BREEDING POPULATIONS OF SEABIRDS IN CALIFORNIA, 1989-1991

VOLUME I - POPULATION ESTIMATES

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ABSTRACT

In 1989-1991, the U. S. Fish and Wildlife Service surveyed breeding populations of seabirds on the entire California coast. This study was sponsored by the Minerals Management Service in relation to outer continental shelf oil and gas leasing. At 483 nesting sites (excluding terns and skimmers in southern California), we estimated 643,307 breeding birds of 21 seabird species including: 410 Fork-tailed Storm-petrel (Oceanodroma furcata); 12,551 Leach's Storm-petrel (O. leucorhoa); 7,209 Ashy Storm-petrel (O. homochroa); 274 Black Storm-petrel (O. melania); 11,916 Brown Pelican (Pelecanus occidentalis); 10,037 Double-crested Cormorant (Phalacrocorax auritus); 83,394 Brandt's Cormorant (P. penicillatus); 14,345 Pelagic Cormorant (P. pelagicus); 888 Black Oystercatcher (Haemotopus bachmani); 4,764 California Gull (Larus californicus); 61,760 Western Gull (L. occidentalis); 2,838 Caspian Tern (Sterna caspia)(excluding southern California); 3,550 Forster's Tern (S. forsteri) (excluding southern California); 272 Least Tern (S. albifrons) (excluding southern California); 351,336 Common Murre (Uria aalge); 15,470 Pigeon Guillemot (Cepphus columba); 1,821 Marbled Murrelet (Brachyramphus marmoratus); 1,760 Xantus' Murrelet (Endomychura hypoleuca); 56,562 Cassin's Auklet (Ptychoramphus aleuticus); 1,769 Rhinoceros Auklet (Cerorhinca monocerata); and 276 Tufted Puffin (Fratercula cirrhata). The inland, historical or hybrid breeding status of American White Pelican (P. erythrorynchus), American Oystercatcher (H. palliatus), Heermann's Gull (L. heermanni), Ring-billed Gull (L. delawarensis), Glaucous-winged Gull (L. glaucescens) and Black Tern (Chlidonias niger) are discussed. Estimates for Gull-billed Tern (S. nilotica), Royal Tern (S. maxima), Elegant Tern (S. elegans) and Black Skimmer (Rhynchops niger) will be included in the final draft of this report.

Overall numbers were slightly lower than reported in 1975-1980 surveys (summarized in Sowls et al. 1980. Catalog of California seabird colonies. U.S. Dept. Int., Fish Wildl. Serv., Biol. Serv. Prog., FWS/OBS 37/80). Recent declines were found or suspected for Fork-tailed Storm-petrel, Leach's Storm-petrel, White Pelican, Black Tern, Caspian Tern, Least Tern, Common Murre and Marbled Murrelet. Recent increases were found or suspected for Brown Pelican, Double-crested Cormorant, California Gull, Western Gull, Forster's Tern and Rhinoceros Auklet. Similar numbers were found for other species or trends could not be determined without additional surveys, studies and/or more in-depth comparisons with previous surveys. The status of terns and skimmers in southern California has not yet been finalized.

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INTRODUCTION

In this report, we have summarized the results of an extensive U. S. Fish and Wildlife Service (USFWS) survey of breeding seabird populations in California in 1989-1991. We have documented the location, number of breeding birds, and species composition of 483 nesting areas of 23 seabird species in coastal marine and estuarine habitats. In addition, we have summarized information but not provided current population estimates for inland nesting areas of 4 species which nest on the coast and in interior California as well as 3 species which only nest in interior California. The total estimated population of breeding seabirds on the coast of California exceeded 643,000 breeding birds in 1989-1991. Species examined in this report are listed in Table 1. In Volume I, we have provided: research methods, species accounts, population estimates for each species at each colony, summary maps of colony locations, literature cited and indices to data on colonies (alphabetical by colony name or numerically by California and USFWS colony numbers). In Volume II, we have provided: detailed colony and subcolony locations indicated on sections of 7.5-minute topographic maps and various appendices providing summarized raw data.

In 1989, we surveyed the outer coastal region of northern California (Oregon border to Point Reyes, Marin County) and central California (Point Reyes to Point Conception, Santa Barbara County)(Fig. 1). These coastal areas had been surveyed completely for the first time in 1979-1980 (Sowls et al. 1980). In 1990, we surveyed the coasts of San Francisco, San Pablo and Suisun bays, an area that was not surveyed previously. In 1991, we surveyed the Channel Islands off the coast of southern California in addition to most of the outer mainland coast (excluding many estuaries and beaches). The Channel Islands had been surveyed completely for the first time in 1975-1978 (Hunt et al. 1979, 1980) although the outer mainland coast had not been surveyed previously. We supplemented our surveys with information on nesting areas of certain species (mainly terns and skimmers and interior nesting areas) provided by other researchers.

Our main goals were to provide current estimates of the numbers of breeding birds at each colony in California and to compare the size of breeding seabird populations to numbers reported from 1975-1980 in the Catalog of California Seabird Colonies (Sowls et al. 1980). In 1989-1991, we aimed:

1) to determine the sizes of breeding populations for all nesting areas at which estimates were obtained in 1975-1980;

2) to determine the sizes of breeding populations at other nesting areas that were known to exist (based on earlier

historical information) but at which estimates were not obtained in 1975-1980;

3) to search for and determine the sizes of breeding populations at "newly-discovered" nesting areas which had been established recently or overlooked in previous surveys;

4) to summarize data from other researchers on seabird populations for species or areas that were not surveyed in 1989-1991;

5) to provide additional historical data on the locations of nesting areas and numbers of breeding seabirds than already provided in summaries found in Hunt et al. (1979) and Sowls et al. (1980); and

6) to document our methods and results in detail to facilitate comparisons to 1989-1991 data in the future.

Current estimates of breeding seabird populations were needed by Minerals Management Service (MMS) and USFWS for evaluation of possible offshore oil and gas leases in California, on-going offshore oil production in southern California and transportation of oil in coastal waters throughout the state. Marine bird populations have been one of the most visibly-affected of all marine resources by marine oil spills in California (Dawson 1911, 1923; Aldrich 1938; Moffitt and Orr 1938; Smail et al. 1971; Straughan 1971; Ainley and Lewis 1974; Sowls et al. 1980; PRBO 1985; Ford et al. 1987; Stenzel et al. 1988; Page et al. 1990; and see Piatt et al. 1990, 1991). In addition, USFWS has required current information for the overall management and monitoring of seabird populations in California over time. Many anthropogenic threats have confronted seabirds in California besides oil pollution, including: loss of nesting habitat, toxic chemicals, fisheries, and many forms of human disturbance (see summary in Sowls et al. 1980). Despite many problems, there has never been a coordinated program at the federal or state level to study and protect seabirds and their habitats in California.

This report also will be valuable for other federal and state agencies responsible for the welfare of seabirds and their habitats (e.g. National Oceanic and Atmospheric Administration, National Park Service, U. S. Navy, U. S. Air Force, U. S. Coast Guard, U. S. Forest Service, California Department of Fish and Game, California Department of Parks and Recreation, California Department of Transportation, California Department of Forestry, Caliornia State Coastal Commission, California State Lands Commission). The information contained in this report also will be used extensively by researchers interested in the population sizes and status of seabirds in California and on the west coast of North America and those interested in surveying and monitoring seabird populations and their habitats over time (e.g. Point Reyes Bird Observatory, San Francisco Bay Bird Observatory, Pacific Seabird Group, University of California [e.g. Davis, Santa Cruz and Irvine], and California State Universities [e.g. Humboldt, San Francisco, Sacramento, Hayward, and San Jose]). Other coastal managers and planners, private land owners, environmental groups and the interested public (especially the bird watching community) also will find this report to be a useful reference.

There has been a long history of exploitation, disturbance and impacts to populations of nesting seabirds in California, especially on offshore islands. Permanent human occupation of most of the Channel Islands and the South Farallon Islands began in the 1800's and led to the decimation or elimination of many species (Ainley and Lewis 1974; Hunt et al. 1979, 1980; Sowls et al. 1980; Ainley and Boekelheide 1990). Common Murre eggs were harvested for human consumption for many years during the late 1800's on the South Farallon Islands and at other colonies along the mainland coast (e.g. San Pedro Rock)(Ray 1909, Doughty 1971; see summaries in Ainley and Lewis 1974, Takekawa et al. 1990). In the mid 1800's, commercial logging began in old-growth coniferous forests in central and northern California which by the 1980's had removed over 90% of the potential nesting habitat of the Marbled Murrelet (Carter and Erickson 1992). Coastal development in central and southern California during the 1900's has reduced available nesting habitat and heavily-disturbed Least Terns (Atwood et al. 1979, Erickson 1985). The construction of the Crescent City breakwater in the 1930's eliminated the largest colony of Fork-tailed and Leach's storm-petrels in the state (Osborne 1972, Sowls et al. 1980). Dumping of toxic chemicals in southern California led to a well-documented decline in Brown Pelicans and Double-crested Cormorants in the 1960's and early 1970's (Anderson and Gress 1983, Gress and Anderson 1983). In interior California, a dramatic change in freshwater habitats for nesting seabirds has occurred due to the massive agricultural and water developments of almost the entire central and coastal vallies, Great Basin parts of the Sierra Nevada Mountains area and most of southern California since the early 1800's, impacting especially White Pelicans, Double-crested Cormorants, Black Terns, Caspian Terns and Forster's Terns (Grinnell and Miller 1944, Remsen 1978).

As a result of declining or very low populations, 3 species of seabirds have been classified as endangered species (Brown Pelican, Least Tern and Marbled Murrelet) and 11 species have been classified as Species of Special Concern in California (Fork-tailed Storm-petrel, Ashy Storm-petrel, Black Storm-petrel, White Pelican, Double-crested Cormorant, California Gull, Gull-billed Tern, Elegant Tern, Black Skimmer, Rhinoceros Auklet and Tufted Puffin)(Remsen 1978, Steinhart 1990). Since surveys in

1975-1980, new or continued declines in some populations (especially Common Murres, Marbled Murrelets, California Gulls and White Pelicans) had been noted or could be expected as a result of changes in nesting habitat and substantial mortality of many seabirds due to gill-net fishing, oil spills and the intense 1982-1983 El Niño-Southern Oscillation (ENSO) event (Atkins and Heneman 1987; Ford et al. 1987; Carter and Erickson 1988, 1992; Stenzel et al. 1988; Ainley and Boekelheide 1990; Page et al. 1990; Takekawa et al. 1990). On the other hand, increases in certain populations also have been noted, especially Brown Pelicans, Double-crested Cormorants, Caspian Terns and Rhinoceros Auklets (Gill and Mewaldt 1983, Ainley and Boekelheide 1990, Stenzel et al. 1991, Ingram 1992). Clearly, the numbers of breeding seabirds have changed over time due to natural and human-related factors. Periodic updates of their status are required over large geographic areas to identify and determine the degree of such changes as well as to manage prudently for their welfare in many areas over time.

It has been difficult to describe and interpret declines and increases for many seabird populations in California, especially when most populations have not been monitored annually. Only four major long-term monitoring programs have existed for some time in California: 1) since the late 1960's, annual monitoring of all colonies of Brown Pelicans has been conducted by the University of California Davis and Channel Islands National Park; 2) since the late 1960's, all colonies of the Least Tern have been monitored through a program coordinated by the California Department of Fish and Game; 3) since 1972, the Point Reyes Bird Observatory has monitored all seabird populations at the Farallon Islands National Wildlife Refuge under a cooperative agreement and funding from the U. S. Fish and Wildlife Service (through the San Francisco Bay National Wildlife Refuge Complex); and 4) since 1985, an annual monitoring program for certain species in the Channel Islands (including Brown Pelicans) has been conducted by Channel Islands National Park. Smaller monitoring programs have existed for: 1) several tern species and California Gulls in southern San Francisco Bay (San Francisco Bay Bird Observatory through agreement with the San Francisco Bay National Wildlife Refuge Complex); 2) California Gulls at Mono Lake (Point Reyes Bird Observatory and Mono Lake Committee); and 3) species found on other National Wildlife Refuges throughout the state. These long-term monitoring programs have been instrumental in documenting trends in seabird populations throughout the state. In addition, studies conducted in association with monitoring programs have helped to explain how sizes of seabird populations respond over time in relation to prey resources, interactions with other species and human impacts. However, trends observed from these programs must be interpreted with caution and have limited application to other species or other parts of the state. Many species and coastal areas have not been examined regularly or in a standardized fashion. For most nesting areas, our knowledge of breeding populations has been derived mainly (or solely) from information obtained through detailed or broad-scale surveys in 1965-1970 (Delong 1967; Crossin and Brownell 1968; Delong and Crossin 1968; Huber 1968; Osborne and Reynolds 1971; Osborne 1971, 1972) and 1975-1980 (Hunt et al. 1979, Sowls et al. 1980).

The description of trends from data that have not been obtained annually can be difficult depending on: the degree of standardization of population estimates (census methods, data collection effort and method of data handling), amount of population change that has actually occurred, amount of annual variation in population size, the length of time that has elapsed between survey periods and the amount and quality of other data that support or refute a particular trend. Such trend assessments often require specific studies and analyses beyond the scope of this report. Annual variation in population size has been of particular focus to many researchers. It has been shown to occur in the size of many seabird populations at the South Farallon Islands due to the varying nature of prey resources (especially rockfish Sebastes sp.) dependent on the California Current Upwelling System (Briggs et al. 1987, Ainley and Boekelheide 1990). Periodic ENSO events have been shown to impact the numbers of breeding birds and breeding success there. Breeding attempts and/or success (and hence future recruitment) as well as adult and/or subadult mortality levels can be relatively high or low for some species (Stenzel et al. 1988; Ainley and Boekelheide 1990). Such variation also has existed in the outer Channel Islands where a rockfish diet has predominated (Hunt et al. 1979) as well as in the inner Channel Islands for Brown Pelicans where the prey base was composed of Northern Anchovy, Engraulis mordax (Anderson et al. 1982).

Despite annual variation in the population size of some species in some areas, longer-term changes in populations have been shown to result from particular series of years of above-average or below-average reproduction, large-scale changes in prey resources, significant changes in nesting habitat and human impacts (Ainley and Lewis 1974, Sowls et al. 1980, Anderson and Gress 1983, Spear et al. 1987, Carter and Erickson 1988, Boekelheide and Ainley 1989, Hunt et al. 1979, Ainley and Boekelheide 1990, Takekawa et al. 1990). Such changes should be most evident and frequent for species that occur near or at the end of their breeding ranges on the California coast.

In this report, we have determined and provided current population estimates for breeding seabirds, discussed census difficulties in recent and past surveys, made brief comparisons with previous data to identify possible trends and cited other data which support, refute or confuse these trends. In 1989-1991, we conducted surveys and treated raw data in a standardized fashion to achieve breeding population estimates that were similar in nature but were not exactly comparable to estimates provided in Hunt et al. (1979) and Sowls et al. (1980). Surveys of seabird colonies over large coastal areas in one year only permitted rough estimates of the number of breeding birds for many species at most colonies in the survey year. We have presented our methods in detail, presented raw data along with the non-rounded breeding population estimate (i.e. rounded only to the nearest breeding bird), provided more specific maps of nesting areas, entered data in databases and archived data in detail. It is our hope that future researchers will be better able to reconstruct how we derived estimates for more direct comparisons with their future surveys.

Figure 1. Map of California indicating place names referred to in the text.

Table 1. Species of breeding seabirds in California and abbreviations used in this report.

Scientific Name and Family	Common Name	Abbreviation
Storm-petrels (Family Hydrobatidae)		
Oceanodroma furcata	Fork-tailed Storm-petrel	FTSP
O. leucorhoa	Leach's Storm-petrel	LHSP
O. homochroa	Ashy Storm-petrel	ASSP
O. melania	Black Storm-petrel	BLSP
Pelicans (Family Pelecanidae)		
Pelecanus erythrorynchus	American White Pelican	WHPE
P. occidentalis	Brown Pelican	BRPE
Cormorants (Family Phalacrocoracidae)		
Phalacrocorax auritus	Double-crested Cormorant	DCCO
P. penicillatus	Brandt's Cormorant	BRCO
P. pelagicus	Pelagic Cormorant	PECO
Oystercatchers (Family Haemotopodidae)		
Haemotopus palliatus	American Oystercatcher	AMOY
H. bachmani	American Black Oystercatcher	BLOY
H. bachmani x H. palliatus	Black X American Oystercatcher Hybrid	BAOY
Gulls (Family Laridae; Sub-family Larinae)		
Larus heermanni	Heermann's Gull	HEEG
L. delawarensis	Ring-billed Gull	RBGU
L. californicus	California Gull	CAGU
L. occidentalis	Western Gull	WEGU
L. glaucescens	Glaucous-winged Gull	GWGU
Terns (Family Laridae; Sub-family Sternidae)		
Chlidonias niger	Black Tern	BLTE
Sterna nilotica	Gull-billed Tern	GBTE
S. caspia	Caspian Tern	CATE
S. forsteri	Forster's Tern	FOTE
S. albifrons	Least Tern	LETE
S. maxima	Royal Tern	ROTE
S. elegans	Elegant Tern	ELTE
Skimmers (Family Rynchopidae)		
Rynchops niger	Black Skimmer	BLSK
Auks (Family Alcidae)		
Uria aalge	Common Murre	COMU
Cepphus columba	Pigeon Guillemot	PIGU
Brachyramphus marmoratus	Marbled Murrelet	MAMU
Synthliboramphus hypoleuca	Xantus' Murrelet	XAMU
Ptychoramphus aleuticus	Cassin's Auklet	CAAU
Cerorhinca monocerata	Rhinoceros Auklet	RHAU
Fratercula cirrhata	Tufted Puffin	TUPU

METHODS

Surveys of nesting seabirds in California were conducted over a three-year period from 1989 to 1991. However, each part of the coast was surveyed in only one year each:

1989 Surveys in Northern and Central California

1) mid April to mid May - USFWS conducted Pigeon Guillemot and Marbled Murrelet boat surveys and transects, Leach's Storm-petrel mistnetting, and mainland surveys between the Oregon border and Eureka;

2) mid May to late June - USFWS conducted a complete survey of all colonies on the outer coast (including Castle Rock and the Farallon Islands National Wildlife Refuges), using boat, mainland, and/or aerial photograph surveys between the Oregon border and Point Conception;

3) July to mid September - USFWS conducted Leach's and Ashy storm-petrel mistnetting, burrow/crevice counts, and mainland surveys at selected colonies between the Oregon border and San Francisco, including Castle Rock and the South Farallon Islands National Wildlife Refuges;

4) April to July - Point Reyes Bird Observatory (PRBO) conducted correction factor counts, breeding phenology, and ground and boat surveys on the South Farallon Islands National Wildlife Refuge; and

5) USFWS surveys were supplemented with population estimates for Least Terns nesting in San Francisco Bay and in San Luis Obispo and Santa Barbara counties.

1990 Surveys in the San Francisco Bay Area

6) June to July - USFWS conducted a complete boat and ground survey of colonies in San Francisco, San Pablo, and Suisun bays, except for colonies located within most salt ponds or certain other restricted areas. In addition, a more complete boat survey of Humboldt and Arcata bays was conducted; and

7) USFWS surveys were supplemented with published and unpublished data for colonies of Double-crested Cormorants, California Gulls, Western Gulls, Caspian Terns, Forster's Terns and Least Terns that were not surveyed by USFWS in the San Francisco Bay area.

1991 Surveys of Southern California

8) January - USFWS conducted a reconnaisance trip in Channel Islands National Park, including mistmetting of Ashy Storm-petrels and Cassin's Auklets at Prince Island;

9) April - USFWS conducted mistnetting of Ashy and Leach's Storm-petrels, conducted Xantus' Murrelet crevice counts and banded adult Xantus' Murrelets in the Channel Islands;

10) May to mid June - USFWS conducted a complete survey of all colonies in the Channel Islands (especially Channel Islands National Park), using boat, ground, mistnetting and aerial photograph surveys;

11) Late June to late July - USFWS conducted a complete survey of the mainland coast from Point Conception to the Mexican border (using boat and ground surveys), except for tern and skimmer colonies. In addition, Leach's, Ashy and Black storm-petrel mistnetting was conducted on the Channel Islands;

12) October - USFWS conducted detailed burrow/crevice counts in the Channel Islands;

13) February to September - University of California Davis conducted detailed ground and boat surveys of Brown Pelicans and Double-crested Cormorants at West Anacapa Island;

14) February to September - Channel Islands National Park conducted ground and boat surveys for certain species at Santa Barbara and East Anacapa islands and assisted USFWS surveys in the Park; and

15) USFWS surveys were supplemented with published and unpublished information on nesting terns and skimmers along the mainland coast.

Interior California

We supplemented information on coastal nesting areas of seabirds from 1989-1991 with general summaries of nesting areas of several species in interior California, including: White Pelican, Double-crested Cormorant, Ring-billed Gull, California Gull, Black Tern, Gull-billed Tern, Caspian Tern, Forster's Tern, and Black Skimmer.

Our basic objectives were to obtain counts of the numbers of nests, birds, and/or potential nest sites at nesting areas using several survey techniques, either at the peak of the breeding season or when peak numbers of breeding birds could be counted.

However, raw counts of nests on a particular census day were usually minimal since they excluded birds that were not nesting that day but did nest at some point during the breeding season (i.e. birds did not lay eggs until after the census day and/or birds laid eggs and underwent nesting failure before the census day). Similarly, raw counts of birds were usually minimal both for the above reason and since they excluded breeding adults that were away from the colony foraging at the time of the count. On the other hand, counts of potential nest sites (usually burrows and crevices) would have produced closer to maximal estimates of numbers of breeding birds since not all potential sites were used. Thus, to derive realistic estimates of the numbers of breeding birds at nesting areas, it was necessary to adjust raw counts of nests, birds or sites with correction factors to account for breeding birds that would be incorrectly included or not included in estimates. The degree of adjustment of raw data varied between species. For some species, numbers of nests or birds were not adjusted, either because it was not necessary or a suitable correction factor was not available.

Below, we have decribed the census techniques used and have discussed how correction factors were applied to derive estimates of the numbers of breeding birds of each species at each colony. We have taken some of the description of census techniques from Sowls et al. (1980) and Takekawa et al. (1990) so that slight differences can be highlighted. In the later section "How to use maps and tables", we have outlined how data have been presented in tables and maps and have discussed the two colony numbering systems used in this report.

SURVEY TECHNIQUES

Boat surveys - All sections of coastline (except for Tomales Bay and certain large sandy beach sections of Monterey Bay and along the mainland of southern California) were surveyed by boat one or more times in 1989-1991. Counts were made using 7X or 10X binoculars or the unaided eye from 14-foot (4.3 m) Zodiac inflatable boats powered with 25 hp outboard engines. These small boats allowed close access to shoreline areas which were often difficult or impossible to view otherwise. Whenever possible, direct counts of nests and individual birds were made. Usually, the boat was slowed or stopped and 1-3 observers counted birds and/or nests at the same or adjacent portions of the colony. Counts were repeated when possible and/or necessary to ensure accuracy. Birds observed flying to or from a colony or those sitting on the water near a colony were also counted for some species. Roosting birds were counted separately from breeding colonies.

Boat transects - Coastal at-sea transects were conducted from inflatable boats between the Oregon border and Humboldt Bay mainly in late April 1989 and along certain more southerly sections of coast from late May to late June 1989. Fixed-width transects were oriented parallel to and 200-600 m off shore. Birds on the water or flying were counted out to distances of 150-250 m on either side of the boat by one or two observers as the boat moved along at moderate speeds. At times, the boat was slowed or stopped to search with 7X or 10X binoculars or more closely examine distant birds. Transects were conducted primarily to systematically document numbers of Pigeon Guillemots and especially Marbled Murrelets along certain coastal sections (see Appendix 5).

Mainland surveys - Except for the North and South Farallon Islands, Redding Rock and Point Saint George Lighthouse, all islands and offshore rocks in northern and central California are within 1 km of the mainland. Counts of nests and/or birds on nearshore rocks, islands, and mainland cliffs often were made from mainland promontories or overlooks using 7X or 10X binoculars or 60-120X telescopes. Generally, these counts underestimated populations since only the landward sides of colonies were visible. However, these counts were at times higher than those obtained from boats due to better observing conditions, especially on the landward side and tops of tall rocks and islands and in some areas that were inaccessible by boat.

Landings and burrow/crevice counts - When possible, landings were made on some islands and rocks from inflatable boats to obtain more accurate counts, except at colonies of Double-crested and Brandt's cormorants and Common Murres (plus haul-out and breeding rookeries of marine mammals) which were especially sensitive to disturbance. When we landed on an island, we counted cormorant, gull, and oystercatcher nests and burrow/crevice sites of storm-petrels and alcids. Island visits during the breeding season were kept as brief as possible to minimize disturbance to nesting birds.

Extensive counts of burrow/crevice sites mainly for Xantus' Murrelets, Cassin's Auklets and Rhinoceros Auklets were conducted after the breeding season at large colonies at Castle Rock and the South Farallon Islands National Wildlife Refuges and Castle Rock, Prince Island, Gull Island, Santa Barbara Island and Sutil Island in Channel Islands National Park. Since these islands and rocks were fairly small (except for the South Farallon Islands and Santa Barbara Island), we individually counted all burrow/crevice sites and estimated numbers only for very small, inaccessible areas of large colonies. The sizes of burrows and crevices were classified as small (i.e. storm-petrel), medium (i.e. Xantus' Murrelet, Cassin's Auklet) and large (i.e. Pigeon Guillemot, Xantus' Murrelet, Rhinoceros Auklet, Tufted Puffin). At Castle Rock National Wildlife Refuge, Del Norte County, we estimated the number of sites for a portion of area 2. Here, numbers of sites were estimated using six 10 foot x 10 foot plots. Areas for extrapolations were determined using a map traced from an aerial photograph which was put to scale using ground tape measurements between conspicuous landmarks. In areas 2 and 10-13, numbers of sites were estimated based on numbers (and percentages of different burrow sizes) observed when walking around the northern periphery. These areas on the northeast side had very fragile soil riddled with burrows; in addition, area 13 was very steep.

Aerial surveys - In northern and central California, all known Common Murre colonies and all Double-crested and Brandt's cormorant colonies estimated at 100 or more breeding birds in Sowls et al. (1980) were aerially surveyed once in 1989: 1) central California colonies between Gualala Point Island and Pismo Beach (including the Farallon Islands) were surveyed on 23-24 May; 2) northern California colonies between the Oregon border and Cape Vizcaino were surveyed on 30-31 May; and 3) northern California colonies in between Cape Vizcaino and Gualala Point Island were surveyed on 16 June. In southern California, all known Brown Pelican colonies and Double-crested and Brandt's cormorant colonies estimated at 100 or more birds in Hunt et al. (1979) were aerially surveyed twice in 1991 (16-17 May; 15-22 June). We added some cormorant colonies which appeared larger than 100 breeding birds during flights. At some colonies, we also were able to obtain complete counts of Western Gull and Pelagic Cormorant nests and birds in photographs.

Surveys were conducted in the refined manner developed by Takekawa et al. (1990). Surveys in northern California were flown at 50-90 knots from a single engine, wing-over Cessna 150 or 182 aircraft at altitudes of 400-500 feet (120-150 m). In central and southern California, a twin engine, wing-over Partanavia aircraft was used at altitudes of 400-650 feet (150-200 m). At Point Bennett and Castle Rock in Channel Islands National Park, photographs were taken from altitudes greater than 1,000 feet (300 m) due to concern about possible disturbance to marine mammals. Colonies were photographed completely by two photographers, each using a 35 mm camera set at rapid shutter speeds (1/500 or 1/1000 secs), a 300 mm telephoto lens, and color slide film (ASA 400). To ensure complete coverage, all nesting areas were photographed several times on several passes. Both photographers used powerwinders for faster exposures and one photographer shot through an open window. Overview photos were also taken using a 50 mm lens and color slide film (ASA 64 in 1989, ASA 200 in 1991). We attempted to pass directly over colonies to minimize oblique photographs. However, when surveying the South Farallon Islands, passes were flown farther off the island due to steep topography and to prevent disturbance. Only a few Common Murres at one or two colonies but no cormorants flushed during our surveys.

Slides of the highest quality (closest and clearest) were selected for counting. Overviews aided in identifying and piecing together close-up views of each colony. Slides were projected using a slide projector with a zoom lens (100-150 mm) onto large white paper. Count areas were demarcated using landmarks or colony outlines. Slides were intensively searched by two observers who dotted each bird and nest with a felt tip pen and later tallied them with a hand-held counter. Due to the high resolution of our slides, we had little difficulty counting birds and/or nests. When cormorant species occurred together, we often distinguished species using different body sizes, throat colors, and nest types. However, we usually confirmed identification during boat and ground surveys.

MIST NETTING

Mist netting of nocturnal seabirds (especially storm-petrels) has been used extensively to sample populations for various purposes (Ainley et al. 1974, 1976; Harris 1974; Furness and Baillie 1981; Copestake et al. 1988; Emslie et al. 1990). In 1989, we made several overnight visits to 8 colonies in northern California and conducted nocturnal mist netting to capture storm-petrels (Table 9, Appendix 3). In 1991, overnight visits and mist netting efforts were used to capture storm-petrels and alcids (Xantus' Murrelets and Cassin's Auklets) at 7 colonies in southern California (Table 9, Appendix 4). By capturing birds in mist nets, we determined: 1) which species of storm-petrel were present at colonies; 2) relative numbers of each species captured; 3) breeding phenology of storm-petrels and Cassin's Auklets; and 4) population estimates of certain species of storm-petrels at certain colonies, using capture-recapture analyses. In addition, we noted vocalizations of storm-petrels and alcids that were not captured in mist nets.

We erected 7-foot (2.1 m) high x 30-foot (9.1 m) long nylon mistnets (1.5 inch [3.8 cm] mesh, four shelf) to capture storm-petrels at all colonies in California. One exception occurred at net site 2 on Prince Island (Santa Barbara County) where a 7-foot high x 18-foot long mist net better fitted a 25-foot long rock outcropping. Usually, nets were oriented parallel to shore or on the tops of islands and as near as possible to potential nesting habitats. At all colonies in northern California and some colonies in southern California, mistnetting was conducted on only one night within a 2-week period. However, at Prince, Santa Barbara and Sutil islands (Channel Islands National Park) in 1991, mistnetting was conducted nightly during visits of up to 8 days (Appendix 4). These islands required greater effort to sample due to the large area of potential nesting habitat. One planned 7-day excursion to Prince Island in April was abandoned after 2 short nights of mist netting due to extremely windy conditions. At Santa Barbara and adjacent Sutil Islands, we mist netted at several sites around the islands to sample as much of the area as possible (Figure 11, Appendix 4). One mist net (site 1) placed in front of a small cave at Elephant Seal Point, Santa Barbara Island, was specifically erected for capturing Cassin's Auklets.

<u>Tape luring</u> - We attracted storm-petrels to net locations by broadcasting recorded vocalizations from small portable cassette tape players placed beside the mist net. This technique has been referred to as "tape luring". Cassette tapes of Ashy Storm-petrel vocalizations recorded at the South Farallon Islands by D. G. Ainley in the early 1970's were provided by the Point Reyes Bird Observatory. Leach's Storm-petrel vocalizations that had been recorded in Maine also were provided by D. G. Ainley. Tapes of Fork-tailed Storm-petrel vocalizations recorded in the Barren Islands, Alaska, were provided by T. R. Simons. Black Storm-petrel vocalizations recorded by D. G. Ainley in Baja California, Mexico, were provided by C. A. Drost.

The amount of broadcast time for each netting night (summarized in Appendices 3 and 4) was not standardized and depended on bird activity and the target species at the colony surveyed. In northern California, we targeted Leach's Storm-petrels, the most abundant species, except at Bird Rock (Marin County) where only Ashy Storm-petrels occurred. In southern California, Ashy Storm-petrels were targeted as the most abundant species, with lesser emphasis on Black and Leach's storm-petrels. When more than one species nested at a colony, we typically broadcasted vocalizations of each species during their respective peak activity periods. For example, Fork-tailed and Black storm-petrels have been shown to be most active at colonies within 1-3 hours after full darkness (Harris 1974, Hunt et al. 1979). For these species, we broadcasted their vocalizations for 1-2 hours after dark and on a more random basis afterwards. Leach's Storm-petrels have been shown to be most active from midnight until dawn (Ainley et al. 1974, Harris 1974). In southern California, we broadcasted Leach's Storm-petrel vocalizations after about 0100 hrs. Ashy Storm-petrels have been shown to be active from 1-2 hours after darkness throughout the night (Ainley et al. 1974, 1976) and we broadcast their vocalizations throughout the night. We also oscillated the broadcast of different vocalizations interspersed with silent periods when birds were not being captured. This action often changed the amount of activity by storm-petrels around the net site.

<u>Banding</u> - Captured storm-petrels were fitted with standard U. S. Fish and Wildlife Service incoloy leg bands. In 1989, stage of incubation patch development (see below) was recorded for all birds whereas primary, retrix and body molt and rump color type (Leach's Storm-petrel only) were recorded for many but not all birds. Rump color type of Leach's Storm-petrels was scored according to Ainley (1980) from a completely-white rump (score=1)

to a completely-dark rump (score=11). For all species of storm-petrels captured in 1991, we systematically recorded: stage of the incubation patch; body, primary and rectrix molt; wing chord, tail, culmen, and tarsus lengths; and rump color type (Leach's Storm-petrel only).

For Cassin's Auklets and Xantus' Murrelets, captured birds were fitted with standard U. S. Fish and Wildlife Service stainless steel leg bands. For Cassin's Auklets, data were collected on stage of the incubation patch (see below), primary molt and iris color (see Manuwal 1972, 1978; Emslie et al. 1990). On Xantus' Murrelets, data were collected on stage of the incubation patch, wing chord, culmen, and tarsus lengths, bill depth, and plumage color morphs. Plumage color morphs followed Jehl and Bond (1975).

<u>Incubation patch</u> - The stage of the incubation patch was scored from 0-5 as follows:

0 - Completely covered with down (i.e. no brood patch).
1 - 5-50% defeathered (i.e. partially downy).
1.5 - 50-95% defeathered (i.e. partially downy).
2 - 95-100% bare, unvascularized.
3 - 95-100% bare, vascularized.
4 - 5-50% refeathered (i.e. refeathering).
4.5 - 50-95% refeathered (i.e. refeathering).
5 - 95-100% refeathered (i.e. no brood patch but careful inspection showed refeathering, the bird regurgitated prey or stomach oil intended for its young or the bird showed the regular molt pattern of adults).

In 1991, these scores were better standardized for storm-petrels. In 1989, 4.5 scores were sometimes lumped with scores of 4, respectively.

The stage of the incubation patch was used to determine the breeding status of each captured bird. Inspection of incubation patches has been a common method of separating breeding birds from non-breeding birds, used widely in studies of seabirds and other birds. In all well studied avian species, only breeding birds develop incubation patches (Jones 1971), although pre-breeding, failed and post-breeding birds may have an incubation patch for some period of time when they are not actively incubating or raising chicks. In storm-petrels, several researchers have reported that nonbreeding birds at times will develop an incubation patch (Furness and Baillie 1969, Harris 1969, Wilbur 1969, Scott 1970). While this assertion has not been proven, most researchers have avoided the use of incubation patch stage as the sole indicator of breeding versus non-breeding status. Another unusual feature of storm-petrels incubation patch cycle is that defeathering can begin far ahead of egglaying (Ainley et al. 1974, 1976). Thus, the presence of an incubation patch in storm-petrels did not necessarily indicate that eggs had been laid already. Other researchers have grouped birds into breeders and nonbreeders based on average wing lengths and whether or not captured birds regurgitated (Ainley et al. 1974, Furness and Baillie 1969). These methods also have not been proven for separating breeders from non-breeders. Although these methods may be adequate for analyzing groups of captured birds, these criteria were not adequate for establishing the breeding status of each bird. Given these difficulties and our desire for a repeatable technique that could be used in the future, we used stage of the incubation patch as the sole determining factor of breeding status in storm-petrels.

The use of incubation patch stage to determine breeding status of a captured bird depended on the time of year and the species considered. For Leach's Storm-petrels, all birds with an incubation patch score of 0, as well as birds with a score of 1 after mid-May (Figures 9, 10), were considered to be not breeding. For Ashy Storm-petrels, all birds captured in January and April were considered to be breeders that were visiting the colony early in the year. After April, all birds with a brood patch score of 0 or 1 were considered nonbreeders (Figures 10, 12, 13). For Black Storm-petrels, all birds captured in May were considered breeders since these birds arrived later to the colony than did other species (Everett 1991) and some breeders may not have developed incubation patches yet (Figure 13). After May, birds with a score of 0 or 1 were considered to be nonbreeders. We also used incubation patch data to estimate timing of breeding in storm-petrels in northern and southern California (Figures 14-16) and in Cassin's Auklets in southern California (Figure 17).

BREEDING PHENOLOGY, ATTENDANCE PATTERNS AND CORRECTION FACTORS

Information on breeding phenology and attendance patterns of seabirds at their breeding colonies in California were important for: 1) conducting counts at the peak of the breeding season or when peak numbers of birds could be counted; and 2) developing adequate correction factors for adjusting raw counts of nests, birds and sites to derive population estimates.

<u>Timing of surveys</u> - We scheduled surveys along different sections of the California coast in 1989-1991, based on past information on breeding phenology, information from monitoring programs early in the survey year and our observations early in the breeding season. Our goal was to survey colonies when peak numbers of nests and birds could be counted at colonies which usually occurred between the end of egglaying and before fledging had occurred. It was impossible to survey each species at each colony during this narrow window of time due to different phenologies between species and the large numbers of colonies and large sections of coast that were surveyed. However, based on

our examination of breeding phenology in California, there was a period of about a month where it was possible to survey most colonies and species at the appropriate time, given good weather conditions and almost continuous surveying efforts. Certain species in some areas were surveyed earlier because bird counts were higher and/or time consuming (Marbled Murrelets and Pigeon Guillemots), mist netting was conducted over the entire breeding season (storm-petrels) and burrow/crevice counts at large colonies were conducted after the breeding season when necessary to prevent disturbance to nesting seabirds and marine mammals. Based on diurnal attendance patterns known at the South Farallon Islands (Ainley and Boekelheide 1990) and the experience of previous researchers (Sowls et al. 1980), we conducted many surveys (especially boat and ground surveys) as early in the day as possible when numbers of birds attending colonies were highest. Fortunately, the best weather conditions for obtaining accurate counts and covering long distances by boat also occurred in the early part of the day.

Breeding phenology - Most knowledge of the timing of breeding of seabirds in California has come from studies at the South Farallon Islands (summarized in Ainley and Boekelheide 1990) and in the Channel Islands (summarized in Hunt et al. 1979). Sowls et al. (1980) summarized data on breeding phenology and depicted variation between different areas of the California coast. Point Reyes Bird Observatory has annually determined the breeding phenology and colony attendance patterns of several species at the South Farallon Islands since 1972. The University of California (Davis) has studied timing of breeding in Brown Pelicans and Double-crested Cormorants since the late 1960's (e.g. Anderson and Gress 1983). The University of California (Irvine) conducted many studies of several species in the Channel Islands during the 1970's. Since 1985, Channel Islands National Park has monitored breeding phenology in certain species (Brown Pelicans, Double-crested Cormorants, Western Gulls, Xantus' Murrelets and Cassin's Auklets).

In 1989, the timing of breeding of 10 seabird species (Ashy Storm-petrels; Double-crested, Brandt's and Pelagic cormorants; Western Gulls; Black Oystercatchers; Common Murres; Pigeon Guillemots; and Cassin's and Rhinoceros Auklets) was determined at the South Farallon Islands (Figure 2; Emslie and Sydeman 1989). Samples of nest sites (n > 30, except for Ashy Storm-petrels and Black Oystercatchers) were monitored every 1-5 days to determine the number and timing of first clutches initiated, hatched, and fledged, as well as second and replacement clutches (Figures 2, 3). For Marbled Murrelets which nest in old-growth forests along the coast, information on breeding phenology in 1989 (Figure 4) was derived from studies by the University of California (Santa Cruz) and others in central California (Naslund 1990, Singer et al. 1991).

In 1991, breeding phenology in southern California was determined for only a few species in Channel Islands National Park (T. Ingram, unpubl. data). Detailed monitoring of Brown Pelicans at West Anacapa Island provided data on breeding phenology at this colony (Figure 18; Gress 1992).

Attendance patterns - Diurnal attendance patterns have been studied in detail previously at the South Farallon Islands (Ainley and Boekelheide 1990). In 1989, attendance patterns of 7 seabird species (Double-crested, Brandt's and Pelagic cormorants; Western Gulls; Common Murres; Pigeon Guillemots; and Tufted Puffins) were determined there (Figures 5, 6; Emslie and Sydeman 1989). Attendance patterns of Pigeon Guillemots and Tufted Puffins also were examined by USFWS at 3 colonies in northern California in 1989 (Figure 7). At the South Farallon Islands, plot attendance by breeding and non-breeding adults was determined for four periods (0600-0800, 1000-1200, 1400-1600, 1800-2000 hrs PDT) throughout one day at 15-day intervals from 15 April to 31 July (Figures 5, 6, and 8). In addition, Pigeon Guillemots rafting around the South Farallon Islands were counted on the same schedule (Figure 6) and Rhinoceros Auklets arriving at dusk at two nesting areas on Southeast Farallon Island were counted on the same 15-day schedule (Figure 8). In 1991, diurnal attendance patterns were not examined in southern California.

Correction factors - Over many years of seabird monitoring around the world, seabird researchers have recognized that correction factors were required to derive population estimates from raw counts for many species (e.g. Ainley and Boekelheide 1990). Such correction factors required specific knowledge of breeding phenology and colony attendance patterns. In addition to annual monitoring work, PRBO conducted specific counts of the numbers of nests and birds in various plots and areas on the South Farallon Islands in 1989 (Emslie and Sydeman 1989). From these counts, we calculated 2 types of correction factors (J and K) for use in adjusting raw counts of nests and birds to obtain breeding population estimates where:

J = the total number of active nests over the breeding season divided by the number of active nests that would be counted on a single census day. J was calculated every 15 days from April to July 1989 from samples of monitored nests at the South Farallon Islands (Figure 3; Table 2).

K = the total number of breeding birds over the breeding season divided by the number of birds (breeding and non-breeding) that would be counted at a particular time on a single census day. K was calculated for four periods of day every 15 days from April to July 1989 for samples of monitored nests in plots at the South Farallon Islands (Figures 5, 6; Table 2).

We applied J and K correction factors to raw counts of nests and birds to derive estimates of the numbers of breeding birds in a standardized fashion. Thus, future researchers could either repeat our technique or modify it as necessary, allowing for more direct comparisons. Without the large additional effort required to evaluate previous surveys, we were unable to directly compare our results to those of 1975-1980 surveys. It was not always clear how their raw counts were adjusted to derive population estimates and such adjustments varied between colonies and investigators. In northern and central California, this less-standardized approach was adopted because of highly-variable observation conditions during counts in 1979-1980 at many colonies (A. L. Sowls, pers. comm.). In 1989-1990, we collected data in a highly standardized fashion under mostly-excellent observation conditions, making it possible and appropriate to then adjust raw counts with standardized correction factors.

We calculated "approximate" J and K correction factors by averaging from 2-6 daily values during the peak of the breeding season (between the dates of median laying and median fledging) on the South Farallon Islands (Table 2). We felt that mean values would be better to apply to raw counts at other colonies where the exact timing of breeding was not known and may have been somewhat different from the South Farallon Islands. In northern and central California, most surveys were conducted from mid May to mid June 1989. Even if the timing of breeding was two weeks earlier or later than at study plots at the South Farallon Islands (see Sowls et al. 1980), censuses would still occur during the peak of the breeding season. In southern California, surveys were similarly conducted from early May to mid June for the same reason. Also, J and K correction factor values were lowest and least variable at this time which allowed for lower and more reliable adjustments.

We prioritized the use of correction factors based on the degree of variability inherent in these factors. The J factor was used wherever an accurate nest count was available because it was not affected much by daily variation. The K factor was used when an accurate nest count was not available but the number of birds were counted. K values were determined for four periods of day because K often varies regularly over the day based on the daily foraging and roosting behavior of breeding adults and attendance by non-breeders at the colony (see Ainley and Boekelheide 1990, Takekawa et al. 1990). In addition, K values can vary between days depending on weather conditions, food availability, and other factors. Thus, K values were considered rougher (i.e. there was more inherent error) than J values.

The L correction factor was used to roughly adjust direct counts of potential burrows and/or crevices on certain colonies to obtain breeding population estimates of Leach's Storm-petrels, Xantus' Murrelets, Cassin's Auklets and Rhinoceros Auklets (see Table 2):

L = the proportion of potential burrow and crevice nest sites in which eggs were laid over the breeding season or "burrow occupancy". Rough L values were derived mainly from the literature.

L correction factors were not directly determined at the South Farallon Islands in 1989. Little past information was available on which to base L values in California. In early May 1989, two Cassin's Auklet plots at the South Farallon Islands were briefly examined; 93% of 47 burrows and 76% of 56 crevices were found to be actively visited (i.e. toothpicks were knocked over) on at least two of three nights (Emslie and Sydeman 1989). However, burrows and crevices can be visited by birds without eggs being laid in them (especially by non-breeding adults) such that these percentages probably are slightly high. Lower values may truly apply to crevice sites since we were less sure that all of these were in fact suitable nest sites than we were for burrows (which had to be dug out by birds). Since other data were not available, we used a very rough L value of 75%) for Cassin's Auklets. We also used rough L values derived from the literature of 75% for Leach's Storm-petrels (Morse and Buchheister 1979, Nelson et al. 1987, Sklepkovych and Montevecchi 1989) and 50% for Rhinoceros Auklets (Wilson and Manuwal 1986). For Xantus' Murrelets (which nested only in crevices and under bushes), we were able to derive specific L correction factors, using data from plots monitored by Channel Islands National Park on Santa Barbara Island in 1991 (see species account).

ADJUSTED BREEDING POPULATION ESTIMATES

Detailed presentations of how we calculated the numbers of breeding birds at specific colonies can be found in species accounts. Below, we have provided several examples of how correction factors were applied to raw counts to derive breeding population estimates.

J and K adjustments - To demonstrate how J and K correction factors were applied, we have explained below how 422 breeding Double-crested Cormorants were estimated at the Russian River Rocks colony in 1989:

1) A total of 176 nests and 198 birds were counted using the highest counts at five subcolonies including: 119 nests and 131 birds at three subcolonies from an aerial survey on 23 May at 1524 hrs; 52 nests and 63 birds at one subcolony from a mainland survey on 5 June at 1000-1057 hrs; and five nests and six birds at one subcolony from a boat survey on 5 June at 1211-1303 hrs.

2) We multiplied the 176 nests by a J value of 1.2 (see Table 2) to account for nests that were not active during censuses, resulting in an adjusted total of 211 nests.

3) Two breeding adults (per mated pair) were applied to each of the 211 nests, resulting in an estimate of 422 breeding birds.

If it had been possible only to obtain a complete count of all birds at all known subcolonies, we would have calculated an estimate of 433 breeding birds at Russian River Rocks in 1989 as follows:

1) 69 birds were counted at 2 subcolonies between 1000-1303 hrs on 5 June. We multiplied the 69 birds by a K value of 2.1 (see Table 2) to account for breeding birds that were not present and nonbreeders present at that time on the census day, resulting in a partial adjusted total of 145 breeding birds.

2) 131 birds were counted at 3 other subcolonies at 1524 hrs on 23 May. We multiplied the 131 birds by a K value of 2.2 (see Table 2) as above, resulting in a partial adjusted total of 288 breeding birds.

3) The sum of 145 and 288 birds above equaled the total of 433 breeding birds.

For Double-crested and Brandt's cormorant colonies, Pelagic Cormorant colonies (south of Del Norte and Humboldt counties in northern California) and Western Gulls, almost all population estimates were derived directly as above using J correction factors. K factors were used only in a few cases where necessary. For Pelagic Cormorants, J and K correction factors at the South Farallon Islands were affected to some degree by the early abandonment of nests there in 1989 whereas such abandonment was not noted to the same extent elsewhere. We felt more comfortable substituting Brandt's Cormorants factors instead which were significantly lower for J but similar for K factors. For Common Murres, Pigeon Guillemots (south of Del Norte and Humbodlt counties in northern California) and Tufted Puffins, almost all population estimates were derived using K correction factors since we could not directly count nests but could count numbers of birds at and in the vicinity of nesting areas. Previous work on Common Murres at the South Farallon Islands (Ainley and Boekelheide 1990, Takekawa et al. 1990) resulted in more specific information on K values than in other species. Instead of using the K value of 1.8 for the period between 0900-1300 hrs (Table 2), we used a mean K value of 1.68 (derived from four years of data) to adjust all counts of Common Murres (see Takekawa et al. 1990). We felt that K values in any one year may vary between colonies and that using a mean value was more appropriate for application to other colonies. Also, the 1.68 value was more comparable with the 1.67 value used by Sowls et al. (1980). For Pigeon Guillemots (south of Del Norte and Humboldt counties) and Tufted Puffins, we also did not use K values directly from those calculated at the South Farallon Islands because Farallon counts only dealt with nesting areas (i.e. birds on land) whereas USFWS surveys included birds on the water, flying nearby, roosting on intertidal rocks, and/or at nesting areas. Since we had no other reliable way of adjusting counts, we roughly reduced the K values by half before use since, by including all birds in the vicinity of colonies, we had already accounted for some breeding birds that were not present and visible on land at nesting areas.

For Pelagic Cormorant and Pigeon Guillemot colonies in Del Norte and Humboldt counties in northern California, we decided not to use Farallon Island correction factors because we had better local information to adjust counts. For Pelagic Cormorants, May and late June-early July counts were compared:

1) if the late June-early July (late incubation-early chick period) nest counts were higher, we used these numbers without adjustment and assumed that all nests were counted; and,

2) if the May (early-incubation) counts were higher, we used a J factor of 4.8 or a K factor of 2.8 to adjust counts. These values were derived from mean differences observed at 19 colonies in this area. Our assumption was that all nests were not counted in May and by late June-early July some nests had failed (see Carter et al. 1984).

For Pigeon Guillemots, April and May counts were compared:

1) if the April (pre-breeding) bird count was higher, we used this number without adjustment and assumed that all breeding birds were counted during morning censuses and that non-breeding birds were not present; and,

2) if the May (incubation) bird count was higher, we used a K factor of 1.3. This value was derived from mean differences observed at 16 colonies in this area. Our assumption was that all birds had not been present or counted in April and that by May not all birds were present and countable at colonies in the morning.

L adjustments - To demonstrate how L correction factors were applied to raw counts of potential sites, we have explained below how 5,638 breeding Cassin's Auklets were determined at the Castle Rock National Wildlife Refuge in 1989:

1) A total of 3,166 potential medium-sized burrows and/or crevices were counted on 12-13 September. These sites were all considered to be Cassin's Auklet sites because they were too small for use by other alcids and burrows probably were too large to have been dug by storm-petrels.

2) A total of 1,300 potential large-sized burrows and/or crevices also were counted. Only 593 sites were considered not to be used by larger alcids (Pigeon Guillemots, Rhinoceros Auklets or Tufted Puffins) based on separate correction factors and thus were available for use by Cassin's Auklets.

3) By applying a L correction factor of 0.75 to the total of 3,759 potential sites, we estimated 2,819 active sites.

4) Two breeding adults (per mated pair) were applied to each active site, resulting in an overall population estimate of 5,638 breeding birds.

<u>Other considerations</u> - For Black Oystercatchers and Rhinoceros Auklets observed only near colonies during the day, there were no suitable correction factors known. Thus, unadjusted raw counts were used for minimal breeding population estimates. We did not adjust estimates of the numbers of breeding Brown Pelicans and Least Terns at colonies that were provided by other researchers. These estimates were determined through detailed and specific monitoring programs and all nests were assumed to be accounted for in estimates. We either used the number of nests multiplied by two adults/nest or, if it appeared that second or replacement nests were included in Least Tern nest counts, we used the high end of the range of numbers of breeding pairs. Similarly, whenever counts of nests were provided by other researchers (e.g. the South Farallon Islands, San Francisco Bay), we assumed that all nests had been counted and we did not adjust these numbers. One exception was Double-crested Cormorants in San Francisco Bay where we had sufficient information about when and how counts were conducted to adjust numbers at all colonies except the Richmond-San Rafael Bridge colony. For many Forster's and Caspian tern colonies in San Francisco Bay, only peak numbers of birds present at colonies have been counted by the San Francisco Bay Bird Observatory in recent years to prevent investigator disturbance. It was necessary to adjust these counts using an approximate K correction factor of 1.25 based on data available for Caspian Terns from five colonies between 1984-1990 (Table 3).

CAPTURE-RECAPTURE POPULATION ESTIMATES

For certain colonies of storm-petrels, we calculated population estimates from mist netting data. We used 3 different analytical methods based on capture-recapture techniques: 1) Lincoln-Petersen method; 2) computer program CAPTURE; and 3) computer program JOLLY.

The Lincoln-Petersen model was designed for closed populations (i.e. no emmigration or immigration) and for data sets with 2 capture periods only. When using the Lincon-Petersen method, we used Chapman's (1951) less biased version as follows:

$$N(hat) = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1$$

where N(hat) is the population estimate, n_1 is the number of birds captured at time period 1, n_2 is the number of birds captured at time period 2 and m_2 is the number of birds recaptured at time period 2. Variance was calculated by Seber's (1970, 1982) unbiased estimate:

$$\text{var } N(hat) = \frac{(n_1 + 1)(n_2 + 1)(n_1 - m_2)(n_2 - m_2)}{(m_2 + 1)^2(m_2 + 2)}$$

The computer program CAPTURE (Otis et al. 1978) was designed to analyze capture data for closed populations with 3 or more capture periods. Several models were included in the program:

The <u>Null Model</u>, M(o), assumed all birds have equal capture probabilities on each occasion and capture probabilities did not vary with time.

The <u>Heterogenity Model</u>, M(h), assumed heterogenity of capture probabilities in the population.

The <u>Behaviorial Model</u>, M(b), assumed that capture probabilities change due to behaviorial response from first capture (i.e. "trap-happy" or "trap-shy").

The <u>Time Model</u>, M(t), assumed time specific changes in capture probabilities.

Other models, including M(bh), M(th), M(tb), and M(tbh), were combinations of the above models.

Models have associated population estimators, except the M(th), M(tb), and M(tbh) models. After putting the capture data through a series of chi-square goodness of fit tests, the program selected the model which best fitted the attributes of the data. However, the model selected was not always correct and it may be necessary for the researcher to use a subjective approach when choosing a model (Otis et al. 1978).

The computer program JOLLY (Pollock et al. 1990) was designed to analyze capture data for open populations (i.e. when immigration and/or emmigration occur) with 3 or more capture periods. Several models were included in the program, including:

<u>Model</u> <u>A</u> - Standard Jolly-Seber model;

<u>Model</u> <u>B</u> - Jolly-Seber model with survival rate assumed constant per unit time and time-specific capture probability; and

<u>Model</u> <u>D</u> - Jolly-Seber model with both survival rate and capture probability assumed contant per unit time.

For all capture-recapture analyses with more than 2 capture periods, we analyzed data with both CAPTURE and JOLLY for comparison. If mist netting was conducted one night at a time, each night was considered a capture period. If mist netting was conducted for several nights at a time, the entire visit was considered a capture period. For mist netting in the Santa Barbara Island area in 1991, mist netting data from May at Santa Barbara Island and on 4-5 June at Sutil Island were lumped into one capture period.

It was not clear which capture-recapture method and model was best to use at any colony. Storm-petrel colonies were not closed populations, even over relatively short periods of time. Nonbreeders occassionally visited colonies, some breeders arrived later than other breeders, failed breeders may depart from the colony and a small number of birds may die during the study period. Visitation by nonbreeders was most likely to introduce the most bias. However, we were interested only in breeding population estimates and excluded nonbreeders from analyses. On the other hand, none of the models in program JOLLY account for heterogeneity of capture probabilities which also can introduce serious bias (Pollock et al. 1990). Due to the often large number of captures and small number of recaptures, goodness of fit tests in both programs often failed, as did some estimation models. Since it was difficult to choose a particular model and we desired a repeatable technique that could be used in the future, we took a mean of the estimates available to derive population estimates (e.g. see Ashy Storm-petrel account).

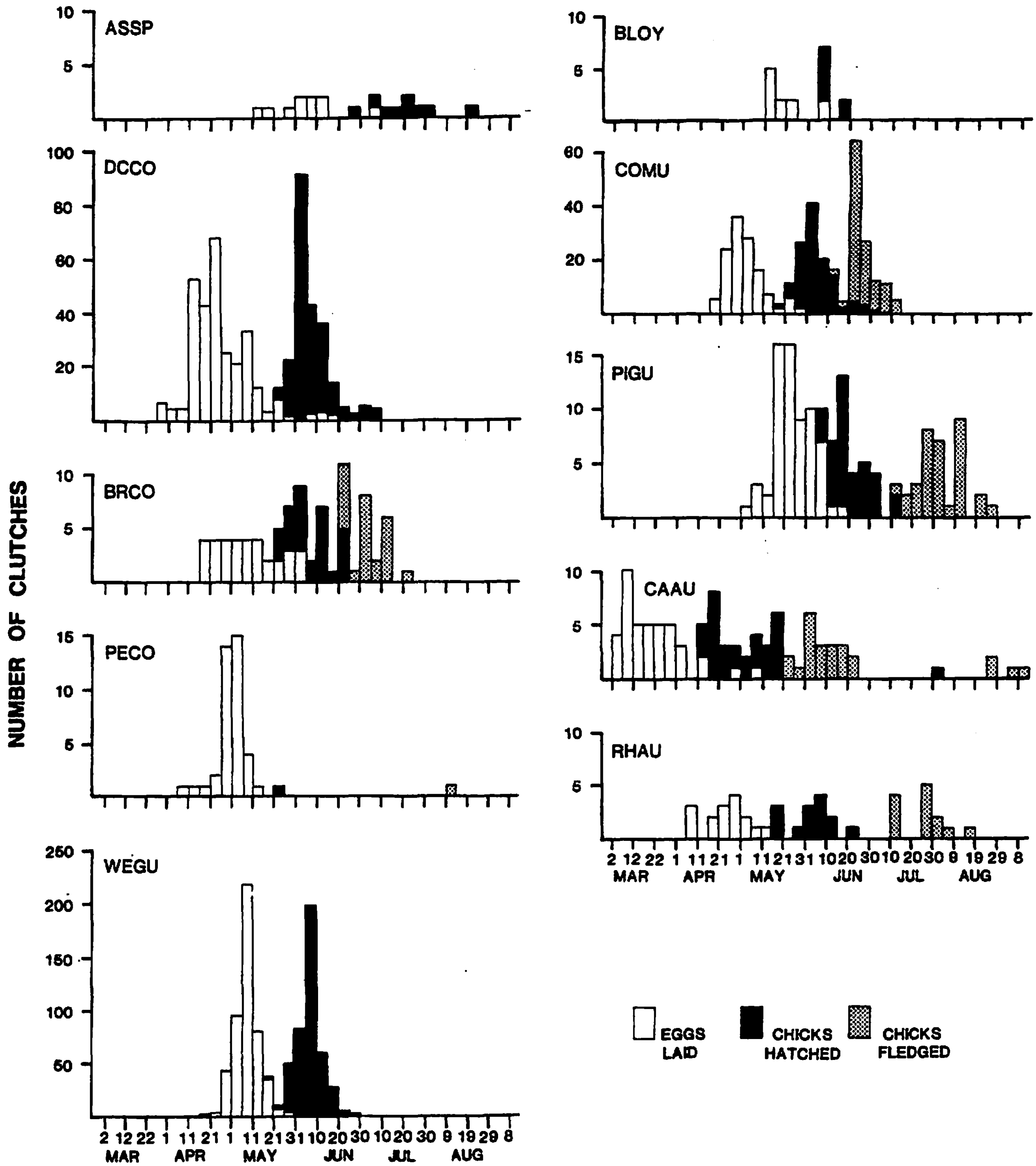


Figure 2. Breeding phenology of 10 seabird species at the South Farallon Islands (National Wildlife Refuge) in 1989 (PRBO, unpubl. data). Numbers of clutches with eggs laid, chicks hatched, and chicks fledged are indicated by five-day period. Fledging dates were not available for DCCO, WEGU, and BLOY whereas, for ASSP, chicks fledged after August. See Table 1 for species abbreviations.

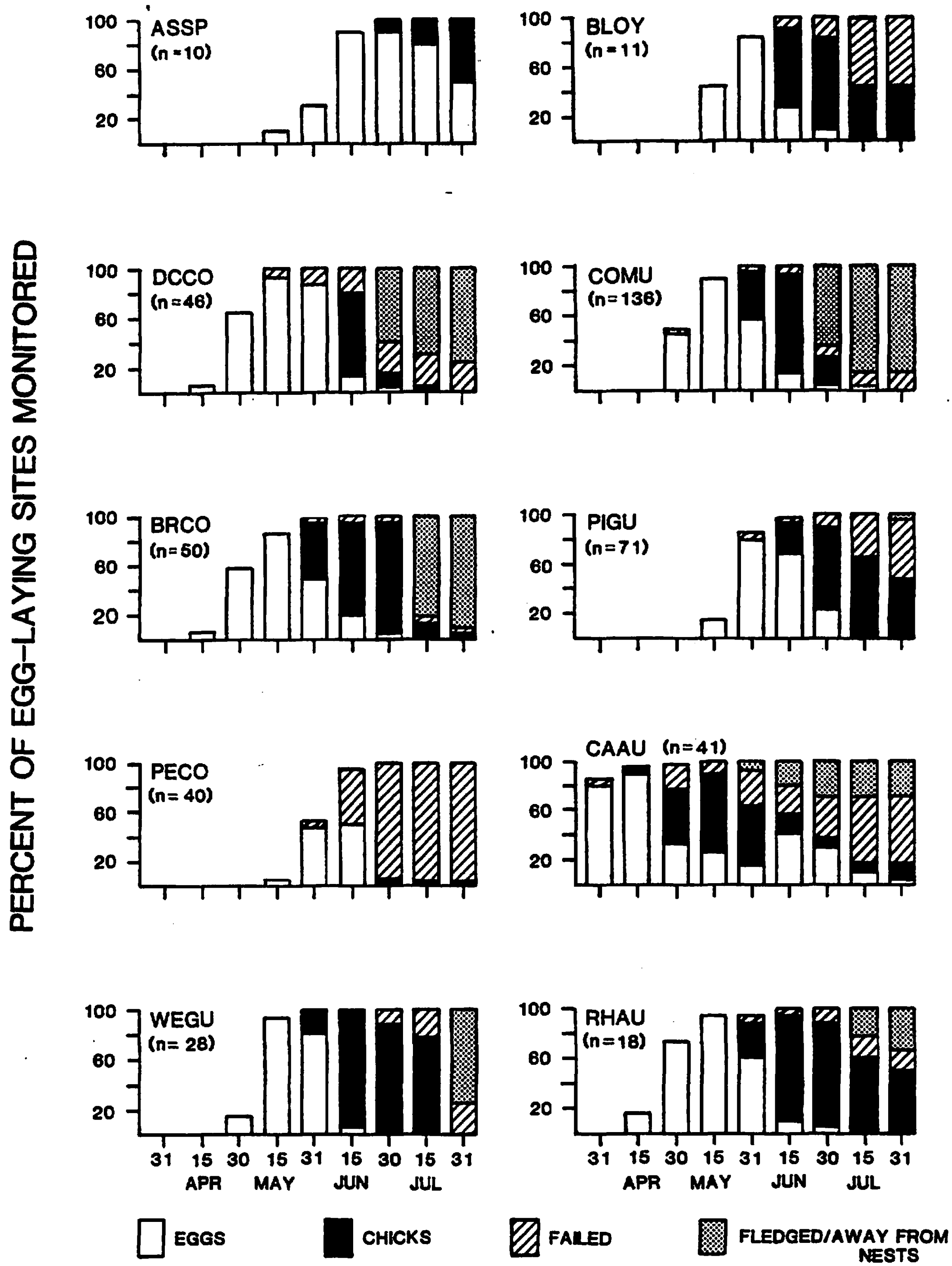


Figure 3. Percent of egg-laying sites (sample sizes of monitored sites in parentheses) with eggs, chicks, failed, or chicks fledged/away from nests by 15-day period for 10 seabird species at the South Farallon Islands (National Wildlife Refuge) in 1989.

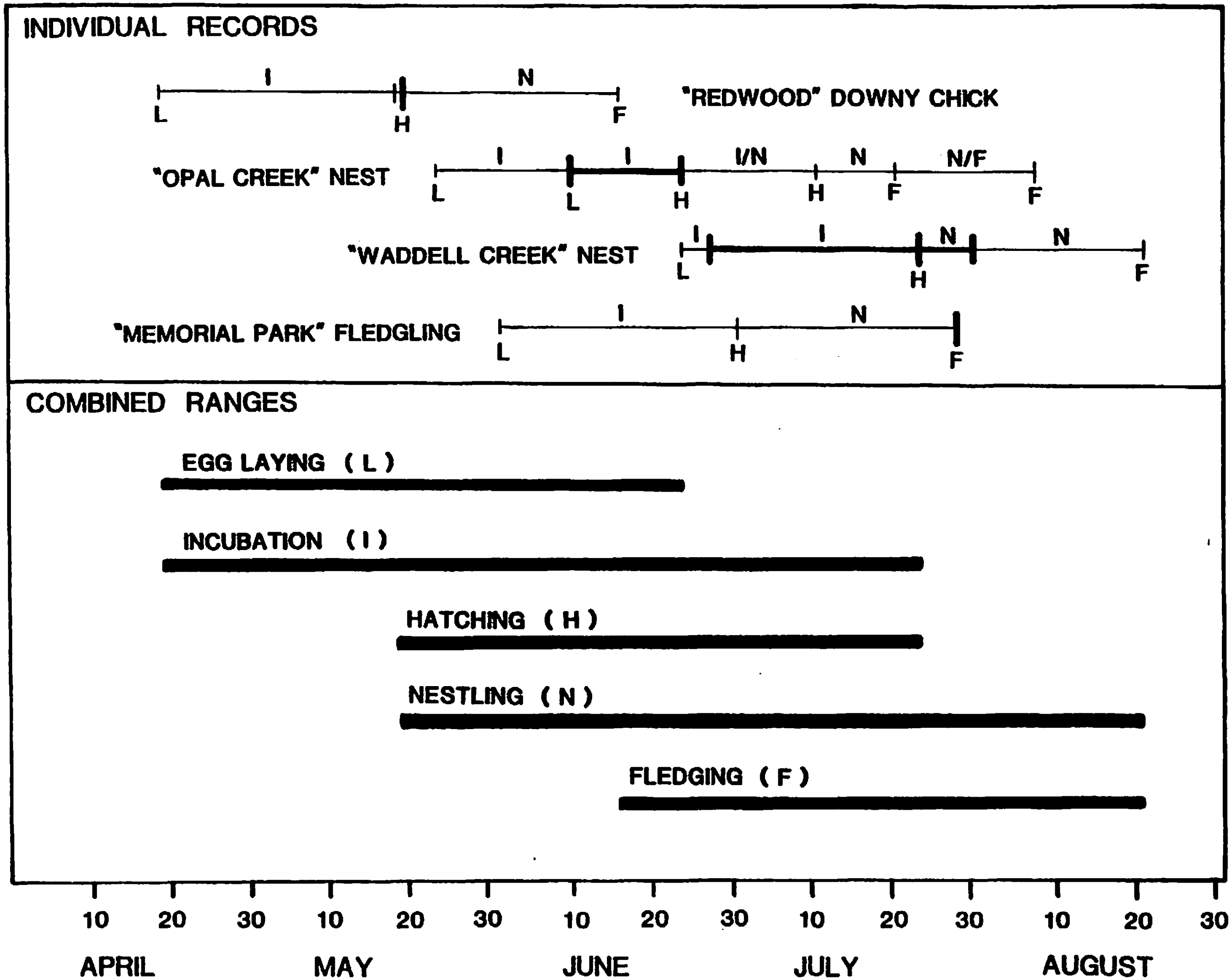


Figure 4. Estimated timing of breeding of Marbled Murrelets in California in 1989, based on nest records and grounded young in central California (Naslund 1990; Singer et al. 1991). In the top portion of the figure, the thick bars indicate definite dates and the thin bars indicate extrapolated dates for each record. In the bottom portion of the figure, the ranges of different stages of the nesting cycle are presented.

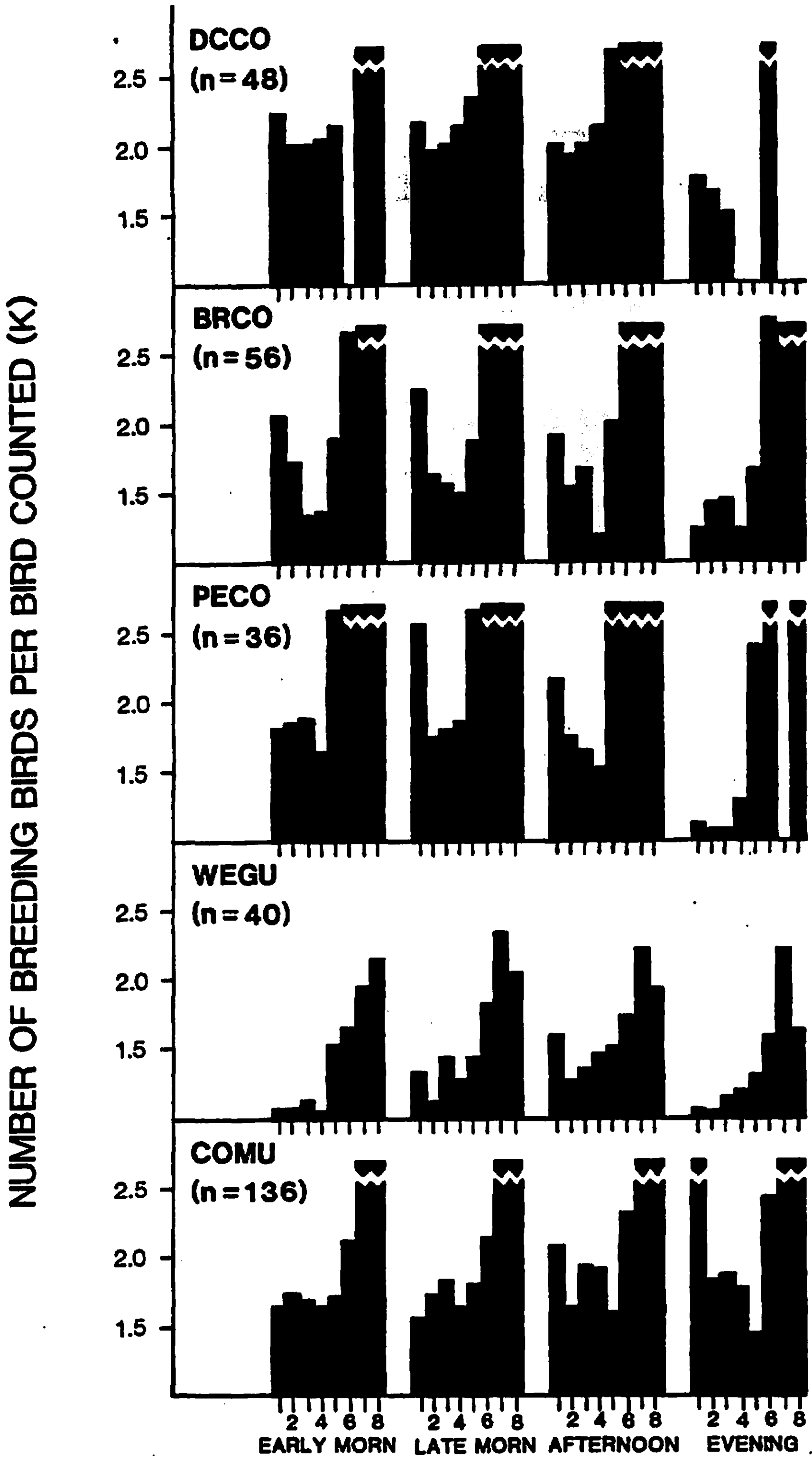


Figure 5. Correction factor K (number of breeding birds per bird counted) values for five seabird species at four times of day for eight 15-day periods from 15 April to 31 July 1989 at the South Farallon Islands (National Wildlife Refuge). Times of day are coded: early morning (0600-0800), late morning (1000-1200), afternoon (1400-1600), and evening (1800-2000). Fifteen day periods occurred at the beginning and midpoint of each month (i.e. 1, 15 April; 2, 30 April; 3, 15 May; etc.).

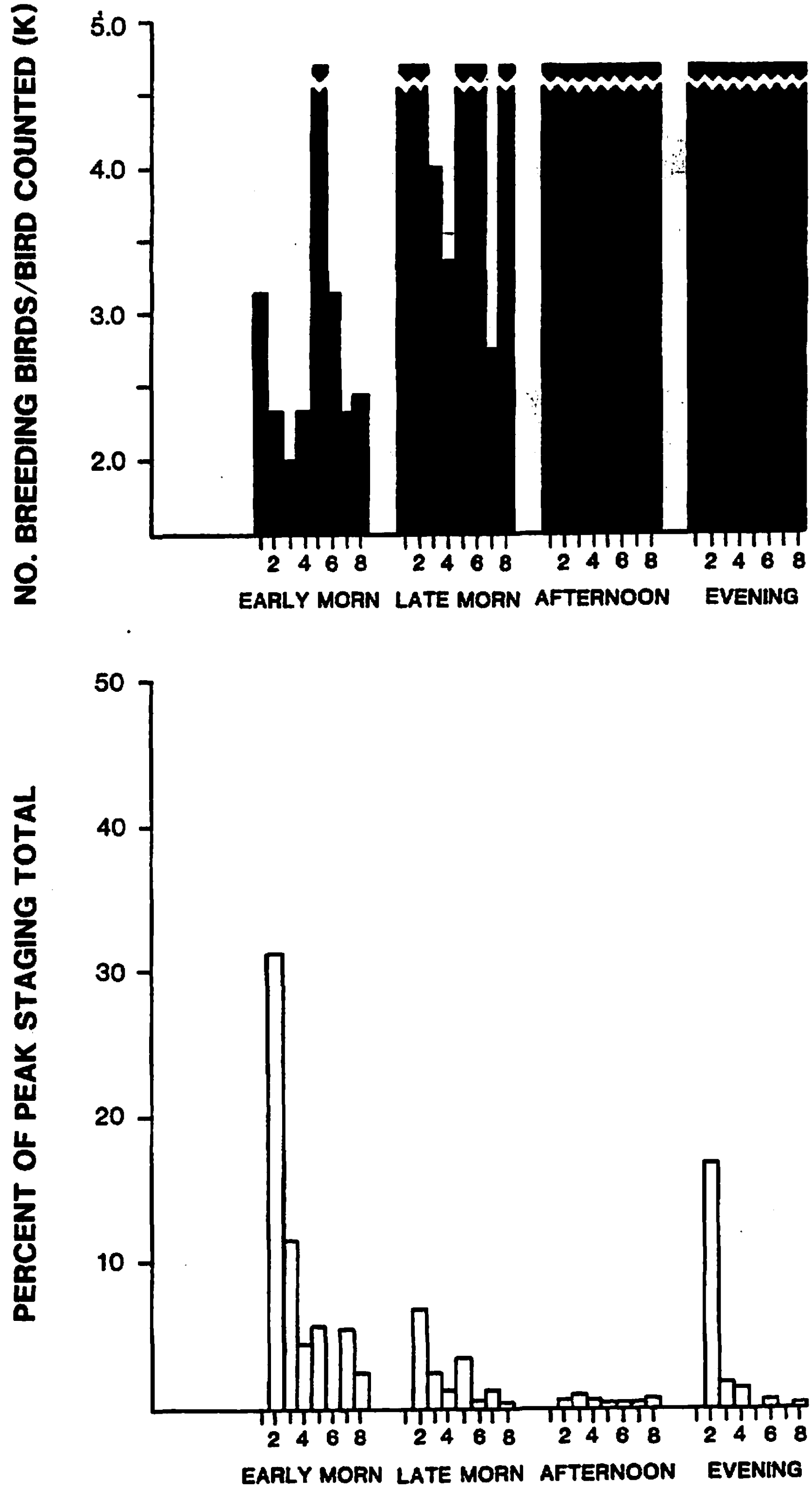


Figure 6. Correction factor K values for Pigeon Guillemots and counts of birds at sea staging/foraging near the South Farallon Islands (National Wildlife Refuge) at four times of day for eight 15-day periods from 15 April to 31 July 1989 (coded as in Figure 5). Counts of staging birds are expressed as a percentage of the peak staging count of 1867 birds recorded at dusk on 9 April 1989.

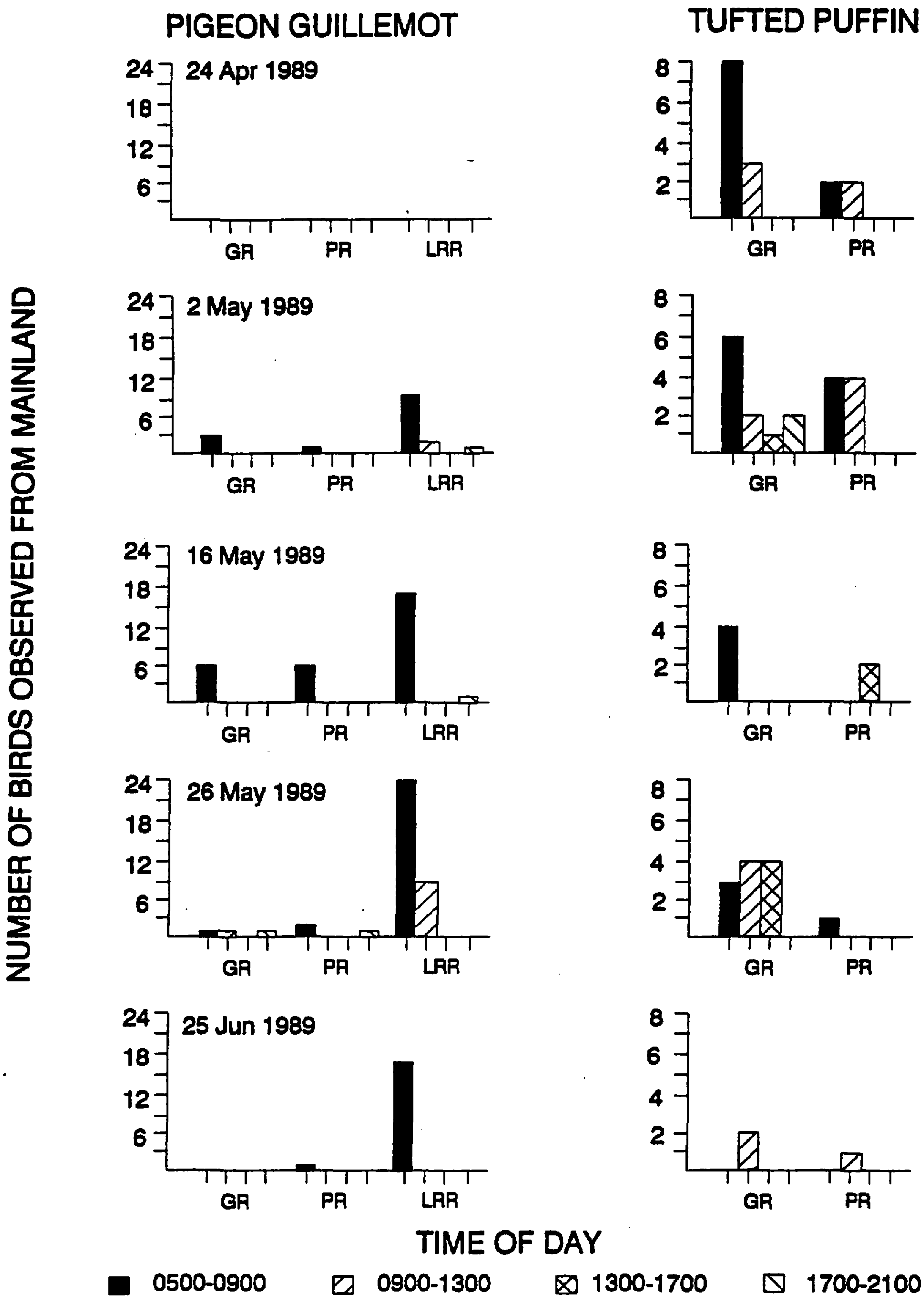
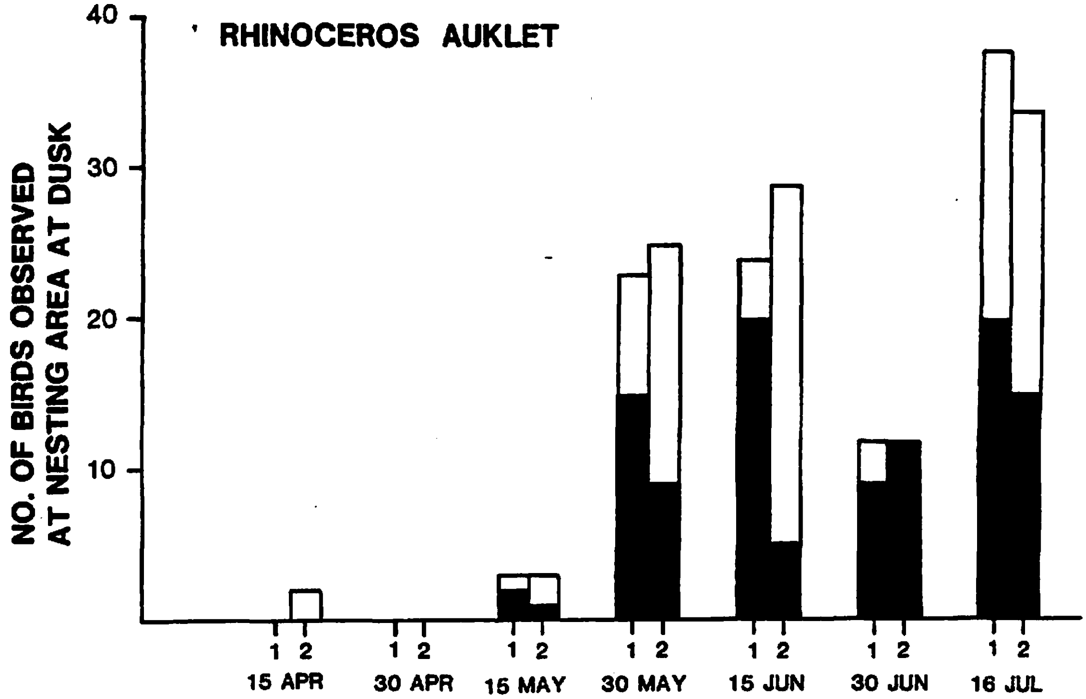


Figure 7. Numbers of Pigeon Guillemots and Tufted Puffins observed at different times of day at Green Rock (GR), Puffin Rock (PR) and Little River Rock (LRR) (California Islands Wildlife Sanctuary), Humboldt County, April-June 1989.



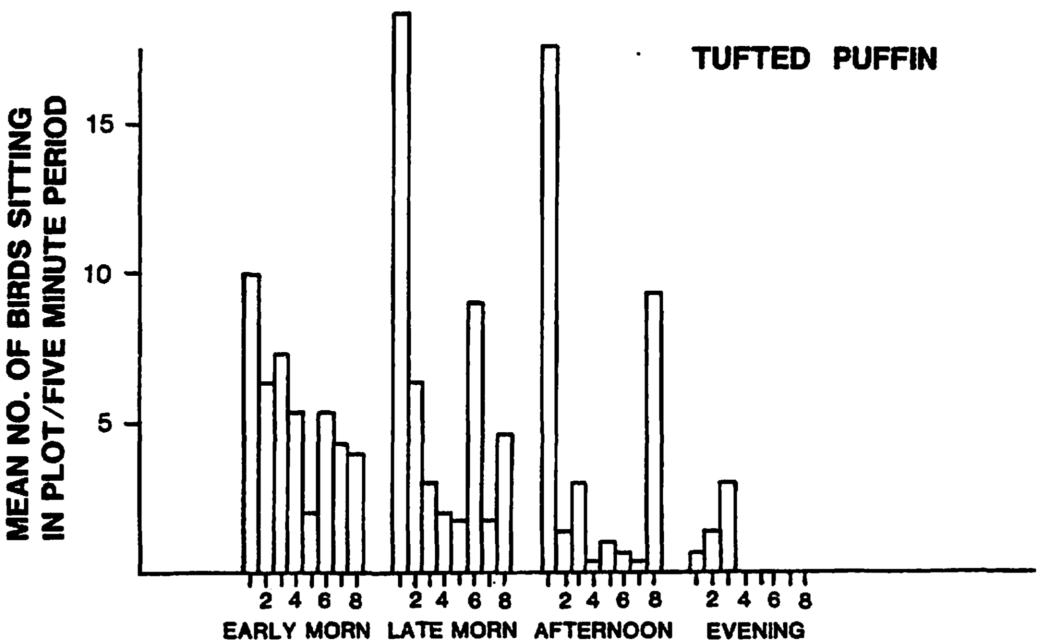


Figure 8. Attendance patterns of Rhinoceros Auklets and Tufted Puffins at the South Farallon Islands (National Wildlife Refuge) in 1989. In the top portion of the figure, dusk counts of Rhinoceros Auklets flying by (open bars) and landing at (solid bars) two nesting areas on Southeast Farallon Island (1, Rabbit Cave Catacombs; 2, Coast Guard House Catacombs) are presented by 15-day period from 15 April to 16 July. In the bottom portion of the figure, mean numbers of Tufted Puffins sitting on land in a plot on "Maintop", West End Island, determined from three consecutive counts at four times of day for eight 15-day periods from 15 April to 31 July (coded as in Figure 5) are presented.

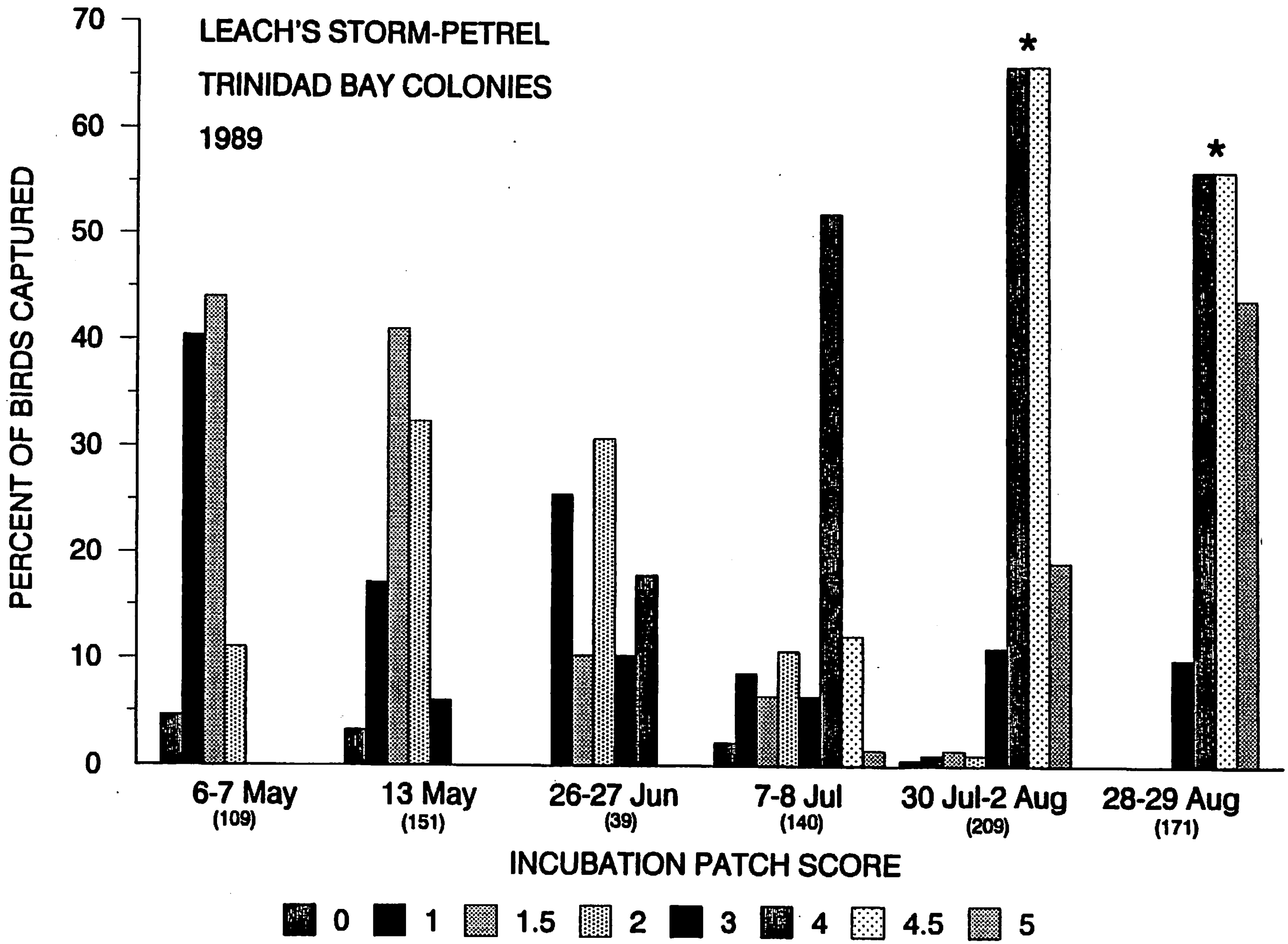


Figure 9. Incubation patch scores of Leach's Storm-petrels at Trinidad Bay colonies (including Prisoner, Button and Little River rocks [California Islands Wildlife Sanctuary]), Humboldt County, in 1989.

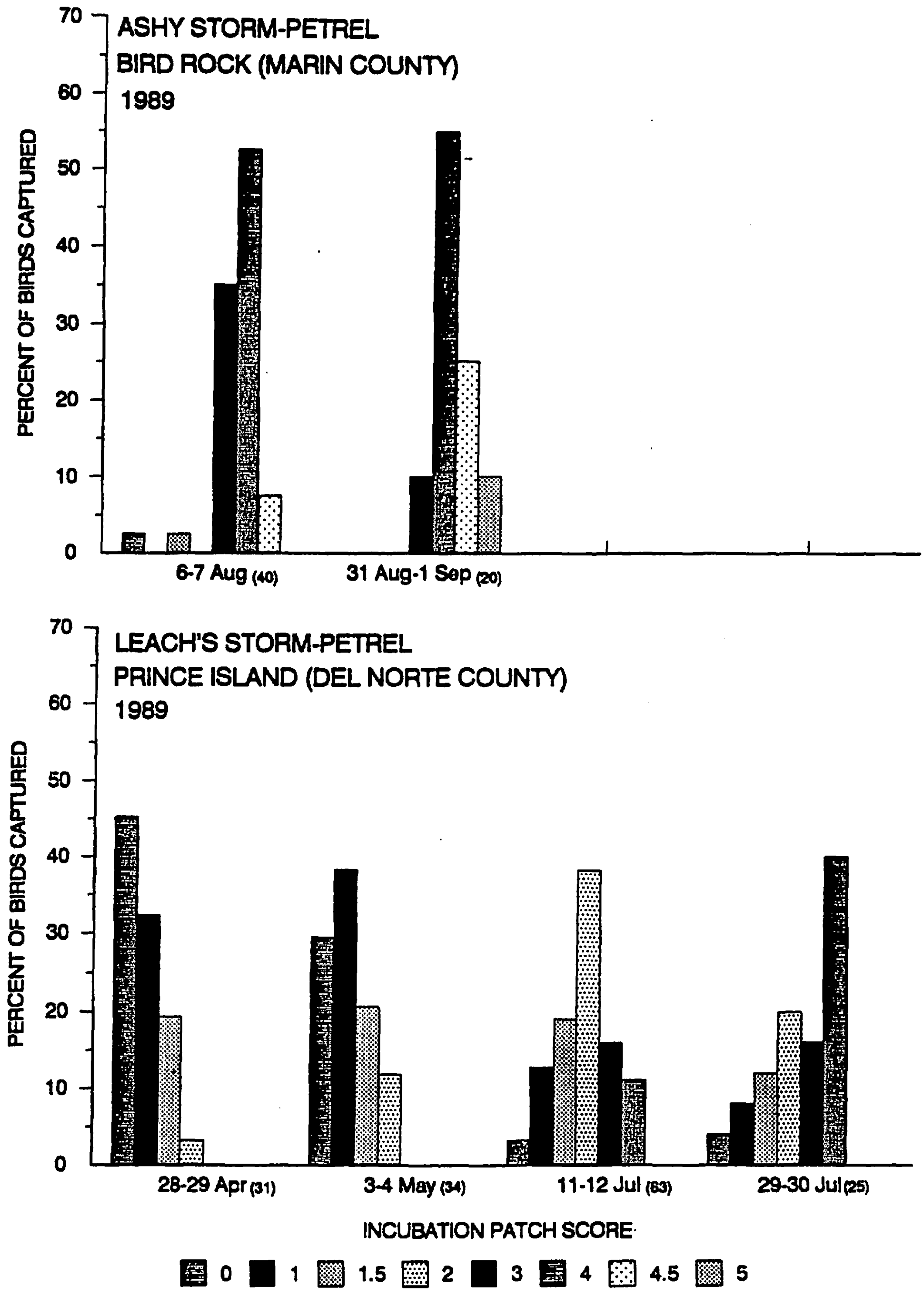


Figure 10. Incubation patch scores of Ashy Storm-petrels at Bird Rock (Point Reyes National Seashore), Marin County, and Leach's Storm-petrels at Prince Island (Tolowa Tribe), Del Norte County, 1989.

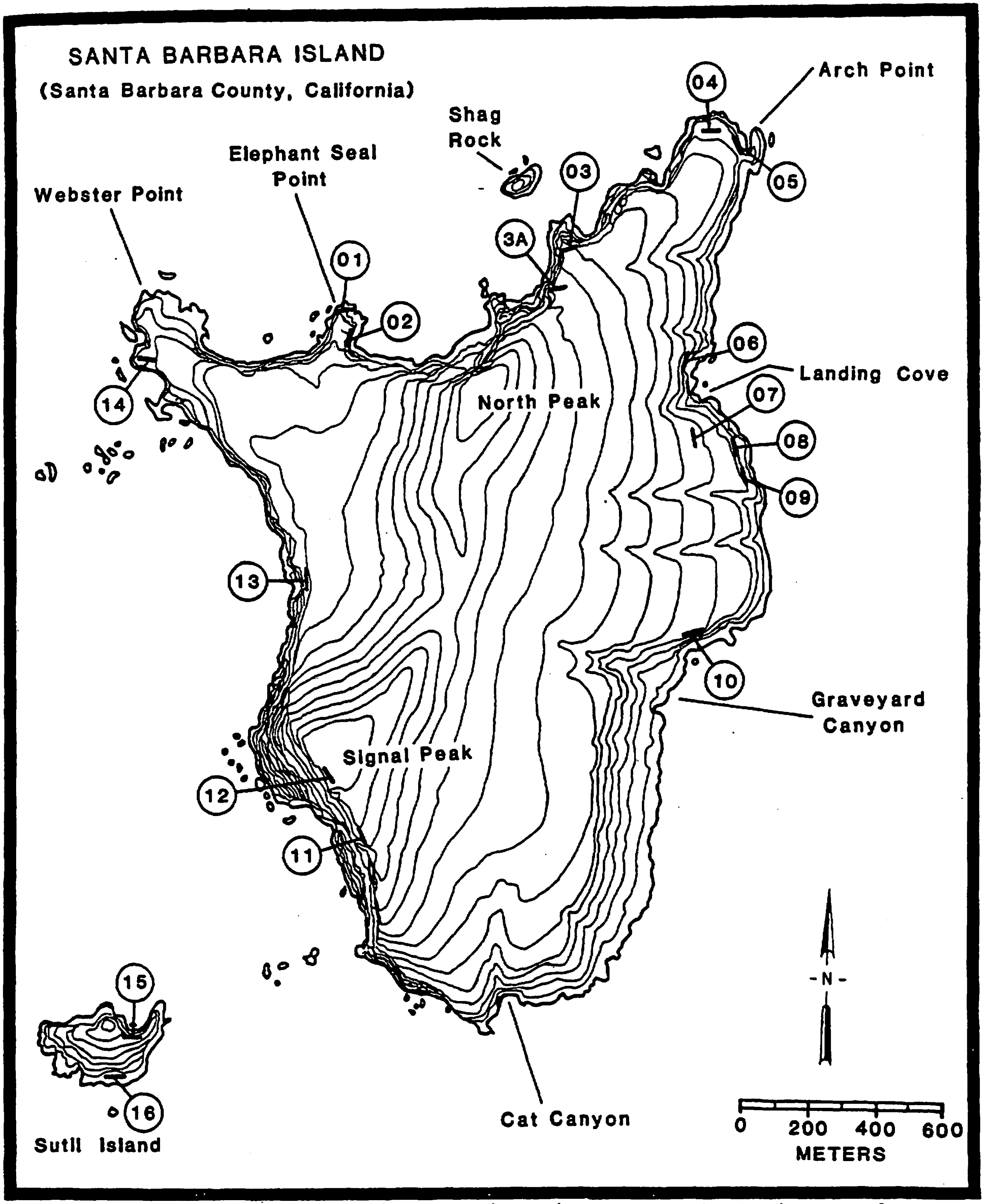


Figure 11. Locations of mist-netting sites on Santa Barbara and Sutil islands (Channel Islands National Park), Santa Barbara County, 1991 (see Appendix 4).

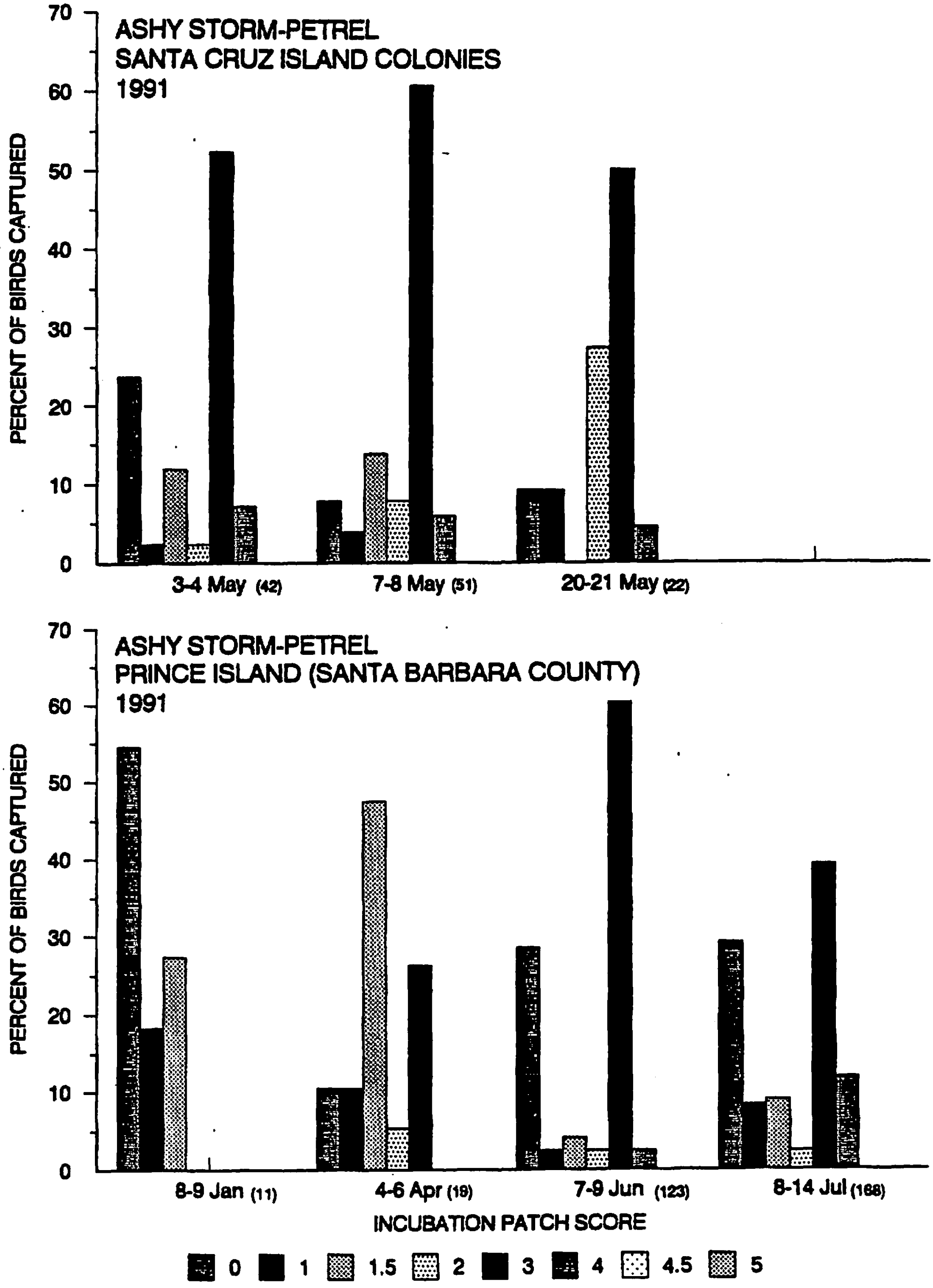


Figure 12. Incubation patch scores of Ashy Storm-petrels at Santa Cruz Island colonies, including Scorpion Rocks (Channel Islands National Park) and Willows Anchorage Rocks (Nature Conservancy), and at Prince Island (Channel Islands National Park), Santa Barbara County, 1991.

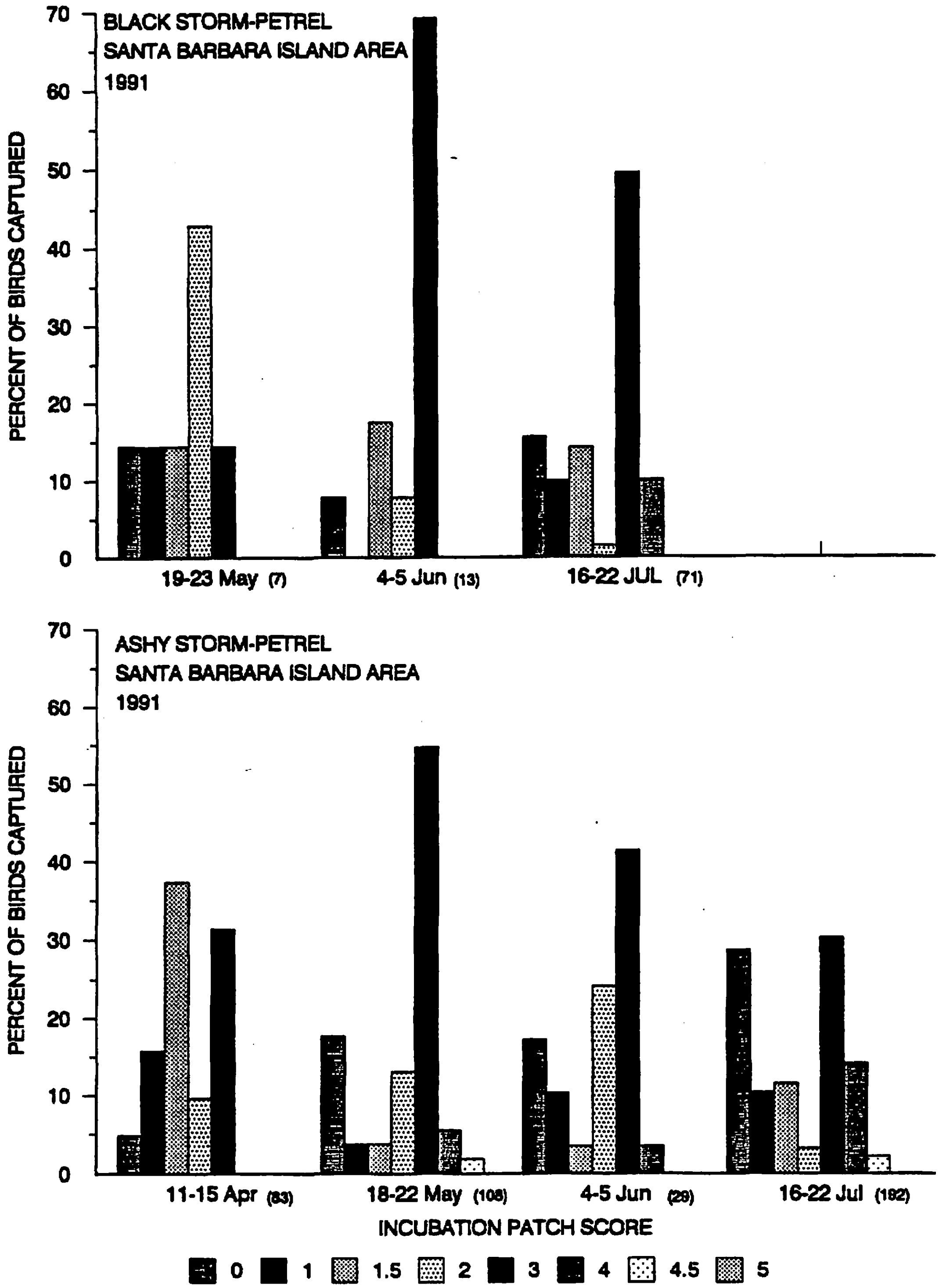


Figure 13. Incubation patch scores of Black and Ashy storm-petrels at Santa Barbara Island area colonies, including Santa Barbara and Sutil islands (Channel Islands National Park), Santa Barbara County, 1991.

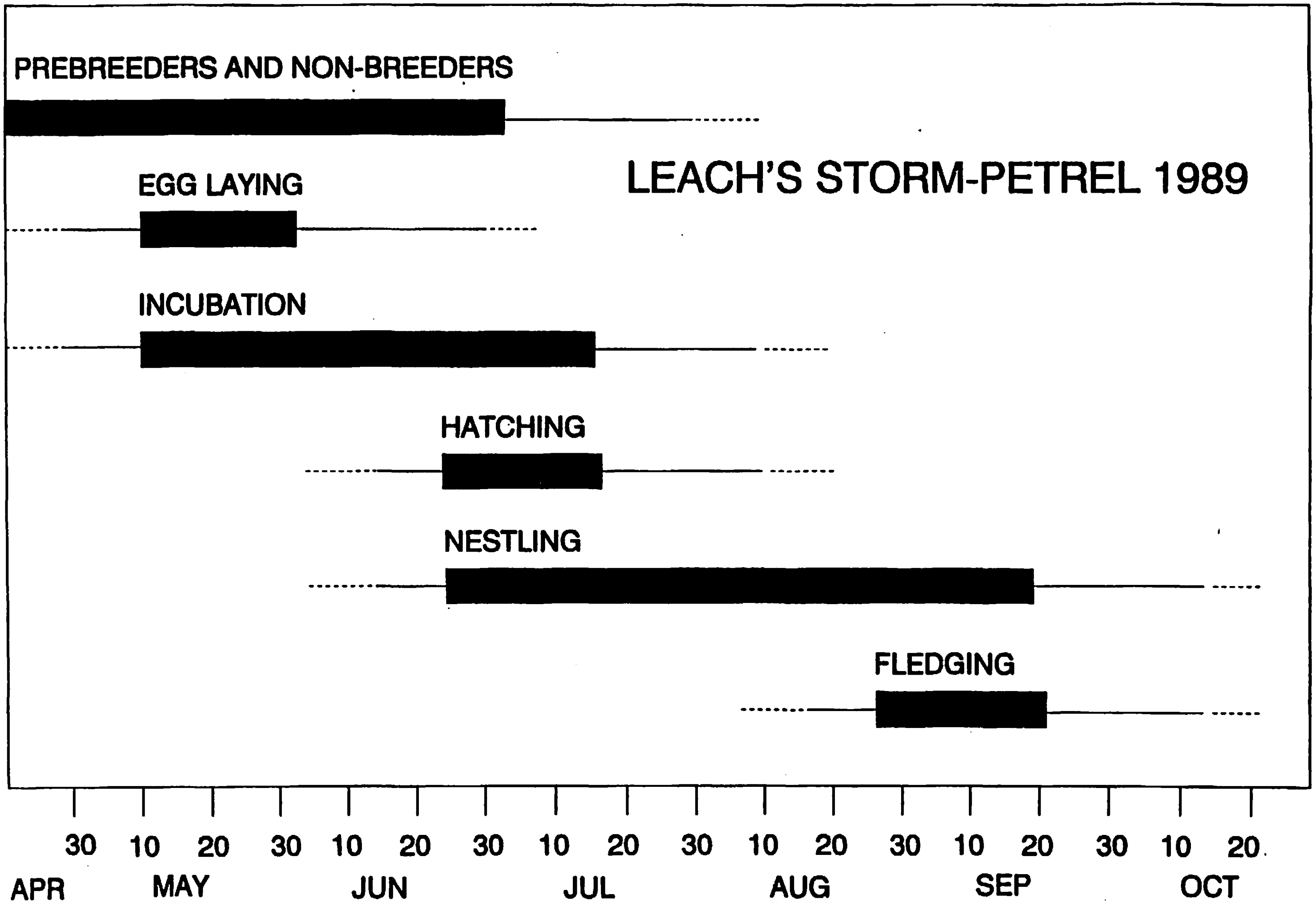


Figure 14. Estimated timing of breeding of Leach's Storm-petrels in northern California in 1989, based on incubation patch condition of 819 birds captured in mist nets at 3 colonies in Trinidad Bay, Humboldt County (see Appendix 3). Thick bars indicate when over 25% of birds occurred or were projected to occur in respective nesting periods. Thin lines indicate observed or projected ranges. Dashed lines indicate that ranges may be greater than shown.

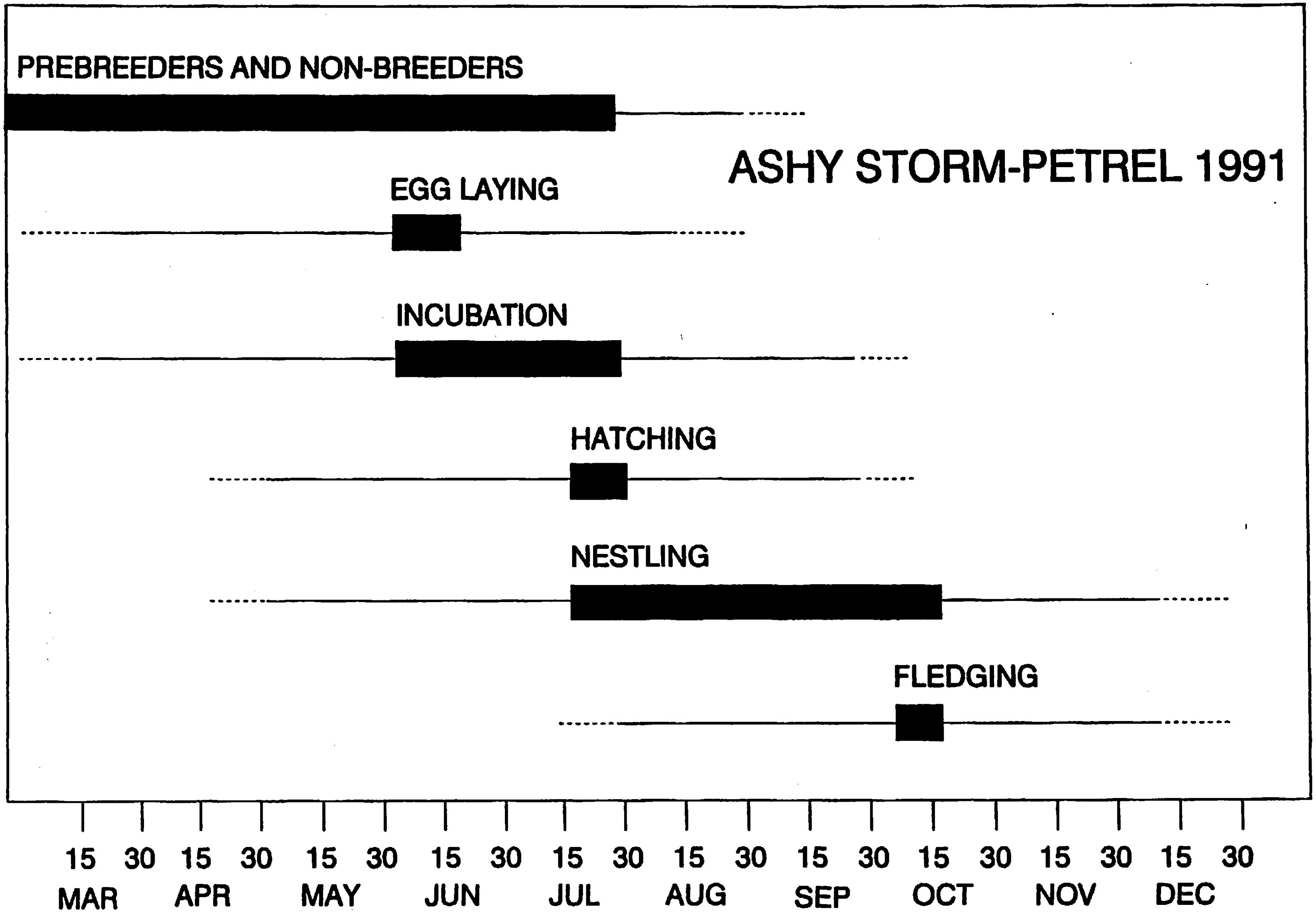


Figure 15. Estimated timing of breeding of Ashy Storm-petrels in southern California in 1991, based on incubation patch condition of 820 birds captured in mist nets at 6 colonies between 8 January and 21 October (see Appendix 4) and nests found at 5 colonies. Symbols as in Figure 14.

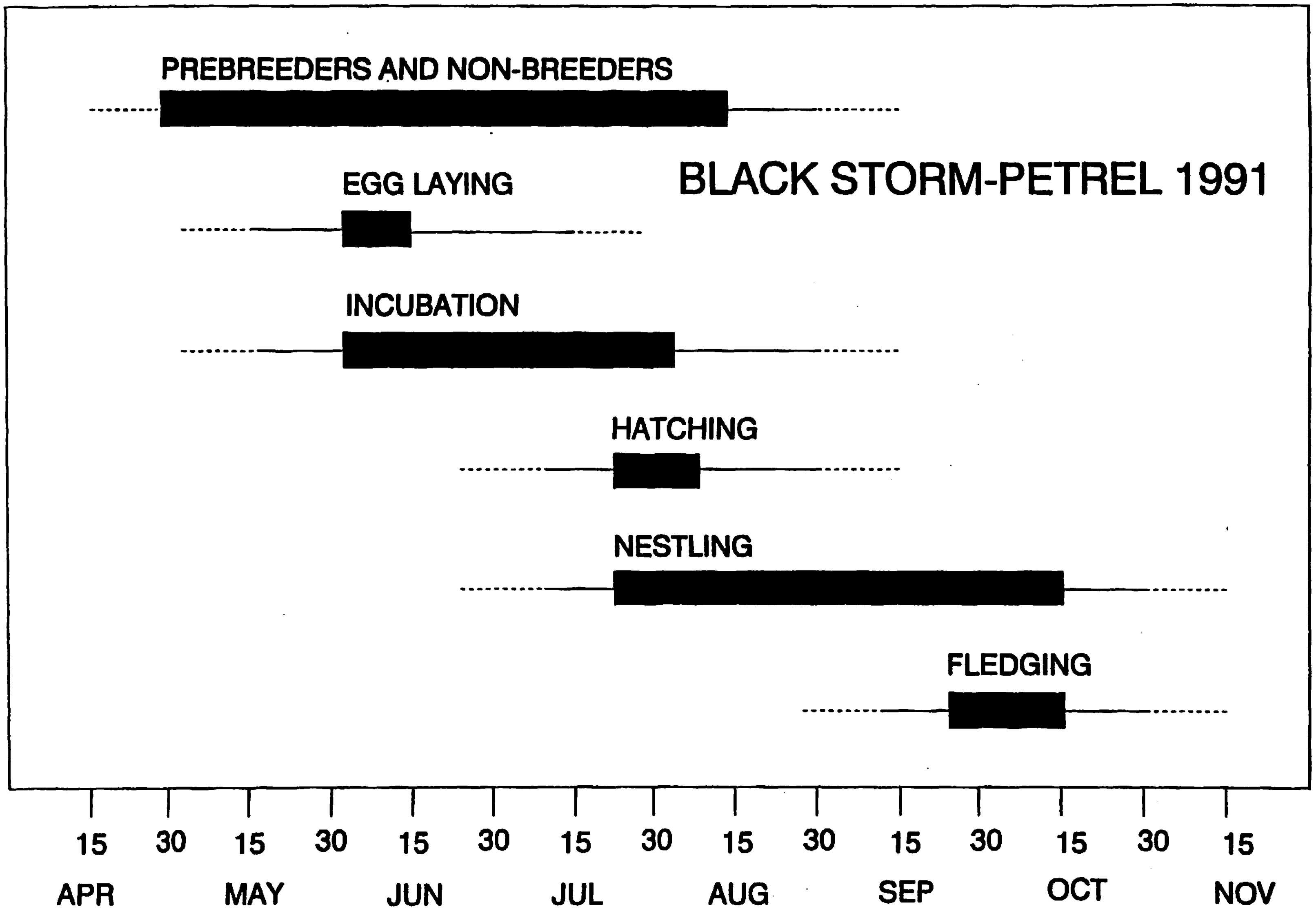


Figure 16. Estimated timing of breeding of Black Storm-petrels in southern California in 1991, based on incubation patch condition of 91 birds captured in mist nets at 2 colonies (see Appendix 4). Symbols as in Figure 14.

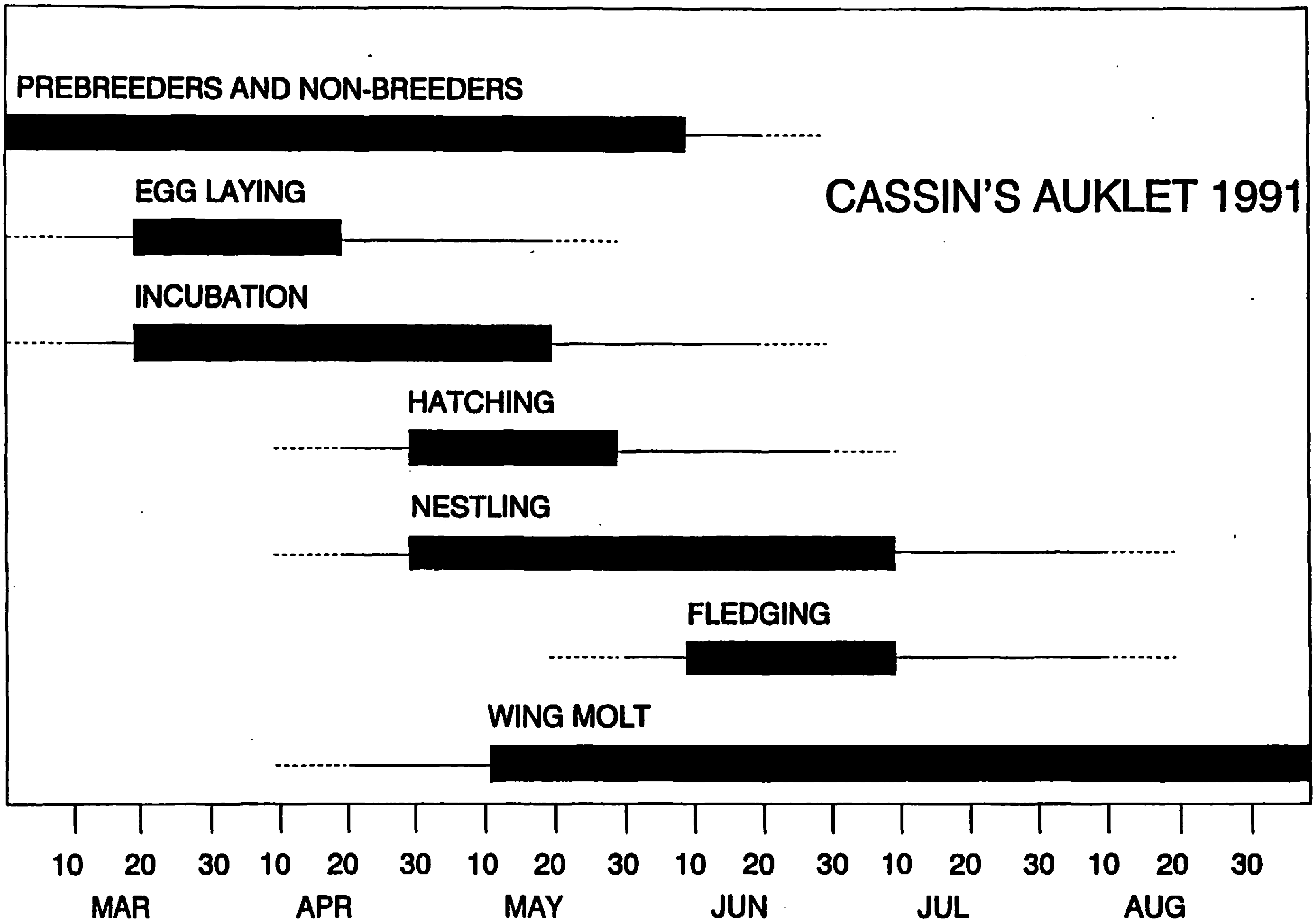


Figure 17. Estimated timing of breeding of Cassin's Auklets in southern California in 1991, based on incubation patch condition of 141 birds captured in mist nets at 4 colonies (see Appendix 3). Symbols as in Figure 14.

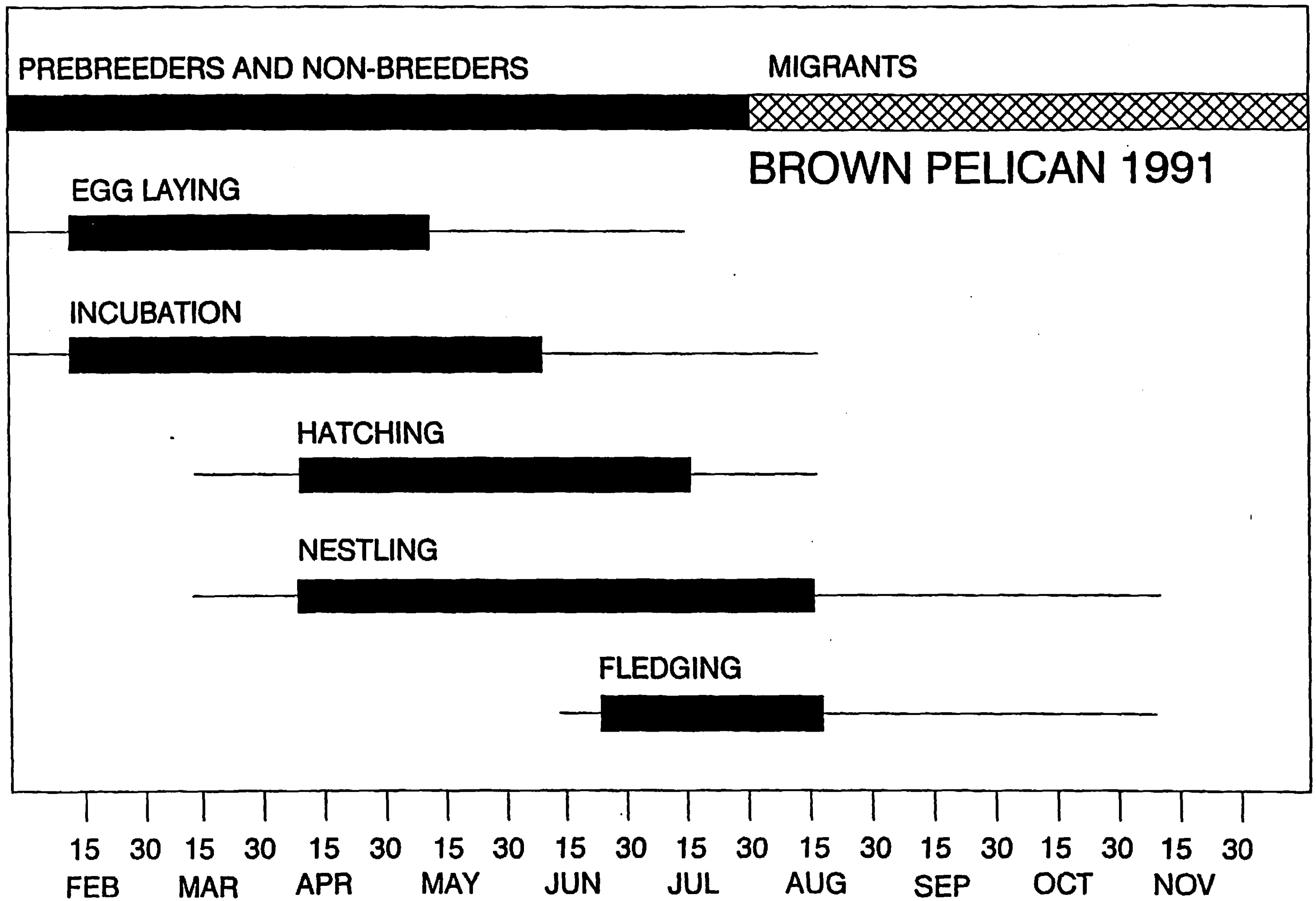


Figure 18. Estimated timing of breeding of Brown Pelicans in southern California in 1991 (Gress 1992). Symbols as in Figure 14.

Table 2. Mean correction factors used to adjust raw counts of nest, birds, or sites to obtain estimates of the total number of breeding birds at a nesting area. J and K factors and median dates were derived from data collected at the South Farallon Islands. The L factor was derived mainly from the literature (see text).

	MEDIAN DATE			CORRECTION FACTORS					
					K				
					Time of day (PDT)				
SPECIES	Lay	Hatch	Fledge	J	<0900	0900-1300	1300-1700	>1700	L
ASSP	5 Jun	21 Jul	-	1.0(4)[1]	-[2]	-	-	-	-
LHSP	-	-	-	-	-	-	-	-	0.75
DCCO	22 Apr	3 Jun	-	1.2(4)	2.0(4)	2.1(4)	2.2(4)	1.6(3)	-
BRCO	7 May	7 Jun	3 Jul	1.1(4)	1.8(4)	2.2(4)	2.4(4)	1.8(4)	-
PECO	31 May	-	-	2.0(2)	2.2(2)	2.3(2)	2.3(2)	1.9(2)	-
WEGU	8 May	7 Jun	-	1.0(3)	1.2(3)	1.4(3)	1.5(3)	1.2(3)	-
BLOY	17 May	8 Jun	-	1.2(2)	-	-	-	-	-
COMU	30 Apr	3 Jun	24 Jun	1.1(3)	1.7(3)	1.8(3)	1.8(3)	1.7(3)	-
PIGU	24 May	21 Jun	6 Aug	1.4(5)	3.3(5)[3]	5.0(4)[3]	-	-	-
CAAU	18 Mar	28 Apr	6 Jun	1.3(5)	-	-	-	-	0.75
RHAU	26 Apr	5 Jun	27 Jul	1.2(6)	-	-	-	-	0.50
TUPU	-	-	-	-	4.7(6)[3]	7.6(6)[3]	-	-	-

[1] Mean value between median laying and median fledging with sample size in parentheses.
[2] When values are not presented, insufficient or no data were available.
[3] These values were reduced roughly by half (50%) before use.

Table 3. Data used to calculate the K correction factor for adjusting peak counts of the number of Caspian and Forster's terns at nesting areas in San Francisco Bay. All data were derived from five Caspian Tern colonies.

CA Colony Number[1]	Census Year	Peak counts Adults	Peak counts Nests	K[2]	Adjusted K[3]	Total breeding birds[4]
SFB-AL-21	1986	365	125	0.68	1.16	456
SFB-AL-32	1984	400	220	1.10	1.10	500
" " "	1985	600	373	1.24	1.24	750
" " "	1986	650	453	1.39	1.39	813
" " "	1989	450	289	1.28	1.28	563
SFB-SM-06	1986	600	171	0.57	1.15	750
" " "	1988	1700	200	<0.01	1.22	2125
" " "	1989	600	400	1.33	1.33	750
SFB-SN-04	1990	133	38	0.57	1.20	166
SFB-CC-17	1990	350	60	0.34	1.25	438
Mean (n=10)	-	-	-	0.85	1.23	-
Mean (n=5)[5]	-	-	-	1.27	-	-

[1] Data for SFB-AL-21, SFB-AL-32, and SFB-SM-06 were provided by P. Woodin (SFBBO, unpubl. data); SFB-SN-04 by R. Leong (unpubl. data); and SFB-CC-17 by F. McCollom (unpubl. data).

[2] Number of breeding birds (based on nest count) per bird counted.

[3] Where more birds were present then could be accounted for by the nest count (i.e. K < 1.0), we assumed that additional birds were "displaced" breeders.

[4] Estimates of the total number of breeding birds were derived by multiplying the peak adult count by 1.25 (average of means 1.23 and 1.27).

[5] Uses K > 1.0 only.

Table 4. Monthly J and K correction factors for Double-crested, Brandt's and Pelagic cormorants at Anacapa Island (Channel Islands National Park), Ventura County, in 1991 (calculated from F. Gress [unpubl. data]).

Colony Name	No. of nesting Areas	Total No. Nests[1]	Census Date: 29-30 Mar J	29-30 Mar K	27-30 Apr J	27-30 Apr K	21-27 May J	21-27 May K	20-27 Jun J	20-27 Jun K	30 Jul J	30 Jul K
Double-crested Cormorant												
Anacapa Island - West	22	360	11.3	12.2	2.1	3.5	1.2	-	1.1	-	1.8[2]	-
Brandt's Cormorant												
Anacapa Island - West	4	20	-	-	2.9	2.2	-	-	1.0	-	1.5	-
Pelagic Cormorant												
Anacapa Island - West	8	57	1.7	1.8	1.6	2.5	1.3	1.7	1.5	3.0	-	-
Anacapa Island - East	6	35	1.4	1.8	1.3	2.0	1.1	1.7	1.3[2]	1.2	-	-
Total	14	92	1.6	1.8	1.4	2.3	1.2	1.7	1.4	2.7	-	-

[1] Total number of nests noted over the entire breeding season.
[2] Used a sample of nesting areas.

DISCUSSION

In 1989-1991, 643,307 breeding birds of 21 species were estimated on the coast of California (Figure 19; Tables 5, 6). However, terns and skimmers in southern california have yet to be added to this total. Once information has been completely summarized, it will be included in the final draft. Totals of 312,106, 232,661 and 96,016 breeding birds were found in northern, central and southern California, respectively, and corresponded to 49%, 36% and 15% of the state total, respectively. We have excluded about 50,000-60,000 seabirds breeding at inland colonies, including White Pelicans (@ 2000), Double-crested Cormorants (@ 1,000-3,000), California Gulls (45,000-50,000), Black Terns (@ 100-300), Caspian Terns (@ 1,000-1,200) and Forster's Terns (@ 1,000-1,500)(Gill and Medwaldt 1983; Dierks 1990; P. Moreno, unpubl. data; see species accounts).

Overall, current population estimates were slightly lower than reported from 1975-1980 surveys (Sowls et al. 1980). However, there were many reasons for differences between 1989-1991 and earlier population estimates besides true increases and decreases in numbers, including: 1) inclusion of newly-founded or overlooked colonies in areas surveyed previously; 2) inclusion of coastal areas (especially San Francisco Bay) that were not surveyed previously; 3) more extensive and refined use of aerial photographs to count large numbers of nesting murres and cormorants; 4) more extensive boat surveys of the Channel Islands and certain parts of the northern and central California coasts; 5) more extensive mistnetting of storm-petrels; 6) use of detailed burrow/crevice counts; 7) use of correction factors to adjust counts in 1989-1991; 8) refinement of previous estimates at the South Farallon Islands by PRBO; 9) detailed ground counts of Western Gull colonies in the Channel Islands; and 10) a variety of other differences between surveys. We have addressed census differences and trends in the species account sections. However, in general, most species still nested where they had been documented earlier, major colonies had not been omitted in previous surveys and there were not tremendous differences between 1989-1991 and 1975-1980 surveys that could not be accounted for by census differences or changing status of species. Recent declines were found or suspected for Fork - tailed Storm-petrel, Leach's Storm-petrel, White Pelican, Black Tern, Caspian Tern, Least Tern, Common Murre and Marbled Murrelet. Recent increases were found or suspected for Brown Pelican, Double-crested Cormorant (coastal population only), California Gull, Western Gull, Forster's Tern (coastal population only) and Rhinoceros Auklet. Similar numbers were found for other species or trends could not be determined without additional surveys, studies and/or more in-depth comparisons with previous surveys.

Nesting areas of special importance

We have identified several nesting areas of special importance in California, based on the concentration of large numbers of breeding birds and/or involving several species in relation to other nearby coastal areas. We have pointed out and discussed research needs at 4 exceptional colonies and listed other important nesting areas.

Farallon Islands (National Wildlife Refuge) - In 1989, these 2 colonies (North and South Farallon islands) contained the largest populations in California, totalling 155,550 breeding birds of 12 species (plus 1 possibly breeding species). This total corresponded to 24% of the state total, including substantial relative numbers of 10 species: Leach's Storm-petrel (11%), Ashy Storm-petrel (55%), Double-crested Cormorant (11%), Brandt's Cormorant (20%), Western Gull (36%), Common Murre (19%), Pigeon Guillemot (12%), Cassin's Auklet (68%), Rhinoceros Auklet (29%) and Tufted Puffin (25%). These colonies hosted the world's largest colonies of Ashy Storm-petrel, Brandt's Cormorant and Western Gull as well as the most southernly colonies of significant size for Rhinoceros Auklets and Tufted Puffins on the west coast of North America.

The relative importance of this colony was lower than indicated by Sowls et al. (1980). Lower numbers at this colony resulted from: 1) revisions of 1979-1980 population estimates for several species by PRBO (see Ainley and Boekelheide 1990); 2) lower numbers of certain species after the 1982-1983 ENSO event; 3) declines in certain species due to gill-net and oil mortality (especially Common Murres); and 4) much lower estimates of Cassin's Auklets in 1989 (see species accounts). Annual monitoring and various studies by PRBO and other researchers have been conducted since 1972 and have greatly improved our understanding of seabird population trends and biology in the center of the California Upwelling System. Changes in soil depth and consistency have been reported by PRBO on Southeast Farallon Island which may have led to decline in numbers of Cassin's Auklets on the southwest marine terrace (see species account). Preliminary descriptions of plant communities and sporadic vegetation monitoring has been conducted since the late 1960's by M. Coulter (unpubl. data). Since the mid 1980's, USFWS has controlled certain exotic plants. A better system of monitoring vegetation and soils should be implemented by USFWS and PRBO. Also, accurate estimates of population sizes have received less attention than have relative measures of population change. More effort and better estimation techniques are required for many species for better long-term monitoring of these important populations (see Takekawa et al. 1990).

Castle Rock (National Wildlife Refuge) - In 1989, this single colony held the second largest population of breeding seabirds in

California, totalling 122,150 birds of 11 species. This total corresponded to 19% of the state total, including substantial relative numbers of 6 species: Fork-tailed Storm-petrel (24%), Leach's Storm-petrel (19%), Common Murre (31%), Cassin's Auklet (10%), Rhinoceros Auklet (58%) and Tufted Puffin (30%). The relative importance of this colony has increased due to lower numbers at the Farallon Islands, despite lower reported numbers of Common Murres (see species account). Despite a long history of visits by naturalists (summarized in Osborne 1972), this colony has not been studied extensively, except for recent surveys of Common Murres (summarized in Takekawa et al. 1990). Nesting habitats (vegetation and soil) have changed dramatically on this colony since the 1930's but this change has been poorly documented (see Osborne 1972). More effort and better techniques for monitoring vegetation, soil and burrow/crevice nesting species are required although access to this large rock has been difficult due to potential disturbance to nesting Brandt's Cormorants and Common Murres plus marine mammals.

San Miguel Island Area (U. S. Navy and Channel Islands National Park) - In 1991, this collection of 12 colonies contained 33,250 breeding birds of 12 species (plus 1 possible and 2 historical species). Most birds and species nested at Prince Island and Castle Rock (15,812 and 7,622 breeding birds, respectively). This total corresponded to 5% of the state total but 40% of the total for the Channel Islands National Park area (CINP). Substantial relative numbers of 3 species were found, including: Ashy Storm-petrels (19% state; 43% CINP), Brandt's Cormorants (19% state; 65% CINP) and Cassin's Auklets (22% state; 92% CINP). In addition, Rhinoceros Auklets, Tufted Puffins and historically Common Murres reached the southern end of their range on the west coast of North America here. Similarly, Xantus' Murrelets and possibly Black Storm-petrels reached the northern end of their range in this area.

The relative importance of this area on the state level has increased due to increases in the numbers of Brandt's Cormorants (especially large new colonies at Point Bennett and Bay Point) and lower numbers at the Farallon Islands. Lower numbers of Cassin's Auklets mirrored lower numbers at the Farallon Islands (see species account). Studies at Prince Island have helped our understanding of how seabirds have responded to the complex and productive marine environment in the vicinity of Point Conception (Hunt et al. 1979, Briggs et al. 1987). At present, we could not assess whether nesting habitats have changed significantly at Castle Rock and Prince islands (although see Hunt et al. 1979). To our knowledge, these habitats have never been adequately described and have not been monitored. This difficult and time-consuming task should be conducted by Channel Islands National Park. The size of seabird populations in the San Miguel Island area should be monitored much more extensively by Channel Islands National Park, especially Ashy Storm-petrels, Brandt's Cormorants and Cassin's Auklets. Currently, only the population size of Double-crested Cormorants and breeding success of Cassin's Auklets at Prince Island has been included in this monitoring program (Lewis et al. 1988, Ingram 1992).

Santa Barbara Island Area (Channel Islands National Park) - In 1991, this collection of 3 colonies contained 14,864 breeding birds of 12 species (plus 1 definite and 2 possible historical species). Most birds nested on Santa Barbara Island proper (13,174 breeding birds). Over time, this nesting area has had the most diverse assemblage of breeding species anywhere in California. This total corresponded to 2% of the state total and 18% of the CINP area. Substantial relative numbers of 5 species were found, including: Ashy Storm-petrels (20% state; 47% CINP), Black Storm-petrel (100% state/CINP), Brown Pelican (10% state/CINP), Western Gull (12% state; 36% CINP) and Xantus' Murrelet (88% state/CINP).

The relative importance of these colonies has increased due to higher numbers of storm-petrels, Brown Pelicans and Western Gulls, despite lower numbers of Xantus' Murrelets (see species account). Studies at this colony have helped our understanding seabird biology (especially Brown Pelicans, Western Gulls and Xantus' Murrelets) in southern California and how seabird populations have responded in non-upwelling based prey resources (summarized in Hunt et al. 1979, Lewis et al. 1988, Ingram 1992). Periodic monitoring of the population size of storm-petrels and Xantus' Murrelets should be conducted by Channel Islands National Park. The low size of the Xantus' Murrelet population at this colony (the most important well-documented colony known on the west coast of North America, including Baja California) nessecitates intensive studies of the status of this rare species in the future.

Other important nesting areas - The following 14 nesting areas contained large numbers of breeding birds, had high species diversity or were otherwise unique, given their geographic location in the state:

1) False Klamath Rock, Del Norte County;
2) Trinidad Area (Green, Puffin, Flatiron, Blank, Pilot, Trinidad Bay and Little River rocks), Humboldt County;
3) Cape Mendocino Area (False Cape Rocks, Sugarloaf Island and Steamboat Rock), Humboldt County;
4) Cape Vizcaino and Rockport Rocks, Mendocino County;
5) Point Reyes National Seashore (Point Reyes, Bird Rock, Point Resistance, Miller's Point Rocks and Double Point Rocks), Marin County;
6) San Francisco Bay Area (including the San Francisco Bay National Wildlife Refuge);
7) Carmel Bay Area (Bird Rock and Bird Island), Monterey County;
8) Anacapa Islands (West, Middle and East), Ventura County;

9) San Nicolas Island, Ventura County;
10) Bolsa Chica Ecological Reserve, Orange County;
11) South San Diego Bay, San Diego County;
12) Old-growth forests in Del Norte, Humboldt, San Mateo and Santa Cruz counties;
13) Klamath Basin Area (Lower Klamath, Clear Lake and Tule Lake National Wildlife Refuges), Siskiyou and Modoc counties; and
14) Mono Lake, Mono County.

This list did not include all important nesting areas in the state. Long sections of coast in Mendocino, Sonoma, San Mateo, Santa Cruz, San Luis Obispo and Santa Barbara counties contained significant numbers of breeding birds dispersed at several small and medium-sized colonies.

<u>Distribution patterns of 4 dominant species</u> - In 1989-1991, 4 species (Brandt's Cormorant, Western Gull, Common Murre and Cassin's Auklet) accounted for 86% of the breeding seabirds on the California coast. In northern, central and southern California, they accounted for 91%, 86% and 73%, respectively. Common Murres bred in the largest numbers, constituting 83% and 40% of the breeding seabirds of northern and central California, respectively, and 55% of the state total. Very small numbers of Common Murres bred historically in southern California at Prince Island, just south of Point Conception. Lower overall numbers of seabirds in southern California (compared to farther north) resulted from the lack of Common Murres breeding there. Brandt's Cormorants were the second most abundant nesting species, comprising 13% of the state total. Highest numbers were found in central California (38,529 breeding birds or 17% of breeding seabirds there) but this species became the dominant species in southern California (29,365 breeding birds or 31% of breeding seabirds there). Western Gulls and Cassin's Auklets were the third and fourth most abundant (10% and 9% of the state total, respectively). As for Brandt's Cormorants, they bred in highest numbers in central California (28,837 [12%] and 38,274 [16%], respectively) but were more dominant in southern California (29% and 13%, respectively). All 3 of the latter species bred in lower numbers in northern California.

Lower numbers of 3 species and high numbers of Common Murres in northern California reflected the limited availability of suitable nesting habitats in most areas. Almost all offshore rocks were small and close to shore in this area. Common Murres have well utilised these limited nesting habitats by crowding onto most of the available larger rocks from Cape Vizcaino north where they foraged over broad portions of the continental shelf usually within 40 km of colonies (Briggs et al. 1987). Suitable burrowing habitat for large numbers of nesting Cassin's Auklets (and many other burrowing species) was found only at Castle Rock. Small and medium-sized colonies of Brandt's Cormorants and

Western Gulls were spread more evenly on small rocks all along the coasts of northern California.

Larger numbers of Brandt's Cormorants, Western Gulls and especially Cassin's Auklets in central California reflected the existence of the South Farallon Islands which provided a large amount of nesting space, excellent breeding habitats for all 3 species (plus Common Murres) and better access to foraging areas on the continental shelf as well as coastal waters. However, seabird populations there have been disrupted by human activities for over a century (see summaries in Ainley and Lewis 1974, Ainley and Boekelheide 1990). Western Gull populations at the Farallon Islands and at other colonies in this area since the 1950's have been higher than they had been since the mid 1800's when they underwent a decline due to persecution and human occupation of the islands. Also, these islands were located near supplementary human food sources in the San Francisco Bay area, especially refuse dumps. Common Murres underwent a large decline due to egging at the Farallon Islands in the late 1800's and remained at low levels (apparently due to mortality from oil pollution) until the 1960's. Murres increased constantly until 1982 when they underwent another decline due mainly to gillnetting and oil spill mortality (Takekawa et al. 1990). Thus, murres were less represented in central California in 1989 than a decade ago but were more represented than most of this century. Egging also affected Brandt's Cormorants which were not a target species but nested in the same habitats as Common Murres. Recovery of the Brandt's Cormorant nesting population at the South Farallon Islands was not reported until the 1950's. Numbers of Cassin's Auklets increased in the late 1800's (possibly due to natural changes in the marine environment) and have been high since then. The Farallon Islands provided the only suitable nesting habitat for large numbers of nesting Cassin's Auklets in central California.

Elsewhere on the outer coast of central California, there was limited availability of nesting islands as in northern California. Common Murres were found nesting on small rocks and mainland cliffs only between Point Reyes and Point Sur where they foraged over the broad shelf in this area (Briggs et al. 1987, Ainley and Boekelheide 1990). Brandt's Cormorants nested in large numbers on small islands located close to shore in the Carmel Bay area (Bird Island and Bird Rock) and in moderate numbers elsewhere. Western Gulls nested in large numbers on Ano Nuevo Island and small to moderate numbers elsewhere.

In southern California, substantial numbers of each of 3 species (minus Common Murres) have bred in the Channel Islands (especially the northern islands) which provided much suitable nesting habitat and access to offshore, shelf and coastal foraging habitats (Hunt et al. 1979, Briggs et al. 1987). However, seabird populations were lower than they could be based on available nesting habitat. The Chumash, Shoshonean and Nicoleno indians had lived on the Channel Islands for about 30,000 years before the few survivors of disease were evacuated between 1787-1816 (Dowty 1984). Their diet included many species of seabirds (Bleitz 1990). In addition, these indians brought the Island Fox (Urocyon littoralis), a predator of seabird eggs, to San Nicolas, San Clemente and Santa Catalina islands whereas fox occurred naturally on San Miguel, Santa Rosa and Santa Cruz islands. It was unclear to what extent indians and fox have limited nesting seabirds. However, as found at the Farallon Islands, seabird populations have been disrupted by human activities at least since the early 1800's (see summary in Hunt et al. 1979). Brandt's Cormorants have been most affected in the southern Channel Islands where small colonies have been eliminated from Santa Catalina, San Clemente and San Nicolas islands, probably due to human disturbance. These islands and their seabirds have suffered from continual disturbance from the establishment of U. S. Navy bases on San Clemente and San Nicolas islands and the intensive development and tourism at Santa Catalina Island. Cassin's Auklets underwent large documented declines at Prince Island in the 1910's, East Anacapa Island (after 1910) and Santa Barbara Island (between 1890-1908). Auklets appeared to recover at Prince Island but the degree of past decline was also less clear there. They were exterminated from East Anacapa Island, perhaps by cats or rats. Cassin's Auklets bred in very large numbers at Santa Barbara Island in the late 1800's. Cats were blamed for essentially exterminating auklets there (Willett 1912, Sumner 1939), although small numbers still breed in inaccessible cliffs and caves on the main island and on nearby Sutil Island. Western Gulls appeared to have been less affected by human activities or they have recovered dramatically from any declines. Current numbers have probably been increased by use of human refuse at some colonies.

Along the southern California mainland coast, there was a complete lack of nesting islands and few suitable cliff nesting areas. Brandt's Cormorants have nested on cliffs at La Jolla and Western Gulls have used cliffs in the same area plus artifical habitats in San Diego Bay.

Global significance of California populations - Using 1989-1991 estimates, California populations of Brandt's Cormorants and Western Gulls accounted for 78% and 66% of the world population of these species, respectively (see Ainley and Boekelheide 1990). On the other hand, Common Murres and Cassin's Auklets occurred in much greater numbers in Alaska and British Columbia. However, the "significance" of populations can be measured in many ways besides raw numbers of breeding birds. Although only 7,209 Ashy Storm-petrels nested in California, this total accounted for essentially 100% of the world population because only 1 very small colony was known in Baja California, Mexico. California also hosted important populations of the endangered

Brown Pelican, Least Tern and Marbled Murrelet. Elegant Terns are known to recently nest at only 3 colonies in the world (2 colonies in California and 1 colony in the Gulf of California, Mexico). Much of the world population of Xantus' Murrelet, particularly the subspecies S. h. scrippsi, bred in the Channel Islands. Separate from population sizes was the great diversity of the 31 species of 8 different families that have nested in California. Certainly, California serves as a junction between northern communities, southern communities and the community of breeding seabirds adapted specifically to conditions along the California coast.

Summary - The distribution of the bulk of the nesting seabird population (especially the 4 dominant species) of California has been determined largely by the availability of suitable nesting habitat on offshore islands, human activities at nesting islands, and the availability of prey resources. Briggs et al. (1987) have examined the preferred marine habitats used for foraging by seabirds in California although they did not adequately assess the affect of availability of nesting habitat and size of breeding populations on observed patterns. Ainley and Boekelheide (1990) pointed out that breeding populations of seabirds at the Farallon Islands were limited by nest-site availability and winter food supply as affected by periodic ENSO events. However, the effects of ENSO events probably were greater at offshore colonies where the prey base can be expected to be upwelling-based. For instance, rockfish (Sebastes sp.) predominated in seabird diets at the Farallon Islands, San Miguel Island and San Nicolas Island (see summaries in Hunt et al. 1979, Ainley and Boekelheide 1990). On the other hand, colonies in the inner Channel Islands appeared to have different prey bases (e.g. Northern Anchovy Engraulis mordax) and other inshore colonies also probably had different prey bases. Thus, these colonies probably were less affected by ENSO events (e.g. Hunt et al. 1979, Anderson and Gress 1983, Ingram 1992; and see species accounts for Brown Pelicans, Brandt's and Pelagic Cormorants and Pigeon Guillemots).

Limited nesting habitats on the California coast have required seabirds to nest at many small and medium-sized colonies as well as a few large colonies. These colonies were distributed all along the coast where seabirds utilized small nearshore rocks, mainland cliffs and artifical habitats to an extent unparalleled elsewhere on the west coast of North America. This nesting distribution has indicated that adequate prey resources have existed all along the coast, especially in northern and central California and in the vicinity of the Channel Islands. The continuous nature of seabird colonies and their close proximity to heavily-populated shores in California also has increased human interactions with seabirds. These interactions have produced only positive impacts for human populations through increased opportunities: 1) to study their incredible adaptations for survival and reproduction in the harsh marine environment; 2) to use this knowledge to further understand the structure and function of the marine environment; 3) to use seabirds as indicators of the health of the marine environment; and 4) to appreciate their vast aesthetic value as a marine wonder in a non-consumptive fashion. In contrast, human interactions have had mostly negative impacts for most seabird species. Some examples of these negative impacts were: 1) loss of nesting habitats due to human occupation of nesting islands, physical development of coastal habitats, logging of old-growth forests, agricultural and water developments and human disturbance related to commercial and recreational activities; 2) introduction of predators to nesting islands; 3) at-sea mortality due to oil pollution and gillnetting; and 4) reduced breeding success due to chemical pollution, changes in prey resources (related to fisheries and other human activities) and human disturbance (related to commercial and recreational activities). The use of artifical nesting habitats has reduced the effects of other negative impacts for some species. The protection of nesting and foraging habitats in the recent past have slowed the rate of change due to negative impacts of human interactions on seabirds in California. However, much more work will be required to prevent certain species with small or highly-restricted populations and threatened by human interactions from declining to extinction in the state in the future (e.g. Ashy and Black storm-petrels, White Pelican, Brown Pelican, Ring-billed Gull, California Gull, Black Tern, Gull-billed Tern, Elegant Tern, Least Tern, Black Skimmer, Marbled Murrelet, Xantus' Murrelet and Tufted Puffin).

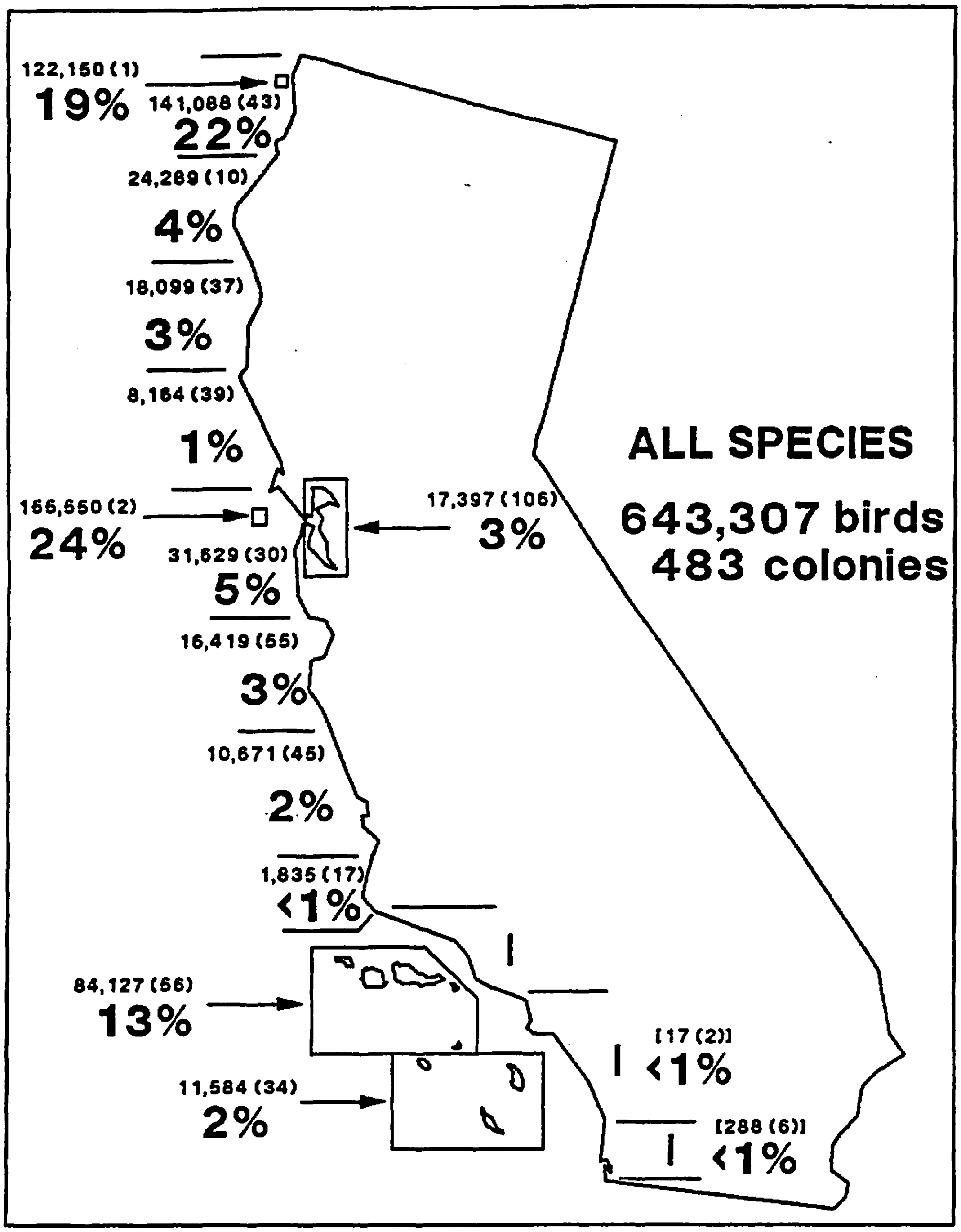


Figure 19. Percentage of total seabird breeding population for all seabird species combined in coastal regions of California, 1989-1991. Regions were defined as one degree of latitude (after Sowls et al. [1980]), except for Castle Rock NWR, Farallon Islands NWR, San Francisco Bay, Channel Islands National Park, and Southern Channel Islands which are indicated separately with arrows. The total number of breeding birds is indicated in smaller text (total number of nesting areas in parentheses) above the percent presented for each region.

Table 5. Comparison of the number of seabird nesting areas found in northern (NCA), central (CCA), and southern (SCA) California in 1975-1980 (Hunt et al. 1979, Sowls et al. 1980) and in 1989-1991 (This study).[1]

	1975-1980 No. of nesting areas				1989-1991 No. of nesting areas			
Species	NCA	CCA	SCA	Total	NCC	CCA	SCA	Total
FTSP	6	0	0	6	5	1	0	6
LHSP	8	1	2	10	9	1	4	14
ASSP	1	1	9	11	2	1	11	14
BLSP	0	0	2	2	0	0	4	4
WHPE	-	-	-	-	-	-	-	-
BRPE	0	0	2	2	0	0	2	2
DCCO	11	2	4	17	16	16	5	37
BRCO	33	31	17	81	32	39	31	102
PECO	99	68	11	178	102	67	46	215
UNCO	1	3	0	4	0	0	1	1
BLOY	61	56	17	134	94	60	58	212
AMOY	0	0	2	2	0	0	0	0
BAOY	0	0	1	1	0	0	3	3
HEEG	0	2	0	2	0	0	0	0
RBGU	-	-	-	-	-	-	-	-
CAGU	0	0	0	0	0	3	0	3
WEGU	86	69	22	177	107	156	87	350
GWGU	0	0	0	0	-	-	0	-
BLTE	-	-	-	-	-	-	-	
GBTE	0	0	-	0	0	0	-	0
CATE	0	2	-	2	0	6	-	6
FOTE	0	5	-	5	0	21	-	21
LETE	0	6	-	6	0	10	-	10
ROTE	0	0	-	0	0	0	-	0
ELTE	0	0	-	0	0	0	-	0
BLSK	0	0	-	0	0	0	-	0
COMU	12	7	0	19	15	8	0	23
PIGU	92	69	12	173	107	94	34	235
MAMU	-	-	-	-	-	-	-	-
XAMU	0	0	11	11	0	0	14	14
CAAU	2	1	9	12	3	1	12	16
RHAU	5	3	0	8	19	10	3	32
TUPU	10	3	0	13	10	2	1	13
ZERO	0	2	1	3				33
TOTAL	113	112	44	269[2]	130	255	98[2]	483[2]

[1] A dash (-) indicates data are not available. Information on terns and skimmers in southern California will be included in the final draft of this report.

[2] Counts are incomplete. Complete counts (i.e. with southern California tern and skimmer data) will be available in the final draft of this report.

Table 6. Summary of breeding populations of seabird species in coastal California in 1989-1991.

Species Name	Species Code	Number of Nesting Areas[1]	Number of Breeding Birds	Percentage of Total Breeding Birds	State Population Trend
Fork-tailed Storm-petrel	FTSP	6	410	0.06	Unknown
Leach's Storm-petrel	LHSP	14	12,551	1.95	Declining
Ashy Storm-petrel	ASSP	14	7,209	1.12	Unknown
Black Storm-petrel	BLSP	4	274	0.04	Unknown
American White Pelican	WHPE	-	-	-	Interior
Brown Pelican	BRPE	2	11,916	1.85	Stable
Double-crested Cormorant	DCCO	37	10,037	1.56	Increasing
Brandt's Cormorant	BRCO	102	83,394	12.96	Stable
Pelagic Cormorant	PECO	215	14,345	2.23	Stable
Unidentified Cormorant	UNCO	1	2	<0.01	-
Black Oystercatcher	BLOY	212	888	0.14	Stable
Black x American Oystercatcher	BAOY	3	3	<0.01	Unknown
Heermann's Gull	HEEG	0	0	0.0	Irregular
Ring-billed Gull	RBGU	-	-	-	Interior
California Gull	CAGU	3	4,764	0.74	Increasing
Western Gull	WEGU	350	61,760	9.60	Increasing
Glaucous-winged Gull	GWGU	-	-	-	Hybrid
Black Tern	BLTE	-	-	-	Interior
Gull-billed Tern [incomplete]	GBTE	-	-	-	-
Caspian Tern [incomplete]	CATE	6	2,838	0.44	Declining
Forster's Tern [incomplete]	FOTE	21	3,550	0.55	Increasing
Least Tern [incomplete]	LETE	10	272	0.04	Declining
Royal Tern [incomplete]	ROTE	-	-	-	-
Elegant Tern [incomplete]	ELTE	-	-	-	-
Black Skimmer [incomplete]	BLSK	-	-	-	-
Common Murre	COMU	23	351,336	54.61	Declining
Pigeon Guillemot	PIGU	235	15,470	2.40	Stable
Xantus' Murrelet	XAMU	14	1,760	0.27	Unknown
Marbled Murrelet	MAMU	-	1,821	0.28	Unknown
Cassin's Auklet	CAAU	16	56,562	8.79	Unknown
Rhinoceros Auklet	RHAU	32	1,769	0.27	Increasing
Tufted Puffin	TUPU	13	276	0.04	Stable
Unidentified alcid	UNAL	9	104	0.02	-
<u>Total</u>		483[2]	643,307[2]		

1 Includes nesting areas active in 1989-1991 only. Incomplete count. Awaiting southern California tern and skimmer data.

2 Includes 33 inactive nesting areas.