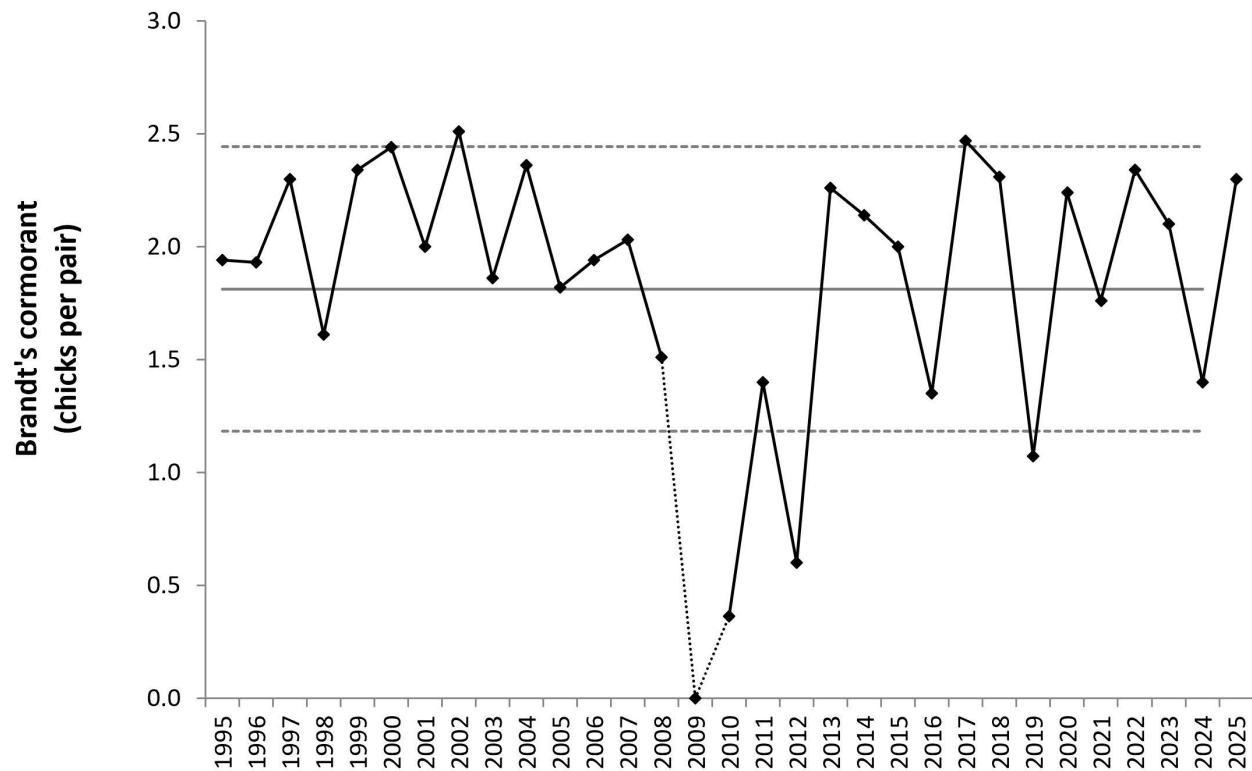


3.9 Brandt's Cormorant Reproductive Success

Over a 30-year period from 1995-2025, the reproductive success of Brandt's cormorants has exhibited increasing variability.

Figure 3.9.1. Brandt's Cormorant Reproductive Success.



This figure shows Brandt's cormorant reproductive success on Alcatraz Island near the mouth of San Francisco Bay, from 1995 to 2025, measured as the mean number of chicks produced per breeding pair per year. Source: Julie Thayer, Farallon Institute (2026)



What does the indicator show?

As conspicuous upper trophic level consumers that respond quickly to changes in prey abundance and food availability, seabirds can be effective indicators of change in marine ecosystems, and specifically the structure of coastal-pelagic food webs (Cairns, 1987; Furness and Camphuysen, 1997; Piatt et al., 2007; Hazen et al., 2019; Velarde et al., 2019). Seabird reproductive success is a particularly well-known and accepted early-warning (i.e., sentinel) indicators of food webs and corresponding prey resource availability, as this parameter responds to shifts in prey availability on high-frequency seasonal and local scales (Cairns, 1987 and 1992; Ainley et al., 1994; Boyd and Murray, 2001; Sydeman et al., 2021; Descamps et al., 2022; Karnovsky et al., 2025; Watanuki et al., 2025).

Brandt's cormorant reproductive success is influenced by the availability of nearshore marine food resources and the ocean conditions that influence these prey resources. Ocean conditions such as sea surface temperature, upwelling, and ocean productivity influence the abundance and distribution of forage fish that Brandt's cormorants rely on. Brandt's cormorants are piscivorous, consuming both benthic (bottom) and pelagic (water column) fishes including northern anchovy, flatfishes, and rockfishes (Elliott et al., 2014; Webb et al., 2015; Robinson et al., 2019). As a result, changes in reproductive success can reflect changes in prey availability and/or broader marine ecosystem conditions.

Brandt's cormorant reproductive success is an integrative ecological indicator rather than a direct measure of climate change. Annual reproductive success is influenced by multiple factors, but marine climate affects ocean conditions and subsequent prey availability that is critical to breeding success. As a result, changes in reproductive success provide insight into how marine ecosystems are responding to changing ocean climate.

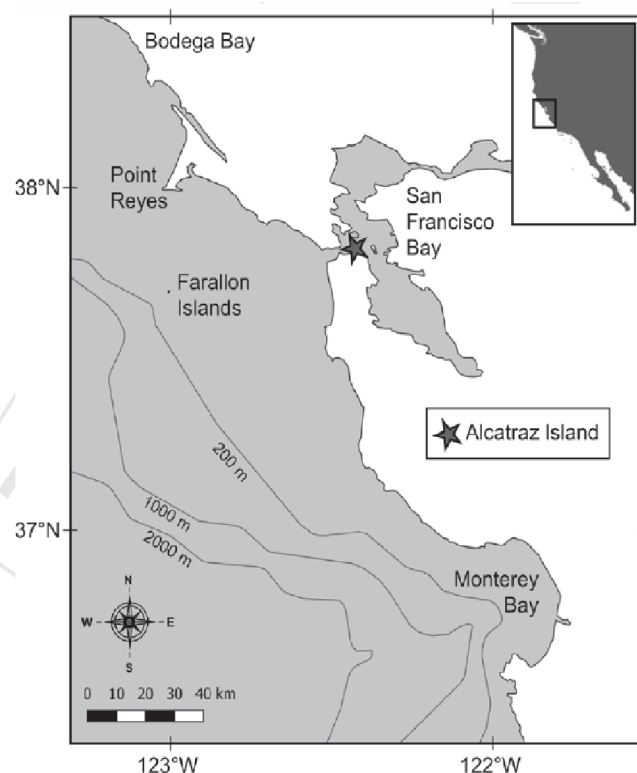
Brandt's cormorant is a resident seabird with high visibility on breeding colonies. Brandt's Cormorants can lay up to 5 eggs in a season, resulting in more potential variability in reproductive success than most seabirds that lay fewer eggs per clutch (e.g., Common Murres lay only 1). These factors contribute to the value of Brandt's



cormorant as a sensitive indicator of local food supplies, regional prey fields, and underlying marine conditions.

Brandt's cormorant reproductive success is measured as the mean number of offspring produced per breeding pair per year and has been monitored consistently since the early 1990s when Brandt's cormorants colonized Alcatraz Island near the mouth of San Francisco Bay (Figure 3.9.2). Cormorant reproductive success at Alcatraz is significantly correlated with that from other California colonies, particularly between Point Sur and Point Reyes (Saenz et al., 2006; J. Thayer/Farallon Institute unpublished analyses; data outside this central California region are limited).

Figure 3.9.2. Map of Brandt's Cormorant Breeding Colony on Alcatraz Island Near the Mouth of San Francisco Bay.



Source: Map provided by Julie Thayer, Farallon Institute (2026)

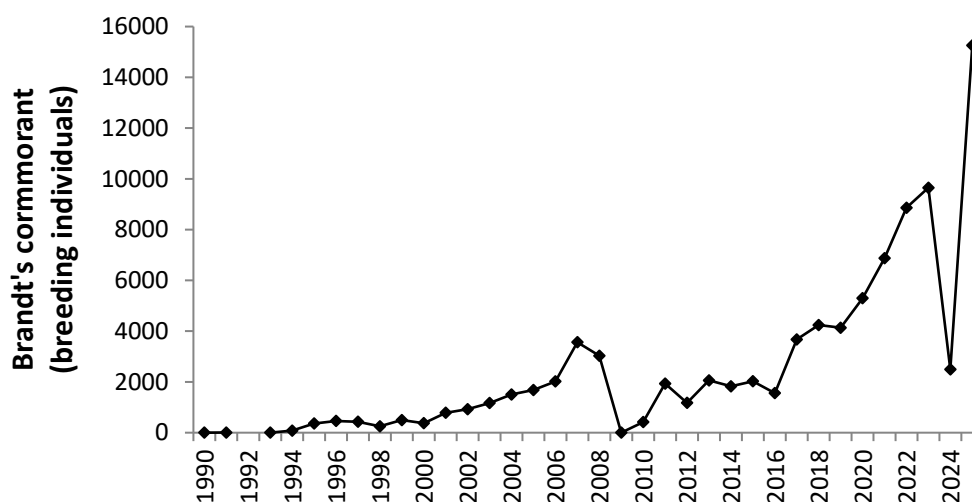
Brandt's cormorant reproductive success is high when there is an abundant variety of prey fish, as in 1995-2007 (except for during the 1998 El Niño event). Reproductive



success declined drastically in 2008 and 2009 (**Figure 3.9.1**) when the northern anchovy population crashed (MacCall et al., 2016; Thayer et al., 2017) and sanddab and other demersal fish species were also less abundant (Santora et al., 2021). Reproductive success rebounded by 2013, but inter-annual differences since 2008 have become quite large, indicating increasing variability (coefficient of variation [CV] pre 2008 = 0.13; CV post 2008 = 0.45). For example, in 2025, reproductive success was high and the breeding population was also elevated (**Figure 3.9.3**), following low reproductive success (and breeding population) in 2024. While there are limited standardized, direct measures of nearshore fish distribution and abundance (due to sampling limitations; see Technical Considerations below), some trawl data suggested that flatfish such as sanddab were above average in 2025 but below average in 2024 (Leising et al., 2025). Similarly, seabird diet data suggested that anchovy were much more available in 2025 than in 2024 or 2026 (J. Thayer/Farallon Institute unpublished data; Hunsicker et al., 2026).

Preliminary 2026 data show extremely low reproductive success with limited availability of anchovy and less diverse prey species in cormorant diet. The population of cormorants attempting breeding is also low (similar to 2024 levels; **Figure 3.9.3**), and a very large cormorant mortality event has been documented so far this year.



Figure 3.9.3. Brandt's Cormorant Breeding Population.

The above graph shows Brandt's cormorant breeding population on Alcatraz Island, near the mouth of San Francisco Bay, from 1990 to 2025. Source: Julie Thayer, Farallon Institute (2026)

Why is the indicator important?

Studies of seabirds suggest that ocean warming and other forms of marine climate change are affecting coastal food webs. Forage fish such as anchovy are one of the top food resources for predators in the California Current System, not only for seabirds (Anderson et al., 1980; Ainley et al., 1981; Sydeman et al., 2001; Warzybok et al., 2018), but also for Chinook salmon (Thayer et al., 2014), California halibut (Szoboszlai et al., 2015), and other important nearshore fishery species, as well as mammals such as humpback whales (Kieckhefer, 1992; Clapham et al., 1997), harbor seals (Gibble et al., 2011), and California sea lions (Robinson et al., 2018; Lowry et al., 2022).

Measurements of Brandt's cormorant reproductive success provides a strong signal of changes in ocean conditions, as reflected in prey availability, in the ecosystem over the period of time when the birds are reproductively active each year (approximately March through August), and may also reflect conditions preceding the breeding season (Schroeder et al., 2009; Elliott et al., 2016).

Therefore, Brandt's cormorant reproductive success can represent ecosystem conditions and prey fields encountered by a broad community of marine predators,

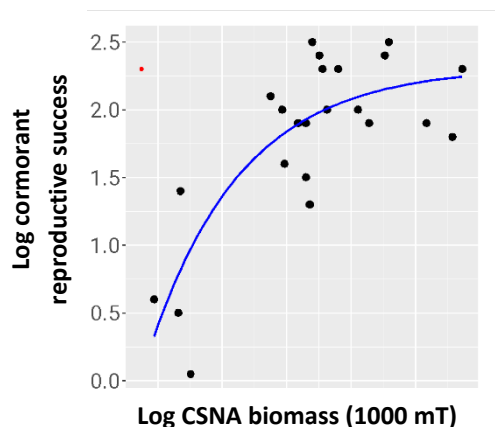


which is difficult to monitor and assess directly. Brandt's cormorant indicators are also cheaper to monitor than shipboard fisheries surveys and reveal characteristics of the nearshore foodweb where it is hard for large survey vessels to maneuver.

What factors influence this indicator?

Marine climate conditions influence prey community composition, abundance, and distribution, which in turn influence Brandt's cormorant reproductive success. Cormorant prey such as rockfishes and flatfishes tends to prefer cooler marine climate conditions (Cloern et al., 2010; Ralston et al., 2015; Schroeder et al., 2019), while anchovy may be more available in relatively warmer conditions (Ralston et al., 2015; Fleming et al., 2015; Santora et al., 2017). Brandt's cormorant reproductive success is significantly related to metrics of prey fish populations, such as abundance of anchovy (**Figure 3.9.4**).

Figure 3.9.4. Brandt's Cormorant Reproductive Success and Biomass Estimates of the Central Stock of Northern Anchovy.



The following figure shows the relationship between the log of Brandt's cormorant reproductive success, and the log of biomass estimates of the central stock of northern anchovy, measured in units of 1000 metric tons (mT). Source: CSNA, Thayer et al. (2022).



Technical considerations

Data characteristics

Data collection on Brandt's cormorants is supported by the National Park Service/Golden Gate National Recreation Area, enabling a long-term monitoring program on Alcatraz. Standardized methods have been used to record Brandt's cormorant population size and reproductive success annually since 1995.

The relationship of Brandt's cormorant reproductive success with anchovy metrics is curvilinear, meaning it is more complicated to interpret than a linear (straight) relationship, but indicates "favorable", "middling" or "poor" anchovy availability which can be helpful for management.

Strengths and limitations

Brandt's cormorant reproductive success aligns with regional biomass indices for the central stock of northern anchovy (**Figure 3.9.4**), but not as well with smaller-scale trawl indices of patchily-distributed and very fast-swimming prey such as anchovy. Nearshore information is important for understanding anchovy as prey, since anchovy populations contract inshore into bays and estuaries at low biomass levels (MacCall, 1990; Checkley et al., 2017). To better establish the spatial extent of the Alcatraz Brandt's cormorant reproductive success indicator, more work should be done comparing this data with that at other California colonies, particularly in far northern and southern California as data become available.

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Julie A. Thayer
Farallon Institute
jthayer@faralloninstitute.org



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