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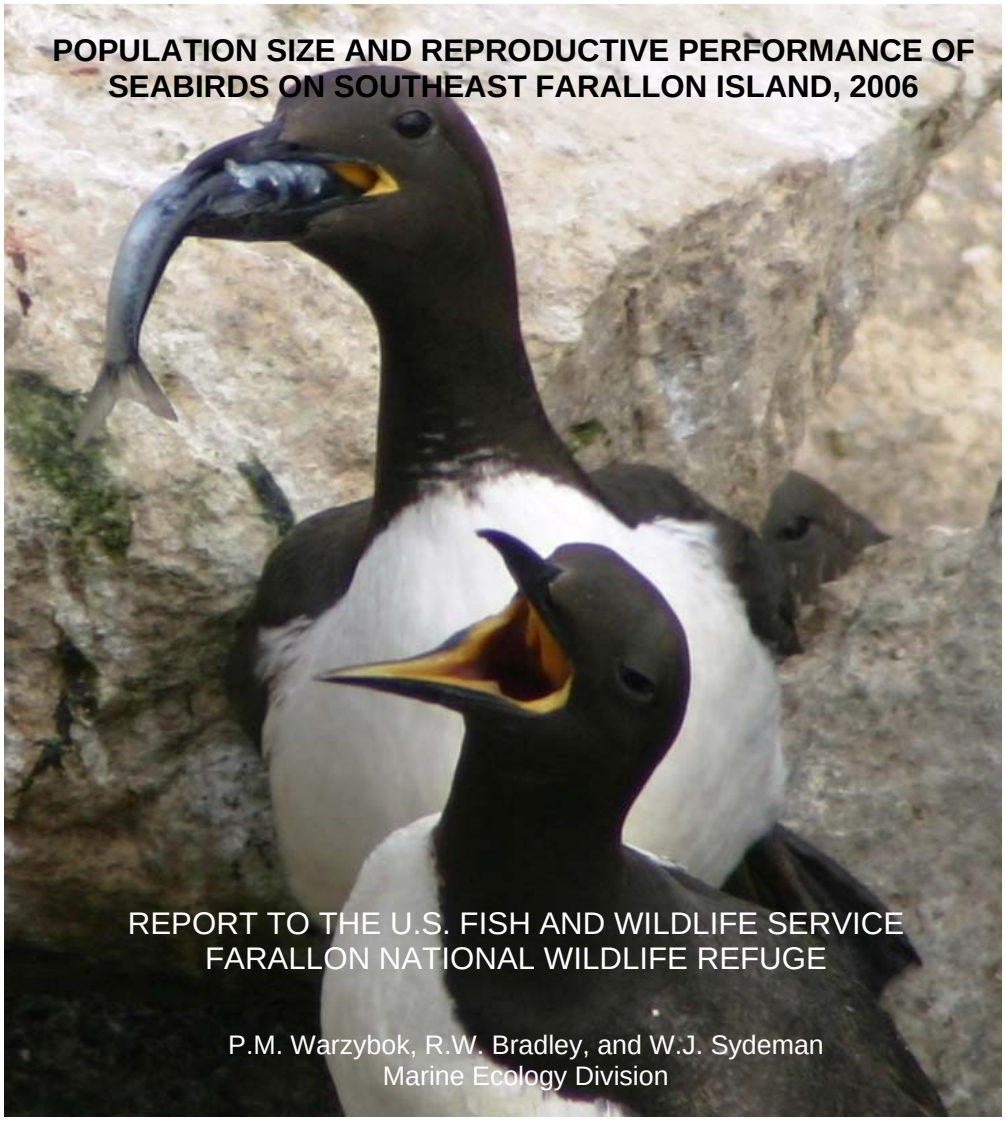

POPULATION SIZE AND REPRODUCTIVE PERFORMANCE OF SEABIRDS ON SOUTHEAST FARALLON ISLAND, 2006

REPORT TO THE U.S. FISH AND WILDLIFE SERVICE
FARALLON NATIONAL WILDLIFE REFUGE

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EXECUTIVE SUMMARY

(1) Under contract with USFWS/Farallon NWR, 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) Breeding populations were larger for some species when compared to last season, while lower for other species. Declines were most noticeable for Cassin's Auklets and Pigeon Guillemots whereas Common Murre and Brandt's Cormorants continued to experience rapid population growth.

(3) All species, except Brandt's Cormorants and Western Gulls, experienced low reproductive success in 2006 relative to their long-term mean productivity. Productivity for Common Murres and Pigeon Guillemots declined while other species exhibited a marginal improvement over last season.

(4) Cassin's Auklets experienced near total reproductive failure for the second consecutive year. There were a greater number of breeding attempts than in 2005, but it was again followed by large scale egg abandonment and high chick mortality. This repeated unprecedented breeding failure is of great concern.

(5) Sea-surface temperature (SST) was cooler than the long-term mean for February and March, anomalously warm in April, average in May, and warm again in June. The mean seasonal SST for 2006 (12.31°C), was cooler than 2005, but still warmer than the long-term mean for this period. The mean SST for the month of April was 12.53, the highest recorded since 1992.

(6) Juvenile rockfish (*Sebastes* spp.) were virtually absent from chick diet, representing only about 1% of the prey consumed for all species. Large anchovies were the predominant prey in the diet of murres and Rhinoceros Auklets, while sculpins comprised the majority of the Pigeon Guillemot diet.

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 2006. We monitored eleven species: Ashy Storm-petrel (ASSP), Double-crested Cormorant (DCCO), Brandt's Cormorant (BRCO), Pelagic Cormorant (PECO), Western Gull (WEGU), Black Oystercatcher (BLOY), Common Murre (COMU), Pigeon Guillemot (PIGU), Tufted Puffin (TUPU), Rhinoceros Auklet (RHAU), and Cassin's Auklet (CAAU).

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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 35 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 nesting areas, no reproductive data were collected for these species.

Brandt's Cormorant – BRCO productivity increased in 2006. Cormorants nesting in the colony under the Cormorant Blind produced 2.05 fledglings per pair this season. This is approximately 6% greater than in 2005 and approximately 40% above the 35-year mean reproductive success (Fig. 1a). Nest abandonment was low with only one nest abandoned among all followed sites. The first eggs were observed on 30 April. Mean clutch size was 3.10 eggs per nest and hatching success (percentage of eggs that hatched) was 81%. Mean brood size was 2.36 chicks per nest. Fledging success was high, with 88% of the chicks that hatched surviving to fledging age.

Pelagic Cormorant **–** Mean productivity was 0.09 fledglings per pair, and few birds attempted to reproduce. Eggs were observed in only three nests, yielding a mean clutch size of 2.3 eggs per nest. Eight additional nests had birds in incubation posture on multiple checks, so it is possible that these birds also attempted to breed, but failed to hatch any chicks. The first eggs were observed late in the season, on 29 June. Adults continued to attend nest sites until mid-July but most did not progress to the well-built nest stage.

Western Gull **–** WEGU productivity rose in 2006 (Fig. 1a). Western Gulls produced, on average, 1.07 chicks per pair. This represents a 30% increase compared to 2005, and is approximately equal to the long-term mean productivity for this species (Fig. 1a). The first eggs were observed on 1 May, approximately 1 week later than usual for this species. Seventy-two percent of the eggs hatched and 53% of those chicks survived to fledge (compared to only 40% in 2005). Mean clutch size was 2.70 eggs per nest. Brood size was 1.95 chicks per nest.

Black Oystercatcher **–** A total of 30 sites were monitored in 2006, of which 18 were active, defined as: (1) a territory occupied by a pair at least twice, (2) a territory in which a bird was seen at least once in incubation posture, or (3) a territory where an egg or chicks were seen. Eggs and/or chicks were documented at 12 of these sites (66%). Based on these 12 breeding sites, we estimate 0.67 fledglings were produced per pair. This is the lowest productivity for this species over the last several years. A total of 8 chicks were observed to have survived to fledging. The first eggs were observed on 16 May. BLOY nests are cryptic and difficult to observe; therefore clutch size, hatching success and fledging success were not determined. Large numbers of California Sea Lions were hauling out in BLOY breeding areas, likely contributing to the low reproductive success this season.

Common Murre **–** During 2006, 228 Common Murre sites were monitored daily in the Upper Shubrick Point (USP) study plot. The number of breeding sites (where at least one egg was laid) was 200. Productivity at USP in 2006 was 0.40 chicks fledged per pair, approximately 22% lower than last season. This value is also 47% lower than the 35-year average of 0.74 and the lowest observed since 1998 (Fig. 1a). The first eggs were observed in this plot on 4 May. Hatching success was low this season with only 68% of the eggs hatching. Fledging success was also very low with only 58% of the hatched chicks surviving to fledge, primarily due to starvation during the first few days after hatching.

The colony of Common Murres in Upper Upper (UU), under the Cormorant Blind, normally breeds later than the colony at USP. Birds did not regularly attend this sub-colony until 1 May, and the first egg was observed on 9 May. Sixty-one sites were monitored in 2006, with 48 of those sites attended by a breeding pair, an increase of 45%. Hatching success at UU was high this season with 90% of eggs hatching, and 70% of those chicks surviving to fledge (see Table 1). Productivity was 0.65 chicks fledged per pair, approximately 86% higher than last season.

Pigeon Guillemot **–** A total of 145 sites were monitored on Lighthouse Hill, Garbage Gulch, and the Habitat Sculpture, of which 79 were observed with at least one egg (56% of the total number of sites). Two sites were located in the Habitat Sculpture, and four in Rhinoceros Auklet nest boxes by Russia House and Murre Blind Hill. Productivity was 0.23 fledglings produced per pair (Table 1). This was 48% lower than 2005, and approximately 74% below the 35-year mean productivity for this species (Fig. 1a). The first eggs were observed on 17 May. The mean clutch size was 1.28 eggs per nest with 72% of those eggs hatching successfully. Mean brood size was 0.93 chicks per nest, but only 25% of the chicks produced survived to fledge.

Rhinoceros Auklet – There were a total of 151 sites (boxes, crevices, and cave sites) monitored in 2006, 51% (n=77) of which were occupied by a breeding pair. Productivity was 0.42 fledglings per pair, which is 27% higher than last season but still 25% below the 20-year average (Fig. 1a). The first eggs were observed on 6 May. Seventy-five percent of the eggs successfully hatched, but only 56% of those chicks produced survived to fledge.

Cassin's Auklet – Occupancy of breeding birds in boxes was high in 2006 with 84% (37 of 44) of the study boxes occupied, compared to just 36% in 2005. Auklets breeding in PRBO study boxes suffered complete reproductive failure for the second straight year. Only five chicks hatched, representing a hatching success of 14%, and all chicks died within a few days of hatching. The first eggs were observed on 11 April. This is approximately equal to the long-term mean lay date for this species and three weeks earlier than last season. Although there were no chicks that fledged from our PRBO study sites, there were a small number of chicks (n=4) that fledged from other followed sites not normally included in our productivity estimates. If all followed sites where an egg was laid are included in the analysis, productivity would be 0.04 chicks per pair (n=102). This estimate may be more reflective of the overall productivity for the population this season.

Ashy Storm-Petrel – ASSP pairs laid eggs in 38% of the 72 followed sites (n=27) in 2006. The first eggs were observed on 5 May. Sixty-three percent of the eggs hatched and 77% of the chicks successfully fledged. Productivity for this species continues to be low with only 0.46 chicks fledged per pair (including all relay attempts). This is 17% lower than the value from 2005 (0.56) and 32% below the long term average productivity for this species (0.68).

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 described otherwise.

Ashy and Leach's Storm-petrels –The mark/recapture study to estimate ASSP population size and survival continued in 2006. We operated two netting locations (Lighthouse Hill and Carp Shop) on 9 evenings between April and August. We banded a total of 580 Ashy storm-petrels and recaptured 137. Our largest single night was 22 May on which 164 birds were caught. There were also 12 Leach's storm-petrels banded this season. One Black storm-petrel was captured on the night of 22 April, an island first.

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 23 counts were made in 2006, beginning on 17 March and ending on 14 July, when juveniles became indistinguishable from adults. On 15 June we counted a peak number of 237 "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 474 breeding birds. This estimate is 265% higher than 2005, and approximately 21% greater the 10-year average population for this species (Table 2). There was a high count of 275 chicks observed during the last census on 14 July.

Brandt's Cormorant – The BRCO breeding population was censused during a ground-based survey on 7 June and a boat based survey on 12 June. A total of 7,846 "well-built" nests were counted (Fig. 2), yielding an overall estimate of 15,692 breeding birds (Table 2). This estimate is 34% greater than the estimate for 2005, and 77% higher than the 10-year average (Table 2). We then multiplied the number of nests by the number of chicks fledged per pair (Table 1) to estimate island-wide production of 16,084 fledglings.

Pelagic Cormorant – The PECO breeding population was censused on 12 and 13 June during land-based and boat based surveys. A total of 20 fair to well-built nests were counted (Fig. 3), yielding a total breeding population of 40 birds (Table 2). This estimate for Pelagic Cormorants is approximately 42% higher than in 2005, but still 88% lower than the 10-year average. Of the 20 nests, three were confirmed to contain eggs and 1 chick hatched. As a result of this, we estimate the island-wide production to be 1 fledgling for this season.

Western Gull – The WEGU census was conducted on 6 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 14,297 (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 (1.5) 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 17,399 birds (Table 2) and overall production of 9,308 fledglings in 2006. The population estimate for WEGU is approximately 5% higher than in 2005 but still 6% lower than the 10-year average.

Black Oystercatcher - We estimated the population of BLOY by surveying all known breeding sites visible from Lighthouse Hill and the marine terrace. Of the 30 sites that were monitored this year, 18 were considered active sites. Therefore, we estimated a breeding population size of 36 birds and a production of 8 fledglings. This estimate does not reflect birds on parts of West End Island not visible from the SEFI vantage points. This estimate is 20% higher than the 2005 estimate.

Common Murre – The COMU breeding population was censused during land-based surveys conducted between 2 and 5 June (Fig. 5). Individual birds were counted during these surveys. The boat portion of the survey was not conducted this year due to unfavorable ocean conditions. The total number of individuals counted during the land-based survey was 73,387. As with WEGU, a correction factor was calculated using data from the USP, UU, and X study plots to account for breeding adults not present during the census (prior to 2002 the correction factor was calculated using only data from the USP plot). The correction factor methodology was changed after the 2002 season in response to a report by Nur and Sydeman (2002) which showed that correction factors for count data are best calculated using multiple counts on multiple plots. The correction factor used in 2006 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 1.50. This method assumes that the extra birds observed in the plots are the mates of breeding individuals and not simply wanderers or non-breeders. Multiplying the raw count by the correction factor yielded an estimate of 110,081 breeding birds.

Since a boat census could not be completed, we also added a second correction factor to account for the proportion of the population that would normally be censused from the boat. Based on the 2002 census data (the last time a complete boat census was completed), 48% of the total population breeds on West End Island and a few other SEFI locations not observable from land. Therefore, we multiplied the corrected count by 1.92 to arrive at an overall estimate of 211,355 breeding adults. We estimated island-wide production at 56,009 fledglings (Note: as with the calculation of the correction factor, productivity data from all three plots was pooled to estimate the overall number

of fledglings produced, yielding an island-wide productivity of 0.53 chicks/pair). Population size in 2006 was approximately 15% higher than in 2005 and also well above the 10-year average (Table 2).

Pigeon Guillemot – Our estimate of the breeding population of PIGU is derived by counting adults rafting on the water around SEFI at dusk throughout the month of April, before the birds begin regular attendance of sites. Our peak count was 777 birds on 2 May. This count was 38% lower than the peak count from 2005 but still 8% higher than the 10-year average (Table 2 and Fig. 7). Over the last several seasons, we have noticed that the number of guillemots observed on the water around the island is much higher in the early morning than in the evening (when raft counts have traditionally been made). So, in 2002, we modified our protocols and initiated morning raft counts (0700-0830), in addition to evening counts, to more accurately reflect the absolute number of birds using the island. Our peak count during morning surveys in 2006 was 2,607 on 25 April. This represents an increase of 90% compared to the peak count of 1,374 during morning surveys in 2005 and is 20% higher than the 5 year mean for morning surveys.

Tufted Puffin – The island-wide TUPU survey was conducted primarily in two parts in 2005; a one-week period from 16 to 21 May and second from 2 to 5 August. Supplemental late season surveys were also conducted on August 13, 29, and September 14. 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 at the same time, (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. During the surveys, a total of 30 active sites were observed, although only 4 of these were confirmed to have chicks based on observations of birds delivering fish to the site. Based on these observations, we estimated a breeding population of 60 birds (Table 2). This represents a slight increase (20%) in the TUPU breeding population numbers as compared to the low numbers observed in 2005 (Fig. 7). It should be noted, however, that there were many more puffins observed throughout the season, but they were not regularly attending breeding

sites and hence are not included in this estimate. It also appeared that puffins were not at peak-chick rearing until mid to late August, and that birds continued to feed chicks throughout September. This suggests that these birds can breed extremely late in the season, and our survey methods may need to be adjusted to allow observations during the most appropriate time periods.

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 2006. A total of 64 new birds were banded and 106 were recaptured (61 birds were captured multiple times during the 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 has not been conducted since 1989, at which time a breeding population of 29,880 birds was estimated (Carter et al. 1992). To estimate the breeding population for 2006, we applied the percent difference between the 1991 and 2006 counts in the index plots to the 1989 estimate. This calculation assumes 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 currently provides our best estimate of population size. We counted a total of 167 burrows in the index plots this season (46% of the 1991 count). Therefore, we estimated a 2005 breeding population of roughly 13,597 birds ([167/367] x 29880). The breeding population estimate is 16% lower than in 2005 and 31% lower than the 10-year average (Table 2). Total island-wide production was estimated at 272 fledglings on SEFI. Note that the calculation for island-wide productivity is based on all known Cassin's Auklet sites monitored this season in contrast to the estimate from the PRBO study boxes (Table 1) that is normally used. This was due to the fact that no chicks fledged from PRBO sites in 2006 and we feel that the "all-site" estimate more accurately reflects true conditions on the island this season.

DISCUSSION

Productivity:

Productivity of seabirds on SEFI during the 2006 breeding season was poor for most species and below the long-term mean for all species except Brandt's Cormorants and Western Gulls (Fig. 1a, b). Pelagic Cormorants and Cassin's Auklets suffered near total reproductive failure again this season, while Rhinoceros Auklets, Pigeon Guillemots, and Common Murre had similar or reduced productivity when compared to 2005. We have included the 80% confidence limits (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 the strong El Niño years fall below this range for most species and that PECO, RHAU, CAAU and COMU are near or below this level for 2006.

Mean monthly sea-surface temperatures (SST) at the Farallones from March to August fluctuated greatly from month to month with periods of very warm water interspersed with periods of relatively cool temperatures (Fig. 6a, b). The mean seasonal SST from March to August (12.31°C) was approximately 0.2 degrees lower than last season, but still approximately 0.15°C warmer than the 35-year average of 12.15°C for these months. Sea-surface temperatures were at or below the long-term mean for the period of January through March before rising sharply in April. The SST for April (12.53°C) was 1.2 degrees higher than the long-term mean for this month and the highest observed since ENSO 1992. Generally, relatively warm SSTs are correlated with low ocean productivity in the California Current System (Barber et al. 1985). Although the SST during the early months of the pre-breeding season was at or near the long-term mean, the very warm water conditions observed in April and again in June were likely key factors contributing to the general low productivity observed this year. Cassin's Auklets initiated breeding in early April, just when the ocean was beginning to warm, and subsequently abandoned those eggs. Also noteworthy was a lack of strong north-west winds during the spring, similar to the pattern observed in 2005. These wind

patterns normally drive upwelling along the California coast, which in turn replenishes nutrients in the surface water and leads to higher ocean productivity. The absence of this pattern and consequential reduction in upwelling likely impacted the amount of prey available to seabirds this season and resulted in the reduction in reproductive success observed. Juvenile rockfish (*Sebastes* spp.) are an important component of seabird diet in high productivity years (Sydeman et al. 2001). In 2006 rockfish were only a minor portion of the diet for Common Murres and Pigeon Guillemots (~1%) and completely absent from Rhinoceros Auklet diet (Fig. 8). National Marine Fisheries Service again found a low abundance of juvenile rockfish in their trawls near the Farallones during their annual May survey. Large anchovies comprised the majority of the chick feedings for most species.

Reproductive success varied greatly between species this season (Fig. 1). Brandt's Cormorants exhibited high productivity with more than two chicks fledged per breeding pair. That coupled with an increasing population resulted in greater than 16,000 chicks present on and around the island in August and September. Pelagic Cormorants, on the other hand, suffered near total reproductive failure for the second year in a row, with only one chick fledged from all known sites on the island. These consecutive poor years came after four extremely productive years from 2001-2004, and may be, along with Cassin's Auklets, one of the strongest signals of a recent shift in the marine ecosystem around the Farallones. While we are unable to estimate productivity for Double-Crested Cormorants due to the remoteness of their colony and difficulty observing chicks at the nest, the breeding population increased substantially this season and a large number of chicks were observed during our censuses. As noted last season, the disparity in success of cormorants is likely a result of differing foraging strategies between these species. BRCO forage farther from the island and were able to locate larger, widely dispersed schooling fish, primarily anchovies, to feed to their chicks. We know this from incidental observations of chick regurgitant. PECO forage closer to the island and are more dependent on rockfish and other small fish that hide in the substrate (Ainley and Boekelheide, 1990), and thus were likely unable to find enough food to breed successfully this season.

Reproductive success of COMU was among the lowest recorded for this species at the Farallones, exceeded only by the strong El Nino years of 1983, 1992, and 1998. Many factors likely contributed to their poor success this season. Anchovies, though abundant, were often too large for the small chicks to swallow (personal observations) and rockfish were virtually absent from the diet (Fig. 8). The result was that many chicks died within the first 5-7 days after hatching (often with a large anchovy sitting next to or on top of them) because adults were not able to locate appropriate size prey items. It was also noted that a large proportion (24%) of eggs failed to hatch or died during the pipping stage. This may be suggestive of poor condition of adults prior to egg laying or less energy invested in the eggs this season. Unfortunately, we are not able to weigh eggs or examine the condition of adults to test this hypothesis.

Productivity of Western Gulls was relatively high this season, approximately equal to the long-term mean and the second most productive season for this species in the past 15 years (Fig. 1). Productivity for this species declined throughout the 1990's, possibly due to changes in prey availability and increased intraspecific predation (Sydeman et al., 2001). This trend appeared to reverse since 2000 with a net increase in productivity of more than one chick per pair, on average, between 2000 and 2004. This high productivity trend continued in 2006 after a dip last season.

Cassin's Auklets suffered near total reproductive failure for the second consecutive year, unprecedented in the history of this species on the Farallones. As noted above, there was complete reproductive failure in the PRBO study boxes from which we normally obtain our estimate of reproductive success. Auklets also exhibited reduced breeding propensity with 61% of the boxes (291 of 478) occupied this season. This is up from only 32% last season but still below the level seen in previous seasons. The reason for this almost complete reproductive failure seems to be oceanographic conditions which led to a reduction in the availability of krill, the auklets primary prey, for much of the spring and early summer. Oceanographic conditions, while not remarkably poor, did not produce the sustained periods of upwelling and resultant productivity normally associated the Gulf of the Farallones. The onset of breeding was approximately equal to the long-term mean, but a change to extremely warm water conditions in April resulted in abandonment of breeding attempts, reduced hatching and

fledging success and high chick mortality among those that hatched. Rate of egg abandonment was high again this season, 88% for all monitored sites and 95% for PRBO study boxes. While this represents an improvement from last season when 100% of eggs were abandoned, it is still an unusually high rate of abandonment. Even in the most extreme El Nino years which negatively impacted auklet breeding (1983 and 1992), the rate of abandonment did not exceed 65%. Adult attendance at nest sites also showed unusual patterns this season, possibly a response to poor foraging conditions near the island. Adults were present at the nest on one check, then absent for the next several checks, then begin attending again. This resulted in longer incubation periods and reduced provisioning for those few chicks that hatched. Although not specifically quantified, adult attendance at the colony was also extremely low this season while the number of auklets observed on the water during the day was higher than in the previous years.

Populations:

Breeding population sizes were higher than the 2005 estimates for all species except PIGU and CAAU. Population increases ranged from 5% for WEGU to 264% for DCCO when compared to 2005 estimates. Among those species which had a decrease in populations, the range was from 16% for CAAU to 38% for PIGU. It is important to note that population estimates for COMU and PIGU do not necessarily represent breeding birds because the census methods used for these species are not able to distinguish between breeders and non-breeders. While this is true for all years, it may be more important in poor reproductive years when a larger proportion of the population does not attempt to breed. This is probably true for PIGU the past two seasons and may explain the contrast between the trends in the morning and evening raft counts. Morning counts most likely reflect the total population attending the colony during the pre-breeding period, whereas the evening counts may be more indicative of the proportion of the population that breeds. Occupancy of monitored PIGU crevices was higher in 2006 (56%) when compared to 2005 (40%) and there were more eggs laid, suggesting a greater breeding effort this season despite lower evening raft counts. Much of the growth in the COMU population over the past several seasons is likely due to the influx

of young birds returning to the colony for the first time. Murres will often return to the colony by age 2, but will not begin breeding until they are between 5 and 9 years of age, so the growth of the breeding population would be expected to lag behind the trend observed in the overall colony counts.

Farallon Cassin's Auklets declined considerably from 1971-1998 (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. Recent analyses indicate that between 1991 and 2006, the overall population trend is a 3.27% decrease per year, though there have been varying periods of growth and decline (PRBO unpublished data). This population suffered substantial mortality during the strong 1997/1998 El Niño event and reached it's lowest abundance (10,458 birds) in 1998. Between 2001 and 2004, the population was increasing rapidly. However, the breeding population suffered a large decline last season and declined further still in 2006. The burrow counts for 2006 were 16% lower than in 2005 and the lowest since 1998 (Table 3), representing a 54% decline in burrow density since the 2004 season. It is as yet unclear if this represents a true decline in the population (i.e. adult mortality) as observed after the 1998 season, or whether a smaller proportion of the population attempted to breed. After two consecutive years of poor ocean conditions, it is likely a combination of these factors.

Sydeman et al. (1998) reported a 35% decline in ASSP numbers from 1972 to 1992 based on a mark/recapture analysis. However, based on the number of birds banded each season and increasing capture rates, the population may be increasing. The mean standardized capture rate (number of birds caught per hour of effort) increased from approximately 11 birds/hour (s.d. = 9.7, n = 9 three hour sessions) to 31 birds/hour (s.d. = 18.35, n = 8 three hour sessions) between 1999 and 2005. The mean capture rate for 2006 was 27 birds/hour of netting effort (s.d. = 14, n= 9 three hour sessions). This observation, however, does not consider the proportion of birds caught that are non breeders, or potential changes in recapture probabilities through time. Future detailed analyses of mark/recapture data will need to be conducted in order to determine the true state of the ASSP population. It is also noteworthy that 21 new storm-petrel sites (defined as having an adult present on at least one check) were

located this season, though there was only a net increase of two confirmed breeding sites (egg or chick observed).

The Common Murre population on the Farallones has exhibited rapid growth over the past several seasons. Historically, this population was estimated at 400,000 birds (Ainley and Lewis, 1974). Sydeman *et al.* (1997) suggested that there may have been closer to 1 million. Egg collecting, oiling, and human disturbance drastically reduced these numbers in the late 1800s and early 1900s. Murres 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. However, favorable oceanographic conditions and abundant prey, coupled with relatively strong reproductive success and probable elevated juvenile survival between 2000 and 2004 has led to incredible population growth over the last 6 years (an average of 27% per year). The 2006 estimate of 211,355 is the highest yet observed since PRBO began standardized studies in 1971 and represents a four fold increase since 2000 (Figure 7). The low productivity observed the last two years may slow this growth as there will be fewer young birds to recruit to the colony in coming years.

Brandt's Cormorants and Pelagic Cormorants have also declined substantially over the past two decades (Nur and Sydeman 1999, Fig. 7), but like many other species on the Farallones, their populations have grown considerably since 1999. In 2005, the BRCO breeding population declined by 30% from 2004, but much of this decline was recovered in 2006 suggesting that the observed decline was primarily a result of birds skipping breeding rather than actual mortality. The high productivity observed this season coupled with continuing strong recruitment should continue the growing trend for this species. The PECO breeding population, on the other hand, did not bounce back in 2006. Although there were more nests built this season, the overall breeding population remains low. It should be noted that our population estimates are based on the number of nests present during the survey window, reflecting the number of breeding birds only. Many more non-breeding birds were present at the colony throughout the season but are not accounted for in our census methods.

In summary, 2006 was a poor year for most species on the Farallones due to warm sea surface temperatures in April and June, presumably due to a lack of

upwelling, and poor ocean productivity during the early part of the breeding season. Seabird reproductive success remained low or further declined for most species, and was the second consecutive year of auklet breeding failures. It appears that unfavorable oceanic conditions during a critical period of the breeding season resulted in the poor reproductive success observed this season. The effect of the poor ocean conditions the past two seasons on adult survival of Farallon seabirds is not yet known, and this may be key to understanding whether breeding populations will continue to grow. The coupling of two consecutive poor breeding seasons with a projected El Nino in late 2006/2007 may further impact seabird productivity and populations over the next few years. The effects of these climate anomalies on Cassin's Auklets and Pelagic Cormorants are of great concern.

RESEARCH AND MANAGEMENT RECOMMENDATIONS

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

1. To further our understanding of ASSP population trends and to determine the current state of the storm-petrel population on the Farallones, the mark/recapture study should be continued in FY 2007. The introduction of novel techniques to aid in our understanding of ASSP populations (such as nest motes, pit tags and radar) should also be considered. While we can accomplish current fieldwork with available funds, costs for the implementation of newer techniques as well as analysis and write-up of existing data cannot be met with present resources, and additional support is needed.

2. Cassin's Auklets have declined dramatically on SEFI over the past three decades and have had extremely poor reproductive success the last two seasons. Because CAAU appear to be one of the most sensitive species to environmental variability, we recommend detailed analysis of existing demographic data and a population dynamics modeling effort. The purpose of this analysis would be to investigate long-term population viability, determine if oceanographic factors are causing population declines, and predict population size in the future. Funds are needed for this work.

3. A complete, island wide census of burrow/crevice sites has not been conducted since 1989 (see Carter et al, 1992). We recommend that this be done using the same methodology (preferably by the same researchers) in order to establish new, baseline population numbers for burrow/crevice nesting species such as Cassin’s and Rhinoceros auklets. We further recommend that this be done in conjunction with newer methods such as radar and habitat assessment modeling in order to develop the best possible methods for obtaining accurate population estimates for these species.

4. To further our understanding of the foraging ecology of SEFI seabirds, we recommend consideration of novel monitoring techniques including deployment of time-depth recorders (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) in support of management decisions. Novel technology will also allow us to examine marine habitat use and foraging behavior, which is critical to the establishment of marine protected areas around the Farallon NWR.

5. Relatively little is know 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 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.

6. We propose assessment and modification of our research methods for surveying breeding populations of Tufted Puffins. The extremely long delay in breeding for birds this year, where most chick rearing occurred after the end of the seabird "season", and the difficulty of assessing breeding status through limited surveys suggest more effective methods need to be developed to asses populations and productivity for this species.

7. In 2003 we began monitoring Rhinoceros Auklet burrow index plots and occupancy rates to aid in estimating breeding population size. We recommend continuing use of these plots to assess changes in both numbers and occupancy rates. Occupancy rates obtained every 5 years, in conjunction with annual burrow counts, quantification of habitat types, and mark/recapture analysis of current banding data, will provide an accurate estimate of breeding population size for this species. Burrow occupancy is scheduled to be surveyed again in 2007.

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Table 1. Mean (± 1 SD) productivity of eight species of seabirds at Southeast Farallon Island, California, 2006. 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	3.10 ± 0.63 *(107)*	2.36 ± 0.93 *(113)*	2.05 ± 1.08 *(134)*	2.05 ± 1.08 *(134)*	0.81 ± 0.27 *(98)*	0.88 ± 0.27 *(106)*
PECO	2.3 ± 1.5 *(3)***	1.00 *(1)***	0.09 ± 0.3 *(11)*	0.09 ± 0.3 *(11)*	? *(1)*	1.00 *(1)*
WEGU	2.70 ± 0.54 *(165)*	1.95 ± 1.00 *(165)*	1.07 ± 1.03 *(163)*	1.07 ± 1.03 *(163)*	0.72 ± 0.35 *(165)*	0.53 ± 0.42 *(144)*
COMU* USP	1.00 *(200)*	0.68 ± 0.47 *(199)*	0.39 ± 0.49 *(200)*	0.40 ± 0.49 *(200)*	0.68 ± 0.47 *(199)*	0.58 ± 0.50 *(133)*
COMU* Upper Upper	1.00 *(48)*	0.90 ± 0.31 *(48)*	0.65 ± 0.48 *(48)*	0.65 ± 0.48 *(48)*	0.90 ± 0.31 *(48)*	0.70 ± 0.46 *(43)*
PIGU	1.28 ± 0.45 *(75)*	0.93 ± 0.62 *(74)*	0.22 ± 0.41 *(79)*	0.23 ± 0.42 *(79)*	0.72 ± 0.42 *(74)*	0.25 ± 0.42 *(57)*
RHAU*	1.00 *(77)*	0.75 ± 0.44 *(76)*	0.42 ± 0.50 *(77)*	0.42 ± 0.50 *(77)*	0.75 ± 0.44 *(76)*	0.56 ± 0.50 *(77)*
CAAU*	1.00 (37)	0.14 ± 0.35 *(37)*	0.00 *(37)*	0.00 *(37)*	0.14 ± 0.35 *(37)*	0.00 *(5)*
ASSP*	1.00 (27)	0.63 ± 0.50 *(24)*	0.46 ± 0.51 *(23)*	0.46 ± 0.51 *(23)*	0.63 ± 0.50 *(24)*	0.77 ± 0.44 *(13)*

* 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 productivity presented here is based on the PRBO study boxes only, so that it can be compared to previous years. Actual productivity from all sites monitored was 0.04 chicks fledged/pair (n=102).

Table 2. Breeding population size estimates of seabird species on the South Farallon Islands, 1996-2006. Estimates include Southeast and West End Islands unless noted.

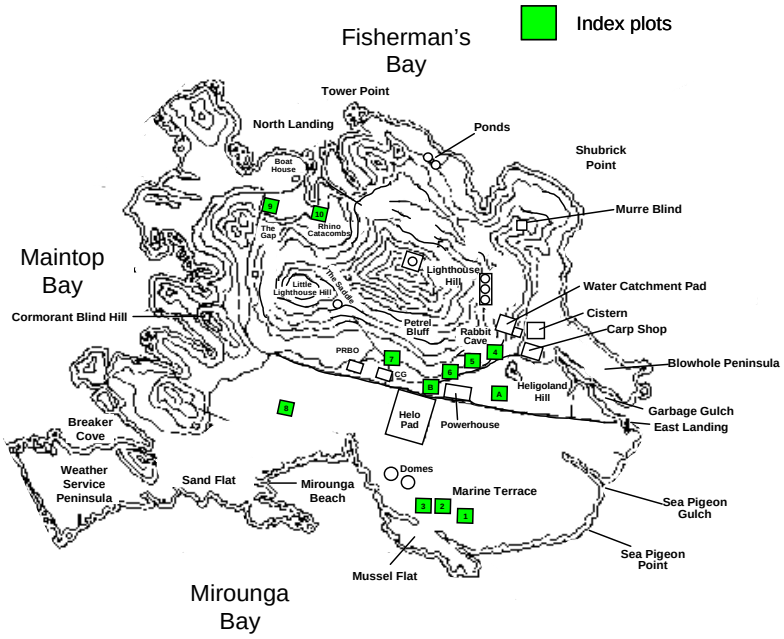
Species	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1996-2005 average
DCCO	474	130	458	392	486	402	402	468	330	?[c]	444	390
BRCO	15,692	11,732	16,754	11,222	9,466	6,570	5,896	6,345	5,092	7,490	8,074	8,864
PECO	40	28	706	510	442	416	260	222	164	316	374	344
WEGU	17,399	16,547	17,969	16,838	15,095	18,235	15,544	19,767	19,707	23,807	20,815	18,432
BLOY	36	30	26	26	22	30	26	30	18	22	12	24
COMU	211,355	183,092	169,079	107,105	103,588	68,194	53,301	58,878[b]	52,670	61,089	65,400	95,946
PIGU	777	1,250	1,096	500	499	502	568	468	294	1273	728	718
TUPU	60	50	190	?	128	102	74	118	50	130	92	104
CAAU [a]	13,597	16,202	29,229	23,692	18,807	16,690	15,239	15,239	10,458	26,892	23,668	19,612

[a] Estimate for Southeast Farallon Island only.
[b] Ammendment to the 1999 COMU population estimate.
[c] Nests counted from Cormorant Blind where visibility of sites was reduced. No comparable estimate made.
[p] Estimates from Sydeman et al. (1997).

Table 3. Cassin's Auklet burrow counts from 12 (10m x 10m) index plots on Southeast Farallon Island, 1991-2006.

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
1992	18	11	14	24	33	14	25	26	80	43	15	24	327
1993	13	9	13	29	34	14	19	12	82	42	12	12	291
1994	19	13	15	20	28	10	13	21	89	47	15	22	312
1995	18	8	19	21	24	26	19	21	88	34	17	16	311
1996	9	10	13	18	19	19	7	14	97	45	14	24	289
1997	20	11	18	18	20	15	9	21	97	52	13	37	331
1998	9	6	5	8	8	7	6	7	36	17	5	13	127
1999	7	3	17	7	9	10	5	10	65	32	7	17	189
2000	11	2	4	9	11	4	10	14	61	32	9	20	187
2001	14	4	12	12	15	5	7	19	58	36	7	16	205
2002	20	9	20	14	20	14	8	13	47	45	6	15	231
2003	20	9	22	15	26	7	15	15	84	49	8	21	291
2004	36	25	37	21	28	10	20	18	95	34	9	26	359
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
1991-2005 average	16	9	16	18	22	12	14	16	75	37	10	20	268

Cassin's Auklet Index Plots



Comment: Still need to add ASSP population estimate for this year to complete this graph

Comment: Should be very soon

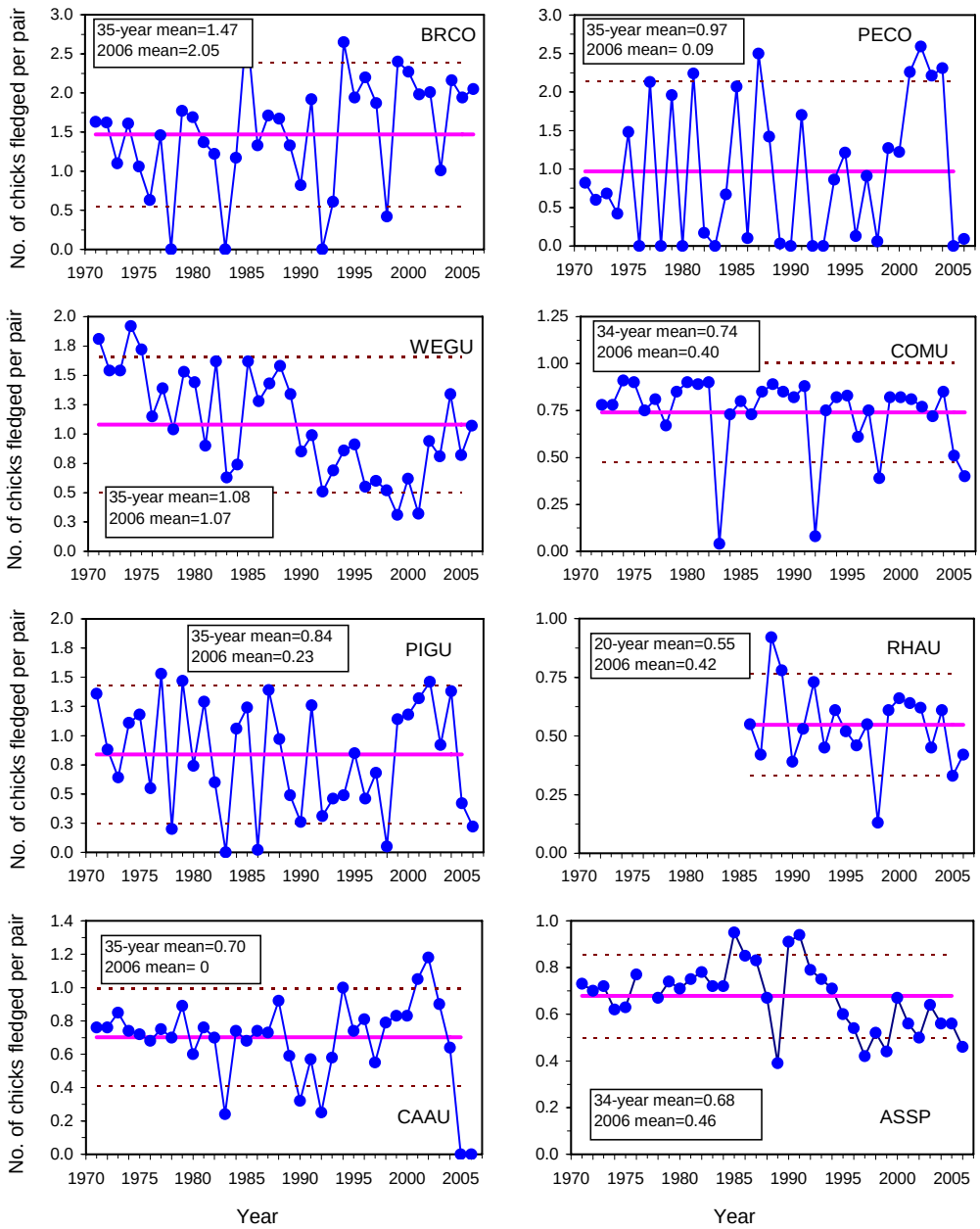


Fig. 1a. Productivity of 8 species of seabirds on Southeast Farallon Island, 1971-2006. Productivity is measured as number of chicks fledged per breeding pair (includes first attempts, relays and second broods). The bold horizontal line indicates mean productivity from all attempts between 1971 and 2005. The dashed lines represent the 80% confidence interval for the long term mean. Please note the different scales on the y-axis.

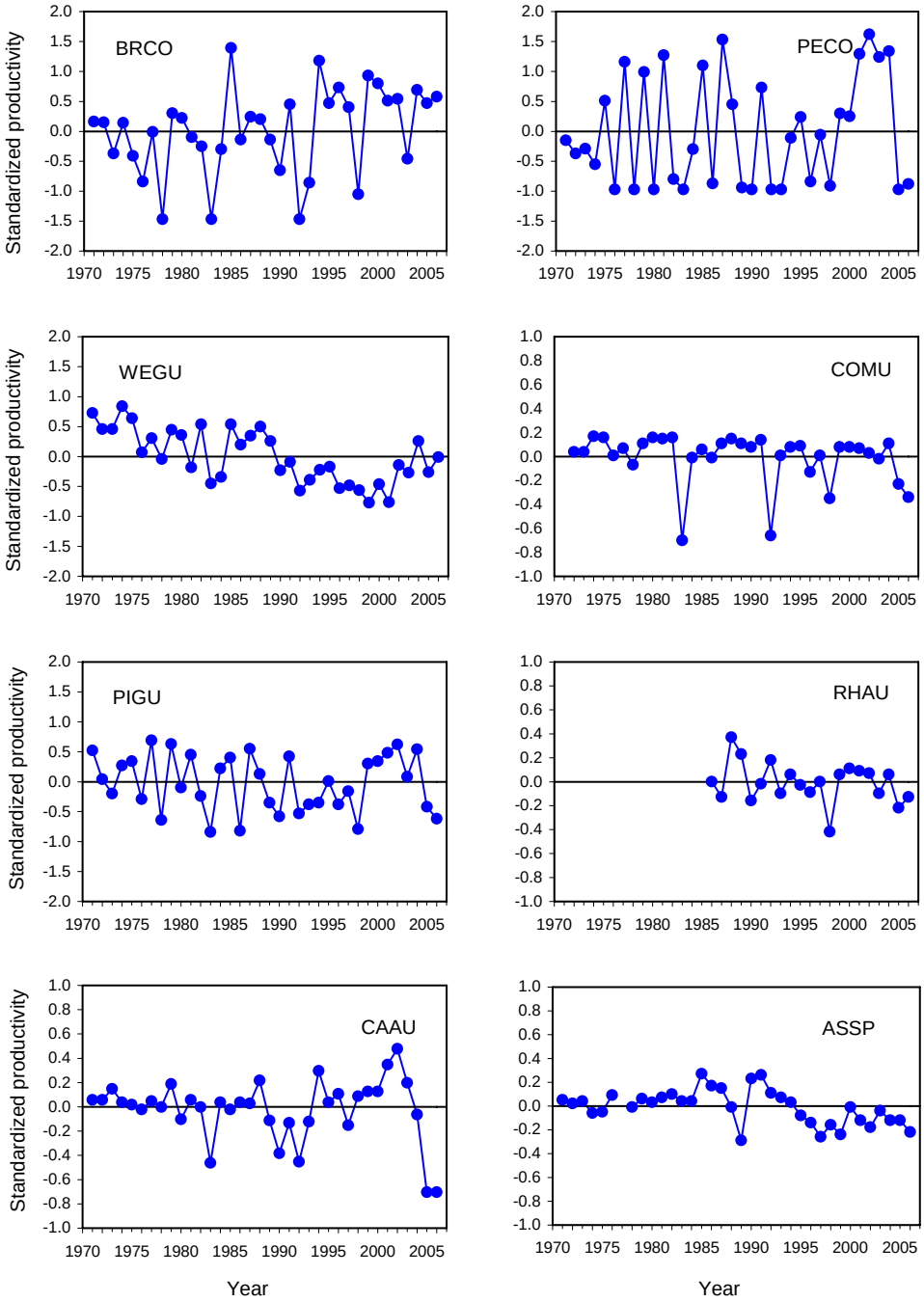


Fig 1b. Standardized productivity anomalies (annual productivity - long term mean) for 8 species of seabirds on SEFI, 1971-2006.

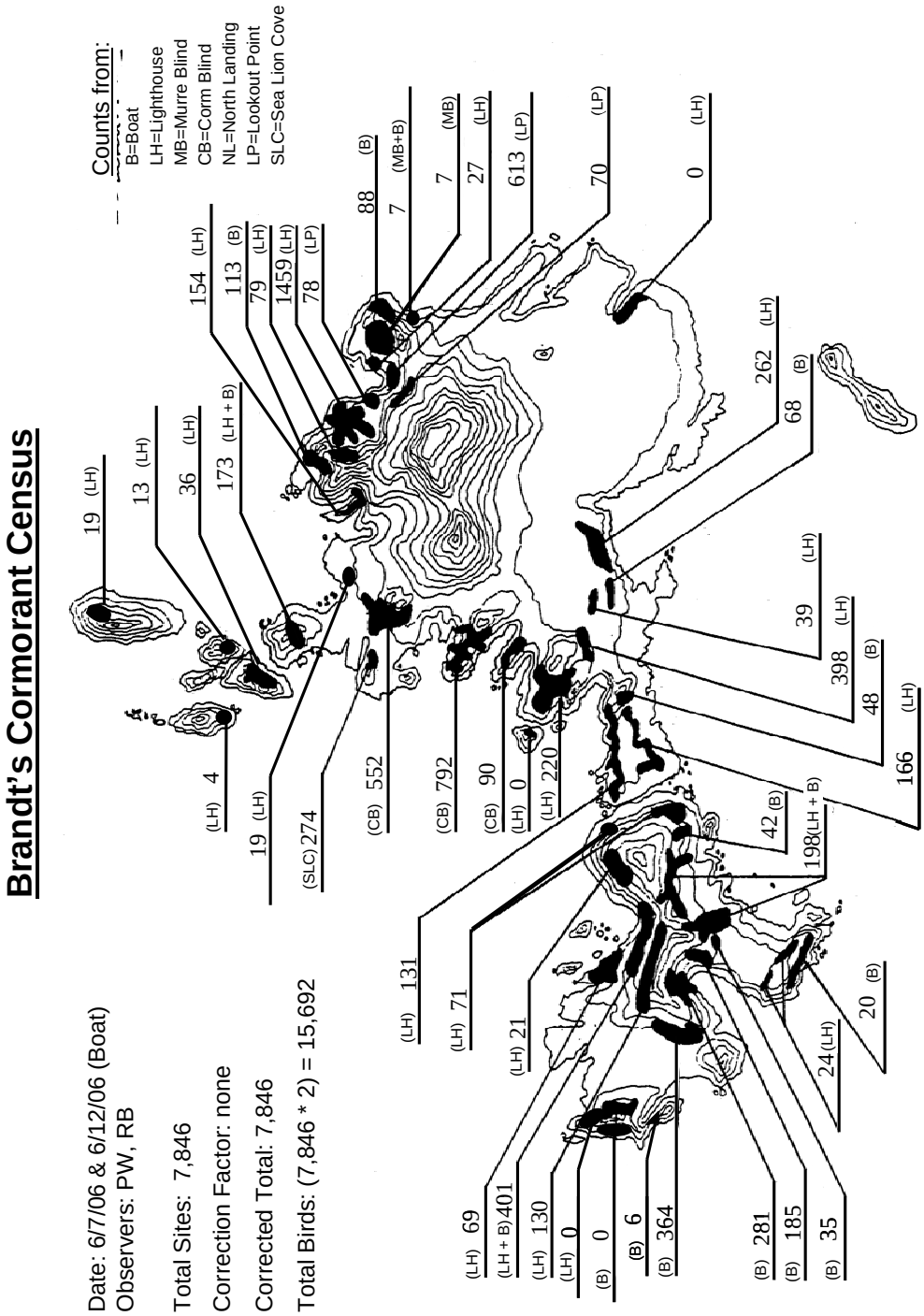


Figure 2: Counts of Brandt's Cormorants on Southeast Farallon Island during the 2006 census. Surveys were conducted from the following locations: Lighthouse Hill (LH), Murre Blind (MB), Cormorant Blind (CB), North Landing (NL), and Boat (B).

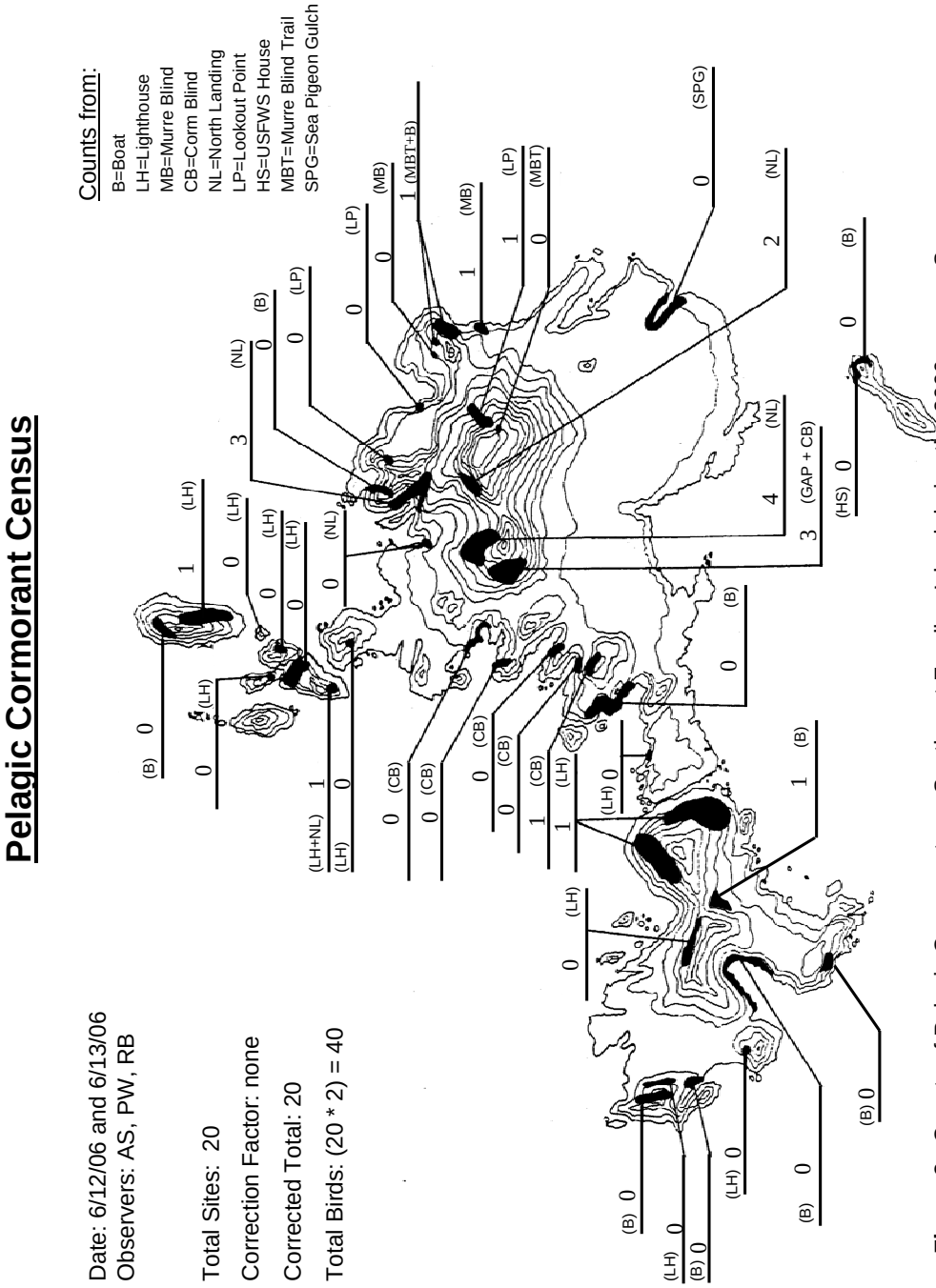


Figure 3: Counts of Pelagic Cormorants on Southeast Farallon Island during the 2006 census. Surveys were conducted from the following locations: Lighthouse Hill (LH), Lookout Point (LP), Murre Blind (MB), Cormorant Blind (CB), North Landing (NL), USFWS House (HS), Murre Blind Trail (MBT), Sea Pigeon Gulch (SPG), and Boat (B).

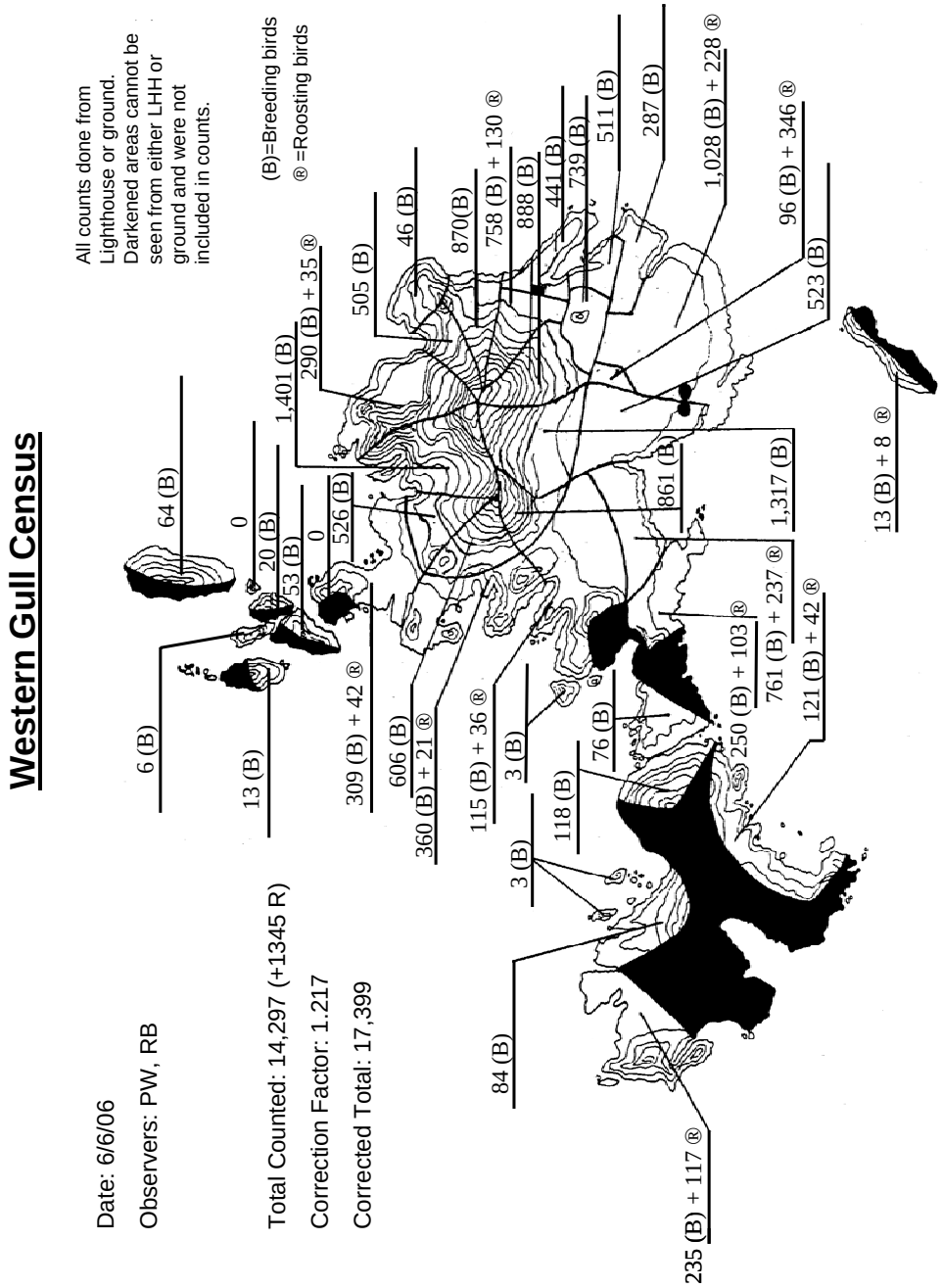


Figure 4: Counts of Western Gulls on Southeast Farallon Island during the 2006 census.

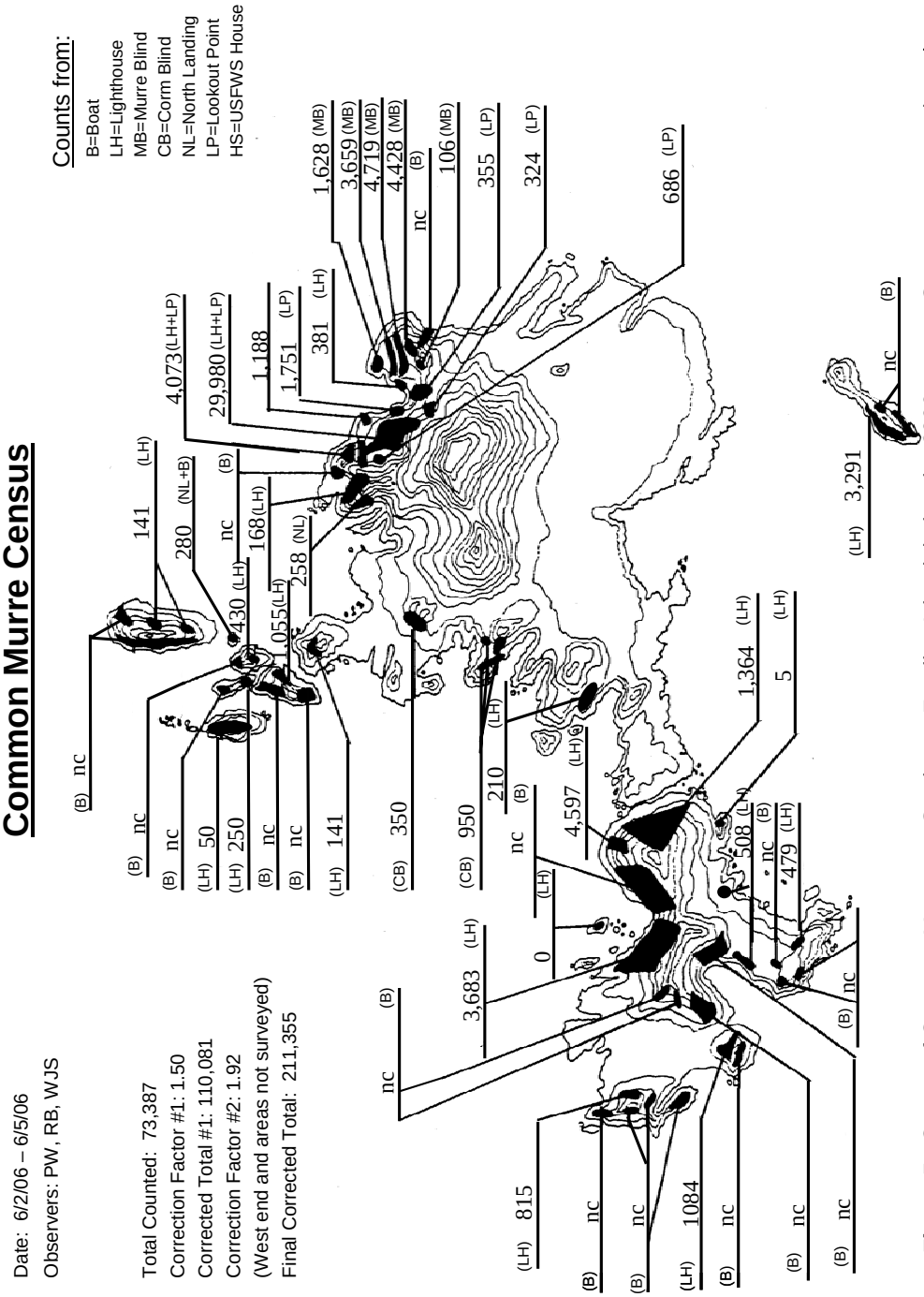


Figure 5: Counts of Common Murres on Southeast Farallon Island during the 2006 census. Surveys were conducted from the following locations: Lighthouse Hill (LH), Lookout Point (LP), Murre Blind (MB), Cormorant Blind (CB), North Landing (NL), USFWS House (HS). The boat survey (B) could not be done this year.

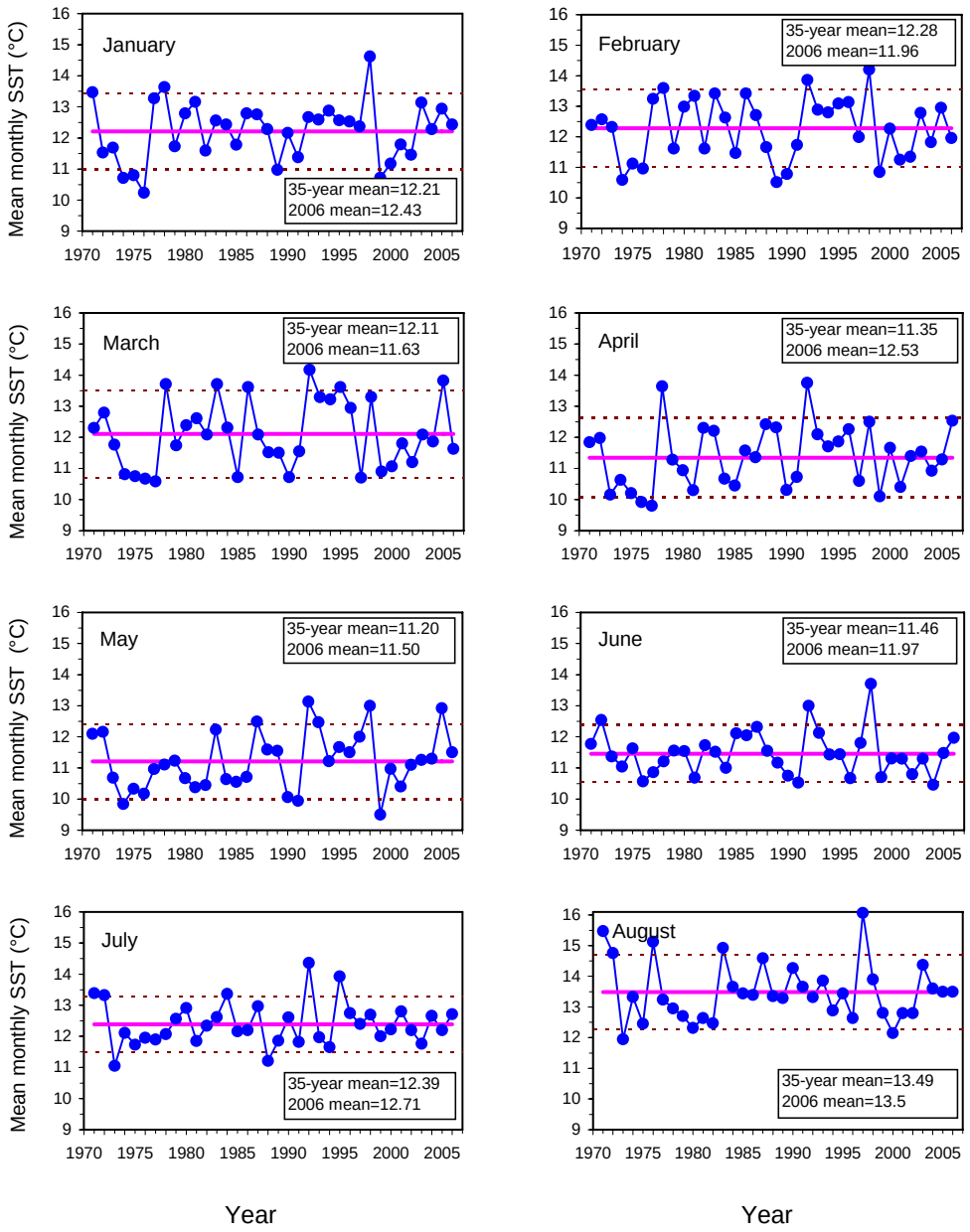


Fig. 6a. Monthly mean sea surface temperature (SST) at Southeast Farallon Island, 1971-2006. SST was measured daily from Water Sample Point, near East Landing. The bold horizontal line indicates mean monthly SST from 1971 to 2005. The dashed lines represent the 80% confidence interval for the long term mean.

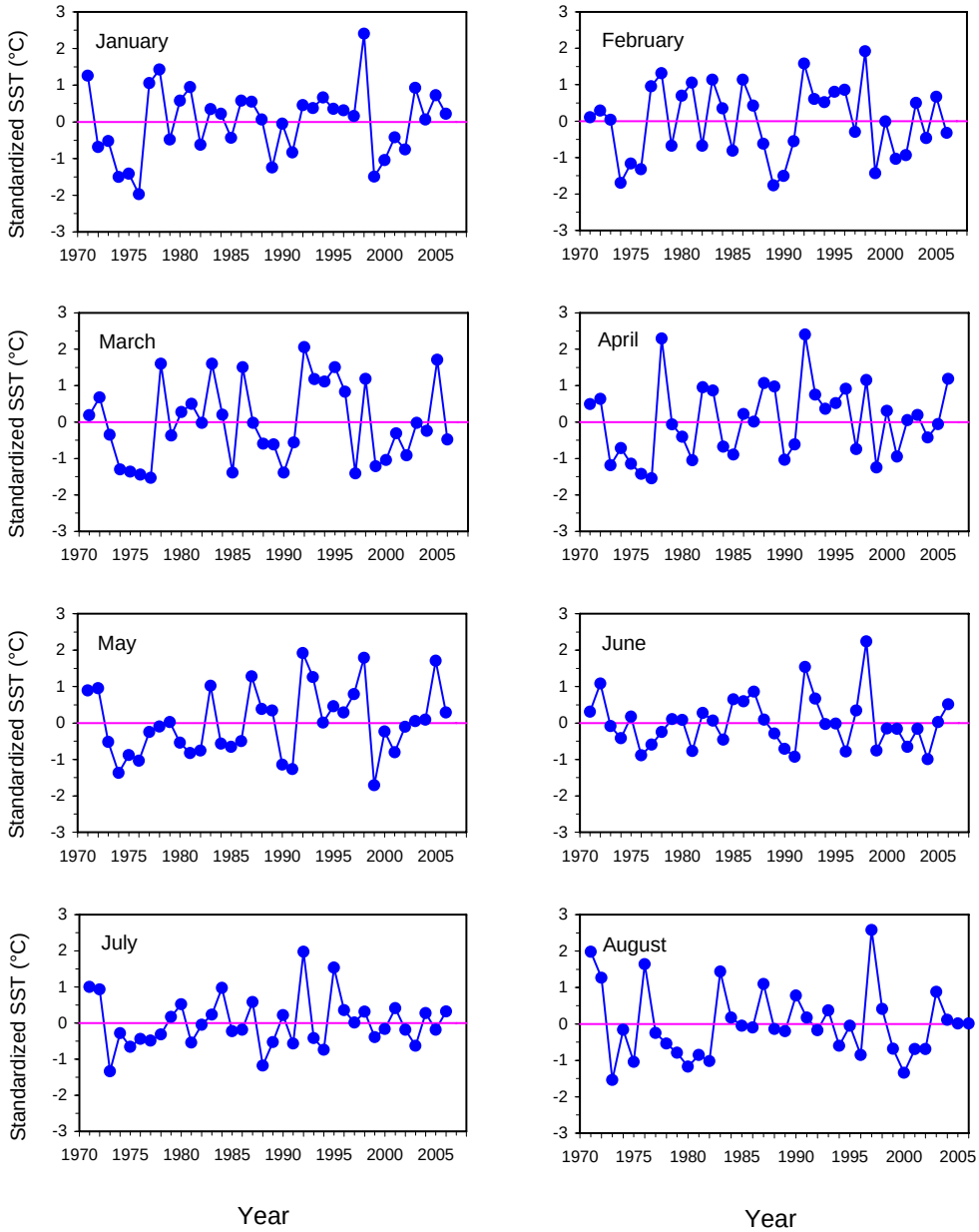


Fig. 6b Standardized Sea Surface Temperature (SST) anomalies (annual mean - long term mean) for SEFI, 1971-2006.

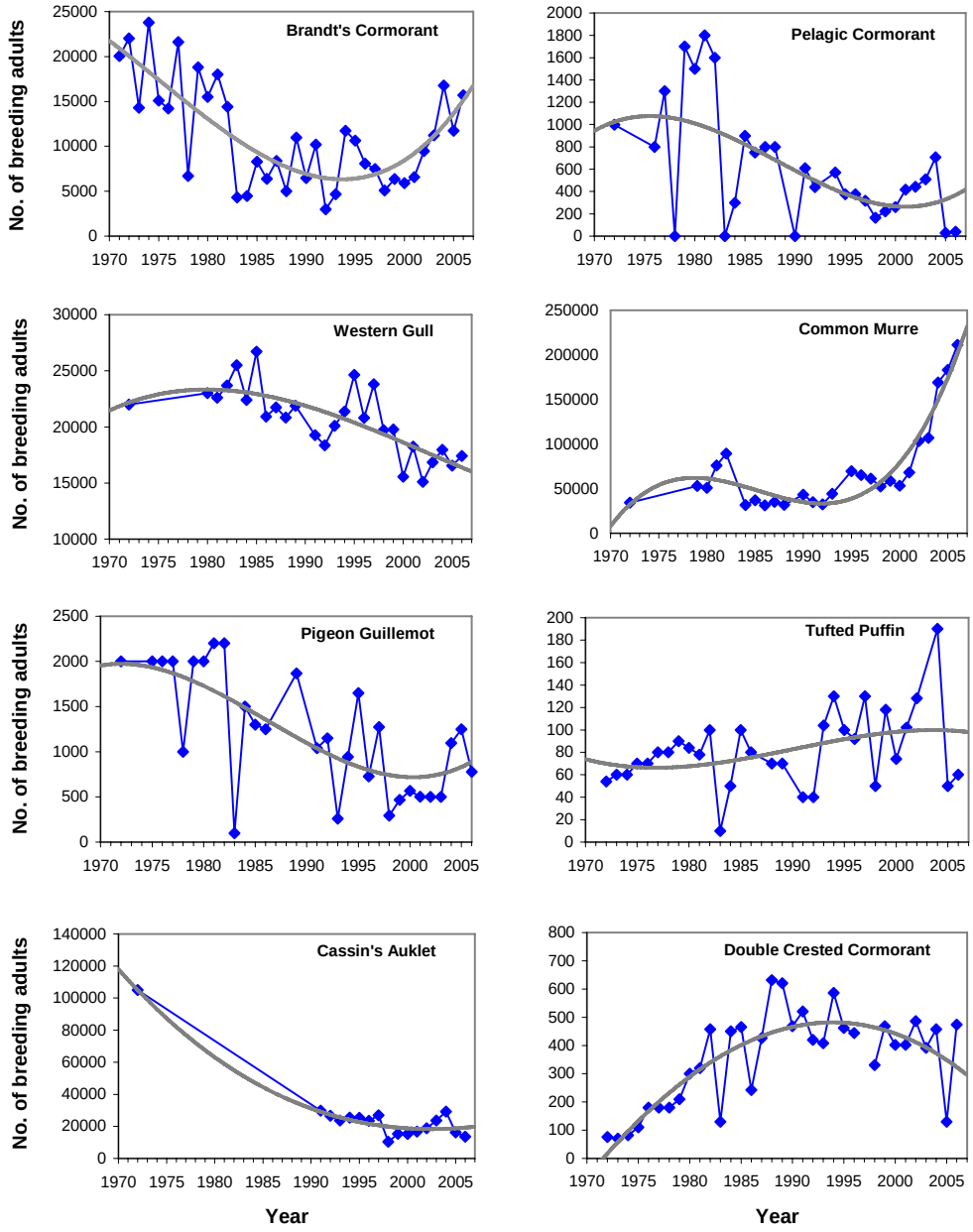


Fig. 7 Population trends for 8 species of seabirds on Southeast Farallon Island, 1972-2006. Populations were determined by counting either individuals or nests on all visible areas on SEFI and West End. Please note the different scales on the Y-axis. We have fitted a third order polynomial trend line (in gray) for each species to help illustrate long term population trends.

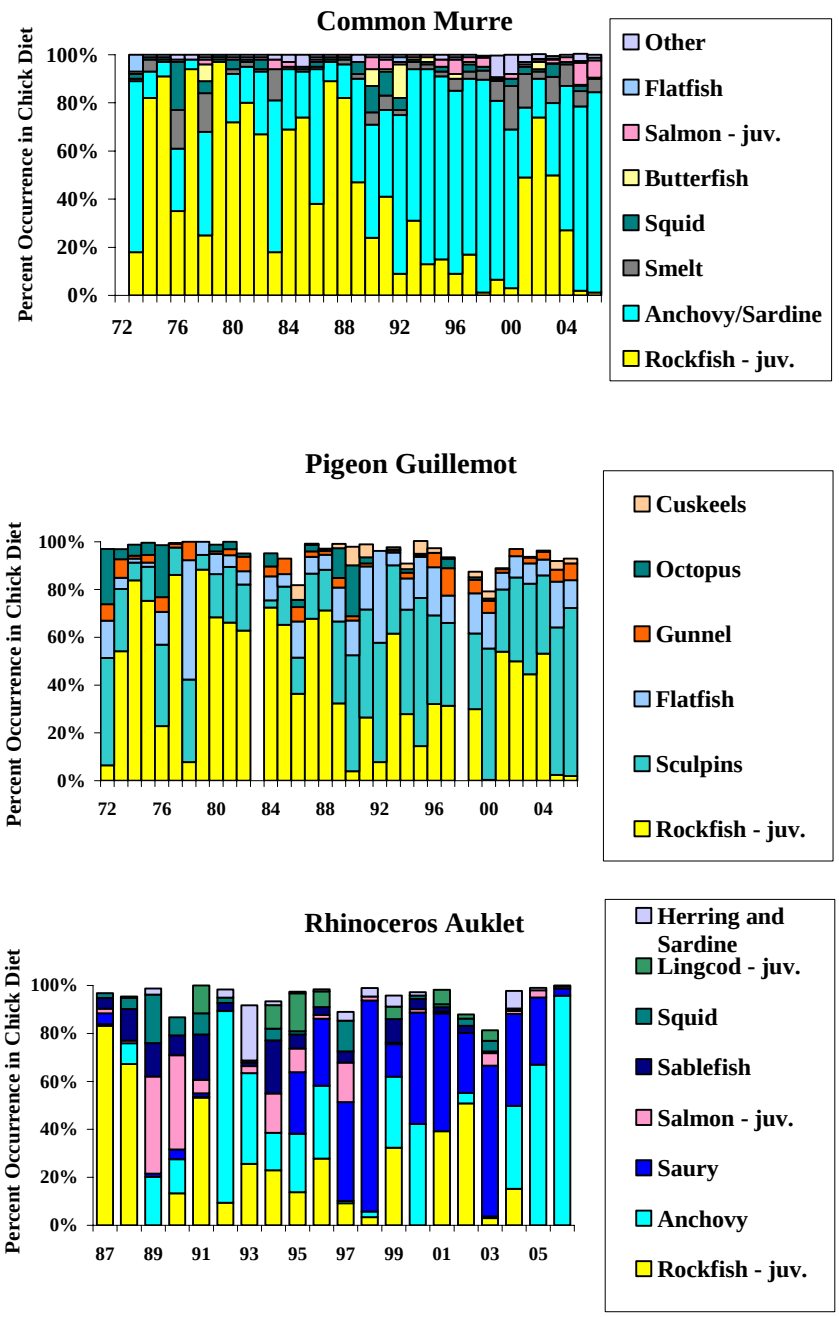


Fig. 8 Percent occurrence of common prey items in the diet of three species of seabirds on Southeast Farallon Island.

Appendix I. Calculation of correction factor for Western Gull population census, 2006.

Area	Nest Count	Bird Count	Correction Factor
C	113	159	1.421
K	134	261	1.027
H (H1 only)	245	407	1.204
Total			**1.217**

Appendix II. Calculation of correction factor for Common Murre population census, 2006. The correction factor was derived by multiplying the number of breeding sites in three study plots (USP, UU, and X) by 2, and then dividing the product by the mean number of adults present in each plot on the census date. 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 2 (1000)	200	248	1.61
June 3 (1000)	200	241	1.66
June 4 (1000)	200	245	1.63
June 5 (1000)	200	239	1.67
Mean	200	243.25	**1.64**

UU

Date (Time)	Breeding Sites	No. of birds	Correction Factor
June 2 (1000)	48	62	1.55
June 3 (1000)	48	63	1.52
June 4 (1000)	48	65	1.48
June 5 (1000)	48	68	1.41
Mean	48	64.50	**1.49**

X plot

Date (Time)	Breeding Sites	No. of birds	Correction Factor
June 2 (1000)	78	107	1.46
June 3 (1000)	78	123	1.27
June 4 (1000)	78	115	1.36
June 5 (1000)	78	114	1.37
Mean	78	114.75	**1.36**

Mean correction factor for SEFI 2006: **1.50**