



Channel Islands National Park

Terrestrial Vegetation Monitoring Annual Report—2019



Malva assurgentiflora at Point Bennet on San Miguel Island.

NPS / DIRK RODRIGUEZ

Channel Islands National Park: Terrestrial vegetation monitoring annual report—2019

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Abstract

Long-term ecological research is critical for evaluating past resource management actions and guiding future decisions. This report presents the data collected at Channel Islands National Park (CHIS) in 2019 as part of its terrestrial vegetation monitoring program. The program's objective is to document long-term trends in the park's vegetation communities consistent with the Mediterranean Network that also includes Santa Monica Mountains National Recreation Area and Cabrillo National Monument.

Monitoring at CHIS began in 1984 to observe vegetation recovery after the removal of nonnative ranched animals. In 2019, field data were collected from 132 out of the 144 transects scheduled. Analyzing all years of data together showed that annual rainfall correlated positively with percent cover of vegetation, and an apparent long-term decline in average percent cover of vegetation that started in the mid-1990s continued in 2019. Analyzing the 2019 dataset by itself provided more nuanced results. Seablite scrub and valley/foothill grassland had consistently low proportions of absolute cover and native richness, respectively, as well as relatively low overall richness. These communities may have been more susceptible to browsing/grazing in the past and currently resistant to passive recovery; both communities could benefit from targeted restoration efforts. Vegetation was, on average, tallest at Santa Cruz and Santa Rosa Islands due to the presence of tree-dominated communities. Perennial plant species achieved significantly higher percent cover at Santa Cruz, Santa Rosa, and San Miguel Islands compared to Santa Barbara Island. Native plant species attained significantly higher percent cover at Santa Rosa Island compared to Santa Barbara Island. Adult shrub density was significantly higher at Santa Cruz, Santa Rosa, and San Miguel Islands compared to Santa Barbara Island. Islands at more northwesterly positions generally supported higher biodiversity.

The tendency for vegetation height, cover of perennials and natives, shrub density, and biodiversity to each decline along a gradient from northwest to southeast indicates that moisture limitation is a strong driver of vegetation recovery after the removal of ranched animals. Moreover, moisture limitation at the park's most southwesterly islands may interact with poor soils at Santa Barbara Island and seabird abundance at Anacapa Island to further inhibit recovery. Therefore, Santa Barbara and Anacapa Islands may benefit greatly from targeted native plant restoration. Santa Barbara Island's high total cover contributed by a high proportion of nonnative species may render this island particularly resistant to recovery since a range of species responses to environmental disturbance can stabilize ecosystem processes.

Acknowledgments

No one accomplishes their work without assistance from others. The National Park Service's Adam Taylor assisted with fieldwork, and Lena Lee helped enter data from the field data sheets. The Santa Barbara Botanic Garden's Stephanie Calloway assisted with data entry, and Sarah Cusser provided a foundation of R code that guided analyses. The data featured in this report were derived from surveys within Channel Islands National Park, which includes Chumash and Gabrieleño/Tongva homelands.



Lupinus albifrons on San Miguel Island. NPS / DIRK RODRIGUEZ

Executive Summary

This report presents the data collected in 2019 as part of the long-term terrestrial vegetation monitoring program at Channel Islands National Park, which consists of five islands off the coast of southern California.

The purpose of this monitoring program is to document long-term trends in the park's vegetation communities. Data are collected from 30-m-long transects using a line-point intercept method. In the past, each transect was sampled annually. However, beginning in 2012 the program began adding randomly located transects to improve the representativeness of the sampling, and transitioned to a rotating panel design. Now only a core subset of the transects are surveyed annually, and non-core transects are assigned to one of four panels (A, B, C, or D), each of which is surveyed once every four years. In 2019, 73 core and 71 Panel C transects were scheduled for survey.

Field data were collected from 132 out of the 144 transects scheduled in 2019, distributed across the islands as follows: Santa Barbara Island ($n = 17$), Anacapa Island ($n = 3$), Santa Cruz Island ($n = 32$), Santa Rosa Island ($n = 67$), and San Miguel Island ($n = 13$). Due to logistical constraints, eleven transects were not visited on Anacapa Island. One transect on Santa Rosa Island was inadvertently skipped.

Key 2019 results and interpretation:

- A long-term decline in average percent cover of vegetation was apparent starting in the mid-1990s. Annual rainfall correlated positively with percent cover of vegetation.
- Seablite scrub and valley/foothill grassland had consistently low proportions of absolute cover and native richness, respectively, as well as relatively low overall richness. These communities may have been more susceptible to browsing/grazing in the past and may currently be resistant to passive recovery; both communities could benefit from targeted restoration efforts.
- Vegetation was, on average, tallest at Santa Cruz and Santa Rosa Islands due to the presence of tree-dominated communities.
- Perennial plant species achieved significantly higher percent cover at Santa Cruz, Santa Rosa, and San Miguel Islands compared to Santa Barbara Island. Native plant species attained significantly higher percent cover at Santa Rosa Island compared to Santa Barbara Island. None of the other pairwise comparisons showed statistically significant differences.
- Adult shrub density, measured as number of individuals per square meter, was significantly higher at Santa Cruz, Santa Rosa, and San Miguel Islands compared to Santa Barbara Island.
- Islands at more northwesterly positions generally supported higher biodiversity, measured using three diversity indices: species richness, species evenness, and Shannon diversity.
- The tendency for vegetation height, cover of perennials and natives, shrub density, and biodiversity to each decline along a gradient from northwest to southeast indicates that

moisture limitation is a strong driver of vegetation recovery after the removal of ranched animals. Moreover, moisture limitation at the park's most southwesterly islands may interact with poor soils at Santa Barbara Island and seabird abundance at Anacapa Island to further inhibit recovery. Therefore, Santa Barbara and Anacapa Islands may benefit greatly from targeted native plant restoration.

- Santa Barbara Island's high total cover contributed by a high proportion of nonnative species may render this island particularly resistant to recovery since a range of species responses to environmental disturbance can stabilize ecosystem processes.



Quercus tomentella keeping watch over Santa Rosa Island. NPS / DIRK RODRIGUEZ

Introduction

Channel Islands National Park (CHIS) hosts at least 800 species of vascular plants, including 70 endemics and 13 taxa protected under the Endangered Species Act. This oasis of biodiversity is comprised of five islands—Santa Barbara Island (SB), Anacapa Island (AN), Santa Cruz Island (SC), Santa Rosa Island (SR), and San Miguel Island (SM)—located off the coast of southern California (Figure 1). Although at least 13,000 years of Native American habitation influenced the ecology of these islands (Orr 1962; Johnson et al. 2000), the relatively brief tenure of browsing and grazing animals introduced through ranching activities from the mid-1800s through 2015 dramatically altered the trajectory of vegetation in the park today (Rick et al. 2014; McEachern et al. 2016).



Figure 1. Map of Channel Islands National Park. NPS

Long-term monitoring is a critical component of environmental science because it is inexpensive compared to the value of the resources it protects and management it guides, and the data can inform interdisciplinary ecological inquiries (Lovett et al. 2007). A formal long-term terrestrial vegetation

monitoring program was initiated at CHIS in 1984 when 54 transects were established across SB, AN, and SM to monitor the dominant island vegetation communities using a line-point intercept method (Halvorson et al. 1988; McEachern 2001). Given the degraded state of vegetation on the islands at the time, these “legacy” transects were placed where native vegetation remained rather than randomly across the landscape. In subsequent years, shrub- and tree-based monitoring protocols were added (McEachern 2000). After the park acquired SR in 1990 and the eastern parts of SC in 1999 and 2001, an additional 86 and 43 transects were established, respectively. The remaining portion (western 76%) of SC is owned and managed by The Nature Conservancy (TNC) and is not included in the park’s long-term vegetation monitoring program.

The Mediterranean Coast Network (MEDN) Inventory and Monitoring (I&M) Division was created in 2000, when long-term terrestrial vegetation monitoring became one of the network’s 15 ‘Vital Signs’ programs (Cameron et al. 2005). Beginning in 2012, improvements to the original monitoring protocol corrected deficiencies to improve the underlying statistical framework. These improvements included (1) adding probabilistically selected transects and (2) transitioning from monitoring all original legacy transects annually to a rotating panel design, in which a core set of transects are visited annually (hereafter, “core” transects), with each of the remaining transects assigned to one of four panels that are visited on a four-year rotating schedule (hereafter, “panel” transects). Both core and panel transects consist of a combination of legacy and probabilistically selected sites. These changes to the framework resulted in a loss of some statistical power to detect interannual variability at legacy transects, but they expanded spatial coverage and provided statistical inference to the islands as a whole. The modified program was then expanded to the two other parks within the MEDN—Santa Monica Mountains National Recreation Area and Cabrillo National Monument. See Tiszler et al. (2016a) for a detailed review of changes to the monitoring program.

This report summarizes the terrestrial vegetation monitoring data collected at CHIS in 2019. The cursory analyses and interpretation provided here are intended as a brief overview of the program’s activities in 2019 rather than a thorough analysis of long-term trends and covariates in the vegetation data. Interpretations are guided primarily by inter-island variation in climate and physiography as well as the history of browsing and grazing by introduced animals.

Methods

Monitoring Dates

The seasonality of monitoring can be an important variable that affects the data collected. California's Mediterranean-type climate is characterized by cool wet winters and warm dry summers, a pattern that drives much of the phenological variation in the state's vegetation, including at CHIS. The optimal period for terrestrial vegetation monitoring at CHIS is between mid-February and early June. The 2019 field schedule fit within this period (Table 1).

Table 1. Field schedule for vegetation monitoring at Channel Islands National Park in 2019. Counts of transects surveyed by island and by core/panel are included, as are the number of transects for which the shrub and tree protocols were implemented.

Island	Dates Visited	No. Transects				
		Total	Core	Panel C	Shrub Protocol	Tree Protocol
Anacapa	04/03	3	2	1	1	0
Santa Barbara	02/12–02/25	17	8	9	10	0
Santa Cruz	03/12–04/01	32	17	15	20	9
San Miguel	06/05–06/11	13	6	7	11	0
Santa Rosa	04/10–05/27	67	34	33	51	8
Total (all islands)	n/a	132	67	65	93	17

Transect Locations

The transects monitored in 2019 consisted of a combination of legacy sites used in the past for early vegetation research, plus a set of modern transects installed specifically to monitor long-term changes in the park's vegetation. Legacy transects were deliberately placed in areas with intact native vegetation, whereas modern transects were placed using a generalized random tessellation stratified survey design (GRTS; Olsen et al. 2012) to achieve a spatially balanced probabilistic sample that allows inference to each entire island, and the park portion of SC. A statistically appropriate analysis would need to take into account this difference in placement of legacy (non-random) versus modern (probabilistic) transects. However, for the purpose of summarizing the 2019 data for this annual report, the data are treated as a simple random sample. A total of 132 transects were surveyed (Figure 2), including 67 designated as core transects and 65 as panel (Table 1). All transects scheduled for 2019 were completed at SB, SC, and SM. Due to logistical constraints, 11 transects were not visited at AN (E004, E304, M002, M003, M300, M306, W002, W005, W006, W301, W314), and one transect at SR (082) was inadvertently skipped.

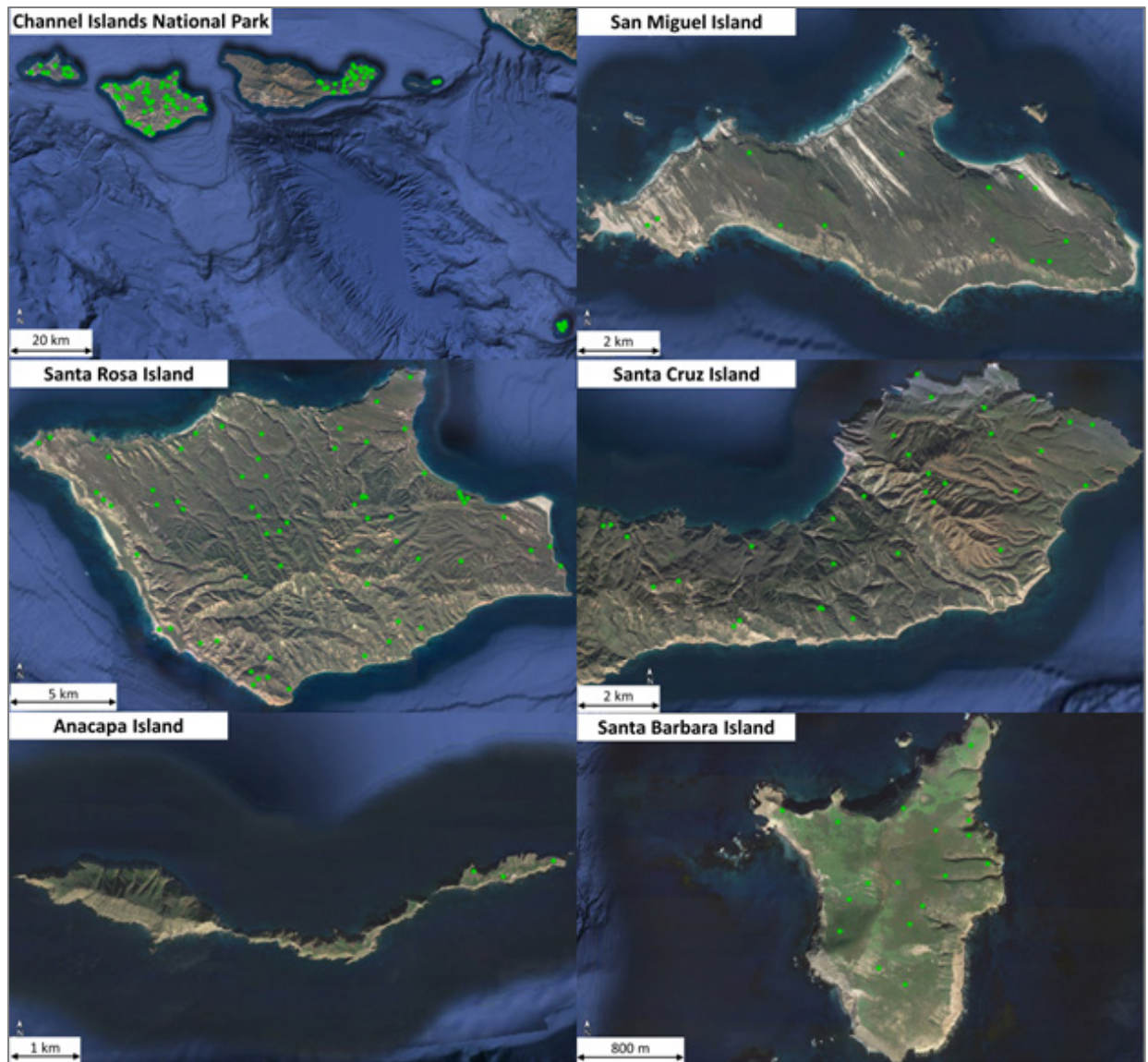


Figure 2. Locations of 132 vegetation monitoring transects surveyed in 2019 across five islands in Channel Islands National Park.

Field Data Collection

A standard operating procedure (SOP) that describes the methods that were used to conduct this vegetation monitoring includes a foliar cover measurement, a species richness count, a shrub density measurement, and a tree density measurement (Tiszler et al. 2016b). Each were referred to as ‘protocols’ in the CHIS legacy vegetation monitoring handbook (Halvorson et al. 1988) and in a USGS report on tree and shrub monitoring (McEachern 2000).

For the foliar cover measurement, a meter tape was stretched between two monument stakes that mark the ends of a transect (Figure 3), and data were recorded every 30 cm along the meter tape using a line-point intercept method. The data recorded at each point were the plant taxa present (both live and, for perennial species, dead tissue) and the height of the tallest vegetation. Each transect was

30 m in length and provided 100 points of data, except for three legacy transects at SB, two of which were 39 m and one 22 m. Differences in transect length were reconciled during the data analysis (see below).

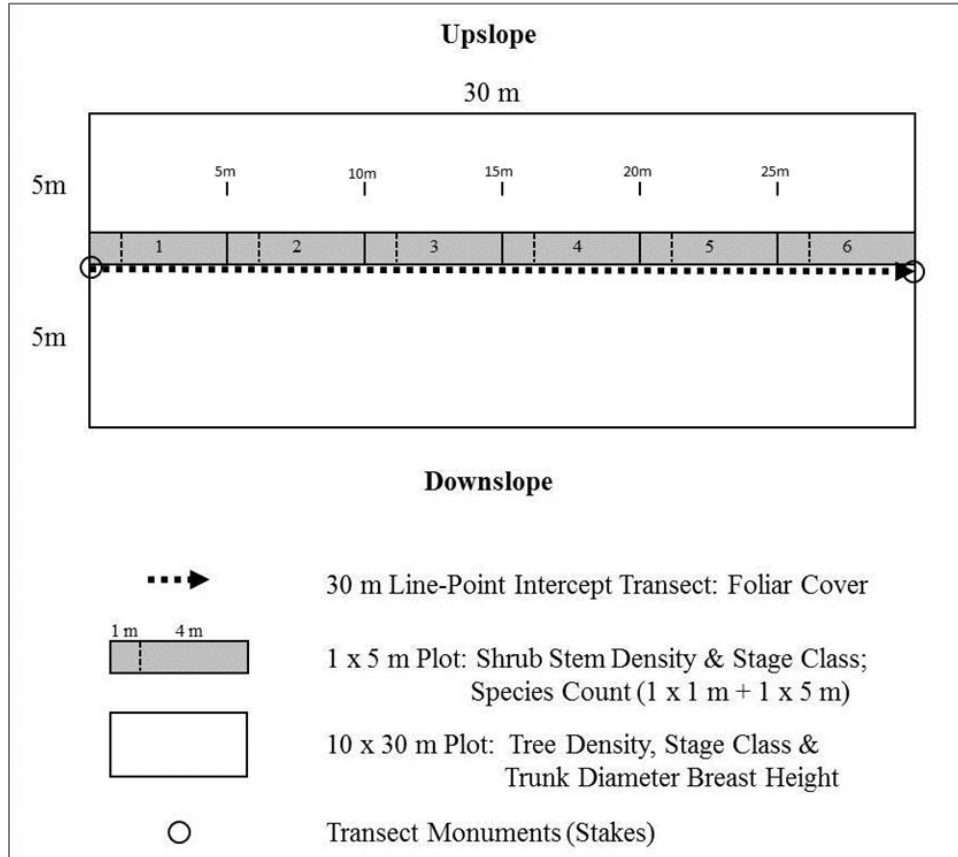


Figure 3. Schematic diagram of a 30-m transect with shrub and tree plots (Tiszler et al. 2016b).

The species richness count captured richness at three different spatial levels: (1) taxa encountered using the line-point intercept method, (2) taxa occurring within a 1-m plot adjacent to the transect line that were not already recorded by the line-point intercept method, and (3) taxa occurring within a 5-m plot adjacent to the transect line that were not already recorded by 1 or 2 above. Importantly, this last spatial level, implemented starting in 2016, represents a departure from the SOP, which described a 10-m wide plot centered on the 30-m line-point intercept transect (Tiszler et al. 2016b).

The density of shrubs, when present, was measured if they were not measured in the previous year. A 1-m $\times$ 30-m plot was placed adjacent to the transect line, divided into six 1-m $\times$ 5-m sub-plots, and the number of individuals present within each sub-plot was counted (Figure 3). Four developmental stages—seedling, juvenile, live adult, and dead adult—were recorded. Importantly, two departures from the SOP occurred. First, the number of individuals, not the number of stems per shrub, was counted. Second, resprouts were not included as a developmental stage. These two departures from the shrub protocol were consistent with past surveys.

In tree-dominated communities, tree density was measured within a 10-m $\times$ 30-m plot centered on the 30-m line-point intercept transect with half of the plot on the uphill side of the transect line and the other half on the downhill side (Figure 3). Within the plot, tree species were recorded in five categories: seedlings, juveniles, live adults, dead adults, and basal resprouts. For the live adult stage, diameter at breast height was also measured.

Data from the foliar cover measurements and species richness counts were recorded directly into an iPad via a FileMaker (version Pro; Claris International 2019) graphical user interface customized for the MEDN long-term vegetation monitoring program. Data files were then shuttled into a Microsoft Access (version 365; Microsoft Corporation 2021a) database maintained by the MEDN I&M data manager. Shrub and tree density measurements were recorded onto paper datasheets and subsequently entered directly into the database.

Precipitation Records

Long-term precipitation records from the park islands are incomplete, so a complete rainfall dataset (1957–present) was retrieved from Station 168 (Ventura County Public Works Agency 2020) located near Oxnard, California to represent the timing and relative quantity of rainfall received by the park as a whole. Annual precipitation from Station 168 was based on water years extending from October to September.

Data Management and Analysis

After fieldwork, all data were quality assured (QA) and quality controlled (QC) by the park botanist. The database was then queried to export summaries of the QA and QC data to Microsoft Excel (version 365; Microsoft Corporation 2021b) as an intermediate step in the workflow. All quantitative analyses were subsequently performed in R (R Core Team 2022) in which community indicators such as vegetation height, cover, and density were calculated along with species richness, evenness, and diversity.

To allow frequency data collected for the foliar cover measurement to be comparable across transects of different length, they were converted to absolute cover by summing across each transect the number of taxa recorded at each point and then dividing that sum by the total number of points. A logarithmic regression model was then used to explore the relationship between precipitation and absolute cover.

Species richness is defined as the number of species in a given area. Included in species richness were taxa encountered during the foliar cover measurement plus any additional species registered within the 1-m $\times$ 30-m belt to improve representation of infrequent taxa, since data from line-point intercept transects typically underestimate infrequent species (Dethier et al. 1993). Species evenness, a measure of relative dominance among species (Smith and Wilson 1996), was represented by Pielou's J (Pielou 1966) for each transect, using Equation 1:

$$J = H' / H'_{max}$$

in which H'_{max} is the maximum possible value of H' , the Shannon index, calculated as follows in Equation 2:

$$H' = - \sum_{i=1}^s P_i \ln P_i$$

(McCune and Grace 2002), where s is the number of species and P_i is the proportion of the entire population or sample made up of species i ; in other words, the number of individuals of species i divided by the total number of individuals across all species within the population or sample. Pielou's J ranges from 0 to 1 and is highest when all species have equal abundance.

Statistical distributions of vegetation height and cover, shrub density, and each of the three diversity indices were checked for normality via Shapiro-Wilk tests. Normally distributed data were compared among islands using ANOVA and then between pairs of islands using Tukey's honestly significant difference (HSD) test. Non-normally distributed data were compared using Kruskal–Wallis tests (Kruskal and Wallis 1952), followed by Conover-Iman tests of multiple comparisons (Conover and Iman 1979). Although all pairwise comparisons between islands were tested for differences, only those that were significant are reported below.

Results and Interpretation

Data from all 132 transects visited in 2019 were included in the analyses. The results and interpretations that follow emphasize among-year relationships between vegetation cover and annual precipitation, as well as among-island comparisons of vegetation height and cover, woody plant density, and diversity indices, but these results and interpretations may have been different if more of the transects scheduled at AN were included. Overall, the data suggest that moisture availability is a strong driver of the rate of vegetation recovery.

Vegetation Height and Cover

The long-term vegetation monitoring data from CHIS has historically portrayed a positive relationship between precipitation and the mean number of ‘hits’ per transect (e.g., Rodriguez 2021), which for a given transect is the sum of the species richness recorded at each point along that transect (Tiszler et al. 2016a). For example, the 2012–2016 California drought, which may have been the driest four years of the previous 1,200 (Dong et al. 2019), manifested as a dip in the mean number of hits per transect during those years (Rodriguez and Williams 2022). A similar pattern emerged when analyzing the data through 2019—absolute cover was positively correlated with annual rainfall (Figure 4). This analysis also revealed an apparent long-term decline in absolute cover, but caution is urged in this interpretation because legacy versus probabilistic transect data would be more appropriate to analyze separately.

Transects that captured the tallest vegetation were at SC and SR, which harbored several tree-dominated communities that were statistical outliers responsible for the non-normality of vegetation height data for these two islands (Figure 5). Vegetation was taller at SC and SR than at AN and SB (Conover-Iman tests, $p < 0.018$ for each of the four pairwise comparisons). The high density of trees in the oak woodland, Torrey pine, and mixed woodland communities supported the tallest canopies, whereas the shortest community was caliche scrub at 2.5 cm tall (Table 2). Caliche soils are thought to restrict root development leading to short-statured vegetation (Buss et al. 2020).

Total plant cover and the cover of perennial and native taxa can help evaluate the condition of the park’s vegetation after years of ranching, as the removal of nonnative herbivores has resulted in substantial natural recovery on the islands (Beltran et al. 2014; Willis et al. 2018; Thomson et al. 2022). Important environmental variables influential to vegetation recovery at the park include land-use history, hydrology, geology, and soil types (McEachern et al. 2016; Schoenherr et al. 2003).

Plant cover comparisons (Figure 6) revealed that total plant cover was higher at SB and SR than AN (Conover-Iman test, $p \leq 0.004$ for each comparison), and also higher at SB and SR than SC ($p < 0.001$). Perennial plant cover was higher at SR, SM, and SC than SB ($p \leq 0.006$), and native plant cover was higher at SR than AN and SB ($p \leq 0.017$).

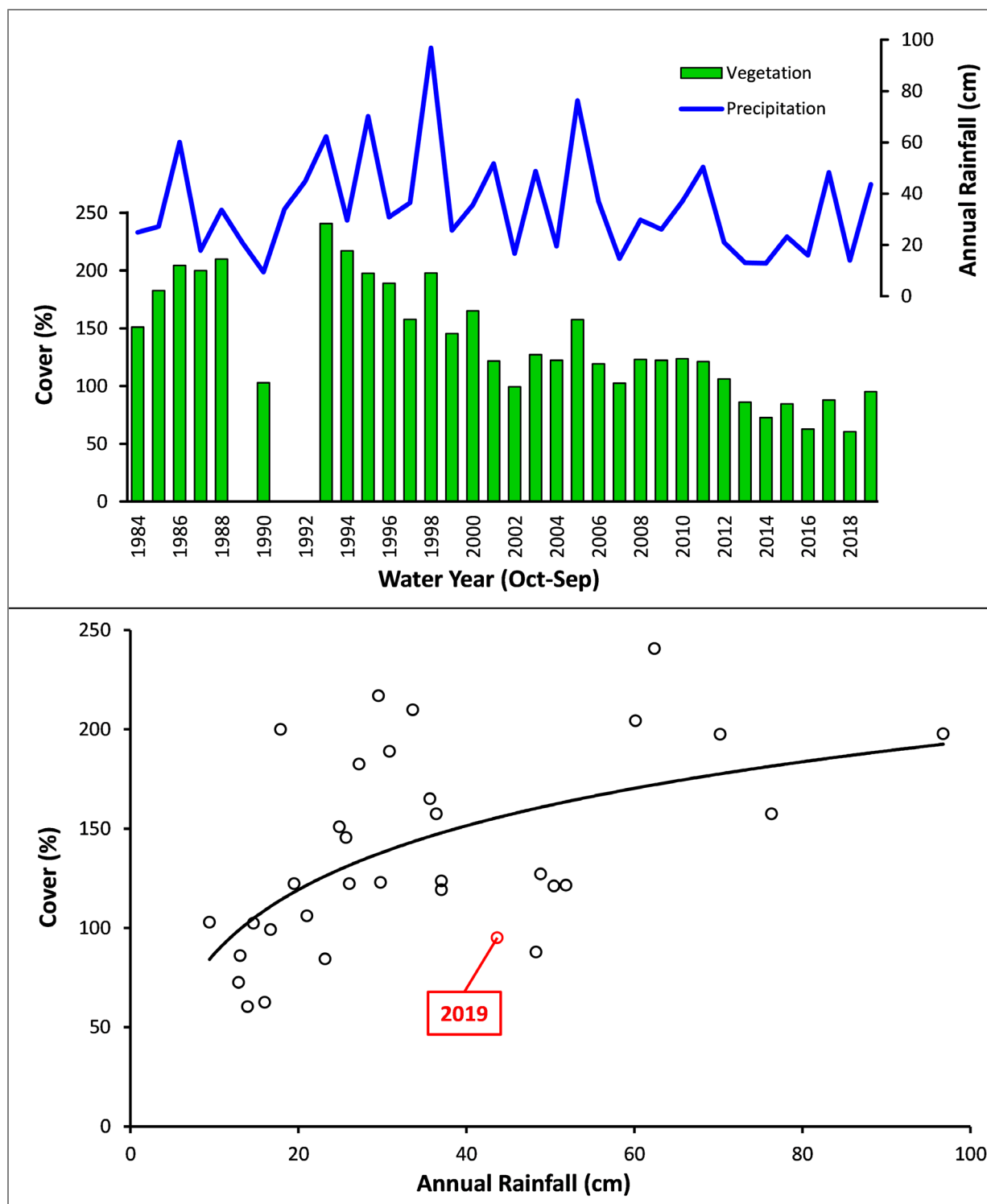


Figure 4. Relationships between annual rainfall and absolute vegetation cover, 1984 to 2019. Upper panel: Percent vegetation cover since 1984, compared to annual rainfall retrieved from Station 168 (Ventura County Public Works Agency 2020) near Oxnard, California. Vegetation data were not collected in 1989, 1991, or 1992. Lower panel: Positive correlation between annual rainfall and absolute cover of vegetation. Data were fit to a logarithmic regression model: $y = 46.47 \ln(x) - 19.95$; ($R^2 = 0.30$).

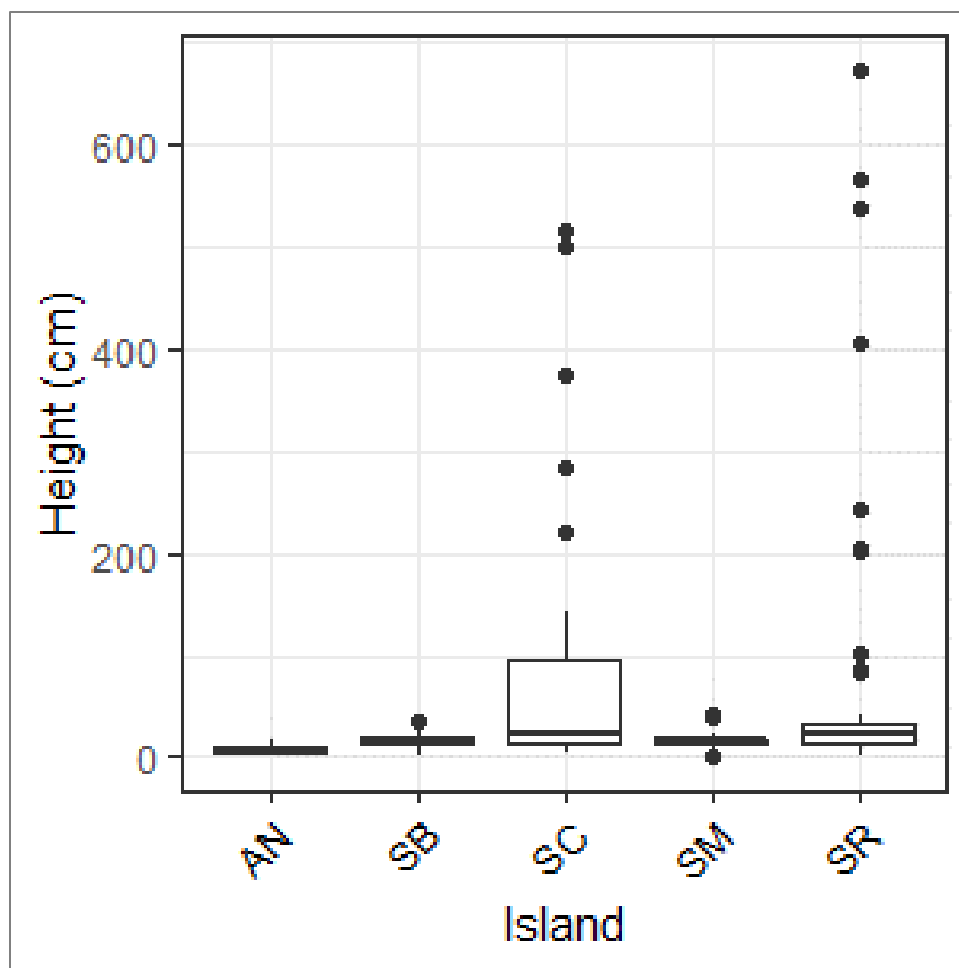


Figure 5. Boxplot illustrating vegetation height compared among islands for 132 transects surveyed at Channel Islands National Park in 2019. Values include unvegetated points recorded as 0 cm height.

Table 2. Vegetation height and count of transects surveyed within each community at Channel Islands National Park in 2019. Values include unvegetated points recorded as 0 cm height.

Community	Mean canopy height (cm)	Transect (count)
<i>Baccharis</i> Scrub	26.5	12
Barren	5.2	1
Boxthorn Scrub	23.1	2
Caliche Scrub	2.5	4
Coastal Bluff Scrub	5.6	2
Coastal Marsh	28.5	1
Coastal Sage Scrub	28.3	15
Coastal Scrub	10.9	9
Coastal Strand	9.5	1
Coreopsis Scrub	22.1	6
Fennel	18.6	1

Table 2 (continued). Vegetation height and count of transects surveyed within each community at Channel Islands National Park in 2019. Values include unvegetated points recorded as 0 cm height.

Community	Mean canopy height (cm)	Transect (count)
Herbaceous Scrub (generic)	8.1	4
Island Chaparral	81.4	9
Lupine Scrub	14.4	3
<i>Lyonothamnus</i> Grove	241.2	1
Mixed Woodland	349.7	4
Oak Woodland	526.6	3
Riparian	16.1	3
Santa Cruz Island Pine	86.0	1
Seablite Scrub	15.5	5
Seacliff Scrub	2.7	1
Shrub Savannah	13.2	2
Torrey Pine Woodland	426.6	3
Valley/Foothill Grassland	24.8	38
Valley/Foothill Grassland - perennial	29.7	1

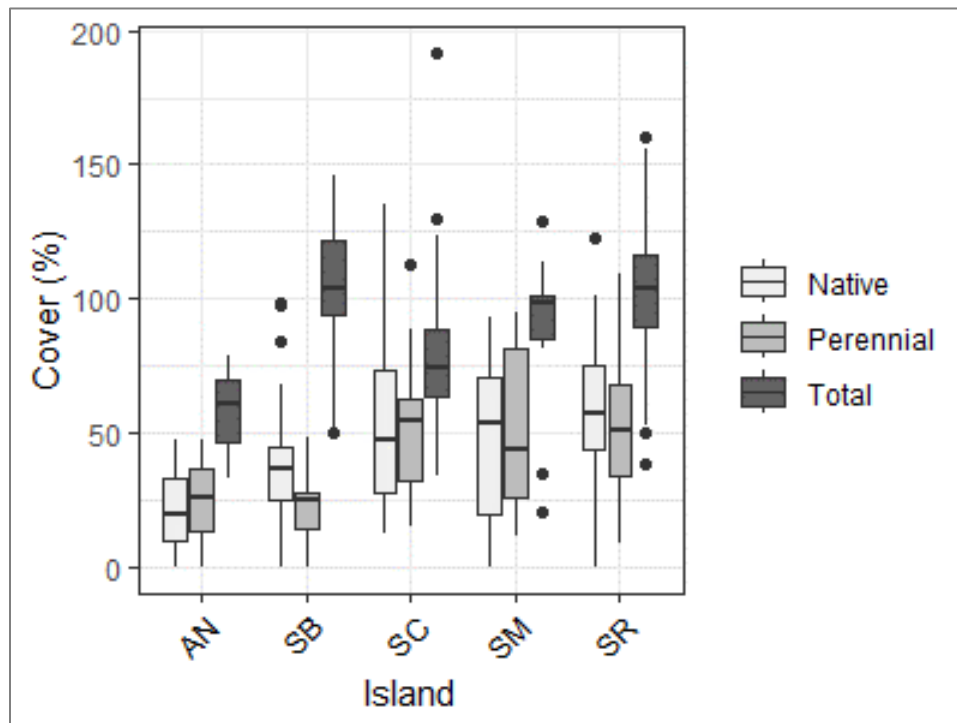


Figure 6. Boxplot illustrating percent cover of vegetation by nativity and longevity compared among islands for transects surveyed at Channel Islands National Park in 2019. “Total” includes native, nonnative, annual, and perennial plants.

The most striking result from this cover analysis was SB's high total cover relative to its low native and perennial cover. This result reflects a large proportion of nonnative and annual plants, and suggests that SB's recovery after browser/grazer removal could be slow compared to SC, SR, and SM. The thin and clayey soils of SB may resist community change away from domination by nonnative annuals (McEachern et al. 2016), and its southeasterly position receives less annual precipitation than the northern four islands (20 versus 40+ cm), which may also play a role in recovery. For example, the nonnative species *Hordeum murinum* (foxtail grass) and *Mesembryanthemum crystallinum* (crystalline iceplant) may switch dominance with the native shrub *Suaeda californica* (seablite) in patterns that are related to climate (Davidson et al. 2019).

On the other hand, SB and AN support the largest nesting seabird colonies in the park. Santa Barbara Island's higher total cover relative to more northerly AN may reflect occupation of AN by a higher density of seabirds that are known to harvest plant material, including woody stems as well as forbs and grasses, to construct nests (U.S. Fish and Wildlife Service 1983). The higher cover of native and perennial vegetation at more northwesterly positions likely reflects a faster rate of woody vegetation recovery on these wetter islands. Low moisture availability at more southeasterly islands likely interacts with seabird abundance at AN, and a combination of seabirds and soils at SB to further slow vegetation recovery.

Shrub and Tree Density

The transition in land use from Native American habitation to animal ranching in the early 1800s resulted in a substantial reduction of woody and succulent plant communities, and the conversion of native shrubland to nonnative grassland and bare ground was particularly widespread (McEachern et al. 2016; Davidson et al. 2019). Comparing the density of woody vegetation among islands can inform rates of recovery after removal of the ranched and feral animals. In 2019, the shrub protocol was implemented at 93 transects (Table 1). Among the four developmental stages considered, the highest shrub density at any individual transect was an outlying 109 seedlings/m² (Table 3), but the large variation in seedling density among transects yielded no significant differences between islands for this developmental stage. However, the density of juveniles at SM was higher than SB and SR (Conover-Iman test, $p \leq 0.007$ for each comparison), and the density of adults was higher at SC, SR and SM than SB ($p \leq 0.017$). These results point toward a higher rate of woody plant recovery for the more northwesterly islands and may be attributable to favorable moisture conditions, consistent with the observation that north-facing slopes tend to be most amenable to vegetation recovery after the removal of ranched animals (Davidson et al. 2019). The tree protocol was implemented for nine transects at SC and eight at SR (Table 1), a sample size that was deemed too small to warrant a comparative analysis of tree density for a single year. This, combined with the high variability in tree density and basal area among transects and communities, renders these data better suited for an analysis of trends over the longer term.

Table 3. Mean and maximum (max) shrub densities (count/m²) by developmental stage compared among islands. Minimum shrub densities were all zero.

Island	Seedling		Juvenile		Adult		Dead	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Anacapa	0.00	0.00	0.00	0.00	0.01	0.03	0.00	0.00
Santa Barbara	0.11	1.41	0.00	0.00	0.14	1.83	0.03	0.13
Santa Cruz	7.38	109.23	0.18	5.30	0.91	8.33	0.20	2.20
San Miguel	0.04	0.40	0.11	1.10	0.86	2.43	0.24	0.90
Santa Rosa	1.08	23.40	0.00	0.00	1.13	8.93	0.17	0.73

Species Richness, Diversity, and Evenness

Species composition exerts a strong influence over susceptibility to invasion by nonnative plants (Hooper et al. 2005), and ecosystem productivity and stability are positively correlated with species richness, species evenness, and Shannon diversity (e.g., Naeem et al. 1994; Wilsey and Potvin 2000; Tilman et al. 2006). Therefore, diversity indices compared among plant communities can be useful tools in evaluating community and ecosystem recovery after environmental degradation, such as that caused by intensive browsing or overgrazing.

At CHIS in 2019, the most species-rich plant communities were at SR, with one transect in a *Lyonothamnus* grove supporting 29 taxa, and transects within *Baccharis* scrub, caliche scrub, and mixed woodland each supporting a mean of 25 taxa (Figure 7). Communities supporting the fewest taxa included coastal strand and seacliff scrub with just three taxa each, and fennel with five taxa. The highest proportions of native species were found in the *Lyonothamnus* grove and Torrey pine woodland communities, whereas the smallest proportions were in barren, seablite scrub, and valley/foothill grassland communities. The lack of statistical replication for many of these communities constrains interpretation. However, seablite scrub ($n = 5$) and valley/foothill grassland ($n = 38$) had consistently low proportions of absolute cover and native richness, respectively, as well as relatively low overall richness. These communities may have been more susceptible to browsing/grazing in the past and are currently resistant to passive recovery; both communities could benefit from targeted restoration efforts. Island chapparral ($n = 9$) and mixed woodland ($n = 4$), which exhibited higher ratios of native to nonnative species, may represent the other end of this spectrum.

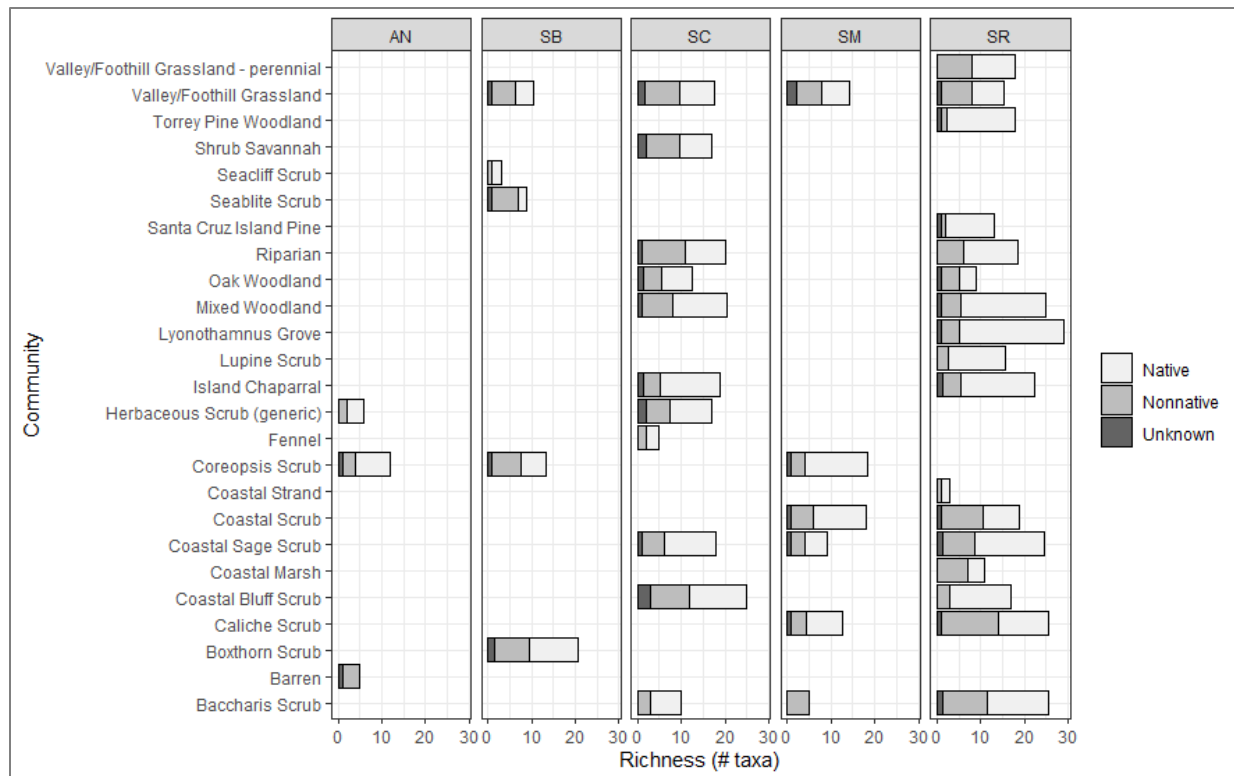


Figure 7. Richness of native and nonnative plants by community compared among islands for monitoring transects visited in 2019. “Unknown” refers to species that could be native or nonnative because they were identified to genus-level taxonomic resolution.

Significant differences in species richness, species evenness, and Shannon diversity were detected among islands (Figure 8). Santa Rosa Island supported significantly higher species richness than SB (19 versus 11 taxa; Tukey’s HSD, $p < 0.001$). Species evenness was higher at SC (0.79) and SR (0.73) than at AN (0.55) and SB (0.65) (Conover-Iman test, $p \leq 0.016$ for each comparison). Species evenness was also higher at SC than SR ($p = 0.008$). Shannon diversity was higher at SR (1.68) than SB (1.27; Tukey’s HSD, $p = 0.044$). Collectively, these diversity indices point toward a broader trend of decreasing ecosystem productivity and stability at drier more southeasterly islands. In particular, SB’s consistently low species diversity indices suggest that this most southeasterly and driest island in the park may be the most resistant to recovery. High species richness is consistently associated with resistance to invasion by nonnative species in part because a range of species responses to environmental disturbance can stabilize ecosystem processes (Hooper et al. 2005). Indeed, although SB yielded the highest total cover (Figure 6), the largest proportional contribution was from nonnative species (Figure 7).

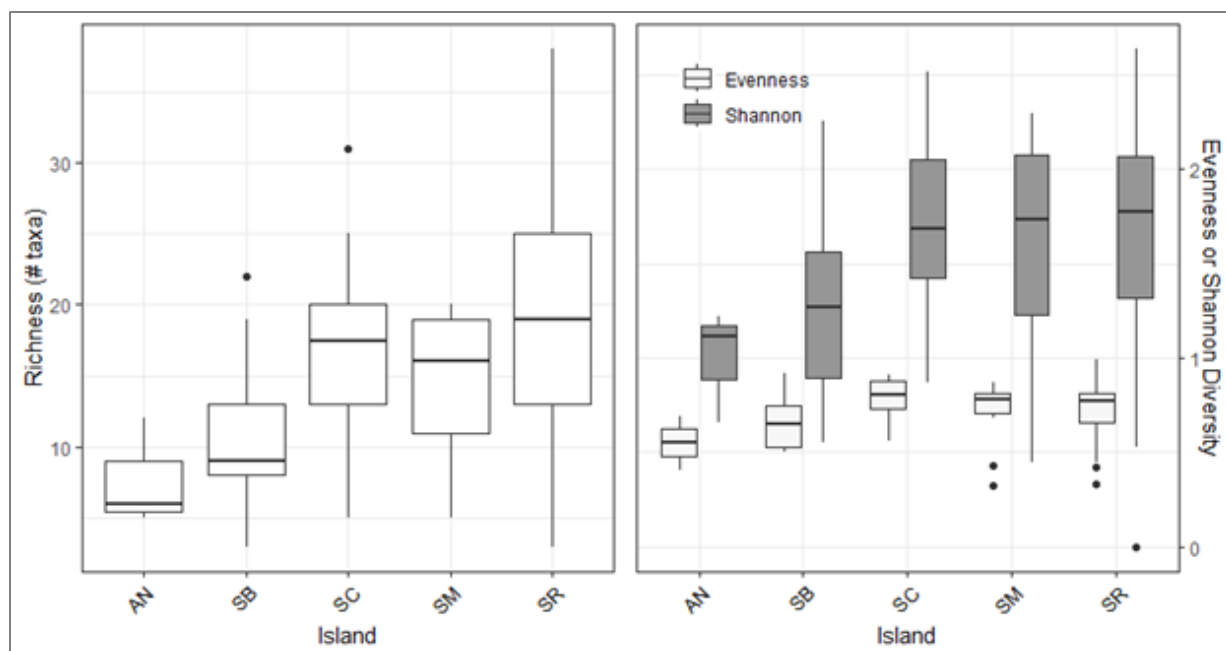


Figure 8. Boxplots illustrating indices of biodiversity compared among islands, for vegetation monitoring year 2019.

Conclusions

Vegetation monitoring data collected from 132 out of the 144 transects scheduled for 2019 spanned all five park islands and included 25 different vegetation communities. A long-term decline in overall vegetation cover appeared starting in the mid-1990s, and the data from 2019 were consistent with this apparent trend. Absolute cover has been positively correlated with annual rainfall since vegetation monitoring began at the park in 1984. Mean vegetation height was tallest at SC and SR owing to tree species forming the canopies of oak woodland, Torrey pine, and mixed woodland communities found on those islands. The relatively high percent cover of native and perennial vegetation in more northwesterly parts of the park likely reflects a faster rate of woody vegetation recovery after browser and grazer removal on these wetter islands. Conversely, moisture limitation at more southeasterly islands may interact with seabird abundance at AN, and a combination of seabirds and soils at SB, to further slow vegetation recovery. Although few transects harbored shrub seedlings when visited in 2019, the densities of juvenile and adult shrubs were highest at more northwesterly islands, which may be attributable to favorable moisture conditions and indicative of a higher rate of vegetation recovery. Islands at more northwesterly positions tended to support higher species richness, evenness, and Shannon diversity, consistent with a pattern of decreasing ecosystem productivity and stability at drier southeasterly islands. In particular, SB's consistently low indices suggest that this most southeasterly and driest island in the park may be the most resistant to recovery. These results together suggest that moisture availability is a strong driver of the rate of vegetation recovery and indicate that SB may benefit most from targeted restoration efforts.

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