Status and Trends of the West Coast's Kelp Forests 2025

Reef Check Foundation
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This report is dedicated to the memory of Jim Wholey, whose extraordinary generosity and commitment made possible much of the long-term data presented here and helped build the knowledge needed to understand, steward, and protect our kelp forests for generations to come. We are deeply grateful to the entire Wholey family, whose generosity, volunteer service, and continued commitment to Reef Check carry forward a remarkable family legacy of ocean stewardship.

Acknowledgments

This report represents far more than 20 years of data. It represents two decades of commitment by a remarkable community of people and organizations who believed that understanding the health of our kelp forests requires sustained observation, collaboration, and stewardship. Reef Check's long-term monitoring program—from Baja California through California, Oregon, and Washington—would not exist without their support.

We are deeply grateful to the foundations, government agencies, institutions, and philanthropic partners that have invested in this work over the years. Supporters have included Resources Legacy Fund, the State of California, the California Ocean Protection Council, the California Department of Fish and Wildlife, California Sea Grant, the Washington Department of Fish and Wildlife, the Washington State Legislature, The Nature Conservancy, The Campbell Foundation, the Paul G. Allen Family Foundation, the Richard and Rhoda Goldman Fund, the Lisa and Douglas Goldman Fund, The Oregon Kelp Alliance, San Diego Foundation, Southern California Edison, Puget Sound Restoration Fund, Puget Sound Partnership, UC Santa Barbara's Coastal Fund, the Community Foundation of Mendocino County, Tides Foundation, Pacific Life Foundation, Patagonia, the Giles W. and Elise G. Mead Foundation, Code Blue Charitable Foundation, the Waitt Foundation, University of California partners, and many others.

We are equally grateful to the many individual donors whose generosity—whether through major gifts, family foundations, donor-advised funds, or contributions made year after year—has provided the continuity that long-term ecological monitoring requires.

We offer special thanks to the following individuals for their exceptional and sustained personal commitment to Reef Check and the long-term monitoring of West Coast kelp forests: Peter Fenton, Louise and Jim Wholey, Andrew Wadycki, Charlotte and Russ Lesser, Helen Brierley, Martha Briscoe, Bill McIlvene and Sue Chen.

Our work has also benefited enormously from the scientists, resource managers, Tribal partners, universities, conservation organizations, aquariums, dive shops, vessel operators, captains, instructors, and community partners who have shared expertise, equipment, vessels, facilities, local knowledge, and countless hours of collaboration. Their contributions have allowed Reef Check to expand monitoring geographically while ensuring that the information collected is useful to the communities and decision-makers working to understand and protect these ecosystems.

Most importantly, we thank the thousands of Reef Check volunteer divers who made this extraordinary dataset possible. Over two decades, they trained as citizen scientists, traveled to survey sites, boarded boats before dawn, carried tanks down beaches and cliffs, returned year after year to the same reefs, and in many cases contributed their own time and resources to participate. The value of their contribution cannot be measured simply in hours or dollars. Because of their dedication, we now have a long-term record of kelp forest ecosystems at a scale that would otherwise have been impossible to achieve.

To everyone who has contributed to this work over the past 20 years: this report—and the knowledge it makes possible—belongs to you as well. Thank you!

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Executive Summary

The Reef Check Kelp Forest Monitoring (KFM) Program completed its twentieth year of monitoring in 2025, marking two decades of standardized, community-based scientific kelp forest surveys across the West Coast of North America. Since the program began in California in 2006, Reef Check has expanded into Oregon, Washington, British Columbia, and Baja California, Mexico, creating one of the largest subtidal kelp forest monitoring datasets in the region. These surveys documented kelp, fish, invertebrate, and habitat conditions. To date, KFM Program encompasses a total of 233 sites, with 2,127 surveys completed since the program's inception.

During the 2025 field season, Reef Check completed surveys at 219 sites across seven regions while engaging a record number of 271 trained volunteer divers, who contributed 1,693 volunteer days to monitoring efforts.

Image E1: Reef Check volunteers and staff after the Kelp Program's completing the 2000th survey on August 8th, 2025.

West Coast Kelp Forest Health at a Glance

The 2025 monitoring season demonstrates both the resilience and vulnerability of West Coast kelp forests. While some ecosystems are stable, others remain in persistent, degraded states more than a decade after the 2014-16 marine heatwave. Continued long-term monitoring, paired with restoration, adaptive management, and strong community engagement, remains essential for understanding ecosystem change.

This report provides an assessment of kelp forest status by region. We do this in two ways: first, we compare the 2025 densities of fish, invertebrate and kelp species to the mean density in the years monitored before the heatwave. This provides an estimated percent change in 2025 relative to their historical pre-heatwave density. Second, we use a linear regression on the last five years of densities to identify more recent increases or declines. **Table E1** highlights species' status and trends for selected species across the monitoring regions.

Regional Highlights

Washington bull kelp populations have remained relatively stable over the four years of monitoring, although strong spatial differences persist among sub-basins. Green and purple sea urchins and sunflower sea stars have shown increasing trends, while the rest of the invertebrates have remained stable. Kelp greenling and brown rockfish also show significant increasing trends; other fish species seem stable.

Oregon continues to experience the effect of widespread kelp decline, with bull kelp now occurring at only a few monitored reefs. Active restoration efforts are now underway at several sites, providing an opportunity to evaluate restoration effectiveness through long-term monitoring. Most invertebrate and fish species have remained stable over the last five years. Of the common fish species, only striped perch show a significant decreasing trend.

Northern California remains the most severely impacted, with bull kelp persisting at only a handful of monitoring sites and purple urchin barrens continuing to dominate much of the coastline. Restoration sites, including Portuguese Beach and Caspar South, illustrate the potential for local recovery through sustained urchin removal and kelp restoration efforts. Several invertebrate indicator species, such as gumboot chiton, red abalone, crab species, and many sea stars have shown significant declines since the heatwave, but their populations have stabilized at these lower densities over the most recent years.

Central California presents a more heterogeneous picture. While most Monterey Peninsula, Carmel Bay, and Big Sur reefs are characterized by elevated purple urchin densities and low kelp densities, some continue to support productive giant kelp forests, while other areas have transitioned toward mixed giant kelp/bull kelp forests. Overall kelp density remains low with both giant kelp and some stipitate kelp showing a declining trend in the last five years.

Southern California generally exhibited more stable giant kelp forests than northern regions, although localized declines were observed around portions of Catalina Island, Palos Verdes, and San Diego. Purple urchin densities have declined in Southern California since the marine heatwave, though the invasive *Sargassum horneri* has continued to persist. Many kelp, invertebrate, and fish populations in Southern California have remained relatively stable over the past five years.

Reef Check Impact

Beyond ecological monitoring, Reef Check continues to serve as an important resource for marine science and management. The program supports academic research, kelp restoration planning and evaluation, environmental assessments, student education, Tribal stewardship, and public outreach. Reef Check data

has contributed to numerous peer-reviewed publications, government assessments, grey literature and scientific conferences.

This report summarizes standardized data from kelp forests across the West Coast of North America. Reef Check strives to provide scientifically accurate, long-term monitoring data to assess trends over time. Restoration, adaptive management, and strong community engagement remain essential for understanding ecosystem change, evaluating conservation actions, and supporting the recovery and resilience of kelp forests throughout the region.

Table E1: Status and recent trend of selected species in the respective monitoring regions. 2025 Status indicates the percent change in mean regional density compared to the long-term average pre-heatwave (2007-2013). 5-year Trend shows trends in species' regional density in the past five years (2021-2025). Up or down arrows indicate significant increase or declines (linear regression); horizontal arrow indicates no significant change in species density.

Species	Region	2025 Status	5-year Trend
 Bull Kelp	Washington	No historical data	→
	Oregon	No historical data	→
	Northern California	-99%	→
	Central California	+92%	→
	Southern California	Not present	Not present
 Giant Kelp	Washington	No historical data	↗
	Oregon	Not present	Not present
	Northern California	Not present	Not present
	Central California	-51%	↘
	Southern California	-8%	→
 Woody Kelp	Washington	No historical data	→
	Oregon	No historical data	→
	Northern California	-100%	→
	Central California	-51%	↘
	Southern California	-21%	→
 Purple Urchins	Washington	No historical data	↗
	Oregon	No historical data	→
	Northern California	+150 x	↗
	Central California	+210 x	↘
	Southern California	-82%	→
 Pinto Abalone Pinto Abalone Red Abalone Red Abalone Green Abalone	Washington	No historical data	→
	Oregon	No historical data	→
	Northern California	-97%	→
	Central California	-85%	↘
	Southern California	+7 x	→
 Sunflower Star	Washington	No historical data	↗
	Oregon	No historical data	→
	Northern California	-100%	→
	Central California	-100%	→
	Southern California	-100%	→
 Rockfish (all)	Washington	No historical data	↗
	Oregon	No historical data	→
	Northern California	+6%	→
	Central California	+38%	→
	Southern California	-95%	→

Introduction

Reef Check is a worldwide non-profit marine conservation organization that empowers local communities to monitor and manage reef health. Through rigorous, standardized training programs, Reef Check enables the collection of standardized reef health data on a global scale. Since its founding in 1996, Reef Check has operated in over 100 countries, has 40 active chapters, and a network of over 10,000 trained volunteers.

In 2006, Reef Check expanded its focus from monitoring tropical coral reefs to temperate kelp forests by launching its Kelp Forest Monitoring (KFM) program. Starting in California, the Reef Check protocol was originally developed by marine scientists to leverage trained volunteer divers in collecting standardized data on kelp forests inside and outside of Marine Protected Areas (MPAs) (Freiwald et al., 2026). This initial approach provided the dual benefit of generating monitoring data, specifically on MPAs, while also increasing public awareness and engagement with ocean conservation.

Due to its reputation for high-quality training and data collection, the Reef Check Kelp Forest Program has since expanded beyond California and MPA monitoring. In 2020, Reef Check completed its first surveys in Oregon and then continued to expand northward into Washington in 2021. Expansion continued into Baja California, Mexico in 2022 and British Columbia, Canada in 2023. The expansion of these surveys not only provides highly relevant and reliable data on a local scale but also provides the ability to track and compare kelp forest health across the West Coast using the same standardized protocol.

After 20 years of monitoring and the expansion into five other regions, this report will provide an overview of surveys completed in all regions and highlight results from the 2025 survey season across California, Oregon and Washington.

Reef Check Kelp Forest Program 2025 Overview

Monitoring Sites Summary

The number of Reef Check survey sites has been steadily increasing, starting with 19 surveys in 2006 to a total of 233 surveys in 2025 (**Figure 1**). Most sites are surveyed once per year, though some, especially sites associated with kelp forest restoration projects, are surveyed multiple times in different seasons. A total of 209 sites were surveyed. Seventeen additional sites were unable to be surveyed due to funding shortages, ocean conditions, or other issues. Over the past 20 years Reef Check has completed a total of 2,127 surveys documenting the state of the West Coast's kelp forests. Reef Check sites range from Bahía Asunción in Baja California, Mexico, to Howe Sound in British Columbia, Canada (**Figure 2**).

Summaries of surveys completed in 2025 are broken down into six regions: Washington (includes British Columbia), Oregon, Northern California, Central California, Southern California, and Baja California.

California's MPA network

Most Reef Check sites in California (117 out of 126) are associated with California's extensive network of MPAs (**Table 2**). In general, for each MPA, two sites are located inside the protected area, and two sites are located outside the protected area as reference sites. Reef Check's three regions in California (**Figure 2)** match California's bioregions as defined in the MPA Monitoring Action Plan (CDFW and OPC, 2018).

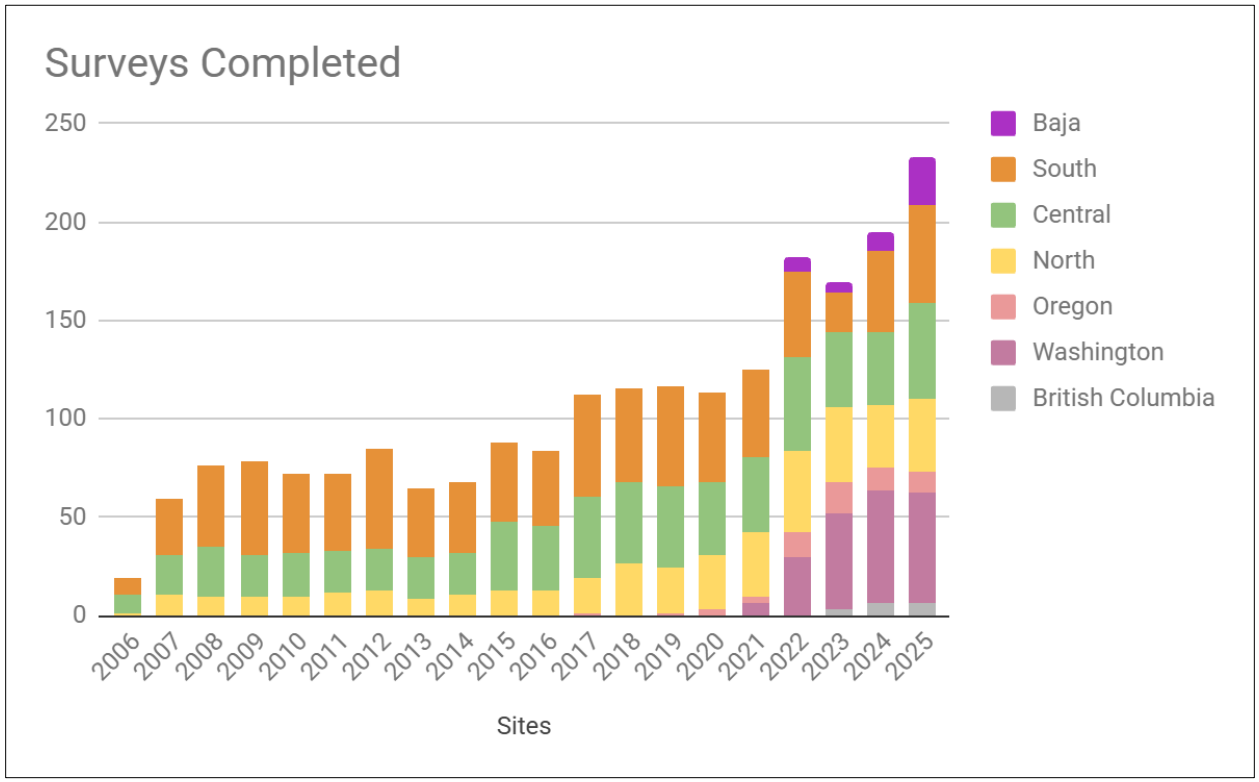

Figure 1. Number of Reef Check surveys completed by year across all regions.

Figure 2. Sites surveyed by Reef Check in 2025, and additional long-term monitoring sites that were not surveyed in 2025.

Table 2: Number of Reef Check sites associated with California Marine Protected Areas

Site	Number of sites associated with this reserve*	Number of sites completed in 2025
Abalone Cove SMCA	3	3
Anacapa Island SMCA	1	1
Anacapa Island SMR	4	4
Asilomar SMR	4	4
Big Creek SMR	4	4
Blue Cavern SMCA	7	7
Carmel Bay SMCA	5	5
Casino Point SMCA	1	1
Cat Harbor SMCA	2	2
Crystal Cove SMCA	2	2
Del Mar SMR	1	1
Edward F. Ricketts SMCA	3	3
Farnsworth Onshore SMCA	3	3
Gerstle Cove SMR	3	3
Greyhound Rock SMCA	1	1
Laguna Beach SMR	4	4
Long Point SMR	3	3
Lovers Point SMR	2	2
MacKerricher SMCA	2	2
Matlahuayl SMR	3	3
Montara SMR	4	4
Naples SMCA	1	1
Pacific Grove Marine Gardens SMCA	2	2
Point Arena SMR	4	0
Point Buchon SMR	4	4
Point Cabrillo SMR	3	3
Point Dume SMCA	2	1
Point Dume SMR	3	2
Point Lobos SMR	4	4
Point Sur SMR	5	5
Point Vicente SMCA	4	4
Pyramid Point SMCA	1	0
Russian Gulch SMCA	2	2
Salt Point SMCA	2	2
Skunk Point SMR	2	0
South La Jolla SMR	4	3
South Point SMR	2	0
Van Damme SMCA	2	2
White Rock SMCA	4	4
Scorpion SMR	4	3
Total	**117**	**104**

*Includes both "MPA" sites inside the MPA and "reference" sites located outside of the MPA

Washington and British Columbia

A total of 63 surveys at 61 sites were completed in Washington and British Columbia in 2025 (**Table 3**). Survey sites were distributed throughout the Salish Sea (**Figure 3**). Six surveys were completed in British Columbia on southern Vancouver Island and in Howe Sound. A total of 992 fish transects covering 59,520 m^2 and 373 swath transects covering 22,380 m^2 were surveyed across the two countries. Temperature loggers are located at two sites, and an additional 14 sites have larger sensor arrays and are monitored by Puget Sound Restoration Fund's Eyes on Kelp initiative.

Table 3: List of Reef Check sites in British Columbia and Washington surveyed in 2025.

Site	Latitude	Longitude	# of years surveyed	2025 Survey Date(s)	# of fish transects	# of swath transects	Temp logger
British Columbia							
Christie Islet	49.499183	-123.303283	1	09/02/2025	6	6	n/a
South Bowyer Island	49.416183	-123.268550	1	09/02/2025	4	4	n/a
Whytecliff Park	49.371154	-123.292206	2	09/01/2025	18	6	n/a
Spring Bay	48.456127	-123.268541	3	09/06/2025	18	6	n/a
Ogden Point	48.413383	-123.388055	3	09/05/2025	6	6	n/a
7751 Reef	48.365835	-123.783186	3	09/04/2025	6	6	n/a
Washington							
Point Whitehorn	48.896331	-122.795095	4	06/27/2025	20	6	n/a
Derelict Conveyor	48.855254	-122.730835	4	06/27/2025	18	6	n/a
Satellite Island	48.684762	-123.191924	2	09/26/2025	6	6	n/a
Lawrence Point	48.660480	-122.741701	3	08/28/2025	18	6	n/a
Reuben Tarte	48.612837	-123.097222	4	09/28/2025	19	6	n/a
Point Caution	48.563167	-123.025641	4	07/29/2025	12	4	n/a
South Shaw Island	48.548389	-122.953611	2	09/27/2025	6	6	n/a
Smallpox Bay	48.541072	-123.161846	4	09/26/2025	21	6	n/a
Reef Point	48.536839	-122.718458	3	09/12/2025	21	6	n/a
Deadmans Bay	48.512846	-123.147129	4	09/26/2025	20	6	n/a
Burrows Lighthouse	48.477268	-122.714451	4	08/27/2025	18	6	n/a
Eagle Cove	48.459734	-123.033258	3	09/27/2025	20	6	n/a
Cattle Point	48.451480	-122.961402	3	09/27/2025	21	6	n/a
Watmough Bay	48.431304	-122.803311	3	09/11/2025	20	6	n/a
Rosario Head	48.415477	-122.664770	4	08/03/2025	22	6	n/a
Smith Island	48.318961	-122.849565	3	08/01/2025	16	6	n/a
Sekiu Point	48.267782	-124.297828	3	08/09/2025	18	6	n/a
Clallam Bay West	48.256822	-124.275318	3	08/09/2025	19	6	n/a
Partridge Point	48.225837	-122.771572	4	06/21/2025	6	6	n/a
Ebeys Landing	48.183840	-122.700400	4	08/02/2025	18	6	n/a
Tongue Point	48.166808	-123.702363	3	08/08/2025	21	6	n/a
North Beach	48.144779	-122.778533	5	07/04/2025	18	6	n/a
Freshwater Bay	48.141606	-123.613191	5	08/04/2025	18	6	n/a
Lower Elwha	48.139640	-123.585069	2	08/17/2025	18	6	n/a
McCurdy Point	48.138791	-122.844791	4	07/06/2025	20	6	n/a

Table 3 (continued): List of Reef Check sites in British Columbia and Washington surveyed in 2025.

Site	Latitude	Longitude	# of years surveyed	2025 Survey Date(s)	# of fish transects	# of swath transects	Temp logger
Dallas Banks	48.133602	-122.934924	3	08/01/2025	19	6	n/a
Lowell Point	48.119417	-122.487037	5	10/11/2025	18	6	n/a
Green Point	48.118525	-123.315716	3	08/16/2025	18	6	n/a
South Hat Island	48.003363	-122.301536	4	10/10/2025	18	6	n/a
Foulweather Bluff	47.941083	-122.601200	4	09/25/2025	7	5	n/a
Possession Point	47.900050	-122.383133	3	10/09/2025	18	6	n/a
Edmonds Shell Creek	47.819549	-122.378380	5	07/12/2025	18	6	n/a
Jefferson Head	47.744509	-122.475293	4	07/08/2025	18	6	n/a
Pulali Point	47.735708	-122.854790	4	07/12/2025	20	6	n/a
Goby Gardens	47.631907	-122.941620	4	06/29/2025	20	6	n/a
Magnolia	47.631423	-122.401099	5	07/08/2025	18	6	n/a
Elliot Bay Marina	47.627001	-122.391019	2	01/28/2025 08/28/2025	12	12	n/a
Grain Terminal	47.624131	-122.369154	2	07/16/2025	18	6	n/a
Sirens of Spring	47.618148	-122.360893	2	01/27/2025 08/29/2025	12	12	n/a
Wing Point	47.615814	-122.488302	5	07/17/2025	18	6	n/a
Seattle Waterfront	47.608873	-122.349157	4	08/22/2025	6	6	n/a
Lincoln Park	47.536153	-122.397348	4	05/31/2025	18	6	n/a
Blake Island South	47.530490	-122.494980	4	07/18/2025	22	6	n/a
Point Vashon	47.512553	-122.473981	4	07/18/2025	18	6	n/a
Glen Acres	47.480050	-122.448455	3	07/19/2025	25	6	Serviced
Sund Rock	47.435996	-123.120220	4	06/13/2025	18	6	n/a
Saltwater State Park	47.372238	-122.327854	3	08/17/2025	19	6	n/a
Point Dalco	47.333519	-122.519126	3	07/20/2025	18	6	n/a
Owen Beach	47.317520	-122.533890	3	06/30/2025	18	6	n/a
Salmon Beach	47.296017	-122.531650	3	08/20/2025	6	6	n/a
Titlow Beach	47.246982	-122.555038	3	06/21/2025	18	6	n/a
Fox Island East Wall	47.228194	-122.589757	3	08/31/2025	18	6	n/a
Squaxin Island	47.167670	-122.895667	5	07/15/2025	6	6	n/a
Ketron Island	47.167661	-122.630570	4	08/31/2025	16	6	n/a
Devils Head	47.166934	-122.761201	4	08/30/2025	22	6	n/a

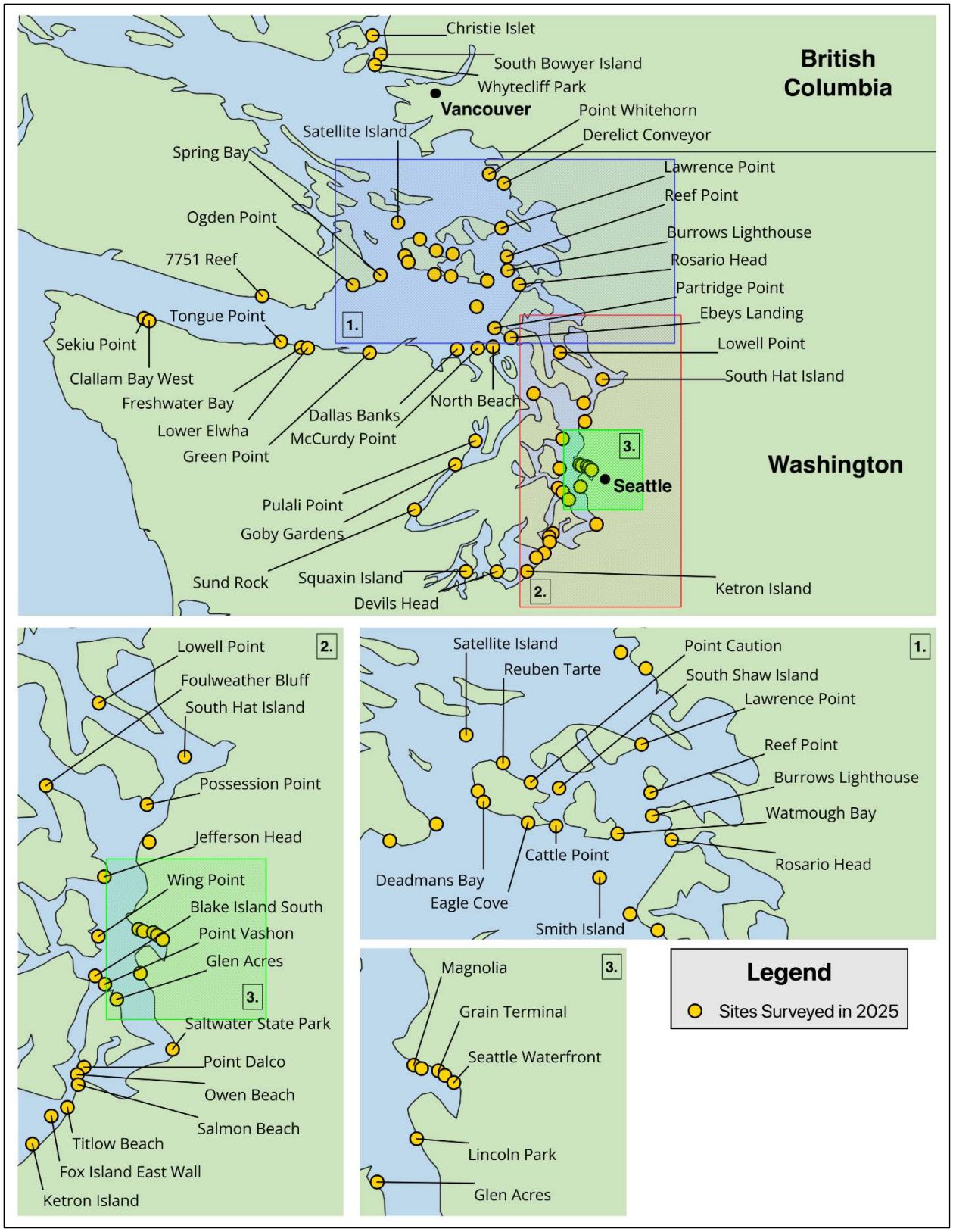

Figure 3. Reef Check sites surveyed in Washington and British Columbia in 2025.

Oregon

A total of 10 surveys at eight sites were completed in Oregon in 2025 (**Table 4**). Of the total survey sites, four were not surveyed in 2025. Survey sites were distributed along the coast, including a cluster of six sites just south of Port Orford (**Figure 4**). A total of 136 fish transects covering 8,160 m^2 and 133 swath transects covering 7,980 m^2 were surveyed. Temperature loggers are located at eight sites, and at two of the sites, data were retrieved in 2025. Restoration efforts have started at many of the long-term monitoring sites, including Nellies Cove West, Pacific City North, and Macklyn Restoration.

Table 4: List of Reef Check sites in Oregon.

Site	Latitude	Longitude	# of years surveyed	2025 Survey Date(s)	# of fish transects	# of swath transects	Temp logger
Pacific City North	45.212570	-123.985372	3	06/29/2025	12	12	Not serviced
Pacific City South	45.210957	-123.985950	2	07/02/2025	12	12	n/a
Simpson Reef	43.317669	-124.405347	2	Not Surveyed	n/a	n/a	n/a
Drake Point	43.300653	-124.399301	5	09/11/2025	6	6	Not serviced
Nellies Cove East	42.736500	-124.506300	5	04/25/2025 09/17/2025	36	36	Not serviced
Nellies Cove West	42.736140	-124.507640	5	04/19/2025 09/15/2025	38	36	Serviced
Redfish Kelp	42.704952	-124.470625	3	Not Surveyed	n/a	n/a	n/a
Redfish Rocks	42.698425	-124.472768	4	04/27/2025	6	6	Not serviced
Humbug	42.669244	-124.442982	3	Not Surveyed	n/a	n/a	Not serviced
Island Rock	42.665514	-124.475554	3	Not Surveyed	n/a	n/a	Not serviced
Macklyn Restoration	42.046206	-124.294438	2	09/13/2025	12	12	Serviced
Guano Rock	42.042610	-124.287750	2	07/24/2025	14	13	n/a

Figure 4. Reef Check sites surveyed in Oregon in 2025 and additional long-term monitoring sites that were not surveyed in 2025.

Northern California

A total of 37 surveys at 23 sites were completed in Northern California in 2025 (**Table 5**). Of the total survey sites, five were not surveyed in 2025. Survey sites were distributed between the California-Oregon border and Sonoma County (**Figure 5**). A total of 535 fish transects covering 32,100 m^2 and 231 swath transects covering 13,860 m^2 were surveyed. Temperature loggers are located at 13 sites, and at nine of the sites, data were retrieved in 2025.

Table 5: List of Reef Check sites in Northern California.

Site	Latitude	Longitude	# of years surveyed	2025 Survey Date(s)	# of fish transects	# of swath transects	Temp logger
Pyramid Point	41.994801	-124.217308	5	Not Surveyed	n/a	n/a	n/a
Trinidad	41.054240	-124.144680	10	09/08/2025	6	6	Not serviced
MacKerricher North	39.490631	-123.800503	7	08/28/2025	6	6	n/a
Glass Beach	39.451186	-123.815711	7	08/27/2025	6	6	n/a
Noyo North	39.429472	-123.813822	6	06/30/2025 10/15/2025	34	12	Serviced
Pomo Bluffs	39.429260	-123.812600	1	06/30/2025 10/15/2025	12	12	n/a
Noyo South	39.426910	-123.813190	8	07/09/2025 10/16/2025	36	12	n/a
Caspar North	39.364647	-123.822133	12	07/27/2025 10/11/2025	38	12	n/a
Caspar South	39.361729	-123.822449	14	04/25/2025 07/20/2025 10/11/2025	54	18	Serviced
Caspar South Restoration	39.361042	-123.821294	4	04/25/2025 07/27/2025 10/16/2025	9	9	n/a
Frolic Cove	39.355026	-123.823868	12	04/28/2025 07/19/2025 10/17/2025	54	18	Serviced
Russian Gulch	39.327984	-123.808800	12	06/28/2025	18	6	n/a
Mendocino Headlands	39.305283	-123.811218	17	08/29/2025	6	6	n/a
Portuguese Beach	39.302264	-123.803283	16	04/26/2025 07/26/2025 10/11/2025	55	18	Serviced
Big River	39.302230	-123.801980	1	05/19/2025 07/25/2025 10/10/2025	36	36	n/a
Van Damme	39.271915	-123.795914	19	06/29/2025	19	6	Not serviced
Dark Gulch	39.240300	-123.776150	5	07/16/2025	18	6	n/a
Albion Restoration	39.228300	-123.774400	5	07/24/2025	18	6	Not serviced
Point Arena Lighthouse	38.952272	-123.743086	6	Not Surveyed	n/a	n/a	n/a
Point Arena MPA	38.946169	-123.738950	9	Not Surveyed	n/a	n/a	n/a
Monument	38.928997	-123.733217	4	Not Surveyed	n/a	n/a	n/a
Point Arena Reference	38.908001	-123.719101	10	Not Surveyed	n/a	n/a	Not serviced
Pebble Beach	38.698219	-123.443249	10	08/24/2025	18	6	Serviced
Gerstle Cove	38.566460	-123.329964	20	08/23/2025	18	6	Serviced
Salt Point	38.564900	-123.329000	9	08/23/2025	18	6	n/a
Ocean Cove	38.555119	-123.305664	18	09/20/2025	19	6	Serviced
Stillwater Sonoma	38.545900	-123.299910	19	09/20/2025	18	6	Serviced
Fort Ross	38.510601	-123.245064	19	08/23/2025	19	6	Serviced

Figure 5. Maps of Reef Check sites surveyed in the Northern California Region in 2025 and additional long-term monitoring sites that were not surveyed in 2025.

Central California

A total of 49 surveys at 45 sites were completed in Central California in 2025 (**Table 6**). Survey sites were distributed between the Golden Gate Bridge and Point Conception (**Figure 6**). A total of 952 fish transects covering 57,120 m^2 and 342 swath transects covering 20,520 m^2 were surveyed. Temperature loggers are located at 29 sites, and at 26 of the sites, data were retrieved in 2025.

Table 6: List of Reef Check sites in Central California surveyed in 2025.

Site	Latitude	Longitude	# of years surveyed	2025 Survey Date(s)	# of fish transects	# of swath transects	Temp logger
Beach Street	37.524400	-122.525800	4	07/22/2025	24	6	n/a
Flat Rock	37.510010	-122.515560	6	07/23/2025	19	6	n/a
Half Moon Reef	37.486328	-122.490440	6	07/25/2025	23	6	n/a
Hurricane Ridge	37.470100	-122.479600	4	07/24/2025	20	6	n/a
Greyhound Rock	37.077791	-122.266187	1	10/08/2025	6	6	n/a
Coral Street	36.637158	-121.926308	20	06/06/2025	21	6	Serviced
Otter Cove	36.634933	-121.919952	20	06/07/2025	21	6	n/a
Asilomar	36.634560	-121.946260	7	06/07/2025	18	6	n/a
Lovers Point	36.625450	-121.911934	20	06/17/2025	19	6	Serviced
Hopkins	36.621710	-121.901381	20	06/20/2025	20	6	n/a
Aquarium	36.619232	-121.899414	19	06/17/2025	21	6	n/a
Spanish Bay	36.617458	-121.950179	10	08/10/2025	23	6	Serviced
McAbee	36.616679	-121.896871	20	06/27/2025	20	6	Serviced
Point Joe	36.610907	-121.966302	17	07/26/2025	24	6	Serviced
Breakwater	36.610451	-121.894333	20	05/22/2025 09/27/2025	40	12	n/a
Tankers Control	36.606691	-121.873057	5	06/14/2025 10/02/2025	36	36	n/a
Tankers Reef	36.604465	-121.880016	5	06/15/2025 09/23/2025	36	36	Serviced
Cypress Point	36.584581	-121.975877	4	08/09/2025	19	6	n/a
Pescadero	36.562302	-121.959602	20	07/18/2025	18	6	Serviced
Stillwater Monterey	36.560200	-121.945900	19	07/18/2025	21	6	Serviced
Copper Roof House	36.546620	-121.931180	2	07/25/2025	19	6	n/a
Carmel River	36.539082	-121.935097	18	08/30/2025	18	6	Serviced
Ribera	36.533870	-121.929350	1	08/31/2025	22	6	n/a
North Monastery	36.526806	-121.926544	18	08/23/2025	21	6	Serviced
South Monastery	36.525299	-121.931900	19	08/24/2025	19	6	Serviced
Middle Reef	36.521869	-121.938973	20	05/28/2025 09/25/2025	37	12	Serviced
Weston	36.511200	-121.946297	19	08/05/2025	18	6	n/a
Malpaso Creek	36.479980	-121.940047	11	08/29/2025	20	6	Serviced
Point Sur	36.288082	-121.892952	10	09/24/2025	21	6	Not serviced
Andrew Molera	36.278454	-121.880859	9	09/16/2025	20	6	Serviced
South Wreck	36.226425	-121.789062	11	09/16/2025	18	6	Serviced
Fullers	36.208107	-121.752167	8	08/27/2025	22	6	Not serviced
Big Sur Reef Restoration	36.205730	-121.746100	4	08/08/2025	18	6	Serviced
Esalen	36.125919	-121.647408	10	08/13/2025	18	6	n/a
Dolan	36.103851	-121.628128	11	08/14/2025	18	6	Serviced
Big Creek	36.068272	-121.601619	19	08/15/2025	18	6	Serviced
Lopez	36.030560	-121.580841	11	08/12/2025	8	6	Serviced

Table 6 (continued): List of Reef Check sites in Central California surveyed in 2025.

Site	Latitude	Longitude	# of years surveyed	2025 Survey Date(s)	# of fish transects	# of swath transects	Temp logger
Daddybob	35.538712	-121.098010	9	09/05/2025	20	6	Not serviced
White Rocks	35.527756	-121.085640	9	09/06/2025	21	6	Serviced
Harmony	35.500275	-121.054932	9	09/07/2025	20	6	Serviced
Estero	35.471779	-121.021248	10	09/04/2025	20	6	Serviced
Spooners Cove	35.281260	-120.893730	14	09/09/2025	22	6	Serviced
Corallina Cove	35.266670	-120.901940	5	09/11/2025	21	6	Serviced
Point Buchon	35.240650	-120.896300	12	09/08/2025	22	6	Serviced
Montana De Oro	35.231201	-120.885345	7	09/10/2025	22	6	Serviced

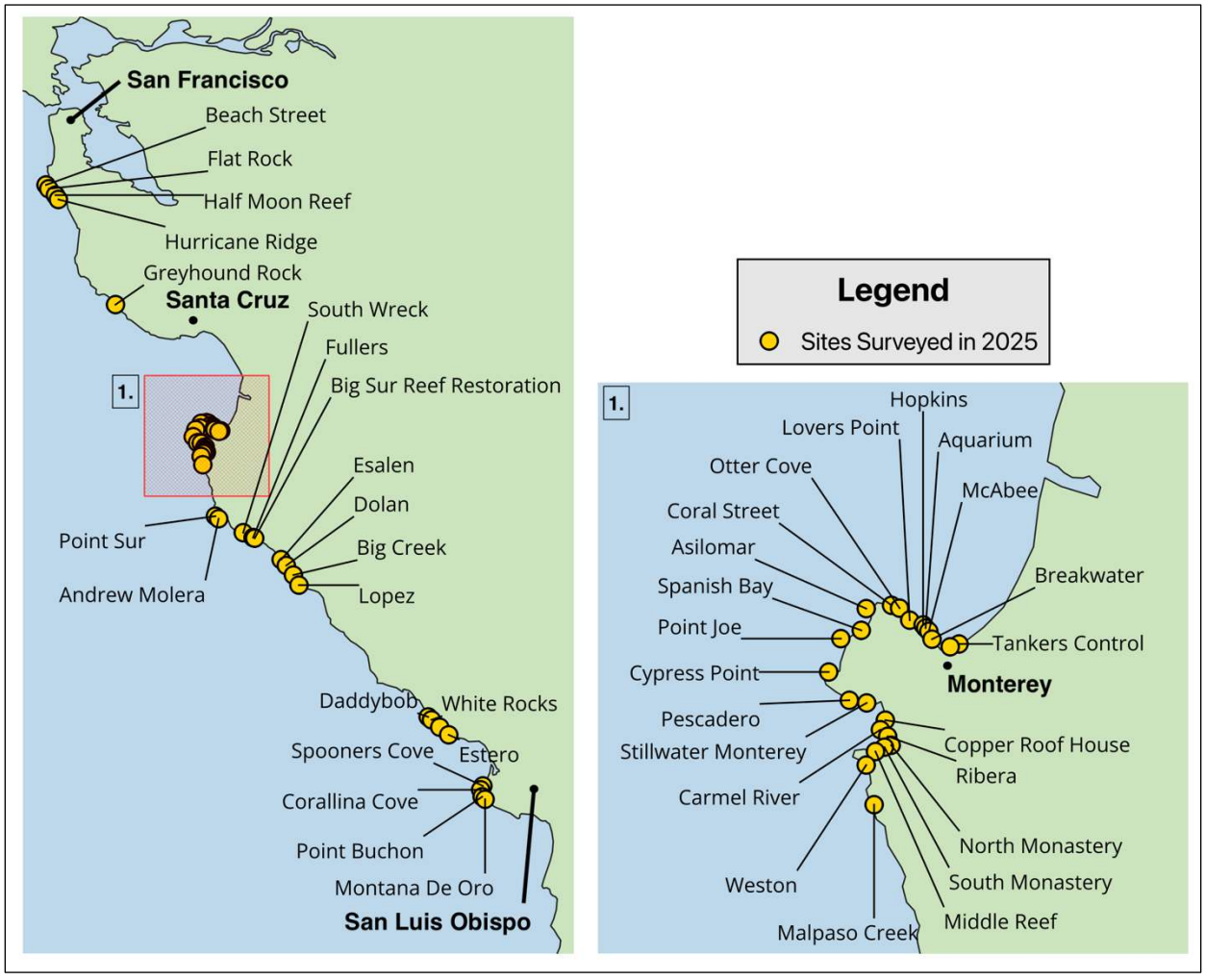

Figure 6. Reef Check sites surveyed in Central California in 2025.

Southern California

A total of 50 surveys at 48 sites were completed in Southern California in 2025 (**Table 7**). Of the total survey sites, eight were not surveyed in 2025. Survey sites were distributed between Point Conception and the California-Mexico border (**Figure 7**). A total of 902 fish transects covering 54,120 m^2 and 300 swath transects covering 18,000 m^2 were surveyed. Temperature loggers are located at 27 sites, and at 25 of the sites, data were retrieved in 2025

Table 7: List of Reef Check sites in Southern California surveyed in 2025.

Site	Latitude	Longitude	# of years surveyed	2025 Survey Date(s)	# of fish transects	# of swath transects	Temp logger
Refugio State Beach	34.461056	-120.066872	20	06/28/2025 11/01/2025	36	12	n/a
Frys Anchorage	34.054161	-119.755997	10	12/06/2025	18	6	n/a
Cueva Valdez	34.053219	-119.811670	10	Not Surveyed	n/a	n/a	n/a
Scorpion Anchorage	34.048515	-119.552299	16	12/06/2025	19	6	n/a
Leo Carillo	34.043533	-118.944946	13	10/22/2025	18	6	Not serviced
Big Rock	34.035168	-118.608086	6	Not Surveyed	n/a	n/a	Serviced
Pelican Anchorage	34.034767	-119.702951	16	12/06/2025	18	6	n/a
Lechuza	34.034035	-118.871315	11	Not Surveyed	n/a	n/a	Serviced
Landing Cove	34.017467	-119.362396	14	10/07/2025	19	6	n/a
Cathedral Cove	34.016499	-119.368385	14	08/08/2025	18	6	n/a
Cathedral Wall	34.015751	-119.371498	14	08/08/2025	22	6	n/a
Goldfish Bowl	34.014729	-119.437500	16	08/08/2025	18	6	n/a
Light House	34.012634	-119.364197	13	10/07/2025	18	6	n/a
Paradise Point	34.004128	-118.792900	11	06/17/2025	0	6	Serviced
Point Dume	33.998531	-118.805634	6	06/17/2025	20	6	Serviced
Elk Ridge	33.956017	-119.972433	7	Not Surveyed	n/a	n/a	n/a
East Point	33.940083	-119.967150	9	Not Surveyed	n/a	n/a	n/a
Johnsons Lee	33.899767	-120.105900	7	Not Surveyed	n/a	n/a	n/a
South Point	33.895000	-120.125000	4	Not Surveyed	n/a	n/a	n/a
Malaga Cove	33.803693	-118.397724	18	09/06/2025	19	6	Serviced
Christmas Tree Cove	33.760399	-118.421051	18	06/05/2025	18	6	Serviced
Hawthorne Reef	33.747002	-118.415886	16	06/05/2025	18	6	n/a
Point Vicente West	33.739700	-118.413696	8	06/06/2025	18	6	Not serviced
120 Reef	33.737919	-118.392014	19	06/06/2025	18	6	n/a
Abalone Cove	33.736149	-118.376320	13	06/18/2025	0	6	n/a
Point Vicente East	33.736000	-118.401199	9	06/05/2025	18	6	Serviced
White Point	33.712844	-118.318026	15	06/18/2025	20	6	Serviced
Little Corona Del Mar	33.587859	-117.869271	18	10/05/2025	18	6	Serviced
Crystal Cove	33.564894	-117.834988	11	10/18/2025	19	6	n/a
Seal Rock	33.545227	-117.804392	18	08/06/2025	18	6	Serviced
Shaws Cove	33.543961	-117.799858	14	08/27/2025	20	6	n/a

Table 7 (continued): List of Reef Check sites in Southern California surveyed in 2025.

Site	Latitude	Longitude	# of years surveyed	2025 Survey Date(s)	# of fish transects	# of swath transects	Temp logger
Divers Cove	33.543393	-117.796384	18	09/13/2025	18	6	n/a
Heisler Park	33.542039	-117.792745	14	08/02/2025	19	6	Serviced
Ship Rock	33.462833	-118.491600	11	06/04/2025	18	6	Serviced
Lions Head	33.453447	-118.501319	14	06/16/2025	23	6	Serviced
Bird Rock	33.450798	-118.487541	11	06/04/2025	19	6	Serviced
Isthmus Reef	33.448318	-118.490601	18	06/03/2025	18	6	n/a
Iron Bound Cove	33.447498	-118.575150	8	06/16/2025	23	6	Serviced
WIES Intakes	33.446999	-118.484848	16	06/22/2025	20	6	n/a
Blue Cavern II	33.443190	-118.473193	7	06/04/2025	20	6	Serviced
Rippers Cove	33.428150	-118.435471	8	06/03/2025	20	6	Serviced
Cat Harbor	33.426090	-118.511810	8	07/15/2025	18	6	Serviced
Twin Rocks	33.417910	-118.397900	10	06/03/2025	22	6	n/a
Long Point West	33.410526	-118.378906	12	06/02/2025	18	6	Serviced
Torqua	33.383010	-118.358430	16	06/02/2025	18	6	Serviced
Casino Point	33.349167	-118.324966	20	07/12/2025 11/09/2025	36	12	n/a
China Point	33.330318	-118.469749	8	07/15/2025	18	6	n/a
Bushings	33.317860	-118.441399	7	07/14/2025	18	6	Serviced
Salta Verde	33.314583	-118.421516	8	07/14/2025	18	6	n/a
La Jolla Cove	32.854092	-117.270467	19	09/20/2025	19	6	Serviced
Kiddie Pool	32.844971	-117.285304	7	09/20/2025	18	6	n/a
Windansea	32.836601	-117.288002	10	11/11/2025	18	6	Serviced
Wipeout	32.821100	-117.287100	6	Not Surveyed	n/a	n/a	n/a
South La Jolla	32.813450	-117.285767	14	09/21/2025	19	6	Serviced
North Hill Street	32.728619	-117.264999	14	09/21/2025	18	6	n/a
Broomtail Reef	32.694233	-117.268066	18	09/20/2025	18	6	Serviced

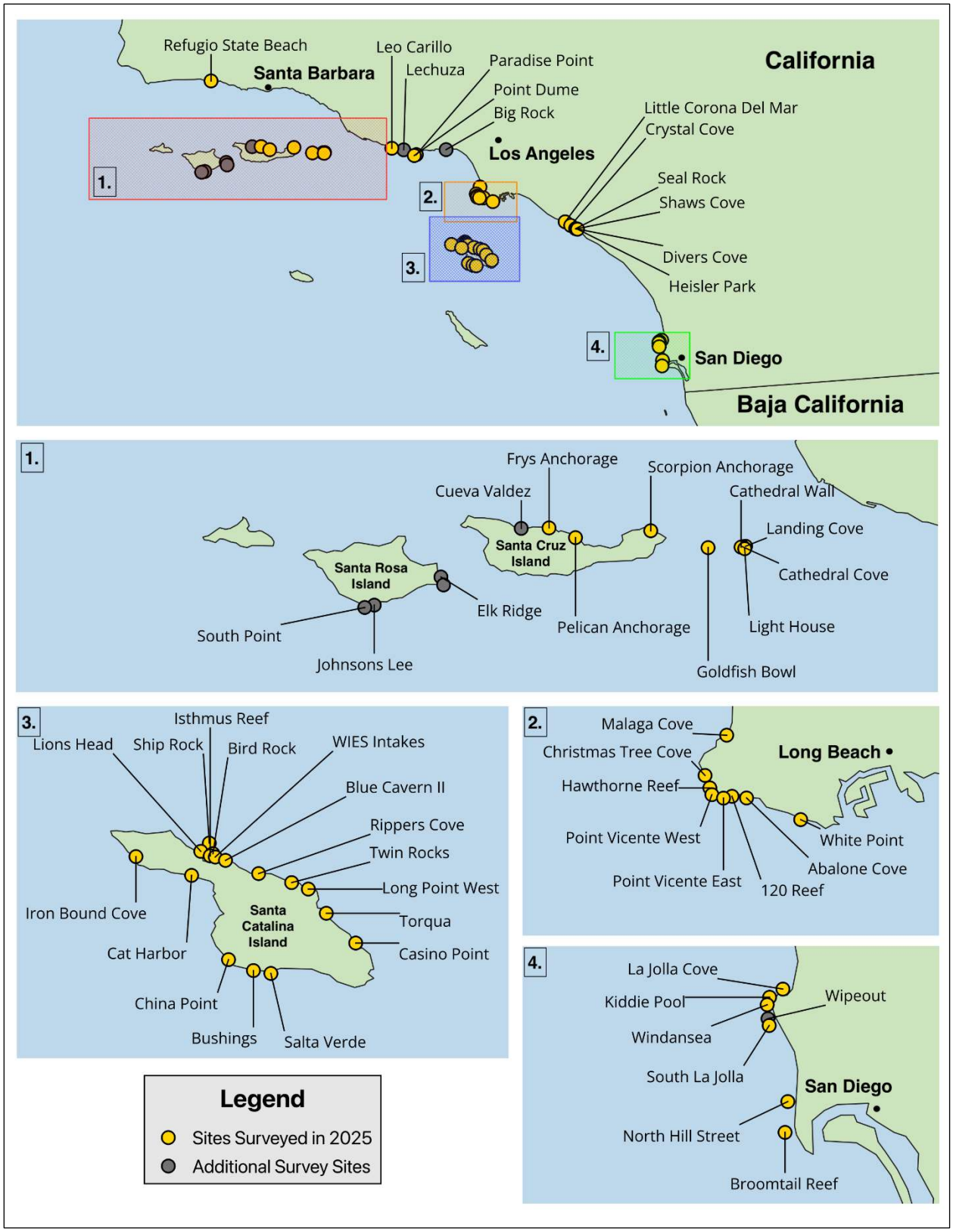

Figure 7. Reef Check sites surveyed in Southern California in 2025 and additional long-term monitoring sites that were not surveyed in 2025.

Baja California, Mexico

A total of 24 surveys at 24 sites were completed in Baja California in 2025 (**Table 8**). Survey sites were distributed along the Pacific side of Baja California and Baja California Sur, with a concentration of sites located near Ensenada (**Figure 8**). A total of 301 fish transects covering 18,060 m^2 and 141 swath transects covering 8,460 m^2 were surveyed.

Table 8: List of Reef Check sites in Baja California, Mexico surveyed in 2025.

Site	Latitude	Longitude	# of years surveyed	2025 Survey Date(s)	# of fish transects	# of swath transects	Temp logger
Coronados Norte Protected	32.443023	-117.296524	3	11/27/2025	6	6	n/a
Coronados Norte Exposed	32.434410	-117.296355	3	11/27/2025	6	6	n/a
Coronados Sur Exposed	32.394387	-117.245535	3	11/28/2025	6	6	n/a
Coronados Sur Protected	32.392179	-117.238824	3	11/28/2025	6	6	n/a
Campo Lopez	32.151333	-116.898888	2	11/02/2025	9	6	n/a
Salsipuedes	31.977110	-116.794640	2	06/27/2025	18	6	n/a
San Miguel	31.910070	-116.756330	3	06/27/2025	18	6	n/a
Todos Santos Faro	31.811552	-116.810600	3	06/28/2025	11	6	n/a
Todos Santos Canal	31.807923	-116.799060	2	06/28/2025	18	6	n/a
Punta Banda	31.738657	-116.736290	3	09/13/2025	18	6	n/a
Campo Kennedy	31.701050	-116.681840	1	09/27/2025	19	6	n/a
Bahia Soledad	31.614480	-116.673440	1	11/03/2025	7	3	n/a
Santo Tomas	31.551050	-116.689100	1	12/09/2025	6	6	n/a
San Martin Exposed	30.492167	-116.124283	1	12/06/2025	6	6	n/a
San Martin Protected	30.484233	-116.099117	1	12/06/2025	6	6	n/a
Sport Fish	29.789980	-115.797480	1	12/06/2025	6	6	n/a
China Town	29.785970	-115.792800	1	12/06/2025	6	6	n/a
Piedras Blanca	27.877027	-115.046270	3	08/24/2025	18	6	n/a
El Reventon	27.872766	-115.057136	1	08/24/2025	18	6	n/a
Gavilanes	27.855280	-115.075780	3	08/25/2025	21	6	n/a
San Roque	27.149030	-114.377650	3	08/27/2025	18	6	n/a
La Barra	27.145073	-114.386697	1	08/27/2025	18	6	n/a
Garropas	27.112346	-114.302208	1	08/26/2025	18	6	n/a
Barra de la Leona	27.106800	-114.300770	2	08/26/2025	18	6	n/a

Figure 8. Reef Check sites surveyed in Baja California in 2025.

Results

To provide an overview of long-term trends across kelp, invertebrate, and fish indicator species over 20 years, we show data for five of the seven regions, ranging from Washington to Southern California. Baja California and British Columbia were not included due to their recent addition to our monitoring program. For all five regions, heatmaps were used to show how kelp forests at monitoring sites have persisted or changed and include densities of the dominant canopy-forming kelp species and purple urchins. In regions that contain data from before the 2014-16 heatwave (California), we compare the 2025 densities of fish, invertebrate and kelp species to the mean density in the years monitored before the heatwave. This provides an estimated percent change in 2025 relative to their historical pre-heatwave density. Changes in densities are visualized in hurricane plots and reported as species' status as a percentage of their historic density in tables. Only sites that were surveyed at least three times before the heatwave and in 2025 are included in this analysis: 6 sites in Northern California, 17 sites in Central California, 33 sites in Southern California (**see Methods section for more details on analysis**). Additionally, for all regions, we are reporting the trend in species densities over the most recent five years (2021-2025) as determined by a linear regression on the annual mean density across the region. Regressions with $p \geq 0.05$ were classified as "No Trend" regardless of slope direction; significant trends ($p < 0.05$) were classified as "Increasing" or "Decreasing" based on the sign of the slope.

A Note on Results

Only species that were recorded at a mean density of greater than one individual per survey in the respective regions are included in the above analysis. Rare species showed much variability, especially in regions where we only had a limited number of sites in the pre-heatwave period (e.g., Northern California). We did not investigate causality for the changes in species' densities in 2025 compared to historic densities. There are many reasons and potential mechanisms for density changes either in response to the heatwave disturbance or other causes. We see some large increases in some of the warmer water species in Northern and Central California; they might have had strong recruitment pulses during the heatwave. Conversely, some of the colder water species show substantial declines in southern regions. Several species also had peaks in density directly prior to the heatwave, resulting in a decline when compared to 2025. Large-scale habitat changes from kelp to barrens might favor certain species and lead to a reduction in others' densities. Additionally, in urchin barrens, some species change from a passive, cryptic behavior to an active, exposed behavior and also may be more visible to observers due to the lack of understory algae (Smith et al., 2024). There is some inherent variability in the data caused by stochasticity when comparing density from one year to a past baseline. The error bars in the hurricane plots illustrate this variability and identify significant changes based on the bootstrapped 95% confidence intervals.

Washington

Bull kelp is the dominant canopy kelp in Puget Sound. After five years of monitoring, bull kelp trends have remained relatively stable with few sites transitioning to a kelp or no-kelp state (**Figure 9**). In 2025, bull kelp was present at approximately 54% of the monitored sites. Sites with the highest kelp densities (75 bull kelp individuals per 60 m^2 or greater) include Point Whitehorn and Burrows Lighthouse in the North Puget Sound, Smith Island, Ebeys Landing, and McCurdy Point in the Eastern Strait of Juan de Fuca, Lowell Point in the Saratoga/Whidbey Basin, Point Dalco in the Central Puget Sound, and lastly Salmon Beach in the South Puget Sound (**Figure 9**). No bull kelp was observed at sites in the Admiralty Inlet (n=1) and the Hood Canal (n=3) in 2025.

Understory kelp species show no significant trend, or there is insufficient data to determine trends (**Table 9**). Giant kelp has limited presence in Washington and was only observed at sites within the Eastern and Western Strait of Juan de Fuca (**Supplementary material**). Though at these sites it has increased in recent years.

Most invertebrates, such as green/pallid urchins, sunflower stars, and purple urchins, all show increasing trends over the last five years (**Table 9**). Purple urchins are uncommon in Puget Sound, and the increasing trend was driven by densities in the Eastern Strait of Juan de Fuca (**Supplementary material**). Sunflower stars were observed in Western and Eastern Strait of Juan de Fuca, Saratoga/Whidbey, and Hood Canal sites.

Regionally, fish such as kelp greenlings and brown rockfish show significantly increasing trends over the last five years; however, densities remain relatively low (**Table 9, Supplementary material**).

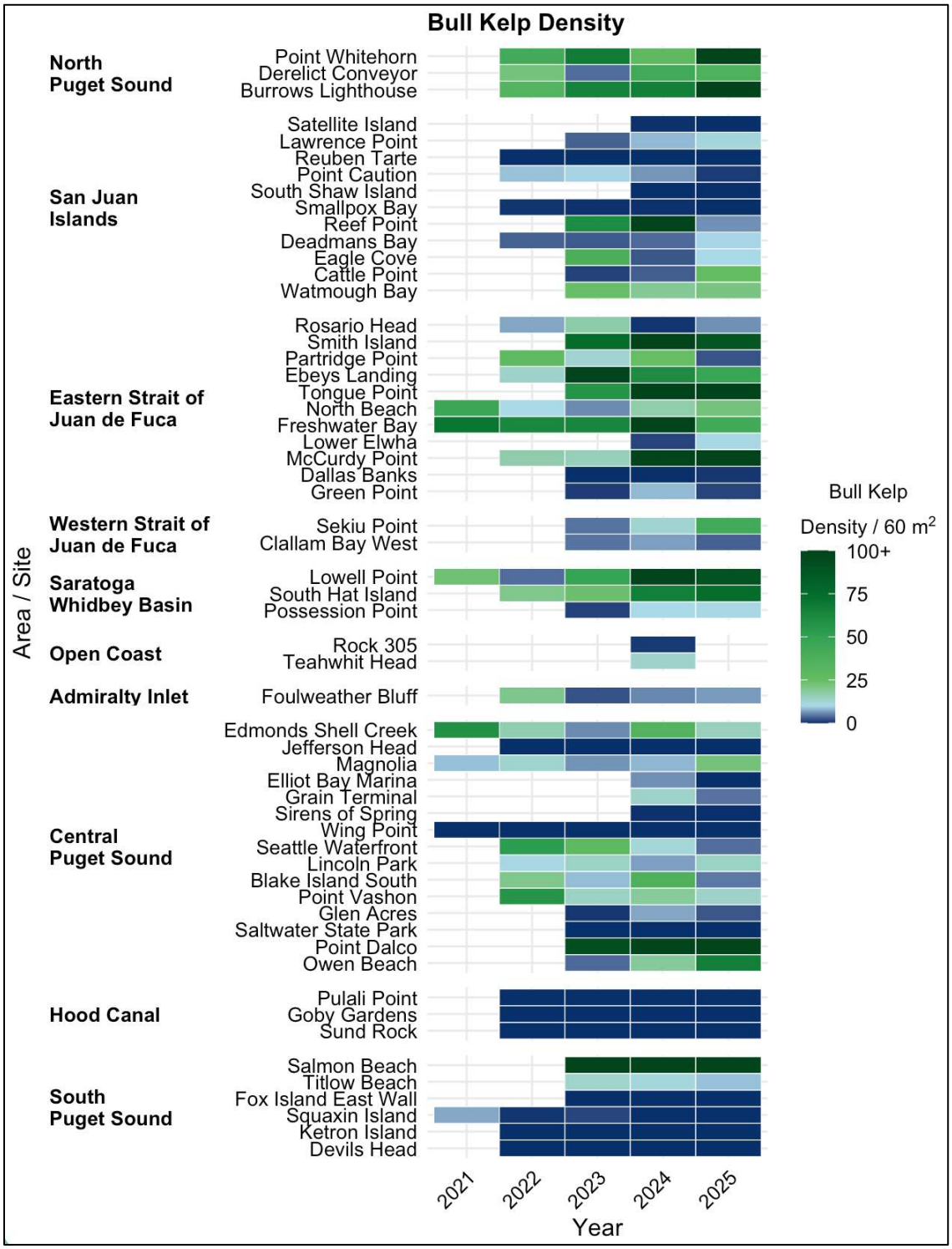

Figure 9. Bull kelp over the years since monitoring started at sites in Washington. The color scale indicates density from low (blue) to high (green). Scale has been capped at 100; all higher values are grouped and shown in dark green. Y-axis shows sampling sites grouped by sub-basin, ordered north to south, and sites within sub-basins are ordered north to south.

Table 9. Status and trends of species in Washington. Since monitoring in Washington commenced after the marine heatwave, a comparison of the 2025 status in relation to pre-heatwave densities is not possible. Trends are estimated by linear regression of the most recent data. Blue arrows indicate significant trends and their direction.

	Species	2025 Status	5-year Trend
Kelp	Acid Weed	No Data	➡
	Broad-Ribbed Kelp	No Data	➡
	Bull Kelp	No Data	➡
	Feather Boa Kelp	No Data	➡
	Five-Ribbed Kelp	No Data	➡
	Giant Kelp	No Data	↗
	Sieve Kelp	No Data	➡
	Sugar Kelp	No Data	➡
	Three-Ribbed Kelp	No Data	➡
	Torn Kelp	No Data	➡
	Winged Kelp	No Data	➡
	Wire Weed	No Data	➡
	Woody Kelp	No Data	➡
Invert	Blood Star	No Data	➡
	California Sea Cucumber	No Data	➡
	Green/Pallid Urchin	No Data	↗
	Gumboot Chiton	No Data	➡
	Hairy Triton	No Data	➡
	Kelp Crab	No Data	➡
	Kelp Crab (Juvenile)	No Data	➡
	Large Anemone	No Data	➡
	Leather Star	No Data	➡
	Mottled Star	No Data	➡
	Ochre Star	No Data	➡
	Orange Cucumber	No Data	➡
	Piddock Clam	No Data	➡
	Plumose Anemone	No Data	➡
	Purple Urchin	No Data	↗
	Red Urchin	No Data	➡
	Rock Crab	No Data	➡
	Rock Scallop	No Data	➡
	Short Spined Star	No Data	➡
	Slender Crab	No Data	➡
	Sunflower Star	No Data	↗

	Species	2025 Status	5-year Trend
Fish	Black Rockfish	No Data	➡
	Brown Rockfish	No Data	↗
	Buffalo Sculpin	No Data	➡
	Copper Rockfish	No Data	➡
	Forage Fish	No Data	➡
	Kelp Greenling	No Data	↗
	Kelp Perch	No Data	➡
	Lingcod	No Data	➡
	Pile Perch	No Data	➡
	Shiner Perch	No Data	➡
	Striped Perch	No Data	➡

Oregon

Oregon continues to experience the effect of widespread kelp decline, with bull kelp now occurring at only a few monitored reefs (Hamilton et al., 2024). Of the seven sites monitored in 2025, bull kelp was present at four: Pacific City North (restoration site since 2025), Pacific City South (control site), Macklyn Restoration (restoration site since 2024), and Drake Point. Macklyn Restoration had the highest kelp densities, with a mean density of 26 individuals per 60 m^2 and Pacific City North reached a mean density of 14 individuals per 60 m^2 (**Figure 10**). Understory kelp, such as broad-ribbed kelp (*Pleurophycus gardneri*) and torn kelp (*Laminaria setchellii*), was also present in 2025 at both restoration sites (**Supplementary material**). The only two sites monitored in 2025 not associated with restoration activities were Drake Point—a site targeted for future restoration—and Redfish Rock.

Restoration efforts include urchin removal via culling efforts led by the Oregon Kelp Alliance (ORKA) and Reef Check. In 2025, purple urchin densities across Oregon are relatively lower than sites in Northern California but still reach between an average of 150 and 400 per 60 m^2, with the highest densities observed at Nellies Cove West—despite active removal efforts—and Redfish Rocks. However, greater than 1,000 per 60 m^2 urchins have been observed in the past across the coast **(Figure 10)**.

The invertebrate species and most fish species do not show significant trends of either decreasing or increasing density over the last five years, except for striped perch, which showed a decreasing trend **(Table 10)**.

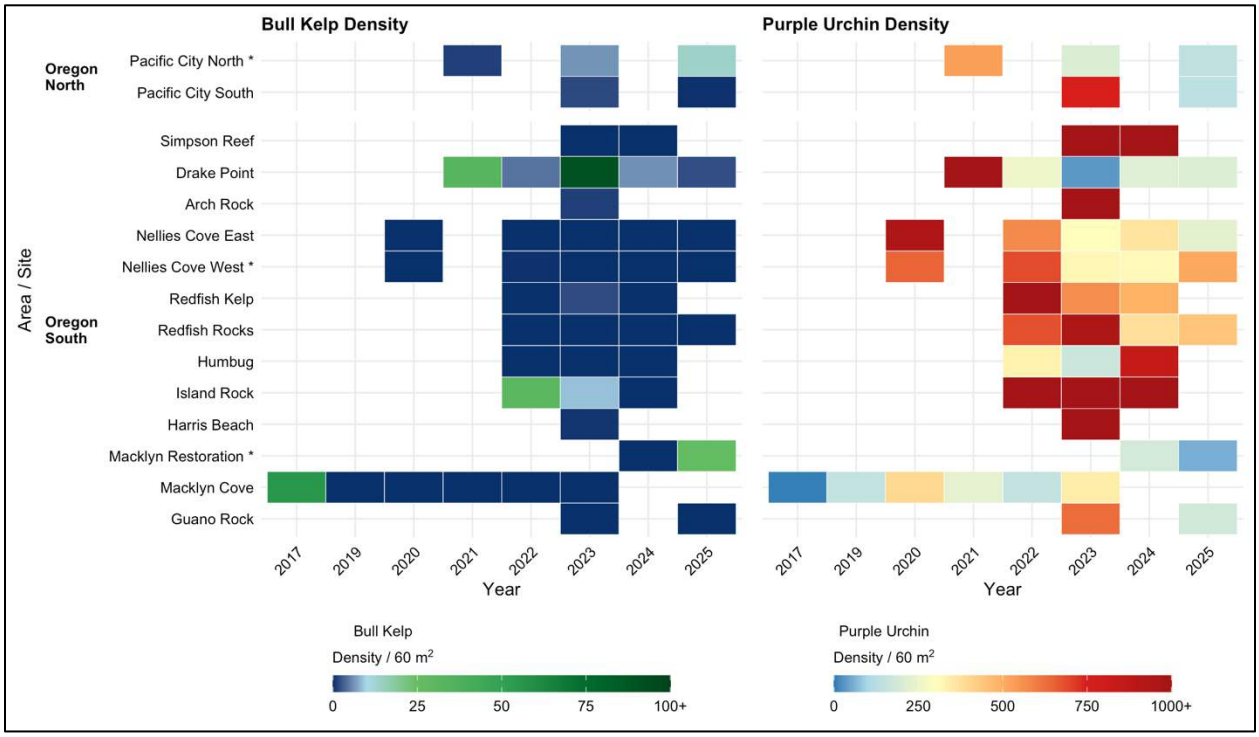

Figure 10. Bull kelp (left) and purple urchin (right) densities over the years since monitoring started at sites in Oregon. The color scale indicates density from low (blue) to high (green/red). Scale has been capped at 100 for bull kelp and 1,000 for urchins; all higher values are grouped and shown in green/red. Y-axis shows sampling sites grouped by sampling area, ordered north to south. Sites undergoing active restoration are starred (*).

Table 10. Status and trends of species in Oregon. Since monitoring in Oregon commenced after the marine heatwave, a comparison of the 2025 status in relation to pre-heatwave densities is not possible. Trends are estimated by linear regression of the most recent data. Blue arrows indicate significant trends and their direction.

	Species	2025 Status	5-year Trend
Kelp	Broad-Ribbed Kelp	No Data	➡
	Bull Kelp	No Data	➡
	Feather Boa Kelp	No Data	➡
	No Blade Kelp	No Data	➡
	Torn Kelp	No Data	➡
	Woody Kelp	No Data	➡
Invert	Bat Star	No Data	➡
	Blood Star	No Data	➡
	California Sea Cucumber	No Data	➡
	Large Anemone	No Data	➡
	Leather Star	No Data	➡
	Mottled Star	No Data	➡
	Ochre Star	No Data	➡
	Plumose Anemone	No Data	➡
	Purple Urchin	No Data	➡
	Rainbow Star	No Data	➡
	Red Urchin	No Data	➡
	Rock Scallop	No Data	➡
	Short Spined Star	No Data	➡
	Sunflower Star	No Data	➡
Fish	Black Rockfish	No Data	➡
	Blue Rockfish	No Data	➡
	China Rockfish	No Data	➡
	Deacon Rockfish	No Data	➡
	Kelp Greenling	No Data	➡
	Lingcod	No Data	➡
	Striped Perch	No Data	➘
	Whitespotted Greenling	No Data	➡

Northern California

Of the 16 sites monitored in 2025, bull kelp was observed at only two sites: Portuguese Beach and Caspar South, both of which are restoration sites. Portuguese Beach is one of the few remaining sites with patchy distribution of kelp since the 2014 heatwave on the Mendocino Coast, but 2023-2024 saw further decline of kelp at this site **(Figure 11)**. Restoration efforts began in 2024 and include kelp outplanting and urchin removal efforts via commercial hand harvest. At Caspar South, restoration efforts led by the Waterman's Alliance began in 2020 and include urchin removal efforts via recreational divers' in situ culling. Some commercial diving removal activities occur in Caspar North, but no kelp was observed in 2025.

Purple urchin densities have boomed at all sites from Mendocino to Sonoma, with a clear transition from kelp forest to urchin barren after the 2014 heatwave **(Figure 11).** At sites where urchins have been actively removed (Caspar South, Caspar North, and Portuguese Beach), urchin densities are considerably lower than the rest of the region. Compared to the pre-heatwave, urchin densities are 15,585% the historical mean and continue to increase **(Table 11)**.

For sites that were monitored pre-heatwave, bull kelp was basically absent in 2025 when restoration sites such as Portuguese Beach are not considered **(Table 11).** Subtidal kelp, such as woody kelp (*Pterygophora californica*) and torn kelp (*Laminaria setchellii)*, were previously prevalent in the region but were also not observed in 2025 **(Figure 12)**. None of the kelp species showed any trends in their densities over the last five years at the sites where no restoration is taking place.

In addition to kelp and purple urchins, the 2014-2016 heatwave had a considerable impact on invertebrate densities on the North Coast. Red urchins also show a significant increase, with 2025 densities reaching 6x higher than the historical mean **(Figure 11).** Gumboot chiton also show a significant decline, with the 2025 status reaching 6% compared to the pre-heatwave mean (**Table 11, Figure 13),** but populations have remained stable over the last five years. Sheep/masking crab and many sea stars were also impacted by the heatwave, showing significant declines **(Figure 13, Table 11**). Some of the sea star species were not observed in 2025, and red abalone densities were at 2.8% of the pre-heatwave densities at monitoring sites in 2025 and show no sign of recovery over the last five years (**Table 11)**.

Fish species, on the other hand, show more variability when comparing densities in 2025 to pre-heatwave densities (**Figure 14**). In 2025, kelp greenling and black perch populations were around 60% of their historic density in 2025. Young-of-Year rockfish densities were extremely high in 2025 compared to pre-heatwave densities, but it remains to be seen if this recent recruitment will lead to an increase in adult rockfish populations (Bauer-Civiello et al., in prep). Black and blue rockfish were more abundant in 2025 than before the heatwave, but this change was not significant (**Table 11, Figure 14)**.

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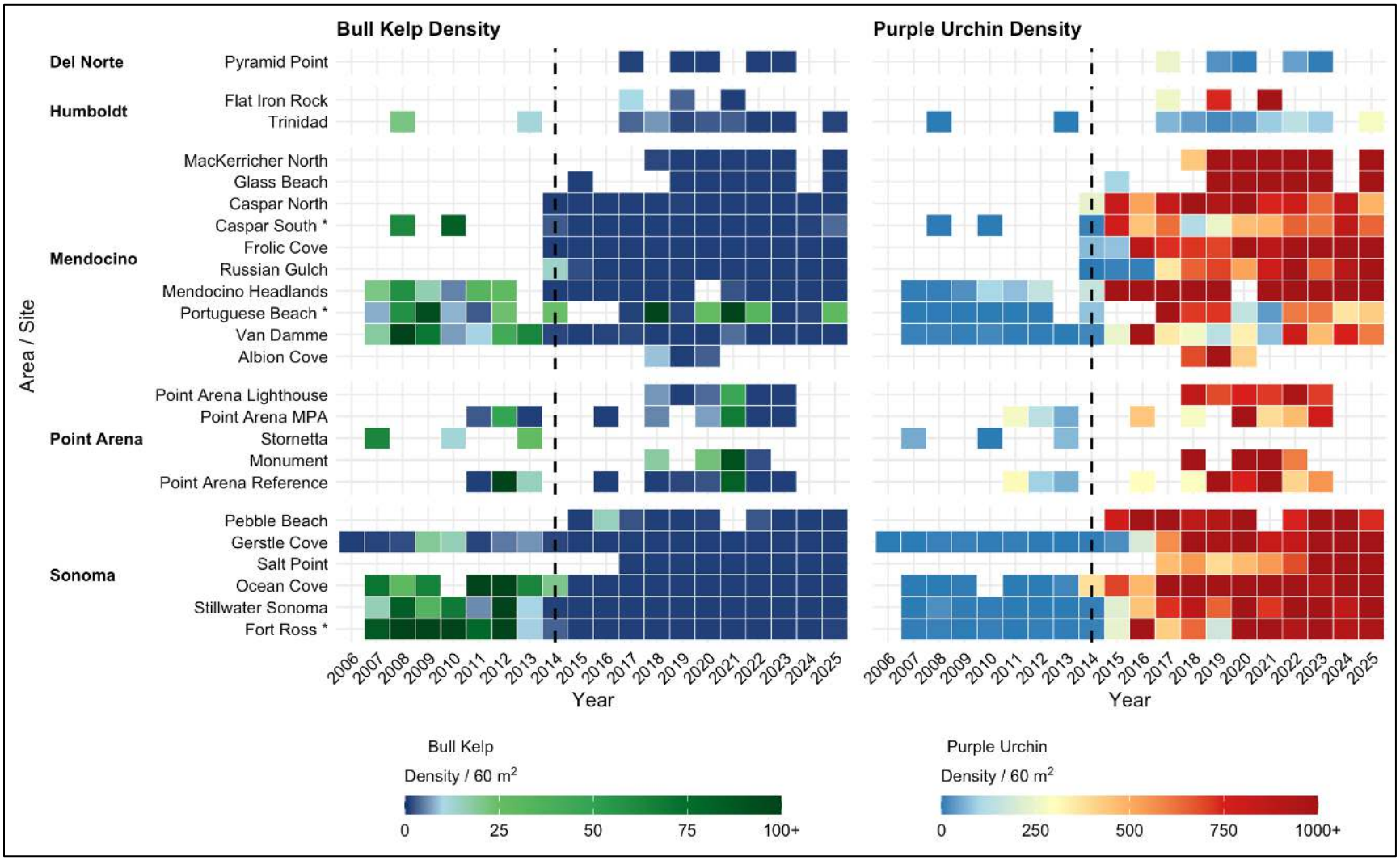

Figure 11. Bull kelp (left) and purple urchin (right) over the years since monitoring started at sites in Northern California. The color scale indicates density from low (blue) to high (green/red). Scale has been capped at 100 for bull kelp and 1,000 for urchins; all higher values are grouped and shown in green/red. Y-axis shows sampling sites grouped by sampling area; areas are ordered north to south (by northernmost site), sites within groupings ordered north to south. Sites undergoing active restoration are identified by asterisk (*).

Table 11. Status and trends of species in Northern California. Status in 2025 shows the percent change in species' density compared to their mean pre-heatwave density (large changes are shown as x-fold for easier readability). Trends are estimated by linear regression of the last five years of data. Blue arrows indicate significant trends and their direction.

	Species	2025 Status	5-year Trend
Kelp	Bull Kelp	-100%	➡
	Torn Kelp	-100%	➡
	Woody Kelp	-100%	➡
Invert	Purple Urchin	156x	↗
	Red Urchin	6x	➡
	Pinto Abalone	4x	➡
	Wavy/Red Turban Snail	4x	➡
	California Sea Cucumber	3x	➡
	Large Anemone	-2%	➡
	Bat Star	-33%	↗
	Sheep/Masking Crab	-74%	➡
	Gumboot Chiton	-94%	↘
	Red Abalone	-97%	➡
	Giant Spined Star	-99%	➡
	Short Spined Star	-100%	➡
	Sunflower Star	-100%	➡
Fish	Blue Rockfish	+51%	➡
	Black Rockfish	+31%	➡
	Kelp Greenling	-39%	➡
	Striped Perch	-43%	➡
	Gopher Rockfish	-48%	➡
	Black and Yellow Rockfish	-87%	➡

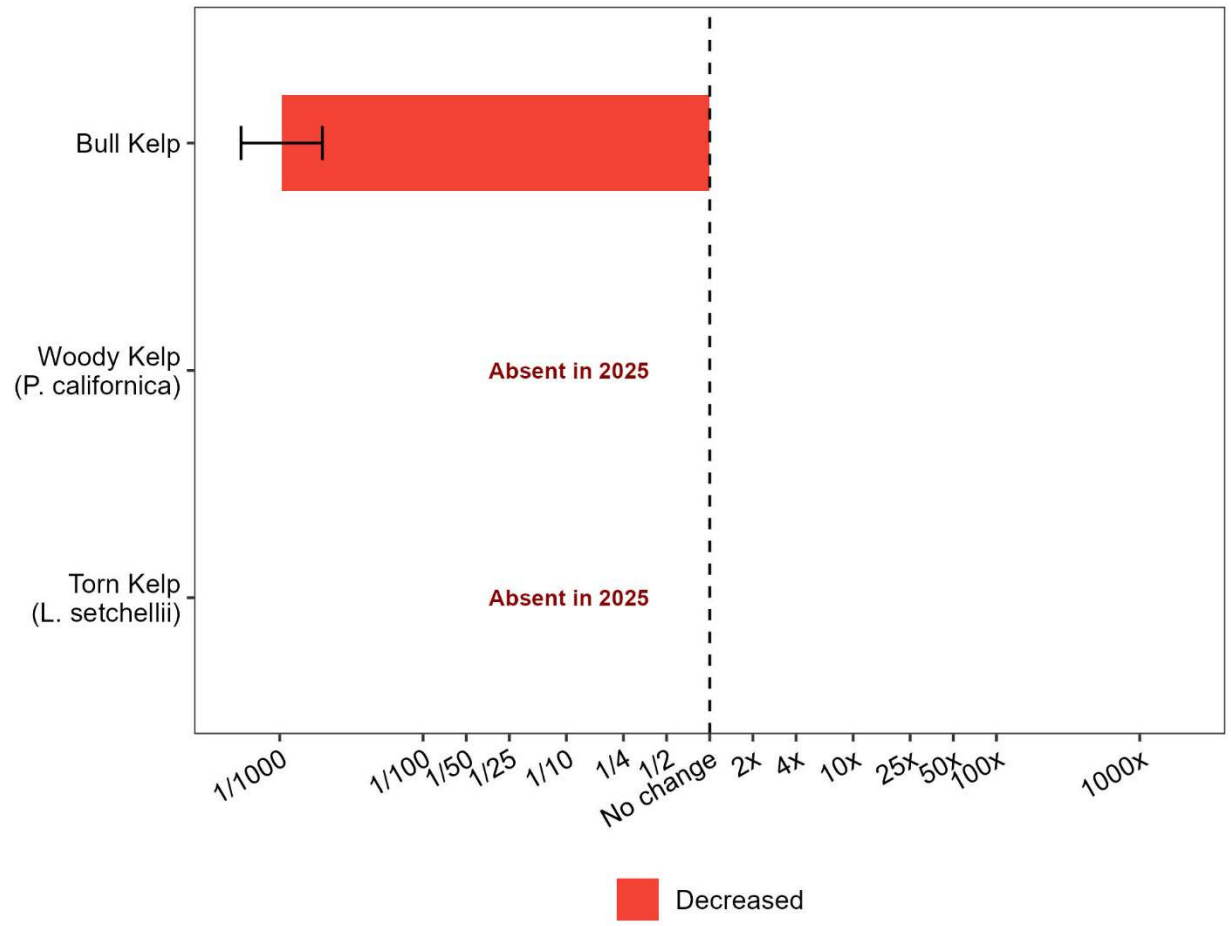

Figure 12. Change in kelp densities in 2025 compared to pre-heatwave densities in Northern California. Log response ratio of mean density is shown to compare pre-heatwave baseline to 2025 surveys. Error bars represent 95% bootstrap confidence intervals. Taxa absent in 2025 surveys are noted accordingly. Data from all sites surveyed at least three times prior to the 2014 heatwave and in 2025 are included.

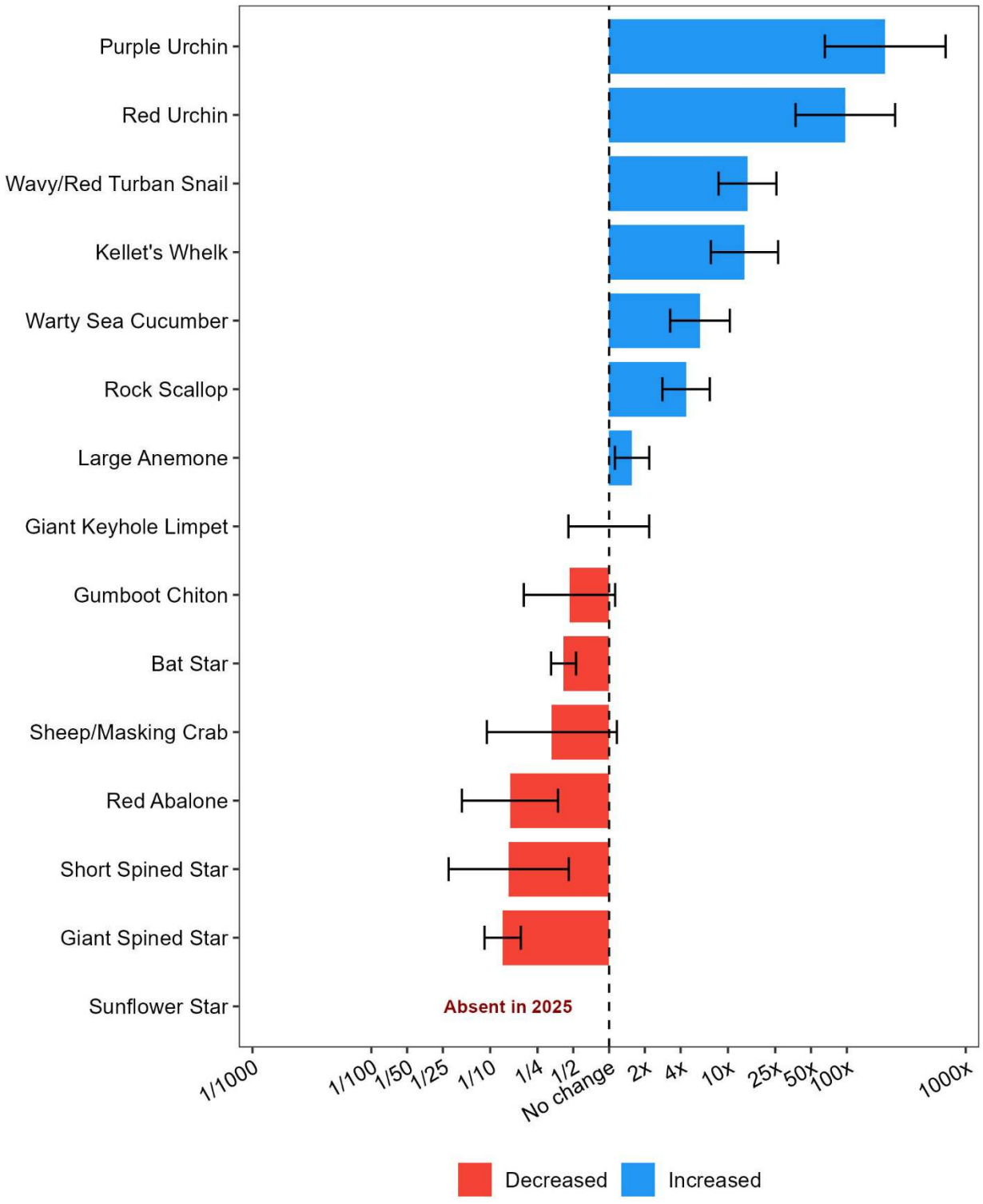

Figure 13. Change in invertebrate densities in 2025 compared to pre-heatwave densities in Northern California. Log response ratio of mean density is shown to compare pre-heatwave baseline to 2025 surveys. Error bars represent 95% bootstrap confidence intervals. Taxa absent in 2025 surveys are noted accordingly. Data from all sites surveyed at least three times prior to the 2014 heatwave and in 2025 are included.

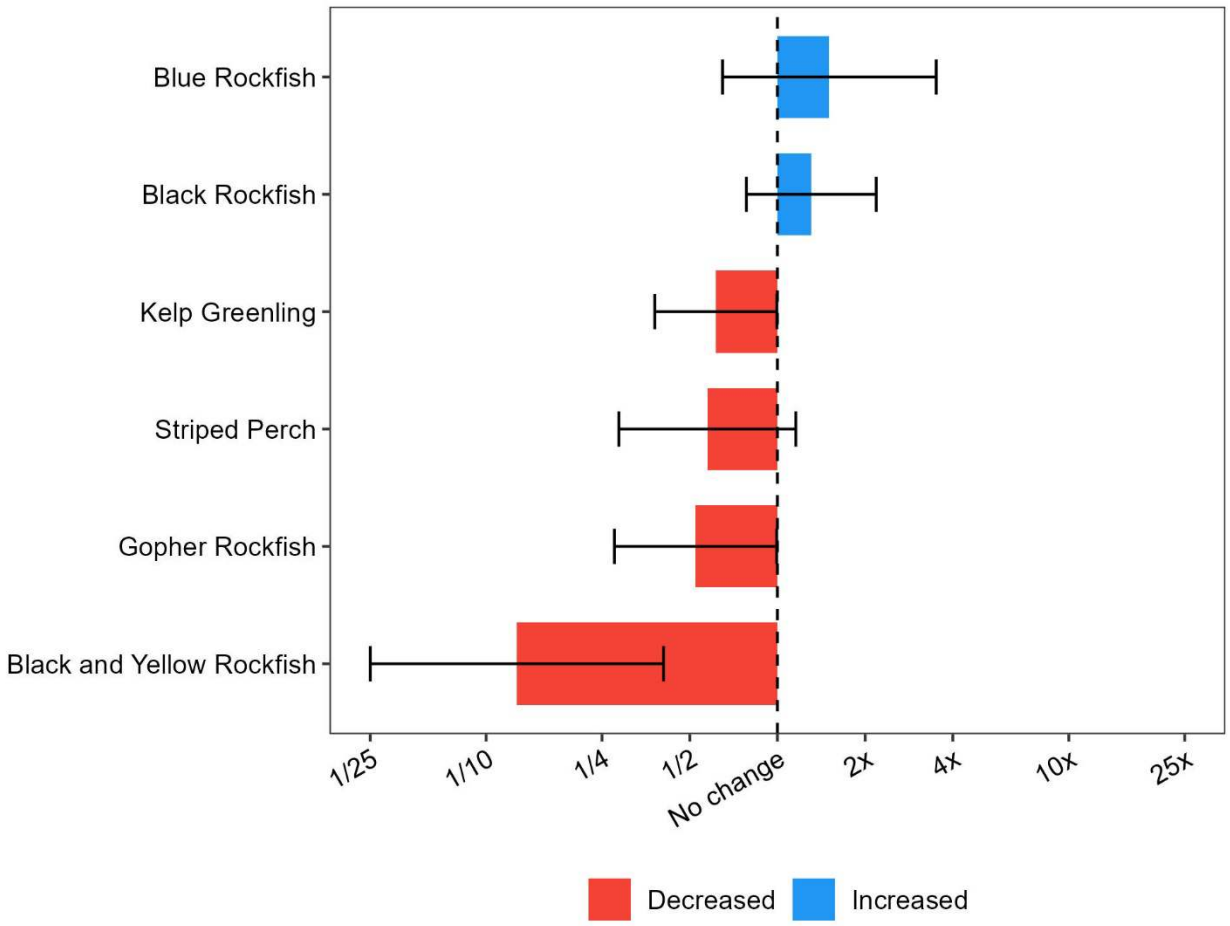

Figure 14. Change in fish densities in 2025 compared to pre-heatwave densities in Northern California. Log response ratio of mean density is shown to compare pre-heatwave baseline to 2025 surveys. Error bars represent 95% bootstrap confidence intervals. Taxa absent in 2025 surveys are noted accordingly. Data from all sites surveyed at least three times prior to the 2014 heatwave and in 2025 are included.

Central California

In Central California, the transition from kelp forest to urchin barren post 2014-2016 heatwave has been much more variable than in Northern California. Within Monterey Bay sites (n=7), four of the monitored sites show persistent giant kelp densities while others have fully transitioned to barrens **(Figure 15).** Within Carmel Bay (n=9), one long-term site (North Monastery) has shown persistently high giant kelp over the last 20 years, while all others have shown notable declines. Many sites in Big Sur and Morro Bay have shown more recent declines in giant kelp and have transitioned into mixed giant kelp-bull kelp forests. While bull kelp has always been present at Monterey Peninsula, Outer Peninsula, and Carmel Bay sites, giant kelp has been the dominant canopy kelp. Sites on the Central Coast that were recorded to have a high giant kelp stipe density (>100 per 60 m^2) in 2025 were: Estero (Morro Bay), Fullers (Big Sur), North Monastery (Carmel Bay), Ribera (Carmel Bay), Breakwater (Monterey Bay), McAbee (Monterey Bay), Aquarium (Monterey Bay), and Hopkins (Monterey Bay). In 2025, sites with a relatively high bull kelp density (>50 or greater per 60 m^2) were Montana De Oro (Morro Bay), Lopez (Big Sur), Dolan (Big Sur), Esalen (Big Sur), South Wreck (Big Sur), and Malpaso Creek (Big Sur).

Purple urchins have increased over time at almost all sites on the Central Coast, varying in density. Prior to the heatwave, it was common to have 0-2 urchins per transect. After the heatwave, some sites on the Central Coast immediately increased in urchin densities, while others were delayed, increasing in 2019-2020. Compared to Northern California, where almost all sites (except for a select few noted above) were recorded to have >1,000 urchins per 60 m^2 in 2025, only six sites in Central California had an average of 1,000 or greater. This included Montana De Oro (Morro Bay), Point Buchon (Morro Bay), Daddybob (Morro Bay), Big Creek (Big Sur), Asilomar (Outer Peninsula), and Coral Street (Monterey Bay). Approximately 20% of Central Coast sites have a mean density of 500 purple urchins or greater (**Figure 15**).

When comparing kelp species densities in 2025 to pre-heatwave densities across the entire Central Coast giant kelp, torn kelp, and southern sea palm are all declining (**Table 12**). However, changes in kelp density were highly variable across sites within the region. Bull kelp density has almost doubled by 2025 compared to very low historic densities, but due to high variability among sites, this increase is not significant **(Figure 16)**.

Invertebrates in 2025 show a more mixed picture of increases and declines in densities when compared to pre-heatwave densities across the entire Central Coast. Some species, such as turban snails, Kellet's whelks, and warty sea cucumbers, show large increases. While others, such as red abalone and several sea star species, decreased substantially or are still absent from survey sites (**Figure 17, Table 12**). Red abalone continue to decline with the 2025 densities significantly lower than the five-year trend.

Fish densities showed considerable variability when comparing 2025 to pre-heatwave densities in the Central Coast **(Figure 18)**. Several of the common species, such as kelp rockfish, black perch, and kelp greenling, had densities lower than 50% compared to pre-heatwave densities, while blue rockfish seem to have higher densities **(Figure 18, Table 12)**. Black perch, some benthic rockfish and señoritas continued to decline over the last five years **(Table 12).**

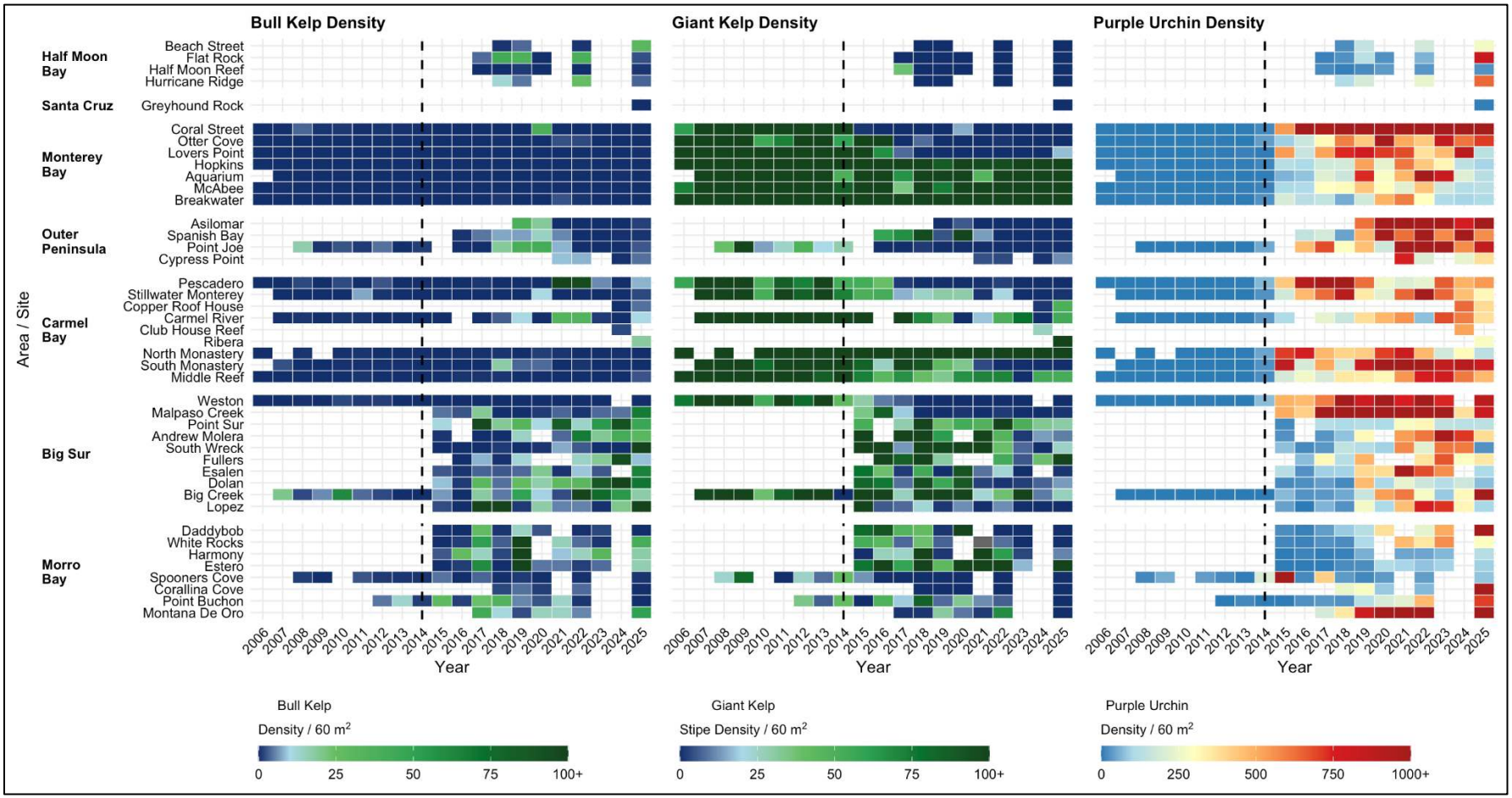

Figure 15. Bull kelp (left), giant kelp (center), and purple urchin (right) densities over the years since monitoring started at sites in Central California. The color scale indicates density from low (blue) to high (green/red). Scale has been capped at 100 for bull and giant kelp and 1,000 for urchins; all higher values are grouped and shown in green/red. Y-axis shows sampling sites grouped by sampling area and sites are ordered north to south.

Table 12. Status and trends of species in Central California. Status in 2025 shows the percent change in species' density compared to their mean pre-heatwave density (large changes are shown as x-fold for easier readability). Trends are estimated by linear regression of the last five years of data. Blue arrows indicate significant trends and their direction.

	Species	2025 Status	5-year Trend
Kelp	Bull Kelp	+92%	➡
	Woody Kelp	-51%	↘
	Giant Kelp	-51%	↘
	Torn Kelp	-81%	➡
	Southern Sea Palm (>30)	-96%	➡
Invert	Purple Urchin	211x	↘
	Red Urchin	97x	➡
	Wavy/Red Turban Snail	15x	➡
	Kellet's Whelk	14x	➡
	Warty Sea Cucumber	6x	➡
	Rock Scallop	4x	➡
	Large Anemone	+56%	➡
	Giant Keyhole Limpet	-1%	➡
	Gumboot Chiton	-54%	↘
	Bat Star	-59%	➡
	Sheep/Masking Crab	-67%	➡
	Red Abalone	-85%	↘
	Short Spined Star	-86%	➡
	Giant Spined Star	-87%	➡
	Sunflower Star	-100%	➡
Fish	Blue Rockfish	+77%	➡
	Black Rockfish	+65%	➡
	Olive/Yellowtail Rockfish	+33%	➡
	Black and Yellow Rockfish	-7%	↘
	Gopher Rockfish	-23%	↘
	Striped Perch	-24%	➡
	Pile Perch	-26%	➡
	Senorita	-43%	↘
	Black Perch	-56%	↘
	Kelp Rockfish	-59%	➡
	Kelp Greenling	-73%	➡

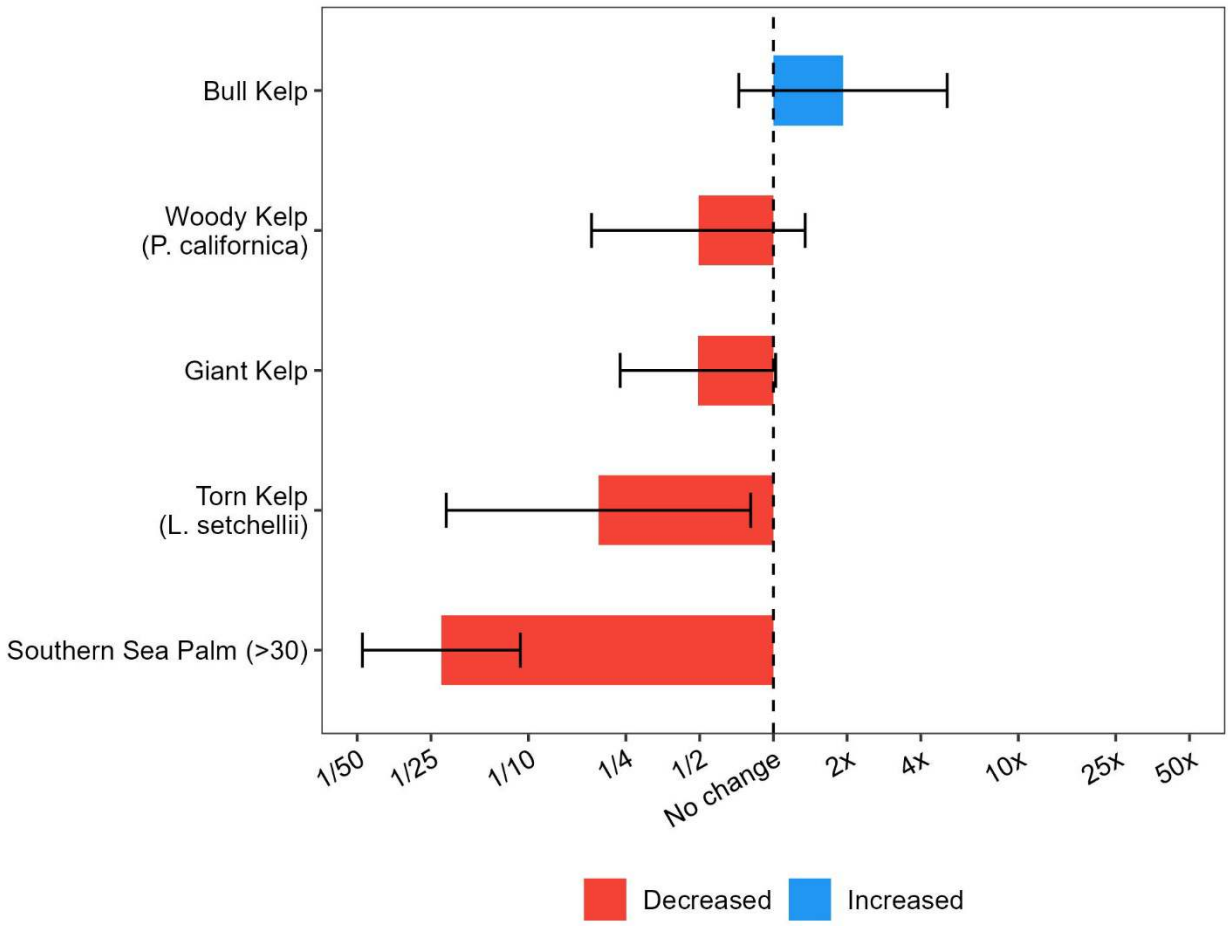

Figure 16. Change in algae densities in 2025 compared to pre-heatwave densities in Central California. Log response ratio of mean density is shown to compare pre-heatwave baseline to 2025 surveys. Error bars represent 95% bootstrap confidence intervals. Taxa absent in 2025 surveys are noted accordingly. Data from all sites surveyed at least three times prior to the 2014 heatwave and in 2025 are included.

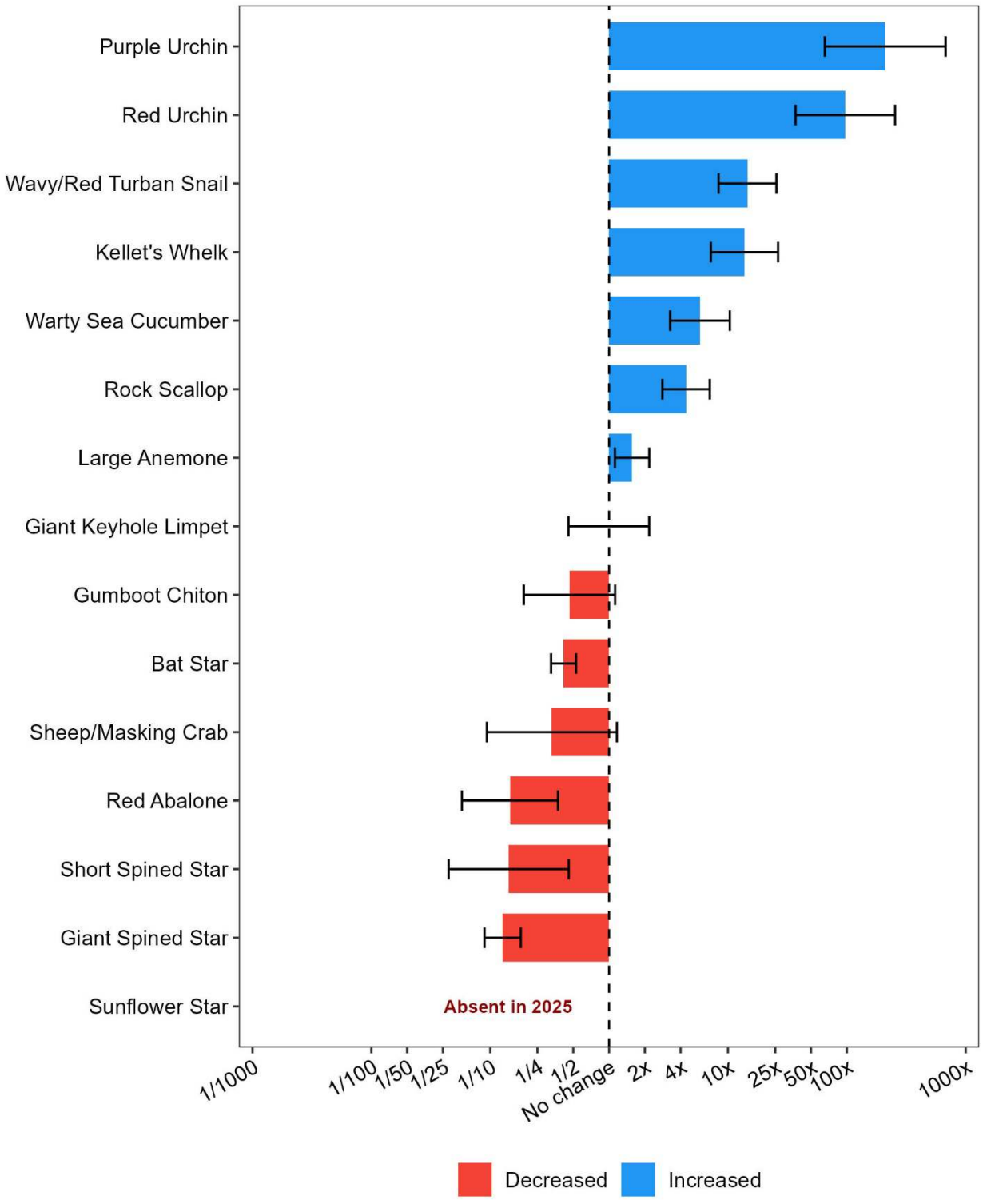

Figure 17. Change in invertebrate densities in 2025 compared to pre-heatwave densities in Central California. Log response ratio of mean density is shown to compare pre-heatwave baseline to 2025 surveys. Error bars represent 95% bootstrap confidence intervals. Taxa absent in 2025 surveys are noted accordingly. Data from all sites surveyed at least three times prior to the 2014 heatwave and in 2025 are included.

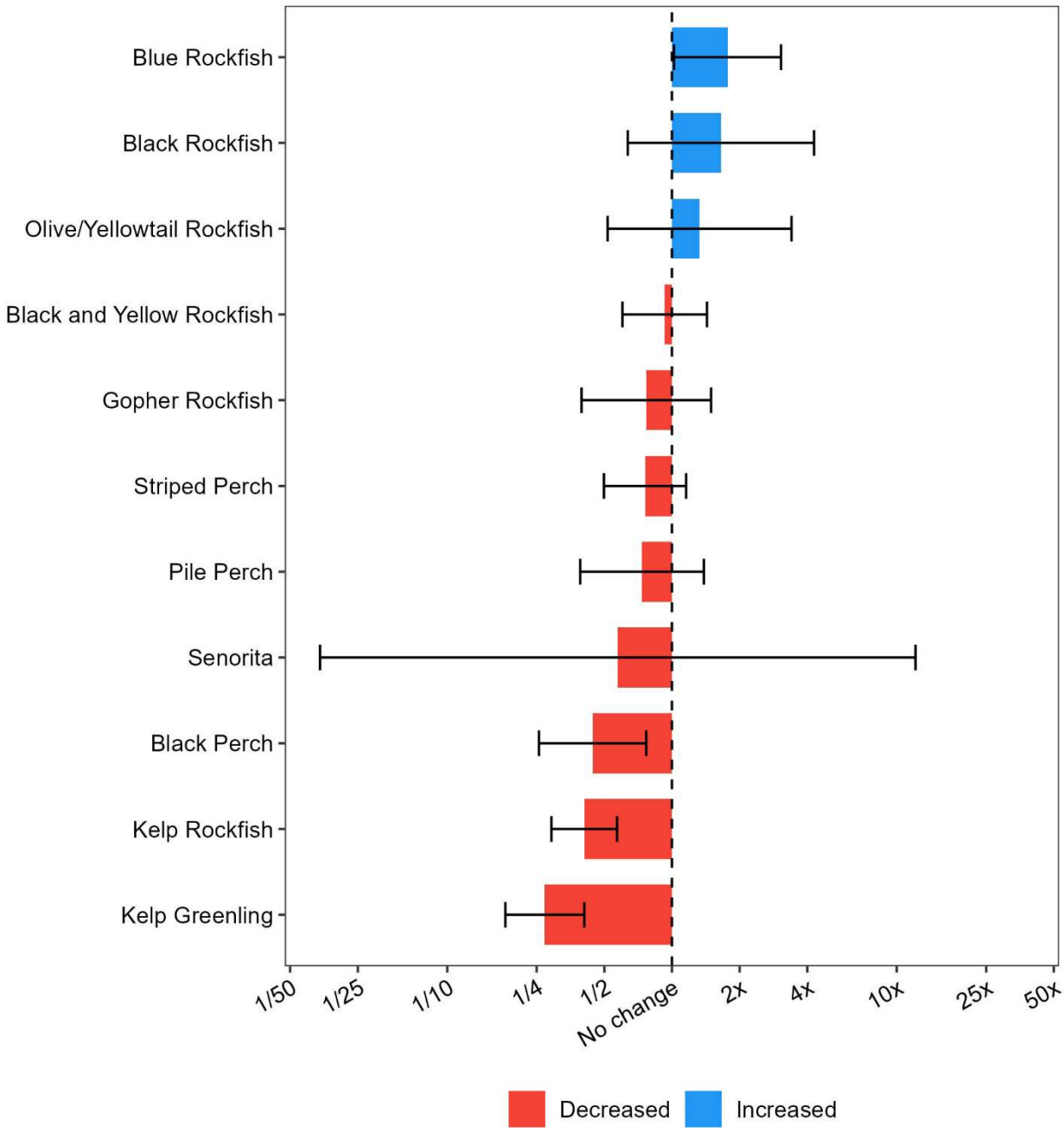

Figure 18. Change in fish densities in 2025 compared to pre-heatwave densities in Central California. Log response ratio of mean density is shown to compare pre-heatwave baseline to 2025 surveys. Error bars represent 95% bootstrap confidence intervals. Taxa absent in 2025 surveys are noted accordingly. Data from all sites surveyed at least three times prior to the 2014 heatwave and in 2025 are included.

Southern California

Giant kelp densities in Southern California appear to be relatively stable at many sites, but there are some clear declines at some sites on the front side of Catalina Island and in San Diego (**Figure 19**). Several sites around Catalina were only monitored in the year following the heatwave, and kelp has been absent or at very low kelp densities at those sites. Other sites, especially around Two Harbors, show some recovery in the most recent two years. Similarly, sites that are monitored in Orange County had low kelp densities in years following the heatwave, but show increasing kelp densities in recent years. Sites around the northern Channel Islands that have been monitored consistently show stable patterns of either high or low kelp densities, and Palos Verdes had very low kelp densities across all sites monitored in 2025 **(Figure 19)**.

When comparing species densities in 2025 to pre-heatwave densities across the entire South Coast Region for sites that were monitored in 2025, the understory southern sea palm densities have declined significantly to 33% compared to pre-heatwave densities, and woody kelp is at 79% of its historic density (**Table 13, Figure 20)**.

Invertebrate species over the region show diverse changes **(Figure 21).** In contrast to other regions, purple and red urchins have decreased compared to pre-heatwave densities to 28% and 21%, respectively, in Southern California. Several sea star species also show significant declines, as well as keyhole limpets and red gorgonians, all less than 50% of their historical means **(Figure 21, Table 13).** Green abalone show much higher densities in 2025 compared to pre-heatwave with an almost 8-fold increase. Wavy/red turban snails and rock scallop increased in density post-heatwave. However, none of the invertebrate species show any significant trends in their densities over the last five years, suggesting relatively stable populations in recent years (**Table 13**).

Fish densities in 2025 compared to pre-heatwave densities in Southern California are in general lower, and some of the colder water species, such as many of the rockfish, were noticeably absent or had much lower densities than before the heatwave **(Figure 22).** Giant sea bass seem to have increased since the heatwave but show high variability across the region, as they are mainly found at few sites, especially around Catalina Island. Most fish species show no trends of the past five years, but sheephead and garibaldi densities were decreasing (**Table 13**).

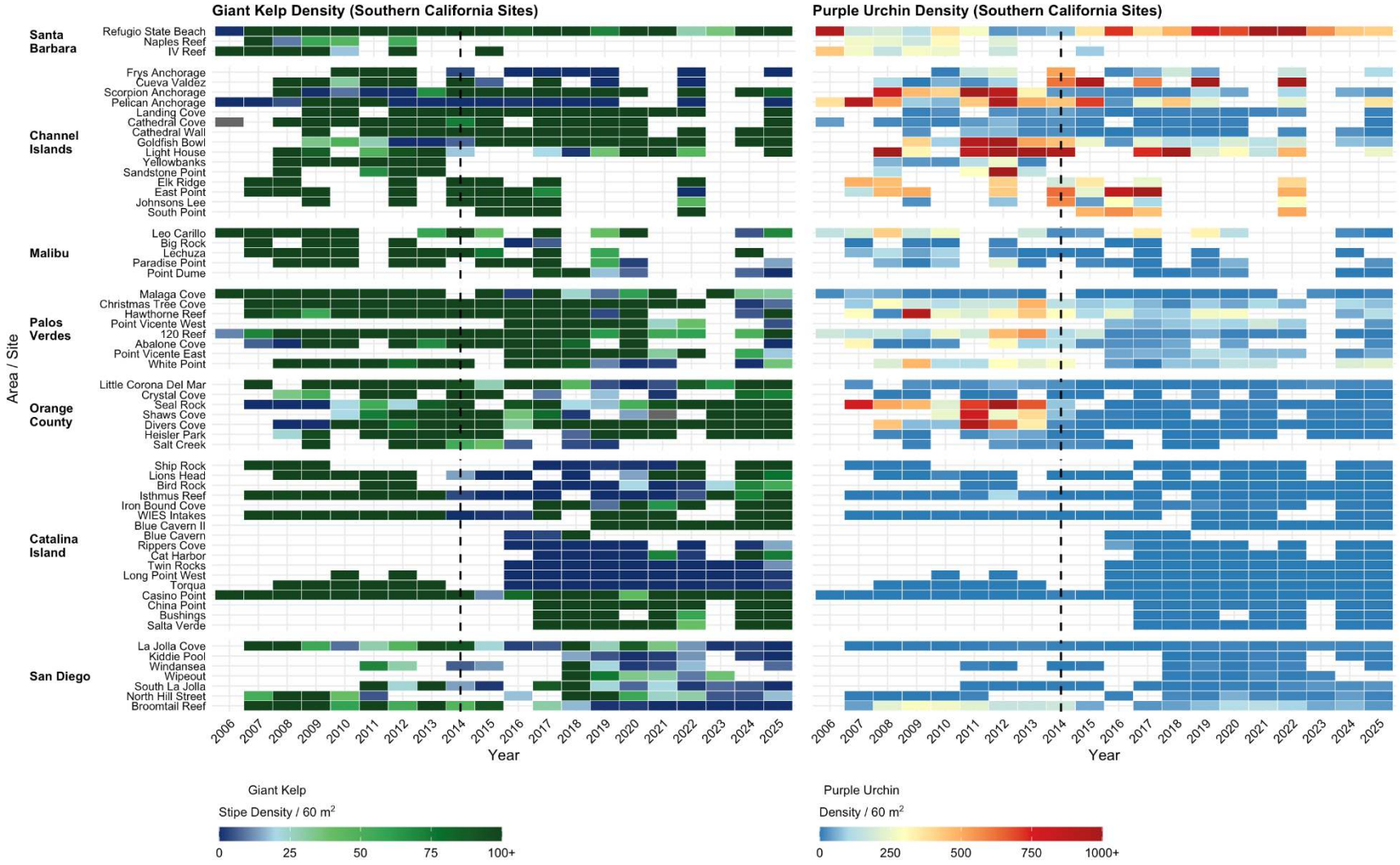

Figure 19. Giant kelp (left) and purple urchin (right) densities over the years since monitoring started at sites in Southern California. The color scale indicates density from low (blue) to high (green/red). Scale has been capped at 100 for giant kelp and 1,000 for urchins; all higher values are grouped and shown in green/red. Y-axis shows sampling sites grouped by sampling area and ordered north to south

Table 13. Status and trends of species in Southern California. Status in 2025 shows the percent change in species' density compared to their mean pre-heatwave density (large changes are shown as x-fold for easier readability). Trends are estimated by linear regression of the last five years of data. Blue arrows indicate significant trends and their direction.

	Species	2025 Status	5-year Trend
Kelp	Oar Kelp	-2%	➡
	Giant Kelp	-8%	➡
	Woody Kelp	-21%	➡
	Southern Sea Palm (>30)	-67%	➡
Invert	Green Abalone	8x	➡
	Rock Scallop	8x	➡
	Wavy/Red Turban Snail	5x	➡
	Kellet's Whelk	3x	➡
	California Spiny Lobster	3x	➡
	Brown/Golden Gorgonian	2x	➡
	Chestnut Cowry	2x	➡
	Crowned Urchin	+81%	➡
	Warty Sea Cucumber	-31%	➡
	Large Anemone	-59%	➡
	Giant Keyhole Limpet	-59%	➡
	Red Gorgonian	-61%	➡
	Purple Urchin	-72%	➡
	Red Urchin	-79%	➡
	Bat Star	-90%	➡
	California Sea Cucumber	-92%	➡
	Giant Spined Star	-98%	➡
	Sunflower Star	-100%	➡

	Species	2025 Status	5-year Trend
Fish	Rock Wrasse	+15%	↘
	Kelp Bass	+3%	➡
	Garibaldi	-30%	↘
	Black Perch	-34%	➡
	Sheephead	-37%	↘
	Blacksmith	-46%	➡
	Opaleye	-53%	➡
	Pile Perch	-59%	➡
	Barred Sand Bass	-61%	➡
	Rainbow Perch	-64%	➡
	Senorita	-73%	➡
	Kelp Rockfish	-98%	➡

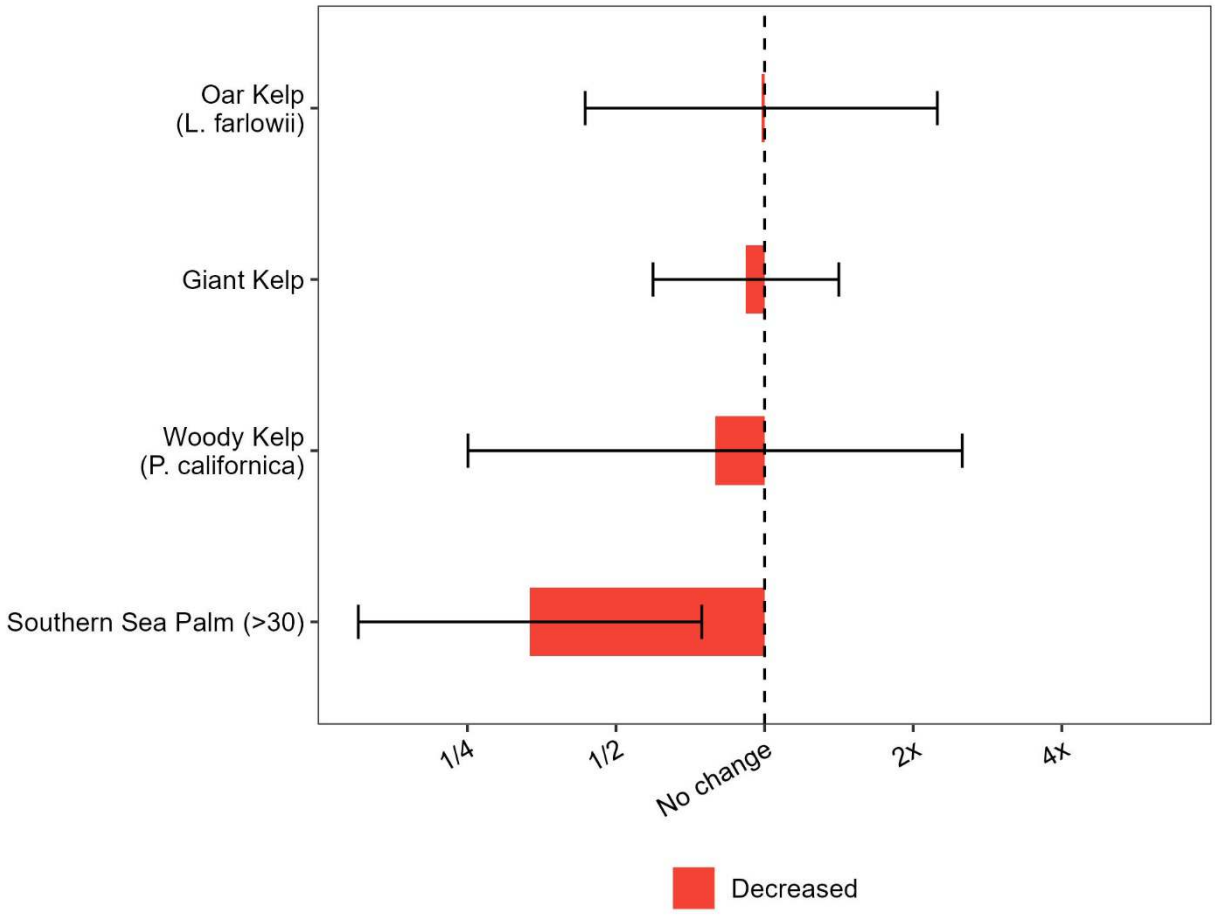

Figure 20. Change in algae densities in 2025 compared to pre-heatwave densities in Southern California. Log response ratio of mean density is shown to compare pre-heatwave baseline to 2025 surveys. Error bars represent 95% bootstrap confidence intervals. Taxa absent in 2025 surveys are noted accordingly. Data from all sites surveyed at least three times prior to the 2014 heatwave and in 2025 are included.

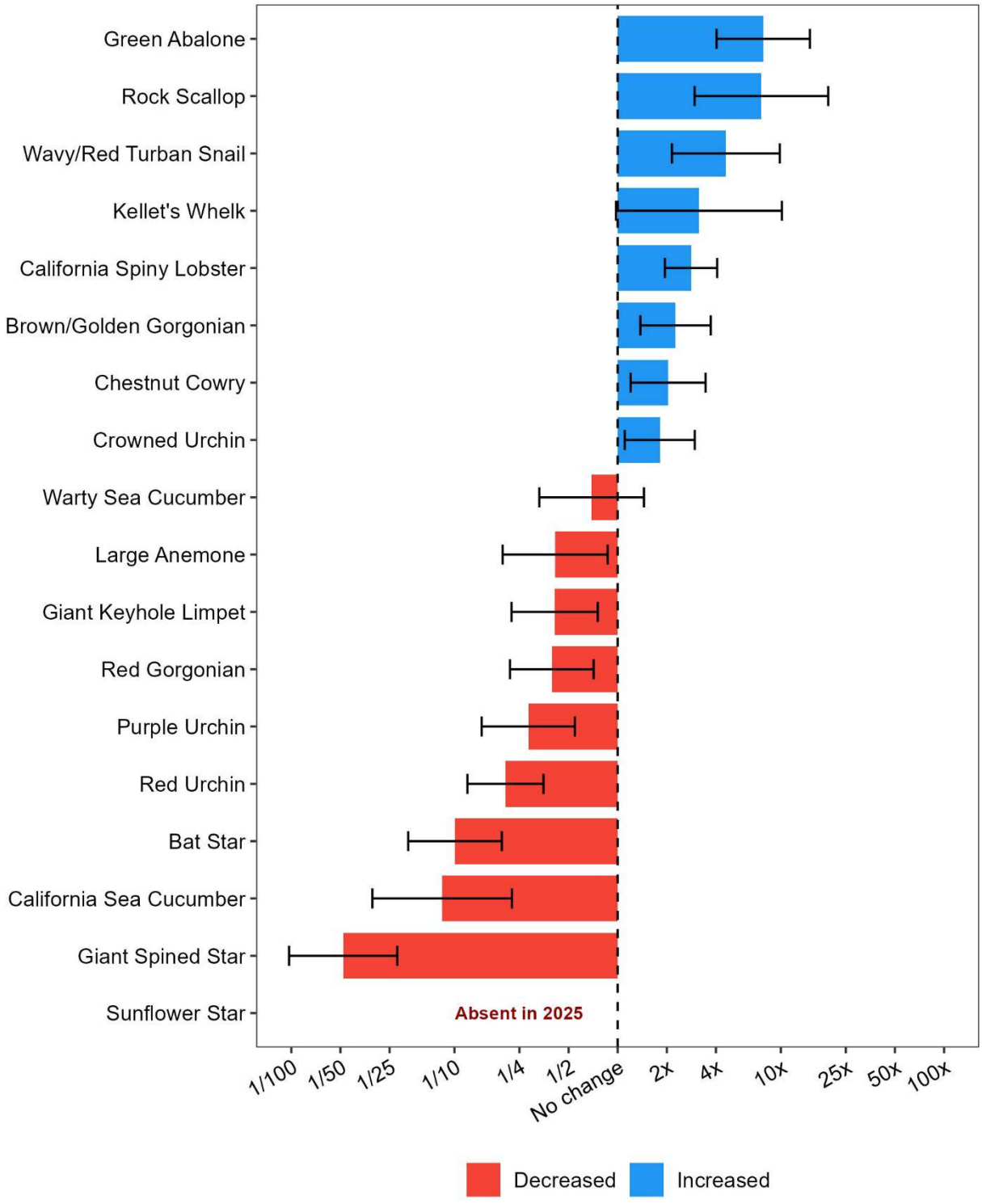

Figure 21. Change in invertebrate densities in 2025 compared to pre-heatwave densities in Southern California. Log response ratio of mean density for is shown to compare pre-heatwave baseline to 2025 surveys. Error bars represent 95% bootstrap confidence intervals. Taxa absent in 2025 surveys are noted accordingly. Data from all sites surveyed at least three times prior to the 2014 heatwave and in 2025 are included.

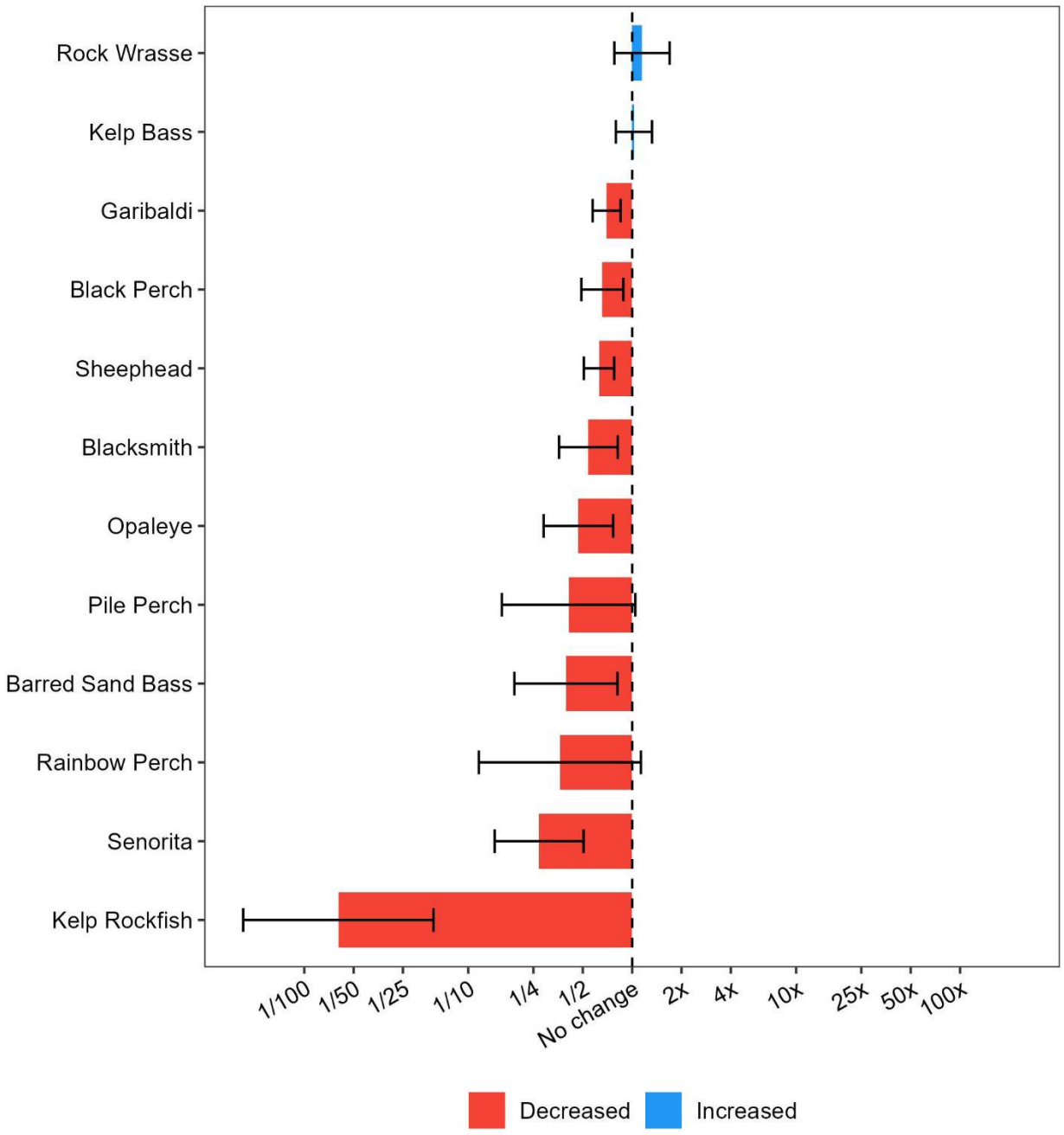

Figure 22. Change in fish densities in 2025 compared to pre-heatwave densities in Southern California. Log response ratio of mean density is shown to compare pre-heatwave baseline to 2025 surveys. Error bars represent 95% bootstrap confidence intervals. Taxa absent in 2025 surveys are noted accordingly. Data from all sites surveyed at least three times prior to the 2014 heatwave and in 2025 are included.

Interesting Species Trend Highlights

Kellet's Whelk- Central California

Significant increases of Kellet's whelk across the Central Coast were observed in recent years, particularly in Carmel Bay, where mean densities in 2025 were over 3 per 60 m^2. Sites off Cannery Row (n=7) had densities of over 20 whelks per 60 m^2 in 2023 but have since declined (**Figure 23**).

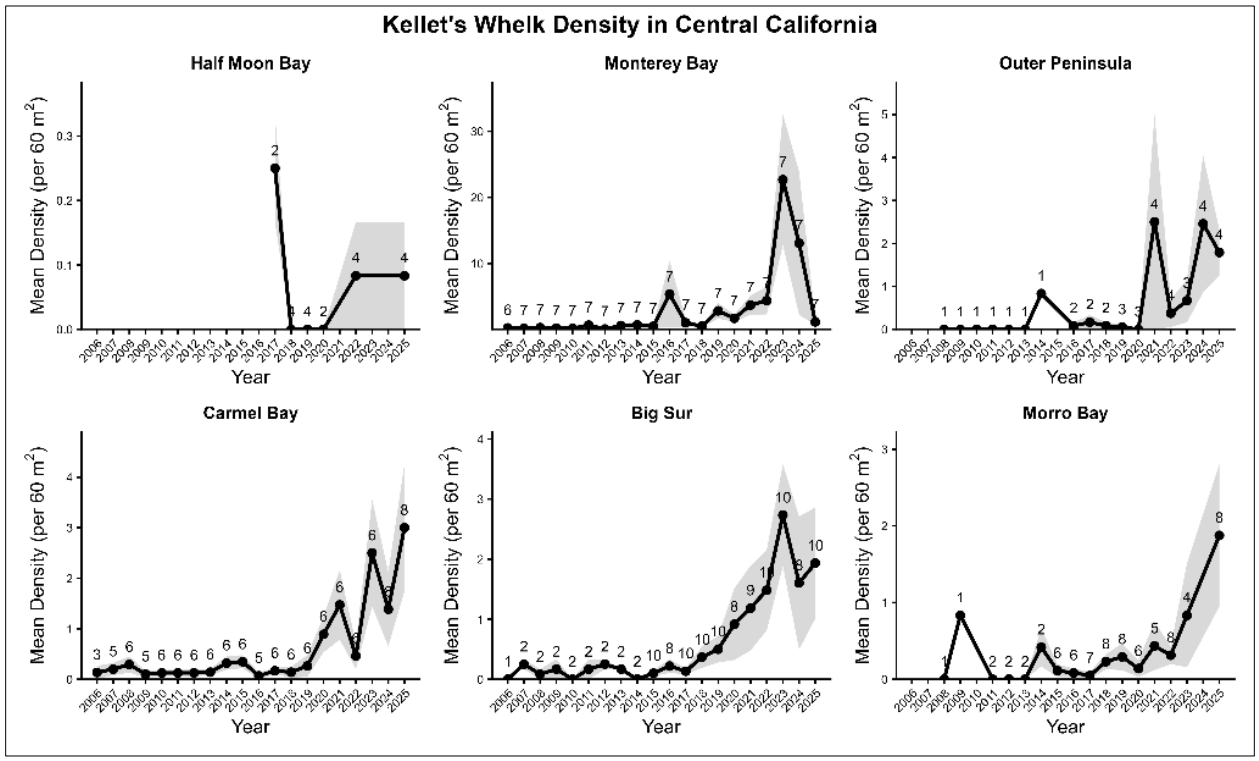

Figure 23: Kellet's whelk trends over time across areas in Central California. The black line indicates means across all monitored sites within the area. The light grey area indicates the standard error. The number above the data points indicates the number of sites used to calculate the mean for each year. Note that the y-axis scale changes for each plot.

Gumboot Chiton- North and Central California

Strong declines in gumboot chitons in Northern and Central California were observed in some areas. On the Central Coast, recent declines were found in the Outer Monterey Peninsula and Morro Bay (**Figure 24**). In Northern California, Mendocino sites showed a more substantial and sudden decline before and after the 2014 heatwave (**Figure 25**). Sonoma sites appear to have more of a steady decline over time, with no apparent drop after the heatwave.

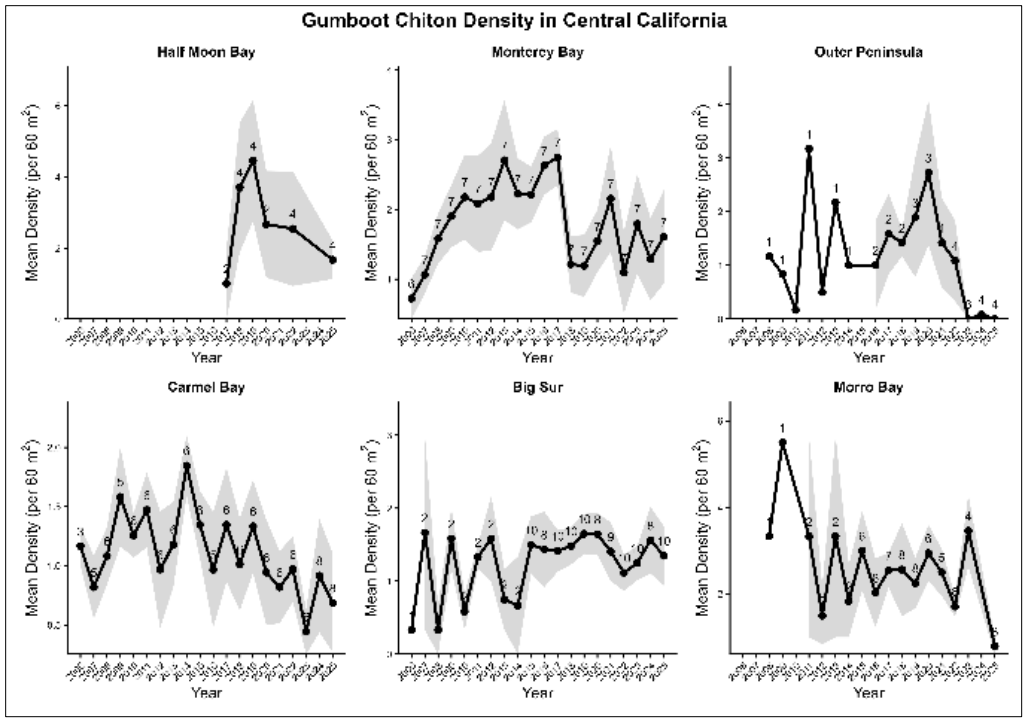

Figure 24. Gumboot chiton trends over time across all sites for areas in Central California. The black line indicates means across all monitored sites within the area. The number above the data points indicates the number of sites used to calculate the mean for each year. Note that the y-axis scale changes for each plot.

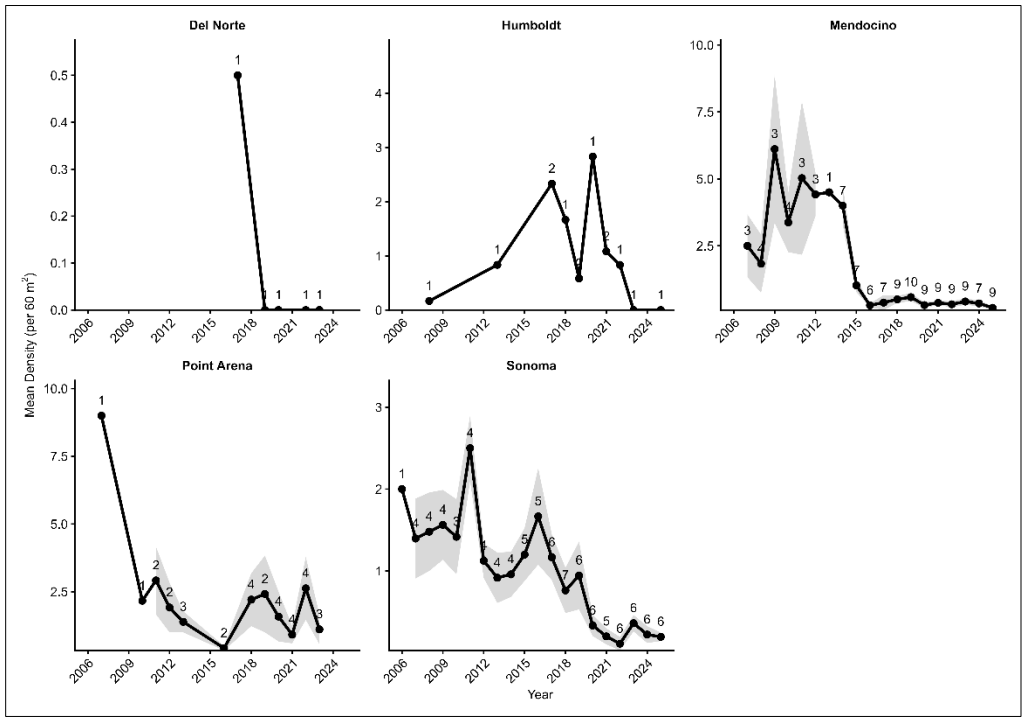

Figure 25. Gumboot chiton trends over time across for areas in Northen California. The black line indicates means across all monitored sites within the area. The light grey area indicates the standard error. The number above the data points indicates the number of sites used to calculate the mean for each year. Note that the y-axis scale changes for each plot.

Wavy/Red Turban Snails- Southern and Central California

Wavy/Red turban snails, family Turbinidae, have increased in densities in Southern and Central California post heatwave (**Figure 26, 27**). In Central California, most increases occurred after 2017, with densities highest in the Outer Monterey Peninsula and Carmel Bay sites with 27-35 individuals ± 15-23 SE/60 m^2. Big Sur and Morro Bay sites have also increased in densities, ranging between 6-9 individuals ± 15-23 SE /60 m^2 in 2025. Sites in Half Moon Bay have increased, but densities remain very low (<1 /60 m^2). In Southern California, turban snail densities are far greater, reaching between 100-200 per 60 m^2 in Malibu, Channel Islands and Palos Verdes sites over the last five years. Densities in Santa Barbara, Orange County, and Catalina Island sites have all increased since surveys began, but maintain densities more like that of Central California.

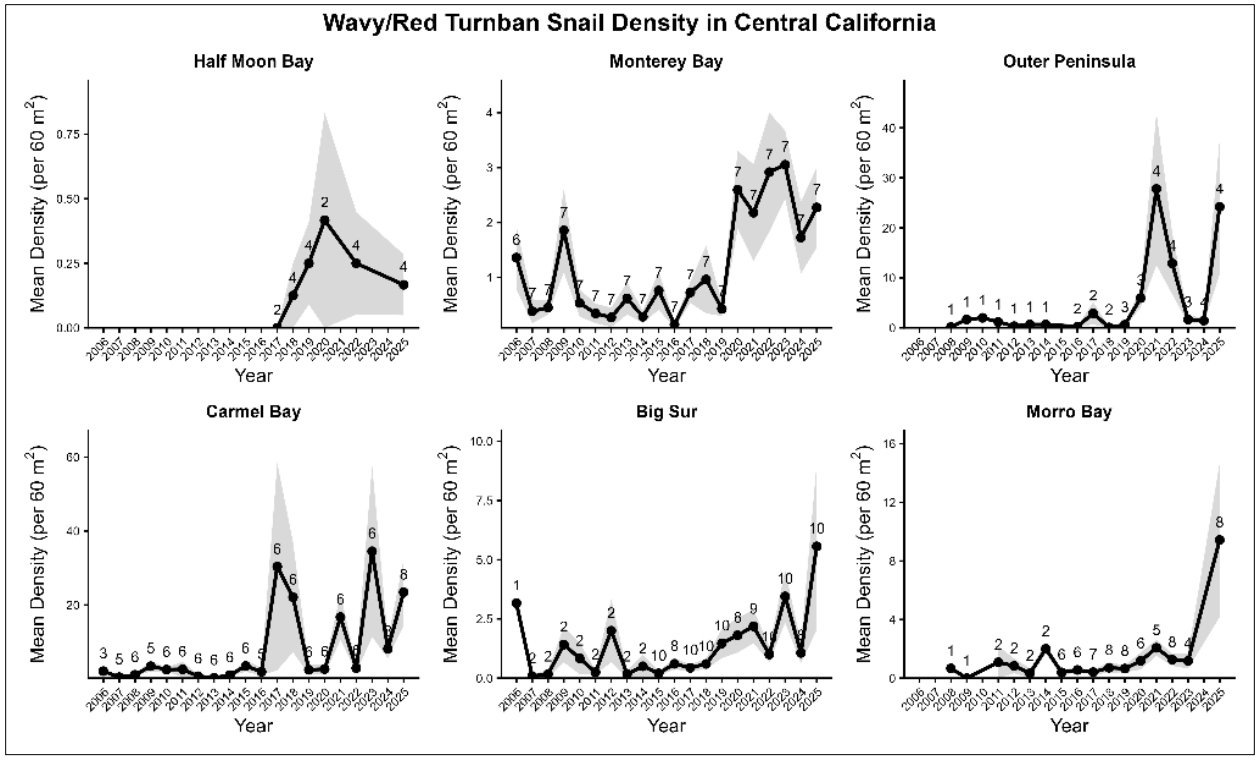

Figure 26: Wavy/Red turban snail trends over time across areas in Central California. The black line indicates means across all monitored sites within the area. The light grey area indicates the standard error. The number above the data points indicates the number of sites used to calculate the mean for each year. Note that y-axis scale changes for each plot.

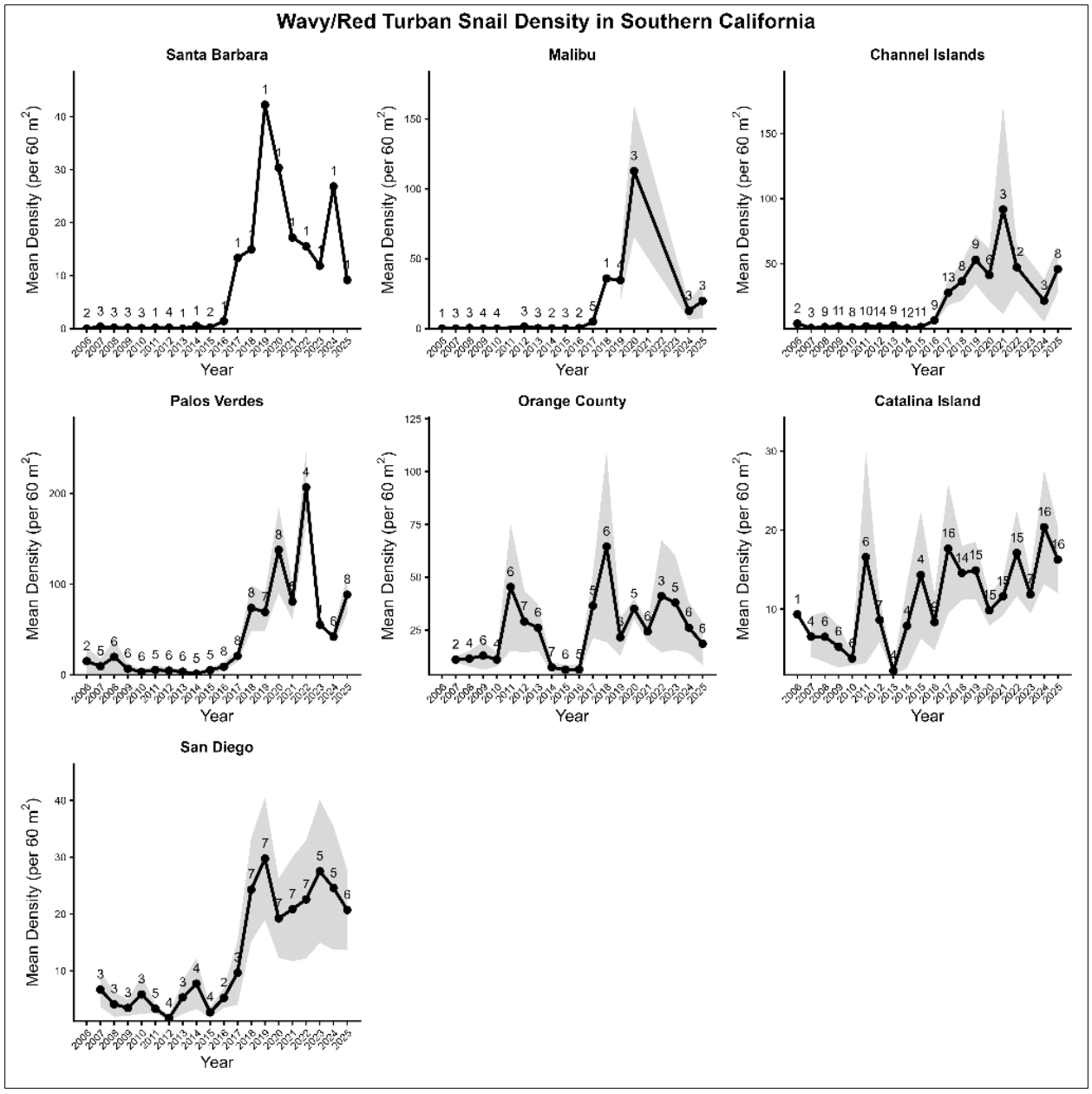

Figure 27: Wavy/Red turban snail trends over time across areas in Southern California. The black line indicates means across all monitored sites within the area. The light grey area indicates the standard error. The number above the data points indicates the number of sites used to calculate the mean for each year. Note that y-axis scale changes for each plot.

Señorita- Southern and Central California

Señorita on the Central and Southern coast of California show a strong peak of densities in most areas during and immediately after the heatwave. Some sites in Monterey, Big Sur, and Carmel Bay show a smaller jump in densities just before the heatwave and drop down again before peaking once more during the heatwave (**Figure 28**). In Southern California, that same peak during the heatwave appeared, but populations seem to show a slower decline following the heatwave (**Figure 29**). Sites in Orange County show the strongest decline in señorita densities, averaging 8-12 fish per 60 m^2, and dropping to

zero in 2025 surveys. Channel Islands sites, Catalina Island, Santa Barbara, and San Diego sites all show a more recent decline after the heatwave, starting around 2017-2018, and staying at low densities since.

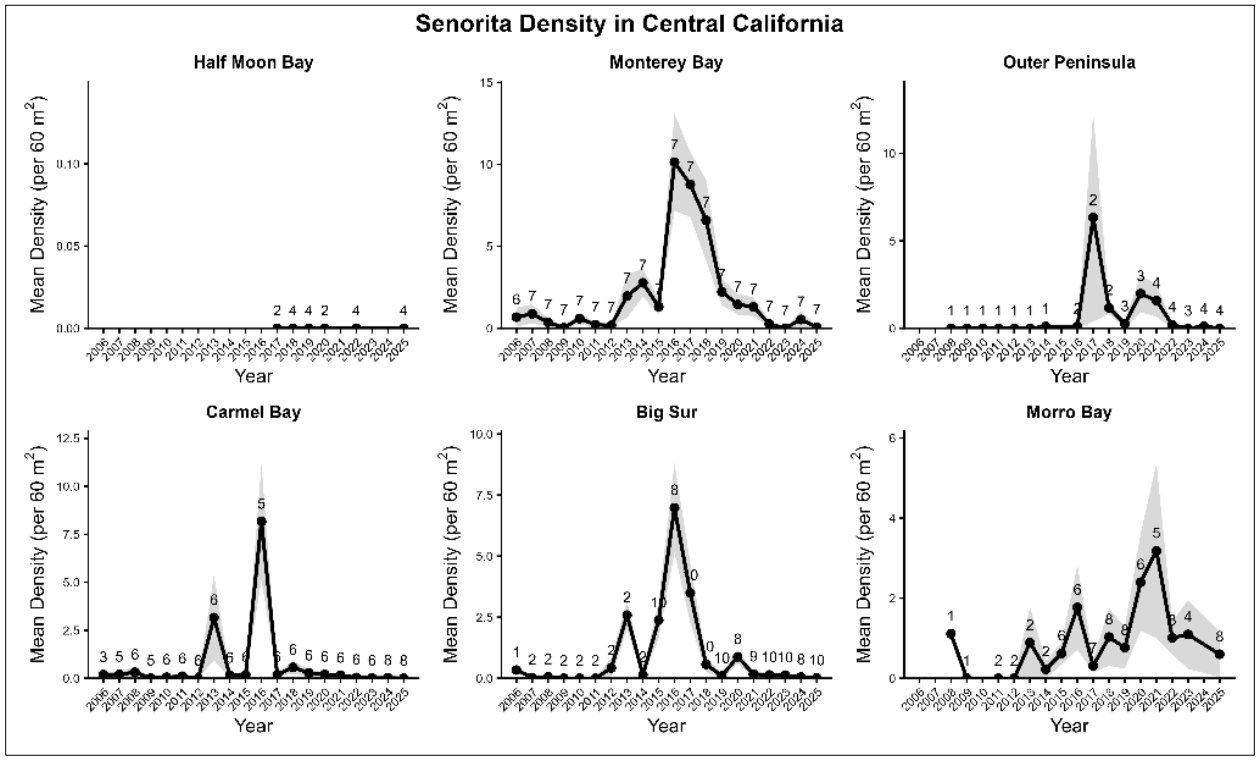

Figure 28: Señorita trends over time across areas in Central California. The black line indicates means across all monitored sites within the area. The light grey area indicates the standard error. The number above the data points indicates the number of sites used to calculate the mean for each year. Note that y-axis scale changes for each plot.

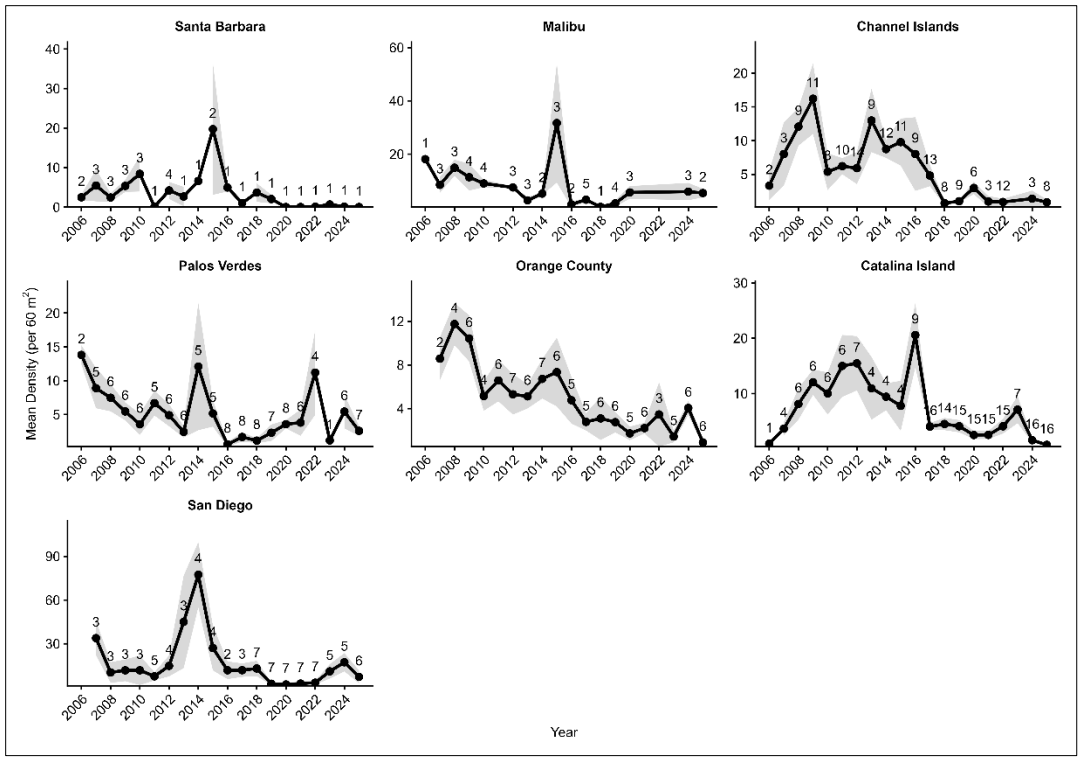

Figure 29: Señorita trends over time across areas in Southern California. The black line indicates means across all monitored sites within the area. The light grey area indicates the standard error. The number above the data points indicates the number of sites used to calculate the mean for each year. Note that y-axis scale changes for each plot.

Sargassum horneri- Southern California

The invasive *Sargassum horneri* was added to algae surveys starting in 2015. Since monitoring began, Catalina Island sites have had by far the highest densities in the Southern California region, with peaks in 2017 and 2019 with approximately 500 per 60 m^2 (**Figure 30**). Orange County sites follow with high densities in the past but appear to have declined as of 2022. Palos Verdes sites also had high densities in 2019-2020 but have also declined. As of 2025, Catalina Island sites have the densest *Sargassum*, with 6.5 ± 2.25 SE per 60 m^2, following Channel Islands (2.40 ± 1.92 SE), and Malibu sites (1.88 ± 0.98 SE).

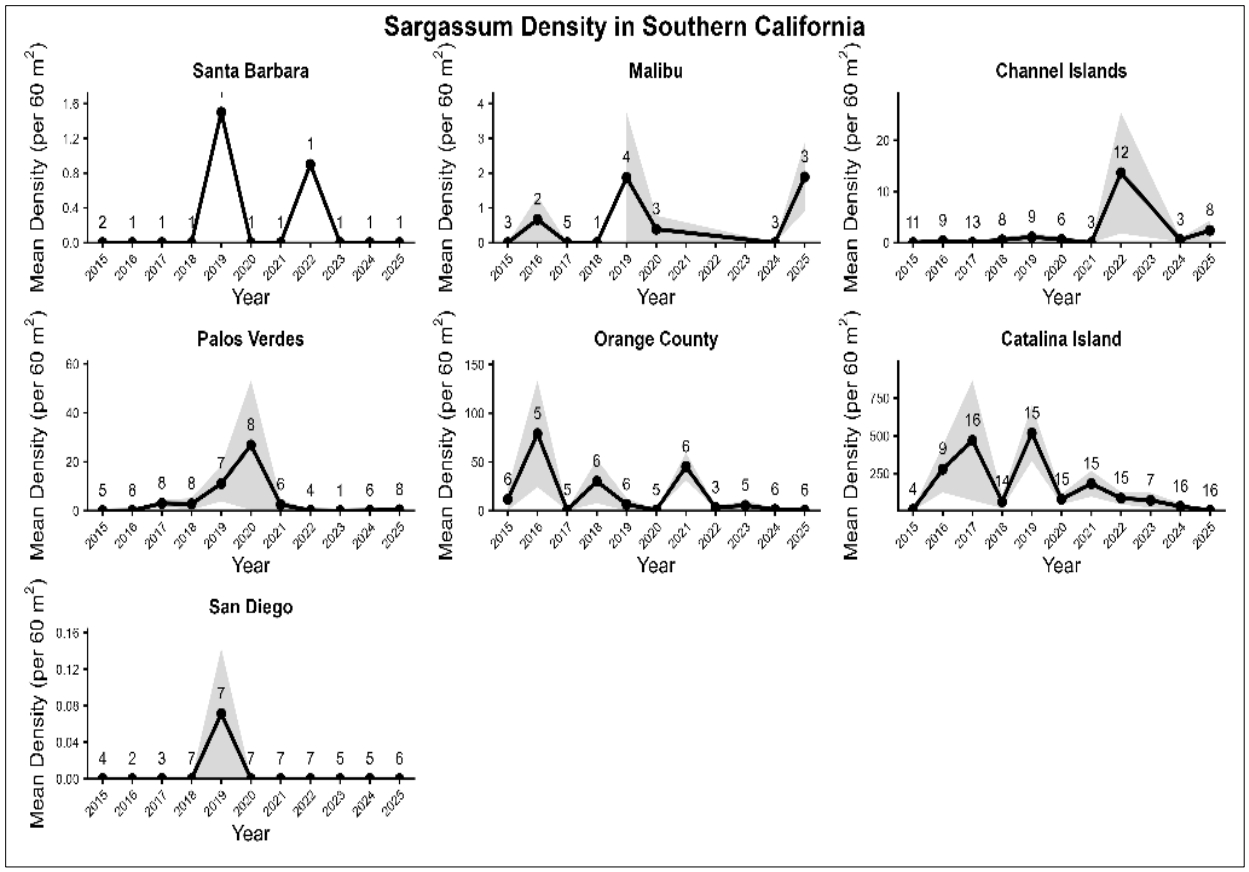

Figure 30: *Sargassum horneri* trends over time across areas in Southern California. The black line indicates means across all monitored sites within the area. The light grey area indicates the standard error. The number above the data points indicates the number of sites used to calculate the mean for each year. Note the y-scale changes for each plot.

Reef Check Volunteers

The number of volunteers participating in monitoring surveys across the West Coast has grown since the program's inception in California in 2006. In 2025, we had a record high number of 271 active volunteers, ranging from Baja California to Washington State, who donated 1,693 days of their time (**Figure 31**).

The numbers of volunteers and volunteer days have increased over time as the program has expanded both by adding more surveys in existing regions and as new regions are added (**Figure 31**). In 2025, several additional trainings were conducted, including a First Nations-focused training in British Columbia and an expanded training in Baja California. Furthermore, a record number of surveys were completed by an increasingly dedicated volunteer base.

While many volunteers contribute only a few days throughout the year, some have contributed over 100 days during their time with Reef Check, and a few have been volunteering since the program started in 2006. For a summary of volunteer demographics, see the 2024 Reef Check California Report.

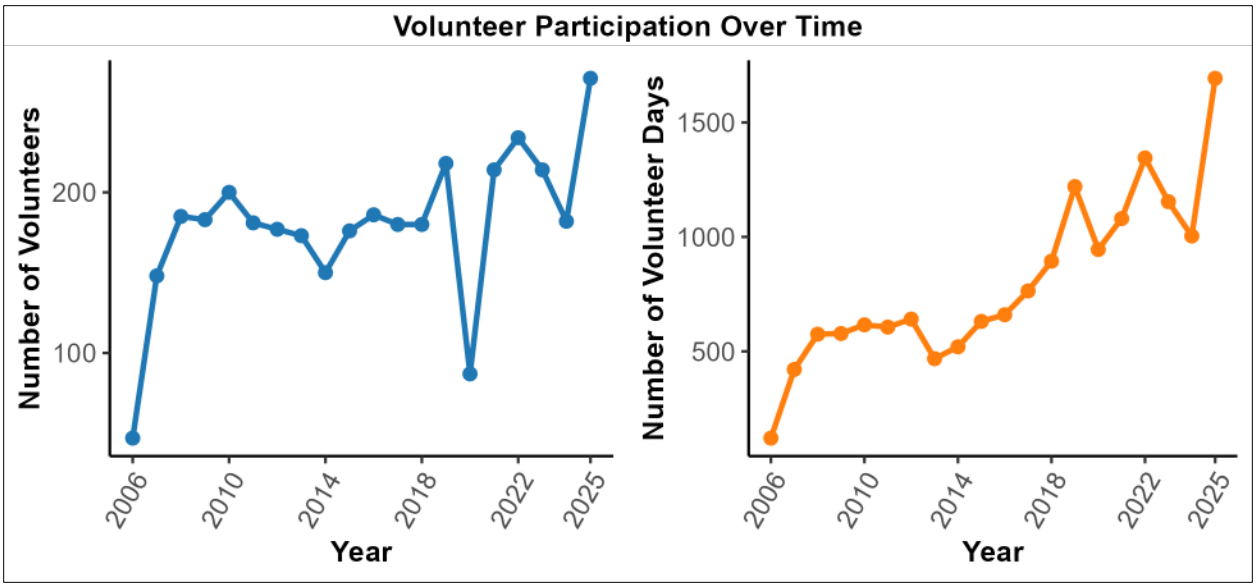

Figure 31: Number of volunteer divers participating annually in the Reef Check monitoring program (left) and the number of diver volunteer days they have contributed annually (right). Note that methods of tracking volunteers have varied over time.

Data Usage

Reef Check data is requested by filling out a form on the Results Page of the Reef Check website. Once requested, Reef Check staff send out data within 48 hours. Along with the dataset request, the users are sent a link to the Metadata for the Reef Check KFM Data document with descriptions of the data tables, as well as a Reef Check Species Lookup Table that provides taxonomic information on the Reef Check species. Although data has been available to the public since 2006, consistent data request tracking only began in 2023. From January 2023 to December 2025, Reef Check has received and fulfilled 302 data requests (**Table 14**). For a detailed description of Reef Check Data Management, refer to the Reef Check Data Management and Quality Assurance/Quality Control Procedures document.

The data requests received since January 2023 can be broken into seven categories:

1. **Academic Research:** Data requests from Postdocs, PhDs, Graduate, and Undergraduate projects, including senior theses, environmental science practicums, undergraduate capstone projects, and fellowship proposals. These requests are often for scientific research that results in peer-reviewed scientific publications and/or presentations at conferences.
2. **Student Learning & Skills Development**: Requests from users focused on learning specific tools or methodologies rather than publishing original research. For example, students are learning GIS, RStudio, Python, and data visualization courses. It also includes requests for general coursework, such as lab reports and university research paper practice.
3. **Professional Conservation & Management:** Requests from professionals using data for legal, governmental, or environmental management. This includes the use for resource assessments, species management, kelp restoration strategies, and economic resource assessment or information needed to obtain collection permits or grants.

4. **Resource Assessment and Mapping:** Locating specific biological features (i.e., urchin barrens), validating remote sensing and mapping results, and site selection for field surveys based on species abundance or environmental characteristics.
5. **Personal Interest & Exploration:** Individuals looking at the data for self-enrichment or hobbyist analysis.
6. **Media and Public Outreach:** Requests for communication-heavy projects intended for public or non-scientific audiences. This includes media and journalism, art installations, and public education.
7. **Tribal Management:** Requests from local stewards for project reporting and identifying issues and intervention.
8. **Development of Citizen Science Programs & Activism:** Requests for data as examples for other citizen science programs and requests to use for activism purposes.

By far, the largest share (41%) of data requests comes from Academic Research (**Table 15**), followed by Student Learning (23%), and Professional Conservation & Management (18%). In 2025 alone, Reef Check data was used in a total of eight peer-reviewed or grey literature reports. Reef Check data has been instrumental in understanding drivers of spatiotemporal variability of kelp forest species (Giraldo-Ospina et al., 2025) and developing status assessments in Washington (Claar et al., 2025, Larsen, 2025) and understanding past kelp forest productivity for the Channel Islands (McFarland et al., 2025). It is also still used to inform marine protected areas along the coastline (Todd et al., 2025) and assess long-term trends in kelp forests (Ricart et al., 2025). At large conferences, such as Western Society of Naturalists (WSN) 2025, Reef Check data was used in 10 presentations, most of which are likely to become peer-reviewed publications. Data requests come from a wide range of universities, government agencies and NGOs around the world (see below).

Table 14. Number of data requests from January 2023 to December 2025.

Year	# requests
2023	100
2024	83
2025	119
Total	**302**

Table 15. Types of data requests from January 2023 to December 2025.

Category	Number of Requests	Percent of Requests
Academic Research	126	41%
Student Learning & Skills Development	69	23%
Professional Conservation & Management	53	18%
Resource Assessment and Mapping	30	10%
Media and Public Outreach	13	4%
Personal Interest & Exploration	5	2%
Tribal use and management	4	1%
Development of Citizen Science Programs & Activism	2	1%
Total	**302**	

List of organizations that requested data from January 2023 to December 2025

Universities & Colleges

- Anglia Ruskin University
- Arizona State University
- Avignon Université
- California Polytechnic State University, San Luis Obispo
- California State Polytechnic University, Pomona
- California State University Channel Islands
- California State University Long Beach
- California State University Monterey Bay
- California State University Northridge
- Cal Poly Humboldt
- Chinese Academy of Sciences
- Duke University
- East Carolina University
- Harvard University
- James Cook University
- Moss Landing Marine Laboratories
- Orange Coast College
- Oregon Health & Science University
- Oregon Institute of Marine Biology
- Oregon State University
- Purdue University
- San Francisco State University
- San José State University
- Scripps Institution of Oceanography (UC San Diego)
- Sonoma State University
- Stanford University
- Stanford University Hopkins Marine Station
- Thompson Rivers University
- UC Berkeley
- UC Davis
- UC Irvine
- UCLA
- UC San Diego
- UC Santa Barbara
- UC Santa Cruz
- University of Adelaide
- University of Bath
- University of British Columbia
- University of Canterbury
- University of Chicago
- University of Iowa
- University of Leeds
- University of Maryland Center for Environmental Science
- University of Nevada, Reno
- University of Oregon
- University of Plymouth
- University of Portland
- University of San Francisco
- University of Southampton
- University of Tasmania
- University of Texas at Austin
- University of Victoria
- University of Washington
- University of Washington Friday Harbor Laboratories
- University of Wisconsin–Madison
- University of Wisconsin–Milwaukee
- University of Wolverhampton
- Wageningen University & Research
- Western Washington University

Government Agencies

- BC Government
- California Department of Fish and Wildlife
- California Ocean Protection Council
- California State Parks – Monterey District
- Chumash Heritage National Marine Sanctuary
- NOAA
- NOAA Fisheries
- NOAA Fisheries / Northwest Fisheries Science Center
- NOAA National Marine Sanctuaries
- Oregon Department of Fish and Wildlife
- U.S. Geological Survey
- US Department of the Interior – Bureau of Ocean Energy Management
- Washington Department of Natural Resources
- WA DNR Nearshore Habitat Program

Nonprofits, NGOs & Conservation Organizations

- Aquarium of the Bay
- Aqualink
- Catalina Island Marine Institute
- CeNCOOS
- Clallam County Marine Resources Committee
- Conservation Works
- Creek Lands Conservation
- Discovery Education
- Friends of Saltwater State Park
- Future Forum
- G2KR
- Get Inspired
- Greater Farallones Association
- Grass Roots Institute
- Hakai Institute
- Island Marine Resources Committee
- Khan Academy
- Lokahi Ocean Science
- Mountains to Sea Wellington
- Monterey Bay Aquarium
- Noyo Center for Marine Science
- Orange County Coastkeeper
- Oregon Kelp Alliance
- Paua Marine Research Group
- Point Defiance Zoo & Aquarium
- Puget Sound Restoration Fund
- Sacred Places Institute for Indigenous Peoples
- Samish Indian Nation
- Seattle Aquarium
- SCUBAnauts International
- Seahorses and Marker Buoys
- Sierra Club
- Smithsonian Magazine
- Sunflower Star Laboratory
- Surfrider Foundation San Luis Obispo Chapter
- The Nature Conservancy
- Urchinomics
- Vashon Nature Center

Companies, Industry & Consulting

- Biola University / NASA JPL
- Bleu World
- Brainerd
- Caribbean Sustainable Fisheries
- Centre Scientifique de Monaco
- Daybreak
- Do Design
- Dudek
- ERM
- FIRA
- Lokahi Ocean Science
- Microsoft
- Monterey Abalone Company
- Polaris Applied Sciences
- Rubin
- WSP

Schools (K–12)

- American School of The Hague
- Channel Islands High School
- Chadwick School
- George Washington High School
- Live Oak School
- Marin Country Day School
- Mission Bay High School
- New Hampshire High School
- San Diego Unified School District
- SCHS
- Washington High School

Other Organizations & Programs

- Cooperative Institute for Climate, Ocean, and Ecosystem Studies
- Marine Biological Association
- Marine Biological Association of the United Kingdom
- Oo-Nee SeaRanch
- Redfish Rocks Community Team
- The Sea Ranch

Methods

All surveys are completed following the Reef Check Kelp Forest Monitoring Protocol (Freiwald et al., 2025). Each survey includes six 30 m by 2 m swath transects consisting of counts of fishes, invertebrates, macroalgae, and 30-point Uniform Point Contact (UPC) observations. Transects are placed haphazardly at the survey site in predetermined depth zones. Along each transect, a set of 83 indicator species, comprising 13 species of macroalgae, 35 taxa of invertebrates, and 35 taxa of fishes, are looked for and enumerated. Indicator species have been selected because they are economically or ecologically important and of relevance to management, especially with respect to MPAs and fisheries (Gillett et al., 2012, Freiwald and Wehrenberg, 2013, Freiwald and Beahrs, 2020). Data on substrate, relief, and cover (sessile organisms) is collected at every meter during the UPC survey along the 30-meter transect. An additional 12+ fish transects (also 30 m by 2 m by 2 m high) are conducted during each survey.

In addition to the data described above, several other data types are collected during Reef Check surveys. Rare species such as white and black abalone, sunflower star, giant black seabass, and largemouth blenny are recorded if they are observed anywhere on the site. Abalone are sized when encountered on invertebrate transects, and roving urchin size frequency surveys are conducted at sites with high urchin densities. All fish are sized to the nearest centimeter. Video imagery is opportunistically collected both during fish transects and after transects are completed.

Long-term in situ temperature loggers are deployed at the sea floor in the kelp forest at most survey sites. The temperature loggers record temperature every 15 minutes. Every six to twelve months, the loggers are retrieved, and a new unit is deployed at that time.

Analyses

Status and 5-year trends

To compare species densities in 2025 to densities from years prior to the 2014 marine heatwave—a decade after this disturbance event—we selected sites that were surveyed at least three times prior to the heatwave and in 2025. Across all three regions of California this is a total of 56 sites.

For each species at each site, we first averaged density across all surveys within a period to obtain a single mean density per site for the pre-heatwave period and in 2025. Sites at which a species was absent in both periods were excluded, so that each species' estimate was based only on sites where it occurred at some point. Since we are generating the ratio of the means, removing sites that had zero observations in both periods does not affect the estimation, but it removes species that were not seen in the respective regions. Some species were not recorded prior to the heatwave, and these species were removed from the analysis to avoid misinterpreting later additions to the species list as colonization. For each species within a region, we then averaged these site-level mean densities across sites to obtain a regional mean density prior to the heatwave and in 2025 (each site weighed equally).

We classified each species–region combination into one of three categories. Species with a non-zero mean density in both periods were classified as present in both periods; species with a non-zero before mean but a zero after mean were classified as locally lost; and species absent in the before period but present in the after period were classified as locally added.

For species present in both periods, we calculated the percentage of the pre-heatwave baseline for each species in 2025:

Status = ($\bar{D}$ _2025/ $\bar{D}$ _pre-heatwave)*100

Where $\bar{D}$ is the mean density in the respective period. For presentation in the tables, we translated this into percent change in 2025 compared to pre-heatwave densities:

Percent Change = Status -100

So that negative percentages indicate a decline and positive percentages indicate an increase in density compared to pre-heatwave density, which is equal to 100%. For very large changes in density (i.e., over 1,000%) we changed the values into X-fold rather than showing percentage for easier comparison.

Further, we quantified change as the log response ratio (LRR):

LRR = ln($\bar{D}$_2025 / $\bar{D}$_pre-heatwave)

Where $\bar{D}$ is the regional mean density in 2025 and the pre-heatwave period, respectively. The log response ratio was plotted in hurricane plots with species ordered from largest increase to largest decline. Negative values indicate a decline and positive values an increase; an LRR of 0 indicates no change. Species classified as lost or as added were displayed separately on the figures rather than assigned a numeric ratio, because their ratios are undefined (division by, or of, zero). We estimated uncertainty in each LRR by bootstrapping over sites. We resampled sites with replacement 2,000 times; for each resample we recomputed the regional mean density in each period and the corresponding LRR, retaining only resamples in which the species was present in both periods. We summarized uncertainty as the 95% bootstrap interval (2.5th–97.5th percentiles of the resampled LRRs); error bars on figures show the half-width of this interval. All analyses were conducted in R (RStudio 2026.01.1+403) using the tidyverse (2.0.0).

To assess recent trajectories in species density (5-year Trend), we fit ordinary least squares (OLS) linear regressions of mean density against year for each species-region combination over the five-year period (2021–2025). For each combination, annual mean density was first calculated by averaging density (individuals per 60 m²) across all sites surveyed within a given region and year, yielding a single site-averaged value per year. A linear model was then fit to the resulting time series of annual means. Analyses were restricted to species-region combinations with a minimum of three years of data within the five-year window; combinations not meeting this threshold were excluded and classified as having insufficient data for trend estimation. For each model, we extracted the slope (rate of annual change in mean density), its associated *p*-value, and the coefficient of determination (R^2). Trends were classified as "Increasing" or "Decreasing" when the slope was significantly different from zero ($p < 0.05$) and positive or negative, respectively, and as "No Trend" when $p \geq 0.05$. This procedure was applied independently to each species within each region, to characterize recent trends in invertebrate density across the study area.

Heatmaps

Annual survey data for bull kelp, giant kelp, and purple urchins were compiled from statewide monitoring datasets and grouped into five long-term monitoring regions. To improve visualization and reduce blank space resulting from infrequently sampled sites, only sites with data from at least three survey years or sites surveyed within the three most recent years of the dataset were retained for plotting.

Annual mean densities (individuals or stipes per 60 m² transect) were visualized as heatmaps using the ggplot2 package in RStudio (version 2026.05.0+218). Survey year was plotted on the x-axis and sampling site on the y-axis, with color representing annual mean density. Sampling sites were ordered from north to south within each region.

To improve ecosystem shift interpretation and comparisons among sites, density color scales were capped at predetermined upper limits for each species. Observations exceeding these thresholds were assigned the highest color category. The color scaling was also lowered to better represent urchin barrens or dense kelp forests. A vertical dashed line was included in 2014 to mark the onset of the marine heatwave, "the Blob", providing a visual reference for comparing species densities before and after this disturbance.

Density time series plots

Annual survey data for algae, invertebrates, and fish were aggregated from statewide monitoring datasets and grouped into five long-term monitoring regions. Data were merged with site metadata containing regional, area, and geographic information. Species included in the analysis were selected from a predefined list. Data were sorted geographically using site latitude. Annual abundance was summarized at three spatial scales: regional, area, and site. For invertebrates and fish, abundance was quantified as mean density (individuals per 60m2 transect) for algae, giant kelp and feather-boa kelp were quantified as mean stipe density (stipes per 60m2 transect). Other algae species were quantified as mean individual density.

For regional analyses, annual mean density was aggregated across all sites within a region for each species. For area level analysis, annual means were aggregated across all sites within the area. Site-level analyses excluded sites with fewer than three years of available survey data to reduce plots without visually interpretable trends.

Temporal trends were visualized using line plots with annual mean abundance displayed as points connected by lines. The number of sites contributing to each annual regional or area-level mean was calculated and displayed above each point. Standard errors were calculated from site-level observations and used to generate shaded confidence ribbons around annual mean estimates. Separate plots were produced for each species at the regional, area, and site level allowing comparison of long-term population trends across multiple levels of spatial distribution. All data processing, statistical summaries, and figure generation were conducted in RStudio (version 2026.05.0+218) using the packages dplyr and ggplot2.

Maps

Maps were created in QGIS (version 3.44.7 - Solothurn) to display the spatial distribution of monitoring sites within each study region. Geographic coordinates for sampling sites were obtained from the statewide monitoring database and imported as point features. Regional boundaries were used to separate sites into the sampling regions.

For each region, a map was generated showing the location of all sampling sites included in the analyses. Base map layers and geographic reference data, including coastlines, state boundaries, and county boundaries, were obtained from Natural Earth (here). Maps were projected using the World Geodetic System 1984 coordinated reference system (WGS 84 - EPSG 4326).

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Appendix 1: Data Management

Accurate data management is one of the most critical components of the monitoring process. Reef Check's kelp forest program conducts over 180 surveys each year, each containing hundreds of data points, over a wide geographic area with a diverse array of teams. Reef Check has developed a robust system of data management to ensure accurate, high-quality data.

The Reef Check data management system begins in the field as soon as possible after the end of the data collection dive (**Figure A1**). Every survey has a designated "Data Captain" who conducts a series of field checks on the recorded observations. Datasheets from completed surveys are photographed and uploaded to an online archive within 24 hours of completion of the survey. Within one week of data collection, volunteers and interns enter the survey into Reef Check's proprietary Global Reef Database. Each datapoint is then double checked (QA/QC'd) by Reef Check staff. After the end of the field season (generally early November), a series of final checks are run on the dataset using R. Finally, the data is packaged and two data formats are made available for export. The summarized "survey means" format provides mean density and standard error of species by survey, whereas the "raw" data format is comprised of the raw counts per transect as well as additional data, such as fish or invertebrate sizes. See **Reef Check Data Management and Quality Assurance/Quality Control Procedures** for a full description of the data management process.

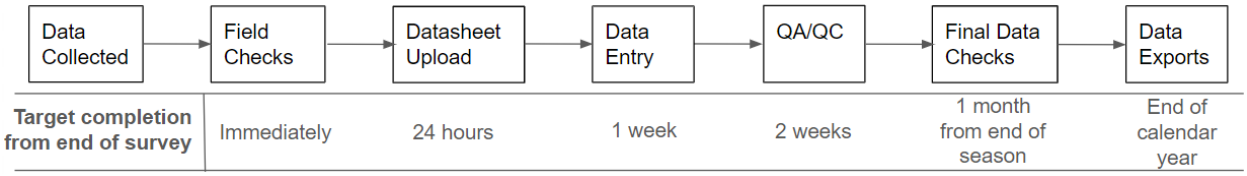

Figure A1. The Reef Check data management process with a timeline for completion.

Appendix 2: Reef Check Indicator Species

Table A2: Reef Check indicator species and scientific names

Reef Check Classcode	Scientific Name
Acid Weed	*Desmarestia ligulata*
Barred Sand Bass	*Paralabrax nebulifer*
Bat Star	*Patiria miniata*
Black Abalone	*Haliotis craherodii*
Black and Yellow Rockfish	*Sebastes chrysomelas*
Black Perch	*Embiotoca jacksoni*
Black Rockfish	*Sebastes melanops*
Black Sea Hare	*Aplysia vaccaria*
Black/Yellowtail YOY	*Sebastes melanops/serranoides* young of the year
Blacksmith	*Chromis punctipinnis*
Blood Star	*Henricia leviuscula*
Blue Rockfish	*Sebastes mystinus*
Blue Striped Sun Star	*Solaster stimpsoni*
Blue/Deacon YOY	*Sebastes mystinus/diaconus* young of the year
Bluntnose Sixgill Shark	*Hexanchus griseus*
Bocaccio	*Sebastes paucispinis*
Bocaccio YOY	*Sebastes paucispinis* young of the year
Broad-Ribbed Kelp	*Pleurophycus gardneri*
Brown Rockfish	*Sebastes auriculatus*
Brown Sea Cucumber	*Isostichopus fuscus*
Brown/Copper/Quillback YOY	*Sebastes auriculatus/caurinus/maliger* young of the year
Brown/Golden Gorgonian	*Muricea fruticosa/californica*
Buffalo Sculpin	*Enophrys bison*
Bull Kelp	*Nereocystis luetkeana*
Cabezon	*Scorpaenichthys marmoratus*
California Moray Eel	*Gymnothorax mordax*
California Sea Cucumber	*Parastichopus californicus*
California Sea Hare	*Aplysia californica*
California Spiny Lobster	*Panulirus interruptus*
Canary Rockfish	*Sebastes pinger*
Canary YOY	*Sebastes pinniger* young of the year
Caulerpa	*Caulerpa spp.*
Chestnut Cowry	*Neobernaya spadicea*
China Rockfish	*Sebastes nebulosus*
Copper Rockfish	*Sebastes caurinus*
Crowned Urchin	*Centrostephanus coronatus*
Dawson's Sun Star	*Solaster dawsoni*
Deacon Rockfish	*Sebastes diaconus*
Dungeness Crab	*Metacarcinus magister*
Feather Boa Kelp	*Egregia menziesii*
Finescale Triggerfish	*Balistes polyepis*
Five-Ribbed Kelp	*Costaria costata*

Table A2 (continued): Reef Check indicator species and scientific names

Reef Check Classcode	Scientific Name
Flat Abalone	*Haliotis walallensis*
Forage Fish	NA
Garibaldi	*Hypsypops rubicundus*
Giant Kelp	*giant kelp*
Giant Keyhole Limpet	*Megathura crenulata*
Giant Pacific Octopus	*Enteroctopus dofleini*
Giant Sea Bass	*Stereolepis gigas*
Giant Spined Star	*Pisaster giganteus*
Gopher Rockfish	*Sebastes carnatus*
Grass Rockfish	*Sebastes rastrelliger*
Green Abalone	*Haliotis fulgens*
Green Crab	*Carcinus maenas*
Green Urchin	*Strongylocentrotus droebachiensis*
Green/Pallid Urchin	*Strongylocentrotus droebachiensis/pallidus*
Gumboot Chiton	*Cryptochiton stelleri*
Hairy Triton	*Fusitriton oregonensis*
Halfmoon	*Medialuna californiensis*
Horn Shark	*Heterodontus francisci*
Horn Weed	*Sargassum horneri*
Kellet's Whelk	*Kelletia kelletii*
Kelp Bass	*Paralabrax clathratus*
Kelp Crab	*Pugettia spp.*
Kelp Greenling	*Hexagrammos decagrammus*
Kelp Perch	*Brachyistius frenatus*
Kelp Rockfish	*Sebastes atrovirens*
Large Anemone	*Urticina spp., Metridium spp., and Anthopleura spp.*
Largemouth Blenny	*Labrisomus xanti*
Leather Star	*Dermasterias imbricata*
Lingcod	*Ophiodon elongatus*
Masking Crab	*Loxorhynchus crispatus*
Mottled Star	*Evasterias troschelii*
Oar Kelp	*Laminaria farlowii*
Ocean Whitefish	*Caulolatilus princeps*
Ochre Star	*Pisaster ochraceus*
Octopus	*Octopus bimaculatus/rubescens*
Olive/Yellowtail Rockfish	*Sebastes flavidus or S.serranoides*
Opaleye	*Girella nigricans*
Orange Cucumber	*Cucumaria miniata*
Spiny Dogfish	*Squalus suckleyi*
Piddock Clam	*Zirfaea pilsbryi*
Pile Perch	*Rhacochilu svacca*
Pink Abalone	*Haliotis corrugata*
Pinto Abalone	*Haliotis kamtschatkana*

Table A2 (continued): Reef Check indicator species and scientific names

Reef Check Classcode	Scientific Name
Plumose Anemone	*Metridium farcimen*
Puget Sound Rockfish	*Sebastes emphaeus*
Puget Sound YOY	*Sebastes emphaeus* young of the year
Purple Urchin	*Strongylocentrotus purpuratus*
Quillback Rockfish	*Sebastes maliger*
Rainbow Perch	*Hypsurus caryi*
Rainbow Star	*Orthasterias koehleri*
Red Abalone	*Haliotis rufescens*
Red Gorgonian	*Leptogorgia chilensis*
Red Irish Lord	*Hemilepidotus hemilepidotus*
Red Urchin	*Mesocentrotus francicanus*
Rock Crab	*Cancer spp.*
Rock Greenling	*Hexagrammos lagocephalus*
Rock Scallop	*Crassadoma giganteum*
Rock Wrasse	*Halichoeres semicinctus*
Rubberlip Perch	*Rhacochilus toxotes*
Sargo	*Anisotremus davidsonii*
Señorita	*Oxyjulis californica*
Sheep/Masking Crab	*Loxorhynchus grandis/crispatus*
Sheephead	*Semicossy phuspulcher*
Shiner Perch	*Cymatogaster aggregata*
Short Spined Star	*Pisaster brevispinus*
Sieve Kelp	*Agarum clathratum/Neoagarum fimbriatum*
Slate Pencil Urchin	*Eucidaris thouarsii*
Slender Crab	*Metacarcinus gracilis*
Southern Sea Palm	*Eisenia arborea*
Spotted Ratfish	*Hydrolagus colliei*
Starry Urchin	*Arbacia stellata*
Striped Perch	*Embiotoca lateralis*
Sugar Kelp	*Saccharina lattisima/Hedophyllum nigripes*
Sun Star	*Solaster spp.*
Sunflower Star	*Pycnopodia helianthoides*
Three-ribbed Kelp	*Cymathaere triplicata*
Torn Kelp	*Laminaria setchellii*
Treefish	*Sebastes serriceps*
Unknown Rockfish	*Sebastes*
Vermilion Rockfish	*Sebastes miniatus*
Vermillion YOY	*Sebastes miniatus* young of the year
Wakame	*Undaria pinnatifida*
Warty Sea Cucumber	*Apostichopus parvimensis*
Wavy/Red Turban Snail	*Megastrea/Lithopoma parvimensis*
White Abalone	*Haliotis sorenseni*
Whitespotted Greenling	*Hexagrammos stelleri*
Winged Kelp	*Alaria marginata*

Table A2 (continued): Reef Check indicator species and scientific names

Reef Check Classcode	Scientific Name
Wire Weed	*Sargassum muticum*
Wolf Eel	*Anarrhichthys ocellatus*
Woody Kelp	*Pterygophora californica*
Yelloweye Rockfish	*Sebastes ruberrimus*
Yelloweye YOY	*Sebastes ruberrimus young of the year*
Yellowtail Rockfish	*Sebastes serranoides*
YOY Rockfish	Sebastes spp. young of the year
Zebra Perch	*Hermosilla azurea*

Supplemental Materials

The following links provide access to time series graphs of species densities in the respective regions. Species data are shown summarized for the entire regions and also for smaller geographic areas within each region. Mean density and standard error among sites are show for each year a species was surveyed.

Washington Species Trends

Oregon Species Trends

Northern California Species Trends

Central California Species Trends

Southern California Species Trends