicaceae	**Brassica nigra**	NA	1979	NA	1980	1940	1978	2019	2019			
Brassicaceae	**Brassica rapa**	1939	NA	1991	NA	NA	NA	1962	1966			
Brassicaceae	**Cakile edentula**	1979	1930	NA	NA	NA	1961	NA	NA			
Brassicaceae	*Cardamine oligosperma*	NA	NA	1925	NA	NA	NA	NA	NA			
Brassicaceae	*Descurainia pinnata*	NA	1932	NA	1962	NA	NA	1976	2017			
Brassicaceae	*Draba cuneifolia*	NA	NA	1970	NA	NA	1993	NA	**1902**			1
Brassicaceae	*Erysimum ammophilum*	1995	1941	NA	NA	NA	NA	NA	NA			1
Brassicaceae	*Sibara filifolia*	NA	NA	1932	NA	NA	NA	NA	2015	1		
Brassicaceae	*Turritis glabra*	NA	NA	1932	NA	NA	NA	NA	2000			1
Cactaceae	*Cylindropuntia prolifera*	NA	1991	1993	1959	1968	1992	2011	1999			
Cactaceae	**Opuntia ficus-indica**	NA	NA	1984	NA	NA	1988	1991	**1920**			
Cactaceae	*Opuntia littoralis*	1930	1930	1988	1959	1966	1995	1996	2012			
Cactaceae	*Opuntia oricola*	1977	NA	1991	1959	1968	1993	1939	1933			
Caprifoliaceae	*Lonicera subspicata* var. *subspicata*	NA	NA	1960	NA	NA	NA	NA	1998			1
Caryophyllaceae	*Minuartia douglasii*	NA	1932	2003	NA	NA	NA	1962	2016			
Caryophyllaceae	*Polycarpon depressum*	1999	NA	1930	NA	NA	NA	1996	**1909**			

Family	Scientific Name*	Northern Channel Islands				Southern Channel Islands				Multi-Island Endemic	Single Island Endemic	Rare non-Island Endemic
		San Miguel	Santa Rosa	Santa Cruz	Anacapa	Santa Barbara	San Nicolas	San Clemente	Santa Catalina			
Caryophyllaceae	*Sagina decumbens* subsp. *occidentalis*	1932	1929	1993	NA	NA	NA	NA	1931			
Caryophyllaceae	*Silene multinervia*	NA	NA	1932	NA	NA	NA	NA	NA			1
Caryophyllaceae	*Stellaria nitens*	NA	1930	1985	NA	NA	NA	NA	2003			
Chenopodiaceae	*Atriplex argentea* var. *expansa*	NA	1930	1992	NA	NA	2019	2019	1931			
Chenopodiaceae	*Atriplex pacifica*	NA	1932	2004	1998	1991	1995	2019	2010			
Chenopodiaceae	*Atriplex serenana* var. *davidsonii*	NA	1929	NA	NA	NA	NA	NA	2000			1
Chenopodiaceae	*Atriplex serenana* var. *serenana*	NA	NA	1930	NA	NA	NA	NA	NA			1
Chenopodiaceae	*Chenopodium berlandieri*	NA	1939	1994	1998	NA	2000	NA	2000			
Chenopodiaceae	*Salicornia pacifica*	1995	2015	1994	1940	NA	2019	1997	2017			
Cistaceae	*Crocanthemum greenei*	NA	1937	1999	NA	NA	NA	NA	1966	1		
Convolvulaceae	*Calystegia macrostegia* subsp. *amplissima*	NA	NA	NA	NA	1961	2019	2019	NA	1		
Convolvulaceae	*Calystegia soldanella*	1979	1998	2012	NA	NA	2019	1936	NA			
Convolvulaceae	*Cuscuta campestris*	1961	NA	NA	NA	NA	NA	NA	NA			
Cornaceae	*Cornus glabrata*	NA	NA	NA	NA	NA	NA	1922	NA			1
Cucurbitaceae	*Marah fabacea*	1939	NA	2019	NA	NA	1939	1996	1995			
Fabaceae	*Acmispon argophyllus* var. *argenteus*	NA	1931	NA	NA	NA	2019	2019	NA	1		
Fabaceae	*Acmispon brachycarpus*	NA	NA	NA	NA	NA	NA	NA	**1901**			1
Fabaceae	*Acmispon heermannii* var. *heermannii*	NA	NA	NA	NA	NA	NA	NA	**1902**			1
Fabaceae	*Acmispon wrangelianus*	1997	1991	2001	1940	NA	NA	NA	NA			
Fabaceae	*Astragalus trichopodus* var. *lonchus*	1939	1989	2012	1994	NA	NA	NA	NA			

Family	Scientific Name*	Northern Channel Islands				Southern Channel Islands				Multi-Island Endemic	Single Island Endemic	Rare non-Island Endemic
		San Miguel	Santa Rosa	Santa Cruz	Anacapa	Santa Barbara	San Nicolas	San Clemente	Santa Catalina			
Fabaceae	*Lupinus albifrons* var. *albifrons*	1979	1988	1989	1941	NA	2016	NA	NA			
Fabaceae	*Lupinus chamissonis*	1985	**1888**	NA	NA	NA	NA	NA	NA			
Fabaceae	**Medicago sativa**	1992	1929	NA	1940	NA	NA	2019	NA			
Fabaceae	*Trifolium barbigerum*	1930	2000	NA	NA	NA	NA	NA	NA			1
Fabaceae	*Trifolium fucatum*	2000	1932	2019	1993	NA	NA	1980	NA			
Fabaceae	*Trifolium gracilentum*	2000	2004	2003	2000	1940	2019	2019	2017			
Fabaceae	*Vicia hassei*	NA	1941	NA	1994	NA	2001	2003	2016			
Gentianaceae	*Zeltnera davyi*	NA	1938	1989	NA	NA	NA	2019	NA			
Geraniaceae	*California macrophylla*	NA	NA	**1888**	NA	NA	NA	NA	2017			1
Geraniaceae	*Erodium texanum*	NA	NA	NA	NA	NA	NA	NA	**1901**			1
Grossulariaceae	*Ribes malvaceum* var. *malvaceum*	NA	1932	2019	1979	NA	NA	NA	NA			
Hydrophyllaceae	*Phacelia ciliata*	NA	NA	NA	NA	NA	NA	NA	**1897**			1
Loasaceae	*Mentzelia affinis*	NA	NA	1993	NA	NA	2019	1997	**1917**			
Malvaceae	*Eremalche exilis*	NA	NA	**1888**	NA	NA	NA	1996	**1901**			1
Montiaceae	*Calandrinia breweri*	NA	1932	1995	NA	NA	NA	NA	NA			
Montiaceae	*Montia fontana*	NA	NA	1932	NA	NA	NA	NA	NA			1
Nyctaginaceae	*Abronia latifolia*	1932	NA	NA	NA	NA	NA	NA	NA			1
Nyctaginaceae	*Abronia maritima*	1987	1998	2019	1938	NA	2019	2019	2015			
Onagraceae	*Camissoniopsis ignota*	NA	NA	1932	NA	NA	NA	NA	NA			1
Onagraceae	*Clarkia prostrata*	NA	1938	NA	NA	NA	NA	NA	NA			1
Onagraceae	*Eulobus californicus*	NA	1927	1993	NA	NA	NA	NA	2010			
Orobanchaceae	*Aphyllon fasciculatum*	NA	1932	NA	1980	NA	NA	NA	NA			
Orobanchaceae	*Aphyllon parishii* subsp. *brachylobum*	2006	1930	2006	NA	NA	1995	NA	2012			
Orobanchaceae	*Castilleja mollis*	1938	2003	NA	NA	NA	NA	NA	NA	1		
Papaveraceae	*Platystemon californicus*	1995	1993	NA	1965	1993	2019	NA	**1890**			
Phrymaceae	*Diplacus brandegeei*	NA	NA	**1888**	NA	NA	NA	NA	NA		1	

Family	Scientific Name*	Northern Channel Islands				Southern Channel Islands				Multi-Island Endemic	Single Island Endemic	Rare non-Island Endemic
		San Miguel	Santa Rosa	Santa Cruz	Anacapa	Santa Barbara	San Nicolas	San Clemente	Santa Catalina			
Phrymaceae	*Diplacus brevipes*	NA	NA	NA	NA	NA	NA	NA	**1890**			1
Phrymaceae	*Diplacus traskiae*	NA	NA	NA	NA	NA	NA	NA	**1901**		1	
Plantaginaceae	*Plantago maritima*	NA	1930	NA	NA	NA	NA	NA	NA			1
Polemoniaceae	*Gilia achilleifolia* subsp. *multicaulis*	NA	1929	NA	NA	1941	NA	NA	NA			1
Polemoniaceae	*Gilia clivorum*	1998	NA	1992	1997	NA	NA	NA	1931			
Polemoniaceae	*Gilia nevinii*	NA	1991	1993	1998	1982	**1901**	2019	NA	1		
Polygonaceae	*Eriogonum cinereum*	NA	1922	NA	NA	NA	2018	NA	NA			1
Rosaceae	*Aphanes occidentalis*	NA	1960	NA	NA	NA	NA	1997	2016			
Rosaceae	*Cercocarpus betuloides* var. *blancheae*	NA	1932	NA	NA	NA	NA	NA	NA			
Rosaceae	*Potentilla anserina* subsp. *pacifica*	1930	NA	2005	NA	NA	NA	NA	NA			
Rubiaceae	*Galium buxifolium*	1998	1930	2019	NA	NA	NA	NA	NA	1		
Salicaceae	*Salix lasiandra* var. *lasiandra*	NA	NA	1960	NA	NA	NA	NA	NA			
Saururaceae	*Anemopsis californica*	NA	NA	2005	NA	NA	1979	1936	2017			
Solanaceae	*Lycium brevipes* var. *hassei*	NA	NA	NA	NA	NA	2019	1936	**1918**			1
Solanaceae	*Lycium fremontii*	NA	1932	NA	NA	NA	NA	NA	NA			1
Solanaceae	*Lycium verrucosum*	NA	NA	NA	NA	NA	**1901**	NA	NA		1	
Verbenaceae	*Verbena lasiostachys* var. *lasiostachys*	1995	NA	NA	NA	NA	1985	NA	1931			
Cyperaceae	*Carex globosa*	NA	1988	2012	NA	NA	NA	NA	1928			
Cyperaceae	**Cyperus involucratus**	NA	NA	1930	NA	NA	NA	NA	NA			
Juncaceae	*pacificus*	NA	1960	NA	NA	NA	NA	NA	NA			
Liliaceae	*Calochortus albus*	NA	NA	2019	NA	NA	NA	NA	1925			1
Liliaceae	*Calochortus venustus*	NA	NA	NA	NA	NA	NA	NA	**1904**			1
Poaceae	*Bromus berteroanus*	NA	1930	1932	1928	1998	NA	1981	**1897**			
Poaceae	*Elymus condensatus*	1977	1998	1993	2019	NA	1979	1936	2016			

Family	Scientific Name*	Northern Channel Islands				Southern Channel Islands				Multi-Island Endemic	Single Island Endemic	Rare non-Island Endemic
		San Miguel	Santa Rosa	Santa Cruz	Anacapa	Santa Barbara	San Nicolas	San Clemente	Santa Catalina			
Poaceae	*Festuca microstachys*	1930	2002	2003	1998	NA	NA	2019	2003			
Poaceae	*Paspalum distichum*	NA	NA	1960	NA	NA	NA	NA	1998			
Poaceae	**Phalaris caroliniana**	NA	NA	1985	NA	1922	2000	2011	**1901**			
Poaceae	*Phalaris lemmonii*	1998	1993	NA	NA	NA	NA	2019	**1897**			1
Poaceae	**Phalaris minor**	2000	1930	1993	2000	1999	2019	2019	2016			
Poaceae	**Poa annua**	1998	1977	1993	1998	1991	1989	1923	2001			
Poaceae	*Poa howellii*	NA	NA	1931	NA	NA	NA	NA	NA			1
Poaceae	**Polypogon interruptus**	2000	1994	2012	NA	NA	NA	1936	NA			
Poaceae	**Polypogon viridis**	NA	1991	2002	1940	NA	NA	1997	1995			
Poaceae	*Stipa lepida*	1965	1977	1994	1998	1939	2019	2019	NA			
Zannichelliaceae	*Zannichellia palustris*	NA	NA	1932	NA	NA	NA	NA	1965			
	Taxa not observed in 60+ years	**16**	**45**	**23**	**11**	**8**	**4**	**12**	**30**	**11**	**3**	**38**
	Percentage of island flora	**5.42**	**8.41**	**3.36**	**3.94**	**5.56**	**1.33**	**2.66**	**4.20**			
	Taxa not observed in 60-80 years	2	4	4	4	1	1			1		2
	Taxa not observed in 80-100 years	13	40	15	7	7	1	9	10	8		21
	Taxa not observed in 100+ years	1	1	4			2	3	20	2	3	15

are based on the more inclusive dataset, which includes specimens with and without latitude and longitude coordinates. Dates of most recent collections are given for all islands on which these plants occur, regardless of year. A color ramp is applied to denote plants in the following categories: not collected in 60-80 years, not collected in 80-100 years, not collected in over 100 years. Three columns indicate for each taxon if it is an island endemic present on multiple islands, a single-island endemic, or a non-island endemic that is rare on the Channel Islands.

The list of historically documented but not recently collected plants contains 129 taxa across the Channel Islands, which is well-over 10 percent of the total flora. Because some of these 129 taxa occur on multiple islands on which they have not been documented for over 60 years, the total number of incidences of non-documentation is 149. Numbers of undocumented for 60+ years taxa vary strongly by island. On the northern Channel Islands, numbers range from 11 on Anacapa Island to 45 on Santa Rosa Island. As a percentage of the total individual island flora, values ranged from 3.36% on Santa Cruz Island to 8.41% on Santa Rosa Island. On the southern Channel Islands, numbers range from 4 on San Nicolas Island to 30 on Santa Catalina Island. As a percentage of the total individual island flora, values ranged from 1.33% on San Nicolas Island to 5.56% on Santa Barbara Island.

Numbers of taxa within each temporal window are uneven. Number of instances in the 60-80-year window was 16, the 80-100-year window was 102, and the 100+-year window was 31. The 80-100-year window was consistently the highest value for all islands but Santa Catalina Island, for which the 100+-year window was the highest value.

A total of 52 taxa in **Table 8** are multiple- or single-island endemics (11 and 3 taxa, respectively), or are non-island endemics that are rare on the Channel Islands (38 taxa).

Discussion

Dataset and analysis caveats

Several caveats pertaining to the dataset and analyses must be considered when interpreting the results presented here. Most critically, the filtered and cleaned dataset used here was a subset of all available data. Due to the volume and variable quality of available plant specimen data, the dataset used here was limited to voucher-based records only. Of potentially available, voucher-based records, the dataset only included digitized and (at least minimally) georeferenced specimens deposited in herbaria and harvested by Cal-IBIS prior to January 2021. Recently collected specimens or those otherwise not yet digitized were not included in the dataset. Dataset completeness is likely one reason why taxonomic richness is lower in this study than, e.g., in the Channel Islands Flora checklist or the previously cited single-island CCH2 checklists.

Second, the specimen data that passed the filtering steps were cleaned only insofar as could be done without physically observing the specimens. Extensive herbarium work was not performed for this project. This meant that taxonomic determinations could not be verified, nor could minimum-rank determinations be made for those specimens lacking them, in most cases. For some taxa with multiple subspecies or varieties on the Channel Islands (e.g., *Isocoma menziesii*), specimen data were collapsed to the species level. While this allows for greater specimen inclusivity, it also has the effect of apparently reducing the taxonomic richness of the Channel Islands.

Third, our specimen analyses only pertain to native and naturalized plants. Our definition of naturalized taxa are those with plants that got to their location naturally/”on their own” and that are producing seeds that are growing into new plants. It’s often not possible to evaluate this for iNaturalist, and some taxa, such as *Eucalyptus erythrocorys*, may have been included that can not properly be considered naturalized.

Spatial patterns

Island-scale spatial patterns

Comparisons of estimated vascular plant taxonomic richness by island showed the clear pattern of increasing taxonomic richness through time for specimen data, with the more recent iNaturalist observation data trailing far behind (Table 1). Additional plants may be added to the flora of individual Channel Islands by several means. Perhaps most intuitively, new taxa may be added to island checklists as previously undocumented native biodiversity is observed and recorded by botanists. With the removal of feral ungulates from most of the Channel Islands, biologists have documented the early stages of ecosystem recovery. During this process, observations of new populations of previously documented native plants, along with entirely new records of previously undocumented plants, have become commonplace on the archipelago.

New taxa may also be added through the recent colonization of the islands by novel, non-native taxa and by recent, human-mediated dispersal of plants native to the mainland. Additions of new, non-native taxa are also common, especially on islands with high visitorship (e.g., Santa Catalina Island, which is visited by over one million people per year). An archipelago-wide biosecurity program is in place to reduce the likelihood of new introductions and to detect and eradiate those that develop.

Perhaps non-intuitively, “new” taxa may also be added to island checklists as existing specimens in herbaria are better studied. Specimen digitization efforts have resulted in the more-expeditious sharing of biodiversity data. Without such efforts, it is often not feasible to locate herbarium sheets that might represent “new” taxa for a given island. Once label-digitized, however, these specimens can be located in string-based and locality-based online searches. In addition, herbarium study of digitized specimens may result in changes in determination that “add” new taxa to island checklists (Guilliams and Hasenstab-Lehman, unpublished data).

While the number of specimens per island was roughly proportional to island size, overall collection intensity across the archipelago might be considered moderate at best for all but the smallest islands of Anacapa and Santa Barbara. Mean taxonomic richness per 1 km^2 grid cell is relatively low, especially for the larger islands. By all measures, Santa Rosa Island, the second-largest of the archipelago, is grossly under-collected. San Miguel and San Clemente islands also appear under-collected in these analyses, but the present dataset does not include any specimens from the recent floristic work of Rebman and Vanderplank on San Clemente Island. San Miguel would benefit from additional floristic work.

Within-island spatial patterns

Not surprisingly, existing voucher-based records are highly unevenly distributed within each of the Channel Islands. Most collections have been made near buildings, roads, trails, and boat landings. This is true for every island, although collection intensity is more evenly distributed on the smaller islands of Anacapa and Santa Barbara. Even on the island with the greatest number of collections, Santa Cruz Island, there are 1 km^2 grid cells with zero voucher-based records of any kind. Within-island collections are especially sparse for Santa Rosa Island. These patterns are similar for iNaturalist observations.

This spatial bias can be ameliorated through focused collection efforts away from infrastructure such as buildings and roads. Although more costly, use of boats and helicopters to more efficiently access remote locations may prove beneficial. Drones may be effective at surveying large swaths of each island to detect more conspicuous, target taxa for collection. All three tools may have limited applicability to areas designated as proposed Wilderness (e.g., most of Santa Rosa Island). In this case and for other reasons as well, partnering with community scientists to generate observation-based records might be an effective way to generate biodiversity data and in so doing, "scout" under-collected but promising island regions.

Temporal patterns

Analysis of temporal patterns revealed a clear trend of periods of elevated collection intensity tethered to the focused work of a small number of important collectors through time. Relatively low levels of collection effort appear to have been sufficient to adequately describe the floras of the smaller islands of Anacapa and Santa Barbara. Even with prodigious and sustained effort, however, the floras of the larger islands of Santa Cruz and Santa Catalina remain incompletely known. Santa Rosa Island has lower collection intensity and fewer peaks of collection intensity relative to other large islands.

Monthly temporal patterns show a clear bias toward collections in the Spring months of March, April, and May on all islands. Collection in the spring is required for nearly all annual plants, during which time shrubs and trees have also be gathered. This temporal bias would result in the under-collection of taxa that have phenological optima outside of the spring months. Such taxa may include, e.g., ferns, perennial graminoid monocots, summer-blooming Asteraceae (e.g., *Isocoma menziesii*, tarweeds), and *Eriogonum* (Polygonaceae). Each of these groups may be prevalent and ecologically important in certain settings. Monthly temporal biases might be best overcome by focused collecting expeditions to target these and other non-Spring blooming taxa.

Taxonomic patterns

The pace of new island discoveries through time as revealed by the species accumulation curves suggests that there are many taxa yet to be found on the islands. This is consistent with state (Taylor, 2019) and global patterns (Antonelli et al., 2020) of biodiversity discovery and description. While the species accumulation curve for Santa Cruz Island appears to be flattening, those for other islands appear far from reaching an asymptote. San Miguel Island, Santa Rosa Island, and surprisingly, Santa Barbara Island would have the greatest number of undiscovered taxa based on the shapes of the curves. With its small size and high collection intensity per km^2, it is unclear if the shape of the species accumulation curve for Santa Barbara Island is truly indicative of a large number of yet-to-be detected plants.

Plant specimens collected on the Channel Island, when summarized by family, reveal interesting, region-specific patterns. The three families with the greatest number of collections on the Channel Islands are all among the largest vascular plant families in terms of species richness globally (Simpson, 2019): Asteraceae (14,167 specimens; 33,000 species), Poaceae (9,706 specimens; 11,300 species), and Fabaceae (7,714 specimens; 19,500 species). A number of families in the Channel Islands flora seem disproportionally well-represented in natural history collections relative to their size globally, e.g., Chenopodiaceae (3,011 specimens; 500 species) and Hydrophyllaceae (1,419 specimens; 240-280 species). These families have diversified in the California Floristic Province (Howell, 1957), so their disproportionate representation on the Channel Islands and in herbaria seems reasonable. Some families present on the Channel Islands are poorly represented in herbaria relative to their sizes globally, e.g., Orchidaceae (95 specimens; 28,000 species) and Cactaceae (170 specimens; 1,200-1,500 species). Much of the taxonomic diversity of the Orchidaceae occurs in the tropics, which in part explains this discrepancy. The Cactaceae are notoriously difficult to collect and require additional processing during specimen preparation, which may explain the relatively small number of collections of members of this family.

iNaturalist observations cover the majority of the plant families known for the islands, albeit generally with many fewer data points, as one would expect since the platform has only been online since 2008. However, some families have more iNaturalist observations than specimens. These families are all succulents and trees, which are more difficult to collect, and indicate a useful taxonomic gap that iNaturalist can help to fill. The twelve families that have similar numbers of specimens and observations tend to contain relatively conspicuous taxa, such as *Asclepias* (milkweed), *Bloomeria* (goldenstar), *Rhus integrifolia* (lemonadeberry), and *Malacothamnus fasciculatus* (bushmallow). However, less conspicuous families, such as the Amaranthaceae (only 2 iNaturalist observations) and Chenopodiaceae, are relatively under-represented in iNaturalist. For data on this platform to be most useful for biodiversity understanding, botanical experts should provide some training to amateurs that use this platform to highlight the more commonly-overlooked taxonomic groups.

A number of plant taxa have been identified as potentially occurring on certain of the Channel Islands on the basis of island size and island geography. If island size is strongly predictive of both taxonomic richness *and* composition, then each of the large islands has a watchlist of absent taxa that may be present, owing to voucher-based records on the other three islands. San Clemente Island has the largest number of absent taxa at 106, some number of which might be reasonable to expect on this fourth-largest island. However, San Clemente Island is situated relatively far from the coast and is the farthest of the southern Channel Islands from the northern Channel Islands. The power of island size as a predictor of taxonomic composition may be diminished owing to the location of the island and distance from sources of new immigrants.

Membership to the northern Channel Islands subgroup of islands is likely a strong predictor of taxonomic composition. These islands were formerly connected into one island landmass, called Santarosae, during a period of lower sea levels (Rick et al., 2014). During this time, there would have been no water barrier to dispersal. In addition, this group of islands is oriented west-to-east, parallel to the Santa Barbara County coastline. They are therefore at roughly the same latitude and experience a similar climate. They are also a similar distance from the mainland. The two largest lists of absent taxa among the northern islands are for San Miguel and Anacapa islands, with lists of 68 and 59 taxa, respectively. While the large list of absent taxa for Anacapa Island is likely attributable in large part to island size, the list for San Miguel Island requires greater scrutiny.

Membership to the southern Channel Islands subgroup of islands as a criterion for developing a list of potentially present taxa may or may not be effective. Because Santa Barbara Island is the smallest in the archipelago, and the other three islands share a number of taxa, the list of absent taxa for Santa Barbara Island is extensive, at 106. When grouped with sets of two other southern islands, however, its small size and depauperate flora likely results in short absent lists of unclear value for the other islands.

Specimen queries performed for this project documented 129 taxa that have not been collected on at least one island in 60 or more years. All islands have at least some taxa in this category, but Santa Rosa Island (45 taxa) and Santa Catalina Island (30 taxa) are both extreme cases. To be clear, not every plant on this list is worthy of rediscovery efforts; some plants on this list are non-native (denoted in bold, non-italics, e.g., *Brassica nigra* on Santa Barbara Island, last collected in 1940), and some are common, native plants that are difficult to collect (e.g., *Opuntia oricola* on San Clemente Island, last collected in 1939). On the other hand, many of these taxa represent native plant biodiversity that has potentially been extirpated from individual islands (e.g., *Erodium texanum* on Santa Catalina Island, last collected in 1901). Critically, 52 instances of non-documentation correspond to taxa that are multiple- or single-island endemic taxa, or native, non-island endemic taxa that are rare on the Channel Islands. Each of these instances represents an important opportunity for future rediscovery initiatives, although the admonishment to remain mindful of dataset completeness and cleaning/filtering applies especially strongly to this particular set of findings.

Recommendations

In this report, spatial, temporal, and taxonomic gaps in the understanding of the vascular plants of the Channel Islands have been illuminated and discussed. The findings in this report are preliminary and caveat-laden, but point to a number of recommendations that may help eliminate historical and future plant biodiversity data gaps and biases.

General recommendations:

1. Acknowledge and accurately depict historical vascular plant biodiversity data gaps whenever possible.
2. Support floristic and taxonomic work as timely and critically-important subdisciplines of plant science.
3. In general, promote novel, observation-based tools for biodiversity documentation (e.g., iNaturalist), while simultaneously recognizing the value of voucher-based biodiversity documentation.
4. For land managers and conservationists, attempt to fairly balance the conservation of plants relative to other kinds of living things, macrofauna (e.g., avifauna, pinnipeds) in particular.

Specific recommendations:

1. Develop and promote initiatives that would ameliorate spatial biodiversity data gaps/biases:
    a. Prioritize floristic and taxonomic work on under-collected islands, in particular San Miguel and Santa Rosa islands.
    b. Consult with Rebman and Vanderplank to reinterpret results for San Clemente Island in light of their recent, unpublished floristic work on that island.
    c. Prioritize traditional floristic and taxonomic work in regions of each Channel Island with low collection intensity and taxonomic richness.
    d. Invest in the development of new technologies and approaches that augment traditional floristic and taxonomic work to accelerate the pace of biodiversity discovery and description (e.g., continued helicopter-based surveys, potential drone surveys).
    e. Develop partnerships with universities, students, and other community members to bolster the acquisition of plant biodiversity data, especially through community science platforms like iNaturalist.
    f. Improve the quality/value of plant-related observations on community science platforms like iNaturalist by funding the digital curation of these data by professional plant biodiversity scientists.

2. Develop and promote initiatives that would ameliorate temporal biodiversity data gaps/biases:
    a. Prioritize and fund island-related herbarium study by botanical experts, as this is one of the only ways that historical/temporal data gaps may be incrementally improved.
    b. Perform a feasibility study to characterize the value of redeploying observation-based data from the gray literature (e.g., survey data, transect data, herbarium specimen label data) in online data portals, as this may be one of the only ways that historical/temporal data gaps may be incrementally improved.
    c. Repeat voucher-based floristic surveys in target, high-value areas of the Channel Islands on decadal intervals at a minimum.
    d. Prioritize floristic and taxonomic work during the non-Spring months on each island.
3. Develop and promote initiatives that would ameliorate taxonomic biodiversity data gaps/biases:
    a. Promote floristic and taxonomic work on the Channel Islands, which may result in the description of novel plant biodiversity; all resulting observations would attain highest value as specimen-based records.
    b. Focus on historically under-collected islands, island locations, and taxa as potential loci for plant biodiversity discovery; all resulting observations would attain highest value as specimen-based records.
    c. Use resources such as "absent taxa" lists as starting points for focused plant surveys.
    d. Perform focused surveys for plant taxa not recently observed on each of the Channel Islands, documenting plants observed with voucher-based records.

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