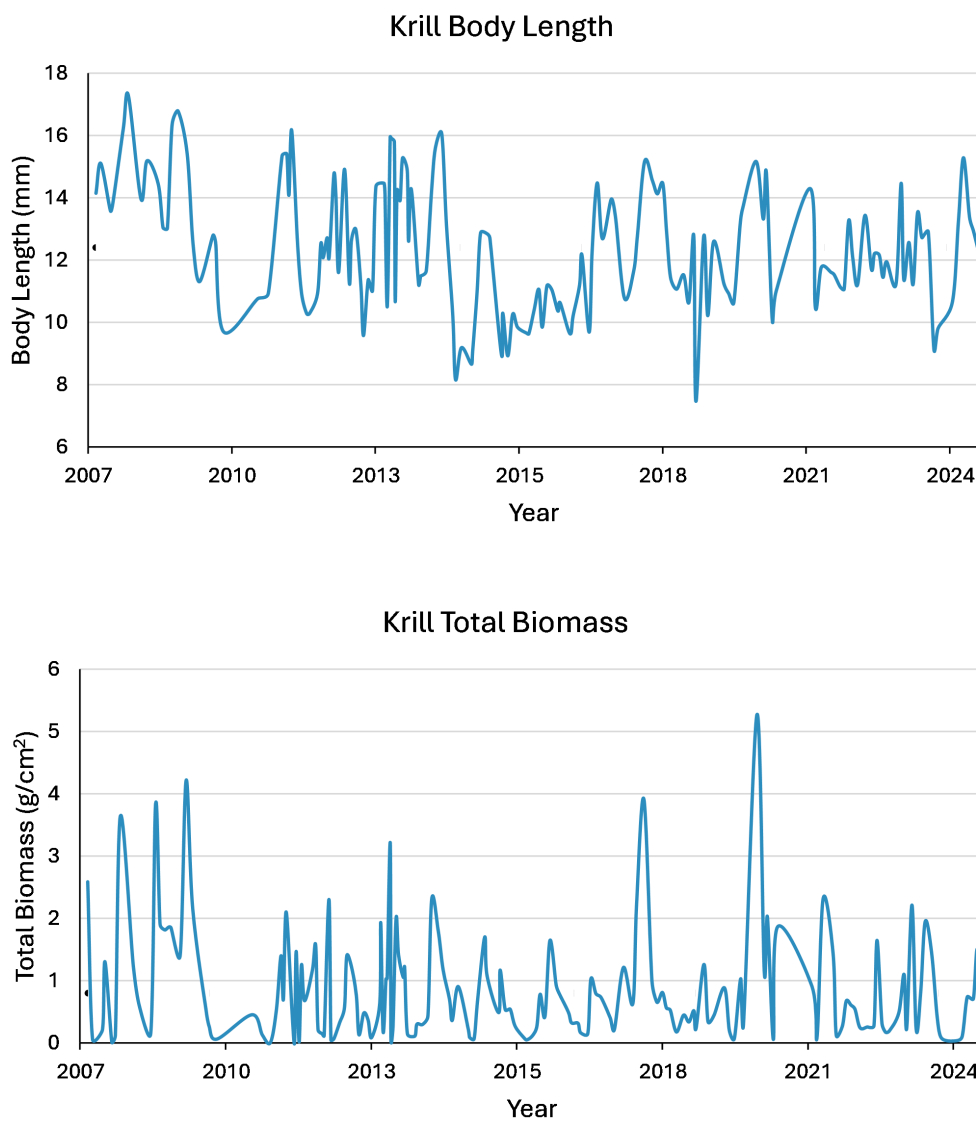


3.8 Krill Length and Biomass

North Pacific krill (*Euphausia pacifica*) are a key prey species in the California Current Ecosystem. Krill respond strongly to ocean climate conditions: warm events such as marine heatwaves and El Niño reduce krill size and biomass, while cooler conditions support recovery. As a result, changes in krill length and biomass provide a sensitive indicator of ecosystem health.

Figure 3.8.1. North Pacific Krill Length and Biomass.



The graphs show the monthly mean adult North Pacific krill length (top) and total North Pacific krill biomass (bottom) measured off Trinidad Head, CA, 2007 - 2024. Total biomass represents



the combined weight of all North Pacific krill in the survey area. The dotted black line indicates the long-term monthly mean (2007–2024). Source: Leising et al. (2025), based on work by Eric Bjorkstedt.

Figure 3.8.2. Trinidad Head Line Location.



The following show the Trinity Head Line (THL) off the coast of northern California. The THL extends 5 - 37 km offshore and consists of five long-term monitoring stations. Source: Left map: CeNCOOS (2026); Right map: Map created with Datawrapper

What does the indicator show?

Mean body length of adults and total biomass of *E. pacifica* indicate productivity at the base of the food web, krill condition, and energy content for predators (Robertson and Bjorkstedt, 2020). Krill body length and biomass vary from year to year, with declines during an unprecedented marine heatwave from 2013 to late 2015 called ‘the Blob’ that engulfed the west coast followed in the 2015-2016 winter by one of the strongest El Niño events of the last 145 years (Figure 3.8.1; NOAA, 2019; Scripps, 2026; USGS, 2020). Since the onset of this unusual heatwave, krill body lengths have generally increased except in 2019 during El Niño conditions. Exceptionally high biomass was seen in summer of 2020 but has declined in recent years (Harvey et al., 2022). North



Pacific krill (*Euphausia pacifica*) are sampled year-round along the THL off the coast of northern California (**Figure 3.8.2**).

Why is this indicator important?

The California Current Ecosystem is a highly productive upwelling current system that supports biodiversity and serves as foraging habitat for many species of migratory fish, marine mammals, and seabirds that travel across the vast Pacific Ocean basin. This ecosystem supports an important ocean economy, including recreational and commercial fishing, tourism, shipping, military training, and emerging ocean aquaculture and offshore wind (NOAA, 2023a).

Krill are among the most important prey groups in the California Current Ecosystem. Krill is the near-exclusive prey for giant blue whales, and seabirds like auklets and shearwaters. Commercially valuable salmon, rockfish, flatfish, sardines and squid thrive on krill. When krill are abundant, animals migrate thousands of miles to feed on them. When the krill population declines, the stability of the entire marine ecosystem is compromised. Larger and more abundant krill provide more energy to predators whereas smaller or fewer krill reduces the energy transfer up the food chain, affecting predator survival, reproduction, and population trends (Kaplan et al., 2025). As a result, animal migration patterns may shift, species unable to forage elsewhere may starve; some seabird species may experience complete breeding failure for, and local ecosystems may collapse (NOAA, 2023b).

Of the 85 krill species worldwide, the two dominant species in northern and central California are *Thysanoessa spinifera* and *Euphausia pacifica*, both of which are less than an inch long. By grazing on microscopic plants (phytoplankton) and microscopic animals (zooplankton), krill transfer energy to larger organisms higher in the food web. From late spring into fall, krill may swarm in swirling bait balls as dense as 100,000 per cubic yard. At times broad, pink swaths of it may stretch for miles and can be seen from the air (NOAA, 2023b).

Krill feed primarily on phytoplankton, which are microscopic organisms that form the foundation of marine ecosystems. When phytoplankton are abundant due to favorable conditions (like cold, nutrient-rich waters), krill can grow larger and reproduce more



successfully. Larger average body sizes and higher total biomass of krill thus generally indicate high primary productivity (Fiechter et al., 2020; NOAA, 2025).

What factors influence this indicator?

Both natural climate variability and human-driven climate change can influence krill body length and biomass, by altering ocean conditions in the California Current Ecosystem. Changes in water temperature, dissolved oxygen, currents, upwelling, and food availability affect krill growth, survival, reproduction, and distribution. The California Current Ecosystem experiences natural climate variability that alters water and air temperature, winds, currents, mixing of ocean waters, water chemistry, and precipitation. Dissolved oxygen (DO) is influenced by processes such as currents, upwelling, air-sea exchange, primary production, and respiration. Low DO (aka hypoxia, concentrations <1.4 ml DO/l) can vertically compress habitat and cause stress or die-offs in sensitive species (Chan et al., 2008). As the ocean absorbs increased anthropogenic atmospheric CO₂, ocean acidification occurs which reduces pH and dissolved carbonate in seawater and is stressful to many marine species (Feely et al., 2008; Busch and McElhany, 2016). Harmful algal blooms (HABs) can further disrupt marine food webs and prey availability (see the *Marine Harmful Algal Blooms* chapter). Changes in krill abundance associated with shifting ocean conditions have been linked to widespread impacts, including starvation of pelicans and a significant mortality event for Cassin's auklets (Leising et al., 2025).

Climate warming and increased marine heatwaves pose significant long-term risks to krill by reducing the cold, nutrient-rich habitat that krill are dependent on (Dorman et al., 2023; Fiechter et al., 2026). Large-scale climate variability also influences krill dynamics. Warm El Niño-Southern Oscillation (ENSO) events, warm phases of the Pacific Decadal Oscillation, and marine heatwaves are consistently associated with lower krill abundance (Marinovic et al., 2002; Brinton and Townsend, 2003; Brodeur et al., 2019; Cimino et al., 2020).

Krill biomass reflects both abundance and body size, and both are sensitive to oceanographic conditions. Coastal upwelling enhances nutrient supply, stimulates primary production, and cools surface waters, supporting higher phytoplankton biomass



and improved feeding conditions for krill (Shaw et al., 2010; García-Reyes et al., 2014). Chlorophyll-a (chl-a), a proxy for phytoplankton abundance, is positively associated with krill abundance and growth (Lavaniegos et al., 2019; Cimino et al., 2020; Robertson and Bjorkstedt, 2020). In contrast, higher ocean temperatures are associated with reduced abundance and slower growth (Marinovic and Mangel, 1999). Adult *Euphausia pacifica* also have body length declines as temperatures rise, particularly above $\sim 14^{\circ}\text{C}$ ($\sim 57^{\circ}\text{F}$) when metabolic efficiency decreases (Iguchi and Ikeda, 1995; Alonzo and Mangel, 2001; Robertson and Bjorkstedt, 2020). For example, mean adult length declined sharply with the arrival of warm 'blob' waters in mid-2014, individuals larger than 12 mm effectively disappeared from samples taken. Larger adults (>15 mm) were briefly abundant during a period of intense upwelling in early 2015, but again disappeared as the 2015-16 El Niño renewed unusually warm conditions along the coast. During this period, the typical seasonal pattern of increasing adult size during spring and summer was diminished, such that mean adult length remained at or below the long-term average ($12.9 \text{ mm} \pm 3.03 \text{ SD}$) and on several occasions was as low as 60-70% of the long-term average (Robertson and Bjorkstedt, 2020).

Technical considerations

Data characteristics

The THL sits between two distinct circulation regimes. To the north, a region characterized by strongly seasonal upwelling and downwelling along a relatively straight coastline. To the south, in the Southern California Bight - the curved coastline between Point Conception and San Diego – there is more complex circulation shaped by coastal topography and mesoscale features, and upswelling is generally more intense and less seasonal. In addition, the area between Cape Blanco and Cape Mendocino is heavily shaped by coastal headlands, which generate upwelling jets and eddies that structure local circulation and productivity (Leising et al., 2025).

Euphausia pacifica is sampled year-round along the THL off northern California (Harvey et al., 2022). Krill sampling occurs monthly during 12-hour cruises. The krill body length was measured in millimeters (mm) from the back of the eye to the base of the telson (Leising et al., 2025).



Strengths and limitations of the data

Krill length and biomass are universally-used metrics to help determine the health of the California Current Ecosystem (Leising et al., 2025). Long-term ecological time series are critical for understanding ecosystem variation and ecological relationships, and for informing ecosystem-based management (Harvey et al., 2020; Sydeman et al., 2013). However, future data updates are uncertain due to changes in federal funding and resources.

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