Reef Check
Kelp Forest Monitoring
California Report
2024

Prepared for
The California Department of Fish and Wildlife

Prepared by the Reef Check Foundation
Jan Freiwald
Dan Abbott
Annie Bauer-Civiello

June 2025

Acknowledgments

We would like to extend a huge thanks to all the funding sources who made data collection in 2024 possible. Thank you to all of our grantors, Coastal Fund, SoCal Edison, Resources Legacy Fund, Sea Trees, and individual donors and thank you to the California Department of Fish and Wildlife for their support in the use of the RV *Garibaldi*. Most of all, we would like to thank the Reef Check volunteers who donated their time, and in many cases money, to help collect this vital data on our state's kelp forests.

Additionally, we would like to thank Jenny Folkesson for her work on figures 22 and 23.

Reef Check

Table of Contents

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 include temperate rocky reefs by launching its California Kelp Forest Monitoring (KFM) program. The Reef Check California (RCCA) protocol was developed by marine scientists to leverage trained volunteer divers in collecting standardized data on kelp forest communities (Freiwald et al. 2021). This citizen science approach provides the dual benefit of generating monitoring data while also increasing public awareness and engagement with ocean conservation.

Reef Check data have played a vital role in establishing baseline datasets for California's MPA network, in documenting the ongoing effects of the 2014-2016 marine heatwave and spread of urchin barrens over the last decade and in informing some of the earliest kelp forest restoration projects in Northern California (Freiwald and Wehrenberg 2013, Freiwald and Wisniewski 2015, Freiwald and Neumann 2017, Ward et al. 2022). For more information on how Reef Check data have been used, visit the publications page on the Reef Check website.

Originally developed to monitor ecosystem changes in Marine Protected Areas (MPAs) in California, Reef Check's KFM program has since expanded beyond California due to its reputation for high-quality training and data collection. The Reef Check Kelp Forest Program now includes programs in Baja California, California, Oregon, and Washington, and its data are widely used to support marine management and conservation efforts. In addition, Reef Check's education and outreach programs have built a dedicated constituency of skilled scuba divers passionate about kelp forest science and conservation. With the launch of the Dive into Science education program, Reef Check continues to increase diversity in the sciences through training participants from underserved and tribal communities in scuba diving and to be citizen scientists.

This report focuses on data from Reef Check California and presents an update on the status of rocky reef ecosystems based on nearly two decades of monitoring data (2006–2024) and highlights results from our 2024 survey season.

Reef Check California 2024 Program Overview

Monitoring Sites

The number of Reef Check California survey sites have been steadily increasing, starting with 19 long-term monitoring sites in 2006 to a total of 126 sites today (**Figure 1**). The majority of Reef Check sites (117 out of 126) are associated with California's extensive network of Marine Protected Areas (**Table 1**). Survey sites are located on rocky reefs at depths between 5 and 18 meters. 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.

Data in this report are broken down into three regions of California: Southern California, Central California, and Northern California (**Table 2**). These regions match California's bioregions as defined in the MPA Monitoring Action Plan (CDFW and OPC, 2018).

Figure 1. Current map of Reef Check survey sites across the state of California.

Table 1: Number of Reef Check sites associated with California Marine Protected Areas

Site	Number of sites associated with this MPA*	Number of sites completed in 2024
Abalone Cove SMCA	3	2
Anacapa Island SMCA	1	1
Anacapa Island SMR	4	1
Asilomar SMR	4	4
Big Creek SMR	4	3
Blue Cavern SMCA	7	7
Carmel Bay SMCA	6	6
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
Laguna Beach SMR	4	4
Long Point SMR	3	3
Lovers Point SMR	2	2
MacKerricher SMCA	2	0
Matlahuayl SMR	3	2
Montara SMR	4	0
Naples SMCA	1	1
Pacific Grove Marine Gardens SMCA	1	1
Point Arena SMR	4	0
Point Buchon SMR	4	0
Point Cabrillo SMR	3	3
Point Dume SMCA	2	2
Point Dume SMR	3	1
Point Lobos SMR	4	3
Point Sur SMR	5	5
Point Vicente SMCA	5	4
Pyramid Point SMCA	1	0
Russian Gulch SMCA	2	2
Salt Point SMCA	2	2
Scorpion SMR	4	1
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	0
Total	**117**	**80**

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

Table 2. Geographic boundaries of Reef Check California Regions

Region	Southern Latitude	Northern Latitude	Southern Boundary	Northern Boundary
Southern California	32.53	35.00	US/Mexico border	Point Conception
Central California	35.00	38.50	Point Conception	Golden Gate
Northern California	38.50	42.05	Golden Gate	California/Oregon border

Reef Check Methods

All surveys are completed following the Reef Check California Monitoring Protocol (Freiwald et al. 2021). 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. An additional 12+ fish transects (also 30 m by 2 m and by 2 m high) are conducted during each survey.

In addition to the data described above, several other data types are collected during RCCA 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. Abalones 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 swatch transects are completed and uploaded to an online archive.

Long-term in situ temperature loggers are deployed at the sea floor in the kelp forest near most survey sites (**Table 3**). 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.

Summary of 2024 Survey Results

In 2024, Reef Check California completed a total of 110 subtidal monitoring surveys at 88 of the 126 long term monitoring sites (**Figure 2)**. Surveys were not completed at 38 sites due to lack of funding and/or poor ocean conditions (**Appendix 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.

Of the surveys completed, 80 were at sites associated with California's network of Marine Protected Areas (**Table 1**). Roughly half of these surveys were located inside of MPAs with the other half being located outside at reference sites. Surveys were not completed at 37 sites associated with MPAs due to lack of funding and/or poor ocean conditions (**Appendix 1**). Surveys were completed at eight sites associated with Restoration projects, including efforts at Noyo, Albion, and Caspar Cove in Mendocino County and Tankers Reef and Big Sur Reef in Monterey County.

During each survey, eighteen 60 m^2 fish transects and six 60 m^2 swath transects (kelp, invertebrates, and UPC) were completed, so that in total 1,928 fish transects, and 633 swatch transects were sampled (**Table**

3). A total of 115,320 m^2 was sampled for fish, 37,620 m^2 was sampled for kelp and invertebrates, and a total of 18,810 UPC points to characterize the relief, substrate, and cover were recorded. Of the completed surveys, approximately 45% of sites are in Southern California, 34% in Central California, and 21% in Northern California.

A total of 49,707 fishes belonging to 35 taxa were recorded during Reef Check surveys in 2024 (**Table 4**). Young-of-the-year rockfish (all species) were the most abundant taxonomic fish group observed with a total of 21,888 observations. Finescale Triggerfish, a pantropical species of the Eastern Pacific that is expanding its range poleward, were looked for but were not observed during the 2024 Reef Check surveys. A total of 18,343 macro algae belonging to nine taxa were recorded. *Pterygophora californica* and giant kelp were the most abundant species observed with 4,346 and 4,187 observations, respectively. A total of 165,534 invertebrates belonging to 30 taxa were recorded. Purple urchin was by far the most abundant species observed, accounting for 120,635 observations. Black abalone, sun stars, and sunflower stars were looked for but were not observed in 2024.

In 2017, Reef Check began deploying temperature sensors at 75 of the ecological monitoring sites. These long-term in situ temperature loggers are deployed at the sea floor in the kelp forest near where the surveys are conducted. In 2024, loggers were retrieved and redeployed at 47 sites across California (approximately 50% of the total surveyed sites) (**Table 3)**.

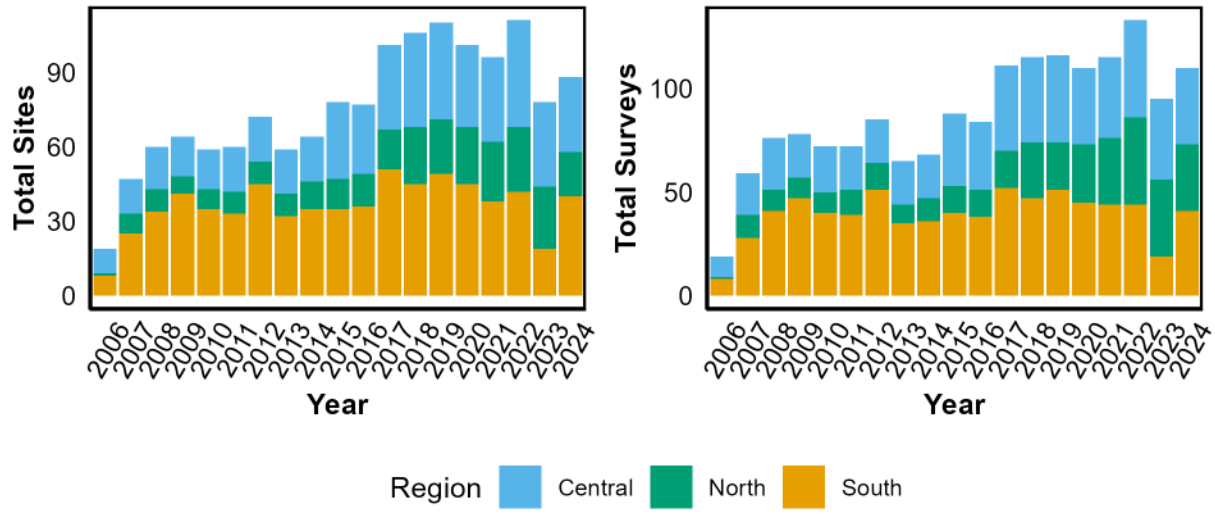


Figure 2. Number of sites (left) and surveys (right) completed by year for Southern, Central, and Northern California.

Table 3. Reef Check sites monitored in 2024.

Site	Latitude	Longitude	# of years surveyed	2024 Survey Date(s)	# of fish transects	# of swath transects	Temperature logger
Pyramid Point	41.994801	-124.217308	5	Not surveyed	n/a	n/a	n/a
Trinidad	41.054240	-124.144680	9	Not surveyed	n/a	n/a	Not Serviced
MacKerricher North	39.490631	-123.800503	6	Not surveyed	n/a	n/a	n/a
Glass Beach	39.451186	-123.815711	6	Not surveyed	n/a	n/a	n/a
Noyo North	39.429472	-123.813822	5	8/2/2024	18	6	Serviced
Noyo South	39.426910	-123.813190	7	7/16/2024	18	6	n/a
Caspar North	39.364647	-123.822133	11	4/19/2024 8/5/2024 10/26/2024	54	18	n/a
Caspar South	39.361729	-123.822449	13	4/2/2024 6/30/2024 10/20/2024	54	18	Serviced
Caspar South Restoration	39.361042	-123.821294	3	4/14/2024 7/14/2024 10/22/2024	9	9	n/a
Frolic Cove	39.355026	-123.823868	11	4/24/2024 7/15/2024 10/17/2024	54	18	Serviced
Russian Gulch	39.327984	-123.808800	11	6/30/2024	18	6	n/a
Mendocino Headlands	39.305283	-123.811218	16	8/22/2024	6	6	n/a
Portuguese Beach	39.302264	-123.803283	15	4/25/2024 8/1/2024 10/6/2024	54	18	Serviced
Van Damme	39.271915	-123.795914	18	10/24/2024	18	6	Not Serviced
Dark Gulch	39.240300	-123.776150	4	4/18/2024 7/31/2024 10/11/2024	54	18	n/a
Albion Restoration	39.228300	-123.774400	4	4/3/2024 8/4/2024 10/5/2024	54	18	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	9	8/25/2024	18	6	Serviced
Gerstle Cove	38.566460	-123.329964	19	8/24/2024	18	6	Serviced
Salt Point	38.564900	-123.329000	8	8/24/2024	18	6	n/a
Ocean Cove	38.555119	-123.305664	17	8/24/2024	18	6	Serviced
Stillwater Sonoma	38.545900	-123.299910	18	9/21/2024	20	6	Serviced
Fort Ross	38.510601	-123.245064	18	9/21/2024	6	6	Serviced
Beach Street	37.524400	-122.525800	3	Not surveyed	n/a	n/a	n/a

Table 3 (continued). Reef Check sites monitored in 2024.

Site	Latitude	Longitude	# of years surveyed	2024 Survey Date(s)	# of fish transects	# of swath transects	Temperature logger
Flat Rock	37.510010	-122.515560	5	Not surveyed	n/a	n/a	n/a
Half Moon Reef	37.486328	-122.490440	5	Not surveyed	n/a	n/a	n/a
Hurricane Ridge	37.470100	-122.479600	3	Not surveyed	n/a	n/a	n/a
Coral Street	36.637158	-121.926308	19	7/6/2024	6	6	Serviced
Otter Cove	36.634933	-121.919952	19	6/29/2024	18	6	n/a
Asilomar	36.634560	-121.946260	6	7/28/2024	22	6	n/a
Lovers Point	36.625450	-121.911934	19	6/29/2024	19	6	Serviced
Hopkins	36.621710	-121.901381	19	6/30/2024	23	6	n/a
Aquarium	36.619232	-121.899414	18	6/30/2024	26	6	n/a
Spanish Bay	36.617458	-121.950179	9	8/2/2024	18	6	Serviced
McAbee	36.616679	-121.896871	19	5/11/2024 9/19/2024	44	12	Serviced
Point Joe	36.610907	-121.966302	16	7/27/2024	18	6	Serviced
Breakwater	36.610451	-121.894333	19	5/27/2024 10/17/2024	36	12	n/a
Tankers Control	36.606691	-121.873057	4	6/1/2024 9/13/2024	36	12	n/a
Tankers Reef	36.604465	-121.880016	4	5/30/2024 9/12/2024	37	12	Serviced
Cypress Point	36.584581	-121.975877	3	10/20/2024	19	6	n/a
Pescadero	36.562302	-121.959602	19	6/22/2024	18	6	Serviced
Stillwater Monterey	36.560200	-121.945900	18	6/22/2024	19	6	Serviced
Copper Roof House	36.546620	-121.931180	1	8/31/2024	21	6	n/a
Carmel River	36.539082	-121.935097	17	8/3/2024	18	6	Serviced
Club House Reef	36.538270	-121.931770	1	9/21/2024	21	6	n/a
North Monastery	36.526806	-121.926544	17	5/12/2024	21	6	Serviced
South Monastery	36.525299	-121.931900	18	8/4/2024	18	6	Serviced
Middle Reef	36.521869	-121.938973	19	5/16/2024 9/27/2024	42	12	Serviced
Weston	36.511200	-121.946297	18	Not surveyed	n/a	n/a	n/a
Malpaso Creek	36.479980	-121.940047	10	8/24/2024	18	6	Serviced
Point Sur	36.288082	-121.892952	9	7/13/2024	18	6	Not Serviced
Andrew Molera	36.278454	-121.880859	8	7/15/2024	19	6	Serviced
South Wreck	36.226425	-121.789062	10	7/14/2024	20	6	Serviced
Fullers	36.208107	-121.752167	7	7/5/2024 9/2/2024	18	6	Not Serviced
Big Sur Reef Restoration	36.205730	-121.746100	3	7/4/2024 9/2/2024	18	6	Serviced
Esalen	36.125919	-121.647408	9	Not surveyed	n/a	n/a	Not Serviced
Dolan	36.103851	-121.628128	10	9/4/2024	18	6	Serviced
Big Creek	36.068272	-121.601619	18	8/15/2024	23	6	Serviced
Lopez	36.030560	-121.580841	10	9/4/2024	19	6	Serviced
Daddybob	35.538712	-121.098010	8	Not surveyed	n/a	n/a	Not Serviced

Table 3 (continued). Reef Check sites monitored in 2024.

Site	Latitude	Longitude	# of years surveyed	2024 Survey Date(s)	# of fish transects	# of swath transects	Temperature logger
White Rocks	35.527756	-121.085640	8	Not surveyed	n/a	n/a	Not Serviced
Harmony	35.500275	-121.054932	8	Not surveyed	n/a	n/a	Not Serviced
Estero	35.471779	-121.021248	9	Not surveyed	n/a	n/a	Not Serviced
Spooners Cove	35.281260	-120.893730	13	Not surveyed	n/a	n/a	Not Serviced
Corallina Cove	35.266670	-120.901940	4	Not surveyed	n/a	n/a	Not Serviced
Point Buchon	35.240650	-120.896300	11	Not surveyed	n/a	n/a	Not Serviced
Montana De Oro	35.231201	-120.885345	6	Not surveyed	n/a	n/a	Not Serviced
Refugio State Beach	34.461056	-120.066872	19	11/9/2024	18	6	Not Serviced
Frys Anchorage	34.054161	-119.755997	9	Not surveyed	n/a	n/a	n/a
Cueva Valdez	34.053219	-119.811670	10	Not surveyed	n/a	n/a	n/a
Scorpion Anchorage	34.048515	-119.552299	15	10/5/2024	18	6	n/a
Leo Carillo	34.043533	-118.944946	12	9/14/2024	20	6	Not Serviced
Big Rock	34.035168	-118.608086	6	Not surveyed	n/a	n/a	Not Serviced
Pelican Anchorage	34.034767	-119.702951	15	Not surveyed	n/a	n/a	n/a
Lechuza	34.034035	-118.871315	11	9/13/2024	20	6	Not Serviced
Landing Cove	34.017467	-119.362396	13	Not surveyed	n/a	n/a	n/a
Cathedral Cove	34.016499	-119.368385	13	Not surveyed	n/a	n/a	n/a
Cathedral Wall	34.015751	-119.371498	13	10/5/2024	18	6	n/a
Goldfish Bowl	34.014729	-119.437500	15	10/5/2024	18	6	n/a
Light House	34.012634	-119.364197	12	Not surveyed	n/a	n/a	n/a
Paradise Point	34.004128	-118.792900	10	Not surveyed	n/a	n/a	Not Serviced
Point Dume	33.998531	-118.805634	5	9/22/2024	18	6	Not 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	17	9/7/2024	18	6	Serviced
Christmas Tree Cove	33.760399	-118.421051	17	7/16/2024	18	6	Serviced
Hawthorne Reef	33.747002	-118.415886	15	7/16/2024	18	6	n/a
Point Vicente West	33.739700	-118.413696	7	Not surveyed	n/a	n/a	Not Serviced
120 Reef	33.737919	-118.392014	18	7/19/2024	18	6	n/a
Abalone Cove	33.736149	-118.376320	12	Not surveyed	n/a	n/a	n/a
Point Vicente East	33.736000	-118.401199	8	7/19/2024	18	6	Serviced
White Point	33.712844	-118.318026	14	8/2/2024	18	6	Serviced
Little Corona Del Mar	33.587859	-117.869271	17	10/8/2024	18	6	Serviced
Crystal Cove	33.564894	-117.834988	10	11/21/2024	18	6	n/a
Seal Rock	33.545227	-117.804392	17	8/29/2024	18	6	Not Serviced
Shaws Cove	33.543961	-117.799858	13	10/7/2024	18	6	n/a
Divers Cove	33.543393	-117.796384	17	8/30/2024	18	6	n/a
Heisler Park	33.542039	-117.792745	13	8/3/2024	18	6	Serviced
Ship Rock	33.462833	-118.491600	10	7/15/2024	19	6	Serviced
Lions Head	33.453447	-118.501319	13	7/15/2024	19	6	Serviced

Table 3 (continued). Reef Check sites monitored in 2024.

Site	Latitude	Longitude	# of years surveyed	2024 Survey Date(s)	# of fish transects	# of swath transects	Temperature logger
Bird Rock	33.450798	-118.487541	10	10/12/2024	18	6	Serviced
Isthmus Reef	33.448318	-118.490601	17	10/12/2024	18	6	n/a
Iron Bound Cove	33.447498	-118.575150	7	7/17/2024	18	6	Serviced
WIES Intakes	33.446999	-118.484848	15	10/11/2024	n/a	n/a	n/a
Blue Cavern II	33.443190	-118.473193	6	8/2/2024	18	6	Serviced
Rippers Cove	33.428150	-118.435471	7	7/17/2024	21	6	Serviced
Cat Harbor	33.426090	-118.511810	7	7/30/2024	18	6	Serviced
Twin Rocks	33.417910	-118.397900	9	7/18/2024	25	6	Not Serviced
Long Point West	33.410526	-118.378906	11	7/18/2024	23	6	Serviced
Torqua	33.383010	-118.358430	15	7/18/2024	19	6	Serviced
Casino Point	33.349167	-118.324966	19	7/13/2024 11/16/2024	36	12	n/a
China Point	33.330318	-118.469749	7	7/29/2024	18	6	Not Serviced
Bushings	33.317860	-118.441399	6	8/1/2024	18	6	Serviced
Salta Verde	33.314583	-118.421516	7	7/31/2024	18	6	Not Serviced
La Jolla Cove	32.854092	-117.270467	18	10/19/2024	19	6	Serviced
Kiddie Pool	32.844971	-117.285304	6	10/19/2024	20	6	n/a
Windansea	32.836601	-117.288002	9	Not surveyed	n/a	n/a	Not Serviced
Wipeout	32.821100	-117.287100	6	Not surveyed	n/a	n/a	n/a
South La Jolla	32.813450	-117.285767	13	10/19/2024	18	6	Serviced
North Hill Street	32.728619	-117.264999	13	10/20/2024	19	6	n/a
Broomtail Reef	32.694233	-117.268066	17	10/20/2024	20	6	Serviced

Table 4. Number of observations of Reef Check indicator species.

Taxa	# of observations
Invertebrates	
Purple Urchin	120,635
Red Urchin	15,874
Bat Star	9,757
Wavy/Red Turban Snail	5,143
Large Anemone	3,194
Crowned Urchin	2,473
Brown/Golden Gorgonian	1,987
Kellet's Whelk	1,031
Red Abalone	868
Leather Star	864
Rock Scallop	735
California Spiny Lobster	709
Warty Sea Cucumber	417
Ochre Star	379
Gumboot Chiton	257
California Sea Cucumber	225
Giant Spined Star	199
Green Abalone	167
Chestnut Cowry	133
Giant Keyhole Limpet	108
Red Gorgonian	102
Pink Abalone	97
Pinto Abalone	70
Sheep/Masking Crab	38
Short Spined Sea Star	29
California Sea Hare	27
Rock Crab	12
Black Sea Hare	2
Flat Abalone	1
Starry Urchin	1
Black Abalone	0
Sun Star	0
Sunflower Star	0
Total Invertebrates	**165,534**
Macroalgae	
Pterygophora californica	4,346
Giant Kelp	4,187
Laminaria farlowii	2,917
Southern Sea Palm	2,291
Bull Kelp	1,968
No Blade Kelp	884
Laminaria setchellii	870
Sargassum horneri	773
Feather Boa Kelp	107
Total Macroalgae	**18,343**

Taxa	# of observations
Fishes	
YOY Rockfish	21,888
Blacksmith	9,282
Senorita	3,433
Kelp Bass	2,968
Blue Rockfish	2,896
Rock Wrasse	2,303
Garibaldi	1,814
Sheephead	1,489
Black Perch	645
Striped Perch	559
Opaleye	335
Sargo	269
Kelp Rockfish	237
Kelp Greenling	218
Black and Yellow Rockfish	205
Black Rockfish	174
Pile Perch	167
Gopher Rockfish	127
Olive/Yellowtail Rockfish	121
Barred Sand Bass	105
Halfmoon	84
Rainbow Perch	81
Vermilion Rockfish	70
Copper Rockfish	52
Lingcod	50
Cabezon	31
Rubberlip Perch	30
California Moray Eel	26
Horn Shark	14
Treefish	12
Brown Rockfish	6
Giant Sea Bass (On-Transect)	6
China Rockfish	5
Grass Rockfish	4
Largemouth Blenny	1
Finescale Triggerfish	0
Total Fishes	**49,707**

Reef Check Volunteers

The number of volunteers participating in RCCA monitoring surveys has remained relatively stable since 2008, with 150 to 200 volunteers participating annually (**Figure 3**). The only exception was 2020, when volunteer numbers were substantially lower due to the COVID pandemic. In contrast, the number of days that volunteers contribute over a year has increased over time, and in recent years, volunteers have donated over 1,000 volunteer days per year. In 2024, 182 active citizen science divers volunteered a total of 1,004 days conducting surveys. 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's inception.

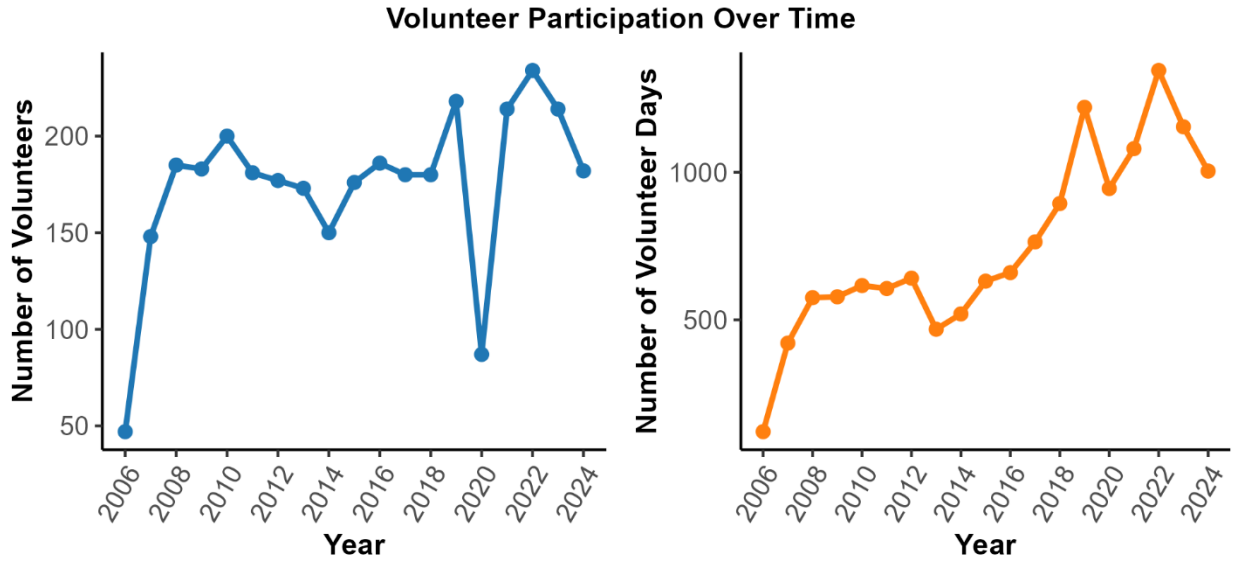


Figure 3. Number of volunteer divers participating annually in the RCCA monitoring program (left) and the number of diver volunteer days they have contributed annually (right).

In 2024, a survey was conducted to collect demographic information of RCCA volunteers. All returning Reef Check volunteers were requested to complete the survey via email, and a total of 28 participants responded (~25% response rate). The results of the survey showed that over 30 percent of participating volunteers are non-white, and roughly a quarter identify as LGBTQ (**Table 5**). According to a 2024 study from the Diving Equipment and Marketing Association (DEMA), divers in continuing education classes tend to be 71% male and only 23% female (DEMA 2024). However, Reef Check volunteers are fairly evenly split between male and female (with 4% non-binary or non-conforming). Contrary to the perception that volunteers tend to be older and retired, Reef Check volunteers are wide-ranging in age and the majority (85%) are employed. A majority of volunteers have graduate degrees, are fully employed, and have household incomes over $150,000 a year. This suggest that though the program has succeeded at getting non-scientists involved in marine monitoring, individuals with high levels of education and relatively high household incomes tend to be overrepresented, most likely due to the high barriers to entry for scuba training (financial and time commitment). It is for this reason that Reef Check launched the Dive into Science program.

Table 5. Breakdown of demographic information of RCCA volunteers.

Category	Number Responding	Percent
Race		
White	18	64%
Latina/o/x	3	11%
Multi-Racial	2	7%
Asian	2	7%
Middle Eastern/ North African decent	1	4%
Decline to State	1	4%
Gender		
Male	15	54%
Female	12	43%
Non-binary	1	4%
Sexual Orientation		
Heterosexual or Straight	21	75%
Lesbian or Gay	2	7%
Choose not to specify	2	7%
Bisexual	2	7%
Other	1	4%
Age		
19 to 24 years old	1	4%
25 to 34 years old	6	21%
35 to 44 years old	7	25%
45 to 54 years old	3	11%
55 to 64 years old	9	32%
65 years or older	2	7%
Education		
Some College	4	14%
Graduated from High School or Equivalent (GED)	1	4%
College Degree 2-Year	1	4%
College Degree 4-Year	5	18%
Graduate Degree	17	61%
Employment Status		
Employed, working 30 hours or more per week	19	68%
Employed, working less than 30 hours per week	5	18%
Not employed, NOT looking for work	3	11%
Not employed, looking for work	1	4%
Household income		
$0 to $19,999	1	4%
$20,000 to $49,999	2	7%
$50,000 to $89,999	3	11%
$90,000 to $129,999	3	11%
Over $150,000	15	54%
Prefer not to answer	4	14%

Dive into Science

The Dive into Science Program was established in 2019 to address barriers to entry and engage citizen science volunteers who better reflect the diversity of the communities in which we operate (**Table 6**). It aims to promote participation from historically underrepresented communities in marine sciences and cultivate the next generation of ocean stewards and leaders. The program trains participants from open

Table 6. Breakdown of demographic information of Reef Check Dive into Science participants. Not all participants answered all questions, therefore the number of responses varies by categories.

Category	Number Responding	Percent
Ethnic Background		
Indigenous American	48	47%
LatinX	18	17%
Black	16	16%
Multi-Racial	9	9%
White	8	8%
Asian/Pacific Islander	1	1%
Middle Eastern/North African decent	1	1%
Native Hawaiian or other Pacific Islander	1	1%
Decline to State	1	1%
Gender		
Male	53	51%
Female	42	41%
Non-binary	5	5%
Gender non-conforming	1	1%
Two-spirit	1	1%
Choose not to specify	1	1%
Age		
16 to 18 years old	17	17%
19 to 24 years old	40	39%
25 to 34 years old	32	31%
35 to 44 years old	6	6%
45 to 54 years old	6	6%
55 to 64 years old	2	2%
Education		
Some College	28	30%
Graduated from High School	25	27%
Some High School	16	17%
College Degree 4-Year	10	11%
College Degree 2-Year	9	10%
Graduate Degree	4	4%
Swimming Experience		
No	48	52%
Yes	44	48%
Household income		
$0 to $19,999	4	12%
$20,000 to $49,999	12	35%
$50,000 to $89,999	8	24%
$90,000 to $129,999	5	15%
$130,000 to $149,999	1	3%
Prefer not to answer	4	12%

water scuba certification to Reef Check Kelp Forest Monitoring training, and full American Academy of Underwater Scientist (AAUS) professional scientific dive training at no cost to the participants. In 2024, the Dive into Science program worked with 10 different cohorts from a wide range of communities including foster youth in Los Angeles County, youth from the Coastal Chumash and Tongva communities in Santa Barbara County, tribal members in Sonoma and Mendocino Counties, and with the Tolowa Dee-ni' Nation near the California-Oregon border.

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 beings in the field as soon as possible after the end of the data collection dive (**Figure 4**). 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 **Appendix 2** for the full description of the Reef Check data management process.

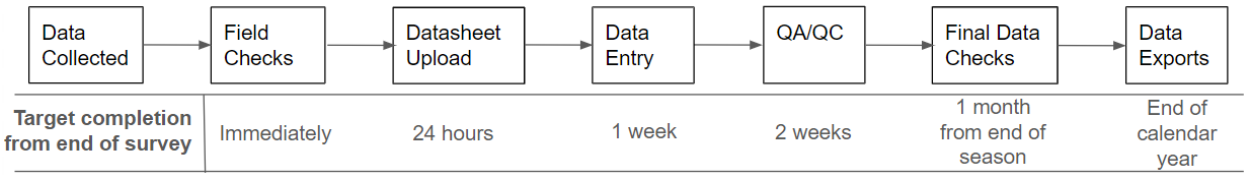


Figure 4. The Reef Check data management process with a timeline for completion.

Data Requests

Data is requested by filling out a form on the Results page on 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. Since January 2023 Reef Check has received and fulfilled 193 data requests from students, academic researchers, resource managers and members of the public (**Figure 5**).

The 88 long-term monitoring sites surveyed in 2024 have up to 19 years of data (**Table 3**). Additional files containing data from all sites and all years (2006-2024) accompany this report. The additional data files consist of data on fish, invertebrates, algae, and UPC in the two data formats outlined above.

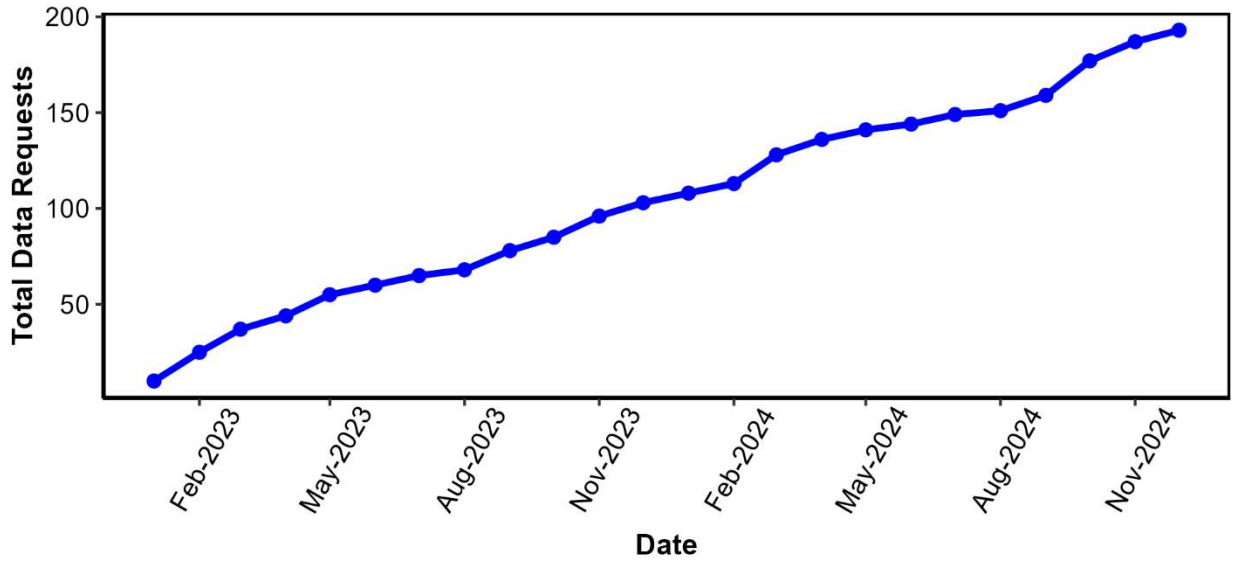


Figure 5. The cumulative number of data requests for Reef Check kelp forest monitoring data from 2023 to 2024.

2024 Select Results

For this report, we selected key species of interest and highlighted some results we have found over the last 19 years. Our selection focuses on canopy kelp, subcanopy kelp, urchins, red abalone, fish biodiversity, and temperature monitoring. Although a few sites were surveyed since 2006, for purposes of this report we are using data from 2007-2024.

Canopy Kelp Trends

Reef Check monitors the two dominant canopy-forming kelps in California, giant kelp (*Macrocystis pyrifera*) and bull kelp (*Nereocystis luetkeana*). Kelp forests in Northern California are historically dominated by bull kelp, and in Central California, both bull kelp and giant kelp are present. In Southern California, kelp forest canopies are formed by giant kelp.

There have been notable changes in giant kelp densities across all regions (**Figure 6**). In Northern California, giant kelp was only observed with limited abundance at one Reef Check site, Van Damme. However, since the 2014-2016 marine heatwave known as "the Blob" no giant kelp has been observed at this site (**Figure 7**). In Central California, overall densities of giant kelp have steadily decreased (**Figure 6**). Giant kelp stipes averaged over 180 stipes per 60 m^2 (+/- 15 SE) across sites in Central California before the Blob and average 49 stipes per 60 m^2 (+/- 15 SE) in recent years. Despite this overall decline, some sites have remained stable. For example, at the following sites in Central California, Breakwater, McAbee, Aquarium, Hopkins, and North Monastery, stipe densities have variable but not decreasing (**Figure 8**). In Big Sur, the Big Creek and Point Sur sites have had variable stipe densities sometimes averaging over 100 per transect, but in 2024 the stipe densities at these sites was significantly lower (**Figure 9**). In Southern California, the overall densities of giant kelp appear to be relatively stable, with a

slight decreasing trend since the Blob (**Figure 6**). However, there was some large interannual variability in average kelp density in the years following the Blob.

Bull kelp densities also varied following the 2014-2016 marine heatwave depending on the region in California. In Northern California, bull kelp averaged 25-50 individuals per 60 m^2 before the Blob and has all but disappeared from the Reef Check sites today (**Figure 10**).

In Central California, bull kelp densities increased after the Blob as giant kelp densities decreased (**Figure 11**). At the monitoring sites around the Monterey Peninsula (Monterey Bay, Carmel Bay, and Point Lobos), bull kelp densities increased to levels not seen in the years prior to the Blob and peaked between 2020 to 2022. This increase seems to have subsided in the last two years, and average bull kelp densities at Reef Check's sites have returned to what they were during the first 10 years of our time series (**Figure 11**). Along the Big Sur coast, where we started monitoring eight sites in 2015, bull kelp density is still increasing in recent years, while giant kelp shows a continuing declining trend (**Figure 11**).

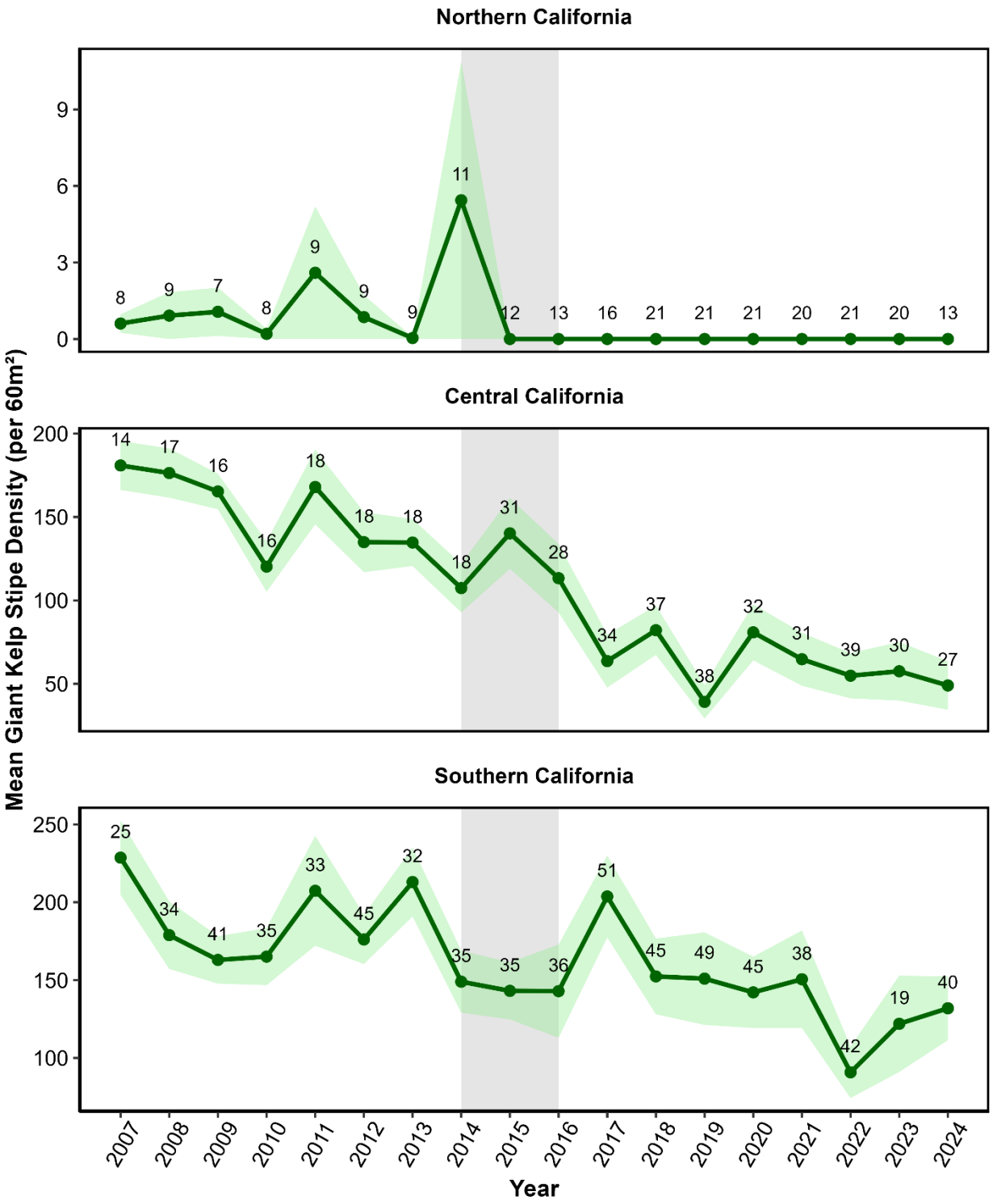


Figure 6. Giant kelp stipe trends over time across all sites for each region in California. The dark green line indicates means across all monitored sites within the region. The light green area indicates the standard error. The gray bar shows the 2014 'Blob' event. The number above the data points indicates the number of sites used to calculate mean for each year.

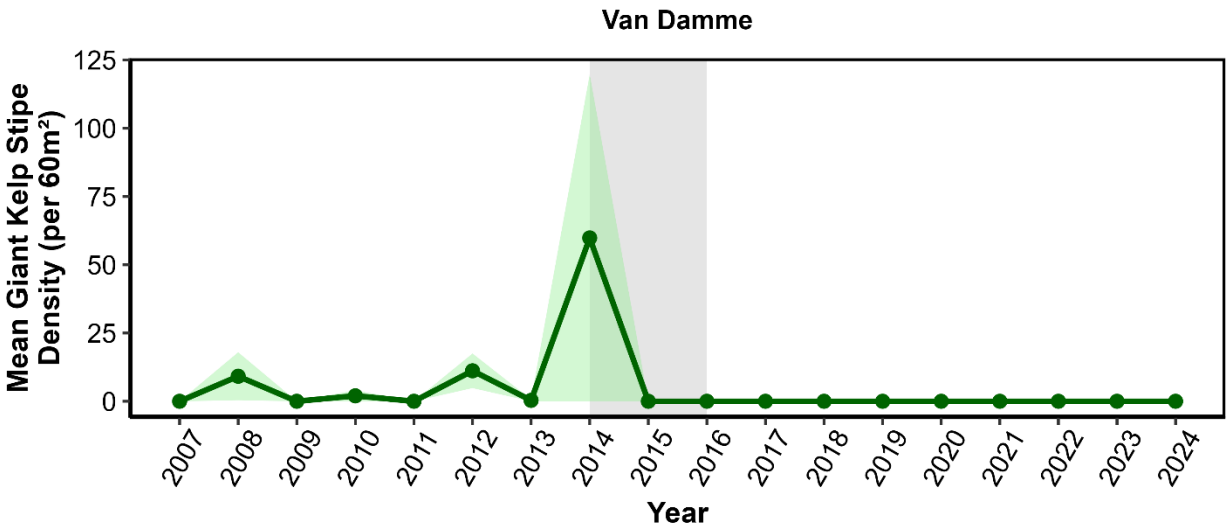


Figure 7. Giant kelp stipe density at Van Damme, the only Reef Check site in Northern California where giant kelp was regularly present before the Blob (displayed by gray bar).

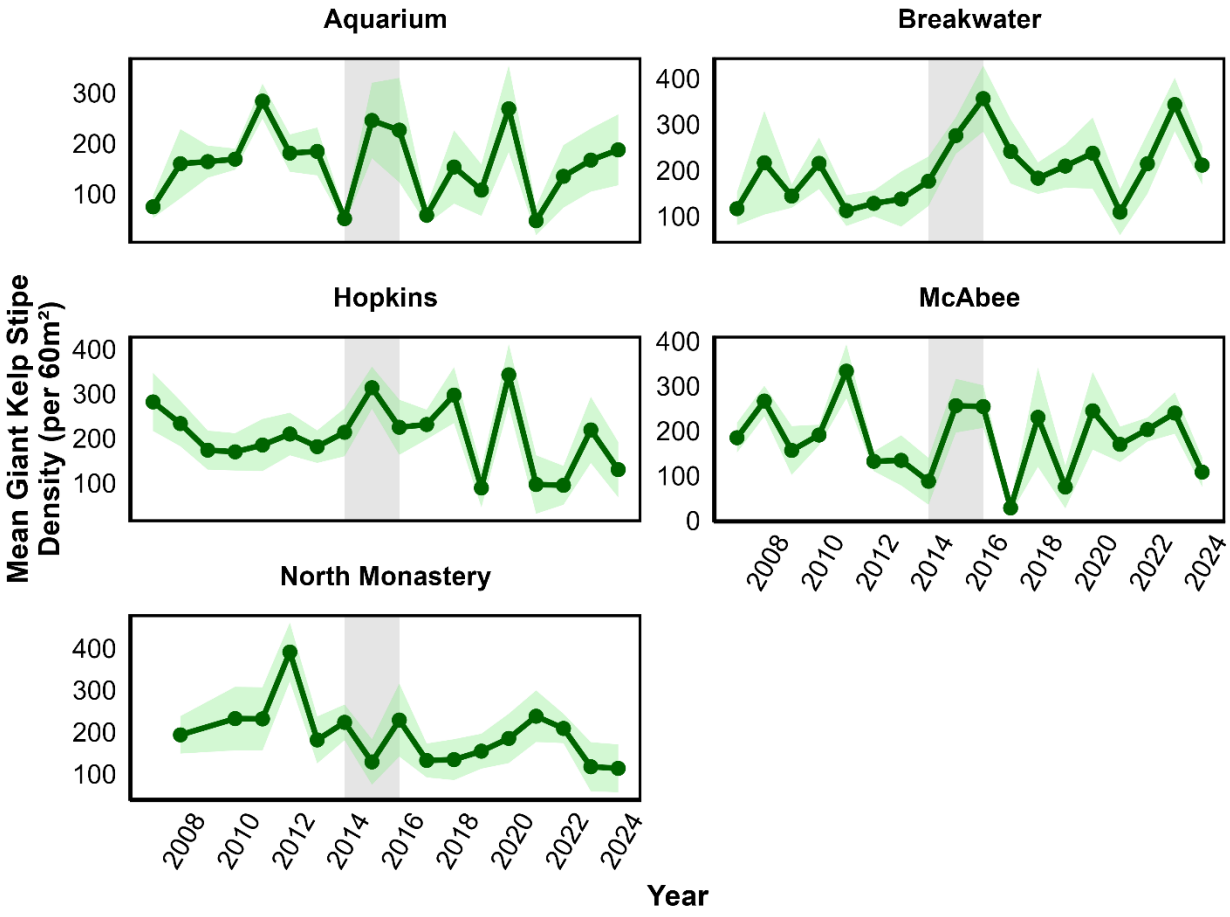


Figure 8. Giant kelp stipe trends over time at five sites in Monterey, California, where densities don't show declining long-term trends. The green line indicates the mean stipe number per 60 m^2. The light green area indicates the standard error. The gray bar shows the 2014 'Blob' event.

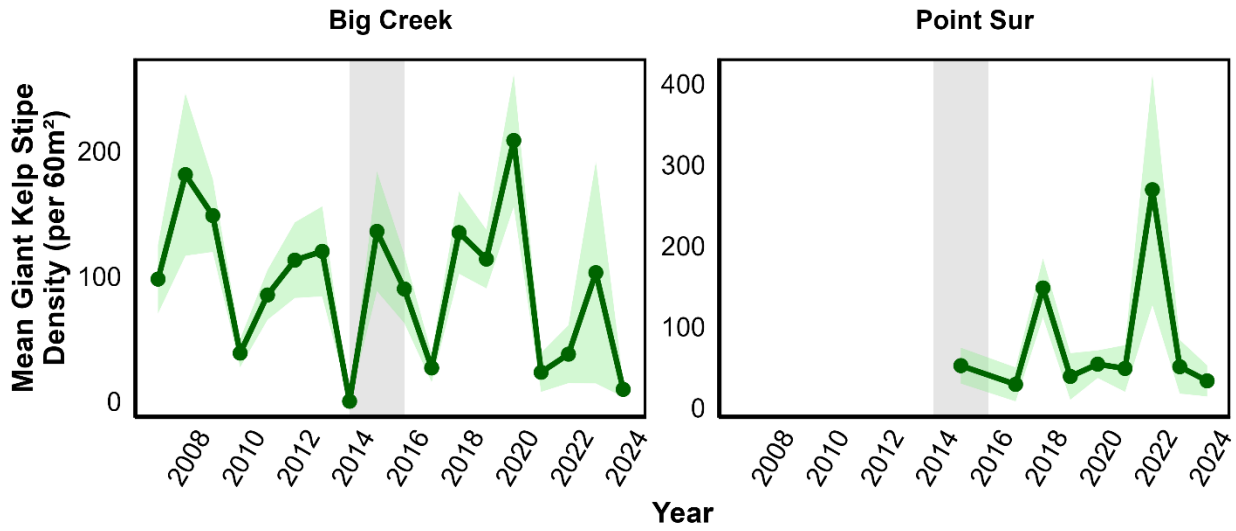


Figure 9. Giant kelp stipe trends over time at two sites in Big Sur, California. The green line indicates the mean stipe number per 60 m^2. The light green area indicates the standard error. The gray bar shows the 2014 'Blob' event.

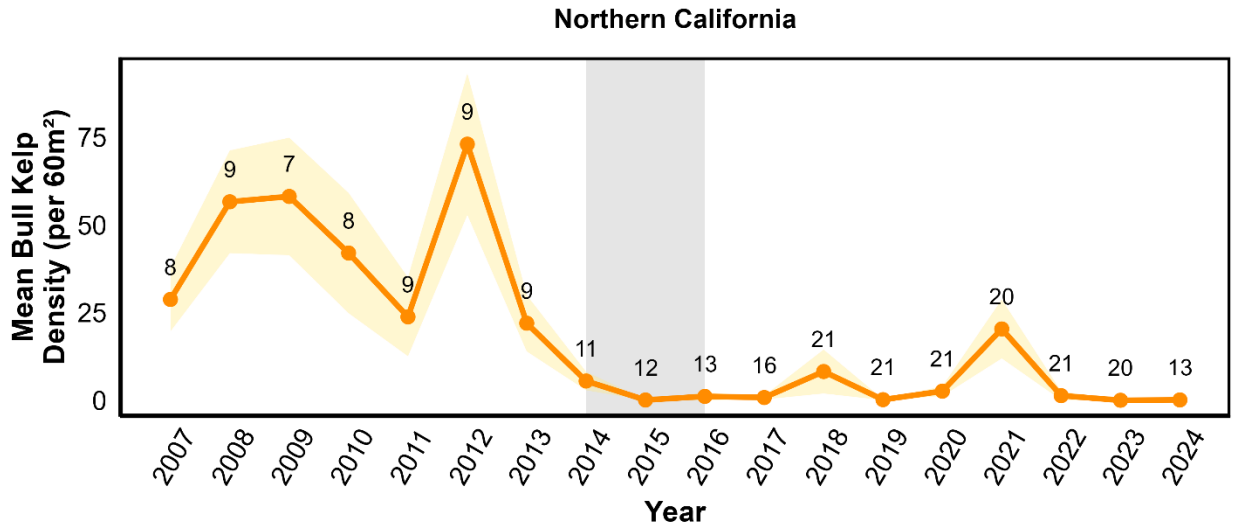


Figure 10. Bull kelp trends in Northern California. The dark orange line represents the mean bull kelp density across all monitored sites within the region, while the light orange shaded area indicates the standard error. The gray bar shows the 2014 'Blob' event. The number above the data points indicates the number of sites used to calculate means for each year.

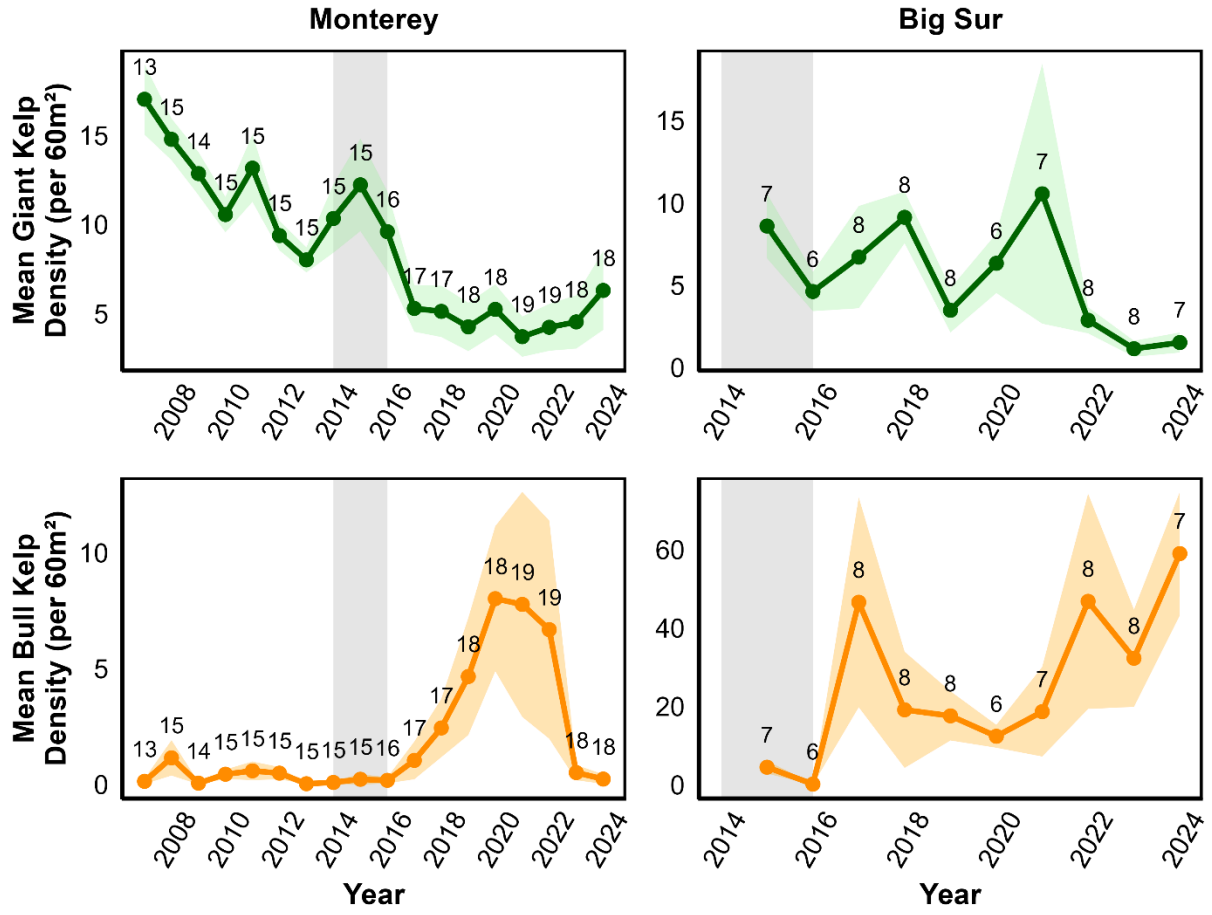


Figure 11. Canopy kelp trends in Monterey sites (left) and Big Sur sites (right), allowing for direct comparison of regional dynamics over time. The green line represents the mean number of giant kelp individuals per survey (60 m^2), with the light green shaded area indicating the standard error. The orange line represents the mean number of bull kelp individuals per survey (60 m^2), with the light orange shaded area indicating the standard error. The gray bar shows the 2014 'Blob' event. The number above the data points indicates the number of sites used to calculate mean for each year. Monterey sites span from Monterey to Malpaso Creek (south of Point Lobos), while Big Sur sites extend from Point Sur to Lopez Point. Monitoring in Big Sur began in 2015, except for Big Creek, which was established in 2007. However, data from Big Creek between 2007 and 2014 were excluded from the regional averages presented in this analysis.

Subcanopy Kelp Trends in Central California

In Central California, the two most dominant subcanopy kelp species are torn kelp (*Laminaria setchellii*) and woody kelp (*Pterygophora californica*). In Monterey, where subcanopy kelp is absent from many sites, trends appear variable, though densities have declined since the 2014-2016 marine heatwave (**Figure 12**). Subcanopy kelp is much more abundant in Big Sur, where over 100 woody kelp individuals can be recorded per 60 m^2 transect (**Figure 13**). Densities of both subcanopy kelps in the central coast were at or near the lowest densities recorded during Reef Check's surveys in 2024.

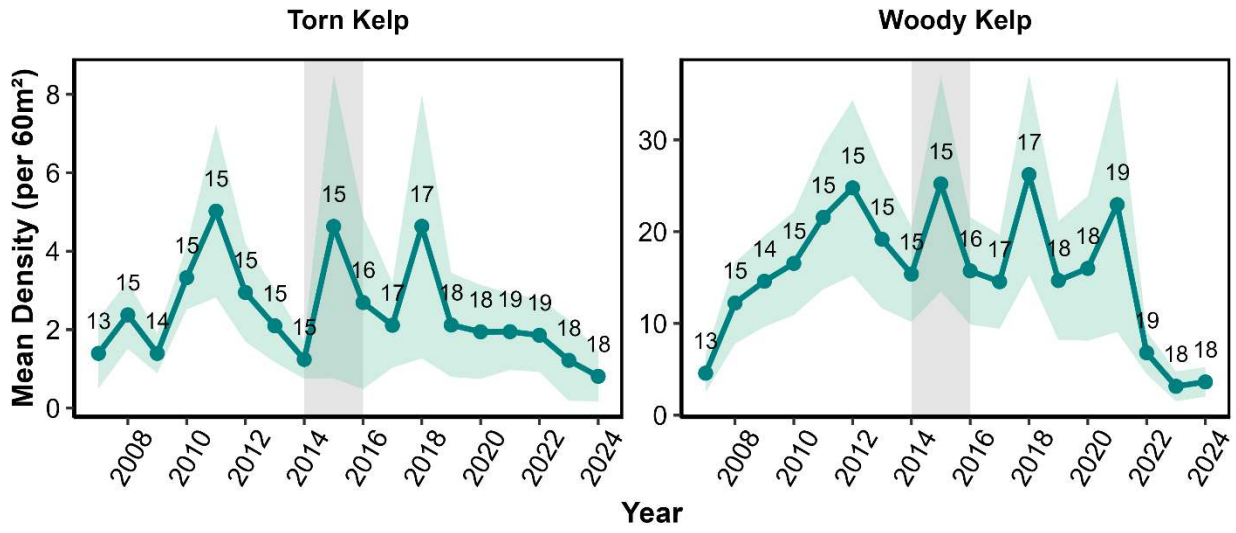


Figure 12. Subcanopy kelp trends at Monterey sites. The teal lines indicate mean kelp individuals per survey (60 m^2). Light teal shaded area indicating the standard error. The gray bar shows the 2014-2016 marine heatwave. The number above the data points indicates the number of sites used to calculate the mean for each year.

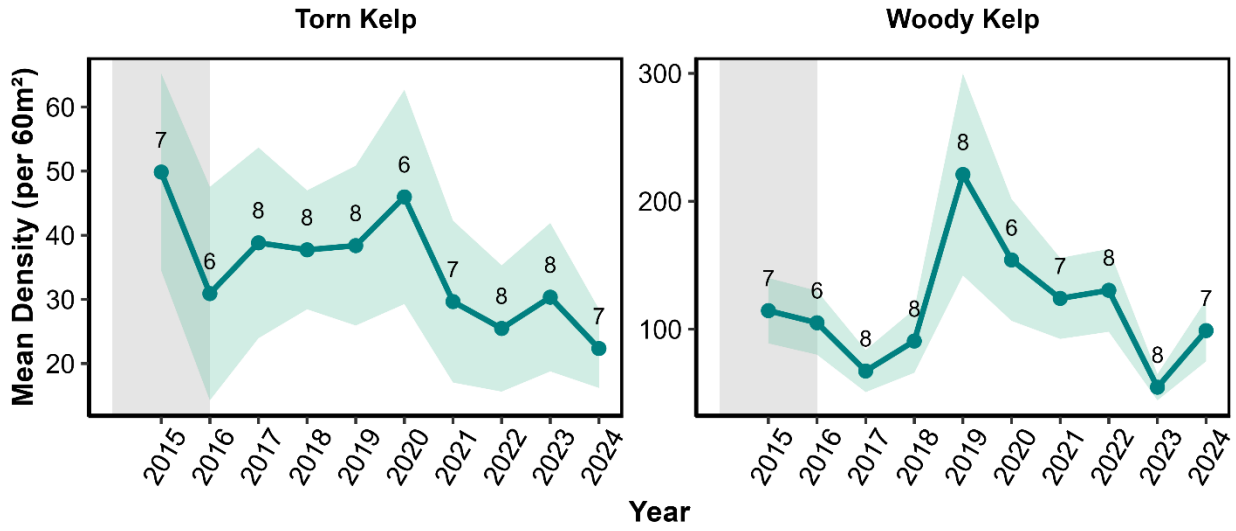


Figure 13. Subcanopy kelp trends at Big Sur sites. The teal lines indicate mean kelp individuals per survey (60 m^2). Light teal shaded area indicating the standard error. The gray bar shows the 2014-2016 marine heatwave. The number above the data points indicates the number of sites used to calculate overall means for each year.

Sea Urchins

Reef Check monitors four species of urchin in California: purple urchin (*Strongylocentrotus purpuratus*), red urchin (*Mesocentrotus franciscanus*), starry urchins (*Arbacia stellata),* and crowned urchin (*Centrostephanus coronatus*). Purple urchins and red urchins are commonly observed across all regions

of California. Crowned urchins have become more abundant in California and were first observed in Central California in 2016, where they have since become common, albeit at low densities. Starry urchins are rare in California and only a single individual was observed during Reef Check surveys in 2024 (**Table 4**). Below, we will highlight trends from crowned urchins, purple urchins, and red urchins.

Densities of both purple and red urchin have increased significantly since the 2014-2016 marine heatwave in both Northern and Central California (**Figure 14**). In Northern California, very high purple urchin density has been observed at some sites, such as Mendocino Headlands that has a mean density of 5,794 urchins per 60 m^2 (+/- 587 SE) in 2024. Sites with high densities of purple urchins were first observed in Southern California but after the 2014-2016 marine heatwave they have become common in Central and Northern California.

Recent surveys indicate a decline in purple urchin densities in Southern California (**Figure 15**). Similarly, red urchin densities have declined during and after the Blob at Reef Check's Southern California sites (**Figure 15**). At the same time, densities of crowned urchins in Southern California began increasing during the Blob and have remained roughly double what they were before the Blob (**Figure 15**). Crowned urchins are particularly abundant along the front side of Catalina Island, where mean densities rose from 32 ± 15 urchins per 60 m² in 2007 to a peak of 124 ± 45 per 60 m² after the heatwave in 2019 (**Figure 16**). In recent years, crowned urchin densities on the front side of Catalina remain relatively stable and are about double the mean density found in Southern California. Densities on the backside of Catalina have declined in recent years and are currently at 7 ± 3 per 60 m² (**Figure 16**).

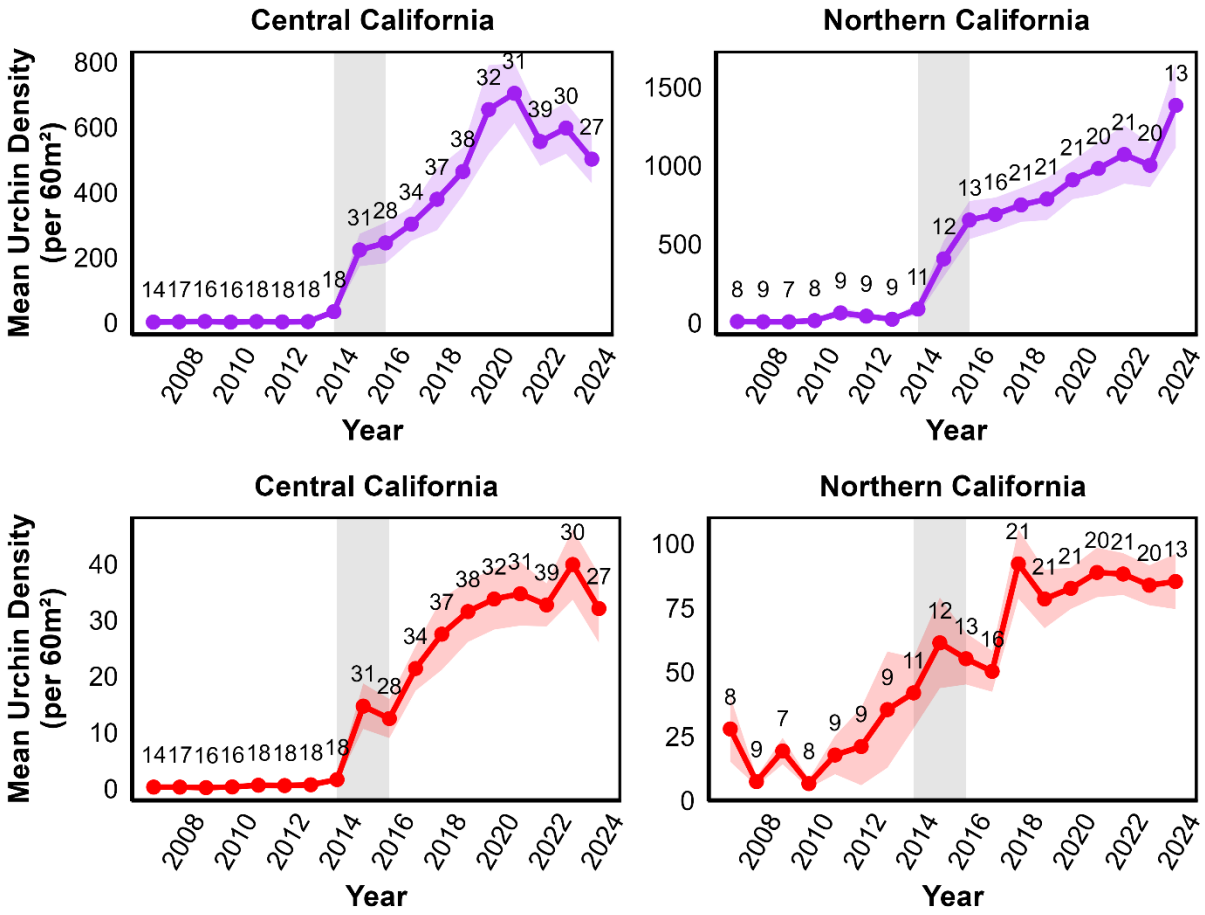


Figure 14. Density of purple and red sea urchin in Central and Northern California. Dark colored lines indicate means, while the lighter shaded areas indicate standard error. The gray bar shows the 2014-2015 marine heatwave. The number above the data points indicates the number of sites used to calculate means for each year.

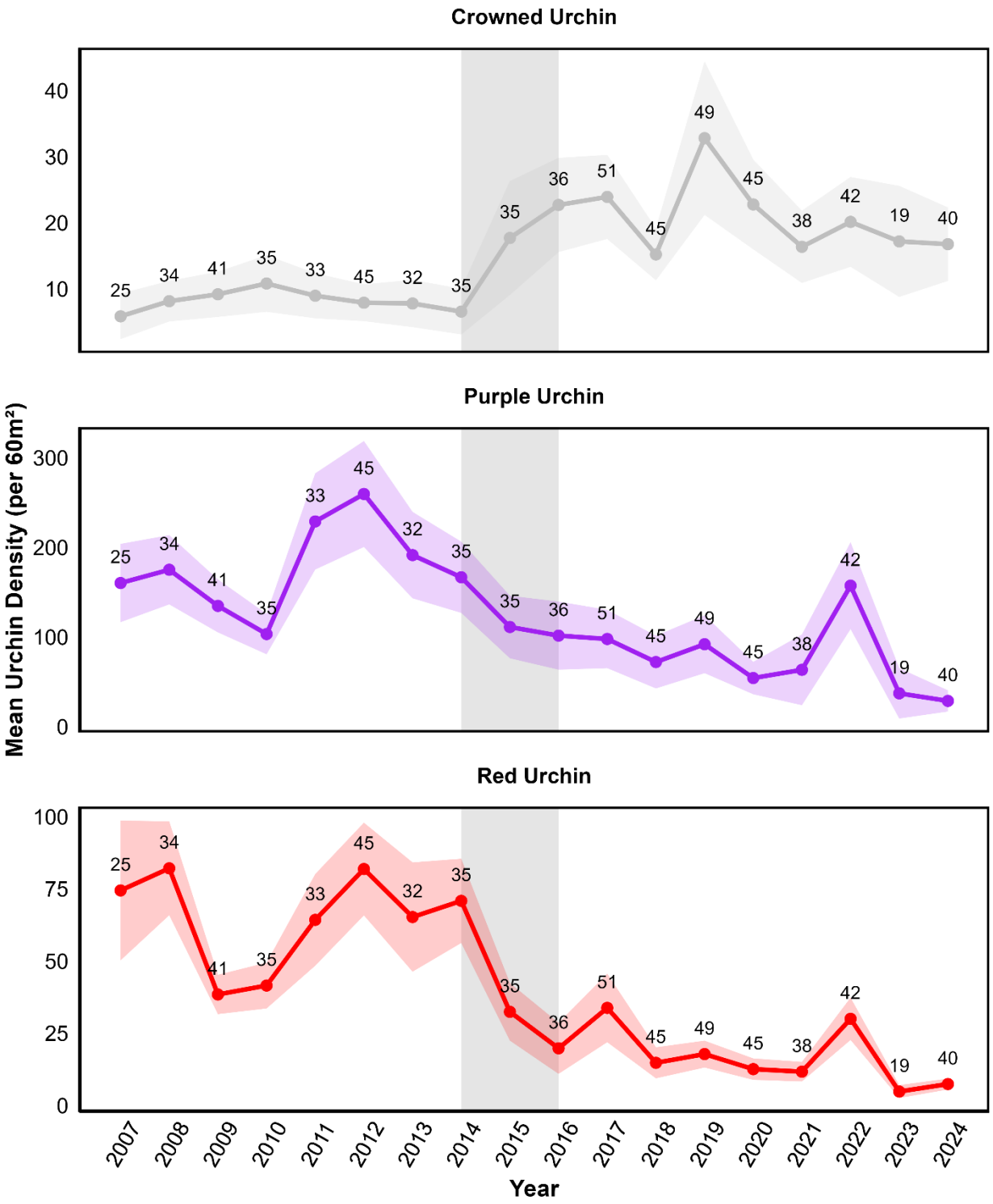


Figure 15. Sea urchin density trends for the three common species across Southern California sites. Dark colored lines indicate means, while the lighter shaded areas indicate standard error. The gray bar shows the 2014-2015 marine heatwave. The number above the data points indicates the number of sites used to calculate means for each year.

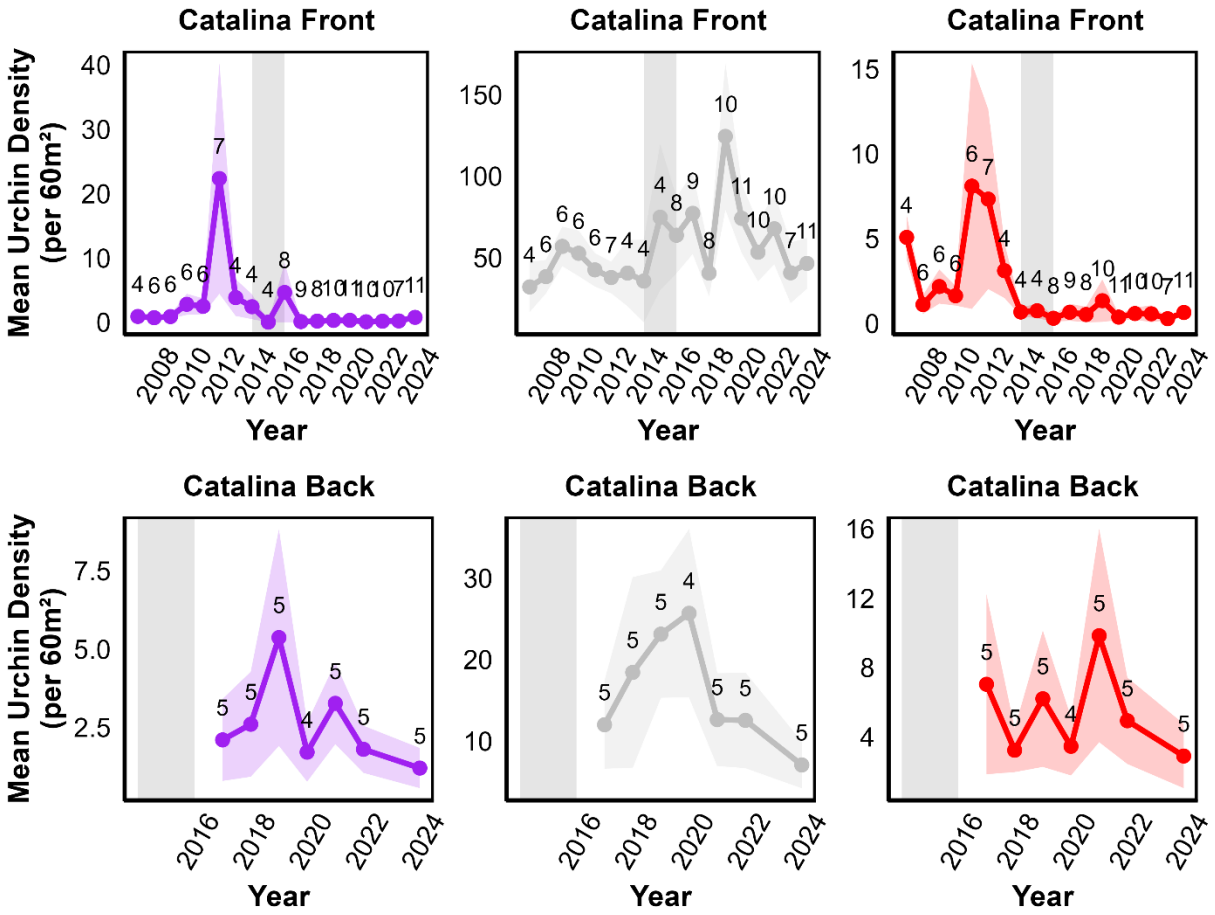


Figure 16. Comparison of mean urchin density trends around Catalina Island between front side (top) and back side (bottom) of the island. Dark colored lines indicate means, while the lighter shaded areas indicate standard error. The purple line indicates purple urchins, grey indicates crowned urchins, and red indicates red urchins. The grey bar indicates the Blob. The number above the data points indicates the number of sites used to calculate means for each year.

Urchin Size Frequency

Size frequency data for purple and red urchin are collected annually at sites with high urchin densities. Urchin test diameter is recorded to the nearest centimeter. In 2024, size frequency surveys were completed at 24 sites across California. To highlight changes in size frequency in regions with the highest urchin densities, data from 51 sites across Northern and Central California were analyzed from 2015 to 2024 to compare size distributions between the two regions (**Figure 17 & 18**). In Northern California, the median size of purple urchins has decreased over time, ranging from 4-6 cm in 2015-2017 to 3 cm in 2023 and 2024. In Central California, the median size of purple urchins has remined relatively stable between 3-4 cm over the years from 2015 to 2024 (**Figure 17**). Red urchins' median size in Northern California decreased over time from 8-9 cm in 2016 and 2017 to 6 cm in the most recent years. Conversely, the median size of red urchin in Central California slightly increased from 4 cm in 2015 to 5 cm in 2024 (**Figure 18**).

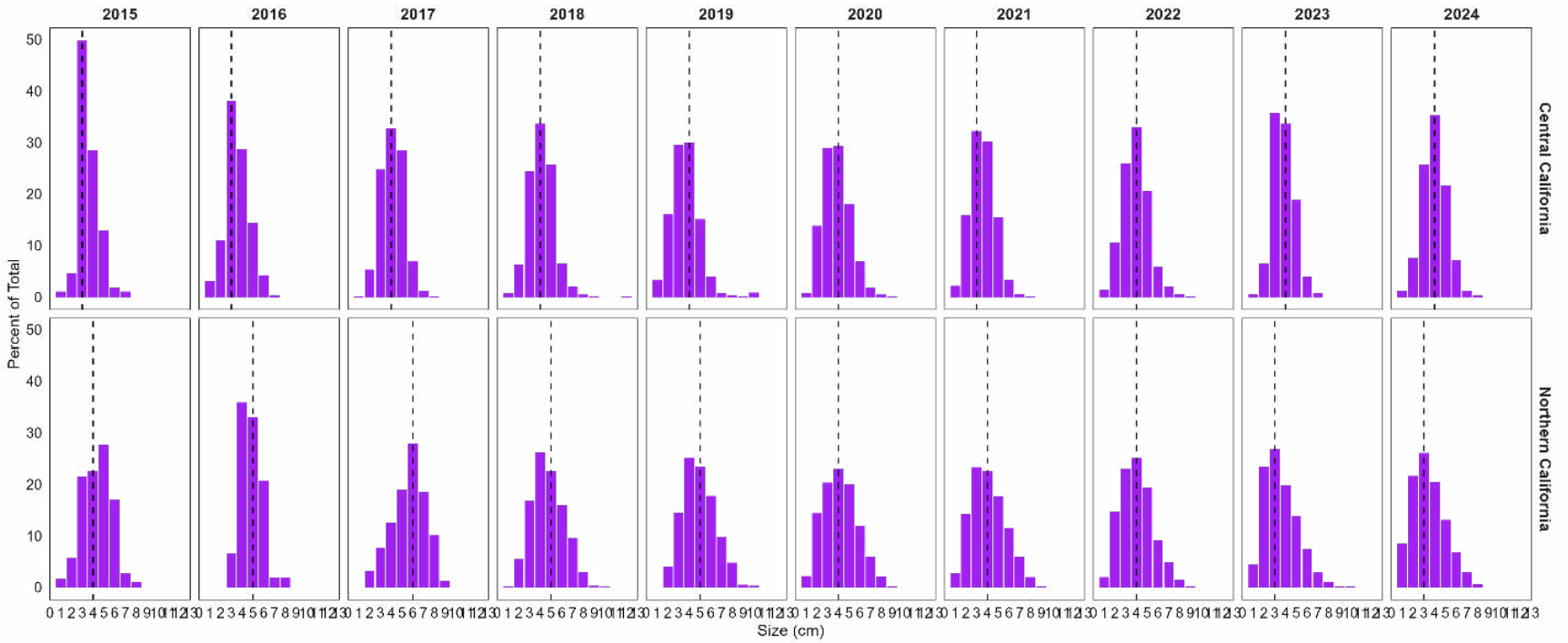


Figure 17. Size frequency of purple urchins measured across all sites in Central and Northern California over time. The dashed line in each panel indicates the median size for each year.

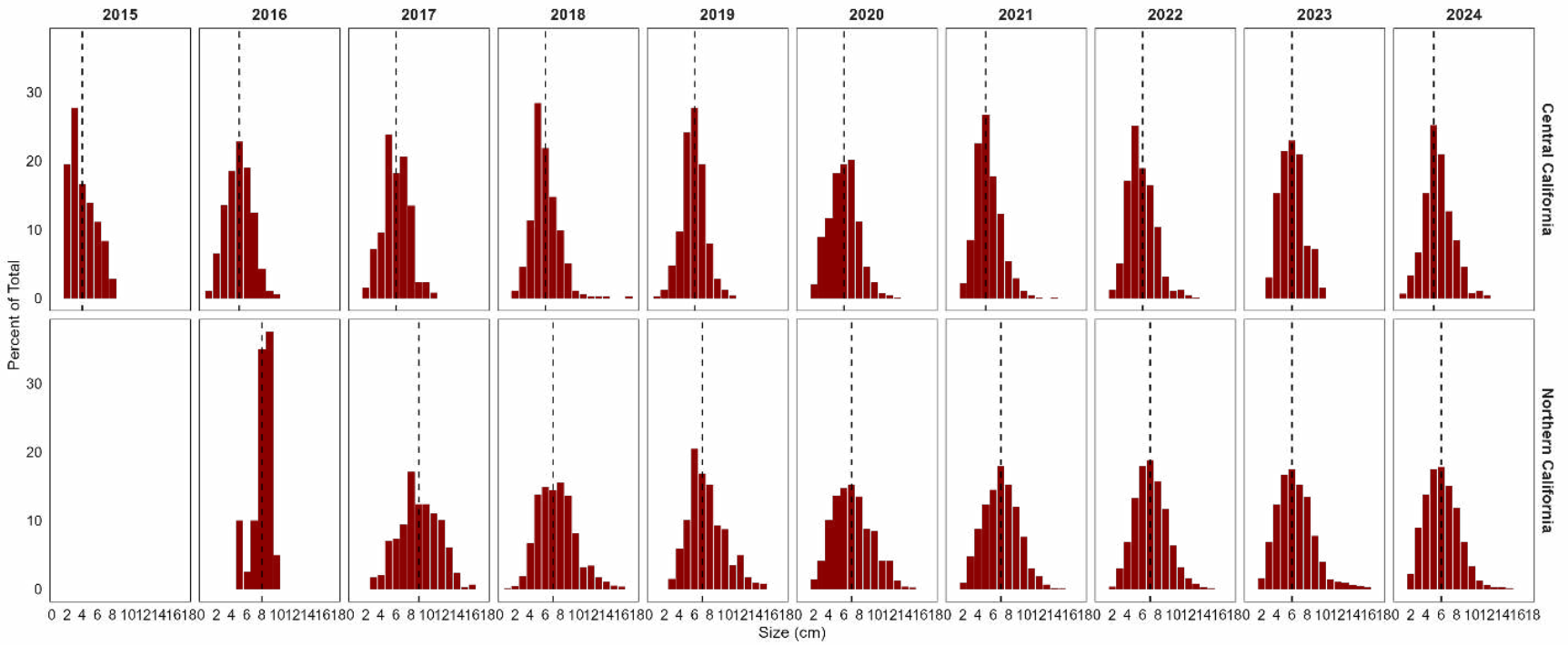


Figure 18. Size frequency of red urchins measured across all sites in Central and Northern California over time. The dashed line in each panel indicates the median size for each year.

Red Abalone (*Haliotis rufescens*)

In Northern California, red abalone shows a rapid decline, along with the loss of kelp in 2014-2016 (**Figure 19**). Since this time, red abalone densities have remained very low but stable, with an average density of 7 individuals per 60 m^2 (+/- 3 SE) in 2024. In Central California, red abalone densities have historically been much lower than in Northern California but appeared to be increasing until the 2014-2016 heatwave. Since then, densities have fluctuated significantly, showing a downward trend, averaging <1 individual per 60 m^2 (0.16 +/- 0.04) in 2024.

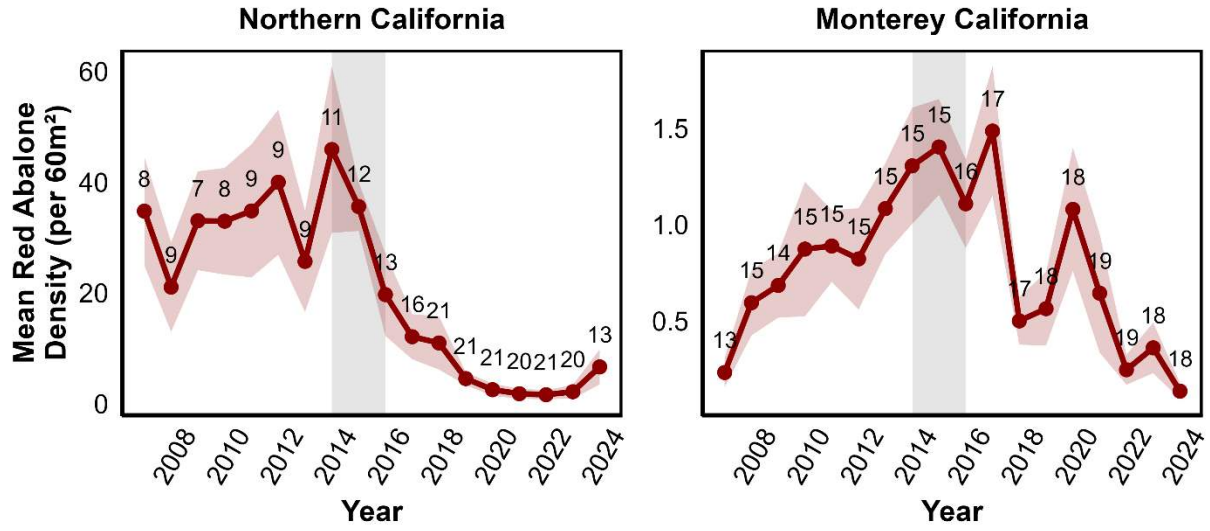


Figure 19. Red abalone density trends for Northern California (left) and Monterey California (right). The dark colored line indicates means, while the lighter shaded areas indicate standard error. The gray bar shows the 2014-2016 'Blob' event. The number above the data points indicates the number of sites used to calculate overall means for each year.

Fish Diversity and Community Trends in Northern California

The loss of the kelp forest in Northern California is leading to significant ecological consequences for the species that rely on these habitats (e.g., red abalone). The consequences for the kelp-associated fish community have been less obvious. We analyzed data from 10 long-term monitoring sites with consistent monitoring data going back to before the 2014-2016 marine heatwave: Caspar South, Fort Ross, Gerstle Cove, Mendocino Headlands, Ocean Cove, Point Arena MPA, Point Arena Reference, Portuguese Beach, Stillwater Sonoma, and Van Damme. We assessed changes in species diversity, species evenness, and overall community composition before and after the 2014-2016 marine heatwave. Diversity was measured using the Shannon diversity index and Evenness estimated as the ratio of Shannon diversity and the natural logarithm of species richness (J' = H'/ln(S)) in the vegan package in R (Oksanen et al. 2020) . Community composition was analyzed using multivariate ordination. To explore patterns in fish community composition before and after the heatwave, we summarized data from three years immediately before the heatwave (years 2011-13) and almost a decade after (years 2022-24) the heatwave

by averaging densities at sites across years. We conducted a non-metric multidimensional scaling (nMDS) ordination based on Bray–Curtis dissimilarity of Hellinger transformed species mean abundance data using the metaMDS function from the vegan package in R (Oksanen et al., 2020). To visualize group-level structure, 95% confidence ellipses were drawn around sites of both groups of sites.

Our results show a decline in both diversity and evenness across the 10 sites (**Figure 20**). Fish community structure from before the heatwave and the community structure 10 years later at the same sites did not show a significant shift in overall fish community composition following the Blob (**Figure 21**). This suggests that while rare species may be declining, dominant species have remained relatively resilient to ecosystem changes. Many of the dominant species (i.e. rockfish) are long-lived and relatively sedentary, and therefore individuals might remain at a local reef for a long time even if the kelp that was present when they recruited has been absent for many years. The diversity and evenness have declined to their lowest values in the two most recent years and have not plateaued yet, suggesting that the fish community might continue to change.

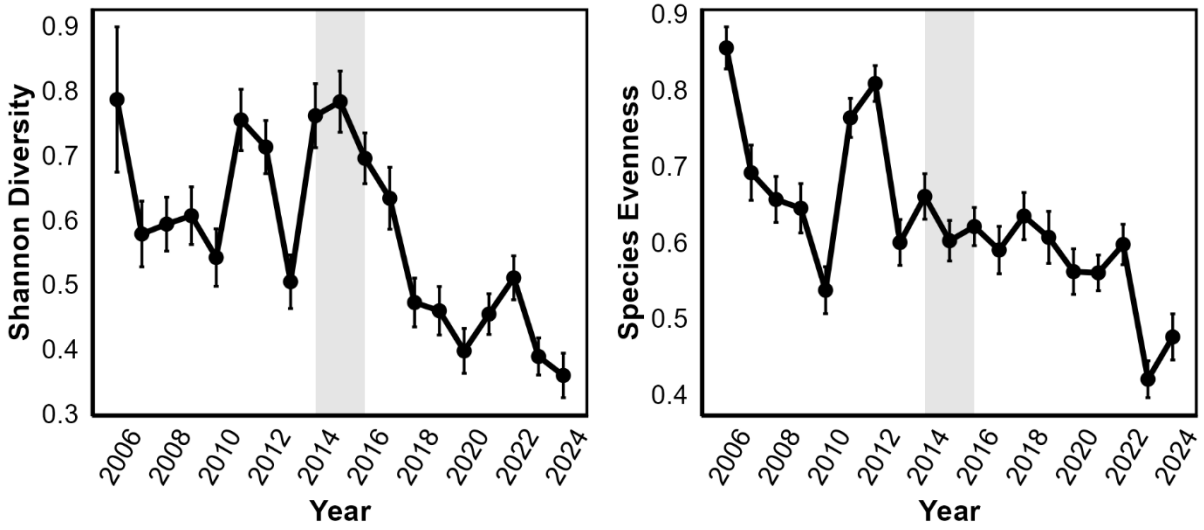


Figure 20. Fish species diversity (left) and species evenness (right) trends in Northern California, at 10 sites in Northern California (Caspar South, Fort Ross, Gerstle Cove, Mendocino Headlands, Ocean Cove, Point Arena MPA, Point Arena Reference, Portuguese Beach, Stillwater Sonoma, and Van Damme). Dark colored lines indicate means with standard error bars. The gray bar shows the 2014 'Blob' event.

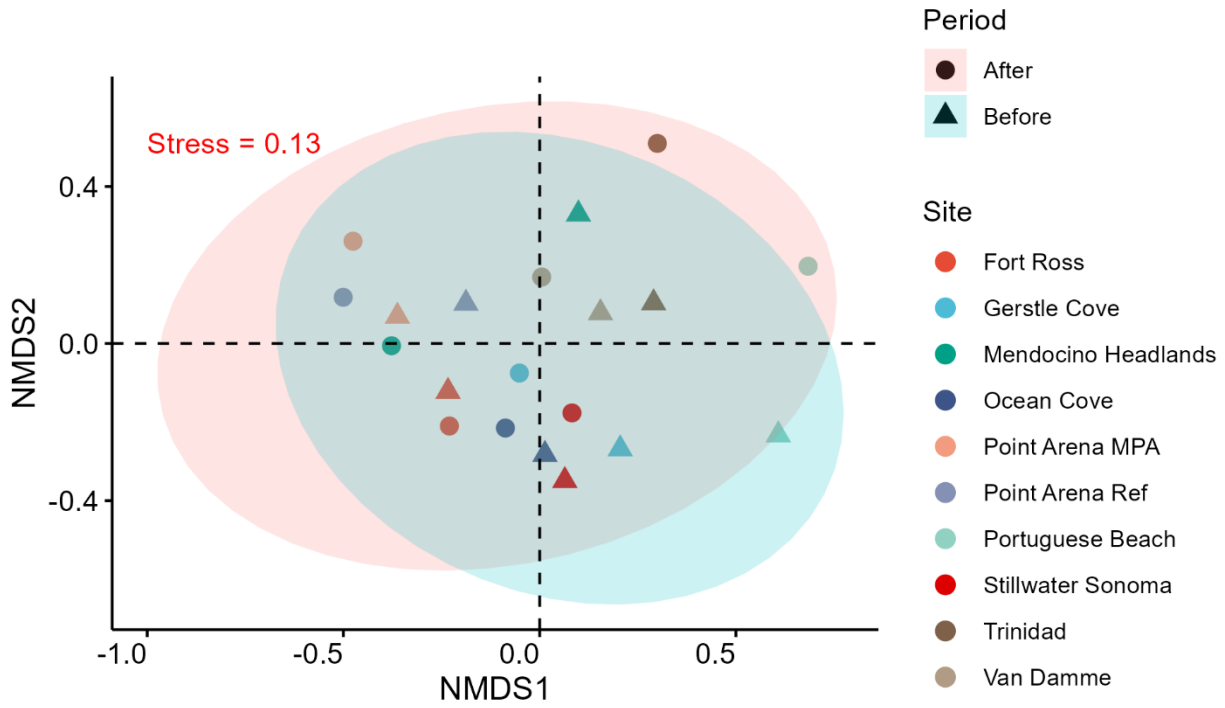


Figure 21. nMDS plot comparing fish community structure before the 2014-2016 heatwave (blue, 2011-2013) and after (red, 2022-2024) across 10 of the long-term monitoring sites in Northern California. Colors dots indicate sites and shape indicates period before or after the Blob. Ellipses are drawn at 95% confidence interval around the sites within each period.

Temperature Monitoring

Subtidal temperature data were collected using HOBO temperature loggers (UA 002-64) from Onset. A list of sites and the number of years of data for each can be found in **Table 3**. To assess temperature trends, we compared benthic temperature loggers to the National Oceanic and Atmospheric Administration (NOAA) Optimum Interpolation Sea Surface Temperature (OISST) dataset across all sites for all years (2018-2024). Overall, the benthic temperature loggers indicate that subsurface temperatures generally follow the same long-term trends as sea surface temperatures. However, sea surface temperatures are consistently warmer than those recorded by Reef Check loggers at depths of 4–18 meters, particularly during the summer months of June through September (**Figure 22**).

The same data were summarized across years and the mean weekly temperature was compared between surface and in situ subsurface temperature to identified how temperature at the reef deviates from the surface temperature across regions and seasons. During the winter months of December-January, there is almost no difference in temperature in any region. The largest temperature difference between the surface and the reef was detected in Central California during the summer, where the difference can be over 2 degrees Celsius (**Figure 23**).

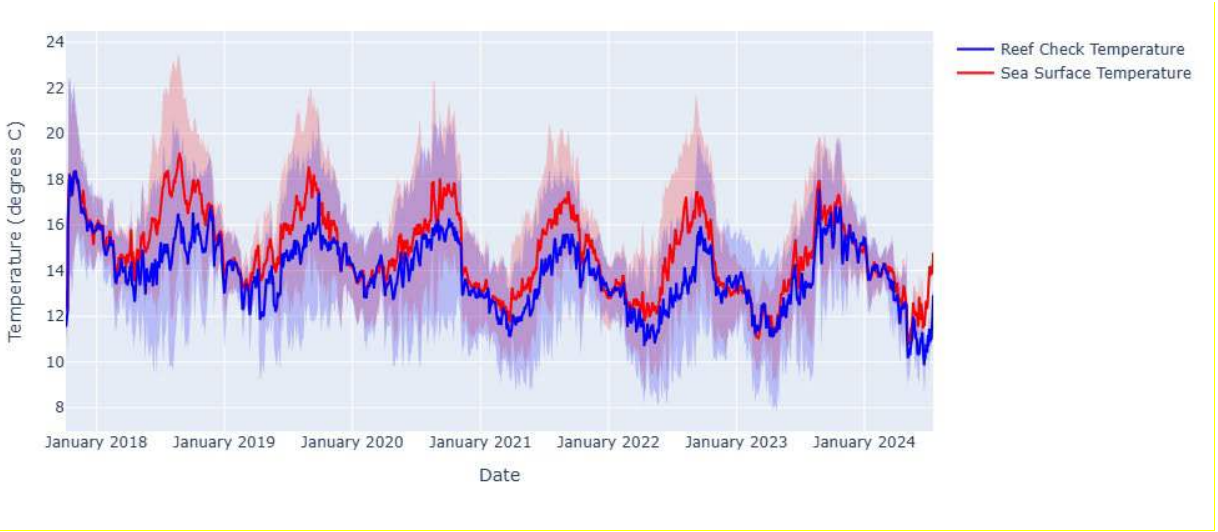


Figure 22. A comparison of Sea Surface Temperature using OIST versus benthic loggers at Reef Check sites across the state of California. Solid lines indicate the mean temperatures, and shaded areas span +/- one standard deviation from the mean.

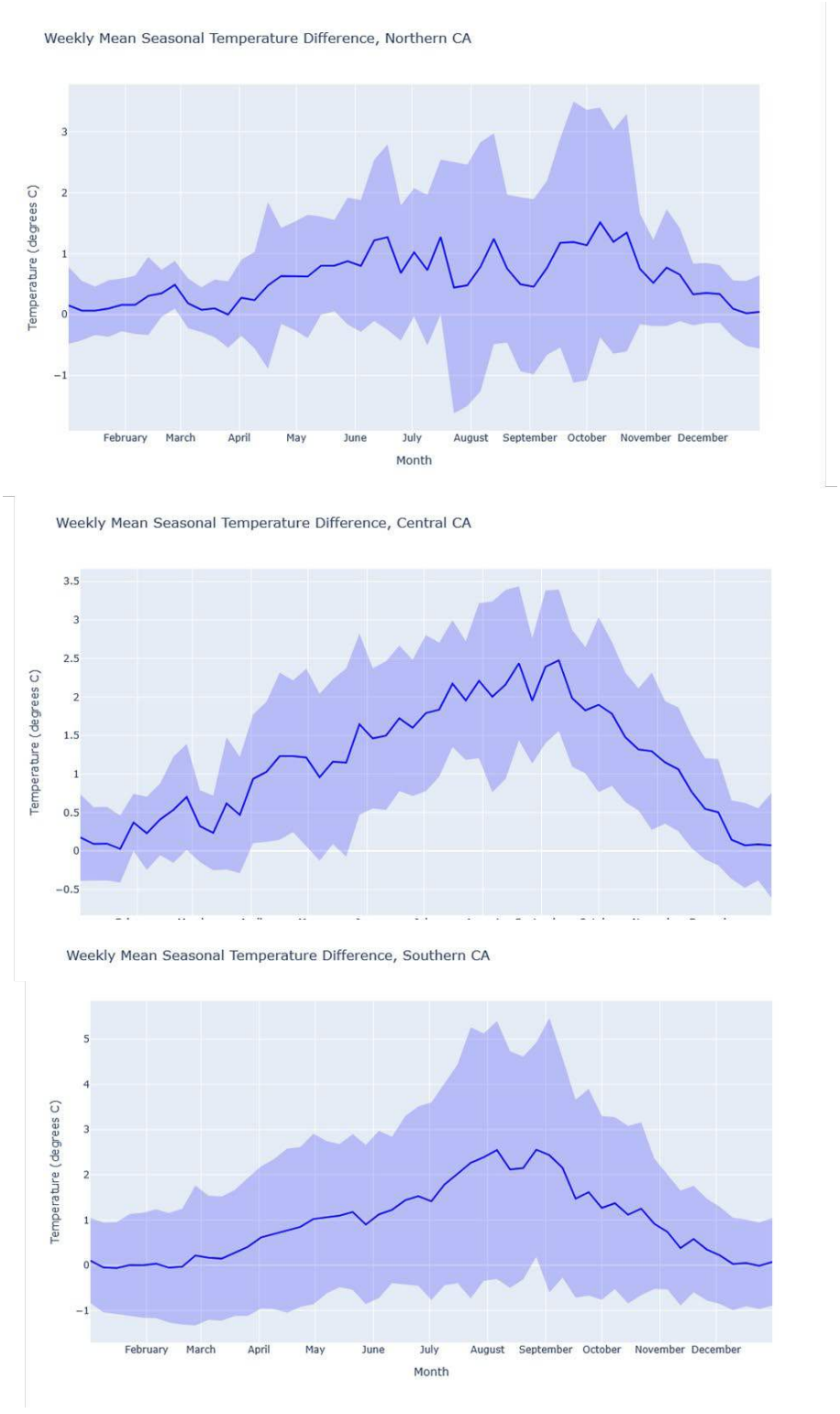


Figure 23. The difference in water temperature from Sea Surface Temperature using OIST versus benthic loggers at Reef Check sites. The dark blue line indicates the mean difference, and the blue shaded areas indicate 95% confidence intervals.

Expansion of the Kelp Forest Monitoring Program

California's kelp forest ecosystems are connected to and affected by kelp forests beyond the borders of the state. Starting in 2021, Reef Check began expanding to regions outside of California. In 2024, Reef Check completed 193 surveys at 167 sites across seven regions (**Figure 24 & 25)**.

Reef Check Oregon

The Oregon program began in 2021 in partnership with the Oregon Kelp Alliance (ORKA) to monitor kelp beds inside and outside of Oregon's Marine Reserves and in response to widespread kelp loss along the Oregon Coast. The last four years of survey efforts have been incorporated into the 2024 Oregon Kelp Forest Status Report, confirming about 900 acres of kelp bed loss since 2010 and the need for restoration efforts along the Oregon coast (Hamilton et al. 2024). Roughly 18 surveys are conducted each year in Oregon, and restoration work is set to begin in 2025 (**Figure 24 & 25**).

Reef Check Washington

In 2021, Reef Check joined the Kelp Expedition (Garfield and et al. 2021), organized to facilitate collaborative science and research on bull kelp in the Puget Sound. Reef Check established the Washington program in 2022 as part of the Eyes on Kelp Initiative (Peabody and Toft 2022), in partnership with Puget Sound Restoration Fund. The first year Reef Check trained 52 divers the Reef Check Washington protocols and monitor 30 sites. Since then, the program has expanded to training roughly 45 citizen science divers a year, working with nine partner organizations, including Puget Sound Restoration Fund, Washington Department of Natural Resources, University of Washington Friday Harbor lab, and the Samish Indian Nation, to complete monitoring at 55 sites.

Reef Check Baja California

Long-term monitoring sites in Baja California were established in 2022, primarily using Southern California volunteer divers. In 2024, the program grew into its own monitoring region. Partnering with researchers from MexCal, Reef Check translated the kelp forest monitoring material to Spanish and has been teaching Mexican citizens the Reef Check protocols. Over 30 surveys have been planned for 2025.

Reef Check British Columbia

Reef Check began conducting surveys in British Columbia in 2023 working with volunteers from Washington State. Three surveys were completed in Southern Vancouver Island in 2023 and 2024, and another four surveys were completed on the mainland in 2024. In 2025, Reef Check launched a program working with Canada's Indigenous Guardian Program, which supports First Nations in indigenous stewardship. This program will teach Reef Check's subtidal kelp forest monitoring protocols to scuba-certified tribal guardians.

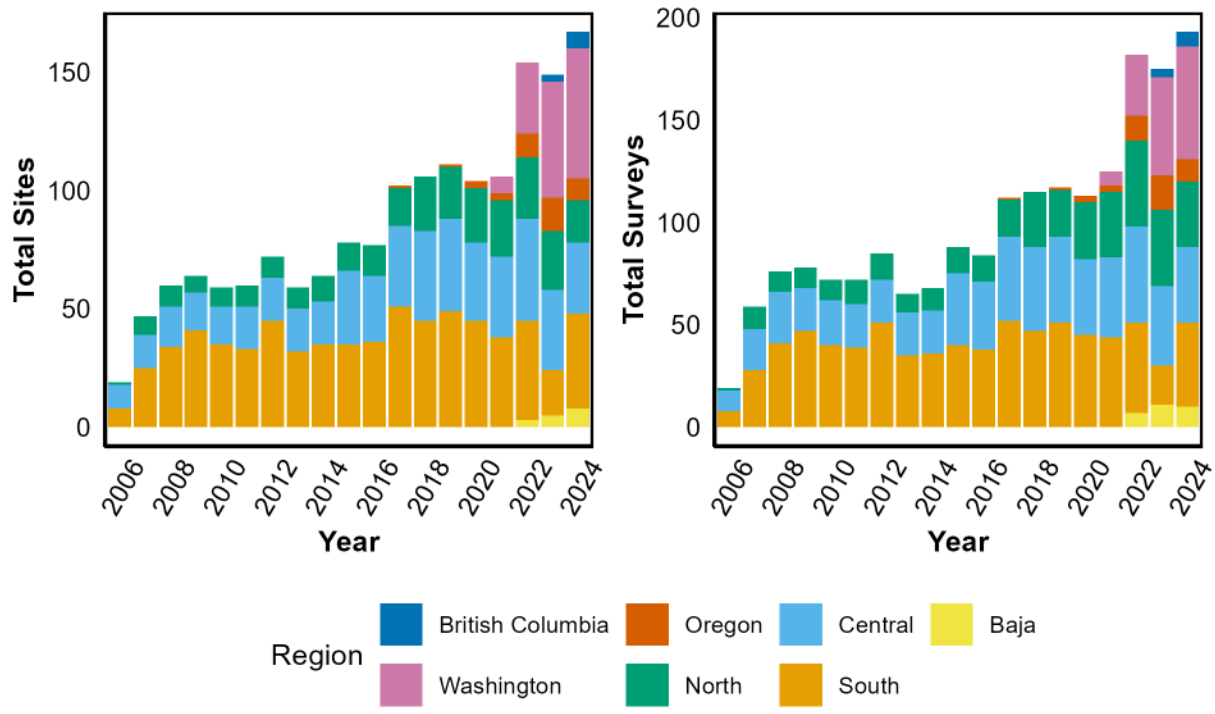


Figure 24. Number of sites (left) and surveys (right) completed each year seven Reef Check kelp forest monitoring regions

Figure 25. Current map of all Reef Check kelp forest monitoring survey sites.

References

CDFW and OPC. 2018. Marine Protected Area Monitoring Action Plan., California, USA.

Freiwald, J., and A. Beahrs. 2020. Reef Check California: SCUBA-diving citizen scientist monitor rock reef ecosystems. Page 313 *in* C. A. Lepczyk, O. D. Boyle, and T. L. V. Vargo, editors. Handbook of citizen science in ecology and conservation. University of Califorina Press, Oakland, Califorina.

Freiwald, J., S. M. McMillan, and D. Abbott. 2021. Reef Check California Instruction Manual: A Guide to Monitoring California's Kelp Forests, 10th Edition. Reef Check Foundation, Marina del Rey, CA, USA.

Freiwald, J., and A. Neumann. 2017. Reef Check California: Citizen Scientist monitoring of rocky reefs and kelp forests: Creating a baseline for California's North Coast MPAs. Report to California Sea Grant (Project # R/MPA-34, Grant # C0100100), Reef Check Foundation, Marina del Rey.

Freiwald, J., and M. Wehrenberg. 2013. Reef Check California: North Central Coast Baseline Surveys of Shallow Rocky Reef Ecosystems. Report to California Sea Grant (Project # R/MPA-13, Grant # 09-015), Reef Check Foundation, Pacific Palisades.

Freiwald, J., and C. Wisniewski. 2015. Reef Check California: Citizen Scientist monitoring of rocky reefs and kelp forests: Creating a baseline for California's South Coast, Final Report South Coast MPA Baseline Monitoring 2011-2014. Report to California Sea Grant (Project # R/MPA-21, Grant # 10-049), Reef Check Foundation, Pacific Palisades.

Garfield, H., and et al. 2021. Kelp Expedition Story Map. https://storymaps.arcgis.com/stories/124e9d24ec1d4e419ea4e32a5ccb42fa

Gillett, D., D. Pondella, II, J. Freiwald, K. Schiff, J. Caselle, C. Shuman, and S. Weisberg. 2012. Comparing volunteer and professionally collected monitoring data from the rocky subtidal reefs of Southern California, USA. Environmental Monitoring and Assessment **184**:3239–3257.

Hamilton, S., T. Calvanese, S. Gravem, A. Galloway, D. Chabot, E. Vidusic, and N. Webster. 2024. Oregon Kelp Forest Status Report. The Oregon Kelp Alliance.

Oksanen, J., F. G. Blanchet, M. Friendly, R. Kindt, P. Legendre, D. McGlinn, P. R. Minchin, R. B. O'Hara, G. L. Simpson, P. Solymos, M. H. H. Stevens, E. Szoecs, and H. Wagner. 2020. vegan: Community Ecology Package. R Project.

Peabody, B., and J. Toft. 2022. Eyes on Kelp Initiative. https://restorationfund.org/programs/eyesonkelp.

Ward, M., T. A. McHugh, K. Elsmore, M. W. Esgro, J. Ray, M. Murphy-Cannella, I. Norton, and J. Freiwald. 2022. Restoration of North Coast Bull Kelp Forests: A Partnership Based Approach. Reef Check Foundation, Marina del Rey.

Appendix 1: Funding

The Reef Check California program was supported by a large variety of funding. The Resources Legacy Fund, The Campbell Foundation, Richard and Rhoda Goldman Fund, and other private foundations were instrumental in the early years and for long-term, consistent funding of the program. During the years of the MLPA MPA baseline monitoring programs in the respective MLPA study regions (2010-2018), Reef Check was supported by California Sea Grant and the Ocean Protection Council to collect baseline data on the newly established MPAs in the North Central Coast, North Coast, and South Coast Regions. From 2019-2022, the Ocean Protection Council supported Reef Check as part of the long-term MPA monitoring program to collect data on the MPA Network. Additionally, donations and a variety of philanthropic support have sustained the program over these 20 years. These sources became especially important as funding from the State of California for Reef Check's kelp forest monitoring program ended in 2023.

In 2024, Reef Check California faced a significant funding shortfall resulting in the completion of only 110 surveys at 88 sites of the 126 long-term monitoring sites in California. This work was completed with support from multiple sources, including a fundraising campaign aimed at individual donors (**Table A1**), to complete as many surveys as possible. The campaign specifically targeted Reef Check volunteers, individuals who dedicate their own time and resources to collect critical monitoring data. It successfully funded an additional 24 surveys. This outcome highlights the strong sense of ownership and connection volunteers feel toward the sites they monitor.

Additional support came from the California Department of Fish and Wildlife, which provided in-kind boat time aboard the RV *Garibaldi* out of Long Beach. Combined with funding from several small grants, this in-kind support enabled Reef Check to complete 17 more surveys around Catalina Island and the Palos Verdes Peninsula.

Thanks to the combined efforts of volunteers, grantors, and partners, Reef Check California completed 74% of its long-term monitoring surveys in 2024.

Table A1: Summary of funding for 2024

Funding source	**# Surveys**
Grant funded (Philanthropy)	37
Restoration program funds	32
Fundraising campaign (individual donors)	24
CDFW in kind support	17
Insufficient funding	32
Unable to complete	6
Total Surveys Planned	**147**

Appendix 2: Reef Check Data Management

Accurate data entry is one of the most critical components of the monitoring process. Reef Check 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. Below is a summary of Reef Check's data management and quality control process.

The Reef Check Data Management System is comprised of the following steps (**Figure A2**):

Field checks: The series of checks conducted in the field immediately after data collection.
Datasheet uploading and archiving: The systematic approach to archiving data sheets and addressing ambiguous data.
Data entry: Entering data into Reef Check's proprietary database, the Global Reef Database (GRD).
QA/QC: A second pass over the entered data where every entered value is rechecked.
Final data checks: Additional checks on the dataset to look for possible errors.
Data packaging and export: A system for requesting, tracking, and exporting data that has been packaged into formats that can easily be used by managers, scientists, and the public.

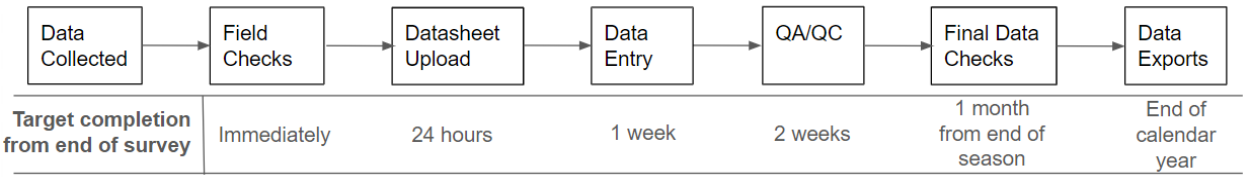


Figure A2. The Reef Check data management process with the target timeline for completion

The initial Data Entry and QA/QC process is to be completed within two weeks of the survey's completion. This ensures that if any issues arise they can be addressed in a timely fashion while the details of the survey are still fresh in people's minds. Once all the data for a season has been collected additional checks are run within one month and the data is packaged for export by the end of the calendar year.

Field Checks

The first level of data quality control is performed at the survey by the diver immediately following the dive either on the boat or on the beach. Each dive team member is instructed to ensure that all fields are complete, and totaled correctly and that all writing is legible.

For fish divers, which tends to be the most complex data, the fish datasheet is then checked by someone other than the person who collected the data, generally the person's buddy. This ensures that the data is clear and legible to at least two people. The checker initials the datasheet in the Field QA/QC box.

The final field check is conducted by the Data Captain or a designate, who collects and reviews all data to ensure the datasheets are legible and asks any questions while the data are fresh in everyone's minds. Divers who also assist with data entry are good candidates to take on this task. For large survey teams,

multiple people can assist with effort with each person checking different aspects of the data. The Data Captain is responsible for data checking and submission of data for entry.

During all three of the steps, divers are encouraged to use the "CRAB" mnemonic when checking data:

Complete: all metadata and data are filled out completely and are totally correctly totaled with subsampling distance when appropriate.
Readable: it's recommended that at least two people agree the data are legible (ex: dive buddy and data captain). Divers must eliminate number ambiguity, by distinguishing similar-looking numbers from one another or revising poor handwriting.
Accurate: observations "make sense" given the location, as a sanity check. Abnormal observations are included and explicitly documented in cover sheet notes. Additionally, ensure transect numbering is correct.
Belong: data from one type of survey must be confined to one datasheet, not spread throughout multiple pages. Data must be transferred and explicitly noted if data are collected across multiple pages. Cross out that data that was transferred so duplicate data is not entered into the database, but the source data is still legible for future reference.

Data Sheet Uploading and Archiving

Within 24 hours of returning the completion of the surveys, datasheets should be washed, dried, photographed in color, converted to a pdf and uploaded to the Reef Check Datasheet Google Drive Archive where they can be easily accessed by staff and data entry volunteers. The original data sheets are labeled and placed into long-term storage.

The PDF's in Reef Check Datasheets Google Team Drive are considered the official record of the survey and both data entry and QA/QC are conducted from these pdf's not the original datasheets. This is to ensure that the datasheets were properly uploaded and so that the comment feature of Google Drive can be utilized to follow up with data collectors on unclear data.

If something is unclear on a datasheet data entry personnel are instructed to highlight the data, create a comment, tag the data collector, and ask a question to clarify the data. The data collector can then respond in the comment resolving the issue. Personnel are instructed to not "resolve" the comment so that these exchanges are on record and may be referred back in the future.

Data Entry

Within one week of the completion of the survey data is to be entered into the Global Reef Database, Reef Check's proprietary data storage system. The GRD is a PostgreSQL database with a data entry portal that has been specially designed for quick and accurate data entry (**Figure A3**). Data entry is conducted by Reef Check staff and interns as well as dedicated data entry volunteers.

All data entry personnel go through a training consisting of watching a recorded lecture, reviewing the Reef Check Data Entry Instructions, and entering a survey that they then QA/QC with Reef Check staff to address any areas of confusion and ensure accurate data.

If there is data that is unclear data entry personnel are instructed to follow up with the diver who collected that information using the comment feature on the pdf in the Google Drive archive. Examples of unclear data that would warrant a follow-up include:

- Subsampling info that is vague
- Species that are rare in the area surveyed
- Tally's not equaling totals.
- Unreadable handwriting
- Fish or abalone that are unusually large or small

Surveys go through three phases during the data entry process:

Draft: A survey has been created and data is being entered. Anyone can edit.
Submitted: Data entry complete, survey ready for the QA/QC process. Only staff can edit.
Finalized: QA/QC is complete and data is live on the Reef Check website for export. Only the administrator can edit.

Data entry personnel use the Data Entry Tracker Google sheet **(Figure A4)** to track the data entry progress in the GRD. Once data entry is complete the survey can be submitted in the GRD and noted on the tracker sheet so that in can be moved on to QA/QC. Surveys can be submitted with unresolved follow-up comments.

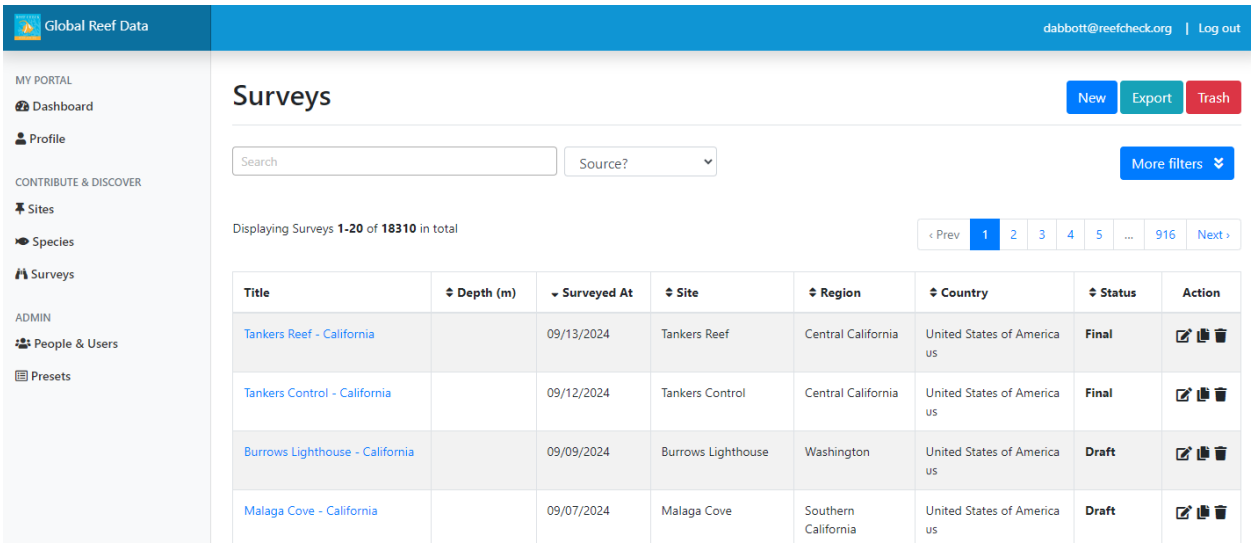
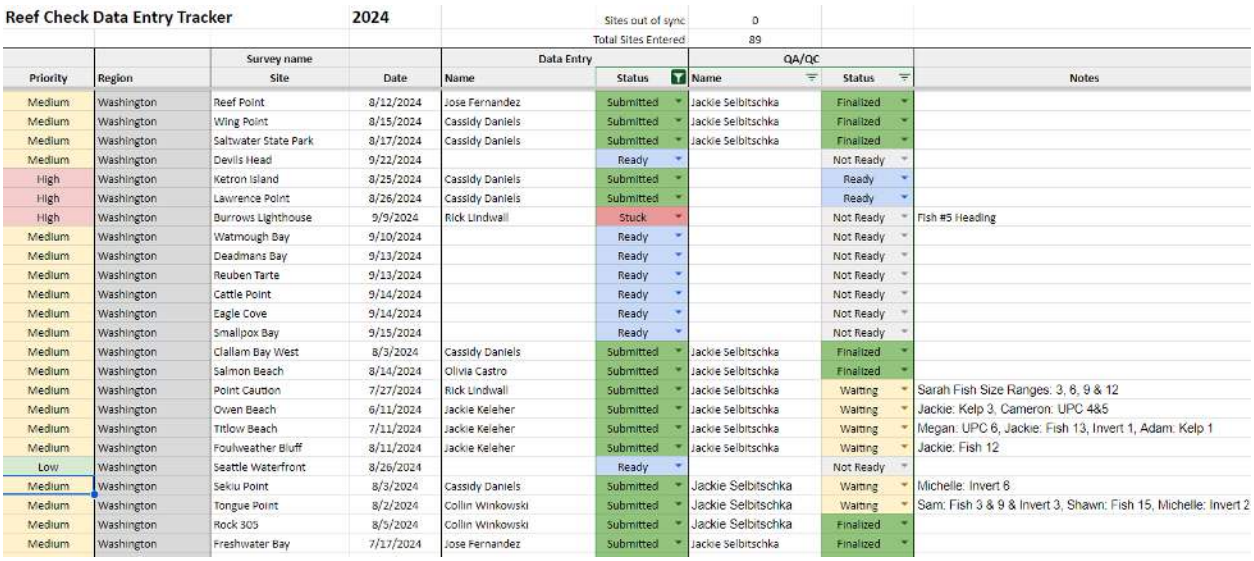


Figure A3. Survey list page of Reef Check's Global Reef Database.



Reef Check Data Entry Tracker 2024

Sites out of sync: 0
Total Sites Entered: 89

		Survey name		Data Entry		QA/QC		
Priority	Region	Site	Date	Name	Status	Name	Status	Notes
Medium	Washington	Reef Point	8/12/2024	Jose Fernandez	Submitted	Jackie Selbitschka	Finalized	
Medium	Washington	Wing Point	8/15/2024	Cassidy Daniels	Submitted	Jackie Selbitschka	Finalized	
Medium	Washington	Saltwater State Park	8/17/2024	Cassidy Daniels	Submitted	Jackie Selbitschka	Finalized	
Medium	Washington	Devils Head	9/22/2024		Ready		Not Ready	
High	Washington	Ketron Island	8/25/2024	Cassidy Daniels	Submitted		Ready	
High	Washington	Lawrence Point	8/26/2024	Cassidy Daniels	Submitted		Ready	
High	Washington	Burrows Lighthouse	9/9/2024	Rick Lindwall	Stuck		Not Ready	Fish #5 Heading
Medium	Washington	Watmough Bay	9/10/2024		Ready		Not Ready	
Medium	Washington	Deadmans Bay	9/13/2024		Ready		Not Ready	
Medium	Washington	Reuben Tarte	9/13/2024		Ready		Not Ready	
Medium	Washington	Cattle Point	9/14/2024		Ready		Not Ready	
Medium	Washington	Eagle Cove	9/14/2024		Ready		Not Ready	
Medium	Washington	Smallpox Bay	9/15/2024		Ready		Not Ready	
Medium	Washington	Clallam Bay West	8/3/2024	Cassidy Daniels	Submitted	Jackie Selbitschka	Finalized	
Medium	Washington	Salmon Beach	8/14/2024	Olivia Castro	Submitted	Jackie Selbitschka	Finalized	
Medium	Washington	Point Caution	7/27/2024	Rick Lindwall	Submitted	Jackie Selbitschka	Waiting	Sarah Fish Size Ranges: 3, 6, 9 & 12
Medium	Washington	Owen Beach	6/11/2024	Jackie Keleher	Submitted	Jackie Selbitschka	Waiting	Jackie: Kelp 3, Cameron: UPC 4&5
Medium	Washington	Titlow Beach	7/11/2024	Jackie Keleher	Submitted	Jackie Selbitschka	Waiting	Megan: UPC 6, Jackie: Fish 13, Invert 1, Adam: Kelp 1
Medium	Washington	Foulweather Bluff	8/11/2024	Jackie Keleher	Submitted	Jackie Selbitschka	Waiting	Jackie: Fish 12
Low	Washington	Seattle Waterfront	8/26/2024		Ready		Not Ready	
Medium	Washington	Sekiu Point	8/3/2024	Cassidy Daniels	Submitted	Jackie Selbitschka	Waiting	Michelle: Invert 6
Medium	Washington	Tongue Point	8/2/2024	Collin Winkowski	Submitted	Jackie Selbitschka	Waiting	Sam: Fish 3 & 9 & Invert 3, Shawn: Fish 15, Michelle: Invert 2
Medium	Washington	Rock 305	8/5/2024	Collin Winkowski	Submitted	Jackie Selbitschka	Finalized	
Medium	Washington	Freshwater Bay	7/17/2024	Jose Fernandez	Submitted	Jackie Selbitschka	Finalized	

Figure A4. Reef Check's Data Entry Tracker.

QA/QC

Within two weeks of the completion of the survey, data is to be QA/QC'd in the Global Reef Database. QA/QC is only conducted by Reef Check staff, generally the regional manager for that region. During QA/QC the review tab of the GRD is used to re-check every entered valued line by line.
If errors are found, they are corrected in the appropriate data entry tab then the review tab is reloaded to confirm the correction was properly recorded. If there is an unclear notation that made it through the data entry step, QA/QC personnel can follow up with data collectors using the comment feature in Google Drive.

Once QA/QC is complete the survey can be finalized in the GRD and noted on the tracker sheet. Surveys can only be submitted once all follow-up comments have been resolved.

Final Data Checks

At the end of the field season once all the data has been collected and entered a series of final checks are run on the data (**Figure A5**). This is to be done within one month from the last survey of the season (two weeks from the completion of the final QA/QC). In general, the Reef Check survey season ends in November though occasionally some surveys are done in December in Southern California.

For the final checks, the database is accessed using *R* and an automated series of checks are run (**Table A2)**. Any potential errors are flagged and investigated. In most cases, the flagged issue is related to something that happened in the field. For instance, if a survey team that was unable to complete a UPC transect on a survey. Generally, these kinds of flagged issues have already been addressed in the comments in the datasheet pdf but are now also addressed by recording the issue in the Data Abnormalities log.

If the issue is an actual data entry error the GRD administrator can edit the finalized survey to address the error. Generally, this process identifies very few actual errors as the data has already been thoroughly checked through the other stages of the data management process.

Once all issues have been addressed the final checks are re-run and it is confirmed that all corrections were properly made and all abnormalities were properly logged.

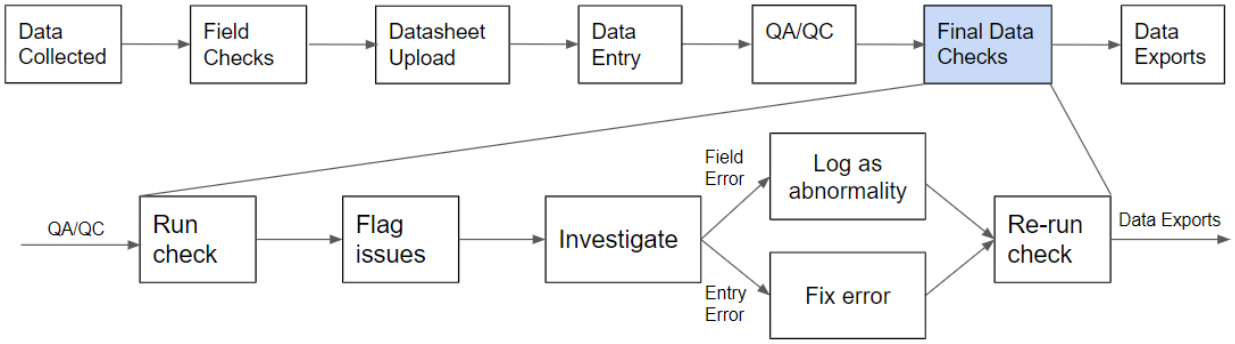


Figure A5. The Reef Check Final Data Checking process.

Table A2. Summary of data checks done during final review (in R).

Spelling of site and species names is consistent
Unusual survey dates
Unusual number of transacts per survey (i.e. not 6 or 18)
NA or 'blanks' in any variable
Zeros in variables that cannot be zero (e.g., size, distance, stipe count, visibility)
Species not on the California species list
UPC counts add up to 30 points per category
Unusually high counts of species
Unusually large sizes (or size <10 cm for YOY rockfish)
Minimum size less or equal to maximum size for fish
Unusual depth (e.g., <5 ft, > 60 ft)
Visibility outside of bounds
Distance > 30 m or < 5 m (invert, kelp)
Unusual subsampling distances or counts (invert, kelp)
Missing data (i.e. missing values, missing transects etc.)
Duplicate data

Data Exports

The final stage of the data management process is to package the data for export so that scientists, marine managers, and members of the general public can make informed decisions regarding the health of our nearshore ecosystems. Packaging is to be completed by the end of the calendar year, regardless of when the season ended.

For the data packaging, the GRD is accessed with *R* and the data is converted into cleaner formats that are easier to understand and analyze. Currently, two formats are offered for export

Means: Mean density and standard error of species per survey

Raw: Counts and area counted of species by transect.

One survey is comprised of six (invert, kelp, and UPC) transects and 18 fish transects, so the summarized "Means" format is smaller and is easier to work with, and is recommended for most users. The “Raw” format is for data users who want to do a deeper dive into the Reef Check dataset and utilize additional datasets such as fish sizes or depths per transect.

Data is requested by filling out a form on the Results page on the Reef Check website. Once requested Reef Check staff send out data within 48 hours. Along with the dataset request users are sent a link to the Metadata for Reef Check KFM Data document with descriptions of the fields included in the export as well as a Reef Check Species Lookup Table that has scientific names and taxonomic information on Reef Check species.

Data exports are tracked and users are requested to credit Reef Check anytime data is used and to share any final projects. Reef Check fulfills roughly a hundred data requests each year.