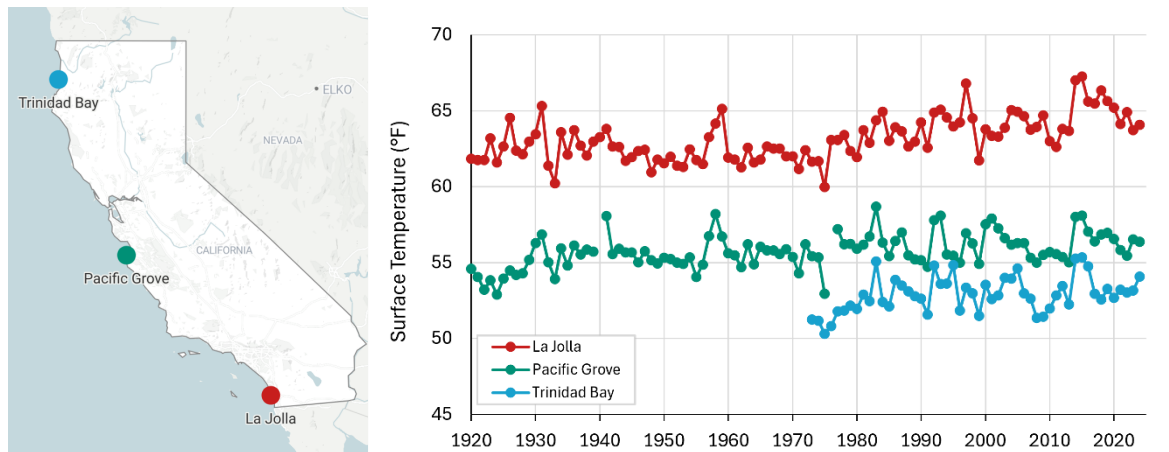


3.3 Coastal Ocean Temperature

Measurements at California's shore stations show that nearshore coastal ocean temperatures have increased over the past century, particularly in Southern California. Similarly, satellite-based records over the past four decades show warming ocean waters off Southern California. In addition to these long-term trends, an unprecedented marine heatwave affected the West Coast of the United States from 2014 to 2016.

Figure 3.3.1. Annual Average Sea Surface Temperatures (SSTs).

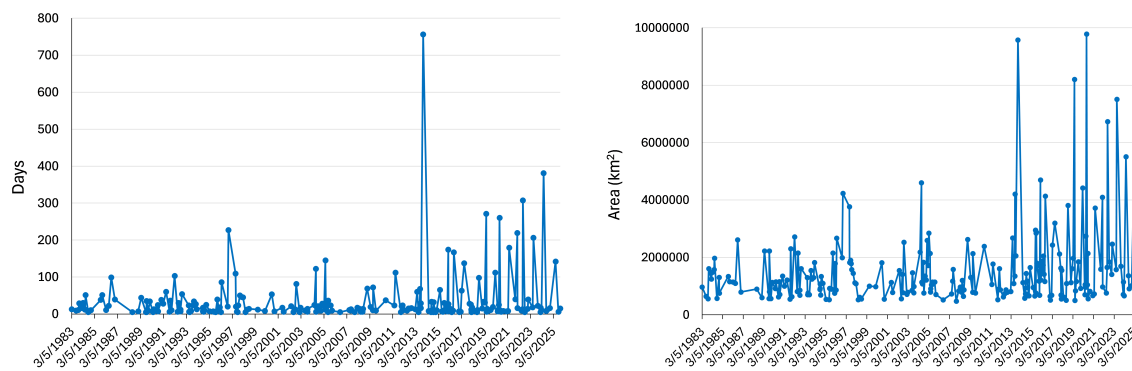


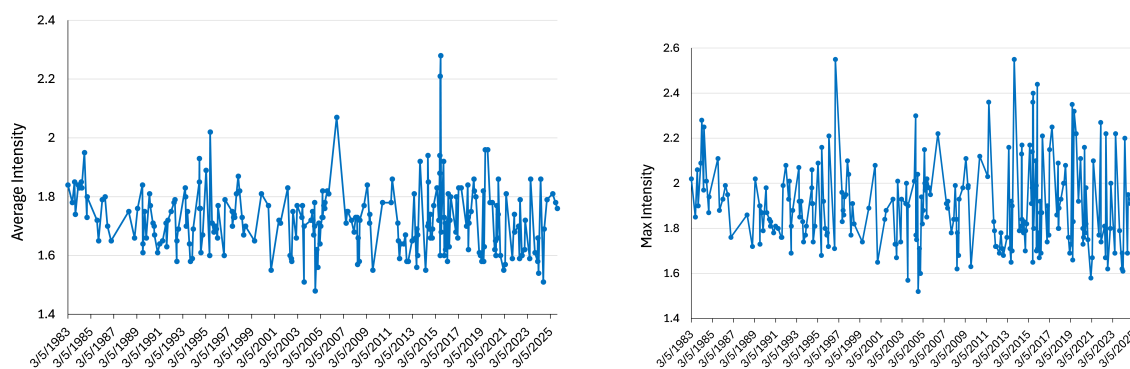
This graph shows annual average coastal ocean surface temperatures at Trinidad Bay (Northern California), Pacific Grove (Central California), and La Jolla (Southern California) shore stations. Records span different time periods depending on data availability, with observations extending from 1917 to 2025

*October to December 2025 are preliminary data

Source: SIO (2026)

Figure 3.3.2. Marine Heatwave Events.





The graphs show the total number of days, surface area, and intensity each year for all heatwaves since 1982 in the Northeast Pacific region along the coasts of California, Oregon, and Washington. Values are reported by the California Current Marine Heatwave Tracker, developed by oceanographers from NOAA Fisheries' Southwest Fisheries Science Center. Source: NOAA (2025)

What does the indicator show?

California coastal ocean temperatures have risen over the past century. Despite natural year-to-year fluctuations, long-term warming trends are evident in shore-station records (**Figure 3.3.1**). Sea surface temperatures have risen by 0.17 degrees Fahrenheit (°F), or 0.1 degrees Celsius (°C) per decade at Pacific Grove (1919–2025), and 0.26°F (0.15°C) per decade at La Jolla (1917–2025). At Trinidad Bay, temperatures increased at a rate of 0.28°F (0.16°C) over a shorter period (1973–2025). All three trends are statistically significant ($p < 0.05$), and additional stations along the coast show similar warming (**Table 3.3.1**), with the strongest increases at the southernmost sites, La Jolla, Granite Canyon, and San Clemente. Warming along California's coast is consistent with global trends — globally, average sea surface temperatures have increased at a rate of 0.14°F (0.08°C) per decade from 1901 to 2023 (US EPA, 2024).



Table 3.3.1. Increasing Trends in Monthly Sea Surface Temperature.

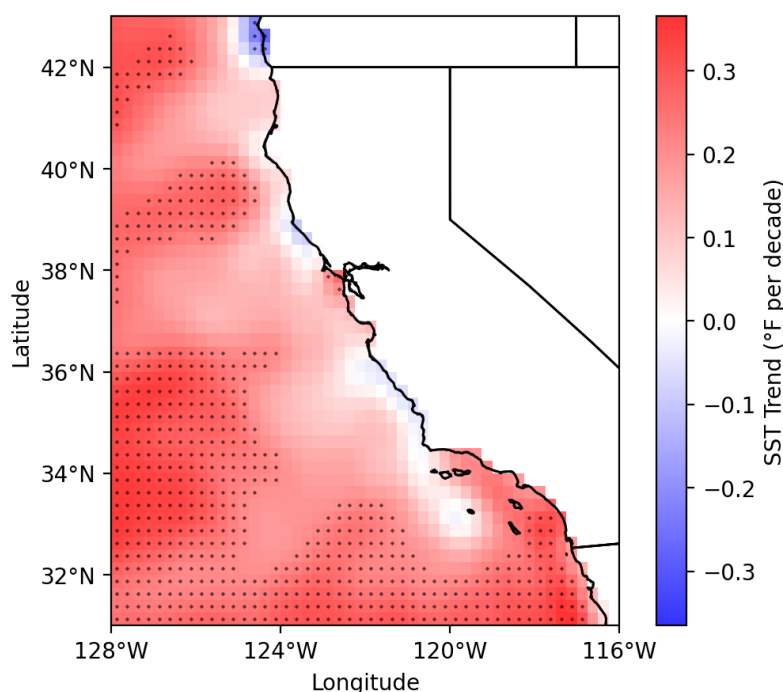
Station	Dates	Decadal Trend	p-value*
Trinidad	01/1973 – 12/2025	0.27	< 0.001
Farallon Island	05/1925 – 12/2025	0.10	< 0.001
Pacific Grove ^a	01/1919 – 12/2025	0.18	< 0.001
Granite Canyon	03/1971 – 12/2025	0.28	< 0.005
Santa Barbara	01/1955 – 12/2025	0.30	< 0.001
Point Dume	12/1956 – 12/2025	0.07	0.29
Newport Beach	11/1924 – 12/2025	0.13	< 0.001
San Clemente	07/1965 – 12/2025	0.34	< 0.001
La Jolla	08/1916 - 12/2025	0.26	< 0.001

This table shows increasing trends in monthly sea surface temperature (°F per decade) for selected California coastal monitoring stations. Trends represent estimated long-term increases in monthly sea surface temperature through 2025. *p-values less than 0.05 indicate statistically significant increasing trends. ^aData with documented uncertainty (Pacific Grove: 1976; Santa Barbara: 1995–2011; Point Dume: 1995–2006) were excluded from analysis.

From 1982–2025, monthly satellite-based sea surface temperature (SST) data from (National Oceanic and Atmospheric Administration) NOAA show mixed warming and cooling trends over the continental shelf that are generally not statistically significant ($p > 0.05$), while offshore waters are generally warming ($p < 0.05$, [Figure 3.3.3](#)). Both nearshore and offshore of the Southern California Border and Mexico exhibit a distinct warming trend, while cooling coastal trends are observed in Oregon.



Figure 3.3.3. Satellite-Based Sea Surface Temperature Trends.



The map shows sea surface temperature trends along the California coast, in °F per decade, for the period 1982 to 2025. Colors indicate the magnitude and direction of sea surface temperature trends, with warmer colors representing increasing temperatures and cooler colors representing decreasing temperatures. Dotted areas denote locations with statistically significant trends ($p < 0.05$). Source: NOAA (2026)

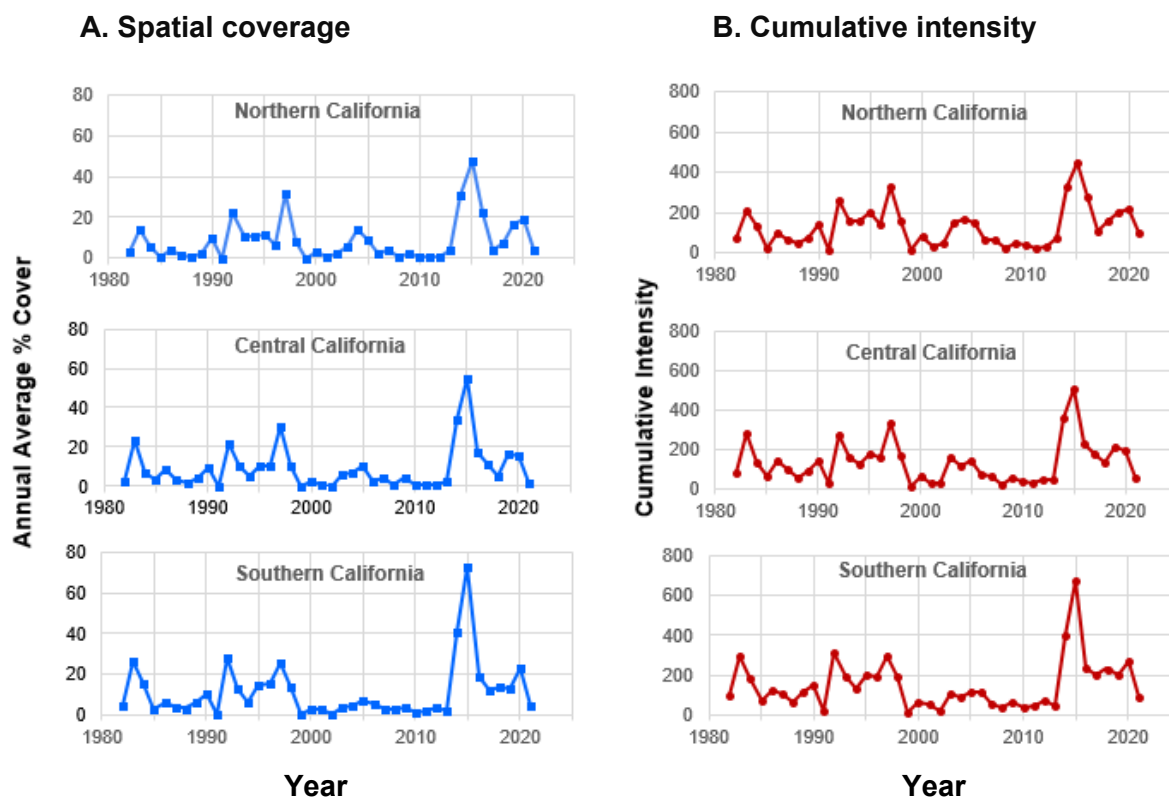
Marine heatwaves—events in which ocean temperatures are far above what is normal for a given place and time—significantly impact ecosystems, biodiversity, and regional economies (NOAA, 2025). Marine heatwaves have become more frequent worldwide and have grown more intense and longer lasting since the 1980s. The frequency of marine heatwaves approximately doubled from 1982 to 2016 (relative to the 1971-2000 climatology), and they have occurred each of the past seven years, from 2019–2025 (IPCC, 2021, NOAA, 2025). Over the past two decades, they have occurred in every major ocean basin (IPCC, 2021). In 2014 a large marine heatwave was identified as it began dominating the northeast Pacific Ocean. Eventually known as “The Blob”, this basin-scale marine heatwave was unique in the history of monitoring in the California Current Ecosystem (CCE) and persisted until mid-2016. While marine heatwaves have



occurred in the past, the magnitude and duration of the warming during this event was unprecedented for the west coast of North America (Di Lorenzo and Mantua, 2016; Gentemann et al., 2017). Researchers documented many ecological effects associated with “The Blob”, including unprecedented harmful algal blooms, shifting distributions of marine life, and changes in the marine food web (NOAA, 2025).

The large marine heatwaves that have occurred each year from 2019 to 2025 all typically began during the spring in the far offshore North Pacific, impacted the US west coast in the fall, and terminated during late winter. Five of the past six years saw the largest heatwaves recorded since monitoring began in 1982 in the region shown in **Figure 3.3.2**. In late May 2025, a major marine heatwave developed and expanded from late July to early August, reaching its maximum size of approximately 10 million square kilometers (km²) on September 10, 2025. This event represents the largest marine heatwave (by area) observed within the Northeast Pacific region analyzed by NOAA. Earlier notable marine heatwaves occurred in 1983, 1992, 1997 (all associated with El Niños; these events originated in the south, rather than from the Central North Pacific) (Leising et al., 2015). **Figure 3.3.4** shows the area and intensity of marine heatwaves from 1982 to 2021 off Northern, Central, and Southern California in the same regions studied in **Figure 3.3.2**.



Figure 3.3.4. Marine Heatwaves off California (1982-2021).

A) Marine heatwave spatial coverage expressed as the annual average percentage of the region in heatwave status, defined as days when sea surface temperature exceeds the 90th percentile relative to the 1971 to 2000 climatology; B) Marine heatwave cumulative intensity, calculated as the annual sum of daily average sea surface temperature measurements above the long-term mean. Source: Data provided by Leising; also available at NOAA (2022)

Why is this indicator important?

Temperature is one of the best-measured signals of climate change. As atmospheric concentrations of greenhouse gases increase, excess heat is absorbed and stored by the oceans and atmosphere. The ocean's large mass and high heat capacity allow it to store large amounts of heat. It is estimated that over 90% of the observed heat energy increase on the Earth over the past 50 years has occurred in the ocean (Jewett and Romanou, 2017; NOAA, 2021; Rhein et al., 2013). In addition to absorbing excess heat, the ocean absorbs approximately 30% of carbon emissions. As a result, the ocean acts as a buffer against global warming (IPCC, 2019).



Shifts in sea surface temperatures along the California coast affect the distribution, abundance, and recruitment of many marine species, including commercially important ones. Temperature variability has been linked to changes in coastal populations (Goericke et al., 2007; IPCC, 2019; Sagarin et al., 1999), largely through its effects on physiology and the timing of key developmental stages. For example, multiple fish species are shifting their spawning times (mostly earlier) in the CCE (Chen et al., 2025; Asch, 2015). Seabirds may also be impacted by marine heatwaves through changes in habitat, behavior, ecological processes, or species interactions (Piatt et al., 2024). Altogether these changes can reshape marine communities by altering interactions with competitors, predators, parasites, facilitators, and prey.

Anomalously high temperatures during marine heatwaves dramatically impact marine ecosystems. Warm offshore waters can compress cool upwelling habitat into a narrow coastal band, altering species distributions (Santora et al., 2020). Marine heatwaves in the 1980s and 1990s that were associated with El Niño events disrupted ecosystems by altering water properties, food webs, and the transport of organisms (Ohman et al., 2017). The 2014–2016 marine heatwave caused mass strandings of marine mammals and seabirds (Cavole et al., 2016; Piatt et al., 2020) and initiated toxic algal blooms that harmed marine mammals (also see the *Marine Harmful Algal Blooms* chapter). Closure of the Dungeness crab fishery due to domoic acid produced by the toxic algal blooms resulted in an estimated \$48 million in lost revenue statewide (Gentemann et al., 2017; Brown, 2016). Marine heatwaves contribute to the rapid and extensive loss of kelp forests in Northern and Southern California (Gleason et al., 2021, Cavanaugh et al., 2019). In Northern California this led to the closure of the recreational red abalone fishery and the commercial red sea urchin fishery (Gleason et al., 2021). Both kelp and abalone are culturally significant species to Native American tribes, such as the Chumash and the Scotts Valley Band of Pomo Indians (Santa Ynez Band of Chumash Indians, 2022; Amah Mutsun Tribal Band, 2022; Big Valley Band of Pomo Indians and Middletown Rancheria of Pomo Indians, 2021). Since kelp provide a wide range of ecosystem services as primary producers and as essential habitat for marine organisms, among other things, the loss of kelp forests has larger scale consequences (Bell et al., 2020; Gleason et al., 2021; Teagle et al., 2017; also see the *Kelp*



Populations chapter). For example, without kelp forests to act as buffers, the coast has become more vulnerable to coastal erosion from high energy storms and swell events; along with sea level rise, coastal erosion is threatening cultural sites along the shoreline in the Amah Mutsun's ancestral territory (Amah Mutsun Tribal Band, 2022).

Tribal Connection 3.3.1

Ocean temperatures are one variable impacting eelgrass beds, which are a critical part of the ecosystem in the Wiyot Tribe's homelands around Humboldt Bay or *Wigi*. The Wiyot Tribe writes, "*Sea level rise and increased storm severity, along with ocean warming and acidification, pose a threat to Wigi eelgrass habitat. Eelgrass is a vital habitat for many species, including Dungeness crab, juvenile salmonids, rockfish, and migratory birds (Merkel & Associates, Inc., 2017). As part of their mitigation efforts to help habitats and species migrate inland, the Tribe is working on an eelgrass suitability distribution model. This model will take temperature, salinity, depth, substrate conditions, and other eelgrass habitat parameters into account to help the Wiyot find locations for future eelgrass survival and protection*" (Wiyot Tribe, 2026).

Temperature changes also affect the chemical and physical properties of the ocean. Since warmer water is less dense than colder water, changes in sea surface temperatures can alter currents and transport patterns. Warming sea surface temperatures can cause more stable layers of seawater to form near the surface, thus increasing water column stratification; when this happens, upwelling and vertical mixing that transports nutrients, oxygen, carbon, plankton and other material across ocean layers is reduced (Roemmich and McGowan, 1995; Jacox and Edwards, 2011). Temperature also affects the solubility of gases in ocean waters. For example, warmer waters contain less oxygen and accelerate oxygen consumption by marine organisms (e.g., Somero et al., 2015; Breitburg et al., 2018).

Surface ocean water temperature affects the occurrence of coastal fog and the strength of winds, as well as the thickness of the marine atmospheric boundary layer. The latter is a primary factor controlling the inland intrusion of cool coastal air and therefore inland weather patterns. Warmer waters play a role in extreme weather events by increasing



the energy and moisture of the atmosphere. Warmer ocean temperatures also contribute to global sea level rise because warming water not only expands but also accelerates the melting of land-based ice sheets (IPCC, 2021). Additionally, Hurricane Hilary in August of 2023 caused record-breaking precipitation, flooding, and damage to Southern California in the form of an uncommon tropical cyclone. Coastal warming patterns of Southern California allowed for easier landfall for tropical cyclones that historically remained offshore (Miles and Xie, 2025).

Globally, oceans are projected to continue to warm in the 21st century. Marine heatwaves are expected to further increase in frequency, duration, spatial extent, and intensity, although changes will not be globally uniform (IPCC, 2021). Given the severe impacts of marine heatwaves on the marine ecosystem and the coastal communities and economies it supports, NOAA oceanographers have developed the [California Current MHW Tracker](#) as a tool for describing current and past large marine heatwaves that could also help with forecasting future marine heatwaves (NOAA, 2022).

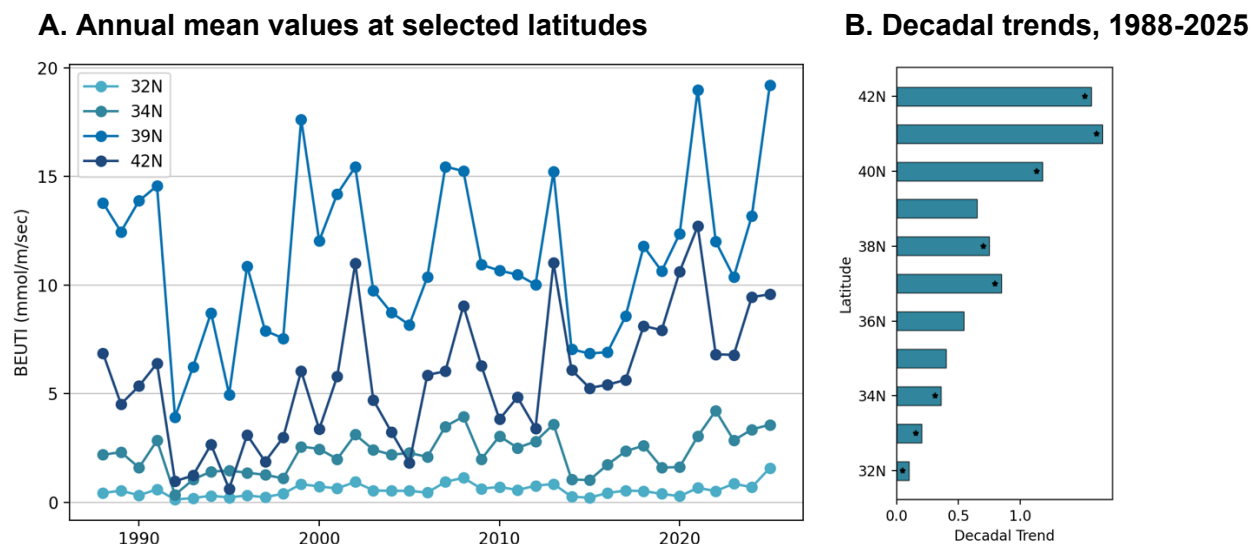
What factors influence this indicator?

Global sea surface temperatures have increased due to net heat flux from the atmosphere stemming from the greenhouse effect. Deeper regions of the oceans have also warmed to depths of 3000 meters during the past several decades (Levitus et al., 2001 and 2012). A combination of oceanic and atmospheric processes, including ocean currents, winds, and climate variability modes like El Niño can lead to the periods of extremely high ocean temperature, and their classification as marine heatwaves depends on the magnitude of ‘normal’ warming events in each location (Hobday et al., 2016).

Near-surface ocean water temperatures along the California coast are also influenced by seasonal upwelling. An index called the Biologically Effective Upwelling Transport Index, or BEUTI, tracks the amount of nutrients (nitrate) in vertically transported waters, providing information about upwelling relevant to biological responses (Jacox et al., 2018; **Figure 3.3.5**). BEUTI shows high interannual variability with a slight increase over time, especially at latitude 34°N in Southern California.



Figure 3.3.5. Biologically Effective Upwelling Transport Index.



A) Annual mean values of the Biological Effective Upwelling Transport Index (BEUTI) at selected latitudes along the California Coast: 32°N, south of San Diego; 34°N, Los Angeles; 39°N near Point Arena, and 42°N near the California-Oregon border; B) Linear trends in BEUTI per decade at different latitudes along the California Coast for the period 1988 to 2025. Black stars denote statistically significant trends (p values < 0.05). Source: NOAA ERDDAP (2025)

Coastal ocean temperature trends are shaped by the combined influence of surface warming and the cooling effect of upwelling. Surface temperatures tend to rise offshore and in sheltered waters, as seen at La Jolla, while open shelf waters, especially off Central and Northern California, remain cooler or unchanged during the upwelling season (Seabra et al., 2019; García-Reyes and Largier, 2010; García-Reyes et al., 2023). The lack of significant warming in these regions over the past four decades reflects upwelling's cooling influence. (Bakun, 1990; García-Reyes et al., 2015; [Figure 3.3.3](#)).

Natural variability in coastal temperature, wind, and circulation drives large year-to-year and decade-to-decade changes. El Niño-Southern Oscillation (ENSO) events cause major swings—El Niño warms California's coastal waters, while La Niña cools them—and occur every 5–10 years. Longer-term patterns like the Pacific Decadal Oscillation (PDO) and North Pacific Gyre Oscillation (NPGO) also influence West Coast temperatures (UCAR, 1994; Di Lorenzo et al., 2008; Mantua et al., 1997). Marine



heatwaves reflect both long-term warming from climate change and amplified short-term fluctuations (Fumo et al., 2020).

Technical considerations

Data characteristics

Coastal California is home to the longest continuous record of sea surface temperatures on the US West Coast and the Pacific Rim. Long-term time series from three sites — Trinidad Bay in Humboldt County, Pacific Grove in Monterey County, and La Jolla in San Diego — are presented in this report; these sites were chosen based upon their long operational duration (~40 to 100 years), public data availability, and regional/geographic coverage. Data for the three sites and other California coastal sites have been collected by the [Shore Stations Program](#) (SIO, 2026). The time series at Scripps Pier, La Jolla Shores, which extends back to August 1916, is the longest running sea surface temperature data set in the state.

Trinidad Bay temperature measurements are taken daily by staff from the [Humboldt State University Marine Laboratory](#), located on the rocky headland between the ocean and Trinidad Bay. Bay temperature is measured from the fishing pier on the southeast side of the headland. Pacific Grove measurements are taken daily by staff from [Stanford University's Hopkins Marine Station](#) from a beach on the north side of Point Cabrillo. This location is representative of coastal conditions on the south side of Monterey Bay. La Jolla temperature measurements are taken daily at Scripps Pier by representatives from [Scripps Birch Aquarium](#). The proximity of the pier to the deep waters at the head of La Jolla submarine canyon results in data representative of oceanic conditions.

The NOAA Optimum Interpolation Sea Surface Temperature (OISST) reanalysis dataset merges satellite and in situ measurements from different platforms into a single gridded SST product. Along the California coast, the dataset provides a spatial resolution of approximately 13 nautical miles (nmi) (here averaged longitudinally to ~30nmi), and daily temporal resolution, starting in September 1981. The dataset is interpolated to fill gaps on the grid and create a spatially complete map of sea surface temperature. Satellite and ship observations are referenced to buoys to compensate for



platform differences and sensor biases (NOAA, 2026). Data is provided by NOAA/National Centers for Environmental Information.

Marine heatwave cover and cumulative intensity are products reported in the California Current Marine Heatwave Tracker, an experimental tool for tracking marine heatwaves from British Columbia to Baja, along the path of the California Current. The California Current is a large, southward-flowing ocean current that forms the eastern boundary of the North Pacific Ocean circulation and transports cool, nutrient-rich water along the west coast of North America from British Columbia to Baja California. The tool was designed to investigate the 2014-2016 marine heatwave (NOAA, 2022). Indices are developed to help track historical and near-real-time marine heatwaves. A marine heatwave is based on the definition in Hobday et al. (2016). However, no time constraint was used since values were summed over relatively large regions. The analysis presented here is based on a long-term baseline mean for the period 1971 to 2000, and the threshold was set at the 90th percentile of all values for the period 1982-2021. Further information about the tracker, including access to the data, is available at the [Integrated Ecosystem Assessment webpage](#).

Five regions along the California Current are monitored, including three in California as shown in **Figure 3.3.4**. For each region, the spatial coverage is calculated as the annual mean of the daily percentage of the area in heatwave status. This describes the size of the marine heatwave each year. Intensity describes how hot the ocean waters are compared to a historical baseline. This index does not depend on whether it is in heatwave status. The cumulative intensity presented in **Figure 3.3.4B** is the sum of daily intensity values in a year for a given region, specifically the sum of average daily SST measurements above the baseline temperature. These temperature measurements are standardized for the location and time of day to ensure that the data are comparable over time.

Strengths and limitations of the data

A growing network of ocean monitoring along California is an important resource for separating natural and anthropogenic influences on increasing temperatures. The California Cooperative Oceanic Fisheries Investigations (CalCOFI) and NOAA National



Data Buoy programs represent the largest coordinated efforts to collect sea surface temperature data across broad spatial scales. In addition, California's regional Ocean Observing Systems (Central, Northern, and Southern California) provide coordinated, long-term monitoring of environmental conditions to support ocean management decisions as part of an eleven-region US Integrated Ocean Observing System (IOOS, 2026).

The NOAA satellite-based product provides a shorter sea surface temperature record than those of the shore stations, however its record has no spatial gaps and a larger cover offshore, allowing a better understanding of the different trends observed in this indicator along the California coast and over the continental shelf (NOAA, 2026). It is important to note that the data points closest to shore cover waters over the continental shelf, and do not represent temperatures near shore (beaches and intertidal) due to its coarser resolution. For nearshore values, the coastal values are more representative, although sparse in space.

Temperature and BEUTI were averaged annually before trends were calculated. This reduces the number of data points and therefore statistical significance. Data from:

<https://mjacox.com/upwelling-indices/>.

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