Point Blue Report

Population size and reproductive performance of seabirds on Southeast Farallon Island, 2016

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

December 2016

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EXECUTIVE SUMMARY

(1) Under cooperative agreement with USFWS/Farallon NWR, Point Blue (formerly PRBO) monitors the population size and reproductive success of seabirds on Southeast Farallon Island (SEFI), California and has done so since 1971. We also collect information on oceanic conditions (sea surface temperature) and prey use (diet composition).

(2) In general, the number of birds attempting to breed and their breeding success were both lower during 2016 relative to recent years. Chicks generally grew slowly and fledged at lower weights when compared to more productive seasons.

(3) Warm water from a strong El Niño and the continued presence of “the blob” in the northeast Pacific contributed to lower overall ocean productivity and consequently poor breeding success. The mean seasonal SST for 2016 was cooler than 2015 but remained moderately warm with high average monthly values persisting through June. In contrast, July and August were at or slightly below the long-term mean values for those months.

(4) During 2016, breeding populations decreased for all species except Double-crested and Pelagic cormorants, Common Murre, and Tufted Puffin, when compared to 2015. After recording the lowest Western Gull breeding population observed during our time series during 2015, this population further declined during 2016. Brandt’s Cormorants, California Gulls, Pigeon Guillemots, and Cassin’s Auklets also exhibited large declines relative to last season. Black Oystercatchers had the lowest breeding population in our time series, equal to last year. In contrast, Tufted Puffins continued to increase, establishing a new high count for the fourth consecutive year.

(5) Reproductive success was lower for most species when compared to 2015, including complete breeding failure for Pelagic Cormorants and the lowest success for Pigeon Guillemots in 10 years. Rhinoceros Auklets were the only species to have higher success relative to last season while Cassin’s Auklet success was equal to 2015.

(6) Juvenile rockfish (Sebastes spp.) remained the dominant component of chick diet for Rhinoceros Auklets and Pigeon Guillemots, though they were less abundant than last season, while Anchovies were the dominant prey item for murres. Krill seemed to be available for Cassin’s auklets throughout the season, allowing for high breeding success and even a few successful second broods – the first observed in 3 years.

INTRODUCTION

This report contains information on the reproductive performance and population size of seabirds on Southeast Farallon Island (SEFI; Farallon National Wildlife Refuge) and West End Island (WEI), California, during 2016. We monitored twelve species: Ashy Storm-petrel (ASSP), Double-crested Cormorant (DCCO), Brandt's Cormorant (BRCO), Pelagic Cormorant (PECO), Western Gull (WEGU), California Gull (CAGU), Black Oystercatcher (BLOY), 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) breed on the island but are grouped with ASSP for monitoring. Peregrine Falcon and Common Raven have also bred on SEFI in recent years but did not attempt to do so in 2016, and have not for several years. Three pair of Canada Geese bred on the island and fledged a total of seven chicks.

METHODS AND RESULTS

Reproductive Performance

The reproductive performance of seabirds on SEFI is summarized in Table 1 and compared to previous years (Fig. 1a, b). 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 the past 44 years for each species. 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.

Brandt's Cormorant –BRCO productivity declined during 2016 relative to last season, but overall reproductive success was close to the long-term mean. Mean productivity for the colony was 1.50 fledglings per pair. This is approximately 13% lower than last season but remains slightly higher than the long-term mean productivity for this species (Fig. 1a). The first eggs were observed on 10 May at the Corm Blind and 15 May at the Sea Lion Cove colony. The mean laying date for the colony was 26 May. The first eggs were observed approximately 10 days later than last season but the mean laying date was equal to the last two seasons and 9 days later than the long-term mean for this species. There were seven nests abandoned out of the 75 sites followed for productivity assessment (9%). In addition, there were 3 abandoned nests that were at the well-built stage and regularly attended but for which eggs had not been confirmed. Three additional nests at the Sea Lion Cove colony were destroyed by California sea lions moving through the colony. Mean clutch size was 2.6 eggs per nest and hatching success was 78%. Mean brood size was 2.05 chicks per nest, 80% of which survived to fledging age. A total of 298 chicks were banded this season with the last chicks departing the colony by early September.

Pelagic Cormorant **–** PECO experienced wholesale reproductive failure during 2016. This followed three years of above average productivity. Of the 70 sites followed for productivity estimates, 40 were regularly attended until late June and 25 were confirmed to have laid eggs. However, cormorants began leaving the nests unattended by June 24 and all sites were abandoned by July 4. Birds began attending sites and building nests in March, but the first eggs were not observed until 5 June. There were no chicks observed this season and it is unlikely that any hatched based on the egg laying dates at visible sites. Adults began sporadically attending nest sites again in late July but did not attempt to relay.

Western Gull **–** WEGU productivity declined in 2016 when compared to last season, resulting in an average of 0.71 chicks per pair. This is approximately 25% lower than last season and 30% below the long-term mean productivity for this species (Fig. 1a). The first eggs were observed on the island on April 23th. Sixty-two percent of the eggs hatched but only 40% of those chicks survived to fledge. Mean clutch size was 2.65 eggs per nest and mean brood size was 1.69 chicks per nest, both roughly equivalent to last season. There were 343 chicks banded at the colony this season with the last chicks fledging and departing the colony by the end of August.

California Gull **–** CAGU once again suffered complete reproductive failure during 2016. They nested in the previously established colonies at Sea Pigeon Point and above Mirounga Beach, as well as establishing a few individual nests among breeding Western Gulls. We monitored productivity of this species by counting the number of birds, nests and young from the lighthouse every 5 days throughout the season. Based on these counts we were able to determine that the CAGU did lay eggs but no chicks were ever observed. Overall breeding effort was severely reduced this season, likely due to continuous disturbance from California sea lions in breeding areas on the marine terrace.

Black Oystercatcher **–** A total of 38 sites were monitored in 2016, of which 14 were considered active. An active site is defined as: (1) a territory occupied by a pair on at least two occasions during the season; (2) a territory in which a bird was seen in incubation posture; or (3) a territory where an egg or chick was observed. Eggs and/or chicks were documented at only 2 of these sites (14%) and 1 chick appeared to fledge this season. This resulted in an estimate of 0.07 fledglings produced per pair. While this average value is slightly higher than during 2015, the total number of chicks fledged is the same, the lowest we have observed in our time series. Unusually large numbers of California Sea Lions continued to haul out high on the marine terrace and other traditional oystercatcher nesting areas, likely contributing to the extremely poor breeding success observed this year. The first eggs were observed on May 24th and the only chick was observed as a mostly-feathered chick on June 28th. BLOY nests are cryptic and difficult to observe; therefore clutch size, hatching success and fledging success were not determined. There were no chicks banded this season.

Common Murre **–** During 2016, 271 Common Murre sites were monitored daily in the Upper Shubrick Point (USP) study plot, of which 216 were breeding sites (where an egg was laid). Productivity was 0.45 chicks fledged per pair. This is approximately 20% lower than last season and 38% below the long-term average of 0.73 (Fig. 1a). Egg laying was slightly later than average with the first egg observed in this plot until 2 May. Overall mean laying date for the plot was 15 May; approximately equal to the long-term mean laying date for this colony. Hatching success was low with only 79% of eggs hatching and only 56% of the hatched chicks survived to fledge.

As has become the pattern the last few years, the colony of Common Murres in Upper Upper (UU), under the Cormorant Blind, performed much better than the colony at USP. The first eggs were observed on May 4th this season but the mean lay date for the plot was 16 May. The murres in the UU plot typically lay a week to 10 days later than in USP but were roughly equivalent this season. There were a total of 151 sites monitored this season; 107 of which were breeding sites. Reproductive success for this colony was 0.83 chicks fledged per breeding pair. Ninety-two percent of the eggs hatched and 91% of the chicks hatched surviving to fledge (see Table 1). There was a much lower incidence of egg loss and gull predation when compared to the USP colony and to previous years at the UU colony.

Pigeon Guillemot **–** A total of 100 sites were monitored during 2016, of which 86 were observed with at least one egg (86% of the total number of sites). The majority of nest sites were located on Lighthouse Hill or at Garbage Gulch, but there were also five sites in the Habitat Sculpture, five in Rhinoceros Auklet nest boxes and one in a Cassin's Auklet nest box. Productivity for 2016 was 0.31 fledglings produced per pair (Table 1). This was approximately 54% lower than 2015 and 62% below the long-term mean productivity for this species (Fig. 1a). The first eggs were observed on 21 May, and the mean egg laying date was 1 June. This is approximately equal to the long-term mean laying date for this species. The mean clutch size was 1.79 eggs per nest with 75% of those eggs hatching successfully. Mean brood size was 1.42 chicks per nest but only 25% of the chicks produced survived to fledging age. Only one site successfully fledged a complete brood of two chicks, while 58 sites laid eggs but were not able to fledge any chicks. There were a total of 27 guillemot chicks banded on SEFI this season with the last chick fledging from a followed site on September 4.

Rhinoceros Auklet – There were a total of 145 sites (boxes, crevices, and cave sites) monitored in 2016, 47% (n=68) of which were occupied by a breeding pair. This includes three Rhinoceros auklets which bred in Cassin's Auklet nest boxes and the first pair to ever breed in the Habitat Sculpture. Forty-four percent of nest boxes were occupied compared to 54% of camera sites, both slightly down from the occupancy rates in 2015. There were also 17 boxes occupied by other species (12 CAAU and 5 PIGU). Productivity during 2016 was 0.70 fledglings per pair. This is approximately 13% higher than the productivity observed in 2015 and 25% above the long-term mean productivity for this species (Fig. 1a). The first eggs were observed on 17 April. Eighty-seven percent of the eggs successfully hatched and 87% of those chicks produced survived to fledge. There were a total of 23 rhinoceros auklet chicks banded this season with the last chick fledging from a followed site on August 20th.

Cassin's Auklet – Occupancy of breeding birds in study boxes was very high during 2016 with 88% of the boxes (414 of 468) occupied this season, including 42 of 44 PRBO study boxes (98%). This is approximately 10% higher than in 2015 and approximately equal to 2014. Productivity of auklets breeding in PRBO study boxes remained high 0.90 chicks fledged per breeding pair (including relay attempts). This was equal to 2015 and 22% greater than the long-term average of 0.74 chicks per pair for this species (Fig. 1a). Ninety-eight percent of the eggs hatched and 93% of those chicks produced survived to fledge. There were only four second broods attempted this season, two of which were successful. Although the second brood rate was remained low compared to the highly productive period from 2010-2013, these were the first successful second broods in the last three seasons. The first egg was observed on 17 March but the mean laying date for PRBO boxes was not until 19 April. This was approximately 5 days earlier than last season and 5 days later than the long term average.

For the past several seasons, we have reported the productivity of all followed sites in addition to that of the PRBO study boxes. This was done because we believed that in years of low breeding propensity (such as 2005) the increased sample size enabled us to more accurately reflect the success of the whole island population. The same is probably true for years of very high productivity. If all followed sites where an egg was laid are included in the analysis for this season, productivity would be 0.85 chicks per pair (n=184). This is approximately 5% lower than the estimate derived from PRBO boxes but within 1% to the "all sites" estimate for 2015. Island wide, there were a total of 360 chicks banded with the last chick fledging from a followed site on September 15th.

Ashy Storm-Petrel – ASSP pairs laid eggs in 45% of the 100 followed sites (n=45) in 2016, approximately 4% higher than the occupancy rate observed last season. Three of these 45 sites were new breeding sites discovered during 2016. There were an additional 5 sites in which an adult bird was observed on at least two occasions but no eggs or chicks were ever confirmed. It is possible that these birds attempted to breed but lost the egg before it could be observed, but for the purposes of our study, they were not considered breeding sites. The first eggs were observed on 9 May. Overall productivity for this species was 0.62 chicks fledged per pair (including all relay attempts). This is approximately 2% lower than last season and 6% below the long-term average productivity for this species (Fig. 1a). It should also be noted that there were seven, previously followed sites destroyed either during the winter or as a result of sections of the wall collapsing during the season. Only one of these sites was known to be occupied.

Other breeders – In past seasons, Peregrine Falcons, Common Ravens and Canada Geese have bred on SEFI during the seabird season. However, during 2016, it appears that only the Canada Geese attempted to breed. Five pairs of Canada Geese were present on the island by mid-March and three attempted to nest on the Marine Terrace. The first nest was discovered on the terrace to the south of the Helo Pad in mid-March with 7 eggs. By the end of the month, two additional nests were discovered; one on lower Lighthouse Hill behind the Power House that contained 6 eggs, and a third nest on the marine terrace near Sea Pigeon Gulch which only laid one egg. Seven chicks (4 from one nest and 3 from another) were frequently seen accompanying the adults and were seen flying for the first time on 5 July. All geese departed the island by July 23rd.

From mid-March until early May, 1-4 Peregrine Falcons were seen daily on SEFI. However, by early May, there was only one falcon sporadically seen around the island and there were no signs of nesting behavior. Peregrines last nested on the island in 2011 Common Ravens were not observed at the island this season and there has been no evidence of nesting since 2011.

Population Estimates

Population size and island-wide chick production was estimated for all species except ASSP and RHAU; breeding population size estimates (number of individuals) are presented in Table 2 and Fig. 7. All estimates include West End Island unless otherwise stated.

Ashy and Leach's Storm-petrels – We continued our long-term mark/recapture study to estimate ASSP population trends. We operated two netting locations (Lighthouse Hill and Carp

Shop) for a total of 7 evenings between April and August. As a result, we banded a total of 321 Ashy storm-petrels and recaptured 38 that had been banded in previous years. In addition, there were 11 ASSP banded this season that were recaptured later in the season. The mean standardized capture rate during 2015 netting sessions was 18.76 birds per hour (s.e. = 2.63, n= 7; see Figure 10). This is approximately 32% lower than during 2015 and 35% lower than the mean capture rate for the last 10 years. Our most productive netting session was on May 31st during which we captured 89 birds, including 3 recaptures of previously banded individuals. There were also 3 new Leach's storm-petrels banded this season. In addition, we saw but did not capture, one fork-tailed storm-petrel and captured one least storm-petrel on July 26th on Lighthouse Hill. The least storm-petrel represented the first island record for the Farallones.

Double-crested Cormorant – The DCCO colony is located on Maintop on West End Island. Counts of this colony were conducted every five days from atop Lighthouse Hill on SEFI using a spotting scope. A total of 17 counts were made in 2016, beginning on 26 April and ending on 31 July, when juveniles became indistinguishable from adults. On 7 June we counted a peak number of 116 "well-built" nests with birds in incubating posture. To estimate the minimum population size we multiplied the number of well-built nests by two, which yields a total of 232 breeding birds. This estimate is approximately 123% higher than 2015 but still 31% below the 10-year average population for this species (Table 2). There was a high count of 81 chicks observed during the 20 July census.

Brandt's Cormorant – The BRCO breeding population was censused during ground-based surveys on 5 June and a boat-based survey on 6 June. The boat census covers approximately 16% of the Brandt's breeding habitat that is not visible from vantage points on SEFI. During the survey we counted 2,412 "well-built" nests (Fig. 2). We then multiplied the number of nests by 2 to yield an overall population estimate of 4,824 breeding birds (Table 2). This estimate is 12% lower than 2015 and approximately 36% below the 10-year average (Table 2). This was the third consecutive year of declining populations after a brief increase in 2013. We multiplied the total number of nests by the mean productivity to estimate an island-wide production of approximately 3,618 fledglings.

Pelagic Cormorant – The PECO breeding population was censused during a boat-based survey on 6 June and a ground-based survey on 8 June. During the census, we counted a total of 154 fair to well-built nests (Fig. 3). We then multiplied this number by 2 to yield an overall breeding population of 308 birds (Table 2). This estimate for Pelagic Cormorants is approximately 32% higher than 2015 and 24% greater than the 10-year average. However, despite a greater number of breeding attempts, all were abandoned by early July.

Western Gull – The WEGU census was conducted on 30 May. 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 8,022 (Fig. 4). 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 (1.252) 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 10,044 birds (Table 2). The population estimate for WEGU was the lowest ever recorded for the Farallon population since regular censuses were initiated in 1972. It is approximately 10% lower than in 2015 and 42% lower than the 10-year average (Table 2). In contrast to last season when much of the reduction in the population was the result of a lower correction factor, during 2016, the correction factor was higher (fewer mates attending) but the raw count was 22% lower. Nest counts in all study plots were also reduced this season. As with other species, we estimated the overall chick production by multiplying the mean annual reproductive success by the number of breeding pairs to estimate an overall production of 3,566 fledglings on SEFI in 2016.

California Gull – CAGU were censused every five days throughout the season beginning on 1 April. A peak count of only 13 “well-built” nests was counted on 21 May resulting in a breeding population estimate of 26 birds. This estimate is approximately 84% lower than the estimate for last season and 91% lower than the 8 year mean for this population. The peak count for total birds was 87 on 12 May, down from a peak count of 222 in 2015 and 570 in 2014. The total count included many immature birds which were present in the colony but not breeding and hence not factored into calculating the breeding population estimate. No chicks were produced this season.

Black Oystercatcher - We estimated the population of BLOY by surveying all known breeding sites visible from Lighthouse Hill and the marine terrace. Of the 38 sites that were monitored this year, 14 were considered active sites. Therefore, we estimated a breeding population of 28 birds, a decrease of 26% relative to 2015 and approximately 28% lower than the 10-year average population. We estimated an island wide production of 1 chicks fledged. This estimate does not reflect birds which may have nested on parts of West End Island not visible from the SEFI vantage points.

Common Murre – The COMU breeding population has grown to the point where counting individual birds has become impossible and we will no longer attempt to census the entire colony. USFWS will continue to conduct annual aerial photographic surveys and count the number of birds present in the photos when money for analysis becomes available. Point Blue will continue to track population trends using data from our Index Plot counts. There are 23 Index Plots set up around SEFI and WEI which are counted in early June during the peak incubation period. Each plot is counted three times each day for 10 consecutive days. 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 during 2015 (Figure 11) and are among the highest we have observed in the time series.

As in previous years, a correction factor was calculated using data from three of our study plots (Upper Shubrick Point, Upper Upper and Tower Point) to account for breeding adults not present during the census (see 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 1.60. 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.

Pigeon Guillemot – 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 regular attendance of sites. Our peak count during these morning surveys was 2,009 birds on 11 April. This count was approximately 36% lower than the peak count from 2015 and 39% lower than the 10 year mean for morning surveys (Table 2 and Fig. 7). It is worth noting that, unlike previous seasons, the counts remained fairly consistent throughout the survey period and did not build to a peak as is typically seen just before the initiation of breeding. The reason for this unusual rafting pattern is unclear.

Tufted Puffin – The island-wide TUPU survey was conducted primarily in two parts; from 26 May to 9 June and a second survey from 2 to 12 August. 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 2016 surveys, a total of 188 active sites were observed. A mostly-feathered chick was seen at the entrance to one site while six more sites were confirmed with chicks based on observations of birds delivering fish to the site. An additional 25 sites were observed with likely prey deliveries. Based on these observations, we estimated a breeding population of 376 birds (Table 2). This estimate is 15% greater than during 2015 and 89% greater than the 10 year average population for this species. The 2016 estimate once again surpassed the previous record high count in our time series (Fig. 7). This is the fourth consecutive season and seventh time in the last eight seasons that the puffin population has set a new high count.

Rhinoceros Auklet – An island-wide estimate of breeding population size for RHAU is difficult to obtain because they nest underground and are crepuscular (active only at dawn or dusk). Netting for mark/recapture and diet sampling was continued in 2016. A total of 68 new birds were banded and 63 were recaptured (23 birds were recaptured multiple times during the season and 4 birds that were banded this season were later recaptured). Capture and recapture rates were similar to last season.

Cassin's Auklet – 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 2016, we counted a total of 311 burrows/crevices in the index plots. Therefore, using the same methodology, but with the updated whole island estimate generated in 2009, we estimated a 2016 breeding population of roughly 20,059 birds ([311/225] x 14512) on Southeast Farallon Island. Total island-wide production (number of breeding pairs x mean productivity) was estimated at 9,027 fledglings on SEFI. The breeding population estimate is approximately 22% lower than in 2015 but still 5% higher than the 10-year average (Table 2). It should be noted that the greatest decline in burrow density occurred in the index plots on the marine terrace which were most heavily impacted by California sea lions.

Ocean conditions and Seabird Diet

Sea surface temperature (SST) is measured daily from water temperature point near East Landing as an indicator of local ocean conditions. During 2016, the mean seasonal SST from March to August was 12.13°C. This was 1.09°C cooler than the 2015 season but still 0.15°C warmer than the long-term mean for these months. Monthly values were above the mean for all individual months except July (Fig. 6a, b), with particularly warm anomalies during the late winter from January through March.

Chick provisioning data is collected throughout the chick rearing period for five species as a means of determining diet and feeding rates and as an indicator of local ocean conditions. Diet data is determined 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). During 2016, juvenile rockfish were once again an important prey item in chick diet throughout much of the chick rearing period (Figs. 8 and 12), but overall proportions in the diet were reduced. Overall, rockfish comprised 49% of the diet for Pigeon Guillemots, 39% for Common Murres, 63% for Rhinoceros Auklets. As was seen during the past two seasons, the vast majority of the juvenile rockfish that were identified to species (85%) this season were Shortbelly Rockfish (*Sebastes jordanii*). The Shortbelly Rockfish were the main species encountered in seabird diet during the 70's and 80's but have generally been less dominant over the past two decades when a more varied species assemblage (including Yellowtail, Widow, Blue and Black Rockfish) has been more common. In addition to rockfish, anchovies were a significant component of the diet for Common Murres and Rhinoceros Auklets during 2016. Anchovy accounted for 53% of the diet for Common Murres and 22% of the Rhinoceros Auklet diet (Fig. 8). Flatfish, sculpins, saury, smelt, hake and squid were other important components of the diet this season but in relatively small proportions. Cassin's auklet diet cannot be identified in the field and is still being analyzed but preliminary results suggest that krill was abundant throughout the season.

DISCUSSION

Weather and Ocean Conditions

Local oceanic conditions were generally warm during 2016, though the seasonal average was lower than the previous two summers. El Niño conditions persisted through the winter and into the spring resulting in very warm water present around the island until mid-summer when sea surface temperatures began to return to more average temperatures. Typically, cool 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). The weather during the months preceding the breeding season were unseasonably calm and mild, leading to a slightly delayed start to the seabird breeding season. However, brief pulses of strong northwesterly winds in March and late-April, produced a period of strong upwelling that resulted in a bloom of primary productivity. Unlike 2015 when brief periods of productivity allowed seabirds to have moderate breeding success, the intermittent upwelling evident this year did not result in favorable breeding conditions for most species.

Rockfish are an important component of seabird diet at the Farallones and a high proportion of rockfish in the diet typically correlates with high productivity. During 2016, while still a significant component of the diet, the proportion of juvenile rockfish was once again reduced. The overall lower abundance in the diet likely played a role in reduced breeding success and lower feeding rates this year for species such as Common Murre and Pigeon Guillemot. If rockfish were less numerous or more patchily distributed, then foraging adults may have had more difficulty locating prey this season and needed to make longer foraging trips when provisioning dependent offspring. During 2015 rockfish were present early and dropped out of the diet as the season went on. In contrast, during this season, rockfish were present throughout the season and even increased later in the season. This suggests that there may have been a slight miss-match between the peak chick rearing period and the peak in rockfish availability

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 a major diet component during the last two years. Anchovies comprised greater than half of the prey items delivered to murre chicks and roughly one-quarter of all prey items collected from rhinoceros auklet diet. These are highest proportions of anchovy observed since 2008.

Productivity

The 2016 seabird breeding season was a poor year for most species (Fig. 1a, b). All species except Cassin's and Rhinoceros Auklets experienced lower breeding success during 2016 relative to the last two seasons. Rhinoceros Auklets were the only species to have higher productivity while Cassin's Auklet success was equal to last season. Though reduced this season, Brandt's Cormorant and Ashy Storm-petrel success remained close to long-term mean values. The productivity for Pigeon Guillemots, Western Gulls and Common Murres were all well below average and Pelagic Cormorants suffered complete reproductive failure. Black Oystercatchers also had very poor reproductive success in 2016 with only 1 chick fledged. This equals last season as the fewest number of chicks produced in the 20 years we have been following oystercatcher breeding success. We suspect that the low success for oystercatchers this season was due primarily to disturbance from an excessively large number of California sea lions hauling out higher on the marine terrace than in previous years.

As in previous years, we have included the 80% prediction interval (dashed horizontal lines) on the long-term productivity graphs (Fig. 1a) to help illustrate the signals in the annual mean productivity and to highlight the extreme years (i.e. those years that fall into the upper or lower 10% of the distribution). Note that strong El Niño years (1983, 1992, and 1998) fall below this range for most species while exceptionally good years will surpass the upper range. The 2015/2016 El Niño was reported as one of the strongest on record so we expected to see similar results to those previous years. This year Pelagic Cormorants (which failed completely), Pigeon Guillemots and Common Murres all approached the lower bounds of the prediction interval (Fig. 1a).

Despite poor conditions, Cassin's Auklets continued to exhibit relatively high productivity. They fledged the vast majority of chicks from first broods and a few individuals were able to successfully raise second broods. Cassin's Auklets are the only alcid capable of successfully fledging multiple broods in the same season, and they only do this in the southern portion of their range (Ainley et al. 2011). This suggests that conditions were good enough throughout the season to allow successful chick rearing and that prey remained available even late into the season.

In contrast, reproductive success of COMU was greatly reduced relative to last season and well below the long-term mean for this species. The apparent reasons for this decline were two-fold. Hatching success was reduced in the main study plot with only 79% of the eggs hatching. This is approximately 5% lower than the long term mean hatching success for this colony. Secondly, there appeared to be a higher rate of Western Gull predation this season, particularly in the USP plot. This coupled with reduced feeding rates and a reduction of juvenile rockfish in the diet led to an unusually low fledging success. Colony wide fledging success was only 69% with USP only fledging 56% of their chicks. In contrast, the UU colony, where predation was not an issue this year, had relatively high fledging success with 91% of chick hatching surviving to fledge. The combination of lower hatching success and higher predation (lower fledging success) resulted in the lowest productivity since 2009 and the third consecutive year of productivity declines. After 23 straight years during which the USP study plot had the highest productivity of the followed sites on the island, the Upper Upper plot has now achieved higher success over the last three seasons (see Table 1). The reasons for the switch seem to be related to higher predation by Western Gulls in this colony.

Rhinoceros Auklets exhibited higher than average breeding success for the fourth consecutive year and the highest overall success since 2010. The overall productive year was likely buoyed by the availability of juvenile rockfishes throughout the season coupled with an increase in anchovy abundance. In contrast, Pigeon Guillemot productivity was dramatically lower due in large part to very poor fledging success, particularly of second chicks. High productivity years for guillemots are driven by their ability to fledge the second chick from their broods. In productive years there is enough food available to feed both chicks and feeding rates are high enough that sibling competition is reduced. The opposite is true in poor years. During 2016, only 1 out of 86 sites which laid eggs was able to fledge both chicks. There was very high chick mortality early in the season but chick survival and fledging success increased as the season went on. This suggests that foraging conditions may have improved during the summer due to either increased prey abundance or reduced competition. As with the auklets, rockfish remained an important component of chick diet but were not as abundant as in the last few seasons while flatfishes were relatively more abundant.

Brandt's Cormorants also experienced lower reproductive success this season compared to 2015 but still achieved roughly average overall productivity. Fewer birds attempted to breed and both hatching and fledging success were reduced. There were several nests abandoned during the season, particularly among inexperienced young breeders. Pelagic Cormorants on the other hand abandoned all nesting attempts by early July. This is the first time since 2012 that they have failed to fledge any chicks.

Cormorants breeding at most other central California colonies also exhibited lower than average breeding success during 2016. Point Blue monitoring sites at Vandenberg Air Force Base continued to experience low breeding population numbers for Brandt's cormorants, while pelagic cormorants appeared to rebound. The Brandt's cormorant population was 40% lower than last year, and 82% lower than 2014. Productivity increased 38% from the low in 2015, but was still below average. While the pelagic cormorant population more than doubled from 2015, it was still 40% lower than the population a few years ago. Productivity for this species was the third lowest in the 17-year monitoring history, 122% below average. Other monitored breeding species held steady or increased slightly in population but declined in productivity. (Robinette et al. 2016; J. Howar pers. comm). Brandt's Cormorant productivity was lower than last season and also below than long-term means at Castle-Hurricane while the Devil's Slide colony experienced better than average productivity. There were a lot fewer nests overall (less than half) in 2016 both from our land based counts and the aerial surveys. Pelagic Cormorant attendance and productivity at Devil's Slide was low but very similar to last season, while all visible nests at Castle-Hurricane had failed by early-mid July (USFWS unpublished; C. Bednar pers. comm.).

Western Gull productivity was reduced again this year and remains well below the long-term mean productivity. Clutch size, brood size and hatching success were all similar to last season, but fledging success declined. Intraspecific predation continued to be the single greatest cause of mortality, but starvation also played a role later in the season.

Ashy storm-petrel productivity decreased relative to last season and was the slightly lower than the long-term mean but remained on par with recent years. As with other species, storm-petrels initiated breeding later with the last chick fledging in late October. There did not seem to be a strong seasonal pattern in relation to fledging success as chicks that hatched earlier in the season fledged at about the same rate as those hatched later.

Populations

Breeding population sizes were lower than the 2015 estimates for all species except Double-crested Cormorant, Pelagic Cormorant, Common Murre and Tufted Puffin. Decreases ranged from approximately 10% for Western Gulls to 83% for California Gulls when compared to last season. These declines included the lowest population estimate in 10 years for Pigeon Guillemots and the lowest ever for Western Gulls, surpassing the all-time low for this population set just last season.

Pigeon Guillemot population estimates reported in this document do not necessarily represent breeding birds because the census method does not distinguish between breeders and non-breeders. The raft counts used to estimate the Pigeon Guillemots 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. During 2016, Guillemot numbers decreased by approximately 36% to the lowest number observed since 2005. In contrast, occupancy of monitored PIGU crevices was higher this season with approximately 86% of historically followed sites used by breeding guillemots during 2016, up from 65% last season. This discrepancy suggests that the breeding population may not be reduced as much as indicated by the raft counts alone. It is possible that our raft count survey period ended prior to the peak in rafting activity of that some birds did not return to the colony until they were ready to breed. Breeding was slightly delayed this season so it is likely that some guillemots also returned to the island later this season and were not captured in our raft censuses.

Historically, the Common Murre population on the Farallones was estimated to be between 400,000 and 1 million birds, but egg collecting, oiling, gill net entanglement and human disturbance drastically reduced these numbers (Ainley and Lewis, 1974, Sydeman *et al.*1997). Murre populations were beginning to recover in the late 1970's and early 1980's (Figure 7), but were then decimated by a series of oil spills and high adult mortality in gill net fisheries. Favorable oceanographic conditions and abundant prey, relatively strong reproductive success, and elevated juvenile survival, coupled with likely immigration from northern murre colonies, led to rapid population growth between 2000 and 2011. This growth trend appears to have leveled off over the last five years (Figure 7).

While we no longer census the entire island, we have continued to track murre population trends using our index plots. Index plot counts indicated a slight increase (~1%) in murre numbers this year when compared to 2015 and overall counts remain approximately 25% higher than the last full island census in 2006. 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 of the plots we get a representative sample for the colony as a whole.

Farallon Cassin's Auklets declined considerably since the early 1970's (Fig. 7), and remain 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 population was increasing rapidly. However, the breeding population declined again during 2005 and 2006, coinciding with reduced breeding effort and lower reproductive success before rebounding to approximate peak numbers by 2014. Warm ocean temperatures over the last two seasons coupled with a large increase in the number of California sea lions that haul out on the marine terrace have led to reduced burrow counts during the last two seasons. Burrow and crevice counts for 2016 were approximately 22% lower than in 2015 but remained higher than the long-term average number of burrows observed since the index plots were established in 1991 (Table 3). The greatest changes in burrow counts were in areas with deep soil on the marine terrace which were overrun with California sea lions this season, leading to burrows being crushed and fewer birds prospecting in these areas. Plots in these areas decreased by an average of 48% while all other plots decreased by an average of only 7%. Very high nest box occupancy during 2016 suggest that the true breeding population likely did not decline as much as is suggested from the index plots. 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.

Tufted Puffin population estimates are based on the overall number of active sites observed during our surveys. The Farallon population was exhibiting an increasing trend during the early part of the decade, but declined substantially following the 2004 season. Since 2008, we have seen continuous and rapid growth with 2016 once again setting a new high for the number of active nest sites observed for this species on the Farallones.

Approximately 50% of the world population of Ashy Storm-petrels breeds on the Farallones, but little is known about their true population status. Sydeman et al. (1998) reported a 35% decline in their population between 1972 and 1992 while analysis of a population index derived from catch per unit effort during netting suggests alternating periods of growth and decline (Nur et al. in review). The mean catch per unit effort this season was approximately 32% lower than the capture rate for 2015 and the lowest capture rate observed at the Farallones since 2003. In contrast, crevice occupancy was slightly higher than last season suggesting that the breeding population may not have dropped as much as the overall catch rate.

Integrating capture-mark-recapture data from our storm petrels into new Jolly Seber modelling methods has provided new insights into recent changes in Farallon storm petrel survival, populations, and predation by Burrowing Owls (Nur et al. in review). Burrowing owl occurrence and activity at the Farallon National Wildlife Refuge reached a peak in 2010/2011. During that same year, ashy storm-petrel survival reached its lowest level in the last decade, having shown a multi-year decline; population size was also declining during this same period that show a steep increase in burrowing owl attendance, 2007 to 2011. Thus, the evidence clearly points to the increased abundance and activity of burrowing owl leading to predation of ashy storm-petrels, thus decreasing survival and contributing to the observed population decline. However, since 2011, fall/winter burrowing owl numbers have been 40% lower in recent years (2011/2012 to 2014/2015) compared to the previous 2 years (2009/2010 and 2010/2011). Average storm-petrel survival for the four most recent year period (2011/2012 to 2014/2015) was greater than the estimate of survival for 2010/2011 by 6.0%. However, survival of ashy storm-petrels for 2014/2015, the year of markedly low burrowing owl attendance, was indistinguishable from survival observed in the previous 3 years, when burrowing owl attendance was on average 68% higher than it was in 2014/2015. Nur et al. (in review) found that ashy storm petrel population trend in recent years has indeed evidenced a change, concomitant with the reduction in burrowing owl attendance. Looking at a longer time series, from 2001 to 2007, the population displayed a strong increase in population size (increasing at 17.5% per year, $P < 0.015$), confirming results from our earlier analysis. However, from 2007 to 2012 the population decreased by 7.0% per year ($P < 0.1$), this decrease coinciding with the period of increase in burrowing owl overwinter attendance. However, from 2012 to 2015 the population showed stability: the estimated change in size is less than 0.1% per year. Thus, the time series indicates that, after 2011 (the year of peak burrowing owl attendance), the population trend changed from decline to stability, just as the level of burrowing owl changed from high to moderate. This change in trend was consistent with the observed pattern of survival for the storm petrels over this time period. It is important to note that results of the statistical analysis provided low confidence in the estimates for any single year. The power of the results of these statistical analysis lies in estimates based on multiple years of data, rather than basing comparison on any single year.

Brandt's Cormorant and Pelagic Cormorant populations declined substantially since the early part of the 1980’s (Nur and Sydeman 1999, Fig. 7) but began to recover during the early 2000’s. The BRCO breeding population expanded rapidly from 1999 to 2007, but declined rapidly following the 2007 season. 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. However, the continued low breeding population, despite a return to more favorable ocean conditions during the last few years, indicates that there was likely significant adult mortality during this period. After a large increase in the breeding population during 2013, the Brandt's population has declined during the past three seasons. The 12% decline observed this season was likely the result of very warm water and poor foraging conditions during the winter and early spring which led some individuals to skip or abandon breeding attempts. Brandt's numbers remain less than one-third of the population observed before the crash but are equivalent to population estimates made during the early 2000's. The Pelagic Cormorant breeding population peaked in 2004. However, the population crashed following that season and has been slow to recover. Breeding populations were extremely low through 2007 but had been slowly increasing in recent years. After four years of continuous growth the breeding population declined during 2015, but rebounded somewhat in 2016 (Fig. 7). However, despite this increase in the number of birds which initiated breeding this season, all sites were eventually abandoned. Other central CA sites experienced similarly reduced breeding effort (i.e. fewer nests initiated).

Summary

The 2016 seabird breeding season was characterized by warm sea-surface temperatures (SST) throughout most of the season. The mean seasonal SST for 2016, though lower than last season, was above the long-term average while mean monthly values remained anomalously warm until July. Warm water conditions, such as those observed during the recent El Niño, typically lead to unproductive ocean conditions, very low breeding success and even breeding failure for seabirds. This more or less proved to be true this season with much reduced breeding populations and reproductive success for most species. Rhinoceros Auklets and Cassin's Auklets were the only species above the long-term mean. Cassin's Auklets attempted few second broods but did manage to successfully fledge chicks from two of them, typically a sign of productive ocean conditions. Though the second broods did not significantly contribute to overall productivity this season, a high success rate for first broods resulted in an overall productive season.

During 2016, effects on breeding populations were mixed. Brandt's Cormorants, Cassin's Auklets, Pigeon Guillemots and Western Gulls all decreased whereas Pelagic Cormorants, Double-Crested Cormorants and Tufted Puffins increased. The Western Gull breeding population estimate was the lowest observed during our 46 years of monitoring while Pigeon Guillemots, Brandt's Cormorants and Cassin's Auklets were the lowest they have been in the last five years.

Juvenile rockfish, always an important component of chick diet in productive years, was much less abundant than during highly productive years in 2013 and 2014 but remained a significant portion of the diet fed to chicks this season. Both of these changes are consistent with observations from previous warm water years. Following strong upwelling bouts in late March and again in late April, primary productivity and zooplankton abundance (primarily krill) both appeared high. Although diet analysis has not been completed, preliminary visual inspection of Cassin's diet samples indicated that krill remained the dominant item in auklet prey. This likely allowed for the higher than expected breeding success this season for Cassin's auklets and resulted in the production of enough juvenile forage fish for other species to fledge their chicks despite overall unfavorable conditions.

In general, although the 2015-2016 El Niño may not have as great an impact as previous events, the number of birds attempting to breed and their breeding success were both reduced during 2016. Chicks generally took longer to grow and fledged a lower weights than in the past few seasons while warm water continued to bring unusual species into the region. These included record numbers of Brown Boobies, a few persistent Blue-footed boobies and the first island record for Least storm-petrel, all species that are normally found in more tropical regions. With El Niño conditions subsiding in late summer and La Nina conditions forecast for this winter and next spring, we would expect conditions to improve and for seabirds to rebound with a more productive season next year.

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. Our results on the impacts of Burrowing Owls on Ashy Storm Petrel populations, form Nur et al. (in review), provide support for proceeding with efforts to reduce burrowing owl numbers on the Farallon National Wildlife Refuge as a means to aid a species of conservation concern and facilitate recovery in the future. Novel techniques to aid in our understanding of ASSP populations should also be strongly considered. First of these should be funded pilot work to utilize PIT tags to increase understanding between the linkages between birds caught during mist-netting and breeding birds.

2. 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. Expanding the use of instrumentation to more species will allow us to tackle 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 around the Farallon NWR.

3. 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 in order to develop a more complete understanding of the factors influencing the Farallon populations. The first step in this direction was taken the last two seasons with the deployment of small GLS tags on Cassin's and Rhinoceros Auklets. These data are currently being analyzed and are showing some interesting patterns and we recommend increased efforts on these and other species.

4. Tufted Puffins are difficult to monitor and little is known about their reproductive success on the Farallones. With populations declining along much of the west coast of the U.S. it becomes more important to develop an understanding of the factors influencing this species. We propose assessment and modification of our research methods, including the potential use of nest boxes or nest cameras to allow limited monitoring of the breeding parameters for this species.

5. To understand and mitigate the effects of increasing average air temperature on seabirds nesting in artificial nest boxes, we have conducted a series of studies which examine differences in microclimate among traditional nest boxes, new nest box designs and natural burrows. Several prototypes for new nest box designs and materials were deployed during 2016 and will be evaluated to help us to come up with a final design that both facilitates research and is adaptable to a changing climate. Initial results support the use of clay nest modules and we have been working with collaborators to modify the design and build a larger sample of prototypes to test next season.

6. The Farallon Islands are a unique and fragile ecosystem which are likely to be greatly affected by the impacts of climate change including increasing air temperature, rising sea level, and disruption of ocean food webs. As such, it is important to conduct a SEFI specific climate change vulnerability assessment and develop a comprehensive climate-smart restoration plan for the Farallon Islands. Once completed, this plan can serve as a model for other coastal islands and seabird breeding areas and lead to island ecosystems with increases in plant and animal populations that are robust enough to survive the impacts of climate change.

7. For the last several years California sea lions have been hauling out on the marine terrace in increasingly large numbers. This behavior was not previously observed and is having an impact on several species of nesting seabirds, including Brandt’s Cormorants, Cassin’s Auklets, California Gulls and Black Oystercatchers. To quantify this impact, we propose to continue monitoring how sea lion distribution is changing and determine how much nesting habitat is being lost as a result. We suggest further analyzing the overall impacts that these changes may have on population estimates and productivity of these species.

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TABLES

Table 1. Mean (± 1 SD) productivity of eight species of seabirds at Southeast Farallon Island, California, 2016. 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	2.60 ± 0.60 *(75)*	2.05 ± 0.90 *(84)*	1.57 ± 0.90 *(90)*	1.58 ± 0.89 *(90)*	0.78 ± 0.34 *(71)*	0.80 ± 0.30 *(75)*
PECO	2.28 ± 0.74 *(25)***	0.00 ± 0.00 *(40)***	0.00 ± 0.00 *(40)*	0.00 ± 0.00 *(40)*	0.00 ± 0.00 *(40)*	0.00 ± 0.00 *(40)*
WEGU	2.65 ± 0.54 *(166)*	1.69 ± 1.08 *(166)*	0.71 ± 0.94 *(166)*	0.71 ± 0.94 *(166)*	0.62 ± 0.38 *(166)*	0.40 ± 0.41 *(134)*
COMU* USP	1.00 (216)	0.79 ± 0.41 (216)	0.44 ± 0.50 (216)	0.45 ± 0.50 (216)	0.79 ± 0.41 (216)	0.56 ± 0.50 (171)
COMU* UU	1.00 (107)	0.92 ± 0.28 (106)	0.83 ± 0.38 (106)	0.83 ± 0.38 (106)	0.92 ± 0.28 (106)	0.91 ± 0.29 (97)
PIGU	1.79 ± 0.41 *(86)*	1.42 ± 0.79 *(86)*	0.31 ± 0.49 *(83)*	0.31 ± 0.49 *(83)*	0.75 ± 0.40 *(86)*	0.25 ± 0.36 *(67)*
RHAU*	1.00 *(68)*	0.82 ± 0.38 *(68)*	0.70 ± 0.46 *(67)*	0.70 ± 0.46 *(67)*	0.82 ± 0.38 *(68)*	0.87 ± 0.34 *(54)*
CAAU* PRBO	1.00 *(42)*	0.98 ± 0.15 *(42)*	0.90 ± 0.30 *(42)*	0.90 ± 0.30 *(42)*	0.98 ± 0.15 *(42)*	0.93 ± 0.26 *(41)*
CAAU* ALL	1.00 (184)	0.91 ± 0.28 *(184)*	0.84 ± 0.37 *(184)*	0.85 ± 0.38 *(184)*	0.91 ± 0.28 *(184)*	0.92 ± 0.28 *(168)*
ASSP*	1.00 *(42)*	0.90 ± 0.30 *(40)*	0.62 ± 0.49 *(42)*	0.62 ± 0.49 *(42)*	0.90 ± 0.30 *(40)*	0.74 ± 0.44 *(35)*

* 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, 2006-2016. Estimates include Southeast and West End Islands unless otherwise noted.

Species	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2006-2015 average
DCCO	232	104	364	364	220	360	260	194	206	444	474	299
BRCO	4,824	5,742	6,566[b]	7,412	3,450[b]	4,916	5,132	1,248	4,840	20,788	15,692	8,221
PECO	308	234	440[b]	372	298[b]	206	320	268	250	64	40	219
WEGU	10,044	11,164	18,686	21,148	15,846	17,406	18,218	15,747	20,152	15,852	17,399	17,162
CAGU	30	184	514	522	70	208	396	192	534	-	-	328
BLOY	28	38	46	36	40	48	38	38	40	42	36	40
PIGU [d]	2,009	3,157	4,459	3,880	3,645	3,461	3,317	2,851	2,875	2,774	2,607	3,303
TUPU [c]	376	326	288	286	244	246	234	216	106	59	108	211
CAAU [a]	20,059	25,606	28,444	22,574	19,607	17,866	12,964	14,512	16,121	19,540	13,597	19,083

[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.

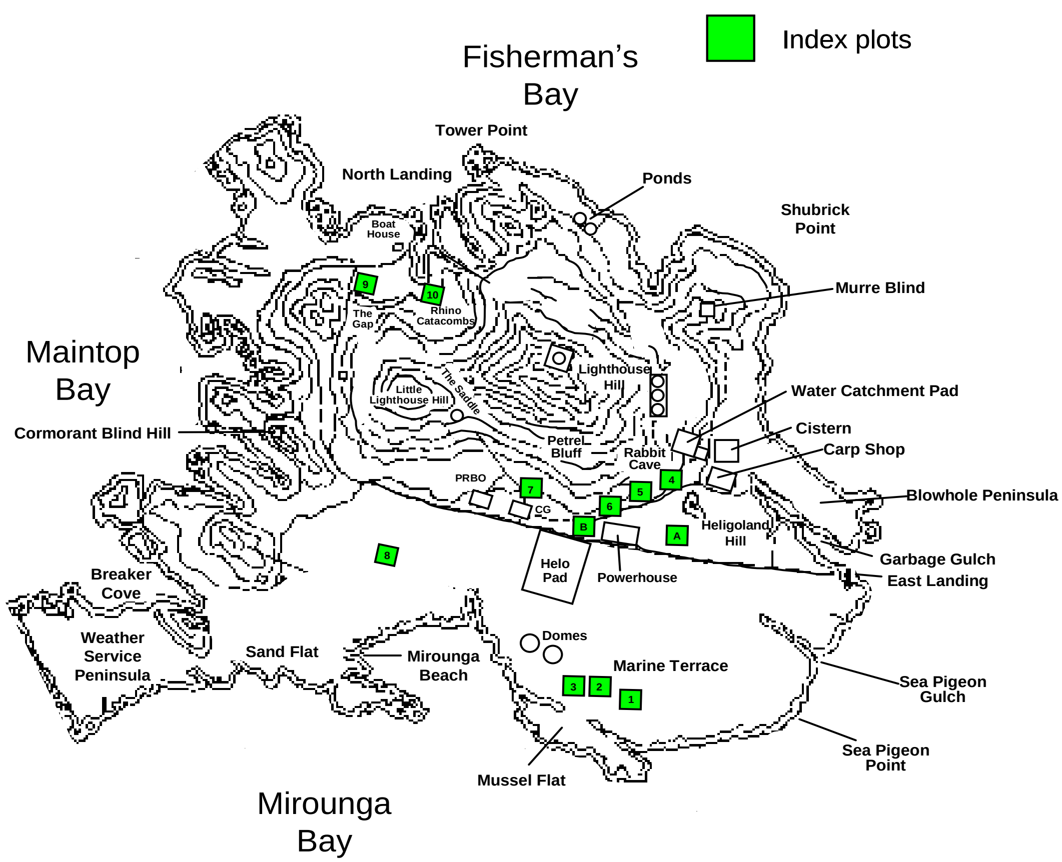
[c] TUPU population estimates were recalculated in 2008 to correct for unequal survey effort in prior seasons (see text)

[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 2016. The previous 10 seasons as well as the initial plot counts from 1991 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
2006	14	5	25	10	11	6	3	8	58	21	3	3	167
2007	26	13	23	18	14	6	17	10	73	22	5	13	240
2008	17	13	20	20	15	8	14	2	53	20	2	14	198
2009	13	11	27	11	5	5	8	8	81	41	2	13	225
2010	14	9	16	10	9	3	11	9	73	29	0	18	201
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
2006-2015 average	24	19	26	16	13	6	15	12	81	43	5	22	280

Cassin's Auklet Index Plots



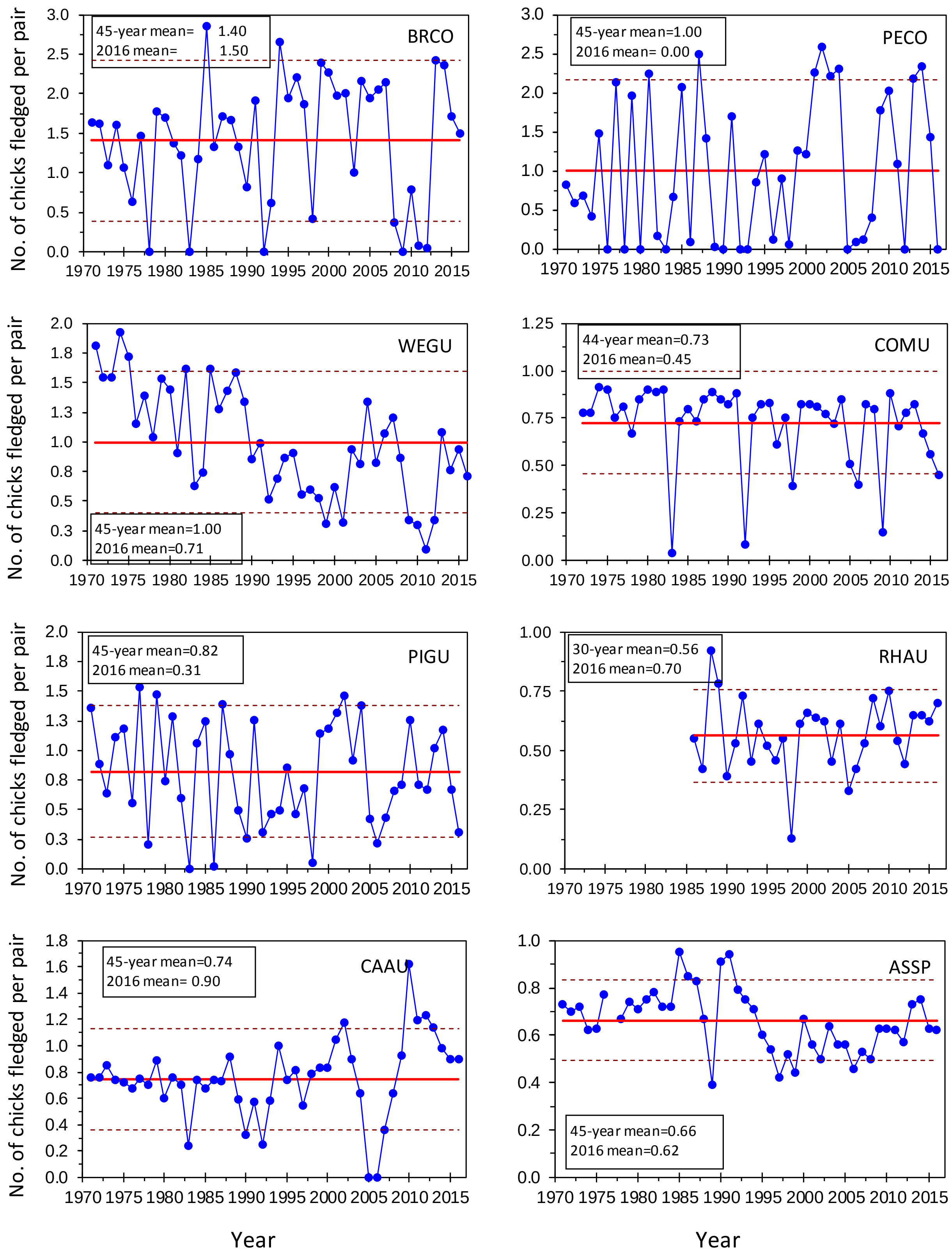


Fig. 1a. Productivity of 8 species of seabirds on Southeast Farallon Island, 1971-2016. Productivity is measured as number of chicks fledged per breeding pair (includes first attempts, relays and second broods). The bold horizontal line indicates mean productivity from all attempts between 1971 and 2015. The dashed lines represent the 80% prediction interval around the long term mean. Please note the different scales on the y-axis.

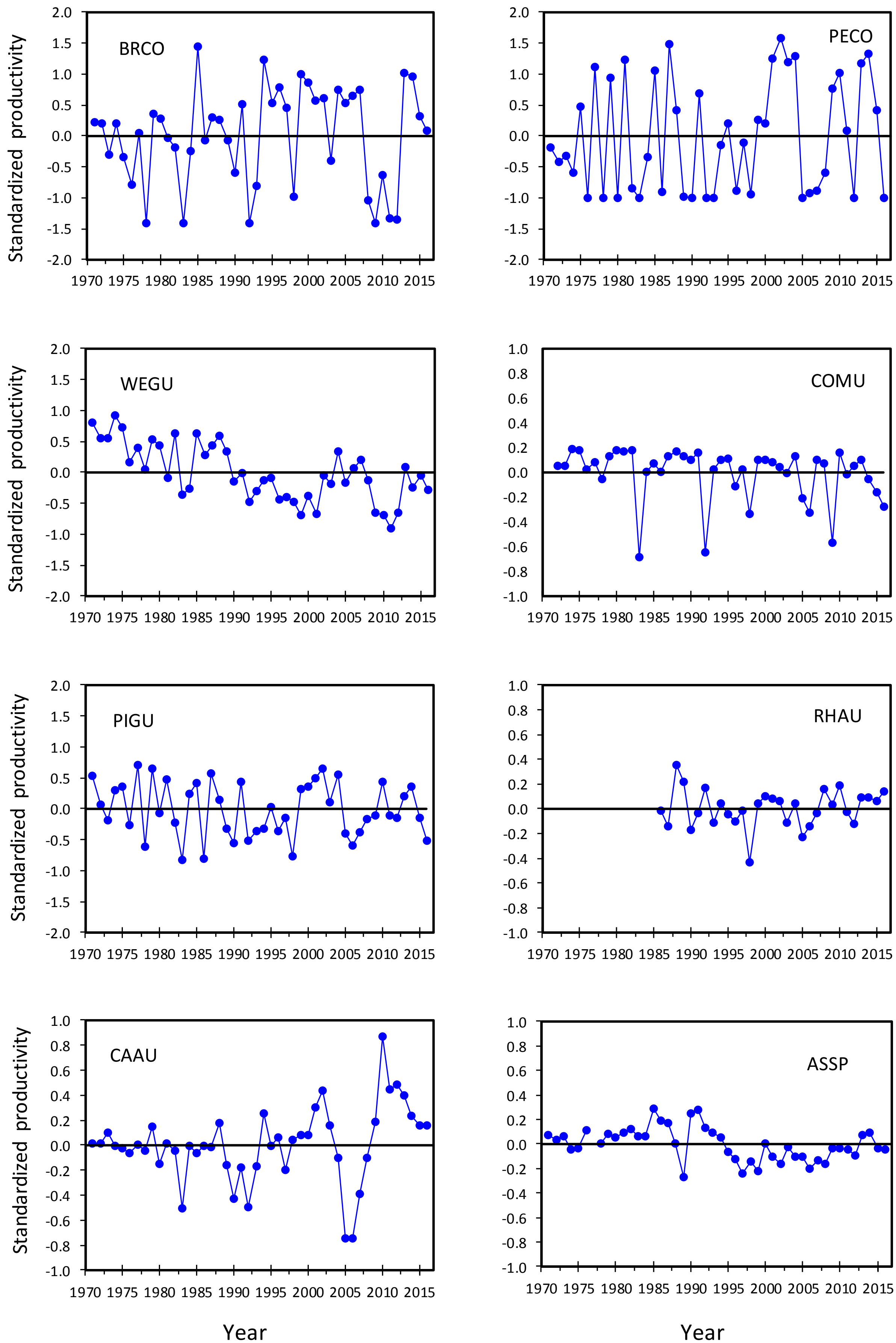


Fig 1b. Standardized productivity anomalies (annual productivity - long term mean) for 8 species of seabirds on SEFI, 1971-2016.

Brandt's Cormorant Census

Date: 6/5/2016 (ground); 6/6/2016 (boat)
Observers: RB, RWB

Total Sites: 2,412

Correction Factor: none

Corrected Total: 2,412

Total Birds: (* 2) = 4,824

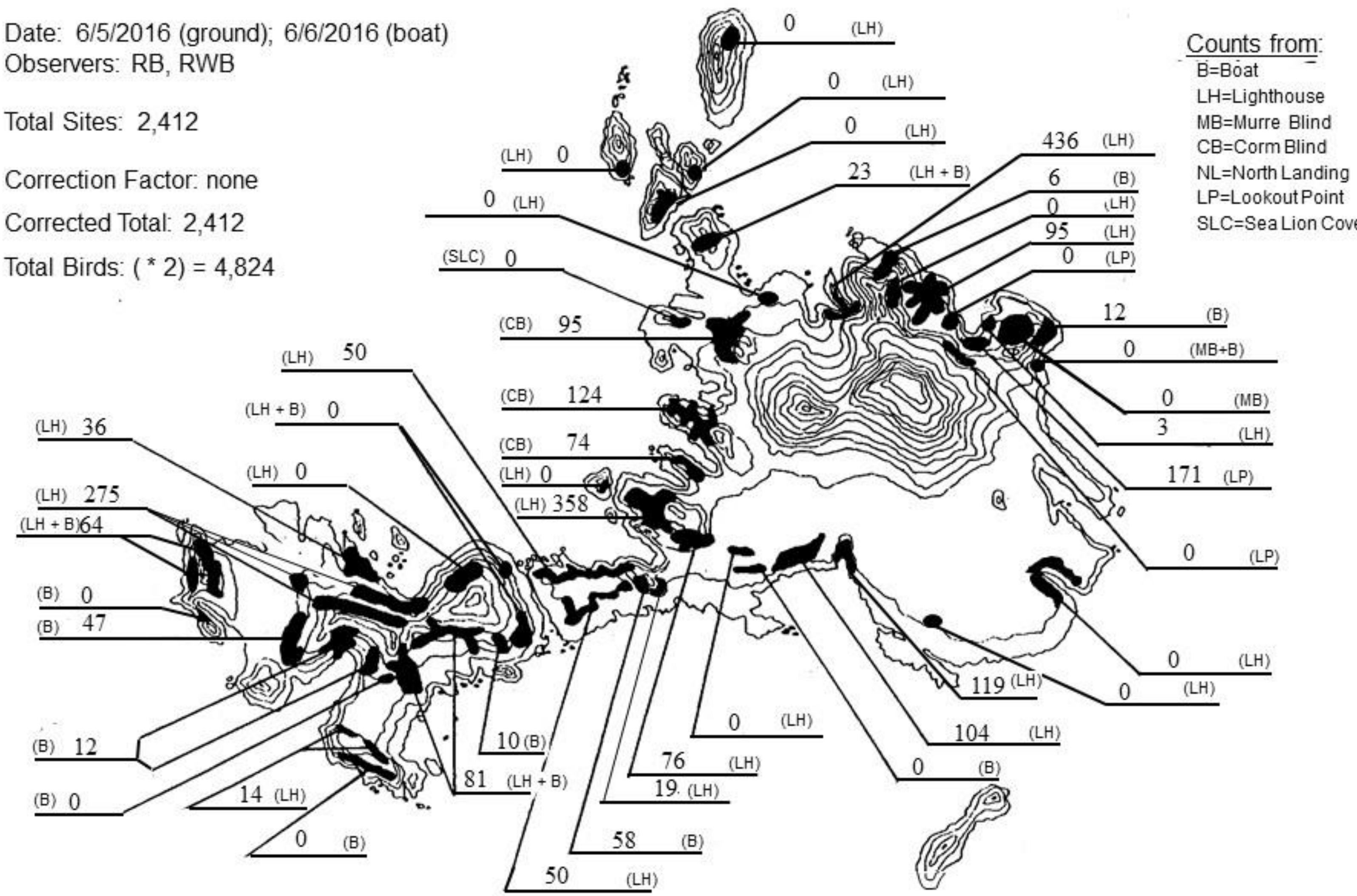


Figure 2: Counts of Brandt's Cormorants on Southeast Farallon Island during the 2016 census. Surveys were conducted from the following locations: Lighthouse Hill (LH), Murre Blind (MB), Cormorant Blind (CB), North Landing (NL), and Boat (B).

Pelagic Cormorant Census

Date: 6/8/2016 (land), 6/6/2016 (boat)
Observers: RB, RWB

Total Sites: 154

Correction Factor: none

Corrected Total: 154

Total Birds: (corrected total * 2) = 308

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

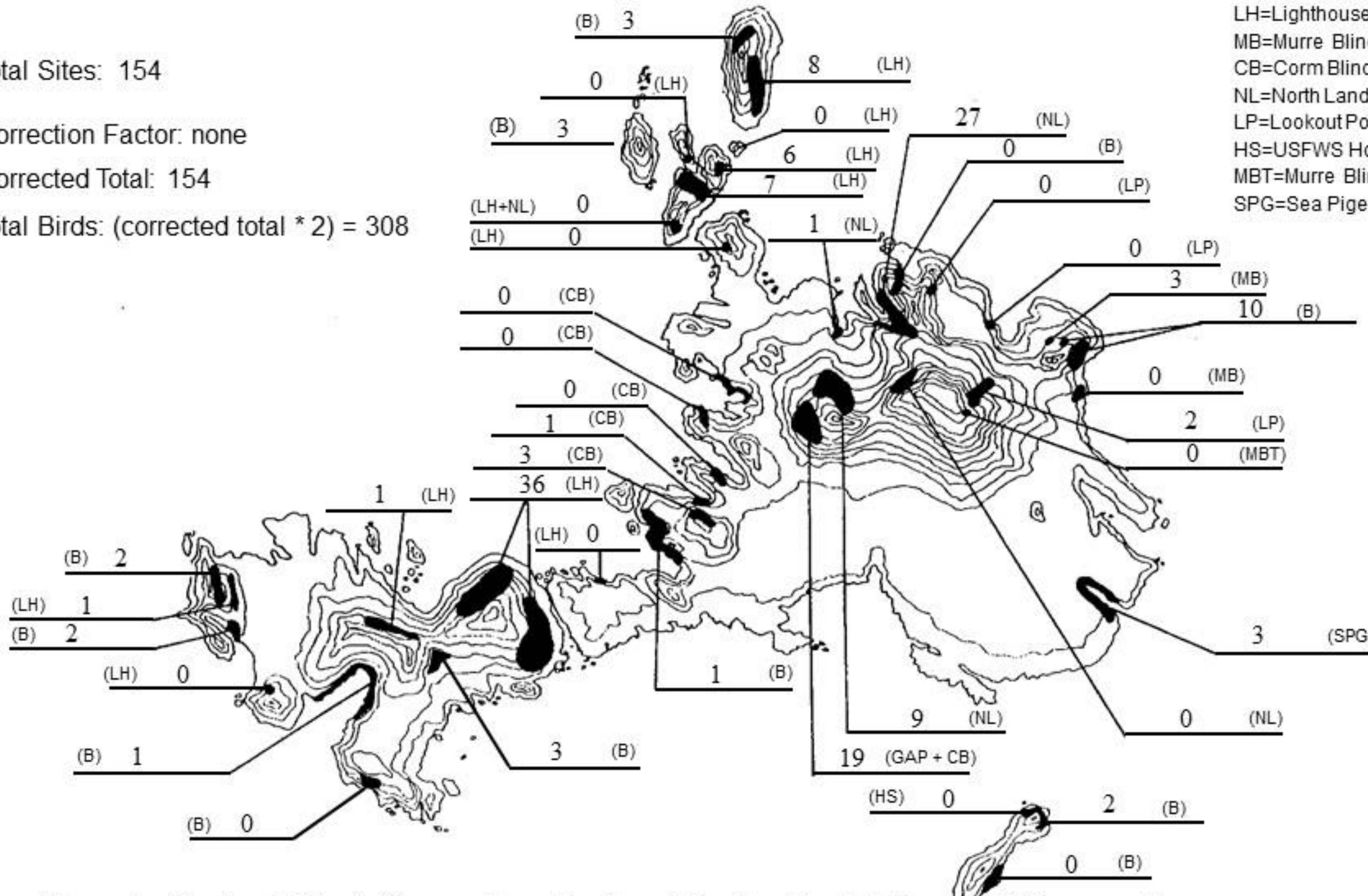


Figure 3: Counts of Pelagic Cormorants on Southeast Farallon Island during the 2016 census. Surveys were conducted from the following locations: Lighthouse Hill (LH), Lookout Point (LP), Murre Blind (MB), Cormorant Blind (CB), North Landing (NL), USFWS House (HS), Murre Blind Trail (MBT), Sea Pigeon Gulch (SPG), and Boat (B).

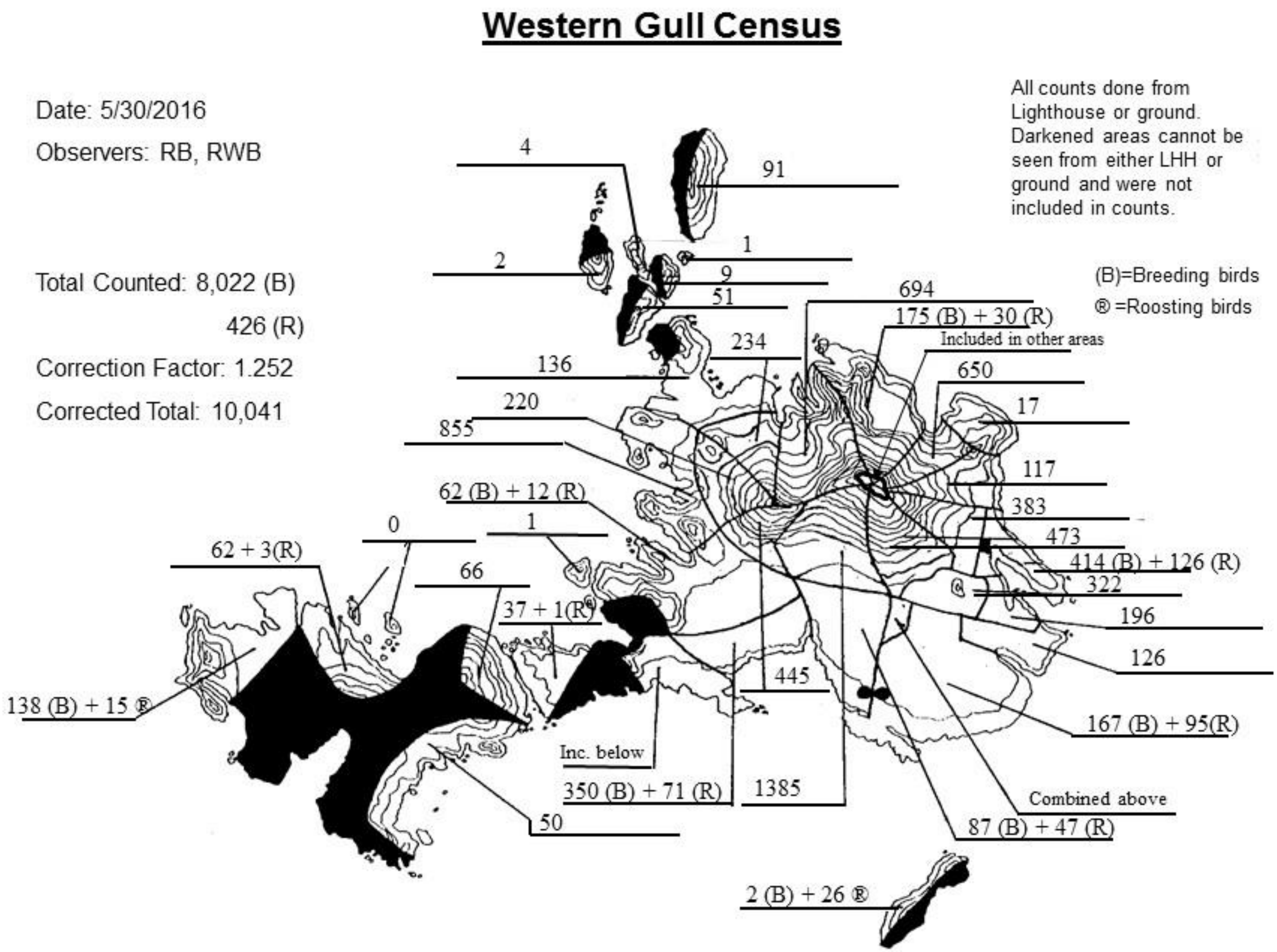


Figure 4: Counts of Western Gulls on Southeast Farallon Island during the 2016 census.

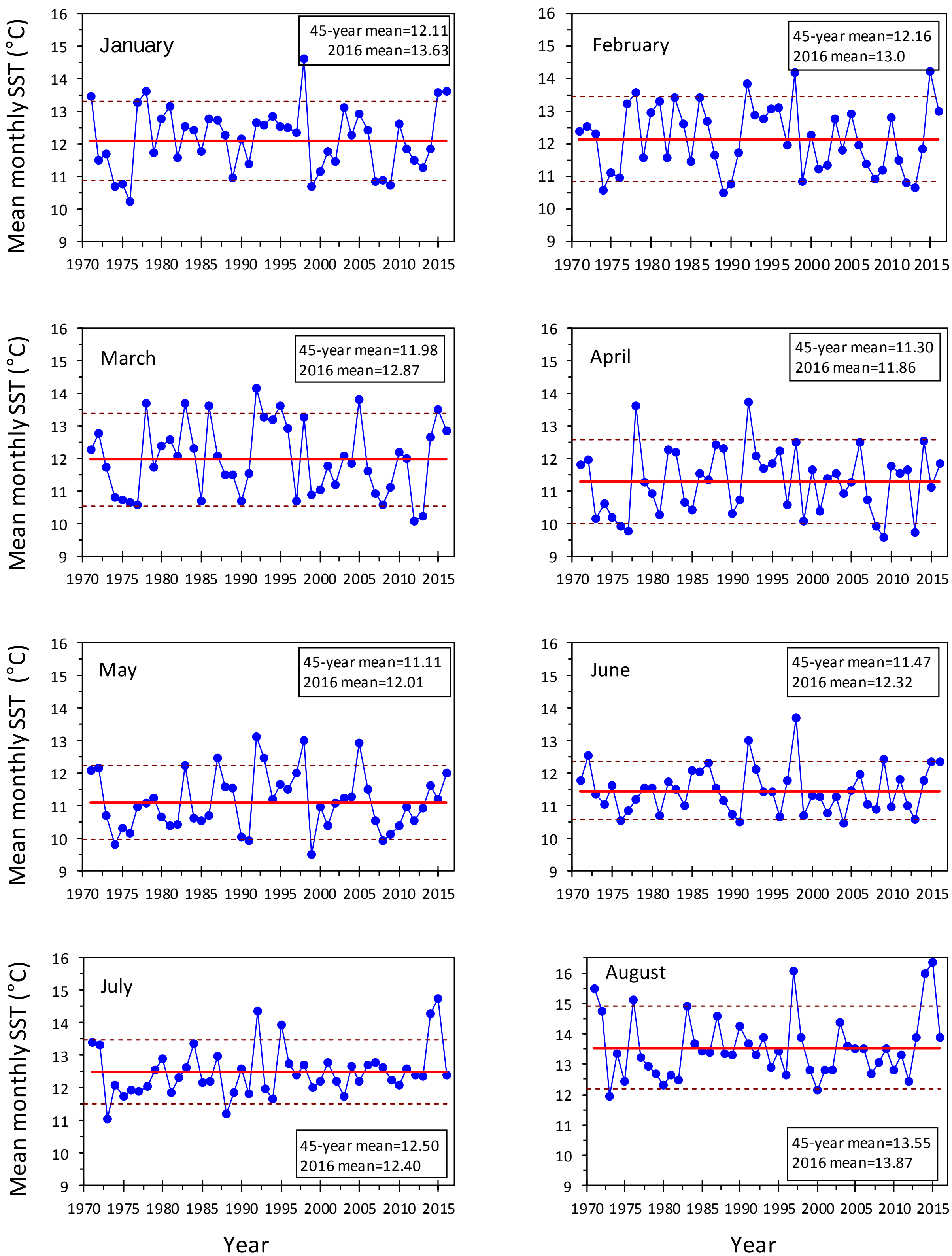


Fig. 6a. Monthly mean sea surface temperature (SST) at Southeast Farallon Island, 1971-2016. SST was measured daily from Water Sample Point, near East Landing. The bold horizontal line indicates mean monthly SST from 1971 to 2015. The dashed lines represent the 80% prediction interval for the long term mean.

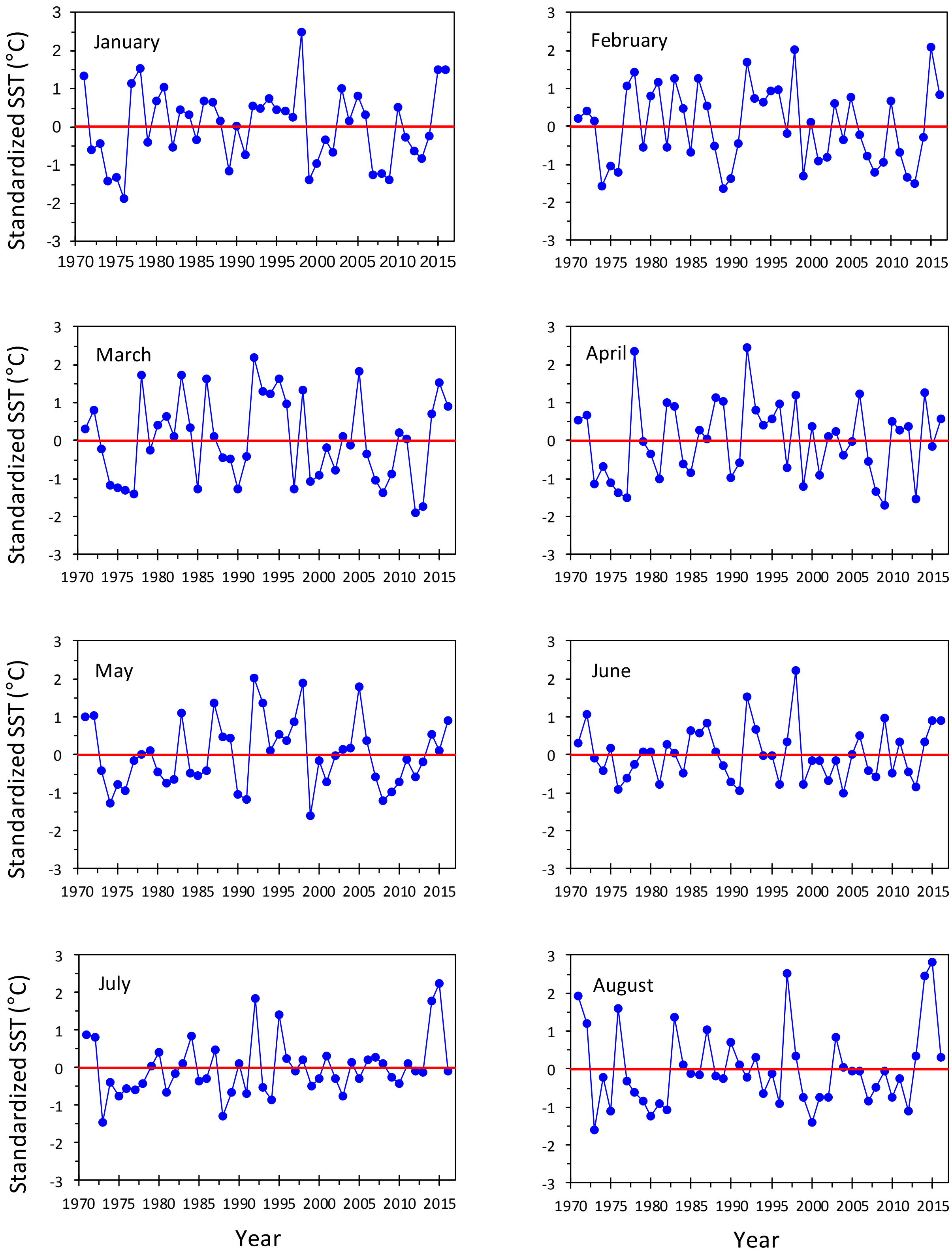


Fig. 6b Standardized Sea Surface Temperature (SST) anomalies (annual mean - long term mean) for SEFI, 1971-2016.

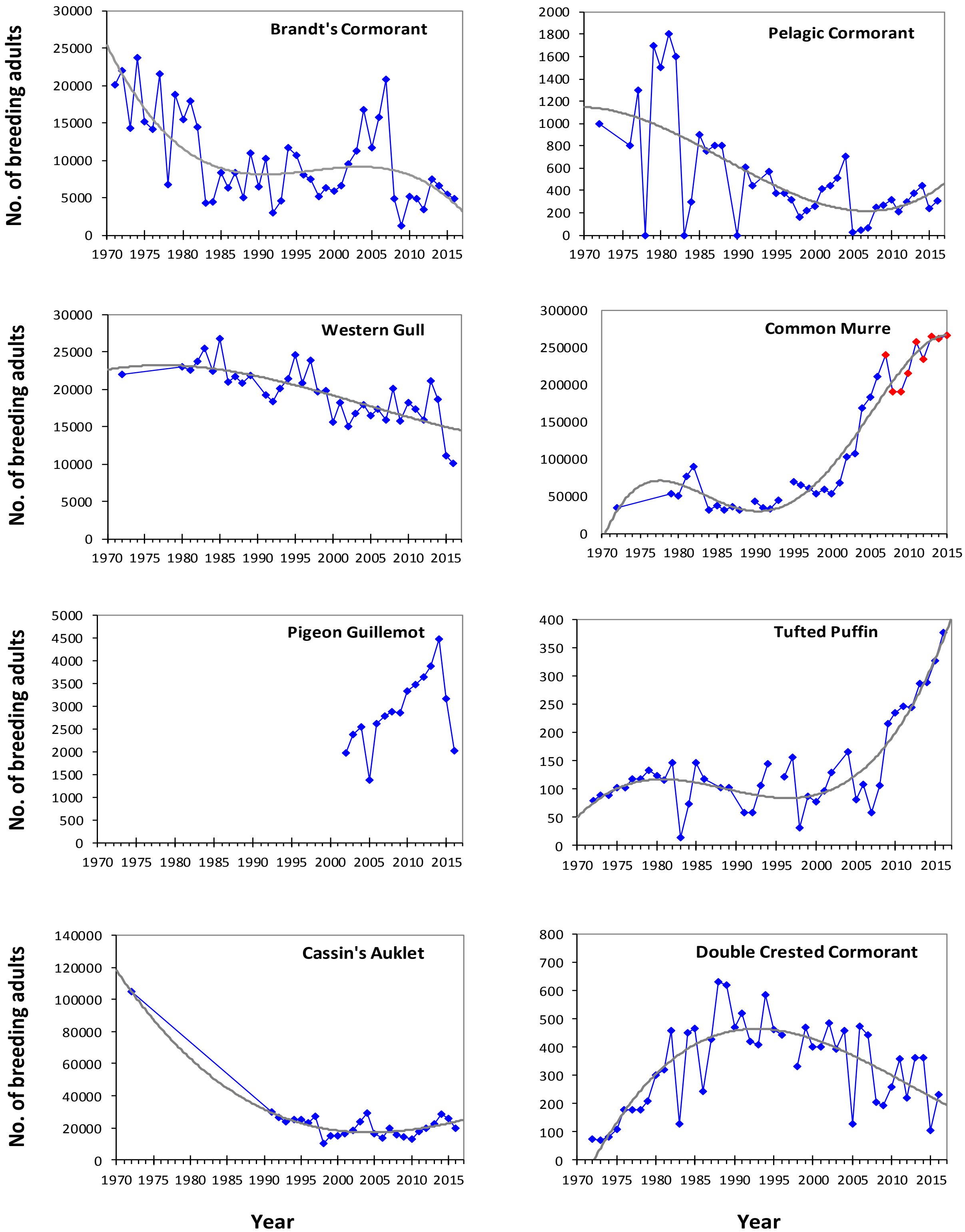


Fig. 7 Population trends for 8 species of seabirds on Southeast Farallon Island, 1972-2016. Populations determined by counting individuals or nests on all visible areas on SEFI and West End. Polynomial trend line (in gray) for each species included to illustrate long term trends. Note the different scales on the Y-axis. PIGU evening raft counts done prior to 2002 are not comparable to current methods and are not displayed. Since 2006, COMU population estimates are based on changes in the index plots (see Fig. 11 and text).

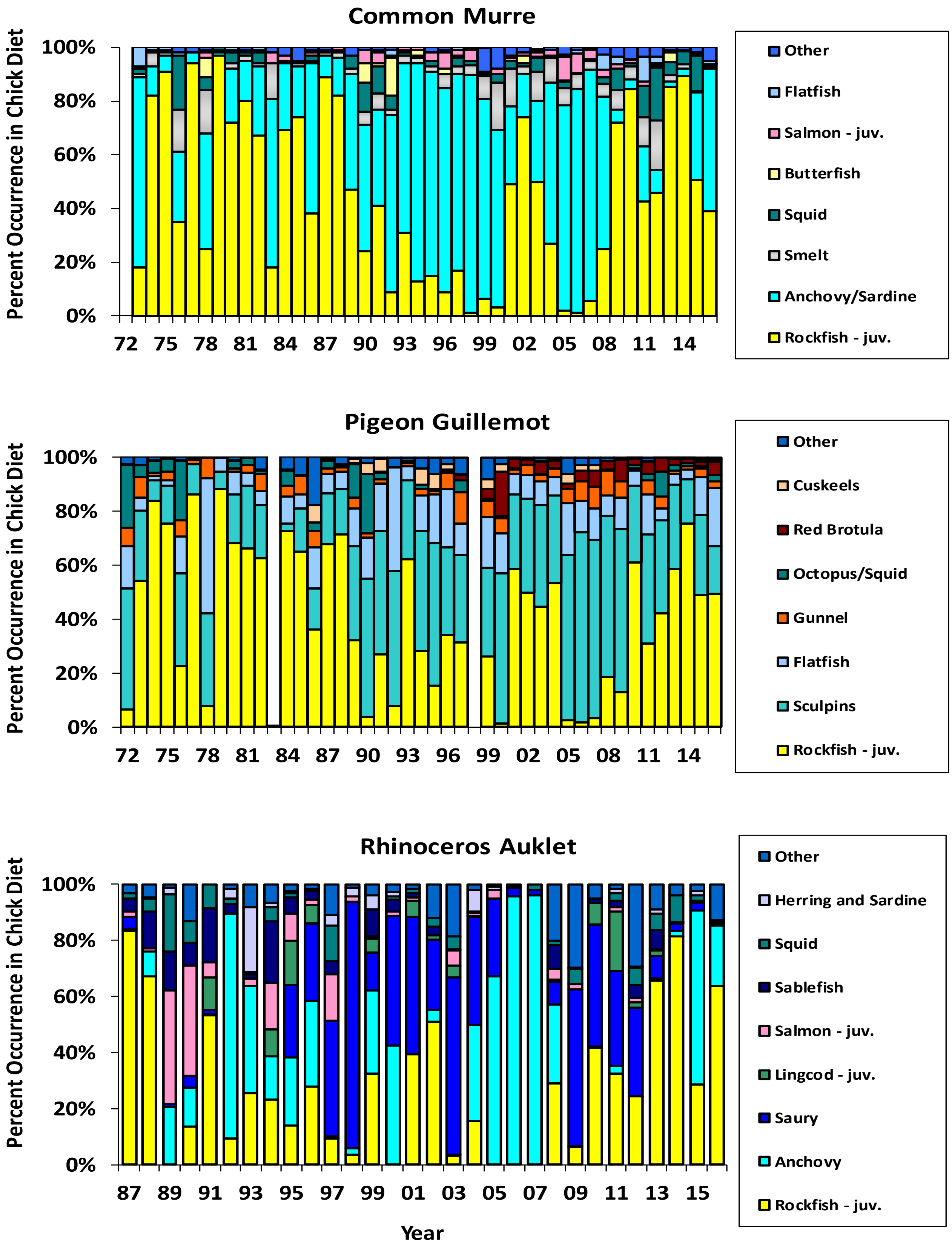


Fig. 8 Percent occurrence of common prey items, by year, in the diet of three species of seabirds on Southeast Farallon Island.

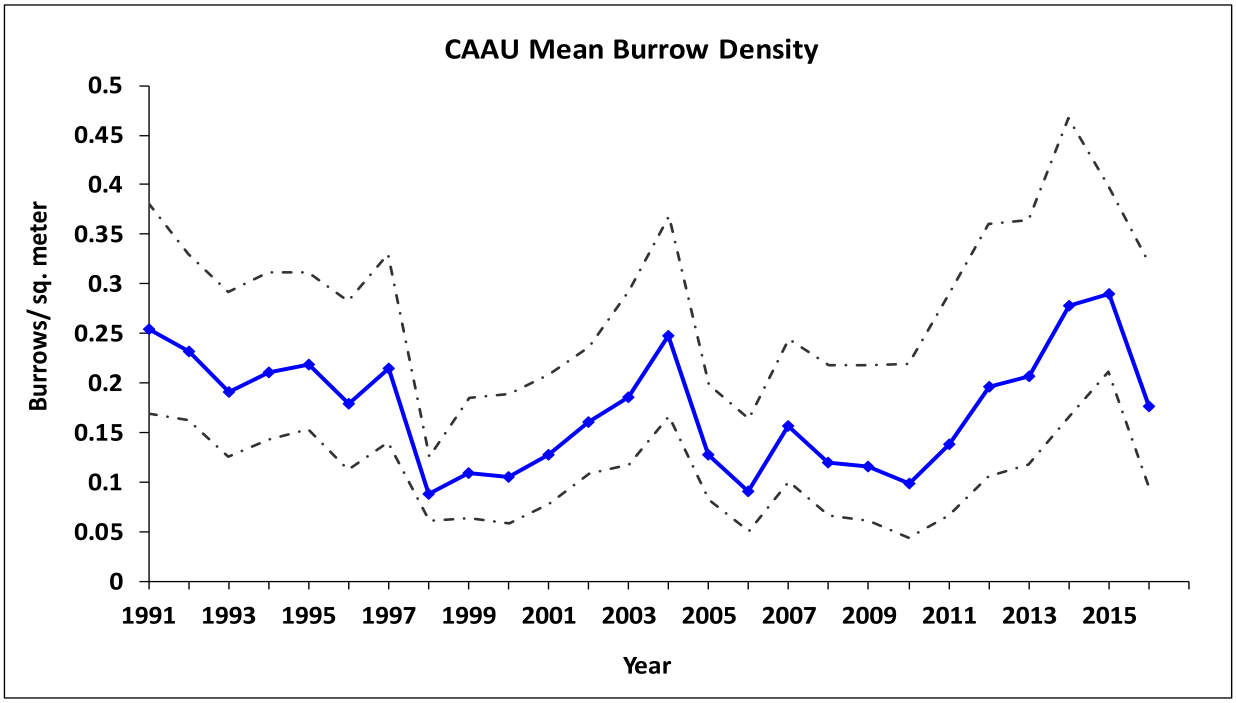


Fig. 9. Geometric mean burrow/crevice density in our 12 Cassin's Auklet Index Plots from 1991 to 2016. The blue line represents the annual mean values. The dashed lines represent the upper and lower bounds of the 95% confidence interval.

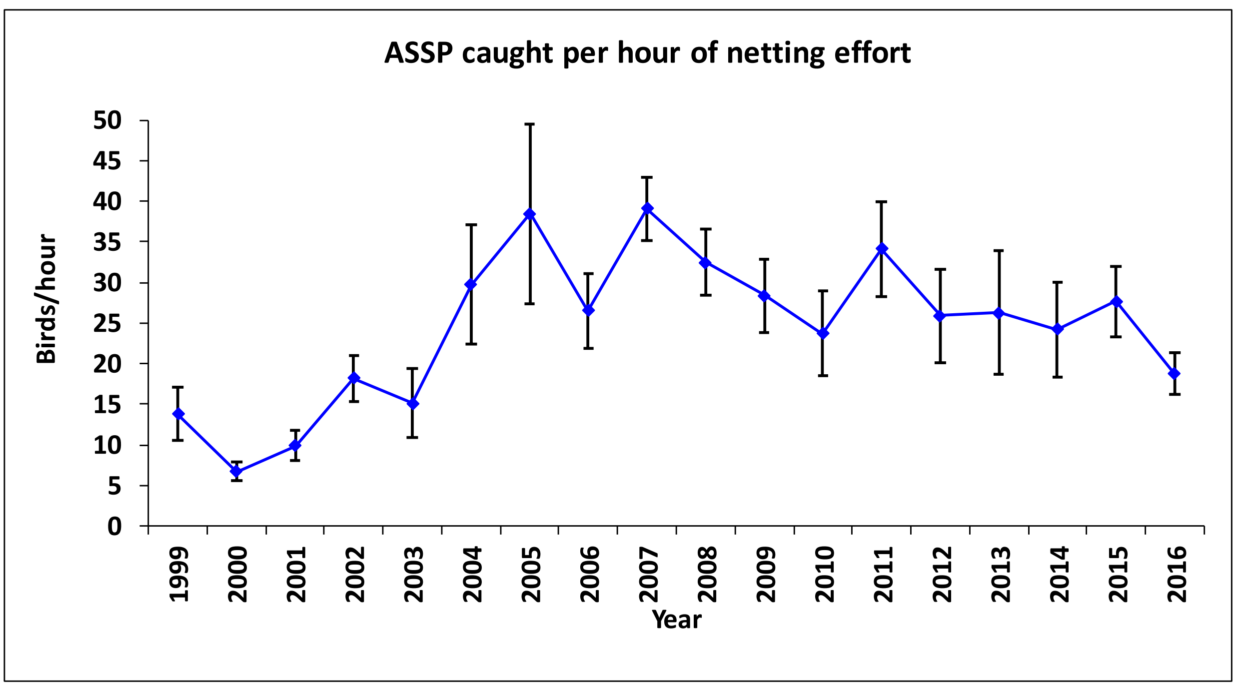


Fig 10. Mean number of Storm-petrels caught per hour of netting effort on SEFI from 1999 to 2016. Error bars represent the standard error for the mean calculated from all capture sessions in a given season.

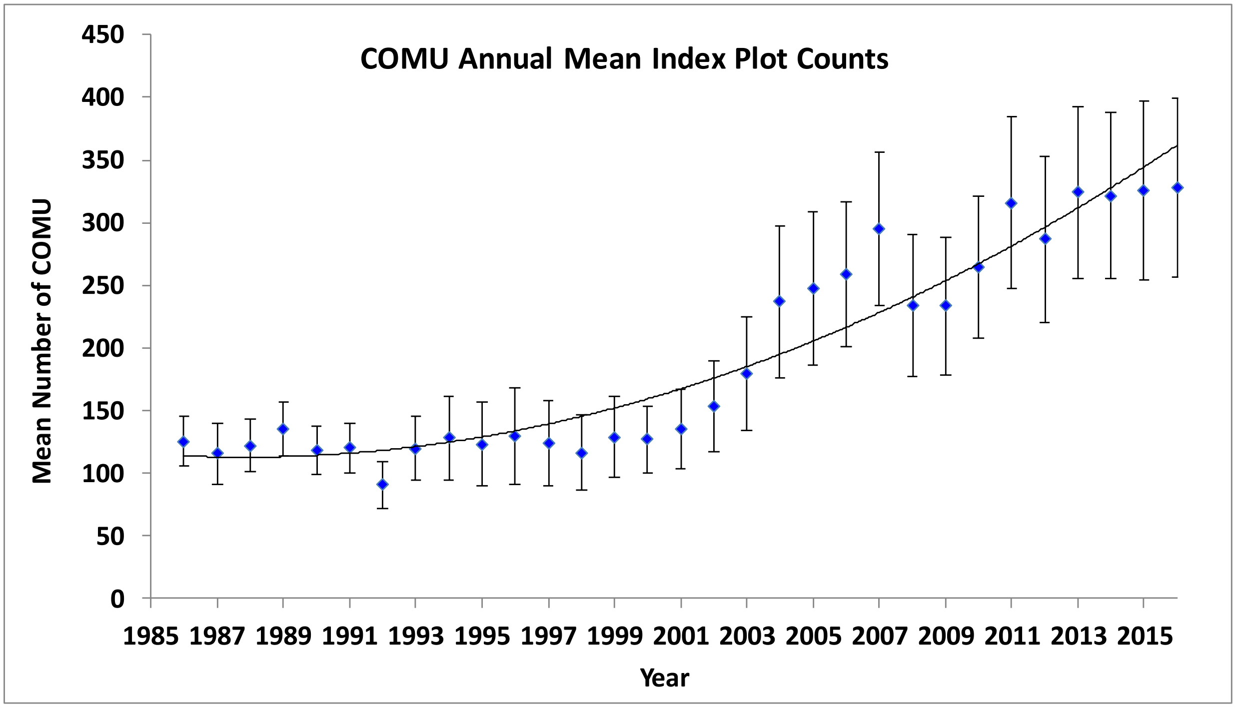


Fig. 11. Mean annual counts for Common Murre Index Plots from 1986 to 2016. Error bars represent the standard error of the mean calculated from all plots counted in any given season.

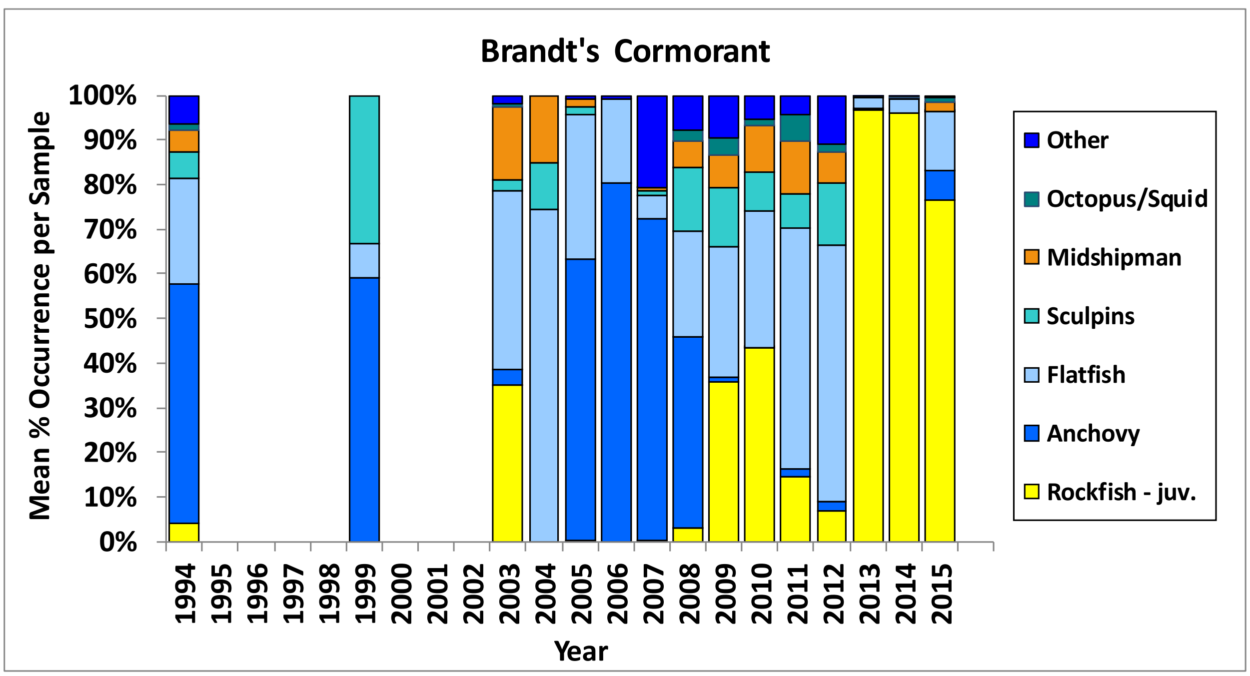


Fig. 12 Mean percent occurrence per sample of common prey items by year in the diet of Brandt's Cormorants on Southeast Farallon Island. Data for 2015 updated from previous report after all pellets analyzed. Pellets for 2016 have been collected and sorted but have not been analyzed as of the writing of this report.

Appendix I. Calculation of correction factor for Western Gull census, 2016.

Area	Nest Count	Bird Count	Correction Factor
C	94	119	1.580
K	96	389	1.049
H (H1 only)	219	183	1.126
Total			**1.252**

Appendix II. 2016. 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
June 1 (1000)	216	272	1.59
June 2 (1000)	216	266	1.62
June 3 (1000)	216	274	1.58
June 4 (1000)	216	267	1.62
Mean	216	270	**1.60**

UU

Date (Time)	Breeding Sites	No. of birds	Correction Factor
June 1 (1000)	107	138	1.55
June 2 (1000)	107	131	1.63
June 3 (1000)	107	133	1.61
June 4 (1000)	107	136	1.57
Mean	107	135	**1.59**

Mean correction factor for SEFI 2016: **1.60**