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Charting The Winds of Fate: Exploring the Role of Wind Stress as a Driver of Coastal Sage Scrub Plant Community Assemblage

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UCSB Library Award for Undergraduate Research Reflective Essay

Schuyler Capita

Out of high school, I entered UCSB as a bright-eyed philosophy major, dead set on pursuing a legal path. Looking back, it seems inconceivable that less than four years later, I would be graduating as an environmental studies major who had fallen head-over-heels in love with research.

My first exposure to research came assisting the D'Antonio Lab with *Carpobrotus edulis* (ice plant) removal at Dangermond Preserve—unbeknownst to me then, the future site of my own project. That led me to the Anderegg Lab, where I religiously signed up for pre-dawn data collection at Sedgwick Preserve and soaked up as much information as I could. By senior year, I realized I was finally primed to conduct independent research, aiming to publish a manuscript as the ultimate capstone to my academic career.

Having established myself as an aspiring phytologist with a propensity for pattern recognition, I was determined to take a crack at explaining a previously unknown component of landscape ecology. Growing up sailing competitively, and being repeatedly regaled by my parents' stories of anchoring off Point Conception and battling chronic winds, I had firsthand appreciation for the raw power of wind. Still, it took weeks of mulling over the literature until I finally arrived at my "aha moment": virtually no research was looking into how wind stress impacts plant community assemblage. I had finally found the perfect question.

The UCSB Library has been nothing less than invaluable throughout this process. My housemates even made it an inside joke to photograph me collapsed over my laptop at the second-floor mountain-side tables—posting them to our bulletin board à la spaghetti western wanted posters. But the truth is, I am never more productive than when I'm at the library. The DREAM Lab let me process spatial data in ArcGIS with efficiency that I simply couldn't have achieved otherwise. Library access to JSTOR, ProQuest, and countless other academic repositories enabled me to dive into the scholarly literature essential for building my background and framing my hypotheses. As bluntly as I can put it, without the library's journal access, my research would never have gotten off the ground in the first place.

Beyond the purely academic, the library also gave me a chance to imbue heart and soul into my project. Through access to the Makerspace, I designed a cohesive, stylized "Anemone-Lobster" logo for my project—in addition to a vibrant, color-printed species ID guide—distributing commemorative pins to my field assistants and advisors. Although seemingly insignificant, I am certain that this helped build a true sense of community among my collaborators and gave my project a life and identity of its own.

In terms of methods and strategies for finding sources, I started with targeted keyword searches through the UCSB Library's portal. I then consulted the Earth, Environmental, and Geographic Sciences research guides to uncover specialized databases and journals that would otherwise have eluded me. I also relied heavily upon government datasets like the USDA SSURGO soils database and NOAA climatological records to strengthen my environmental

models, all accessible thanks to library resources. The curated field guides provided through the library were also indispensable for in-situ plant identification. However, in spite of all this assistance, my preliminary research plan didn't even survive first contact with the field.

After my initial preserve orientation, I had come to the painstaking realization that the vegetation shapefiles I was basing my site selections on were laughably inaccurate—what was labeled coastal sage scrub turned out to be degraded, inaccessible, or simply nonexistent. As a result, I completely restructured my methodology. I selected sites based on direct field observation, positioning my transects along a series of continuous northwest-facing hillsides to cleverly control for environmental variability and maximize my ability to isolate wind stress as a predictor. However, to put it lightly: challenges were abundant.

At the start, every day felt like a microcosm of all five stages of grief. I would call my partner like clockwork on the drive home, lamenting that I was "never going to be a scientist" and that all my work would amount to nothing. Early results were painstakingly slow, especially when shipment delays left me with fewer anemometers than planned. From flat tires, ticks, sunburns, and ultimately, the excruciating decision to drop soil moisture and salinity from my study when they yielded inconsistent results, data collection was a genuine 'struggle-fest'.

But through it all, upon repeated introspection, I realized that, ultimately, I kept going because I loved it. As Dostoyevsky wrote, humans are "extraordinarily, passionately, in love with suffering," and I finally grasped that in the field, cursing at myself for forgetting to pack enough flagging tape.

I evaluated my sources critically, prioritizing peer-reviewed journals, official government datasets, and institutionally credible media. In an area as understudied as wind-driven plant community assembly, I knew ensuring scientific rigor in my background literature was of the utmost importance. As such, I cross-referenced studies across different ecosystems—alpine, steppe, coastal—to hone and adapt existing theories to my novel coastal sage scrub context.

Reflecting on the past two quarters, I genuinely believe I've undergone more personal and intellectual development than in the rest of my academic career combined. As a first-generation college student, research demanded that I become self-sufficient in a way few other endeavors could. I had no immediate familial guidance on how to navigate experimental design, grant applications, or academia. The onus to seek out mentors, ask the right questions, and push through doubt fell squarely on my shoulders.

However, the biggest takeaway I've gleaned thus far from the research process is that scientific success isn't about brilliance, rather, it's about persistence and creativity in the face of adversity—failing, learning from it, and persevering nonetheless. Two years ago, I would have laughed at the notion of myself as a scientist. Today, I can't imagine a future being anything else.

Charting The Winds of Fate - Exploring the Role of Wind Stress as a Driver of Coastal Sage Scrub Plant Community Assemblage

A capstone research project by Schuyler Capita, 4th year undergraduate environmental studies major, expected graduation from the University of California, Santa Barbara June '25

1) Purpose:

It has been well documented that wind has tangible impacts on functional plant morphology, impacting myriad individual regulative functions, including evapotranspiration rate, assimilation, and growth.¹ However, previous studies investigating wind stress—a combination of wind speed and exposure—have primarily focused on treeline restriction and wind erosion with a spatial concentration in steppes and alpine ecosystems. As such, there is currently a stark gap in the literature on the impact of wind stress on plant community assemblage, structure and function in coastal ecosystems.² Although the environmental variables of fire, drought, and herbivory have all been explored extensively, thus far, there has been no research exploring the impact of wind stress on coastal sage scrub (CSS) plant community assemblage in particular.³ Also known as low chaparral, CSS is typified by chronic onshore wind exposure. This presents a unique research opportunity at the Jack and Laura Dangermond Preserve along Point Conception—the foremost headland along the California coastline—to analyze the impact of prevailing northwesterly wind stress on the CSS plant community. With rising temperatures continuing to alter global wind gradients, increasing both the frequency and intensity of extreme weather events, it has never been more important to understand how native plant communities and ecologically sensitive habitats—of which CSS is both—respond to these climatic shifts. Additionally, preservation of this ecosystem is essential both for buffering sea level rise, noting CSS's positive effects on erosion reduction, and the conservation of habitat for a high concentration of endangered, endemic species.^{4,5}

2) Objectives:

Site selection is ubiquitous in the environmental sciences, but collecting data in situ can be a laborious, error-prone, and time consuming process. If I am able to find that wind stress is a strong predictor of species distribution and richness, it could rapidly expedite data collection in applied and academic CSS restoration contexts. Furthermore, a more robust understanding of how wind stress impacts CSS will enable researchers to more accurately model and prepare for the impacts of climate change on remaining CSS stands.

3) Research Questions:

As such, my research questions stand as the following:

- I. Is wind stress a driver of coastal sage scrub community assemblage?
 - A. Across a landscape level spanning 10 continuous ridgelines?

¹ Coutts, M.P., Grace, J., 1995. Wind and Trees. Cambridge University Press, London, UK.

de Langre, E., 2008. Effects of wind on plants. Annual Review of Fluid Mechanics 40, 141e168.

² Momberg M, Hedding DW, Luoto M, le Roux PC. Exposing wind stress as a driver of fine-scale variation in plant communities. J Ecol. 2021; 109: 2121–2136.

³ Ibid.

⁴ Cox, R.D. and Allen, E.B. (2008), Stability of exotic annual grasses following restoration efforts in southern California coastal sage scrub. Journal of Applied Ecology, 45: 495-504.

⁵ Bowler, P. Ecological Restoration of Coastal Sage Scrub and Its Potential Role in Habitat Conservation Plans. Environmental Management 26 (Suppl 1), S85–S96 (2000).

B. Across a within-slope level from individual valley to peak?

II. Does wind stress impact community-level functional trait expression in coastal sage scrub?

III. How does wind stress compare in terms of predictive value with regards to existing community response variables (soil moisture, soil salinity, % cover, and solar irradiance)?

4) Site Description:

Point Conception is located within the Jack and Laura Dangermond Preserve, 24,346 acres of privately protected land owned and operated by The Nature Conservancy, in Lompoc, CA (Figure 1.). An exceptionally preserved vestige of native California coastal sage scrub ecosystem, Dangermond is a spatially unique laboratory—the most significant headland of the California coast, and the point at which it shifts directionality from North-South to East-West—resulting in high levels of floristic biodiversity and chronic wind stress alike.⁶ The latter of which typifies the site, with consistently high wind speeds of **15-25 knots (7-13 m/s)** blowing from an overwhelming prevailing northwesterly direction (Figure 7.).⁷

5) Methods of Data Collection:

I will be collecting data on multiple community composition variables across a **2.5 km** global transect spanning **10** continuous **400-600 m** hillsides of coastal sage scrub (Figure 2.). At each hillside, in situ surveys will be conducted across **3** nested **100 m** local transects along the ridgeline, midslope, and upper-toe of the windward slopes, oriented perpendicular to the northwest-facing (**270°**) aspect, holding elevation constant across individual transects and standardizing site aspect and orientation across the topographically variable replicates (Figure 3.). Transects will be laid out using chaining pins to secure a **100 m** open reel tape measure, physically denoting transect start and end points with marking flags—which will be promptly removed following the conclusion of my data collection window—in addition to recording GPS coordinates on ArcGIS Fieldmaps. Percent (%) cover data and maximum species height will be collected every **5 m** across the **30** transects, sampled within a **0.5 m²** plot, oscillating quadrat position relative to the transect (upslope/downslope) every collection interval (Figure 8.). Volumetric water content (VWC) and bulk electrical conductivity (EC) data will be collected every **20 m** along the **30** transects, consisting of **5** randomly distributed samples aggregated within each **1 m²** plot, similarly oscillating quadrat position (Figure 8.). These variables will be sampled using a HandiTrase TDR Soilmoisture Meter and GroLine Soil Test Direct Soil Conductivity Tester respectively.

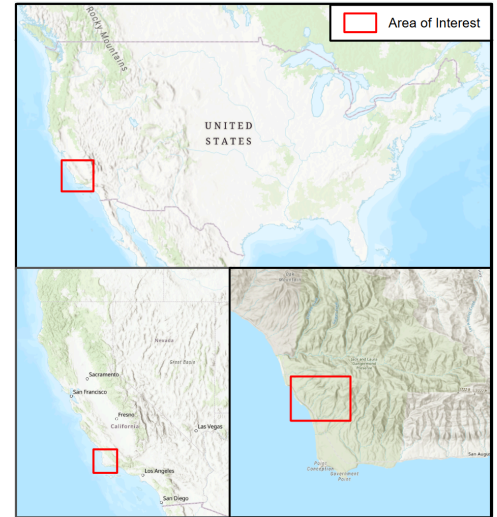


Figure 1. Site Location

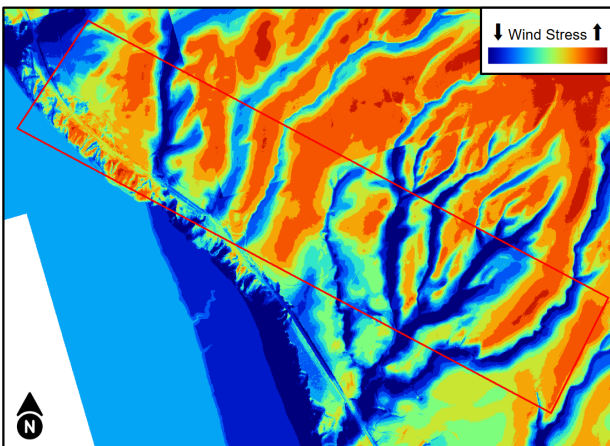


Figure 7. SAGA GIS Wind Stress Map

⁶ Preserve overview. Dangermond Preserve and Point Conception Institute. (n.d.).

⁷ Surfline\Wavetrak, Inc. (2024, November 4). PT Conception Marine Weather & Wind Forecast. Buoyweather.

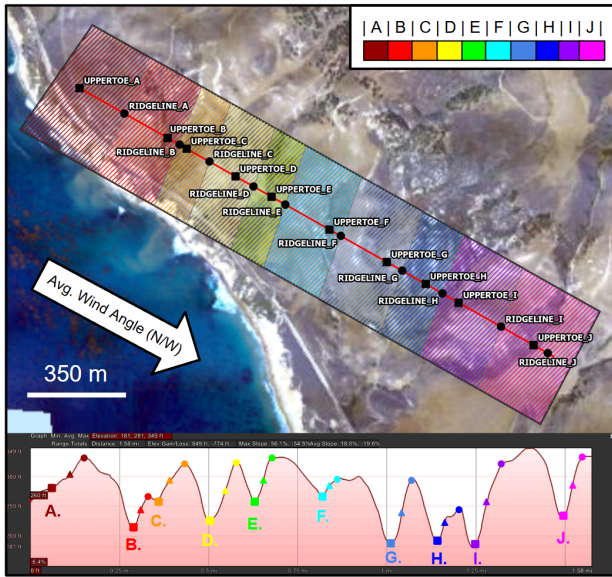


Figure 2. Broad Site Synopsis

The in-situ wind speed data will be combined with the **1 m** resolution USGS DSM to generate a fine-scale wind stress index using the SAGA GIS module. If said in-situ data is exceedingly variable in nature, I plan to fit said data to a scalar model in order to account for exactly how attenuated the wind is, generated using open source data from the UCSB North Beach Weather Station, located along the southern scope of my site range (-120.47099, 34.45675).⁸

The continuous site nesting was chosen to account for potential non-independence bias but still retain inter-plot environmental similarity by proxy of spatial autocorrelation, effectively holding soil type and geologic strata constant and

collecting data on all other potential environmental inputs to utilize sites (A-J) as replicates.

6) Methods of Analysis:

All of the previously listed community response variables will be analyzed through individual generalized additive models (GAMs), modeled against species richness—which will be calculated using both the Simpson and Shannon diversity indices to internally validate their respective outputs—in order to compare their

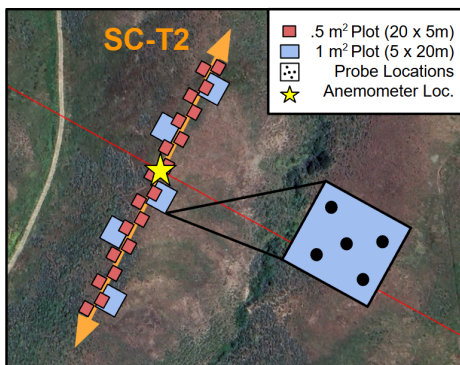


Figure 8. Sampling Protocol

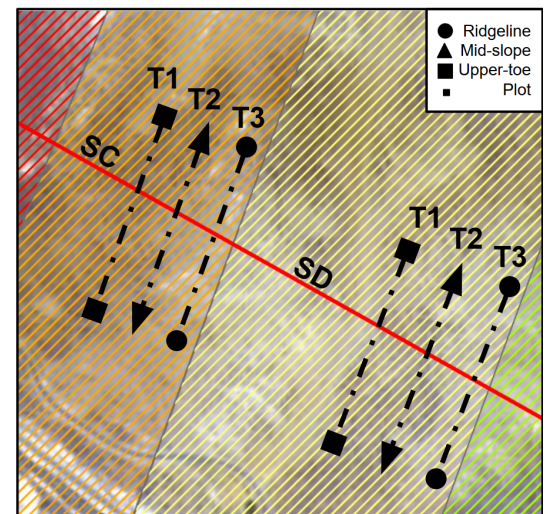


Figure 3. Sample Transects

⁸ National Science Foundation EarthCube. (n.d.). The Nature Conservancy - Dangermond_UCSB_North_Beach. Dendra.Science.

predictive value. Additionally, principal component analysis (PCA) models will be utilized to condense data while minimizing distortion between relationships. Variable importance will be further calculated and assessed using a linear mixed effects model, similarly composed of all community response variables

SITE	SHAN_DYN	SIMPSON_DIV	WS_SCALAR	WD_SCALAR	RICHNESS	EVENNESS	CWM_HEIGHT	SOLAR_EXP	ASPECT	WIND_STRESS	SLOPE
SA_T1	3.1219231	0.9457374399	0.5899044205	0.355620856	9	1.420848434	36.10615079	1333760.288	-1.613391	0.05579124956	0.189499
SA_T2	2.700098179	0.9259176027	0.5662836137	0.474076478	6	1.506953487	34.51727447	1297631.119	-1.485755	0.05195892457	0.286438
SA_T3	3.191595799	0.9522875817	1.044366327	0.39191004	8	1.534833144	23.58913043	1326863.345	-1.592164	0.1748672612	0.210407
SB_T1	3.146626874	0.9479233099	0.182950208	0.744922229	10	1.366562688	44.91959799	1260199.267	-1.686526	0.005406428623	0.393364
SB_T2	2.936549184	0.9374150298	0.240041203	0.557195904	7	1.509087758	34.31380338	1201928.621	-1.516134	0.009304264623	0.435489
SB_T3	3.20300681	0.9708502215	0.5415257487	0.735331266	7	1.646482399	28.62809917	1332265.452	-1.957563	0.0473677637	0.266124
SD_T1	2.840598209	0.9519140601	0.5152795475	0.863210858	6	1.585368046	42.35724332	1194761.147	-1.199046	0.04496628858	0.356037
SD_T2	3.044605211	0.9417849171	0.5993897123	0.692244756	7	1.554618085	32.39069767	1157161.588	-1.27399	0.06084428555	0.458147
SD_T3	3.185696968	0.9642445213	1.137527105	0.735455259	5	1.978384817	20	1250885.006	-1.325477	0.2191415562	0.317439
SE_T1	3.219733241	0.9482448778	0.2996562687	-0.667408463	12	1.295715974	39.88966203	1047660.926	-1.121314	0.02630479534	0.457707
SE_T2	3.10223825	0.9436060127	0.3429250215	0.022174374	9	1.411889473	39.12749004	1294266.318	-1.340177	0.003444978704	0.212638
SE_T3	2.802595246	0.9327365562	0.6906758431	0.256854577	6	1.564158189	34.22967033	1174793.776	-1.176092	0.01397498786	0.372385
SF_T1	3.206502425	0.9532148879	0.5448361417	0.902063503	8	1.542001716	41.02753108	1088885.819	-1.024838	0.03125640053	0.465375
SF_T2	2.96971828	0.9428013393	0.7352055469	0.923379611	6	1.65743133	46.63392857	1244422.903	-1.084613	0.05689400019	0.256248
SF_T3	3.243109435	0.9575095663	1.005299782	0.916614245	7	1.666674814	28.4040404	1304170.932	-1.162232	0.1063748389	0.176394
SG_T1	3.292912517	0.9566859757	0.4349380919	0.740824932	10	1.430093735	41.90207715	1074355.38	-1.40946	0.01141783104	0.619599
SG_T2	2.867638813	0.9332157399	0.724031586	0.065121982	8	1.379042813	36.6364513	1223891	-1.593417	0.03163979332	0.429979
SG_T3	3.051716075	0.9448740434	1.105339335	0.091863149	9	1.38889584	29.91203704	1313504.116	-1.603978	0.07374265929	0.254609
SH_T1	2.578297986	0.9171411215	0.8078421293	0.062141176	5	1.601986592	47.15308151	1220967.567	-1.13165	0.08990543218	0.272099
SH_T2	2.808579448	0.9355466296	0.9975248129	0.908815702	8	1.350541214	31.60739979	1107534.54	-1.258105	0.02400100117	0.529427
SH_T3	2.782204915	0.929848319	1.484590302	0.820422368	6	1.552778128	27.51125113	1190342.236	-1.327135		
SJ_T1	3.217197086	0.9546902737	0.4814086608	0.259430254	9	1.484209494	35.41965318	1091925.966	-1.384551		
SJ_T2	3.076175784	0.951730631	0.7367681186	0.732552097	5	1.911335479	29.05550146	1066829.644	-1.074435		
SJ_T3	2.946418001	0.9392303024	1.286048851	0.965993746	6	1.644427197	26.38810484	1249940.125	-1.193875		

Table 4. Model Datasheet

composition, abundance, and richness at both the fine-scale and landscape level. I will also be able to quantitatively testify to the role of wind stress as a driver of CWM traits, in addition to the predictive value of wind stress.

These results will be presented in the form of an academic manuscript intended for publication in a scientific journal, in addition to a poster to be presented at the 2025 UCSB URCA week, EEMB Undergraduate Research Symposium, Ecological Society of America annual conference, and American Geophysical Union annual meeting.

I anticipate my results to indicate one of two trends:

- I. Either wind stress acts as a selection buffer and facilitates lower species richness by proxy of filtering out less-resilient species,
- II. Or wind stress is a regulative variable that prevents disproportionate community assemblage.

I hypothesize that the former relationship will be

supported by my

data, in addition to

solar radiation,

height, moisture, and SLA peaking with low wind stress.

Inversely, I hypothesize that salinity and sapwood area will peak at high wind stress. I anticipate that the within-slope trend of wind stress being inversely correlated to species richness will be mirrored across the global transect, assuming wind shear and frictional drag are sufficiently impactful to drive observable differences in community assemblage (Figure 5.).

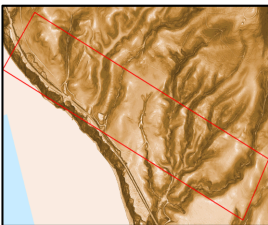


Figure 9. Slope

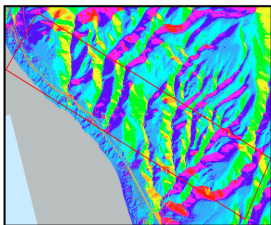


Figure 10. Aspect

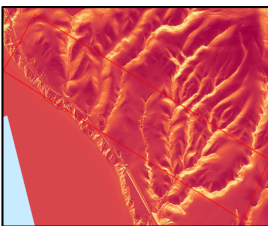


Figure 11. Solar Radiation

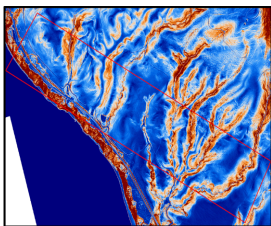


Figure 12. Terrain Ruggedness

modeled against species richness.

Community distribution will be further analyzed spatially using spatial autocorrelation, interpolation, habitat suitability and ecological niche models (MaxEnt).

7) Anticipated Results:

The aforementioned methods of analysis will enable me to make substantive conclusions regarding wind stress as a driver of community diversity,

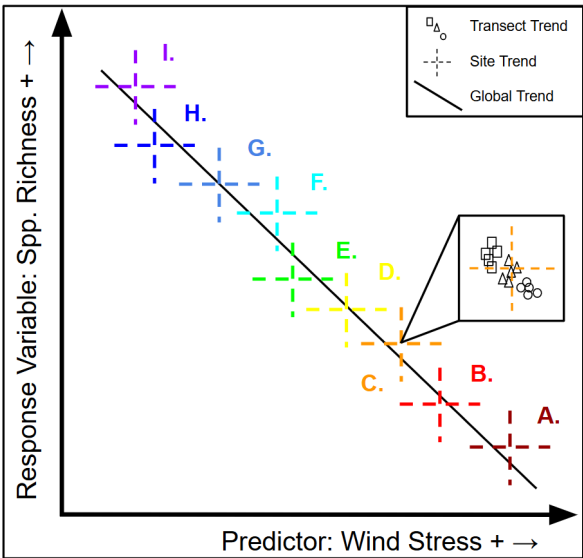


Figure 5. Hypothesized Outcomes

8) Larger Investigation:

I have sourced and am collaborating with an interdisciplinary team of UCSB advisors on the project, including the following members: Dr. Leander Anderegg, (EEMB|LEAF Lab), Dr. Amy Frazier (GEOG|SCALE Lab), Dr. Shane Dewees (ENVS|VEG Lab), Michael Burnett (EEMB|LEAF Lab), Izzy Lopez (GEOG|SCALE Lab), and Dr. Karly Miller (ENVS). I am able to leverage these partnerships with the LEAF, SCALE, and VEG labs to source specialized equipment and high-quality spatial data, offsetting budgetary costs and enriching research quality. Furthermore, noting the multitude of restoration projects actively taking place at the Preserve, there are numerous opportunities for further applied collaboration, both during and after my data collection window.

9) Funding:

This project is made possible thanks to the generous financial support of the Gene and Susan Lucas Undergraduate Research Fund, the Coastal Fund, and the Undergraduate Research and Creative Activity (URCA) Grant (Table 2.). Although unlikely, if the outstanding budget is deemed insufficient, supplemental funding will be pursued in the form of the following sources: The Garden Club of Santa Barbara Grants & Civic Projects Program, and the UCSB High Impact Project Proposal Program. Surplus funding in excess of current budgetary scope will be used to acquire more anemometers, increasing the amount of sites I can concurrently survey (noting practical spatial and temporal constraints), both expediting the data collection process and bolstering my statistical rigor.

Grant Supplier:	Amount:	Status:
Coastal Fund Minor Grant	\$964	Approved
GSL UG Research Fund	\$1,000	Approved
UCSB URCA Grant	\$746	Approved
CNPS Student Research Grant	\$1,000	Denied
CNPS CI Scholarship	\$1,500	Denied
UCSB Wenger Scholarship	\$2,000	Approved
Total Approved:	\$4,710	

Table 2. April 2025 Budget

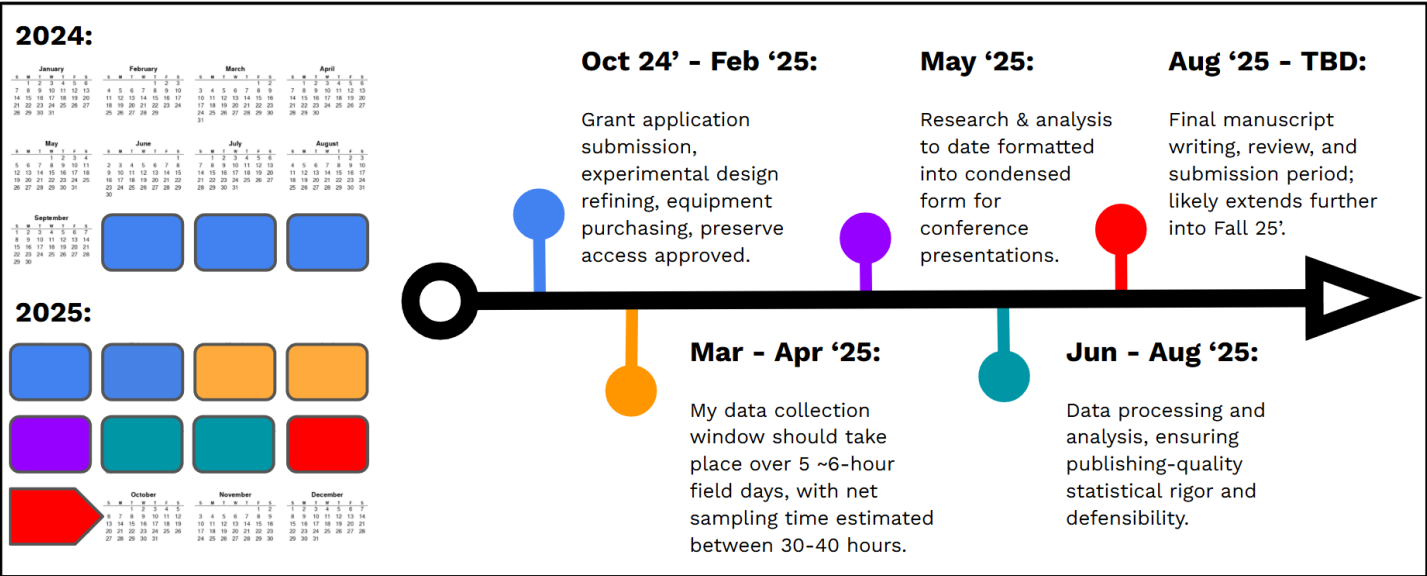


Figure 6. Project Timeline

10) Preliminary Results:

Out of the 10 initially identified hillsides, after concluding my preliminary sampling window, I ended up with 8 sites worth of localized wind speed, vegetation, and height data, electing to eschew using sites C and I—the former of which I deemed too small to garner any interesting results from, and the latter of which was simply too overgrown to access—as well as dropping the soil moisture and salinity measurements, both of which were exorbitantly time consuming and generating highly inconsistent results. Across all 24 transects, I identified 22 unique native species, aggregating invasive grasses as “BGP” (bare ground; plant). Early data analysis has shown that wind stress is weakly correlated ($r < 0.25$) to the majority of other predictor variables, indicating that collinearity is unlikely to be a major issue. Additionally, wind stress appears to negatively influence species richness and community weighted mean plant height at higher exposure levels, which strongly supports my hypothesis that wind is acting as a species filter.

SCIENTIFIC_NAME	COMMON_NAME	SPP_CODE
Baccharis pilularis	Coyote Brush	BAPJ
Artemisia californica	California Sagebrush	ARCA
Acemison glaber	Deerweed	ACGL
Solanum umbelliferum var. xanti	Purple nightshade	SOUM
Elymus condensatus	Giant Wild Rye	ELCO
Scrophularia californica	California bee plant	SCCA
Pseudognaphalium californicum	California Cudweed	PSCA
Isocoma menziesii	Menzies' G'oldenbush	ISME
Calystegia macrostegia	Coast morning glory	CAMA
Salvia mellifera	Black sage	SAME
Eriogonum parvifolium	Seacliff buckwheat	ERPA
Corethrogyne filaginifolia	California aster	COFI
Toxicodendron diversilobum	Pacific poison oak	TODI
Rhus integrifolia	Lemonade berry	RHIN
Galium nuttallii	San Diego bedstraw	GANU
Salvia spathecea	Hummingbird sage	SASP
Ribes speciosum	Fuchsiaflower Gooseberry	RISP
Encelia californica	California bush sunflower	ENCA
Marah fabacea	California manroot	MAFA
Eschscholzia californica	California poppy	ESCA
Rhamnus crocea	Spiny redberry	RHCR
Dipterostemon capitatus	Blue dicks	DICA
Sanicula arguta	Sharptooth sanicle	SAAR

Table 3. Observed Species List

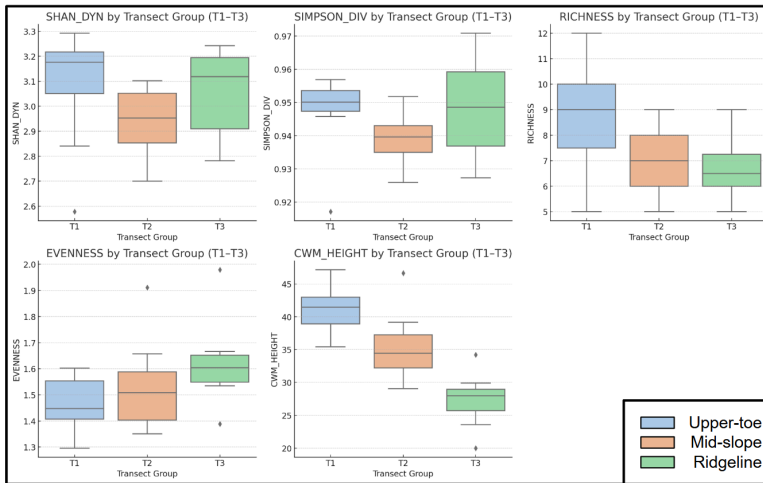


Figure 14. Transect Grouped Multivariate Model Results

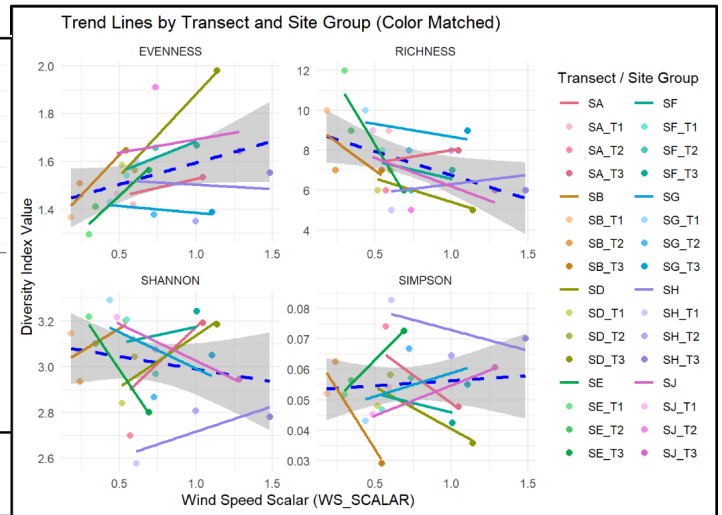


Figure 13. Wind Speed v. Diversity Metrics

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Schuyler Capita

Bibliography Style: APA 7th Edition

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