Point Blue Report

Population size and reproductive performance of seabirds on Southeast Farallon Island, 2015

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

December 2015

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Table of Contents

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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) During 2015, breeding populations decreased for all species except Tufted Puffin, when compared to 2014. The Western Gull breeding population estimate was the lowest observed during our 45 years of monitoring. Pigeon Guillemots, Pelagic Cormorants, Brandt's Cormorants and Cassin's Auklets also exhibited significant declines relative to last season. Double-crested Cormorants had their lowest breeding populations since 1974. In contrast, Tufted Puffins continued to increase, again establishing a new high count.

(3) Reproductive success was lower for most species when compared to 2014, but remained near or above long-term mean values. Common Murres and Pigeon Guillemots were the only species below the long-term mean, while Western Gulls were the only species to have higher success relative to last season. Black Oystercatchers had the lowest productivity and population ever observed for this colony, due primarily to disturbance caused by sea lions.

(4) For the second consecutive year, Cassin's Auklets failed to produce any successful second broods resulting in their lowest productivity in six years. However, a high success rate for first broods resulted in an overall productive season.

(5) In general, the number of birds attempting to breed and their breeding success were both down during 2015 relative to recent years. Chicks generally took longer to grow and fledged a lower weights than in the past few seasons while warm water brought unusual species into the region. These included first island records for Wedge-rumped storm-petrel and Kelp Gull and record numbers of Brown Boobies.

(6) 2015 was characterized by very warm sea-surface temperatures (SST) throughout most of the season. The mean seasonal SST for 2015 was the warmest since 1992 and joins 1992, 1998 and 2014 as the only years in which the seasonal mean was greater than 13°C. While April and May were close to the long-term average, the mean monthly values for both July and August were the highest ever recorded at the Farallones.

(7) Juvenile rockfish (Sebastes spp.), though still an important component of chick diet, was much less abundant than the previous two years and anchovies returned as a major prey item for the first time since 2008. Krill seemed to be abundant prey for seabrirds early but likely dropped out as water temperature increased during the late season.

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 2015. 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 2015. Two pair of Canada Geese bred on the island and fledged one chick.

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 – While BRCO productivity was much lower relative to last season, overall reproductive success during 2015 remained higher than the long-term mean. After suffering very poor reproductive performance from 2008 to 2012, this marks the third consecutive year of above-average reproductive success. Mean productivity for the colony was 1.72 fledglings per pair. This is approximately 27% lower than last season but remains 25% higher than the long-term mean productivity for this species (Fig. 1a). The first eggs were observed on 30 April at the Corm Blind and 5 May at the Sea Lion Cove colony. The mean laying date for the colony was 26 May. While the first eggs were observed approximately 10 days earlier than last season, the mean laying data was equal to 2014 and 9 days later than the long-term mean for this species. There were no incidences of nest abandonment observed this season at any of the 139 sites followed for productivity assessment. There were however 4-6 nests at the Sea Lion Cove colony that were destroyed by the Northern Gannet when it displaced the incubating Brandt's and took over their nests. Mean clutch size was 3.0 eggs per nest and hatching success was 80%. Mean brood size was 2.42 chicks per nest, 69% of which survived to fledging age. While hatching success was actually greater than last season, fledging success was significantly reduced, resulting in overall lower productivity. A total of 323 chicks were banded this season with the last chicks departing the colony by early September.

Pelagic Cormorant **–** Like the Brandt's, PECO also experienced lower, but above average reproductive performance during 2015. Mean productivity for the colony was 1.43 chicks fledged per breeding pair. This is almost 40% lower than during 2014 but still 47% higher than the long-term average for the Farallon colony. Hatching success and fledging success are difficult to determine for this species due to the small number of nests where we can see the entire contents. However, for those we were able to observe, mean clutch size was 3.11 eggs per nest, while brood size was 1.62 chicks per nest. Eggs and/or chicks were observed in 41 of the 93 followed sites and there were an additional 5 sites that had birds in incubation posture for extended periods. These were likely breeding sites, but it was not possible to confirm the presence of eggs or chicks. Birds began attending sites and building nests in March, but the first eggs were not observed until 15 May. The first chicks were observed on 2 July and the last chicks had fledged and departed the colony by September 1. Twelve nests were abandoned during 2015.

Western Gull **–** WEGU productivity increased in 2015 when compared to last season, resulting in an average of 0.94 chicks per pair. This is approximately 24% greater than last season but still 7% below the long-term mean productivity for this species (Fig. 1a). The first eggs were observed on the island on April 26th and in study plots on May 1st. Sixty percent of the eggs hatched and 55% of those chicks survived to fledge. Mean clutch size was 2.63 eggs per nest and mean brood size was 1.63 chicks per nest. There were 470 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 2015. 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 and hatch chicks but no chicks survived to fledging.

Productivity for this species remains very low due to high rates of predation by the larger and more aggressive Western Gulls.

Black Oystercatcher **–** A total of 38 sites were monitored in 2015, of which 19 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 10 of these sites (53%) but only 1 chick appeared to fledge this season. This resulted in an all-time low estimate of 0.05 fledglings produced per pair. Both the number of breeding sites and the total number of chicks produced were lower than the previous record low observed during 2014, making 2015 the lowest productivity observed for this species since we began keeping records in 1997. Unusually large numbers of California Sea Lions hauling out high on the marine terrace and other traditional oystercatcher nesting areas likely contributed to the extremely poor breeding success observed this year. The first eggs were observed on May 9th and the first chicks on June 6th. 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 2015, 275 Common Murre sites were monitored daily in the Upper Shubrick Point (USP) study plot, of which 243 were breeding sites (where an egg was laid). Productivity was 0.56 chicks fledged per pair. This is approximately 16% lower than last season and 23% below the long-term average of 0.73 (Fig. 1a). Egg laying was later than average with the first egg not observed in this plot until 10 May. Overall mean laying date for the plot was 21 May; approximately one week later than the long-term mean laying date for this colony. Hatching success was low with only 79% of eggs hatching and only 70% of the hatched chicks survived to fledge.

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 14th this season but the mean lay date for the plot was 22 May. There were a total of 146 sites monitored this season (up 8 from 2014); 109 of which were breeding sites. Reproductive success for this colony was higher than USP in 2015 with 0.82 chicks fledged per breeding pair. Eighty-seven percent of the eggs hatched and 94% 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 97 sites were monitored during 2015, of which 80 were observed with at least one egg (82% of the total number of sites). The majority of nest sites were located on Lighthouse Hill or at Garbage Gulch, but there were also two sites in the

Habitat Sculpture, five in Rhinoceros Auklet nest boxes and one in a Cassin's Auklet nest box. Productivity for 2015 was 0.68 fledglings produced per pair (Table 1). This was approximately 42% lower than 2014 and 17% below the long-term mean productivity for this species (Fig. 1a). The first eggs were observed on 27 May, and the mean egg laying date was 5 June. This is approximately 5 days later than the long-term mean laying date for this species. Egg laying was also extremely synchronous this year with 72% of all eggs laid between 1 and 6 June. The mean clutch size was 1.86 eggs per nest with 78% of those eggs hatching successfully. Mean brood size was 1.53 chicks per nest but only 45% of the chicks produced survived to fledging age. There were only 2 sites which were able to fledge a complete brood of two chicks (down from 29 sites in 2014) and 29 sites which were not able to fledge any chicks. Two sites failed when the nest boxes were crushed by California sea lions that were hauled out exceptionally high at Garbage Gulch. There were a total of 59 guillemot chicks banded on SEFI this season with the last chick fledging from a followed site on September 9.

Rhinoceros Auklet – There were a total of 145 sites (boxes, crevices, and cave sites) monitored in 2015, 54% (n=79) of which were occupied by a breeding pair. This includes three Rhinoceros auklets which bred in Cassin's Auklet nest boxes. Forty-nine percent of nest boxes were occupied compared to 62% of camera sites. There were also 12 boxes occupied by other species (7 CAAU and 5 PIGU). Productivity during 2015 was 0.62 fledglings per pair. This is approximately 5% lower than the productivity observed in 2014 but still 11% above the long-term mean productivity for this species (Fig. 1a). The first eggs were observed on 16 April. Sixty-nine percent of the eggs successfully hatched and 92% of those chicks produced survived to fledge. There were a total of 26 rhinoceros auklet chicks banded this season with the last chick fledging from a followed site on August 19th.

Cassin's Auklet – Occupancy of breeding birds in study boxes was high during 2015 with 80% of the boxes (382 of 478) occupied this season, including 42 of 44 PRBO study boxes (98%). This is approximately 10% lower than in 2014 but remains among the top 5 years for nest box occupancy in the time series. Similarly, productivity of auklets breeding in PRBO study boxes was reduced compared to the last several seasons with 0.90 chicks fledged per breeding pair (including relay attempts). While this was down 8% when compared to 2014, it remains 22% greater than the long-term average of 0.74 chicks per pair for this species (Fig. 1a). Ninety percent of the eggs hatched and 97% of those chicks produced survived to fledge. There were no second broods attempted this season for the first time since 2007. The first egg was observed on 11 April and the mean laying date for PRBO boxes was 24 April. This was approximately 2 weeks later than last season and 10 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 0.84 chicks per pair (n=170). This is approximately 7% lower than the estimate derived from PRBO boxes and 2% lower than the "all sites" estimate for 2014. Island wide, there were a total of 305 chicks banded with the last chick fledging from a followed site on September 10th.

Ashy Storm-Petrel – ASSP pairs laid eggs in 41% of the 98 followed sites (n=40) in 2015, approximately 3% higher than the occupancy rate observed last season. Four of these 40 sites were new breeding sites discovered during 2015. There were an additional 9 sites in which an adult bird was observed on at least two occasions but no eggs or chicks were ever confirmed, bringing the total occupancy rate up to 50%. 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 0.63 chicks fledged per pair (including all relay attempts). This is approximately 16% lower than last season and 5% below the long-term average productivity for this species (Fig. 1a). After two straight years of very strong reproductive performance, the decline observed this season brings Ashy productivity back to the level observed between 2009 and 2011.

Other breeders – In past seasons, Peregrine Falcons, Common Ravens and Canada Geese have bred on SEFI during the seabird season. However, during 2015, it appears that only the Canada Geese attempted to breed. Three pairs of Canada Geese were present on the island by mid-March and two of those pairs nested on the Marine Terrace. The first nest was discovered on the terrace in front of the Coast Guard House on 26 March with 7 eggs. The second was discovered on the East Terrace by the old fog horn on 2 April with 3 eggs. On 23 April the first nest had hatched one chick while the other 6 eggs in the clutch were abandoned. The second nest was destroyed by large numbers of California sea lions which began hauling out high on land. One almost adult sized gosling was frequently seen accompanying the adults and was seen flying for the first time on 4 July. The gosling was gone by 27 July and is assumed to have fledged. All geese departed the island by the beginning of March. 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. Common Ravens were not observed at the island this season and there was no evidence of nesting.

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 8 evenings between April and August. As a result, we banded a total of 570 Ashy storm-petrels and recaptured 64 that had been banded in previous years. In addition, there were 23 ASSP and 1 LHSP banded this season that were recaptured later in the season. The mean standardized capture rate during 2015 netting sessions was 27.66 birds per hour (s.e. = 4.4, n= 8; see Figure 10). This is approximately 14% higher than during 2014 but remains 10% lower than the mean capture rate for the last 10 years. We captured 121 birds during our two most productive netting sessions on 9 June at Lighthouse Hill and 9 July at the Carp Shop. There were also 10 new Leach's storm-petrels and 2 Fork-tailed storm-petrels banded this season. In addition, we captured 2 wedge-rumped storm-petrels, one on Lighthouse Hill on 19 April and a second, different, individual on 20 May at the Carp Shop. These represented the first two records for the Farallones of this extremely rare, southern hemisphere species.

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 20 counts were made in 2014, beginning on 26 April and ending on 4 August, when juveniles became indistinguishable from adults. On 10 June we counted a peak number of 52 "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 104 breeding birds. This estimate is approximately 71% lower than 2014 and 66% above the 10-year average population for this species (Table 2). This was the lowest count since 1974. There was a high count of 17 chicks observed during the 20 July census.

Brandt's Cormorant – The BRCO breeding population was censused during a boat-based survey on 1 June and a ground-based surveys on 10 June. The boat census was conducted a little earlier than the ground census this season to take advantage of a good weather window and covers approximately 16% of the Brandt's breeding habitat that is not visible from vantage points on SEFI. During the survey we counted 2,736 "well-built" nests (Fig. 2). We then multiplied the number of nests by 2 to yield an overall population estimate of 5,472 breeding birds (Table 2). This estimate is 17% lower than 2014 and approximately 33% below the 10-year average (Table 2). This was the second 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 4,705 fledglings.

Pelagic Cormorant – The PECO breeding population was censused during a boat-based survey on 1 June and a ground-based survey on 10 June. During the census, we counted a total of 117 fair to well-built nests (Fig. 3). We then multiplied this number by 2 to yield an overall breeding population of 234 birds (Table 2). This estimate for Pelagic Cormorants is approximately 46% lower than 2014, but just 2% lower than the 10-year average. We multiplied the total number of nests by the mean productivity to estimate an island-wide production of approximately 167 fledglings.

Western Gull – The WEGU census was conducted on 7 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 was 10,366 (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 number of adults present in the plots during the census. We then multiplied the average correction factor (1.077) of these three plots by the total number of adults counted, to arrive at our population estimate (Appendix I). Therefore, we estimated a breeding population of 11,164 birds (Table 2). The population estimate for WEGU was the lowest since regular censuses were initiated in 1972. It is approximately 40% lower than in 2014 and 44% lower than the 10-year average (Table 2). Of note, the raw count was only 9% lower than last year, but the correction factor was 34% lower. There were actually more birds present in the study plots when the survey was conducted, but fewer nests, suggesting that both mates were present at the time of the survey and leading to a lower correction factor. 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 5,247 fledglings on SEFI in 2015.

California Gull – CAGU were censused every five days throughout the season beginning on 1 April. A peak count of 92 "well-built" nests was counted on 22 May resulting in a breeding population estimate of 184 birds. This estimate is approximately 64% lower than the estimate for last season and 47% lower than the 7 year mean for this population. The peak count for total birds was 222 on 11 May, down from a peak count of 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.

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, 19 were considered active sites. Therefore, we estimated a breeding population of 38 birds, a decrease of 7% relative to 2014 and approximately 3% lower than the 10-year average population. We estimated an island wide production of 1 chicks fledged. This estimate does not reflect birds 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 2014 (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 1.62. 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.

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 3,157 birds on 6 April. This count was approximately 29% lower than the peak count from 2014 and roughly equivalent to the 10 year mean for morning surveys (Table 2 and Fig. 7). It is worth noting that the counts began to build in early April but quickly declined to only a few hundred present by the end of the month.

Tufted Puffin – The island-wide TUPU survey was conducted primarily in two parts; from 6 to 16 June and a second survey from 1 to 11 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 2015 surveys, a total of 163 active sites were observed, 6 of which were confirmed to have chicks based on observations of birds delivering fish to the site, while an additional 45 sites were observed with likely prey deliveries. Based on these observations, we estimated a breeding population of 326 birds (Table 2). This estimate is 13% greater than during 2014 and 64% greater than the 10 year average population for this species. It also represents the new all-time high count in our time series (Fig. 7).

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 2015. A total of 66 new birds were banded and 74 were recaptured (18 birds were recaptured multiple times during the season and 6 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 2015, we counted a total of 397 burrows/crevices in the index plots, a greater than 10% decline compared to 2014 but still the second highest burrow count since index plots were established in 1991. Therefore, using the same methodology, but with the updated whole island estimate generated in 2009, we estimated a 2015 breeding population of roughly 25,606 birds ([397/225] x 14512) on

Southeast Farallon Island. Total island-wide production (number of breeding pairs x mean productivity) was estimated at 11,523 fledglings on SEFI. The breeding population estimate is approximately 10% lower than in 2014 but remains approximately 41% greater than the 10-year average (Table 2). It should be noted that the greatest decline in burrow density occurred in those areas 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 2015, the mean seasonal SST from March to August was 13.22°C. This was only 0.6°C warmer than the 2014 season but 1.29°C warmer than the long-term mean for these months. This season joins only 1992, 1998 and 2014 as years in which the seasonal mean SST exceeded 13°C. Likewise, monthly values were above the mean for all individual months except April (Fig. 6a, b), with the highest values ever experienced for the months of February (14.25°C), July (14.76°C) and August (16.36°C), and exceptionally warm SST values recorded for January, March and June (Fig. 6a).

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 2015, 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, 51% for Common Murres, 29% for Rhinoceros Auklets, and 73% for Brandt's Cormorants. For all species, this represents a significant reduction in the proportion of rockfish observed in the diet when compared to the last two seasons but is roughly equal to what was observed in 2012. As was seen during 2014, the vast majority of the juvenile rockfish that were identified to species (80%) 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 contrast to the last several seasons, anchovies were a significant portion of the diet for Common Murres and Rhinoceros Auklets during 2015. Anchovy accounted for 33% of the diet for Common Murres and 62% of the Rhinoceros Auklet diet (Fig. 8). Anchovy were also present (~1.5%) in Brandt's Cormorant diet (Fig 12) and a few were even observed in Pigeon Guillemot diet. While anchovy is an unusual prey item for guillemots, almost all of the anchovy observed this season was on the same day in July, suggesting they were taking advantage of a school that happened to be close to the island that day. Sculpins, lingcod, saury, smelt, octopus 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 during April, May and June but dropped out of the diet during July and August, coinciding with warmer water and breeding effort.

DISCUSSION

Weather and Ocean Conditions

El Niño conditions began developing in our region towards the end of 2014 and carried over into 2015. Locally, oceanic conditions were generally very warm during 2015. Warmer than average water was present in the region around the island throughout the winter and reached record highs by July. 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). Unseasonably warm and calm weather patterns during January through March allowed water temperatures to rise and led to a later start to the seabird breeding season. However, strong northwesterly winds returned to the region in mid-April, leading to closer to average SST and a period of strong upwelling that resulted in a visible pulse of primary productivity. Average SST persisted through April and May before warming again in June. This relatively brief period of apparently favorable conditions was likely the reason that seabirds achieved moderate breeding success despite the strong El Niño conditions.

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. While the proportion of juvenile rockfish in the diet was reduced this season when compared to the previous two years, it still comprised the majority of the prey items delivered to dependent chicks. 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 but there were still enough rockfish available to prevent it from being a poor year. This suggests that foraging adults had more difficulty locating prey this season and that they needed to make longer foraging trips when provisioning dependent offspring. It is worth noting that the proportion of rockfish in the diet declined as the season went on and water temperatures increased. For example, while rockfish comprised greater than 75% of the murre diet in June, it declined to less than 50% by early July and was absent by mid-July when diet watches ended. Similarly, rockfish comprised almost 90% of the Rhinoceros Auklet diet during the first netting session in June but only 9% for the last three netting sessions in July. This suggests that while rockfish may have been abundant early in the season, their numbers may have declined or their distribution changed as the season progressed, making them unavailable to the birds.

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 was once again a major component during 2015. Cormorant pellets were collected from breeding colonies in August and are currently being analyzed. Figure 12 depicts the recent trends in Brandt's Cormorant diet, including preliminary results from a subsample of pellets collected during 2015. Note that cormorant diet during 2015 continued to be dominated by juvenile rockfishes, but that flatfishes, anchovies and squid were more frequent than in the past two seasons.

Productivity

The 2015 seabird breeding season was an average to slightly above average year for most species (Fig. 1a, b). While all species except Western Gulls experienced lower breeding success in 2015 relative to the last two seasons, overall productivity was close to the long-term averages. Brandt's Cormorants, Pelagic Cormorants, Rhinoceros Auklets and Cassin's Auklets all exhibited higher than average breeding success during 2015 while productivity for Western Gulls, Pigeon Guillemots and Ashy Storm-petrels was only slightly below the long-term mean. Common Murres exhibited low breeding success with a decline both relative to last season and well below the long-term mean. Black Oystercatchers also had very poor reproductive success in 2015 with only 1 chick fledged. This is the fewest number of chicks produced in the 19 years we have been following oystercatcher breeding success, even worse than the previous all-time low of 4 set just last season. 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. While, Brandt's Cormorant, Pelagic Cormorant and Cassin's Auklets have exceeded the upper prediction interval several times in the last 5 years, all species were comfortably within the prediction interval this season (Fig. 1a).

Cassin's Auklets continued to exhibit relatively high productivity despite an 8% decline relative to 2014. There were no second broods even attempted this season, meaning that all productivity was the result of first brood success. As was the case in 2014, this suggests that conditions were good enough during the spring and early summer to allow for successful chick rearing, but declined later in the season. Most high productivity years are driven by high rates of successful second broods, but that was not the case this season. 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). While there were no successful second broods during 2014 either, the 2015 season was the first time since 2007 that no followed birds even attempted a second brood.

Reproductive success of COMU was also much lower than 2014 and well below the long-term mean for this species. The reasons for this decline were two-fold. Hatching success was lower than average in all plots except Upper Upper with only 78% of the eggs hatching. This is approximately 6% 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, resulting in an unusually low fledging success. Colony wide fledging success was only 73% with USP only fledging 70% of their chicks. In contrast, the UU colony, where predation was not an issue this year, had high fledging success with 94% 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. The reasons for the lower hatching success are unclear, but may be related to the unusually warm water conditions that murres experienced during the winter. If food resources were less abundant during the pre-breeding period then perhaps females were in poorer condition resulting in lower quality eggs. Early during chick rearing, murres seemed to thrive on a high abundance of juvenile rockfish but feeding rates were lower than in the last three seasons and rockfish became less abundant in the diet as the season progressed. Similar to last season, but unlike most seasons, the USP study plot did not have the highest productivity of the four study plots followed on the island. The Upper Upper plot had higher success in 2015 (see Table 1). There was a lower proportion of eggs that failed to hatch and no losses from Western Gull predation; something very unusual for this plot, especially considering the higher than normal rate of predation in the other plots. It is also worth noting that during September and October, abnormally high numbers of recently fledged murres were found dead on area beaches. It is likely that although these chicks fledged from the colony, foraging conditions were poor during the post-fledging period, resulting in starvation for these inexperienced birds. This will likely result in a less productive cohort than the productivity data would otherwise suggest.

Rhinoceros Auklets exhibited higher than average breeding success for the sixth time in the last eight years and were only slightly lower than the productivity observed last season. As with other species, Rhino chicks took a longer time to fledge, grew at a slower rate and fledged at lower weights than in previous years but overall productivity remained strong. The overall productive year was likely buoyed by the abundance of juvenile rockfishes early in the season and the return of anchovies to the diet later in the year. In contrast, Pigeon Guillemot productivity declined below the mean due in large part to the poor fledging success for 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 2015, only 2 out of 68 sites which fledged chicks were able to fledge both chicks (~3%). In contrast, almost 40% (29 out of 73) of sites were able to fledge both chicks in 2014. Furthermore, many close to fledging or recently fledged chicks were found dead outside their crevices this season. These chicks were likely either attempting to fledge or wandering outside their crevices in search of food during daylight hours and were killed by Western Gulls. This pattern of mortality is unusual and typically only observed when the chicks are food stressed. This coupled with slower feeding rates than the past few seasons and the low survival rate of second chicks suggest that it was more difficult for foraging guillemots to locate prey this season. 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 and Pelagic Cormorants both experienced lower reproductive success this season compared to 2014, averaging fewer than 2 chicks per pair but still achieved above average overall productivity. Fewer birds attempted to breed and both hatching and fledging success were reduced. Surprisingly, nest abandonment was not a large issue this season. In the past several years, even those with ultimately high productivity, cormorants often went through phases of nest initiation and abandonment. That was not observed this season.

Cormorants breeding at most other central California colonies also exhibited lower than average breeding success during 2015. Brandt's Cormorant productivity was less than long-term means at Devil's Slide and Point Reyes, but greater than long-term means at Castle-Hurricane. While Pelagic Cormorant productivity at Devil's Slide was both reduced compared to last season and below the long-term mean for that colony. (USFWS unpublished; A. Fuller pers. comm.). Point Blue monitoring sites at Vandenberg Air Force Base also experienced reduced productivity. Pelagic cormorant productivity was the lowest in the 16-year monitoring history. Brandt's cormorant productivity was lower than the 16-year average, down 23% from last year. Other monitored breeding species held steady or increased slightly in population and productivity. (Robinette et al. 2015; J. Howar pers. comm.).

Western Gulls were the only species to achieve higher productivity during 2015 when compared to last season, though overall productivity was still slightly below the long-term mean (Fig. 1). Clutch size, brood size and hatching success were all similar to last season, but fledging success increased. 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 than the last couple of seasons and extended well into November. 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. All chicks seemed to take longer to fledge than in the past couple of years.

Populations

Breeding population sizes were lower than the 2014 estimates for all species except Tufted Puffin and Ashy Storm-petrel (based on number of captures per hour of netting). Decreases ranged from approximately 10% for Cassin's Auklets to 71% for Double-crested Cormorants when compared to last season. These declines included the lowest population estimate in 40 years for Double-crested Cormorants and the lowest ever for Western Gulls.

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 2015, Guillemot numbers decreased by approximately 30% to the lowest number observed since 2009. This was also the first season that guillemot numbers did not increase since the 2005 season. Occupancy of monitored PIGU crevices was also reduced this season with approximately 65% of historically followed sites used by breeding guillemots during 2015, down from 72% last season.

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 over the last decade. 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 2014 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 slowly rebounding. The burrow counts for 2015 were approximately 10% lower than in 2014 but remained the second highest count recorded 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. Overall population estimates for 2015 coupled with continued high nest box occupancy suggest that there was a small decrease in the number of birds attending monitored plots but that the overall population remains relatively stable. 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 2015 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 14% higher than the capture rate for 2014. Evaluating catch per unit effort is useful for determining a coarse trend but does not consider the proportion of birds caught that are non-breeders, or potential changes in recapture probabilities through time and as such cannot be used to estimate the true population. However, knowing if a population is increasing, decreasing or stable is still extremely important for management. Recent analysis of CPUE data has been used to generate a new population index for storm-petrels at the Farallones (Nur et al. 2014). This index shows a population decline from 1992 to 2001, followed by large increases in storm-petrel captures between 2001 and 2007, and a declining trend from 2007 to the present. The nature of the increase in capture rates from 2001 to 2007 is unclear, but corresponded with other seabird species which demonstrated strong population growth during consistent productive ocean conditions in the early 2000's (Warzybok and Bradley 2010). The reversal of this rapid growth starting in 2007, resulting in decline, is associated with observations of high Burrowing Owl abundance and high predation on storm-petrels in the most recent years, suggesting further evidence of the impacts of increased Burrowing Owl abundance and predation on storm-petrels. Using a population-dynamic model based on population trends in recent years, with no reduction in Burrowing Owl abundance (assuming recent conditions continue into the future), the Farallon ashy storm-petrel population is expected to decline (by 3.36-7.19% per year) or remain nearly stable under the most positive interpretations of the data, without the possibility of substantial population growth (Nur et al. 2014).

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 crashed 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 two seasons. The 16% 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 have been slowly increasing over the past seven years. After four years of continuous growth the breeding population declined by 46% during 2015 (Fig. 7). Other central CA sites experienced similarly reduced breeding effort (i.e. fewer nests initiated) with Point Blue monitoring sites at Vandenberg Air Force Base experiencing a 70% decline in breeding populations for Brandt's and pelagic cormorants relative to 2014.

Summary

The 2015 seabird breeding season was characterized by very warm sea-surface temperatures (SST) throughout most of the season. The mean seasonal SST for 2015 was the warmest since 1992 and joins 1992, 1998 and 2014 as the only years in which the seasonal mean was greater than 13°C. While April and May were close to the long-term average, the mean monthly values for both July and August were the highest ever recorded at the Farallones since data collection began in 1925. Warm water conditions, such as those observed during the current El Niño, typically lead to unproductive ocean conditions, very low breeding success and even breeding failure for seabirds. However, that was not the case this season. Although overall seabird breeding success was lower than it has been in the last several years, most species were able to fledge chicks at a rate on par with or slightly above the long-term average productivity for this population. Common Murres and Pigeon Guillemots were the only species below the long-term mean, while Western Gulls were the only species to have higher success relative to last season. For the second consecutive year, Cassin's Auklets failed to produce any successful second broods resulting in their lowest productivity in six years. However, a high success rate for first broods resulted in an overall productive season.

While seabird reproductive success this season was much greater than in previous El Niño years, the warm conditions did impact breeding populations and seabird diet. During 2015, breeding populations decreased for all species except Tufted Puffin, when compared to 2014. The Western Gull breeding population estimate was the lowest observed during our 45 years of monitoring while Pigeon Guillemots, Pelagic Cormorants, Brandt's Cormorants and Cassin's Auklets also exhibited significant declines relative to last season.

Juvenile rockfish, always an important component of chick diet in productive years, was much less abundant than the previous two years while anchovies returned as a major prey item for the first time since 2008. Both of these changes are consistent with observations from previous warm water years. Following a strong pulse of upwelling in April and early May, krill seemed to be abundant early in the season, but disappeared later in the year. 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 El Niño did not have as great an impact as previous events, the number of birds attempting to breed and their breeding success were both reduced during 2015. Chicks generally took longer to grow and fledged a lower weights than in the past few seasons while warm water brought unusual species into the region. These included record numbers of Brown Boobies and first island records for Wedge-rumped storm-petrel and Kelp Gull, all species that are normally found in more tropical regions. With El Niño conditions expected to continue throughout the winter and into next spring we expect seabirds to have a more difficult time breeding next season.

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. Ashy Storm-petrels remain a species of concern on the Farallones. Recent analysis of netting data demonstrate a declining trend over the last 5-7 years and a reduced population when compared to historic estimates. Analysis of the complex dynamics of the relationship between House Mice, Burrowing Owls and Ashy Storm-Petrels was completed during 2014 and the results are available in Nur et al. (2014 submitted). The introduction of novel techniques to aid in our understanding of ASSP populations (such as nest motes, pit tags and radar) should also be strongly considered.

2. To further our understanding of the foraging ecology of SEFI seabirds, we recommend continuation of novel monitoring techniques including deployment of time-depth recorders and GPS tags (or similar devices on select species) and, measurements of physiological state (e.g. body condition, possibly endocrine analysis). Novel monitoring tools will greatly enhance our ability 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.

4. Tufted Puffins are difficult to monitor and little is known about their reproductive success on the Farallones. We propose assessment and modification of our research methods, including the potential use of nest boxes 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 shaded nest boxes, unshaded nest boxes, and natural burrows (see Appendix III in the 2010 Farallon Island Seabird Report) as well as the effect of temperature on incubation behavior and nest attendance (see Kelsey 2014). We are now in the process of evaluating new box designs and mitigation measures that will allow us to create artificial habitat that both facilitates research and is adaptable to a changing climate. Several prototypes for new nest box designs and materials were deployed during 2015 and will be evaluated to help us to come up with a final, climate-smart design.

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.

LITERATURE CITED

Ainley, D.G., W. J. Sydeman, S.A. Hatch, and U.W. Wilson. 1994. Seabird population trends along the west coast of North America: causes and the extent of regional concordance. Studies in Avian Biology 15: 119-133.

Ainley, D.G. and T.J. Lewis. 1974. The History of Farallon Island Marine Bird Populations, 1854-1972. Condor 76:432-446.

Ainley, D.G. and R.J. Boekelheide (eds.) 1990. Seabirds of the Farallon Islands: Ecology, Dynamics, and Structure of an Upwelling-system Community. Stanford University Press. Stanford, CA.

Ainley, David, D. A. Manuwal, Josh Adams and A. C. Thoresen. 2011. Cassin's Auklet (Ptychoramphus aleuticus), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/050 doi:10.2173/bna.50

Bradley, R., P. Warzybok, D. Lee, and J. Jahncke. 2011. Assessing Population Trends of the Ashy Storm Petrel on Southeast Farallon Island, California. Unpublished report to the US Fish and Wildlife Service. PRBO Conservation Science, Petaluma, California. PRBO Contribution Number 1780.

Barber, R.T., F.P. Chavez, and J.E. Kogelschatz. 1985. Biological effects of El Niño. pp. 399-438. In: M. Vegas (Ed) Seminario Regional Ciencas Tecnologia y Agression Ambiental: El Fenomeno 'El Niño'. Contec Press, Lima, Peru.

Carter. H.R., G.J. McChesney, D.L. Jaques, C.S. Strong, M.W. Parker, J.E. Takekawa, D.L. Jory, and D.L. Whitworth. 1992. Breeding populations of seabirds in California, 1989-1991. Unpublished Report of the U.S. Fish and Wildlife Service, Dixon, California.

Hester, M.M., T.G. Schuster, W.J. Sydeman, and P. Pyle. 1996. Population size and reproductive performance of seabirds on Southeast Farallon Island, 1996. Report to the Farallon National Wildlife Refuge, Newark, California.

Kelsey, E. 2014. Turn of events: How environmental temperatures and artificial nest habitats influence incubation behaviors of Cassin's Auklets (*Ptychoramphus aleuticus*). Unpublished Masters Thesis. San Jose State University, San Jose, CA.

Nur, N. and W.J. Sydeman. 1999. Survival, breeding probability, and reproductive success in relation to population dynamics of Brandt's Cormorants *Phalacrocorax penicillatus*. Bird Study, 46:2-13.

Nur, N. and W.J. Sydeman. 2002. Statistical analysis of the 'k' correction factor used in population assessments of murres: Implications for monitoring. Unpublished Final Report, Point Reyes Bird Observatory, Stinson Beach, CA; U.S. Fish and Wildlife Service, Newark, CA.

Nur, N., R. Bradley, L. Salas, and J. Jahncke. 2014. Modeling the Impacts of House Mouse Eradication on Southeast Farallon Island. Unpublished report to the US Fish and Wildlife Service. PRBO Conservation Science, Petaluma, California. PRBO Contribution Number 1880

Nur, N., R. Bradley, L. Salas, and J. Jahncke. Submitted. Evaluating Population Impacts of Reduced Predation by Owls on Storm Petrels as a Consequence of Proposed Island Mouse Eradication. Ecological Applications.

Robinette, D.P., J. Howar, A. Fleishman, and L. De Maio. 2014. Seabird Population Dynamics and Roost Utilization at Vandenberg Air Force Base, 2014. Unpublished Report, Point Blue Conservation Science, Petaluma, CA.

Sakuma, K. 2014. Rockfish Recruitment and Ecosystem Assessment Cruise Report: May1-26, 2014. Unpublished report. NOAA NMFS SWFSC FED, Santa Cruz, CA.

Sydeman, W.J., S.D. Emslie, and P. Pyle. 1987. Population size and reproductive success of seabirds breeding on the Farallon Islands National Wildlife Refuge in 1987. Report to the Farallon National Wildlife Refuge, Newark, California.

Sydeman, W.J., H.R. Carter, J.E. Takekawa, and N. Nur. 1997. Common Murre *Uria aalge* population trends at the South Farallon Islands, California, 1985-1995. Unpublished Final Report, Point Reyes Bird Observatory, Stinson Beach, CA; U.S. Geological Survey, Dixon, CA; and U.S. Fish and Wildlife Service, Newark, CA.

Sydeman, W.J., N. Nur, E.B. McLaren, and G.J. McChesney. 1998. Status and trends of the Ashy Storm-petrel on Southeast Farallon Island, California, based upon capture-recapture analyses. The Condor, 100: 438-447.

Sydeman, W.J., M.M. Hester, J.A. Thayer, F. Gress, P. Martin, J. Buffa. 2001. Climate change, reproductive performance and diet composition of marine birds in the southern California Current system, 1969-1997. Progress in Oceanography, 49:309-329.

Thayer, J.A., T.C. Murray, M.M. Hester, and W.J. Sydeman. 1998. Conservation biology of rhinoceros auklets, *Cerorhinca monocerata*, on Año Nuevo Island, California, 1993-1998. Progress report to Año Nuevo State Reserve, California Department of Parks and Recreation, Bay Area District, California.

Thayer, J.A. and W.J. Sydeman. 2002. Breeding biology and ecology of Rhinoceros auklets, *Cerorhinca monocerata*, on Año Nuevo Island, California, 2002: Population assessments and estimates of food requirements. Unpublished report to the National Fish and Wildlife Foundation. PRBO Conservation Science, Stinson Beach, CA.

TABLES

Table 1. Mean (± 1 SD) productivity of eight species of seabirds at Southeast Farallon Island, California, 2015. 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	3.02 ± 0.71 *(133)*	2.42 ± 1.01 *(134)*	1.72 ± 1.27 *(134)*	1.72 ± 1.27 *(134)*	0.80 ± 0.29 *(133)*	0.69 ± 0.41 *(124)*
PECO	3.11 ± 0.57 *(19)***	1.62 ± 1.35 *(34)***	1.43 ± 1.04 *(47)*	1.43 ± 1.04 *(47)*	0.55 ± 0.45 *(14)*	0.86 ± 0.20 *(21)*
WEGU	2.63 ± 0.53 *(201)*	1.63 ± 1.11 *(202)*	0.94 ± 0.97 *(202)*	0.94 ± 0.97 *(202)*	0.60 ± 0.39 *(201)*	0.55 ± 0.40 *(157)*
COMU* USP	1.00 (243)	0.79 ± 0.41 (243)	0.55 ± 0.50 (242)	0.56 ± 0.50 (242)	0.79 ± 0.41 (243)	0.70 ± 0.46 (191)
COMU* UU	1.00 (100)	0.87 ± 0.34 (100)	0.82 ± 0.39 (99)	0.82 ± 0.39 (99)	0.87 ± 0.34 (100)	0.94 ± 0.24 (86)
PIGU	1.86 ± 0.35 *(80)*	1.53 ± 0.75 *(79)*	0.67 ± 0.52 *(79)*	0.68 ± 0.52 *(79)*	0.78 ± 0.37 *(79)*	0.45 ± 0.29 *(66)*
RHAU*	1.00 *(75)*	0.73 ± 0.45 *(75)*	0.62 ± 0.49 *(73)*	0.62 ± 0.49 *(73)*	0.73 ± 0.45 *(75)*	0.87 ± 0.34 *(52)*
CAAU* PRBO	1.00 *(42)*	0.90 ± 0.30 *(42)*	0.88 ± 0.33 *(42)*	0.90 ± 0.30 *(42)*	0.90 ± 0.30 *(38)*	0.97 ± 0.16 *(42)*
CAAU* ALL	1.00 (170)	0.87 ± 0.34 *(170)*	0.82 ± 0.39 *(170)*	0.84 ± 0.37 *(170)*	0.87 ± 0.34 *(170)*	0.94 ± 0.24 *(148)*
ASSP*	1.00 *(40)*	0.83 ± 0.38 *(40)*	0.63 ± 0.49 *(40)*	0.63 ± 0.49 *(40)*	0.83 ± 0.38 *(40)*	0.76 ± 0.44 *(33)*

* 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, 2005-2015. Estimates include Southeast and West End Islands unless otherwise noted.

Species	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2005-2014 average
DCCO	104	364	364	220	360	260	194	206	444	474	130	302
BRCO	5,742	6,566[b]	7,412	3,450[b]	4,916	5,132	1,248	4,840	20,788	15,692	11,732	8,178
PECO	234	440[b]	372	298[b]	206	320	268	250	64	40	28	229
WEGU	11,164	18,686	21,148	15,846	17,406	18,218	15,747	20,152	15,852	17,399	16,547	17,700
CAGU	184	514	522	70	208	396	192	534	-	-	-	348
BLOY	38	46	36	40	48	38	38	40	42	36	30	39
PIGU [d]	3,157	4,459	3,880	3,645	3,461	3,317	2,851	2,875	2,774	2,607	1,375	3,124
TUPU [c]	326	288	286	244	246	234	216	106	59	108	82	199
CAAU [a]	25,606	28,444	22,574	19,607	17,866	12,964	14,512	16,121	19,540	13,597	16,202	18,143

[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.

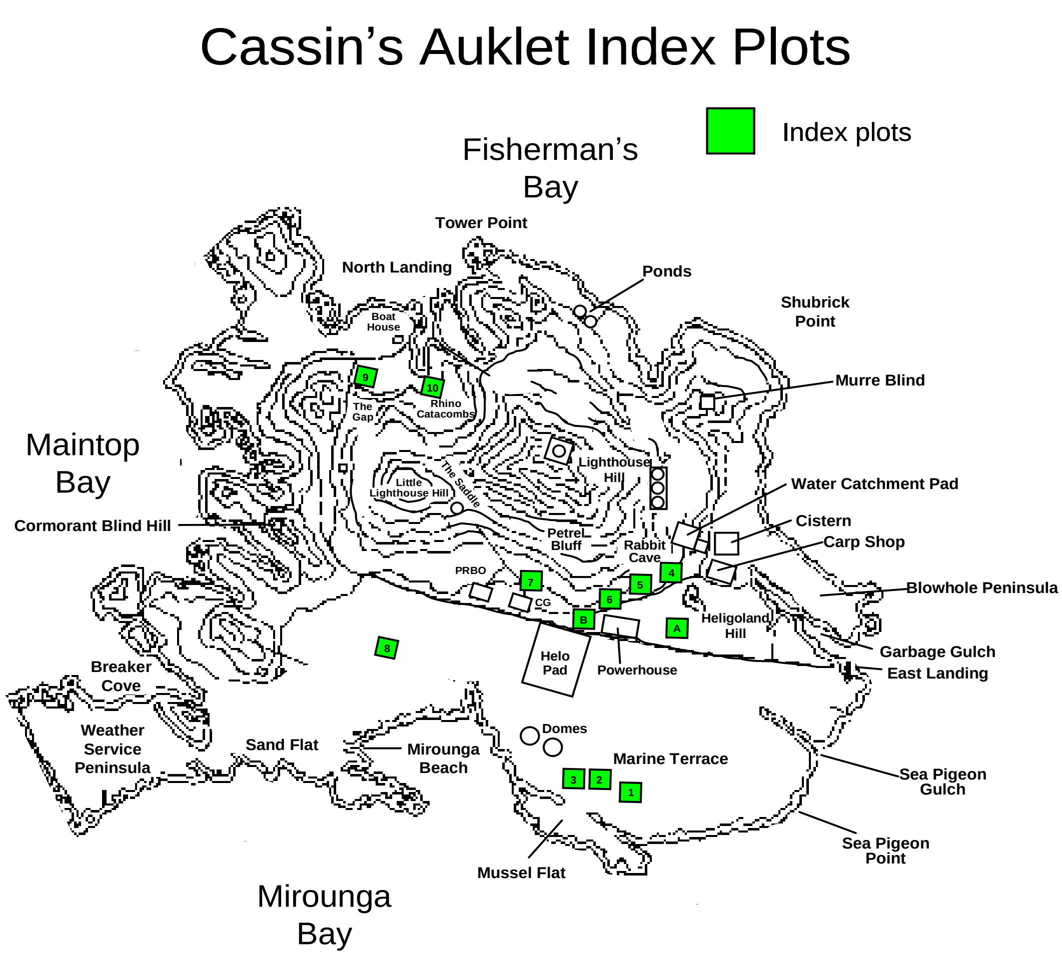
[c] TUPU population estimates were recalculated in 2008 to correct for unequal survey effort in prior seasons (see text)

[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 2015. 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
2005	15	10	23	11	14	5	9	11	65	20	5	11	199
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
2005-2014 average	22	17	26	14	12	5	13	11	78	39	4	20	260

Note: Plot MT8 not counted in 2012 due to high pinniped numbers and cormorants breeding in the area. Low burrow counts in plots MT2 and MT3 in 2015 likely due to extremely high numbers of California Sea Lions hauling out and crushing burrows in those areas.



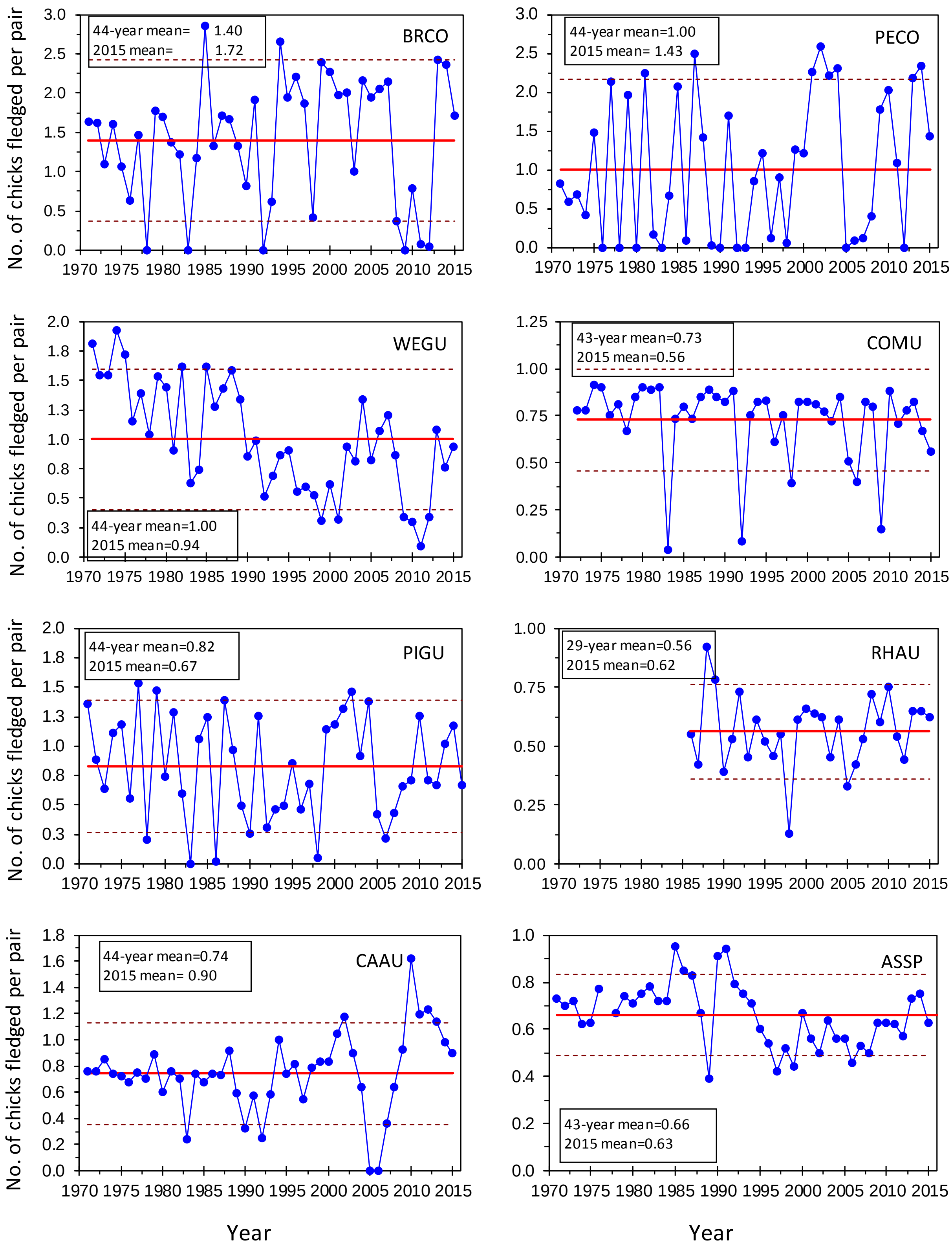


Fig. 1a. Productivity of 8 species of seabirds on Southeast Farallon Island, 1971-2015. Productivity is measured as number of chicks fledged per breeding pair (includes first attempts, relays and second broods). The bold horizontal line indicates mean productivity from all attempts between 1971 and 2014. The dashed lines represent the 80% prediction interval around the long term mean. Please note the different scales on the y-axis.

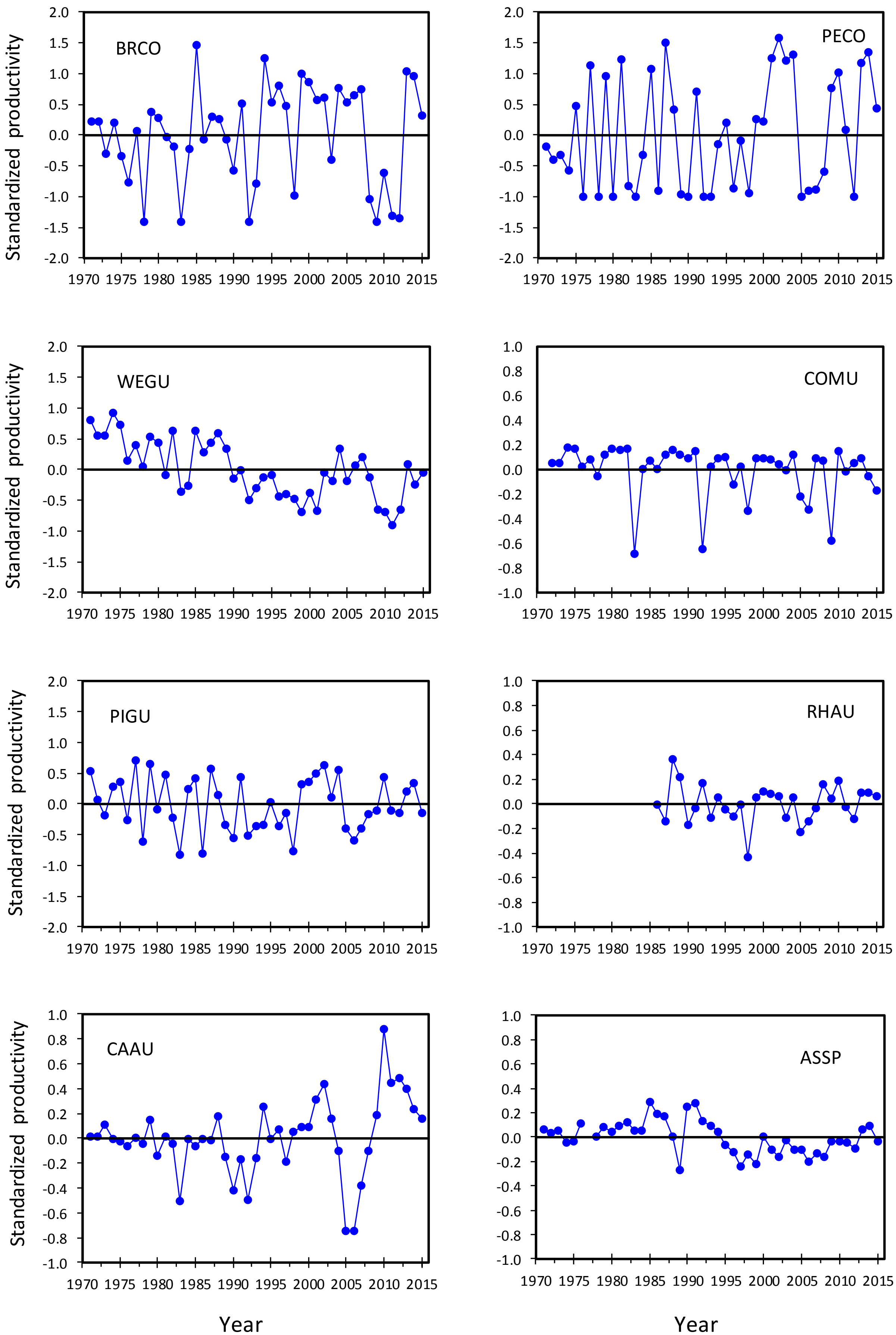


Fig 1b. Standardized productivity anomalies (annual productivity - long term mean) for 8 species of seabirds on SEFI, 1971-2015.

Brandt's Cormorant Census

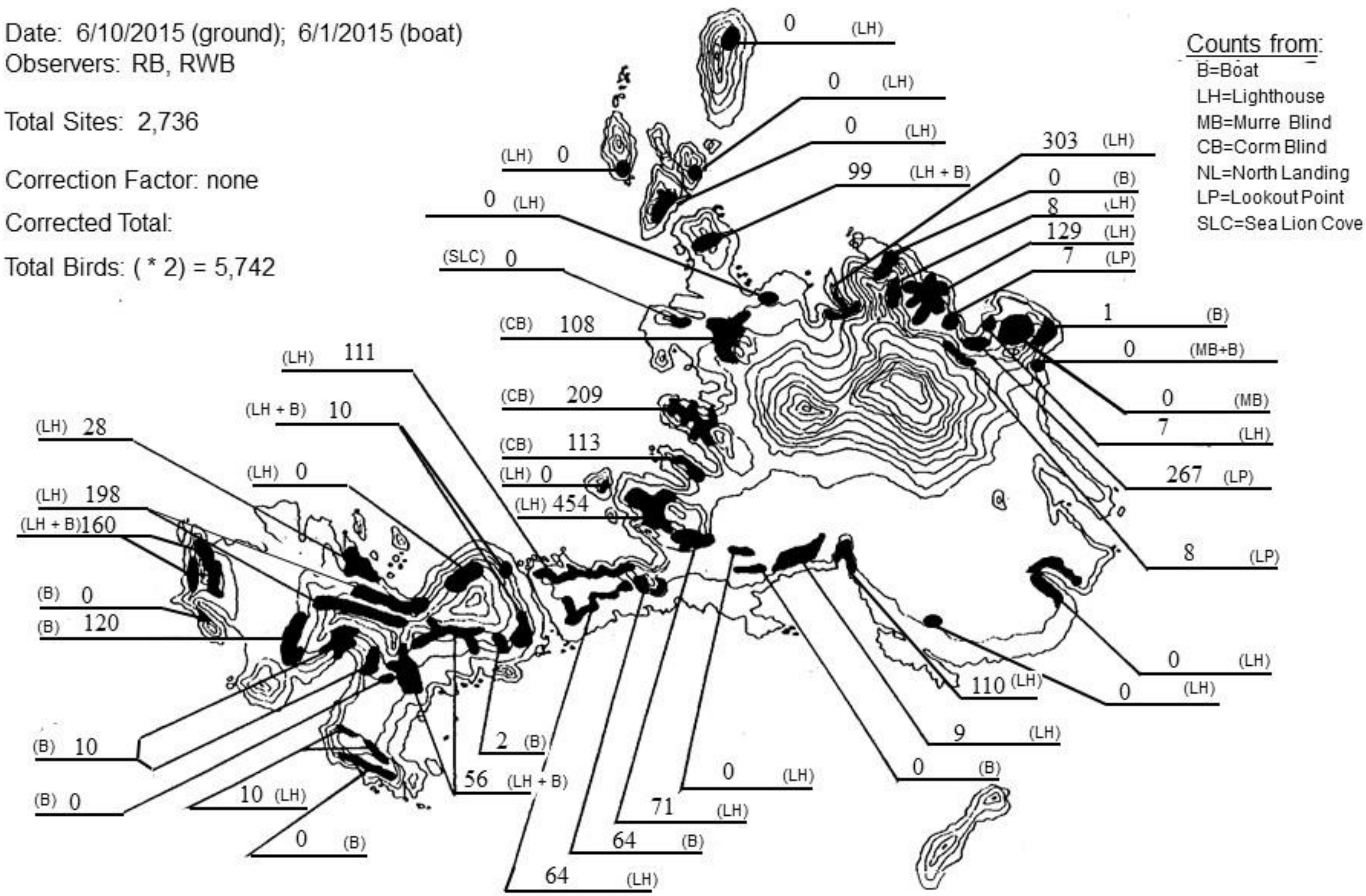


Figure 2: Counts of Brandt's Cormorants on Southeast Farallon Island during the 2015 census. Surveys were conducted from the following locations: Lighthouse Hill (LH), Murre Blind (MB), Cormorant Blind (CB), North Landing (NL), and Boat (B).

Pelagic Cormorant Census

Date: 6/10/2015 (land), 6/1/2015 (boat)
Observers: RB, RWB

Total Sites: 117

Correction Factor: none

Corrected Total: 117

Total Birds: (corrected total * 2) = 234

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

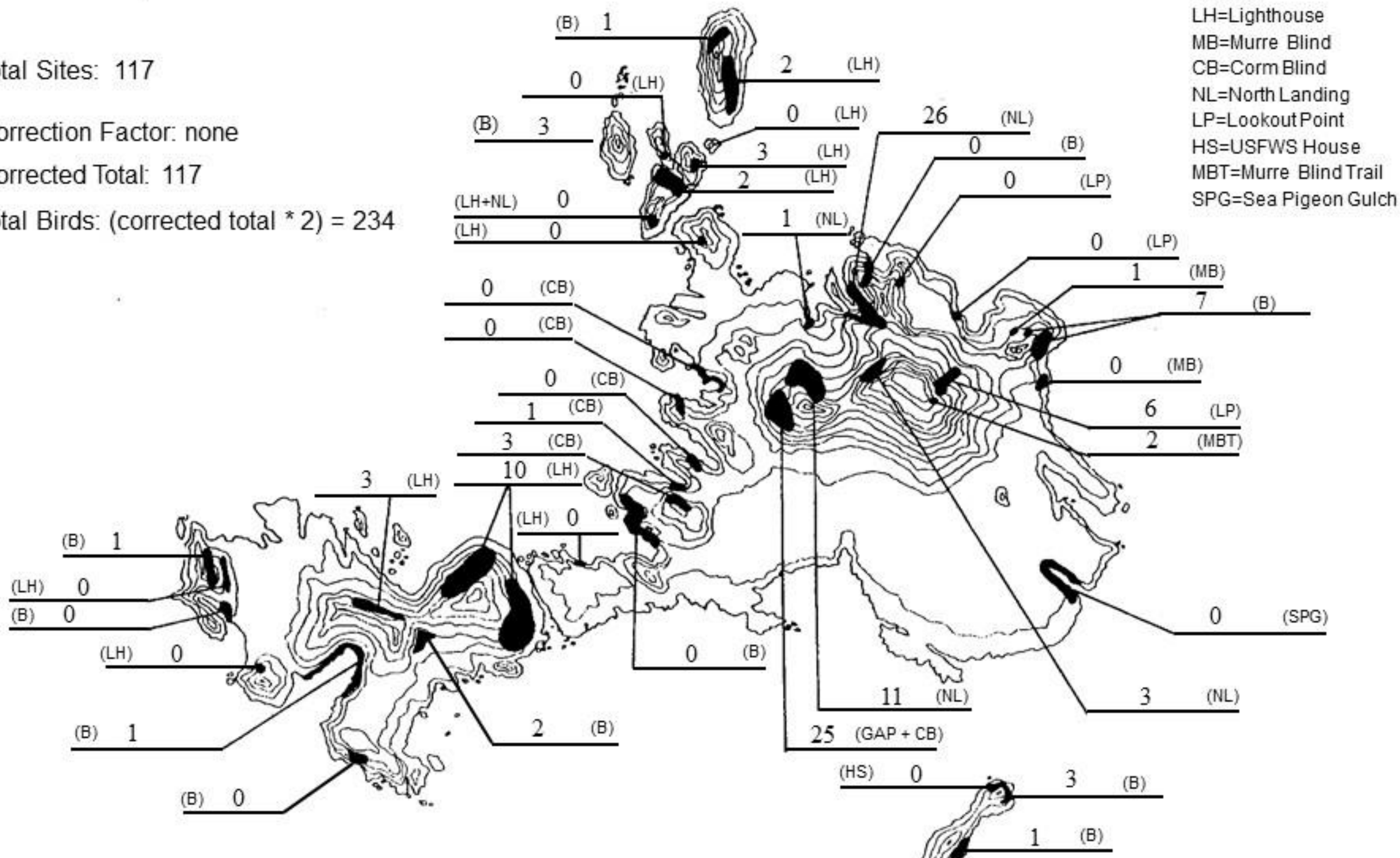


Figure 3: Counts of Pelagic Cormorants on Southeast Farallon Island during the 2015 census. Surveys were conducted from the following locations: Lighthouse Hill (LH), Lookout Point (LP), Murre Blind (MB), Cormorant Blind (CB), North Landing (NL), USFWS House (HS), Murre Blind Trail (MBT), Sea Pigeon Gulch (SPG), and Boat (B).

Western Gull Census

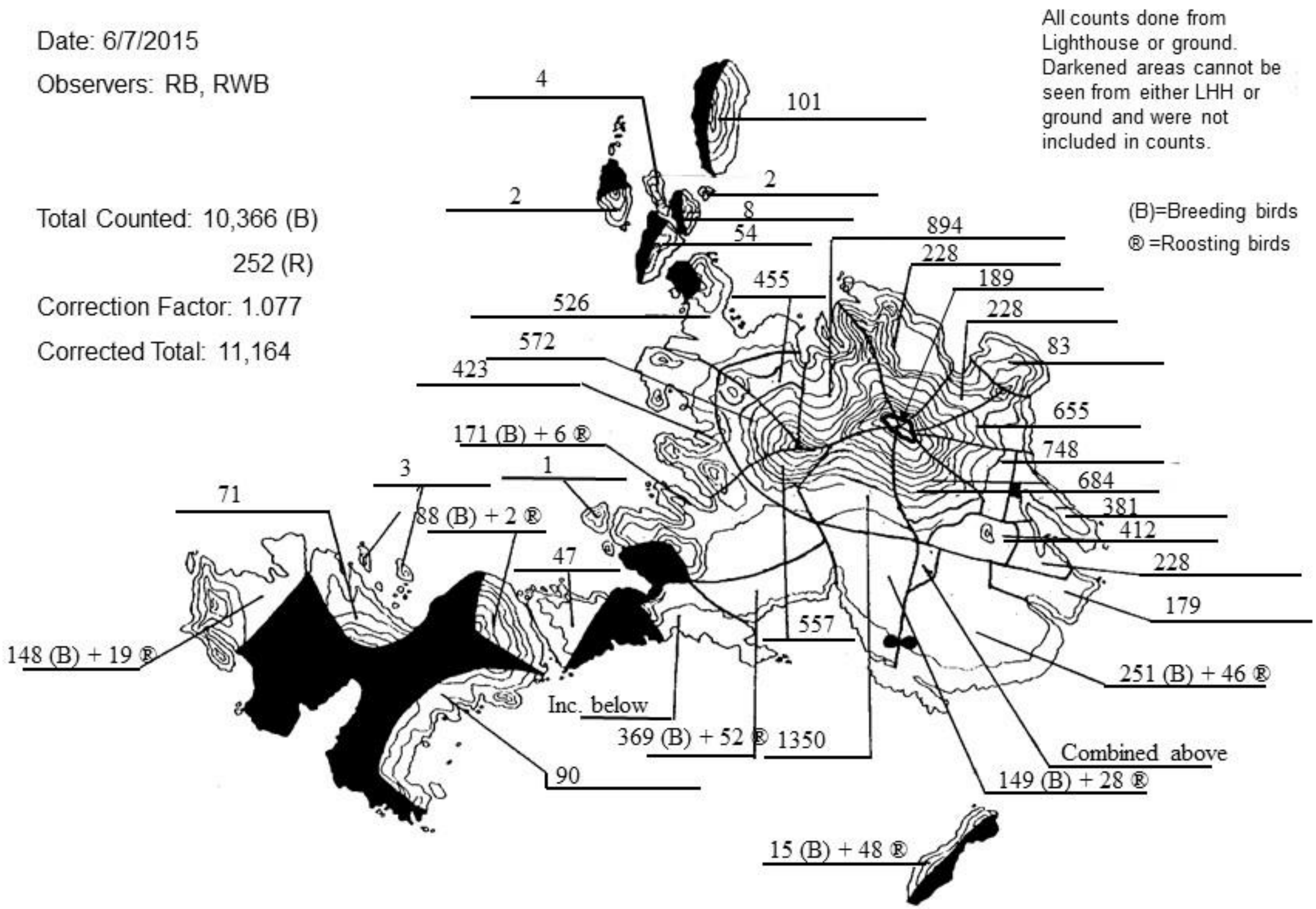


Figure 4: Counts of Western Gulls on Southeast Farallon Island during the 2015 census.

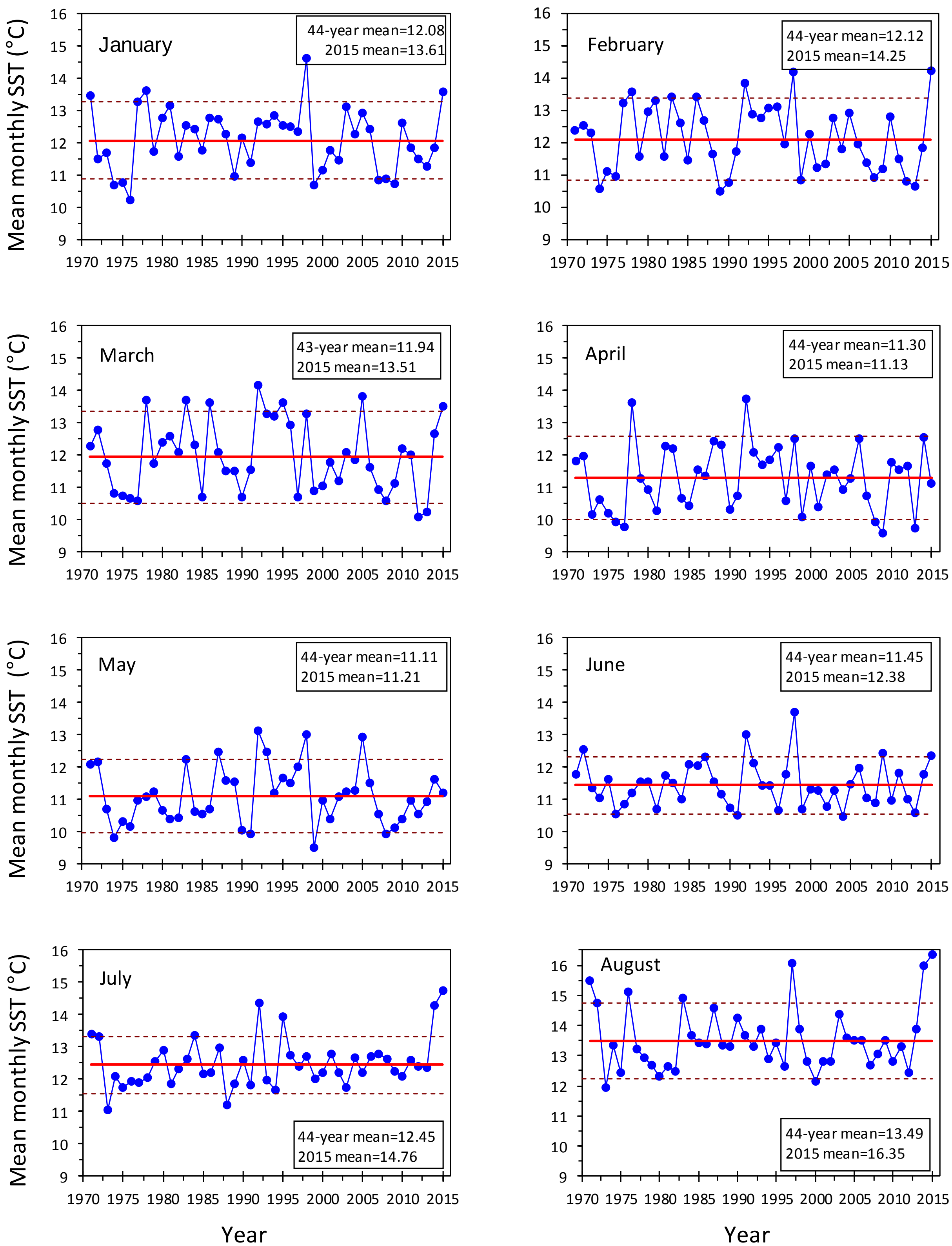


Fig. 6a. Monthly mean sea surface temperature (SST) at Southeast Farallon Island, 1971-2015. SST was measured daily from Water Sample Point, near East Landing. The bold horizontal line indicates mean monthly SST from 1971 to 2014. The dashed lines represent the 80% prediction interval for the long term mean.

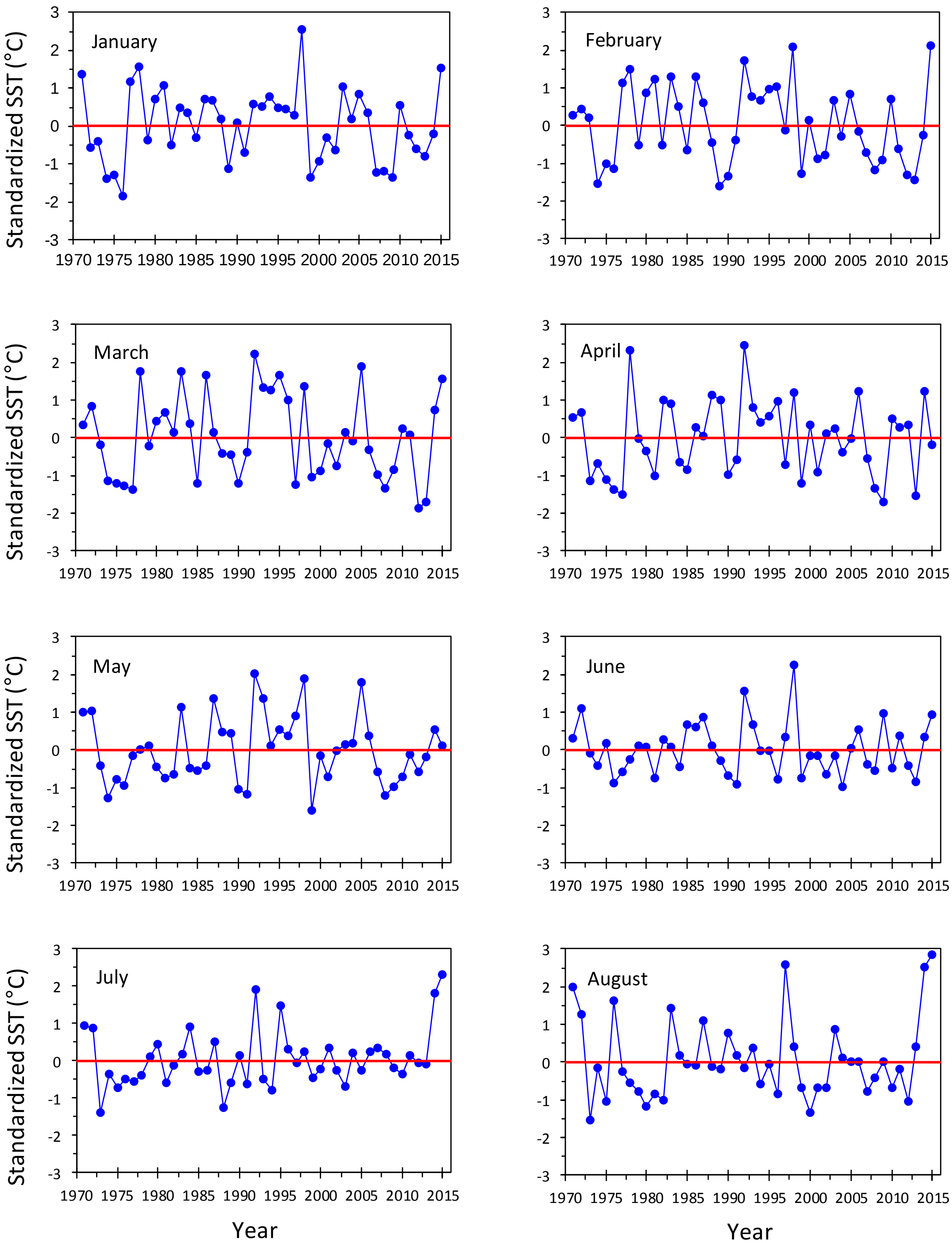


Fig. 6b Standardized Sea Surface Temperature (SST) anomalies (annual mean - long term mean) for SEFI, 1971-2015.

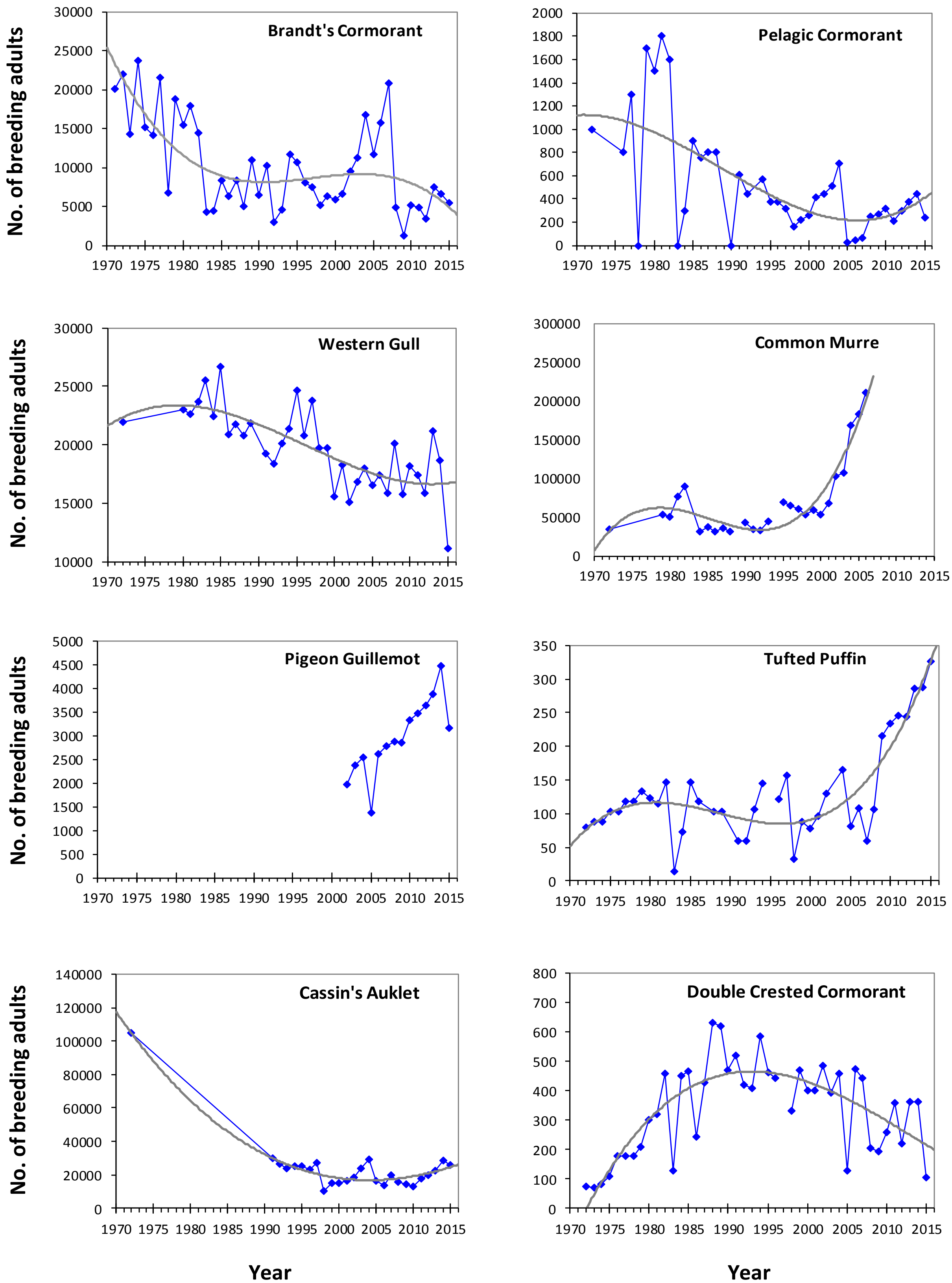


Fig. 7 Population trends for 8 species of seabirds on Southeast Farallon Island, 1972-2015. Populations were determined by counting either individuals or nests on all visible areas on SEFI and West End. We have fitted a third order polynomial trend line (in gray) for each species to help illustrate long 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. COMU whole colony counts have not been made since 2006.

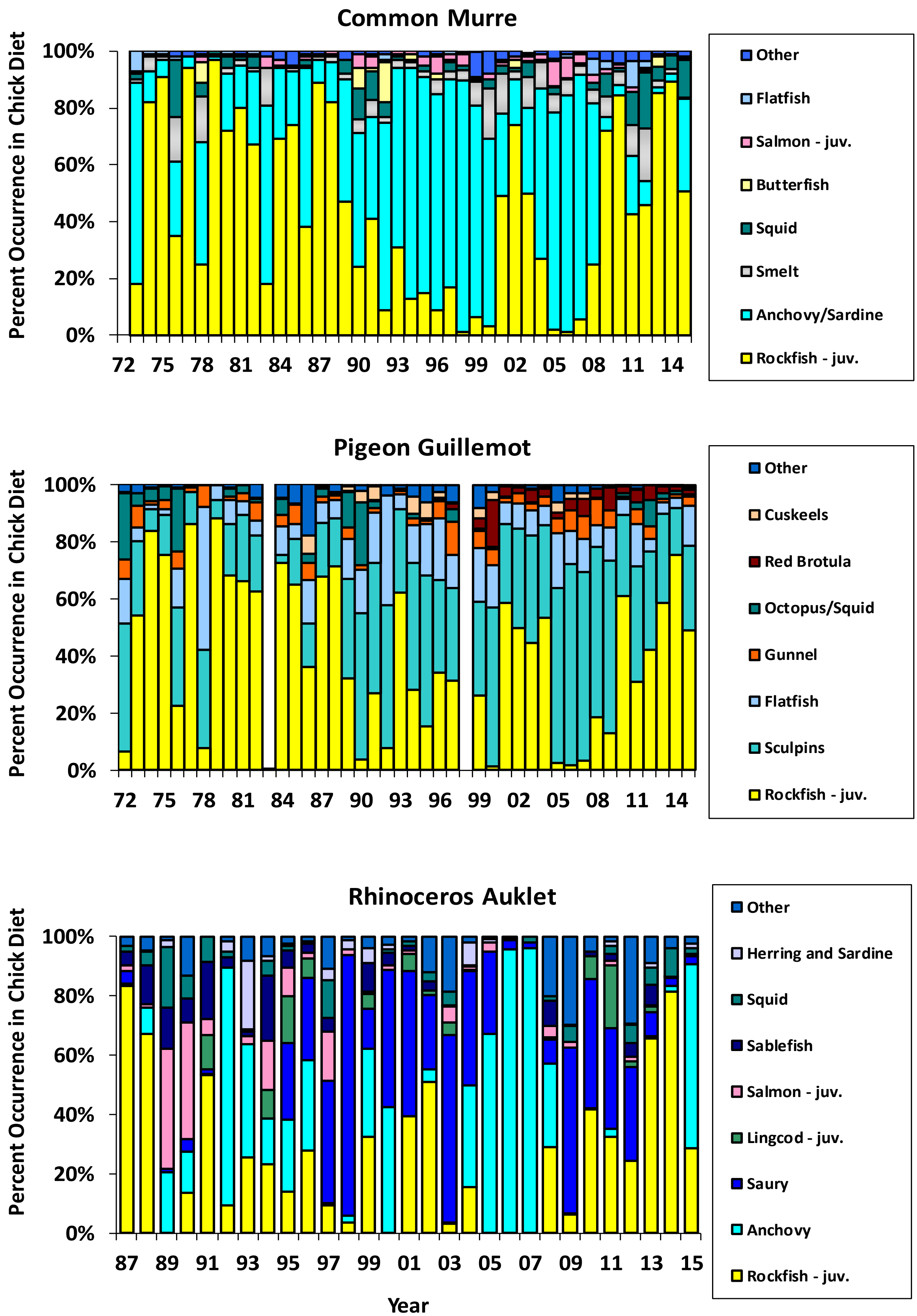


Fig. 8 Percent occurrence of common prey items, by year, in the diet of three species of seabirds on Southeast Farallon Island.

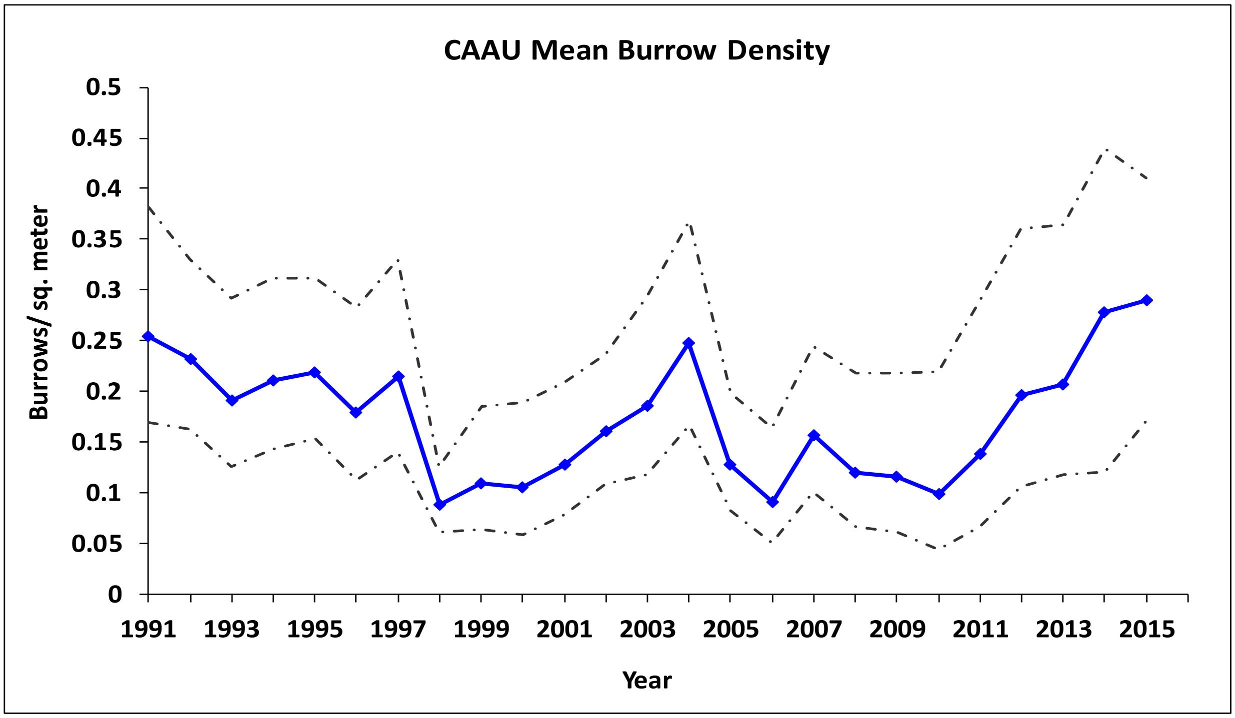


Fig. 9. Geometric mean burrow/crevice density in our 12 Cassin's Auklet Index Plots from 1991 to 2015. The blue line represents the annual mean values. The dashed lines represent the upper and lower bounds of the 95% confidence interval.

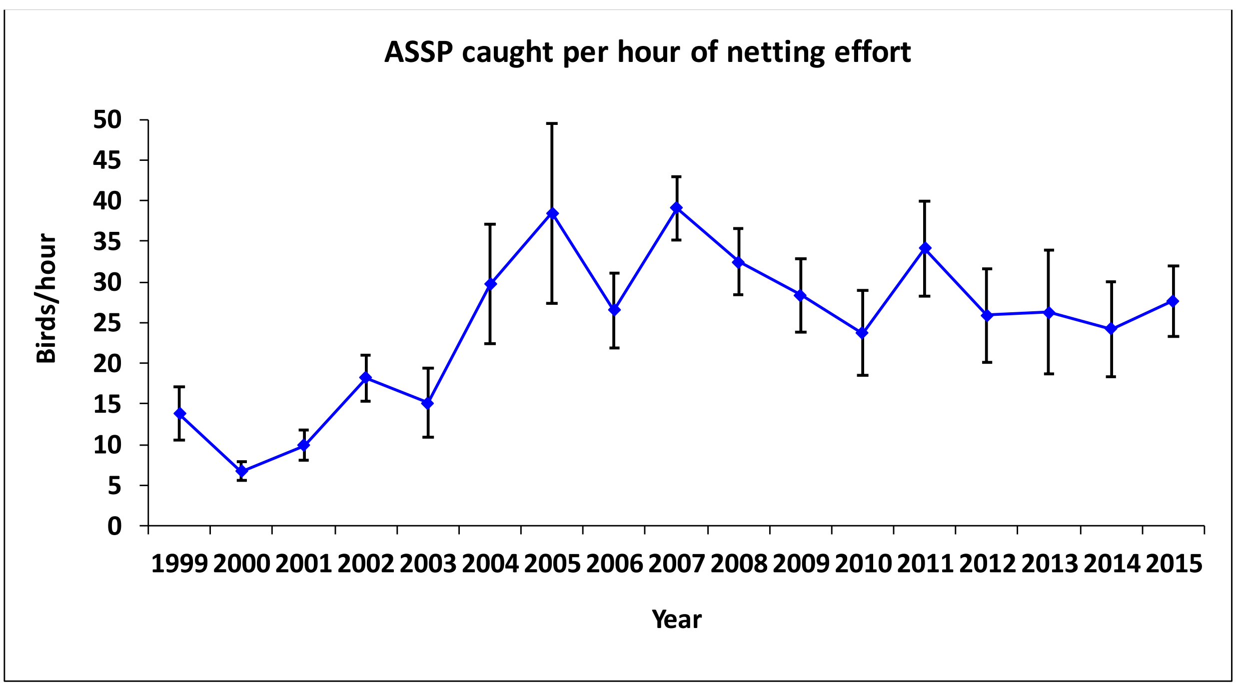


Fig 10. Mean number of Storm-petrels caught per hour of netting effort on SEFI from 1999 to 2015. Error bars represent the standard error for the mean calculated from all capture sessions in a given season.

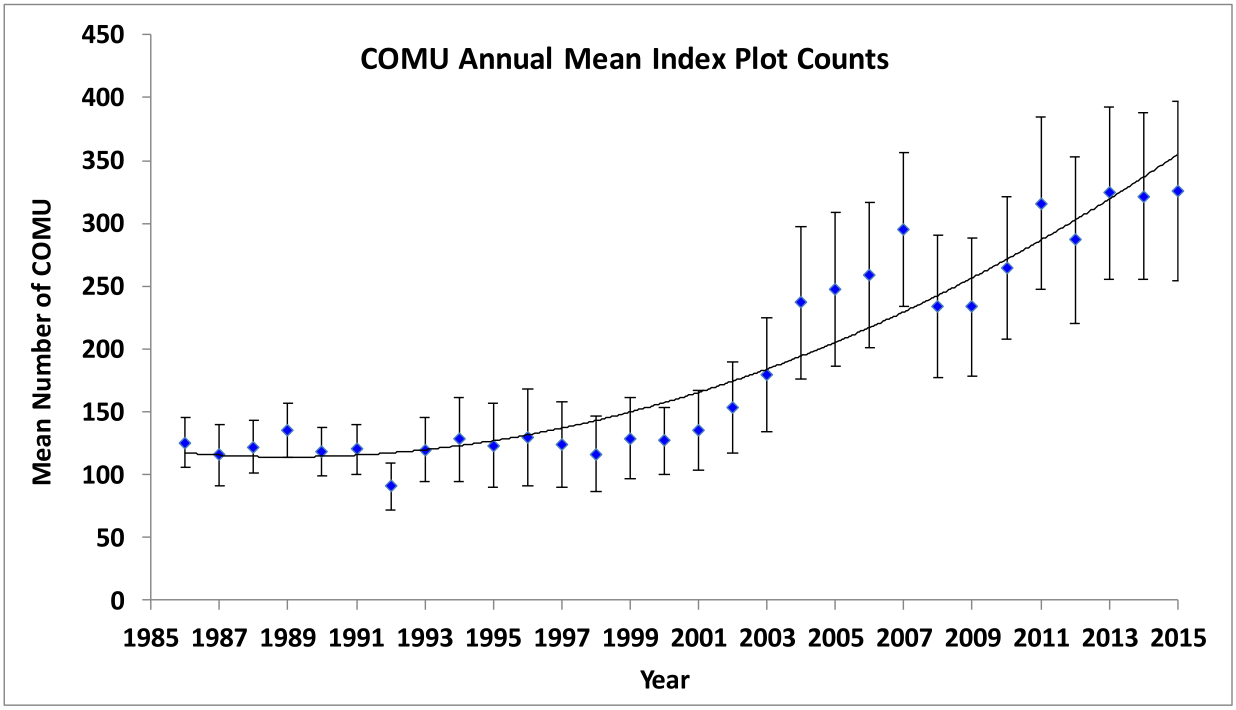


Fig. 11. Mean annual counts for Common Murre Index Plots from 1986 to 2015. Error bars represent the standard error of the mean calculated from all plots counted in any given season.

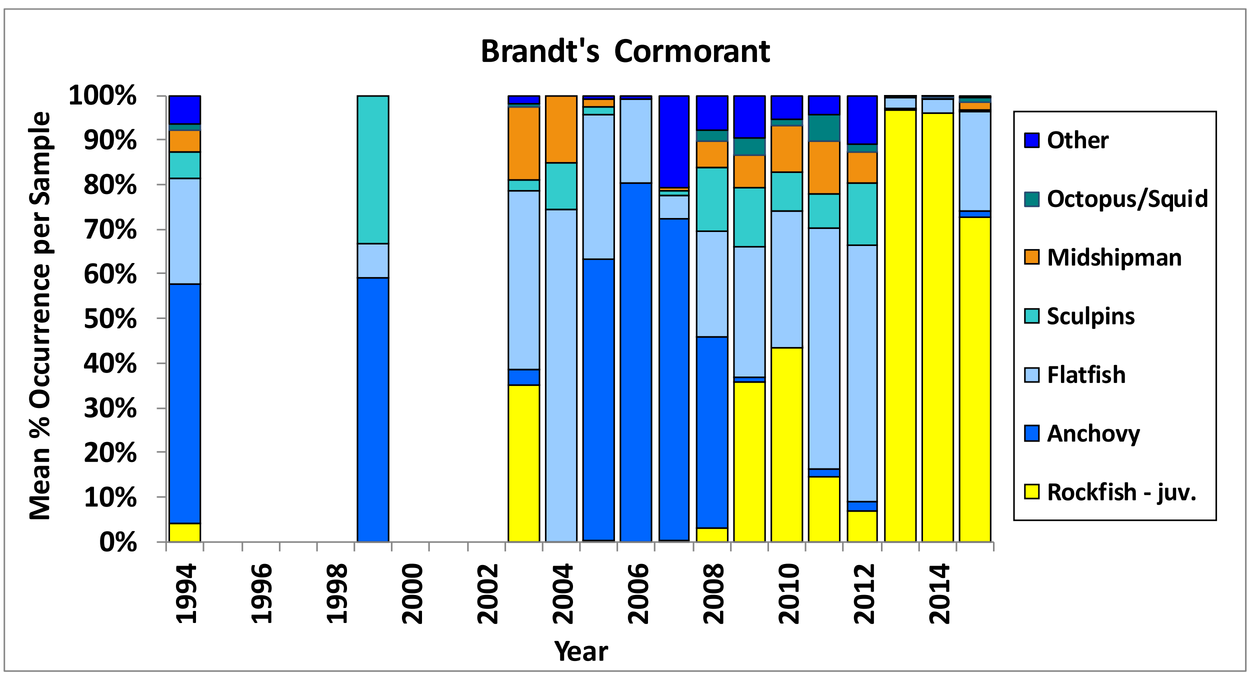


Fig. 12 Mean percent occurrence per sample of common prey items by year in the diet of Brandt's Cormorants on Southeast Farallon Island. Please note that 2015 results are based on ~50 pellets examined by Nov. 10th and should be considered preliminary until all pellets have been analyzed.

Appendix I. Calculation of correction factor for Western Gull census, 2015.

Area	Nest Count	Bird Count	Correction Factor
C	102	181	1.125
K	118	235	1.003
H (H1 only)	255	463	1.102
Total			**1.077**

Appendix II. 2015. The correction factor was derived by multiplying the number of breeding sites in three study plots (USP, UU, and TP) 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 4 (1000)	243	258	1.88
June 5 (1000)	243	281	1.73
June 6 (1000)	243	280	1.74
June 7 (1000)	243	297	1.64
Mean	243	279	**1.75**

UU

Date (Time)	Breeding Sites	No. of birds	Correction Factor
June 4 (1000)	100	116	1.72
June 5 (1000)	100	122	1.64
June 6 (1000)	100	121	1.65
June 7 (1000)	100	127	1.57
Mean	100	122	**1.65**

TP

Date (Time)	Breeding Sites	No. of birds	Correction Factor
June 4 (1000)	109	131	1.66
June 5 (1000)	109	159	1.37
June 6 (1000)	109	162	1.35
June 7 (1000)	109	145	1.50
Mean	109	149	**1.47**

Mean correction factor for SEFI 2014: **1.62**