Point Blue Report

Population size and reproductive performance of seabirds on Southeast Farallon Island, 2021

Report to the U.S. Fish and Wildlife Service
Farallon Islands National Wildlife Refuge

May 2022

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December 2021

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Acknowledgements

We are indebted to our research assistants Olivia Boisen, Danielle Devincenzi, Katie Douglas, Rebecca Forney, Sarah Hecocks, James Lee, Amy Miles, Theresa Rizza, and Stella Solasz for their invaluable assistance in the field; along with assistance from collaborators Drs. Scott Shaffer with San Jose State University and Josh Hull with the University of California Davis. Point Blue staff biologists Mike Johns, Amanda Spears, and Pete Warzybok trained and supervised research assistants. Garrett Duncan supervised early-season data collection and Jim Tietz supervised the late-season. We are also very grateful for the continued financial and logistical support provided by the U.S. Fish and Wildlife Service, Baker Trust, Marisla Foundation, Campini Foundation, Bernice Barbour Foundation, Kimball Foundation, RHE Charitable Foundation, Volgenau Foundation, Grand Foundation, National Fish and Wildlife Foundation, Farallon Islands Foundation, Farallon Patrol, individual donors to our Farallon Program, and Point Blue colleagues on the mainland. This is Point Blue contribution no. 2411.

Suggested Citation

Spears, A., M.E. Johns, P. Warzybok. 2021. Population Size and Reproductive Performance of Seabirds on Southeast Farallon Island, 2021. Unpublished report to the U.S. Fish and Wildlife Service. Point Blue Conservation Science, Petaluma, California. Point Blue Conservation Science Contribution Number 2411.

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Cover photo credit/caption: *Research assistant Rebecca Forney with a Rhinoceros Auklet by Point Blue*

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EXECUTIVE SUMMARY

(1) Under cooperative agreement with USFWS/Farallon Islands NWR, Point Blue Conservation Science has monitored the population size and reproductive success of seabirds on Southeast Farallon Island (SEFI), California since 1968. We also collect information on oceanic conditions (sea surface temperature) and prey use (diet composition).

(2) Sea surface temperature measurements from the island suggest strong upwelling conditions started early in February and were consistent through May. The mean seasonal SST for 2021 was cooler than 2020 and the long-term mean, providing further evidence for a good upwelling season around SEFI this year. Monthly values except June and August were all below average when compared to the long-term record, especially March and April which were 1.8 and 1.1 degrees cooler, respectively.

(3) Most species showed increases in the breeding population compared to 2020. Brandt's Cormorants, Pelagic Cormorants, Common Murres, and Tufted Puffins continued a growing trend; Cassin's Auklets, California Gulls, and Pigeon Guillemots continued a stable trend over time; and Double-crested Cormorants continued a declining trend.

(4) Reproductive success for 2021 was higher for most species except Brandt's Cormorants, Cassin's Auklet, and Ashy Storm-petrel when compared to last season. Brandt's Cormorants, Cassin's Auklets, and Ashy Storm-petrels did show higher success compared to the long-term average. Pelagic Cormorants, Pigeon Guillemots, and Rhinoceros Auklets all continued to experience substantial increases in chick success when compared to 2020. Common Murre productivity was lower than average for the USP colony, but above average for the UU colony.

(5) Northern anchovy were the dominant component of chick diet for Common Murres and Rhinoceros Auklets, with juvenile rockfish representing a smaller component of the chick diet. Krill abundance appeared high until the end of June, when Cassin's Auklets made a noticeable switch to mysids. Subsequently, most of the second-brood attempts made by Cassin's Auklets in 2021 failed, reflective of a decrease in productivity from 2020.

INTRODUCTION

This report contains information on the current and long-term reproductive performance and breeding population size of seabirds on Southeast Farallon Island (SEFI; Farallon Islands National Wildlife Refuge) and West End Island (WEI), California. Eleven species are monitored annually on SEFI, including the Ashy Storm-petrel (ASSP), Double-crested Cormorant (DCCO), Brandt's Cormorant (BRAC), Pelagic Cormorant (PECO), Western Gull (WEGU), California Gull (CAGU), Common Murre (COMU), Pigeon Guillemot (PIGU), Tufted Puffin (TUPU), Rhinoceros Auklet (RHAU), and Cassin's Auklet (CAAU). In addition, small numbers of Leach's Storm-petrels (LHSP) that breed on the island are grouped with ASSP for monitoring. Non-seabird breeding species include the Canada Goose, Eurasian Collared-Dove, and Barn Owl. Peregrine Falcon and Common Raven have historically bred on SEFI but did not attempt to do so in 2021.

GENERAL METHODS

The reproductive performance of seabirds on SEFI is summarized in Table 1 and compared to previous years in Figure 1. All reproductive parameters reported in Table 1 are based on nests in which at least one egg was produced. Clutch size, brood size, hatching success, and fledging success were determined for first attempts only. Hatching success is calculated as the number of chicks hatched divided by the number of eggs laid. Fledging success is calculated as the number of chicks fledged divided by the number of chicks hatched, for clutches in which at least one egg hatched. Productivity (number of chicks fledged per pair) was determined for first attempts and for all attempts (including first attempts, relays, and second-broods). We compared productivity for all attempts to values from our long-term data for each species. We include the 80% prediction interval (dashed horizontal lines) with the long-term productivity graphs (Fig. 1a) to help highlight the extreme years (i.e., those years that fall into the upper or lower 10% of the distribution). For a detailed description of the methods used to determine reproductive success and breeding population size see Sydeman et al. (1987, 2001). Due to inaccessibility of TUPU crevices, and poor visibility of DCCO and CAGU nesting areas, detailed reproductive data were not collected for these species.

Population size and island-wide chick production was estimated for all species except ASSP and RHAU. These estimates are derived through a combination of island-wide counts (WEGU, BRAC, DCCO, TUPU), index plot counts (COMU), and burrow density (RHAU, CAAU). Catch per unit effort during mist netting seasons was used as a proxy for population trends for ASSP, as their nocturnal behavior and cryptic breeding sites makes it difficult to obtain an accurate census. Breeding population size estimates (number of individuals) are presented in Table 2 and Figure 5. All estimates include West End Island unless otherwise stated.

RESULTS & DISCUSSION BY SPECIES

Ashy Storm-petrel
ASSP (*Oceanodroma homochroa*)

Photo by Mario Balitbit

Overview
Approximately 50% of the global population of Ashy Storm-petrels breeds on the Farallones, although little is known about their true population status. Sydeman et al. (1998) reported a 35% decline in the Farallon breeding population between 1972 and 1992, while analysis of a population index derived from catch per unit effort during mist netting suggests alternating periods of growth and decline (Bradley et al. 2011; Nur et al. 2019). Nur et al. (2019) modeled storm-petrel population trend through 2012 and confirmed a strong negative relationship between the abundance of burrowing owls during the winter and survival of ashy storm-petrels. They then used that model to project forward into the future and demonstrated that the population is likely to decline by as much as 60% in 20 years if conditions remain the same (i.e., similar mouse and owl abundance). More recent analysis of CPUE data from island mist-netting through 2021 confirmed a continued apparent population decline (Nur et al. in prep). It has been proposed that further reduction in owl numbers is needed to produce an increasing population (Nur et al. 2019).

Reproduction and Timing
ASSP pairs laid eggs in 67% of the 61 followed sites (n=41) during 2021, approximately 7% lower than the occupancy rate observed last season. No sites contained a confirmed breeding pair of Leach's Storm-petrel this year. The first eggs were observed on 19 May and the median laying was 8 June. This is the same median lay date as last season (Fig. 2). Overall productivity for this species was 0.70 chicks fledged per pair (including all relay attempts). This is approximately 4% lower than last season but 4% above the long-term average productivity for this species (Fig. 1).

Breeding Numbers
We continued our long-term mark/recapture study to estimate ASSP population trends. This involved mist-netting at regular locations (Lighthouse Hill and Carp Shop) on 7 evenings between April and August. As a result, a total of 344 new Ashy Storm-petrels were banded and 62 birds that had been previously banded were recaptured, for a total of 406 birds handled. The mean standardized capture rate during 2021 netting sessions was 19.14 birds per hour (se =

2.43, n= 7; Fig. 10). This is approximately 43% lower than during 2020 and 21% lower than the mean capture rate for the previous 10 years. Our most productive netting session was on 3 July during which we captured 83 birds during a 3-hour period at the Carp Shop site. There were also 3 new Leach's Storm-petrels banded this season, and a Fork-tailed Storm-petrel recaptured on 3 July originally banded in 2017.

Brandt's Cormorant

BRAC (*Phalacrocorax penicillatus*)

Overview

The population of Brandt's cormorants on the Farallones has gone through periods of growth and decline since the early 1980's (Nur and Sydeman 1999, Fig. 5) but began to recover during the early 2000's. The BRAC breeding population expanded rapidly from 1999 to 2007, followed by a rapid decline in 2007. It is likely that some of the apparent decline was a result of birds either skipping breeding due to unfavorable conditions or moving to a different colony. A regional population trend analysis has demonstrated a shift in the population from the Farallones to more mainland colonies in response to changes in the abundance and distribution of northern anchovy (Ainley et al. 2018). After a sharp increase in 2013, the Brandt's cormorant population on the Farallones had gradually declined up until 2017. The population has since rebounded to the 2013 estimate; however, the numbers suggest they are still less than one-third of the population observed before the crash in 2007.

Reproduction and Timing

Productivity information was gathered from two sub-colonies viewed from the Corm Blind and Sea Lion Cove Blind. Mean productivity for the Corm Blind colony was 1.70 fledglings per pair. This is approximately the same as last season and 18% higher than the long-term mean productivity for this species (Fig. 1). The first eggs were observed on 5 May at the Corm Blind and 20 May at Sea Lion Cove. Median laying date for both colonies was 4 June, 18 days later than the long-term median for this species (Fig. 2). Mean clutch size was 2.62 eggs per nest and hatching success was 63%. Mean brood size was 1.74 chicks per nest, 92% of which survived to fledging age. A total of 493 chicks were banded this season with the cohort combo blue over metal on the right leg. Our banding effort this year was restricted due to a large presence of murres in the colonies later in the season than typical.

Breeding Numbers

The BRAC breeding population was censused with a ground-based survey only this year, during which 4,448 "well-built" nests were counted (Fig. 6). This number was corrected to account for the lack of a boat-based survey and multiplied by 2 to yield an overall population estimate of

10,408 breeding birds (Table 2). This estimate is 8% higher than 2020 and approximately 55% above the 10-year average (Table 2). We multiplied the total number of nests by the mean productivity to estimate an island-wide production of approximately 8,847 fledglings.

Pelagic Cormorant

PECO (*Phalacrocorax pelagicus*)

Photo by Mario Balitbit

Overview

The small population of breeding Pelagic Cormorants on the Farallones has exhibited major swings in estimated population size and breeding success throughout the long-term record. The breeding population was extremely low through 2007 but has been somewhat stable at approximately 300 birds between 2008 and present (Fig. 5). Complete reproductive failures have been frequently observed since 1976.

Reproduction and Timing

Mean productivity was 2.34 fledglings per pair. This estimate is 12% above the 2020 estimate and 139% above than the long-term mean productivity for this species (Fig. 1). Although most sites are difficult to view to confirm the timing of egg laying and clutch status, the first eggs from visible nests were observed on 30 April. Mean clutch size was 3.11 eggs per nest and hatching success was 81%. Mean brood size was 2.49 chicks per nest, 95% of which survived to fledging age.

Breeding Numbers

The PECO breeding population was censused during a ground-based survey only this year, where a total of 211 fair to well-built nests were counted (Fig. 7). This number was corrected for a lack of a boat-based survey and multiplied by 2 to yield an overall breeding population of 422 birds (Table 2). This estimate is 45% higher than 2020 and approximately 70% above the 10-year average (Table 2).

Double-crested Cormorant

DCCO (*Phalacrocorax auritus*)

The only Double-crested Cormorant colony on the island is located on Maintop on West End Island. Counts of this colony were conducted every five days (weather permitting) from atop Lighthouse Hill on SEFI using a spotting scope. A total of 21 counts were made in 2021, beginning on 26 April and ending on 5 August, when juveniles became indistinguishable from adults. A high count of 36 "well-built" nests with birds in incubating posture was first made on 31 May. Minimum population size was estimated by multiplying this high count of well-built nests by two, yielding a total of 72 breeding birds. This estimate is approximately 5% lower than 2020 and 69% below the 10-year average population for this species (Table 2). There was a high count of 46 chicks observed during the 5 August census.

Western Gull

WEGU (*Larus occidentalis*)

Photo by Mario Balitbit

Reproduction and Timing

Western gull productivity was 1.41 chicks per pair, approximately 1.5% higher than last season and 41% higher than the long-term mean productivity for this species (Fig. 1). The earliest lay date across followed plots was 28 April, with a median lay date of 13 May (Fig. 2). Mean clutch size was 2.55 eggs per nest and mean brood size was 2.08 chicks per nest, 65% of which survived to fledge. There were 595 chicks banded at the colony this season with the cohort combo blue over metal on the right leg.

Breeding Numbers

The WEGU census was conducted on 9 June. To facilitate counting, the island was sub-divided into plots that were counted individually. Breeders and non-breeding (roosting) birds were counted separately. Counts of roosting birds were not included in the population estimate. The total number of birds counted on the island was 9,452 (Fig. 8). Because not all breeding birds were present at the time of the census, we calculated a correction factor to convert counts of individuals into breeding pairs. The correction factor was derived by multiplying the number of nests in the three study plots (C, H, and K) by 2, then dividing the product by the mean number of adults present in the plots during 3 replicate counts conducted at the same time as the all-island census. We then multiplied the average correction factor (1.59) of these three plots by the total number of adults counted to arrive at our population estimate (Appendix I). Therefore, we estimated a total breeding population of 15,028 birds (Table 2). The population estimate for

WEGU is approximately 15% higher than 2020 and 1% higher than the 10-year average (Table 2). The estimated overall production of fledglings on SEFI in 2021 was 10,595.

California Gull

CAGU (*Larus californicus*)

Only a small number of CAGU were seen on nests in 2021. As in previous years, we monitored productivity of this species by counting the number of birds, nests, and young visible from the lighthouse every 5 days throughout the season. Based on these counts we were able to determine at least 19 well-built nests on May 21st resulting in a breeding population estimate of 38 individuals. This is a slight decrease from the 24 nests observed in 2020 and remains far below the peak count of 267 nests in 2008. There was a maximum count of 18 large chicks observed by 5 July. This was only the third time (but second year in a row) since the colony was established that any chicks were presumed to have fledged. Competition with Western gulls, continual disturbance from California sea lions in the two main breeding areas on the Marine Terrace, and a history of breeding failure, likely contribute to overall low breeding effort. Although numbers have increased the past two seasons, it is unlikely that the population of CAGU on SEFI will recover to past numbers and become a viable breeding colony. The peak count for total birds was 158 on 1 July, mostly of roosting individuals on the Marine Terrace.

Common Murre

COMU (*Uria aalge*)

Reproduction and Timing

Productivity is monitored annually from two followed study plots; Upper Shubrick Point (USP) from the Murre Blind and Upper Upper (UU) from the Corm Blind. A total of 219 active Common Murre breeding sites were monitored daily in the USP study plot, where productivity was 0.64 chicks fledged per pair. This is approximately 25% higher than last season but still 9% lower the long-term average of 0.70 (Fig. 1). The first egg was observed in this plot on 16 April. Median laying date for USP was 4 May, approximately 10 days earlier long-term median lay date for this colony. Eighty-two percent of eggs hatched of which 78% survived to fledging age.

The colony of Common Murres in Upper UU had much better reproductive success compared to the colony at USP. This was explained primarily by low survival rates of chicks in the USP plot that failed to reach fledgling age. Reproductive success for this colony was 0.87 chicks fledged per breeding pair. This is roughly 4% higher than the long-term mean of 0.66 for the UU colony. Ninety-three percent of the eggs hatched and 91% of chicks survived to fledge (Table 1). The first eggs were observed on 4 May, with a median lay date just a few days later than USP of 15 May. A total of 150 breeding sites were monitored in UU this season.

Photo by Mario Balitbit

Breeding Numbers

The COMU breeding population is estimated in two ways. USFWS conducts annual aerial photographic surveys and counts the number of birds present in the photos when money for analysis becomes available. Unfortunately, while the raw photos exist, counts are not completed for all seasons. So, to continue to track population trends on an annual basis, Point Blue biologists count a subsample of the population contained within 23 individual Index Plots set up around SEFI and WEI. These are counted in early June during the peak incubation period. Each plot was photographed using a DSLR and telephoto for 10 consecutive days. Total COMU within plots in photos were counted using the program ImageJ. Trends are determined by comparing the overall seasonal mean plot counts to the counts from the previous year to develop an index of population change. The mean plot counts for this season were approximately 1% higher than 2020 (Fig. 11) and 41% higher than during the last complete all-island count in 2006. If we were to apply the percent difference in the index plots to the last complete all-island count, we may estimate a population of approximately 297,822 birds (Fig. 7). This is the largest population estimate ever made for the Farallones colony and provides preliminary evidence for continued growth. Though this remains low compared to historic estimates that exceeded half a million birds, it represents tremendous recovery from previous population declines (Ainley and Lewis, 1974; Sydeman et al. 1997).

As in previous years, a correction factor was calculated using data from two of our study plots (Upper Shubrick Point and Upper Upper) to account for breeding adults not present during the census (Nur and Sydeman 2002). The correction factor was derived by multiplying the number of breeding sites in each plot by 2, and then dividing the product by the mean number of adults present on the survey dates (Appendix II), yielding a correction factor of 1.62. This method assumes that the additional birds observed in the plots are the mates of breeding individuals and not simply wanderers or non-breeders. This correction factor may be used to convert the number of birds counted during USFWS aerial surveys into an estimate of breeding pairs

It should be noted that although we believe that overall index plot trend reflects the population trend for the island, much of the change may be driven by differences in only a few of the index plots, particularly in the lower density plots on Fertilizer Flat, West End and the Islets. Other plots have remained stable or changed in opposition to the overall trend. The relative ability to detect changes in murre numbers is related to the level of saturation in a plot. Plots that are already very dense would not have the power to detect population growth because there is simply no room for more birds to breed in these areas. Conversely plots that are sparse have plenty of area for more birds to colonize but would not necessarily detect declines. Therefore, we believe that by combining the data from all plots we get a representative sample for the colony as a whole. It is also important to note that the change in methods for counting plots (images vs. averaged daily replicate counts) may change annual count numbers. We feel, however, with the increase in density of birds within some plots, using photographs will make counts more accurate going forward.

Pigeon Guillemot

PIGU (*Cepphus columba*)

Reproduction and Timing

A total of 103 sites were monitored during 2021, of which 80 were observed with at least one egg, 5 fewer active sites than in 2020. Most nest sites were located on Lighthouse Hill or at Garbage Gulch, with a few additional sites in the Habitat Sculpture, as well as in Rhinoceros Auklet and Cassin's Auklet

Photo by Olivia Boisen

nest boxes. Productivity for 2021 was 0.98 fledglings produced per pair (Table 1). This was approximately 34% higher than 2020 and 24% higher than the long-term mean productivity for this species (Fig. 1). The first eggs were observed on 27 April on the first day of site checks, so we could not confirm this lay date within 5-days. This tied the earliest lay date recorded in our long-term record from just last year (see figure below). For sites with lay dates known within 5-days, the first eggs were found on 27 April, with a median lay date of 17 May (Fig. 2). This was 1 day earlier than last season and 12 days earlier than the long-term median lay date for this species. The mean clutch size was 1.80 eggs per nest with 73% of those eggs hatching successfully. Mean brood size was 1.37 chicks per nest with 69% of those chicks surviving to fledging age. High productivity for guillemots is driven by a pair's ability to successfully fledge a second chick, which typically occurs when food availability and feeding rates are high enough to reduce sibling competition. During 2021, 68 out of 93 active sites (80%) contained a complete clutch of two eggs, from which 22 were able to fledge two chicks. A total of 81 guillemot chicks were banded on SEFI this season.

Breeding Numbers

Our estimate of the breeding population of PIGU is derived by counting adults rafting on the water around SEFI at dawn (0700 - 0830) throughout the month of April, before the birds begin to regularly attend breeding sites. Our peak count during these morning surveys was 3,010 birds on 12 April. This count was approximately 7% higher than the peak count from 2020 but 4% lower than the 10-year mean for morning surveys (Table 2 and Fig. 5). However, poor weather and viewing conditions during the peak window for raft counts may have resulted in an unrealistically low high count this year. This population estimate does not necessarily represent breeding birds because the census method does not distinguish between breeders and non-breeders. The raft counts most likely reflect the total population attending the colony during the pre-breeding period but may not represent the proportion of the population that breeds. That said, they typically rise or fall in concordance with measures of nest site occupancy, suggesting that they are a reliable index of overall trends in breeding guillemot abundance.

Tufted Puffin

TUPU (*Fratercula cirrhata*)

Breeding Numbers

The island-wide TUPU survey was conducted in two parts; the first survey takes place from late May to early June and the second survey from late July to early August. Tufted Puffin population estimates are based on the overall number of active sites observed during the two surveys. The criteria for determining if a site was occupied by a breeding pair were as follows: (1) two or more sightings of a bird entering the site or two birds seen at the site on multiple occasions, (2) one or more sightings of a bird entering the site with nesting material early in the season, or (3) one or more sightings or a bird entering a site with fish late in the season. Note that survey methodologies were changed after the 2007 season to include a more comprehensive late season survey. See the 2008 report for details. During the 2021 surveys, a total of 241 active sites were observed. Based on these observations, we estimated a breeding population of 482 birds (Table 2). This estimate is 2% higher than 2020 and 41% greater than the 10-year average population for this species. This is once again the highest population estimate ever made for TUPU on SEFI (Fig. 5).

Rhinoceros Auklet

RHAU (*Cerorhinca monocerata*)


Photo by Mario Balitbit

Reproduction and Timing

A total of 131 sites (boxes and natural crevices/burrows) were monitored in 2021, 73 of which were occupied by a breeding pair. This includes sites in CAAU nest boxes, PIGU nest boxes at Garbage Gulch, and the Habitat Sculpture. Rabbit Cave sites were not followed in 2021. Forty-four percent of nest boxes were occupied compared to 78% of camera sites. This represents slightly lower occupancy of boxes and slightly higher occupancy of camera sites compared to 2020. Productivity during 2021 was 0.65 fledglings per pair. This is approximately 25% higher than the productivity observed in 2020 and 14% higher than the long-term mean productivity for this species (Fig. 1). The first eggs were observed on 7 April, and the median laying date was 26 April. This is approximately 10 days earlier than the long-term median for this species (Fig. 2). Seventy-seven percent of the eggs successfully hatched and 82% of those chicks survived to fledge. A total of 94 adults and 25 chicks were banded this season.

Cassin's Auklet

CAAU (*Ptychoramphus aleuticus*)

Overview

The Cassin's auklet breeding population has declined considerably on Southeast Farallon Island since the early 1970's (Fig. 5) and remains at less than one-third of the population estimate made in 1972. Unfortunately, no information is available on population numbers between 1972 and 1989. This population suffered substantial mortality during the strong 1997/1998 El Niño event and reached its lowest abundance (10,458 birds) in 1998. Between 2001 and 2004, the breeding population increased rapidly, before declining again in 2005 and 2006, which coincided with reduced breeding effort and lower reproductive success. The population again rebounded to approximate peak numbers by 2014.

Reproduction and Timing

Photo by Mike Johns

Productivity of Cassin's Auklets breeding in PRBO study boxes was estimated at 0.87 chicks fledged per breeding pair (including relay attempts and second broods). This is 24% lower than 2020 but still 16% higher than the long-term average of 0.75 chicks per pair (Fig. 1). Eighty-two percent of the eggs hatched and 92% of those chicks survived to fledge. Cassin's Auklets are the only Alcid capable of successfully fledging multiple broods in the same season; a behavior only exhibited in the southern portion of their range (Ainley et al. 2011). Given the ability to double brood is driven, in part, by the most capable breeders (Johns et al. 2018) during periods of high productivity in the region (Johns et al. 2017), conditions were apparently favorable enough this season to support 19 double brooding attempts in the PRBO study. However, unlike last year, double brooding was largely unsuccessful with only 1 chick fledged from a second brood. The first egg was observed on 17 March and the median laying date for PRBO boxes was 27 March. This was approximately 10 days later than last season but still 17 days earlier than the long-term average (Fig. 2). A total of 77 adults and 337 chicks were banded this season.

We also report the productivity of all followed sites, which include roughly 400 boxes in the Known-age Study in addition to the PRBO study boxes. This is done to account for years of low breeding propensity (such as in 2005) or high propensity (such as 2010) by increasing the sample size to more accurately reflect the success of the whole island population. If all followed sites where an egg was laid were included in the analysis for this season, productivity would be 0.78 chicks per pair (n=211). This is approximately 12% lower than the all island estimate from 2020 and 10% lower than the estimate derived from PRBO boxes.

Breeding Numbers

Similar to the RHAU, CAAU is another burrow/crevice-nesting nocturnal seabird that is difficult to census. In 1991 we established twelve 10 x 10m index plots to monitor burrow density (Table 3). A complete census of nest sites on SEFI was conducted in 1989, at which time a breeding population of 29,880 birds was estimated (Carter et al. 1992). To estimate the breeding population in prior years, we applied the percent difference between the 1991 and current year counts in the index plots to the 1989 estimate. This calculation assumed that burrow counts in our index plots did not differ substantially between 1989 and 1991. Although index plot counts from 1989 are not available to test this assumption, this method provided our best estimate of population size and was employed until 2009. In September of 2009, we conducted a new all island burrow count, replicating the methods used by Carter et al. (1992). This method resulted in an estimate of only 14,512 Cassin's Auklets on SEFI and 17,640 including West End and the Islets. During 2021, we counted a total of 355 burrows/crevices in the index plots. Therefore, using the same methodology, but with the updated whole island estimate generated in 2009, we estimated a 2021 breeding population of roughly 22,897 birds ([355/225] x 14512) on Southeast Farallon Island. Total island-wide production (number of breeding pairs x mean productivity) was estimated at 9,960 fledglings on SEFI. The breeding population estimate is approximately 36% higher than in 2020 and 6% higher than the 10-year average (Table 2).

It should be noted that long-term averages were used in place of actual burrow counts in plot MT8 this year to avoid disturbance to adjacent BRAC colonies. Continued California Sea Lion incursions into historic auklet breeding habitat on the marine terrace has likely led to the reduction in burrow densities in those areas. Our breeding population estimate assumes that habitat availability and mean nest site occupancy rates are relatively stable and similar to those observed during the last full island census in 2009. The loss of some nesting habitat due to the sea lion incursion may artificially lower our estimate if those birds were able to move to a different location on the island.

Non-seabird Species

Canada Goose, Peregrine Falcons, Eurasian Collared-Dove, Common Ravens

At least seven pairs of Canada Geese were present on the island by mid-April that attempted to nest. From these nests a total of at least 10 goslings successfully fledged, with the last fledgling observed on 12 July. Although no Eurasian-collard Dove nests were found during 2021, one dove fledgling was confirmed on 25 May. From mid-March until late July, two to three Peregrine Falcons were seen regularly. Nesting activity was never confirmed, and it is unlikely any pairs nested on SEFI this season. The last confirmed nesting attempt on SEFI was in 2011. Common Ravens were not observed at the island this season and there has been no evidence of nesting since 2011.

OCEAN CONDITIONS AND SEABIRD DIET

As an indicator of local ocean conditions, sea surface temperature (SST) was measured daily from Water Temperature Point near East Landing. During 2021, the mean seasonal SST from March to August was 11.54°C (Fig. 3). This was 0.46°C cooler than the long-term mean for these months. The upwelling season started off strong and early this year, as indicated by colder than average SST values between January and May (Fig. 4). Conditions warmed slightly (0.5°C) above average in June, were exactly average in July, and warmer again during August (Fig. 4).

Chick provisioning data is collected from five species as a means of determining diet and feeding rates, and as another indicator of local ocean conditions. Diet data was recorded from standardized diet watches (COMU and PIGU), collection of dropped or regurgitated prey items (CAAU and RHAU), or by collecting regurgitated pellets of indigestible materials at the end of the season (BRAC). Once again, juvenile rockfish made an early showing in the diet of Common Murres and Pigeon Guillemots, but overall represented a relatively small percentage of the chick diet compared to previous years (Figs. 12 and 13). Rockfish comprised 16% of the diet for Common Murres, 15% for Rhinoceros Auklets, and 18% for Pigeon Guillemots. In contrast, anchovies continued to be the most significant component of seabird diet during 2021, which accounted for 71% of the diet for Common Murres and 58% of the Rhinoceros Auklet diet (Fig. 12). Flatfish, sculpins, saury, sablefish, and squid were other important components of the diet this season but in relatively small proportions. Along with juvenile rockfish, flatfish (20%) and sculpins (38%) were the primary prey targeted by Pigeon Guillemots (Fig. 12). Interestingly, anchovies also comprised a small but significant proportion of the diet late in the season. This is a species not often observed in guillemot diet. Pellet samples collected from the Brandt's cormorant colony also show a diet dominated by anchovy (Fig. 13). Cassin's Auklet chick diet was primarily composed of euphausiids (55%) and mysids (42%) during 2021.

SUMMARY

The 2021 seabird season was characterized by continued high breeding success for all species followed except Common Murres and were equal to or higher than 2020 values for all species except Cassin's Auklets (Fig. 1a, b). Likewise, all species except Common Murres surpassed the long-term mean breeding success for each species. As in the previous few seasons, murre breeding success may be suppressed at the main USP study plot due to localized predation by Western Gulls. Reproductive success estimate for the UU plot was 36% higher than at USP and was higher than the long-term mean for this colony. This suggests that the estimate for USP may not be representative of the entire colony this season. Cassin's Auklet reproductive success was considerably lower than during 2020 but remained well above the long-term mean. Much of this reduction is a result of low fledging success for second broods in 2021. When comparing the success of first/only broods across years, 2021 productivity was only slightly lower than during 2020. Pelagic Cormorants also continued to have very high reproductive success in 2021 and continue a "boom and bust" pattern of high success and complete failures. California Gulls likely fledged as many as 18 chicks this year, the highest number of chicks produced in several years. However, continued overall poor breeding effort may reflect intrinsic

or ecological factors beyond environmental condition. For example, the California Gull colony has been declining for the last several years and has been largely unsuccessful since they colonized the island in 2008, while populations in and around San Francisco Bay continue to thrive.

Annual variability in reproductive effort generally tracks conditions leading up to the breeding season, where improved foraging conditions and adequate prey abundance can lead to lower winter mortality, increased colony attendance, and a greater occurrence of breeding birds. Increases in the estimated population size of piscivorous Brandt's Cormorants, Common Murres, Pelagic Cormorants, Tufted Puffins, and Pigeon Guillemots suggest fish stocks were in ample supply near the island this season. We expected that juvenile rockfish would have played a more important role in chick provisioning this year given strong upwelling conditions, however, it seemed the most abundant prey available in 2021 were once again anchovy. High breeding effort and slightly increased burrow densities of Cassin's Auklets this year also suggest a strong showing of krill around the island.

As a more direct measure of environmental condition and indirect measure of marine productivity, local SST measured from the island was lower in 2021 when compared to the long-term records for the summer upwelling season. Typically, cooler SSTs are correlated with greater ocean productivity in the California Current System resulting from stronger upwelling along the coast, whereas warmer waters are generally nutrient poor and less productive (Barber et al. 1985). As may be expected, the favorable oceanic conditions this year resulted in high breeding success for most species. Reproductive timing was also earlier than our long-term record for many species this year, particularly for Cassin's Auklets and Pigeon Guillemots with record breaking early lay dates. This provides further evidence that seabirds were cueing in on and responding to improved foraging conditions leading up to the breeding season. However, this seemed to change later in the season with warmer, less productive conditions leading to largely unsuccessful second broods for Cassin's auklets.

Finally, diet information collected from provisioning parents provided a measure of prey availability during the breeding season and a metric for the capacity of the local environment to support certain fish species. Juvenile rockfish have played an important role for seabirds at the Farallones in recent years, where a high proportion of rockfish in the diet of chicks has typically correlated with high breeding success. During 2021, juvenile rockfish represented less than 20% of the chick diet for the Rhinoceros Auklet, Common Murre, and Pigeon Guillemot, indicating that it did not play a large role in ecosystem function this year. Seabirds instead relied more heavily on anchovy, flatfishes, and other alternate prey to make up for an apparent absence of rockfish around SEFI. Seabirds are frequently able to successfully switch prey in response to availability, but it often comes at the cost of longer foraging trips and more energy expended by adults when provisioning dependent offspring (Warzybok et al. 2018). Historically, anchovies were the most important component of chick feedings for murres and auklets between 2002 and 2008 and were also a major component of Brandt's cormorant diet during years of high reproductive success (Fig. 12). This important prey had all but disappeared from the diet of Farallon seabirds between 2009 and 2014 but has returned as the major diet component during the last four years, surpassing juvenile rockfishes the last two years.

RESEARCH AND MANAGEMENT RECOMMENDATIONS

In addition to the continuation of research efforts, we recommend the following actions (listed in order of priority) for enhancing the protection, conservation, and management of seabirds on SEFI:

(1) To further our understanding of the foraging ecology of SEFI seabirds, we recommend continuation and expansion of novel monitoring techniques including deployment of time-depth recorders, GLS and GPS tags (or similar devices) on multiple species of marine birds. This work has begun for CAAU, RHAU, PIGU, and now COMU and should be considered for BRAC and, if possible, ASSP. Expanding the use of instrumentation to more species will allow us to inform management challenges from a community (instead of individual species) approach and to understand Farallon population trends (e.g. how food is affecting Cassin's Auklets and Brandt's Cormorants) in support of management decisions. Novel technology will also allow us to examine marine habitat use and foraging behavior, which is critical to the evaluation of current and potential new marine protected areas, both locally around the Farallon Islands NWR and in their overwintering habitat.

(2) Relatively little is known about the activities of Farallon seabirds during the non-breeding season. We recommend the development of new research initiatives to examine the diet, energy expenditure, behavior, habitat use and environmental interactions of seabirds during the portion of their annual cycle when they are away from the colony to develop a more complete understanding of the factors influencing the Farallon populations. The first step in this direction has been taken with studies of winter habitat use by Cassin's auklets, Rhinoceros Auklets, and Pigeon Guillemots over the last few years. These data are currently being analyzed and are showing some interesting patterns. We recommend increased efforts on these and other species as well as future studies to help examine how conditions at their wintering grounds impact populations and reproductive success for the Farallon colony.

(3) Tufted Puffins populations are in decline along much of the west coast of the U.S., and it is becoming increasingly important to develop an understanding of the factors that influence

their breeding success. We recommend exploring possible methods to monitor the productivity of TUPU either using burrow cams or nest boxes. This would require locating suitable sites that are safe to access yet result in minimal disturbance to the SEFI ecosystem.

(4) We recommend thorough evaluation of new auklet “climate-smart” nest modules to determine how well they perform in buffering auklets against the impacts of climate change. As of 2022, 40 of the new style boxes have been deployed and more are being constructed. However, prior to large scale replacement of existing boxes and/or expansion to other species we must be able to determine if they are achieving the desired effect.

(5) Begin implementing the use of drones to create a timeseries of imagery. These high-resolution image tiles can be leveraged to conduct a more accurate census of surface nesting species like Western Gulls and Brandt’s Cormorants, accurately count breeding pinnipeds and map haul out expansion of California Sea Lions, and track changes in vegetation and habitat that might impact breeding success of seabirds. Additionally, emerging technologies such as heat signatures from infrared devices mounted to drones might be applicable for getting at island-wide burrowing occupancy rates of auklets. These technologies are being deployed successfully at other seabird colonies and should be strongly considered for future monitoring of wildlife resources on the Refuge.

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TABLES & FIGURES

Table 1. Mean (± SD) productivity of eight species of seabirds at Southeast Farallon Island, California, 2021. Sample sizes in parentheses. All values based on first attempts only unless stated otherwise.

Species	Clutch Size (no. eggs laid)	Brood Size (no. chicks hatched)	Chicks Fledged/Pair	Chicks Fledged/Pair (includes relays)	Hatching Success	Fledging Success
BRCO	2.62 ± 0.71 *(76)*	1.74 ± 1.12 *(76)*	1.59 ± 1.14 *(75)*	1.70 ± 1.09 *(74)*	0.63 ± 0.38 *(76)*	0.92 ± 0.25 *(59)*
PECO	3.11 ± 0.78 *(9)*	2.49 ± 0.76 *(51)*	2.34 ± 0.72 *(50)*	2.34 ± 0.72 *(50)*	0.81 ± 0.34 *(9)*	0.95 ± 0.13 *(49)*
WEGU	2.55 ± 0.61 *(161)*	2.08 ± 0.92 *(161)*	1.41 ± 0.99 *(161)*	1.41 ± 0.98 *(161)*	0.81 ± 0.31 *(161)*	0.65 ± 0.35 *(149)*
COMU* USP	1.00 (219)	0.82 ± 0.38 (219)	0.64 ± 0.48 (219)	0.64 ± 0.48 (219)	0.82 ± 0.38 (219)	0.78 ± 0.41 (180)
COMU* UU	1.00 (149)	0.93 ± 0.25 (149)	0.85 ± 0.36 (149)	0.87 ± 0.34 (150)	0.93 ± 0.25 (149)	0.91 ± 0.28 (139)
PIGU	1.80 ± 0.40 *(80)*	1.37 ± 0.83 *(79)*	0.95 ± 0.78 *(80)*	0.98 ± 0.76 *(80)*	0.73 ± 0.42 *(79)*	0.69 ± 0.36 *(61)*
RHAU*	1.00 *(73)*	0.77 ± 0.43 *(73)*	0.63 ± 0.49 *(72)*	0.65 ± 0.48 *(72)*	0.77 ± 0.43 (73)	0.82 ± 0.39 *(55)*
CAAU* PRBO	1.00 (45)	0.82 ± 0.39 (45)	0.76 ± 0.43 (45)	0.87 ± 0.40 (45)	0.82 ± 0.39 (45)	0.92 ± 0.28 (37)
CAAU* ALL	1.00 (211)	0.82 ± 0.38 (211)	0.73 ± 0.45 (211)	0.78 ± 0.44 (211)	0.82 ± 0.38 (211)	0.88 ± 0.33 (174)
ASSP*	1.00 *(40)*	0.90 ± 0.30 *(40)*	0.65 ± 0.48 *(40)*	0.70 ± 0.46 (40)	0.90 ± 0.30 (40)	0.72 ± 0.45 (36)

* COMU, RHAU, CAAU and ASSP lay only one egg per clutch

** PECO sites are difficult to see into. Numbers are based on the maximum number of eggs or chicks observed

Note: CAAU "PRBO" productivity presented here is based on the PRBO study boxes only, and is the same as the long-term timeseries. CAAU "ALL" is the mean productivity observed across all monitored sites including PRBO, Known-Age and Habitat Sculpture boxes.

Table 2. Breeding population size estimates of seabird species on the South Farallon Islands, 2011-2021. Estimates include Southeast and West End Islands unless otherwise noted.

Species	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2011-2020 average
DCCO	72	76	198	214	226	232	104	364	364	220	360	236
BRCO	10,408[b]	9,658	7,240	7,246	4,582[b]	4,824	5,742	6,566[b]	7,412	3,450[b]	4,916	6,720
PECO	422[b]	292	162	160	312[b]	308	234	440[b]	372	298[b]	206	248
WEGU	15,028	13,013	13,820	13,769	13,245	10,044	11,164	18,686	21,148	15,846	17,406	14,814
CAGU	38	48	18	9	10	30	184	514	522	70	208	161
PIGU [d]	3,010	2,812	2,351	3,500	2,044	2,009	3,157	4,459	3,880	3,645	3,461	3,132
TUPU [c]	482	470	374	406	396	376	326	288	286	244	246	341
CAAU [a]	22,897	16,834	16,511	26,573	21,026	20,059	25,606	28,444	22,574	19,607	17,866	21,510

[a] Estimate for Southeast Farallon Island only. Estimate from 2009 to present based on 2009 whole island burrow/crevice count. Prior to 2009 all estimates were based on 1989 survey (see text)

[b] No boat census conducted. Total estimate generated using correction factor for areas not surveyed.

[c] TUPU population estimates were recalculated in 2008 to correct for unequal survey effort in prior seasons (see text)

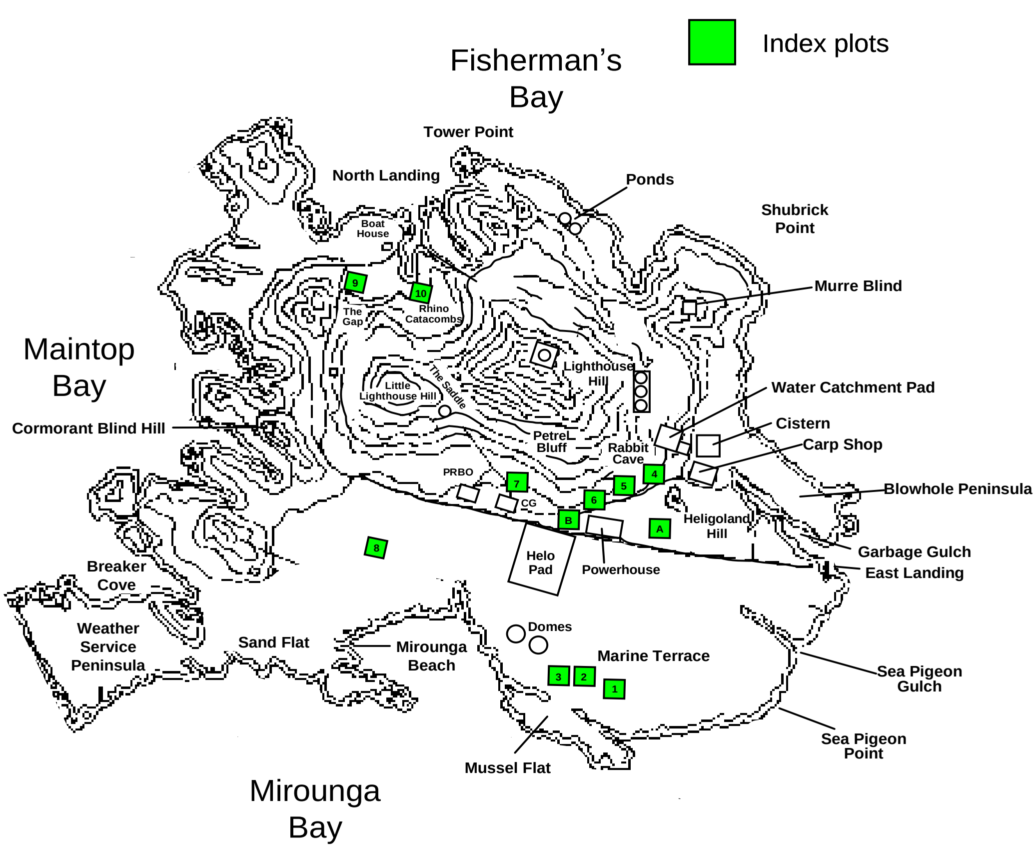
[d] Estimates derived from morning raft counts. Evening counts used prior to 2002 and are considerably lower (see text).

Table 3. Cassin's Auklet burrow counts from 12 (10m x 10m) index plots on Southeast Farallon Island for 2021. The previous 10 seasons as well as the initial plot counts from 1991 and 2009 are shown for comparison.

Year	MT1	MT2	MT3	S4	S5	S6	S7	MT8	R9	N10	EA	EB	Total
1991	18	9	12	43	42	22	31	20	80	49	14	27	367
2009	13	11	27	11	5	5	8	8	81	41	2	13	225
2011	17	14	27	12	9	4	17	9	90	54	1	23	277
2012	31	25	33	15	11	4	14	-	91	48	6	26	304
2013	31	31	26	17	15	4	16	11	98	60	7	34	350
2014	39	41	38	15	18	7	24	28	101	78	8	44	441
2015	39	25	23	29	27	17	21	26	90	54	14	32	397
2016	4	13	27	25	23	5	24	7	84	60	9	30	311
2017	10	14	37	24	27	8	4	20	83	47	16	36	326
2018	4	9	25	29	33	5	23	25	109	87	21	42	412
2019	6	9	9	12	14	3	14	12	72	58	17	30	256
2020	6	8	13	16	14	6	19	15	86	27	17	34	261
2021	8	16	11	21	16	7	16	17	100	85	16	42	355
2011-2020 average	19	19	26	19	19	6	18	17	90	57	12	33	334

Note: Plot MT8 not counted in 2012 due to high pinniped numbers and cormorants breeding in the area. Low burrow counts in plots MT1,2,3 and 8 in 2016, 2018, and 2019 are likely due to extremely high numbers of California Sea Lions hauling out and crushing burrows in those areas. The long-term averages for MT8 were used in place of counts in 2020 and 2021 to avoid cormorant disturbance.

Cassin's Auklet Index Plots



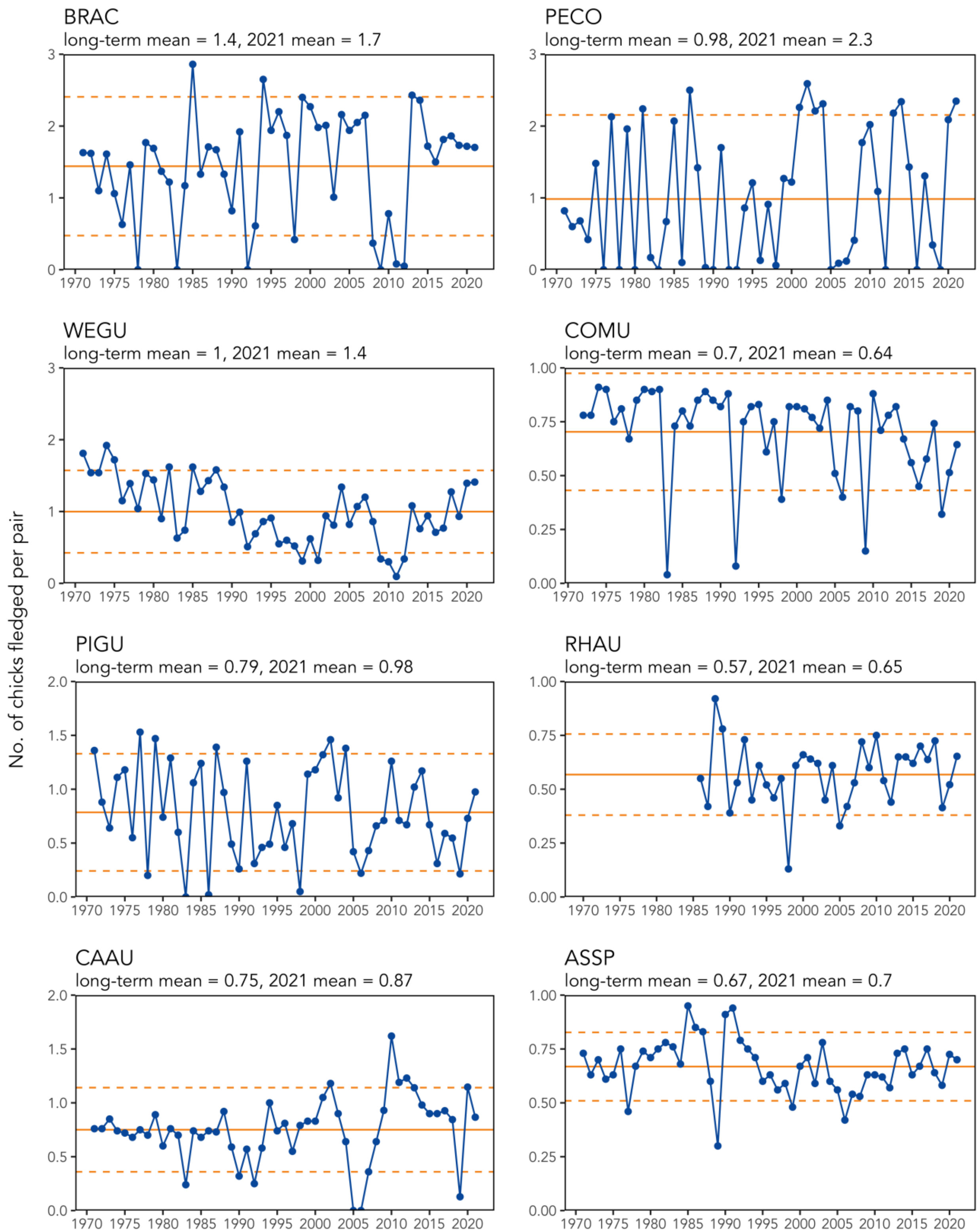


Figure 1a. Productivity of 8 seabird species on Southeast Farallon Island, 1971 – 2021, measured as the number of chicks fledged per breeding pair (includes first attempts, relays, and second broods). The solid orange line indicates mean productivity from all attempts between 1971 and 2020. Dashed orange lines represent 80% prediction intervals around the long-term mean.

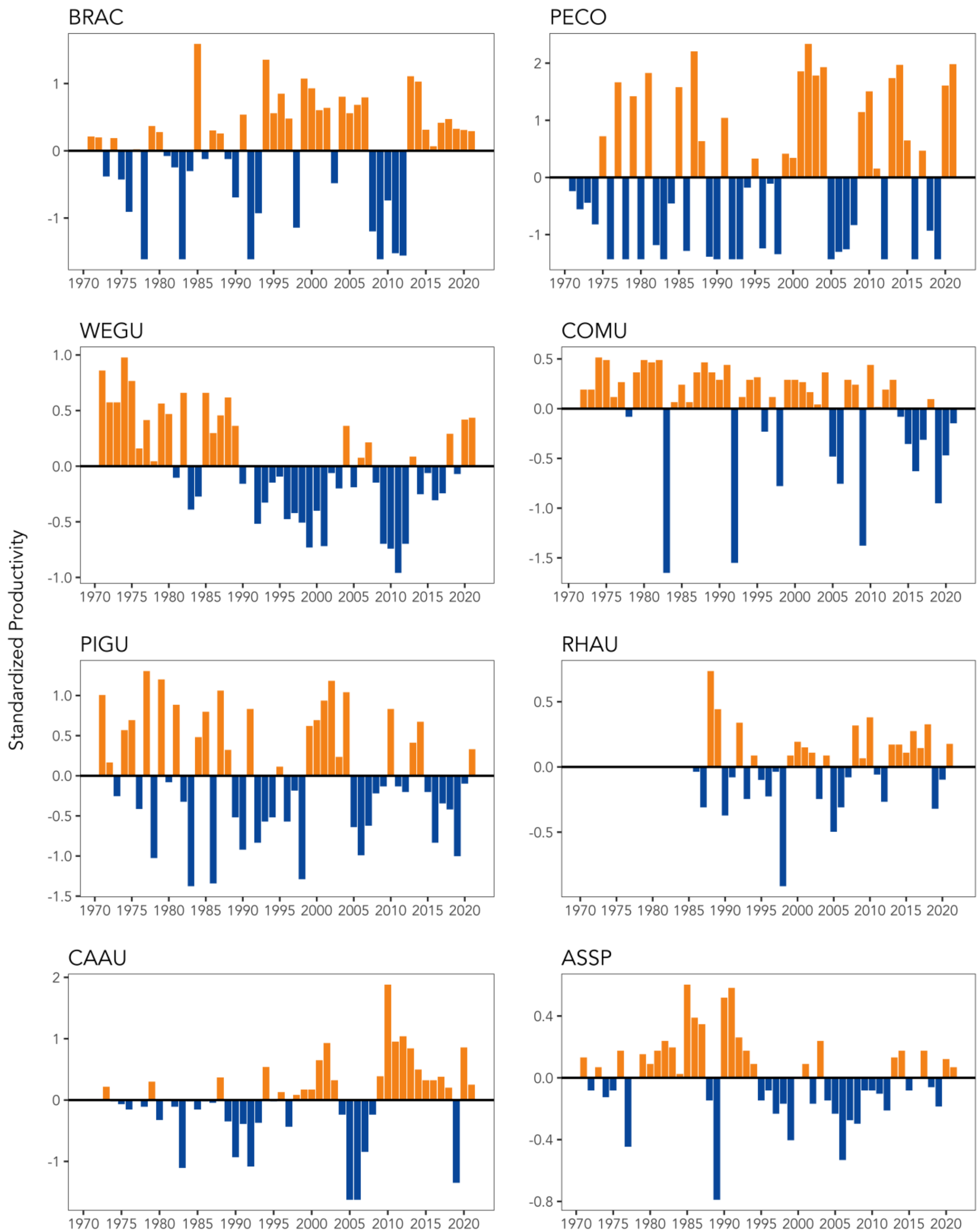


Figure 1b. Standardized productivity anomalies (annual productivity – long-term mean) for 8 seabird species on Southeast Farallon Island, 1971 – 201.

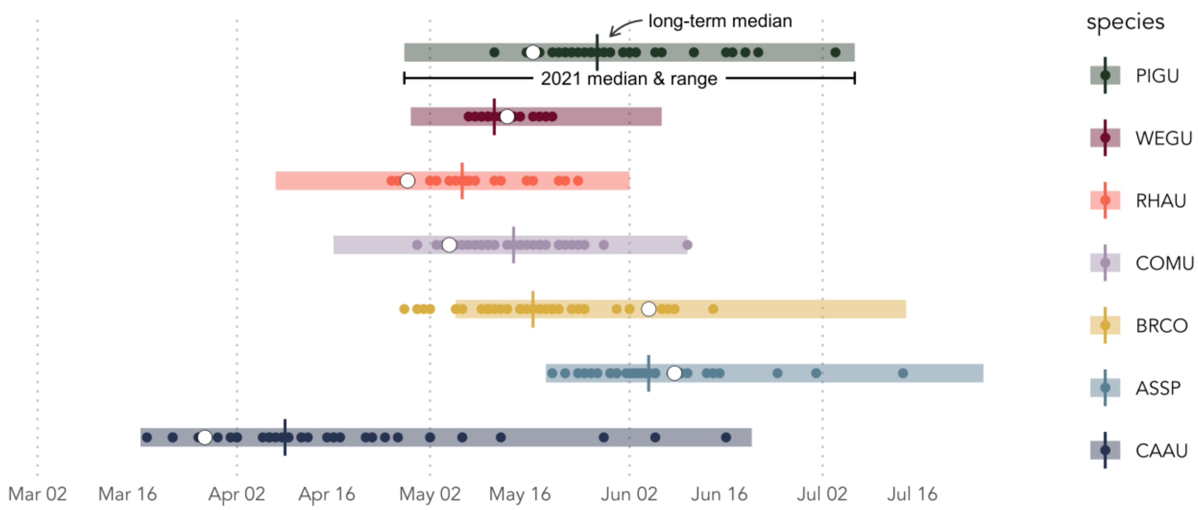


Figure 2. Phenology for 7 seabird species on Southeast Farallon Island colored by species, for the first egg in first attempts only. Filled circles represent long-term annual median lay dates, vertical lines the median across all previous years, the shaded bar the range (min and max) of lay dates during 2021, and the open circle the 2021 median lay date.

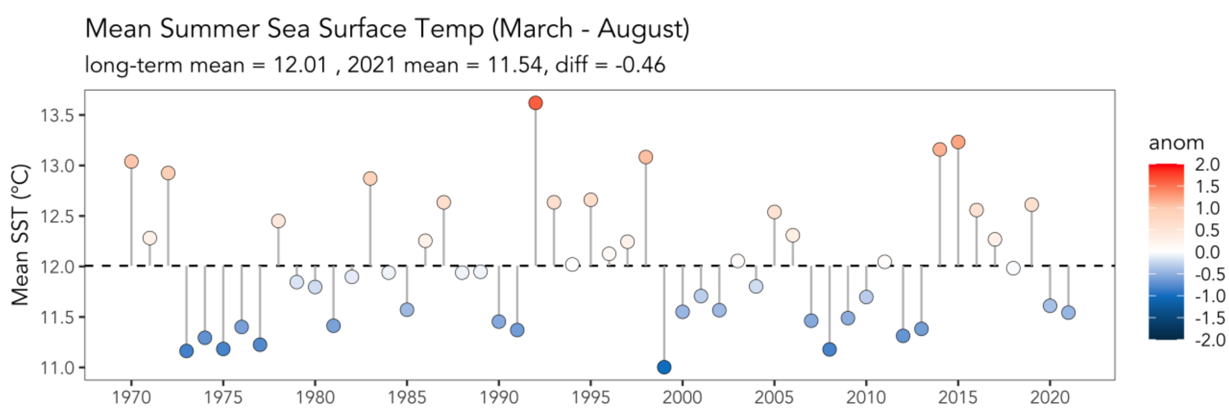


Figure 3. Annual mean summer (March – August) sea surface temperature (SST) for Southeast Farallon Island, 1968 – 2021. Dashed line represents the long-term mean for the summer season, and circles the annual mean SST colored by the difference from the long-term mean (anomaly). SST was measured daily from Water Sample Point, near East Landing. Lighter shades represent warmer temperatures, darker shades cooler temperatures.

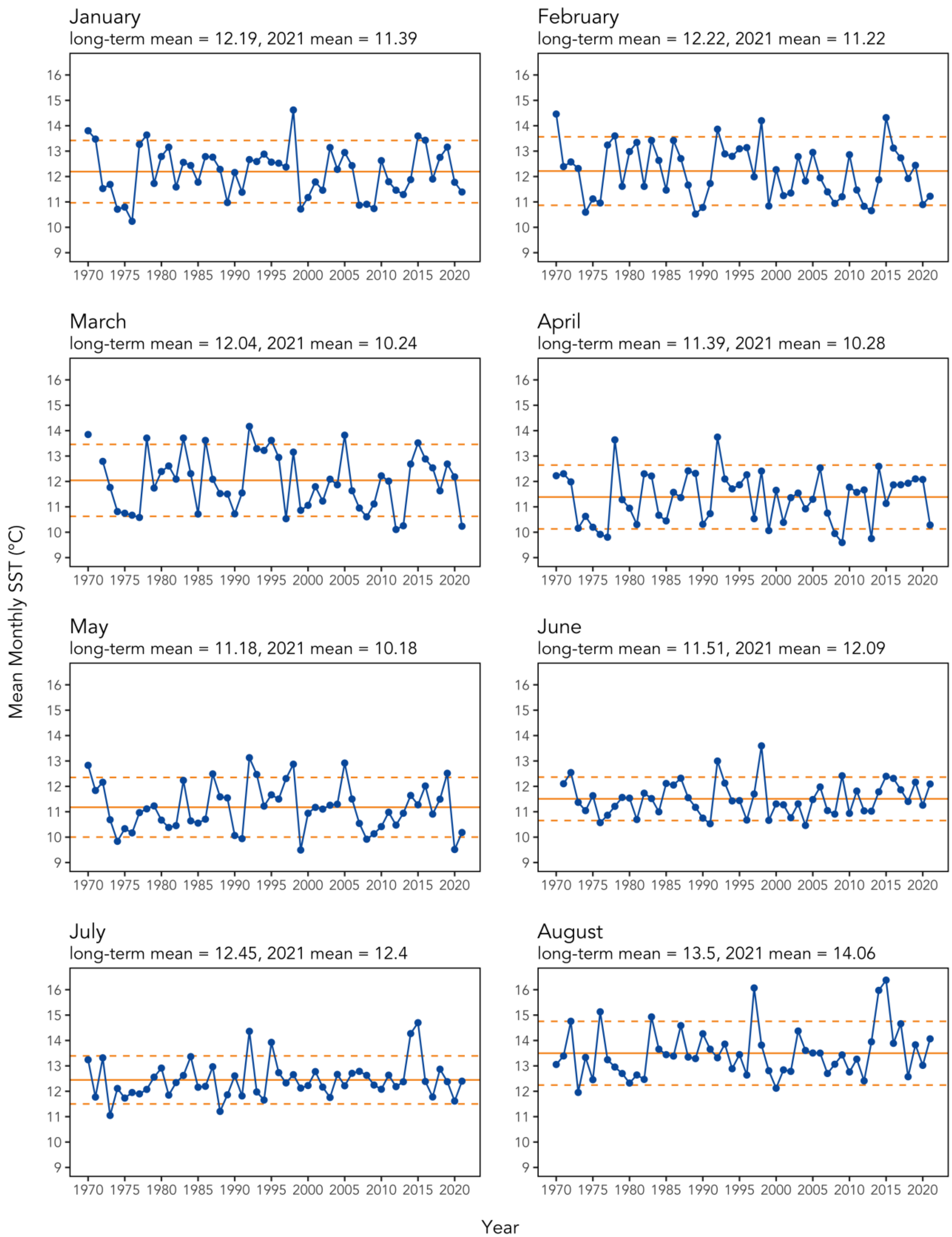


Figure 4a. Monthly mean sea surface temperature (SST) at Southeast Farallon Island, 1971 – 2021. SST was measured daily from Water Sample Point, near East Landing. The solid orange line indicates the long-term mean, and dashed orange line the 80% prediction interval for the long-term mean.

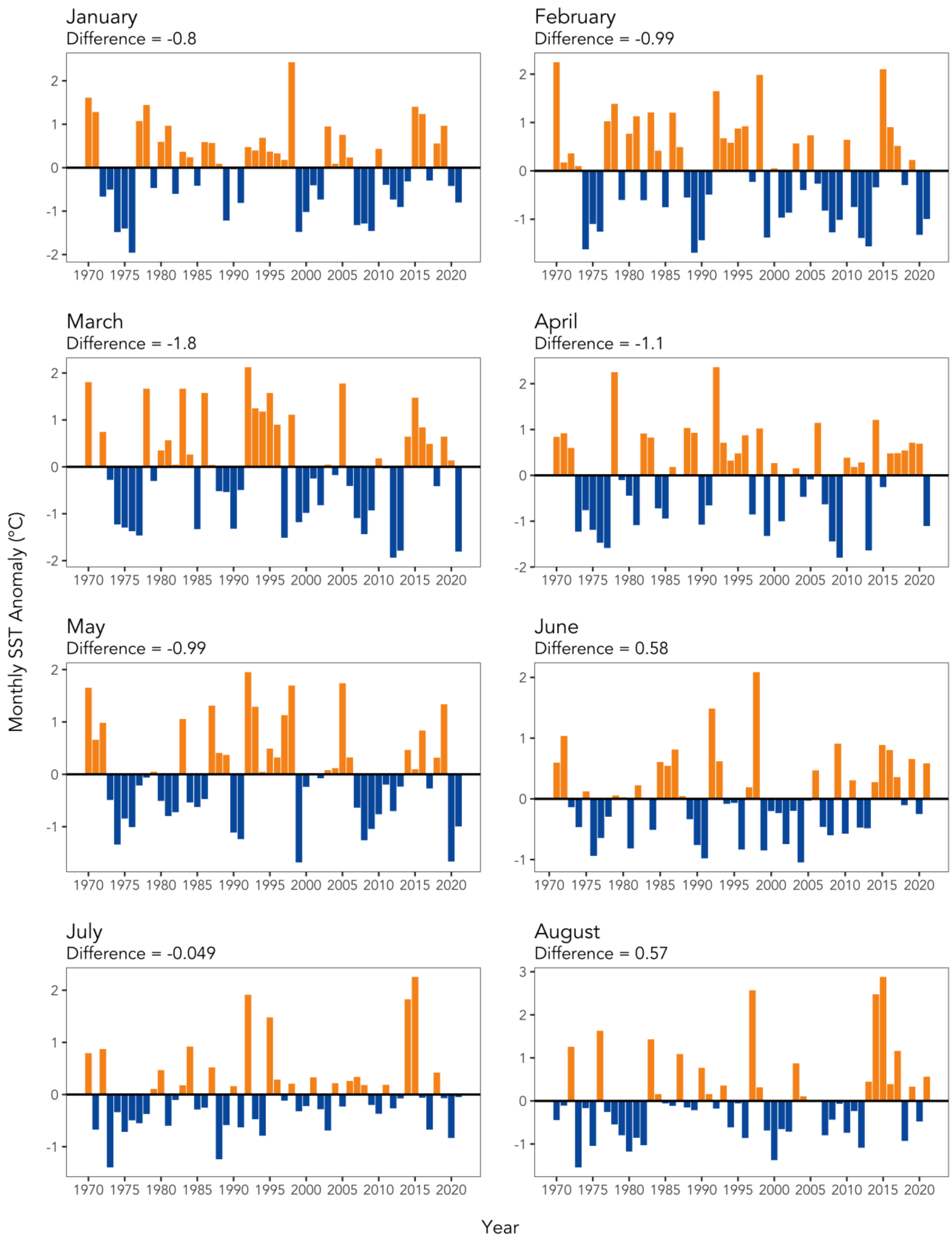


Figure 4b. Standardized monthly sea surface temperature (SST) anomalies (annual mean – long-term mean) for Southeast Farallon Island from 1971 – 2021.

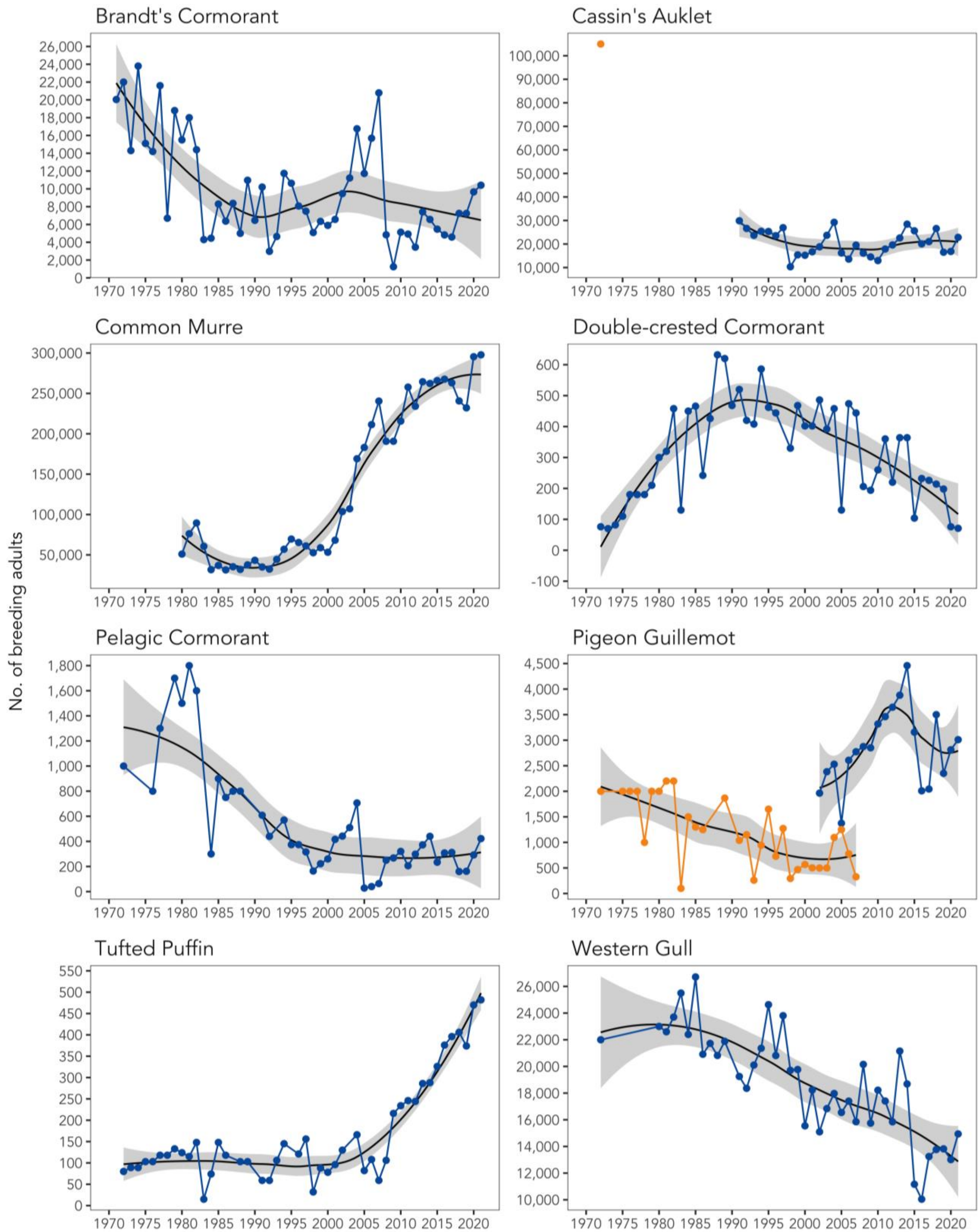


Figure 5. Population trends for 8 seabird species on Southeast Farallon Island, 1971 – 2021, determined by counts of individuals or nests in all visible areas on SEFI and West End. Loess trend lines and shaded confidence intervals illustrate long-term trend. For PIGU, blue points correspond to evening raft counts and orange dots to morning raft counts. Since 2006, COMU estimates are based on changes in index plots (see Fig. 11 and text).

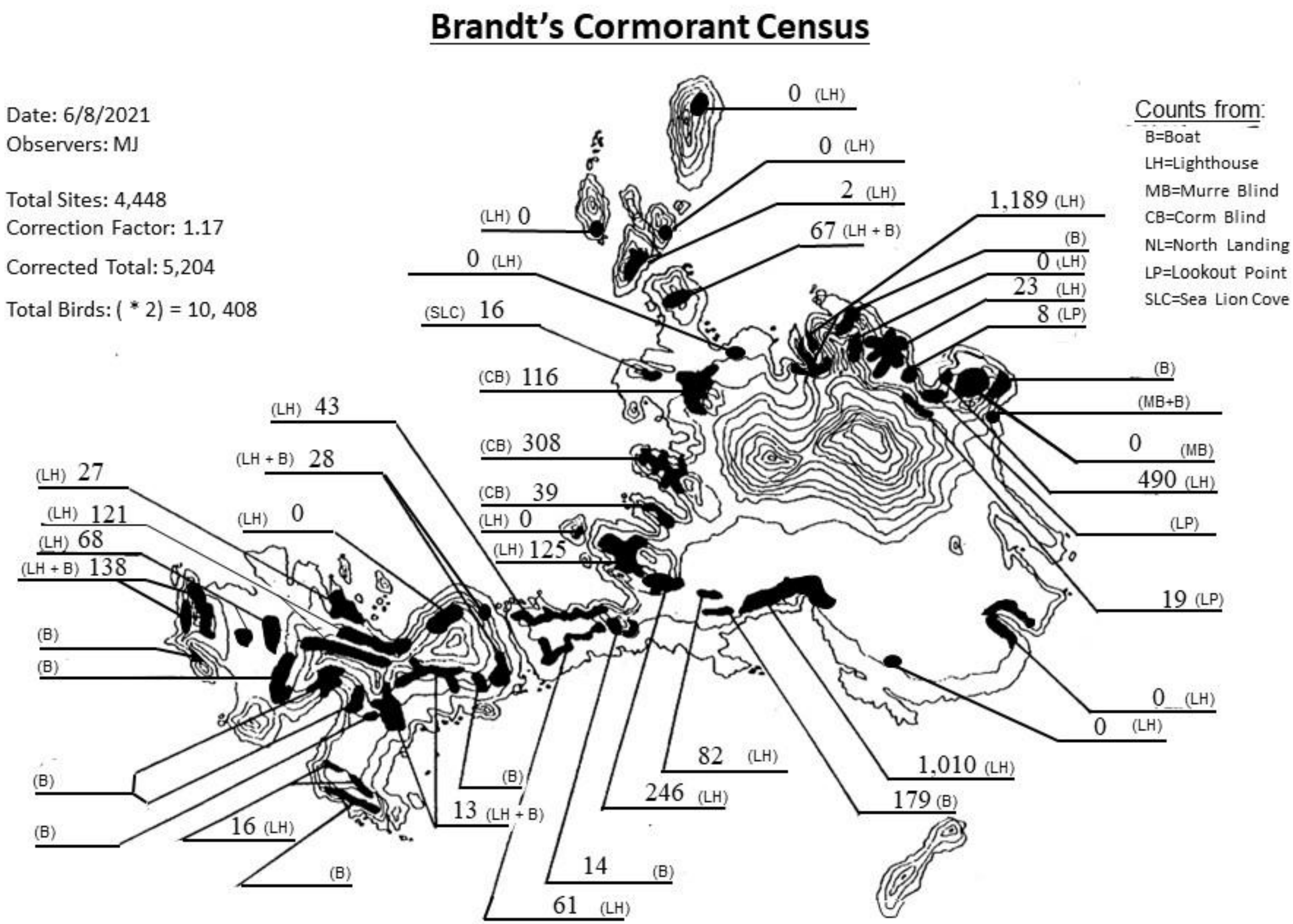


Figure 6: Counts of Brandt's cormorants on the South Farallon Islands during the 2021 census. There was no boat census conducted during 2021.

Pelagic Cormorant Census

Date: 6/8/2021

Observers: MJ

Total Sites: 165

Correction Factor: 1.28

Corrected Total: 211

Total Birds: (corrected total * 2) = 422

Counts from:

B=Boat
LH=Lighthouse
MB=Murre Blind
CB=Corm Blind
NL=North Landing
LP=Lookout Point
HS=USFWS House
MBT=Murre Blind Trail
SPG=Sea Pigeon Gulch

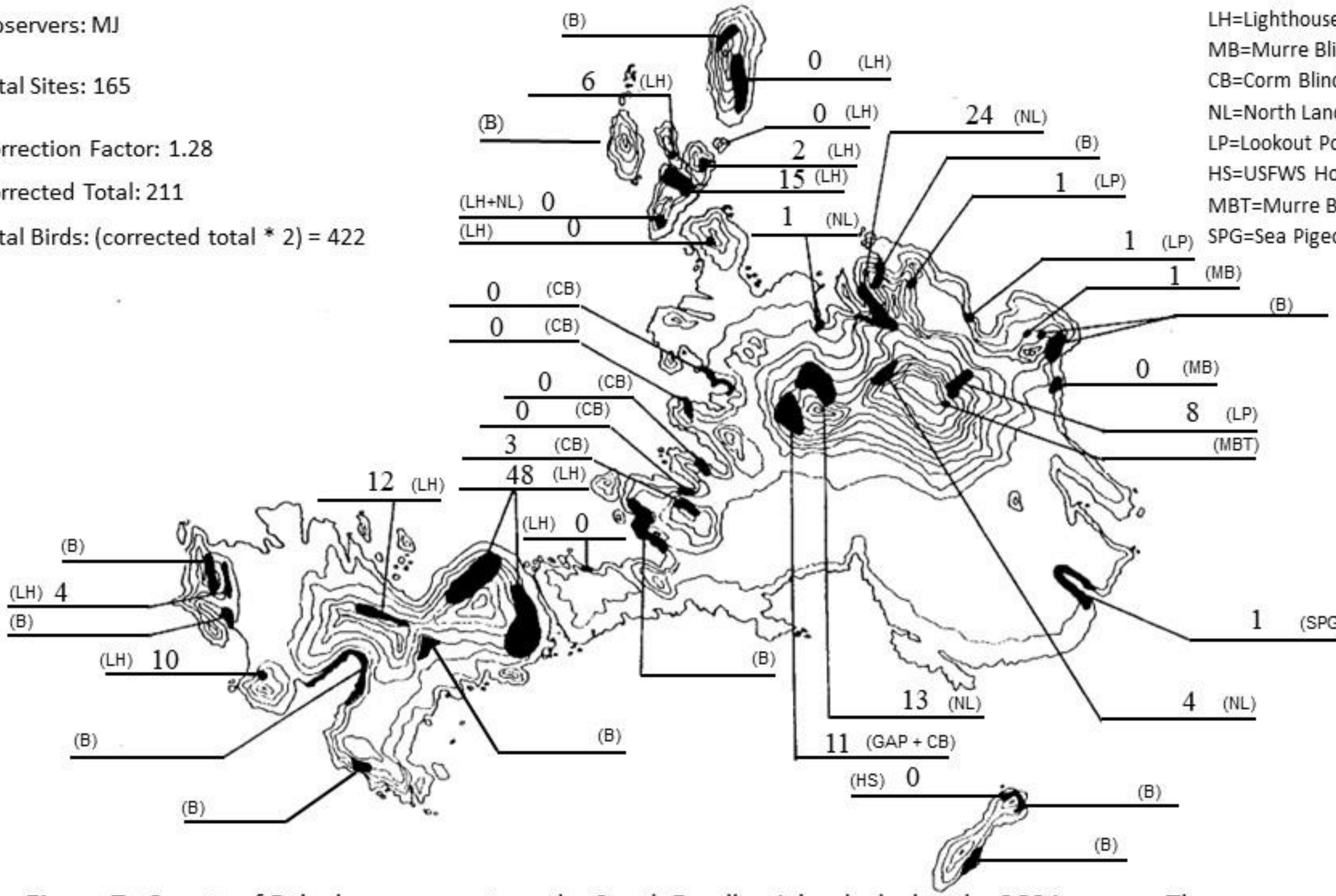


Figure 7: Counts of Pelagic cormorants on the South Farallon Islands during the 2021 census. There was no boat census conducted during 2021.

Western Gull Census

Date: 6/9/2021

Observers: MJ, AS

Total Counted

Breed: 9,452

Roost: 447

Correction Factor: 1.59

Corrected Total: 15,028

All counts done from Lighthouse or ground. Darkened areas cannot be seen from either LHH or ground and were not included in counts.

(#) =Roosting birds

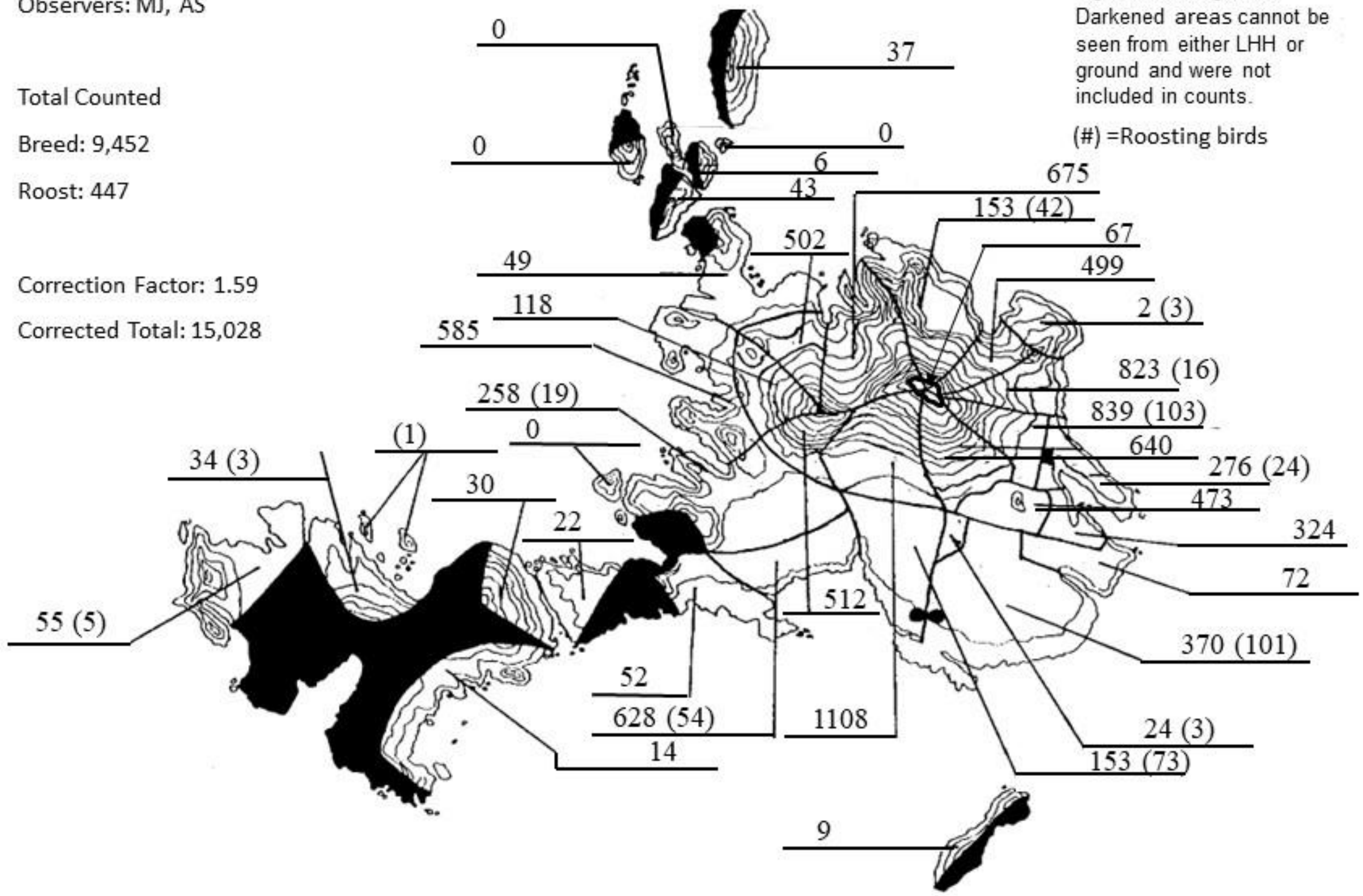


Figure 8: Counts of Western Gulls on the South Farallon Islands during the 2021 census.

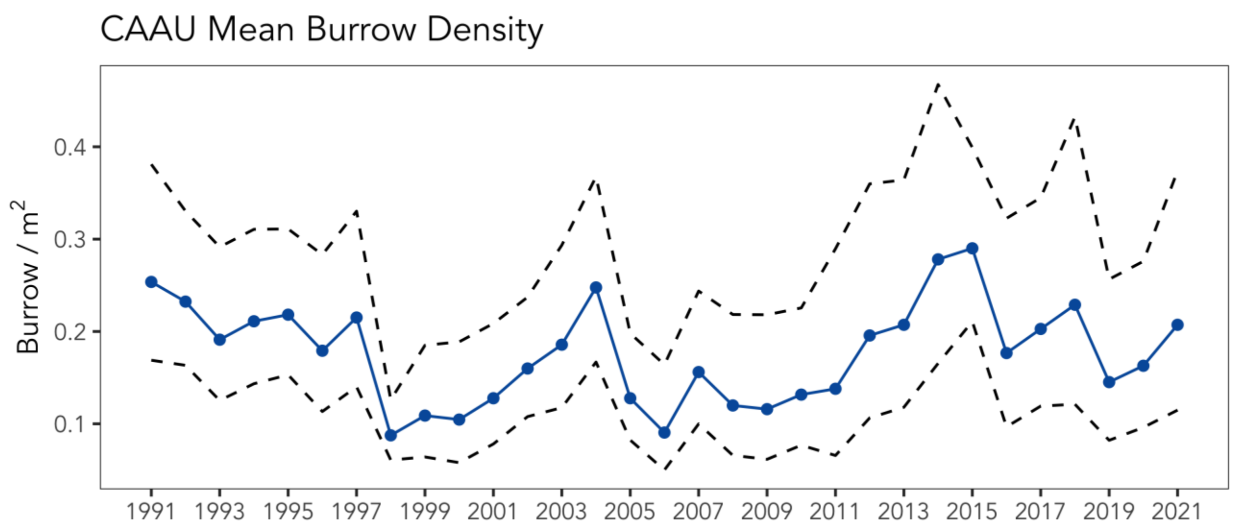


Figure 9. Geometric mean burrow/crevice density in 12 Cassin's Auklet index plots from 1991 to 2021. The blue line represents annual mean values. The dashed line represents the upper and lower 95% confidence intervals.

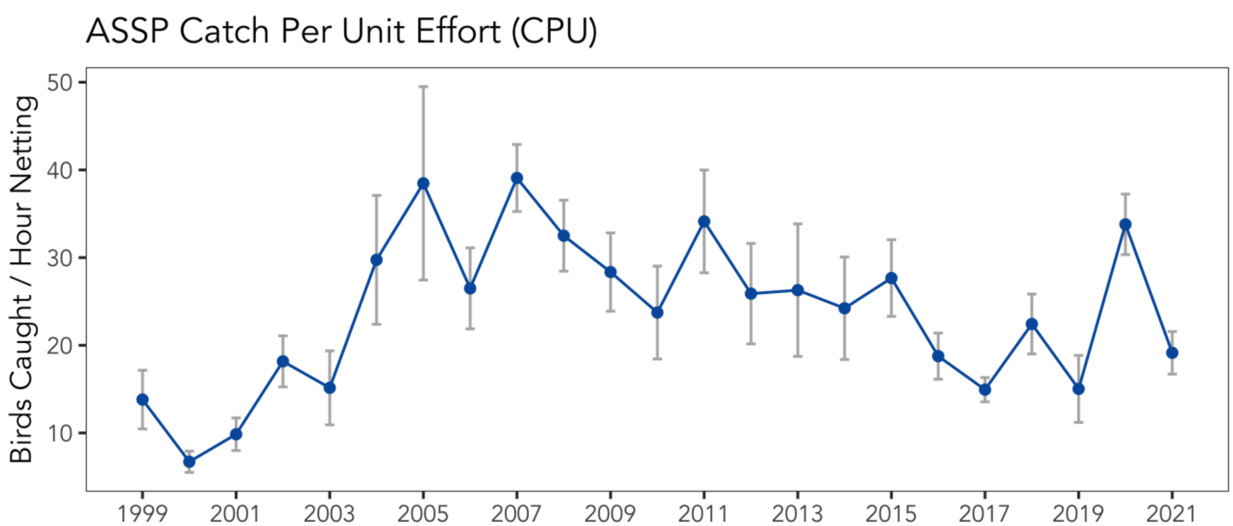


Figure 10. Mean number of Storm-petrels caught per hour of netting effort on SEFI from 1999 to 2021. Error bars represent the standard error for the mean calculated from all capture sessions in a given season.

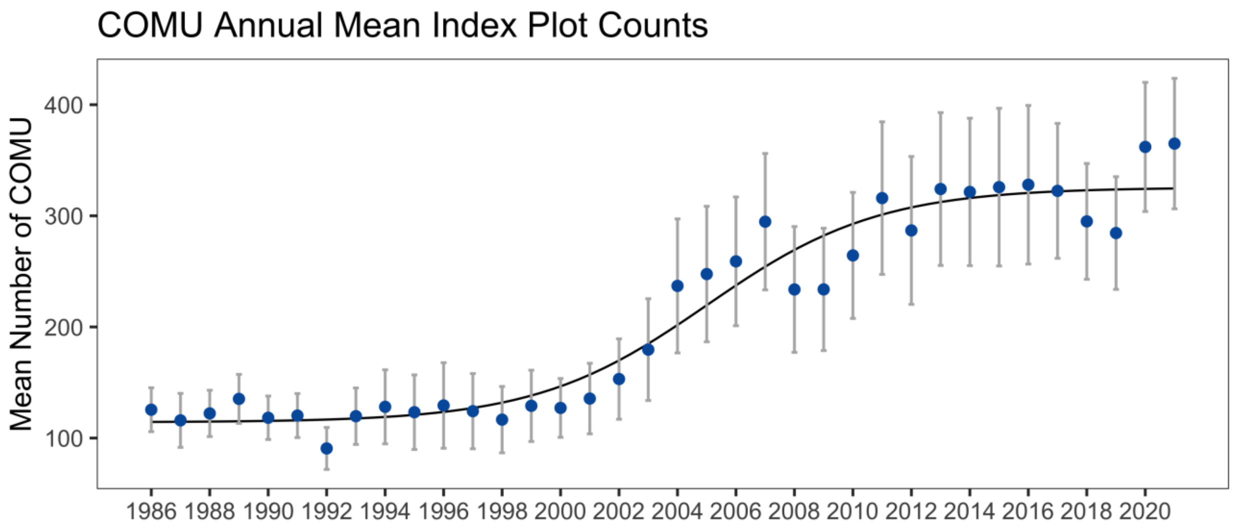


Figure 11. Mean annaul counts for Common Murre index plots from 1986 to 2021. Error bars represent the standard error for the mean calculated from all capture sessions in each season. Solid line shows a fitted logistic growth function.

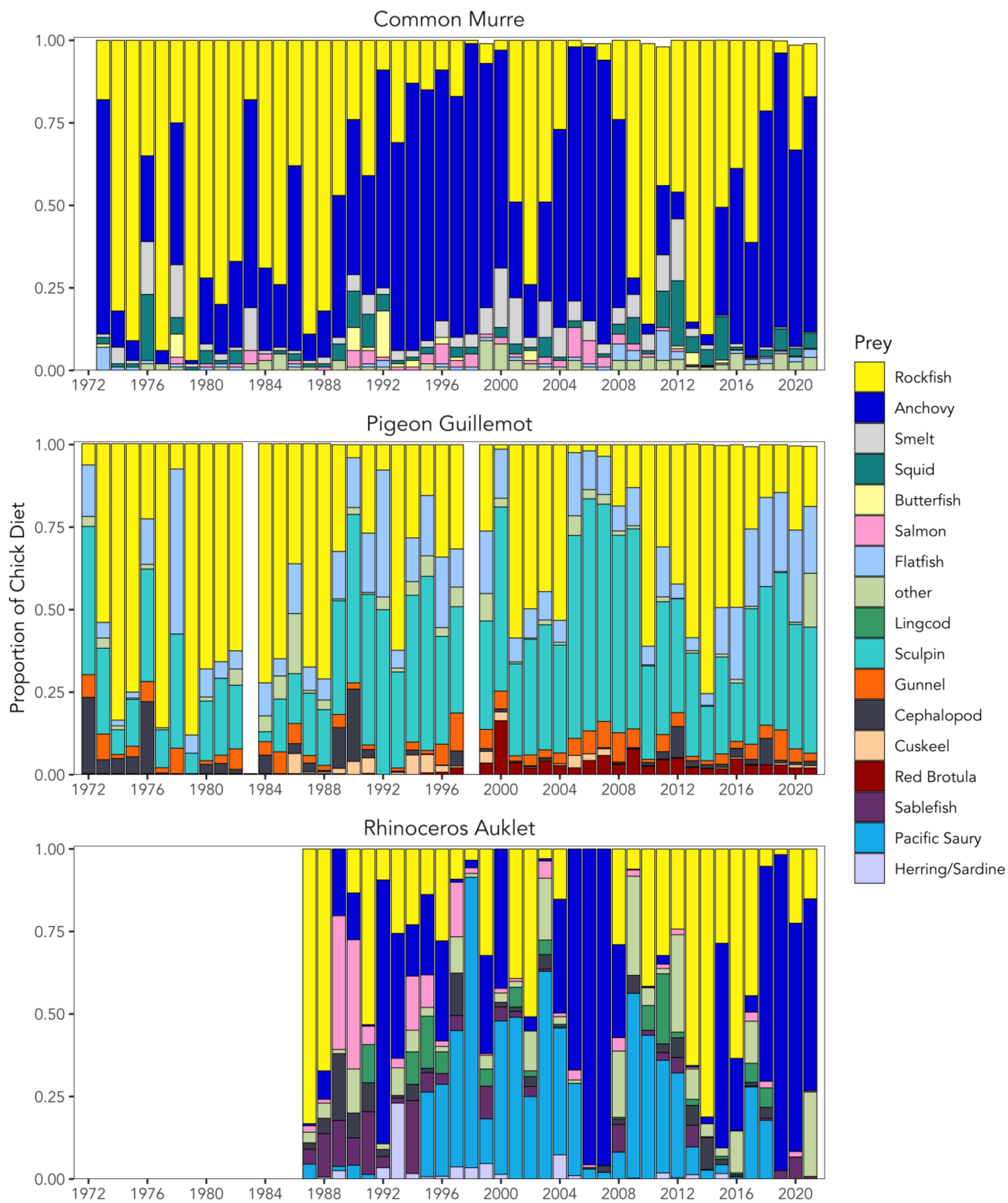


Figure 12. Annual proportion of common prey items in the chick diet of three species of seabirds on Southeast Farallon Island.

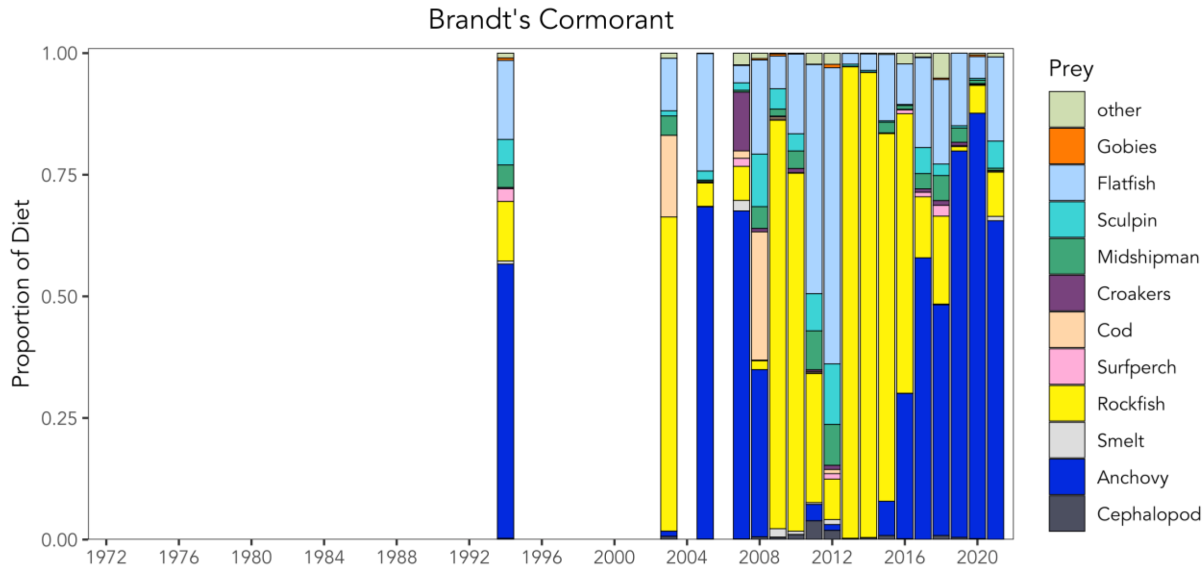


Figure 13. Mean percent occurrence per sample of common prey items by year in the diet of Brandt's Cornorants on Southeast Farallon Island.

APPENDICES

Appendix I. Calculation of correction factor for Western Gull census, 2021.

Area	Nest Count	Bird Count	Correction Factor
C	79	97	1.629
K	102	132	1.545
H (H1 only)	181	225	1.609
Total			**1.594**

Appendix II.

Calculation of correction factor for Common Murre colony attendance, 2021. The correction factor was derived by multiplying the number of breeding sites in our two main study plots (USP and UU) by 2, and then dividing the product by the mean number of adults present in each plot on the census dates. The correction factors generated for each plot were then averaged to derive a correction factor for the entire population.

USP

Date (Time)	Breeding Sites	No. of birds	Correction Factor
May 27 (1115)	219	282	1.55
May 28 (1120)	219	293	1.49
May 29 (1120)	219	283	1.55
May 31 (1120)	219	288	1.52
Mean	219	287	**1.53**

UU

Date (Time)	Breeding Sites	No. of birds	Correction Factor
June 5 (1030)	149	169	1.76
June 6 (1030)	149	173	1.72
June 7 (1030)	149	172	1.73
June 8 (1030)	149	181	1.65
Mean	149	174	**1.72**

Mean correction factor for SEFI 2021: **1.62**