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THE OCCURRENCE OF SEABIRDS IN THE COASTAL REGION OF CALIFORNIA

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Abundance and species composition of marine birds are specific to different oceanographic regions; these in turn are defined by characteristic physical and biological conditions. This has been discussed most graphically by Murphy (1936, 1967), Kuroda (1955), Sanger (1970, 1972), and Shuntov (1972). Ideally, biologists should be familiar with the physical and biological environmental factors affecting the occurrence of marine birds, since the diversity of environmental conditions that often occur over equal areas on land is not present. Yet our understanding of how ocean factors affect seabird abundance and distribution is incomplete because of the relative inconvenience and expense of studying pelagic life, and the fact that marine biologists as a general rule ignore birds (Ashmole 1971, Sanger 1972). The distribution of marine birds in the North Atlantic (see Wynne-Edwards 1951, Murphy 1967) and Central Pacific oceans (see King 1970, 1974) is relatively well known, but little work has been done elsewhere except in restricted areas (e.g. Sanger 1970).

One of the oceanographically best known areas in the world is the California Current region off California and Baja California. Information has been amassed through efforts of component agencies in the California Cooperative Oceanic Fisheries Investigations (see Cal-COFI Reports and Atlases). However, knowledge of birds in this area has never been intensively analyzed except locally, e.g. Monterey Bay (Loomis 1895-96, Beck 1910, Baldridge unpubl.), or for a few selected species, e.g. Black-footed Albatross (Miller 1940, McHugh 1950, Thompson 1951, Sanger 1974a).

In California, boats have frequently been chartered to observe marine birds in the nearshore region of the California Current 15 to 80 km offshore. This paper discusses seabird abundance and distribution in this coastal area based on analysis of observations published from 1955 to 1973 in *American Birds* (formerly *Audubon Field Notes).* Where possible, an attempt is made to correlate seabird occurrence to oceanographic conditions. Bird observations were less frequent prior to 1960 than subsequently, but extremely interesting oceanographic conditions occurred from 1955 to 1960. I therefore included that early period in the analysis.

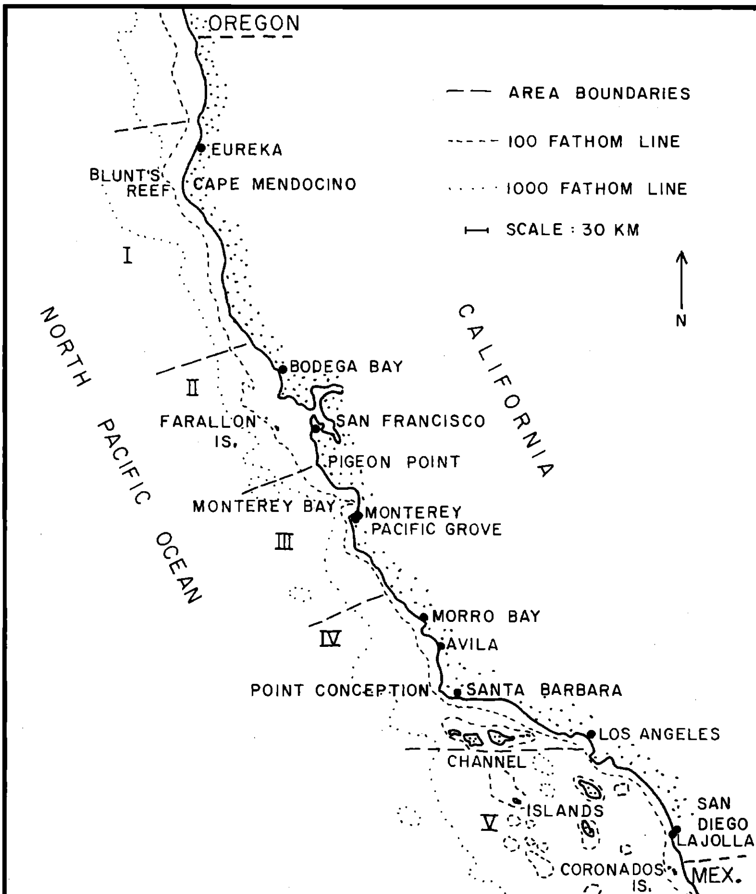


Figure 1. California coastal geographic areas and places mentioned in the text.

Table 1. A summary of oceanographic and cruise characteristics for each of the study areas.

AREA	REGION COVERED	OCEAN AREA	DISTANCE TO SHORE	WATER TEMP. °C MEAN (X) RANGE	MEAN SALINITY RANGE ‰
1	Cape Mendocino	West of Cape	30-60 km	X=10.7 8.3-14.9	30.7-34.5
2	Bodega to Pigeon Pt.	Farallon Is. and shoals	30-40 km	X=12.1 9.2-16.1	28.9-34.5
3	Monterey Bay	Monterey Canyon and Pt. Pinos	15-25 km	X=13.1 10.4-16.4	31.6-34.5
4	Morro Bay to Los Angeles	N. Channel Islands	30-60 km	Avila* 10.5-18.0 S. Barbara* 12.0-20.1	30.5-34.5
5	Los Angeles to San Diego	San Clemente Is., Los Coronados Is.	15-80 km	X=16.7 12.2-22.1	33.0-34.0

*Mean temperatures not available; observations too infrequent.

METHODS AND STUDY AREA

Census areas. The coast was divided into five census areas according to the distribution of ports from which boat trips departed and the ocean areas covered (Figure 1). These areas, with general ocean conditions, are reviewed in Table 1. Trip coverage of the five areas during the 19-year study period is summarized in Table 2.

Analysis of bird data. Bird records were taken from the regional reports published four times each year from 1955 to 1973 in *American Birds* and its predecessor *Audubon Field Notes.* A regional editor summarizes sightings for the season from information on numbers, species, date and route, sent in by bird observers. Almost all boat trips are "led" by at least one observer having extensive knowledge and experience in the identification of pelagic species. The two *American Birds* regions covered here are the Southern Pacific Coast Region (San Diego north to Point Conception) and the Middle Pacific Coast Region (Point Conception to the Oregon-California line).

Certain characteristics of the data have affected the analysis. First, species that breed in California and are commonly seen were rarely included in the reports so that, with a few exceptions (e.g., the storm-petrels and Xantus' Murrelets), sufficient data for analysis were available only for species breeding outside California. Also, most species of *Larus* gulls were excluded from reports. I did not analyze reports of jaegers or phalaropes because of the preponderance of observations

Table 2. A summary of coverage for each year and for areas north (N) and south (S) of Point Conception. The number of trips (dates) in each of the regions is shown. Shore observations were included if gathered as in a "sea watch" but miscellaneous reports, e.g., "two Marbled Murrelets were seen from shore at Pigeon Point" were not included.

YEAR	AREA	MONTH												
		J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
1955	N	2	2	1		1				4	3	2	2	17
	S	1	2							2		1	1	7
1956	N		1		2	1	2	3	4	4	3	4		24
	S	1		1			2			3				7
1957	N	1	2		2	1		2		1	1	4	2	15
	S			1					3	2		2		8
1958	N	2	1	3					2	3	1		1	13
	S	2		1		1	1	2		4		4	2	17
1959	N	1	1	1	2	1	1		4		3	2	1	17
	S			1		2			2	1	3	1		10
1960	N				2	1			1		3	3		10
	S	1	1		1				3	3		2		11
1961	N				1								1	2
	S			1	2	2	1		2	1		1	1	11
1962	N	1		1	2	1	1			1	2			9
	S	1				1				1		1		4
1963	N			1	1	1		2		1	2	2		10
	S	1				1				1		1		4
1964	N	1		1	1	1		1	1		1	2	1	12
	S	1			1	2			1	1	1			7
1965	N	1			1				1	1	2	1	1	8
	S			1				1	1	1	1			5
1966	N	2			1	1			2	2	3	1	1	13
	S								1	1	1		1	4
1967	N				1	1	1	2	1		1	1	2	10
	S	1		1	1					1		1	1	6
1968	N	1	2		1	3	1	2	2	3	2	1	1	19
	S	1		1	2	1	1	1		1		1		9
1969	N	1	1	1	2	1	2	3	1	1	5	2	1	21
	S					1			1			1	1	4
1970	N	1	1	1	2	1	2	3	1	1	5	2	1	21
	S	1	1		1	1	1			2		1		8
1971	N	1	1	1	2	4	1	3	3	2	4	2	1	25
	S	1			1	1	1	1	1	1		1		8
1972	N			1	1	4	1	3	3	2	4	1	2	22
	S					1	2		1	1	3		1	9
1973	N				2	2	1	2	1	4	3	2	1	18
	S					2	1	2		1	1	1		8
TOTAL	N	15	12	12	26	25	13	26	27	30	48	32	19	
	S	12	4	8	9	16	10	7	16	28	10	19	8	

made from shore, and I did not analyze Brown Pelican *(Pelecanus occidentalis)* reports since analysis of their occurrence patterns are presented elsewhere (Anderson and Anderson 1976). Second, the detail of quantitative remarks in the Audubon reports usually decreased as the abundance of the species increased. For example, every Flesh-footed Shearwater was counted and reported, since usually no more

Table 3. A summary of data useful in assessing the relative abundance of species in each study area and to a lesser extent the relative abundance of one species compared to another. For each species in each study area are given the mean number of birds reported per year in years when reported followed by the number of years reported in parentheses; below those two numbers is the range of numbers reported all years considered. The rarest species are not included.

SPECIES	STUDY AREAS 1	2	3	4	5
Black-footed Albatross	109 (6) 2-200	13 (15) 2-100	40 (17) 1-225	8 (4) 1-20	17 (14) 1-48
Laysan Albatross	2 (1)	2 (1)	1 (3)	1 (1)	0
Northern Fulmar	46 (4) 1-150	101 (9) 1-500	400 (15) 1-2000	89 (7) 1-200	70 (9) 1-200
Flesh-footed Shearwater	2 (3) 1-3	2 (4) 1-3	2 (8) 1-4	1 (1) –	2 (7) 1-9
Pink-footed Shearwater	72 (3) 1-200	28 (14) 1-102	550 (10) 19-2000	155 (4) 1-950	448 (13) 2-2200
Sooty Shearwater	–	$3x10^5$(12) 150-10^6	$3x10^5$(11) 4000-10^6	$2x10^5$(8) 4000-10^5	$9x10^4$(11) 11-10^5
Short-tailed Shearwater	–	2 (4) 1-2	2 (7) 1-8	–	3 (5) 1-4
Manx Shearwater	–	62 (5) 1-300	62 (10) 1-500	105 (8) 1-300	605 (13) 9-5000
Buller's Shearwater	105 (6) 1-400	81 (7) 5-401	77 (17) 1-500	59 (3) 1-175	4 (4) 1-9
Fork-tailed Storm-Petrel	1 (3)	2 (5) 1-6	27 (15) 1-250	10 (3) 1-27	1 (1)
Leach's Storm-Petrel	1 (1)	15 (1)	2 (8) 1-8	16 (4) 2-50	165 (11) 1-465
Ashy Storm-Petrel	13 (3) 1-35	13 (5) 1-39	1820 (16) 1-7000	23 (4) 10-50	19 (11) 1-70
Black Storm-Petrel	1 (1)	0	375 (17) 1-5000	18 (4) 2-50	211 (14) 8-1000
Least Storm-Petrel	1 (1)	0	3 (3) 2-3	500 (1)	420 (9) 1-3600
Wilson's Storm-Petrel	0	0	1 (6) 1-2	1 (1)	1 (1)
Blue-footed Booby	0	0	4 (1)	7 (1)	4 (3) 1-11
Magnificent Frigatebird	0	1 (3)	3 (2) 1-5	3 (8) 1-14	6 (13) 1-32
Red-billed Tropicbird	0	0	1 (1)	1 (3) 1-2	4 (8) 1-12
Skua	1 (2)	2 (7) 1-8	4 (13) 1-16	2 (3) 1-2	2 (3) 1-4
Sabine's Gull	–	46 (7) 1-98	47 (8) 15-100	23 (7) 5-100	63 (13) 2-200

Table 3 (cont.)

SPECIES	STUDY AREAS 1	2	3	4	5
Black-legged Kittiwake	1 (1)	56 (6) 5-200	1311 (8) 2-5000	131 (4) 10-500	91 (9) 1-500
Horned Puffin	1 (1)	1 (3)	1 (4)	2 (2)	1 (1)
Marbled Murrelet	21 (2) 3-39	11 (5) 1-32	9 (8) 2-11	12 (4) 1-45	4 (3) 1-8
Ancient Murrelet	10 (3) 5-20	22 (8) 1-86	31 (8) 1-80	11 (7) 1-33	14 (4) 3-50
Xantus' Murrelet	1 (1)	2 (3) 1-6	7 (10) 1-19	21 (7) 7-57	53 (10) 2-354
Craveri's Murrelet	0	0	2 (2)	2 (2)	2 (5)

NOTE: The lack of information on the occurrence of a species in a region is treated in two ways. If it is likely that the species was just not reported (e.g. Sooty Shearwater in area 1) then a dash is inserted; if it is probable that the species did not occur in a region (e.g. Blue-footed Booby in area 2) then a zero is inserted.

than a few were seen each season; but Sooty Shearwaters often were reported with qualitative descriptions, such as abundant, scarce, etc., the meanings of which differ with region, observer, editor, and reader. Thus an analysis is restricted for abundant species. Third, on some trips few numbers or only common local species were seen, and thus reports were not published. Finally, bird trips in the Cape Mendocino area have been few, so analysis for this region is even more preliminary. In spite of these shortcomings, the Audubon reports constitute an important bank of information, as should become evident in the following pages.

Relative abundance of each species among the five areas is compared in Table 3. Only the most general comparisons are possible, but I thought that some sort of analysis of relative abundance should be attempted. The mean number reported in years when reported, the range in numbers for all years considered, and the number of years reported during the 19-year period are all given for each species within each study area. Absolute, precise statements on bird density cannot be made on the basis of these data, and only gross trends in relative abundance of species among census areas can be assessed; for example, fulmars are much more abundant in areas 3-5 than in 1-2, and *not* fulmars are four times more abundant in area 3 than in area 2. To compare abundance of one species relative to another, one has to be even more careful. The mean number, the range in values and the number of years in which each species was reported all have to be considered. Only where the mean numbers for one species differ by one to two or more orders of magnitude from the mean of another would I consider that one species might be more abundant; even then the difference will be tem-

Table 4. A summary of hydrographic data coverage.

AREA	LOCATION	YEARS	TEMPERA- TURE	SALIN- ITY	AGENCY
1	Blunt's Reef, Mendocino Co.	1956-1972	X	X	U.S. Coast Guard
2	Farallon Is., San Francisco Co.	1956-1971	X	X	U.S. Coast Guard
		1971-1973	X	X	Pt. Reyes Bird Obs.
3	Pacific Grove, Monterey Co.	1956-1972	X	X	Hopkins Marine Sta.
4	Avila, San Luis Obispo Co.	1956-1972	X	X	U.S. Coast & Geodetic Survey
	Santa Barbara, Santa Barbara Co.	1956-1972	X		S.B. Harbor Dept.
5	La Jolla, San Diego Co.	1956-1972	X	X	Scripps Institution of Oceanography
1-5	Cape Mendocino to La Jolla	1963-1973	X		U.S. Coast Guard Airborne Radiation Thermometer Program

pered by considering the other two types of values in the table. Take for example Manx and Buller's shearwaters in area 3. An average of 62 Manx have been reported for the 10 years when reported, and an average of 77 Buller's have been reported for the 17 years they were reported. The same range in values have been reported for both species. They thus seem to occur in about equal abundance in area 3, but the Buller's Shearwater seems to occur more often. As one moves south into areas 4 and 5, Manx Shearwaters obviously become much more abundant than Buller's and are seen much more frequently. In the case of Sooty Shearwaters, estimates for bird numbers based on qualitative descriptions were treated as follows: "millions" and "abundant"=1 million birds; "common" and "thousands"=500 thousand; "hundreds"= one to 100 thousand; "scarce"=less than one thousand. These definitions were based on comparison with my own censuses made twice per month for four years in the Farallon Island area.

Seasonal abundance was calculated in two ways; one summarizes all data from all five areas (Figure 2), and the other compares seasonal abundance between areas north and south of Pt. Conception, a natural oceanographic boundary area (Hubbs 1963; Figure 3). In the first, the number of birds reported in the 19 years was totalled by species for each month. Percentages of the totals were then figured for each month, and the results were compared to the nesting cycle of each species based on published information. In the other analysis, monthly percentages were figured for areas 1, 2 and 3 combined and were compared with combined percentages for areas 4 and 5.

Yearly abundance of each species (Figure 4) was calculated with the formula: (X x Y)/Z, where X is the total number of birds per species reported that year, Y is the number of areas reporting that species, and Z is the number of dates (trips) on which the species was reported. The results were then graphed for each species. The year having highest "abundance" was given a score of 10 with values for other years being scored proportional to that one. Thus scores are comparable only within species, although one can compare species to see whether year-to-year trends are similar or different.

Analysis of oceanographic data. Data Reports of the Scripps Institution of Oceanography, published annually for the years 1956 through

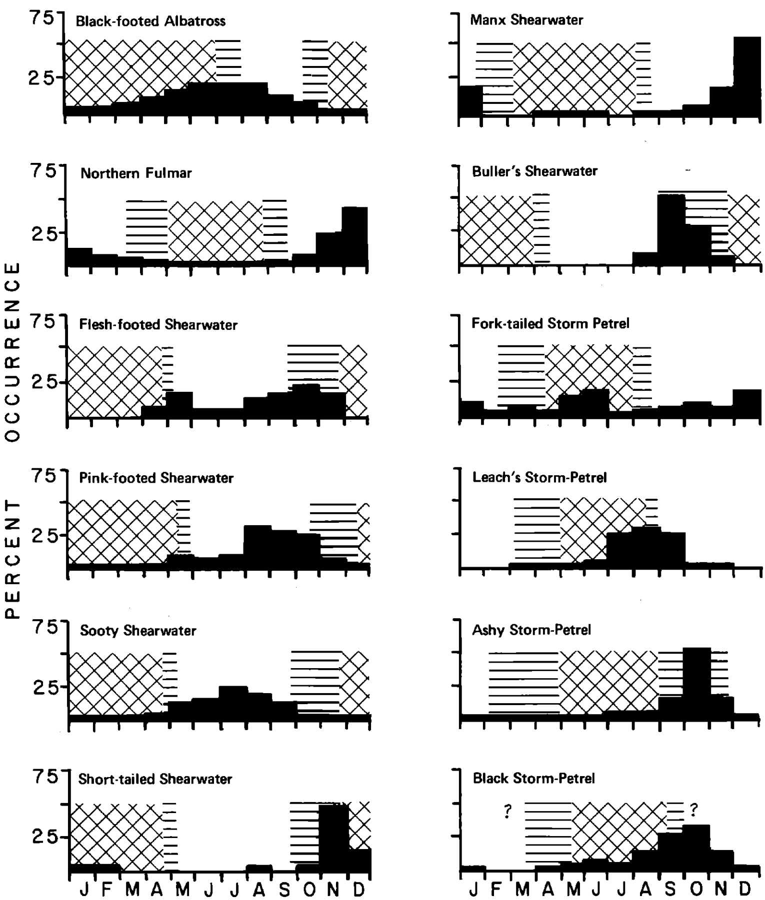
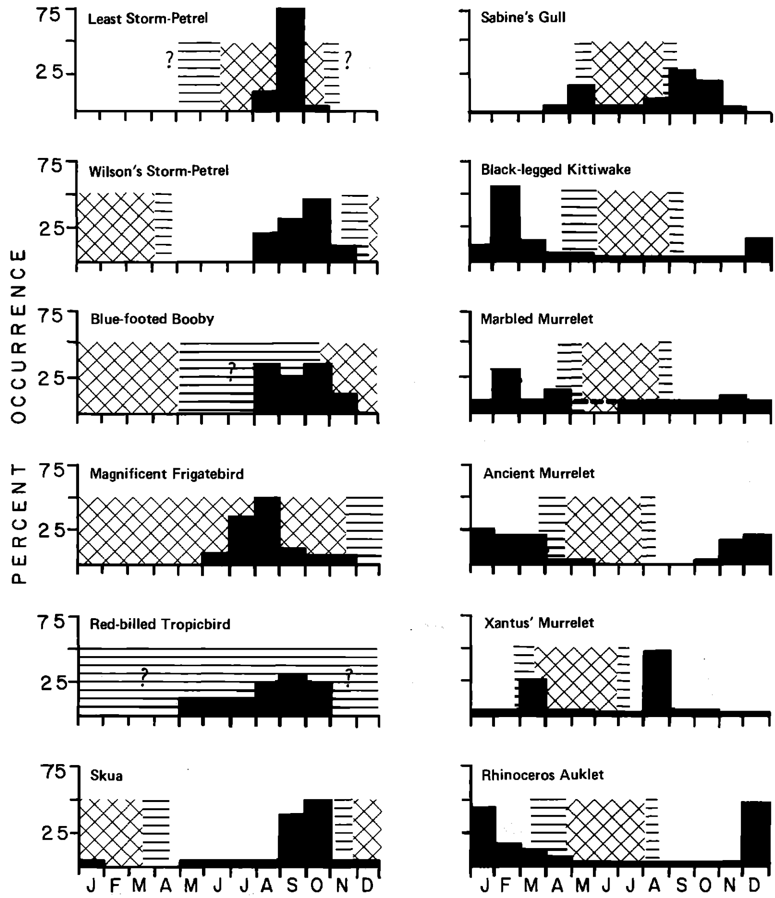


Figure 2. The occurrence of pelagic species off California each month compared to their nesting cycles at respective breeding sites. The latter information is taken

1972, report surface water temperatures taken daily at shore stations from Puget Sound to La Jolla. Some stations also collected daily salinity samples, as reviewed in Table 4. *Data Reports,* for temperature and salinity, give the mean and its standard deviation, the range, and the sample size for each month, and also the mean and the maximum and minimum for the year. In some years for some stations an insufficient number of observations were made for derivation of a valid mean, but maxima and minima were often reported.

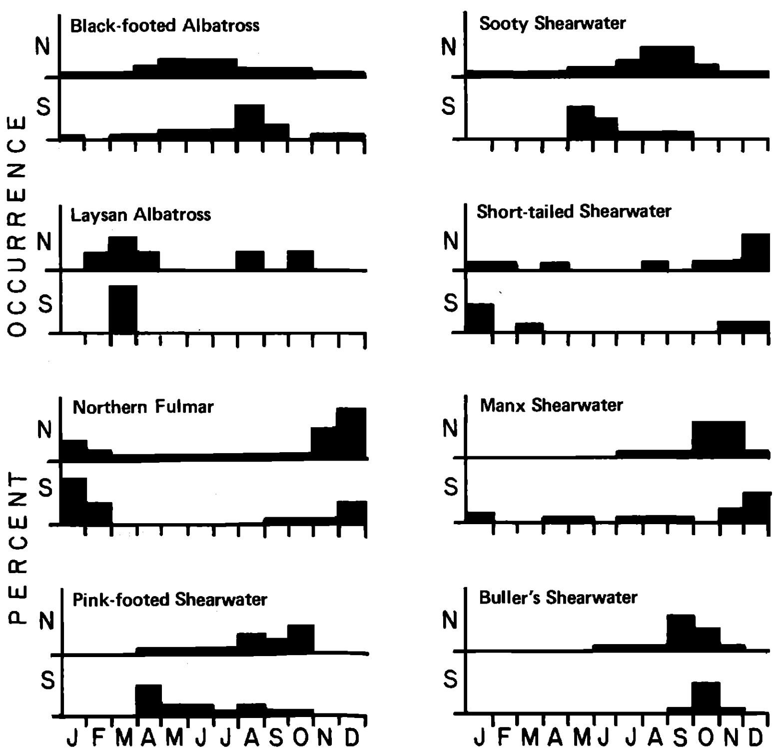
These data were analyzed in two ways. First, the annual temperature and salinity cycles at each station were determined by examining means



from Ainley et al. 1974; Bent 1919, 1921, 1922; DeLong MS; Drent and Guiguet 1961; Murphy 1936; Palmer 1962; Richardson 1961; Sealy 1974; and Serventy et al. 1971.

and ranges for the 17 years (Figures 5 and 6). Except for temperature records from the Farallones, data are unavailable for 1973. There were no 1955 data, but hydrographically it was similar to 1956 (Reid et al. 1958, Bolin and Abbott 1963). This analysis gives a general comparison of hydrographic conditions among areas and seasons. Second, for each of the stations, the yearly means, maxima and minima were plotted (Figure 7). Data for Avila were too incomplete to include. The degrees to which yearly means and yearly mean maxima and minima differed from the 17-year means were summarized in Figure 8. These analyses allow comparison of yearly variations in hydrographic conditions.

The relationship between the water temperatures recorded at these shore stations to those farther offshore was determined by comparison with isotherm maps prepared monthly by the U.S. Coast Guard, Radiation Thermometer Program. General comparisons of these data are presented below for each of the five census areas.



Bolin and Abbott (1963) and Abbott and Albee (1967) compare yearly differences in phytoplankton volumes for Monterey Bay, in central California. These authors felt that conditions in Monterey Bay gave an index to general conditions in coastal waters the length of California. As shown below, these data helped explain yearly differences in bird numbers. While marine birds do not feed directly on phytoplankton, the latter are at the base of the birds' food web. Higher in the web are the zooplankton and some marine birds do eat some of them. Smith (1971) mapped zooplankton volumes in the California Current off California for the years 1951 to 1966. His analysis is summarized in Figure 9. These data also help explain yearly differences in bird occurrence.

The hydrographic cycle. The seasonal changes in oceanographic conditions in coastal California presented in fine detail by Bolin and Abbott (1963) are summarized briefly here. The seasons in the area of their study, Monterey Bay, are indicative for the entire California coastal

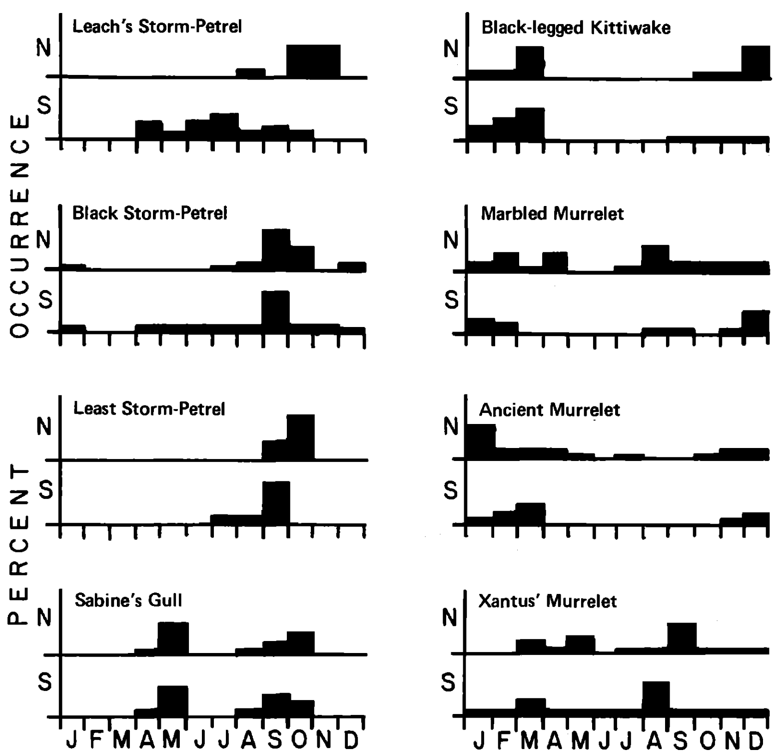
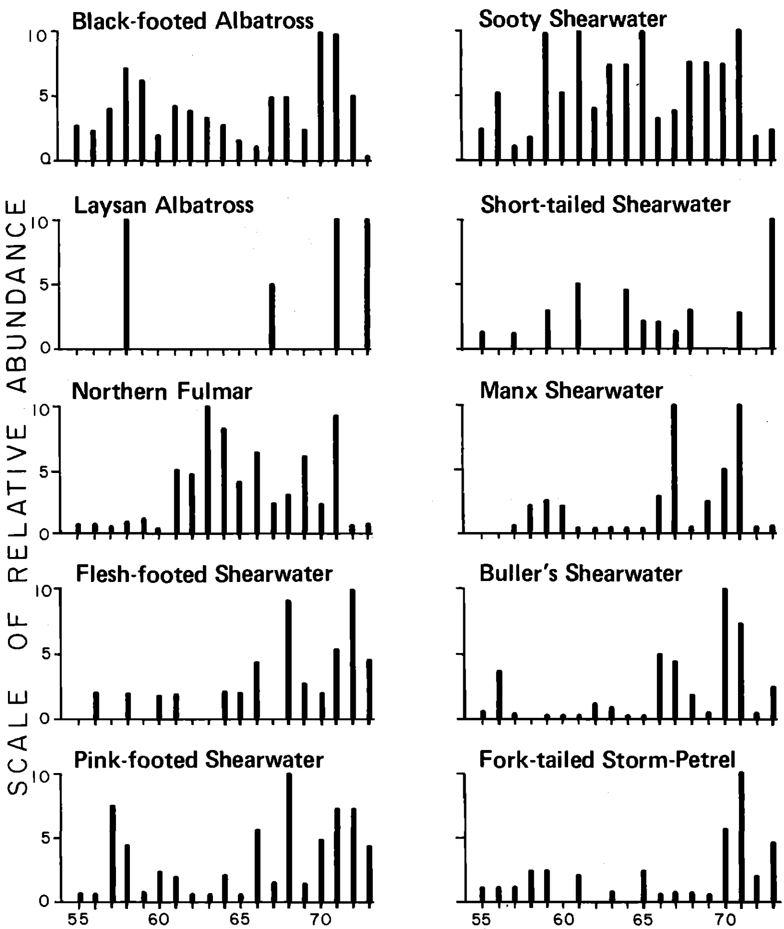


Figure 3. A comparison of species occurrence each month for areas north (N) and south (S) of Point Conception.

area, and are repeated annually, but with differences in the timing, intensity, and duration (Bakun 1973). There are also differences in degree and timing of the seasons among the census areas. These differences have important bearing on the occurrences of seabirds, as noted further in this paper.

Three distinct seasons are apparent in the annual hydrographic cycle of coastal California: the Davidson Current period, the upwelling period, and the oceanic period. These three result from the direction and strength of prevailing winds and resultant pattern of water flow. During spring and summer when northwest winds occur frequently, surface wa-



ter flows south and offshore to be replaced by nutrient-rich water from below (a process called upwelling). Temperatures reach the annual low while salinities reach the annual high and then begin to slowly decline.

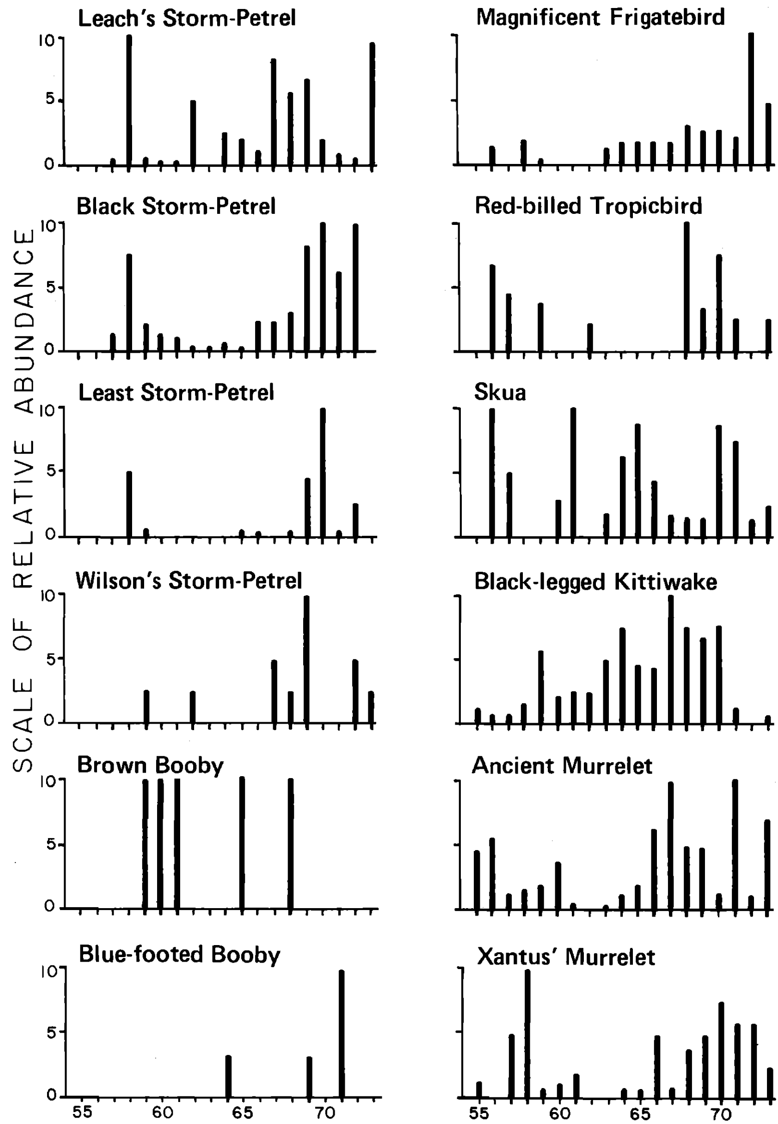


Figure 4. Annual fluctuations in the abundance of seabirds in the coastal region of California, 1955-1973.

There is much mixing of water from different depths, and plankton production is at its maximum rate. During the following oceanic period, winds cease and southward water flow slackens to allow inshore and northward flow of warm sub-tropical waters, normally displaced westward by the upwelled cold water. Temperatures are at the annual high, salinity remains high, and phytoplankton production is at the lowest level for the year. In the winter, with the strong southerly winds that accompany storms, the Davidson Countercurrent moves northward close

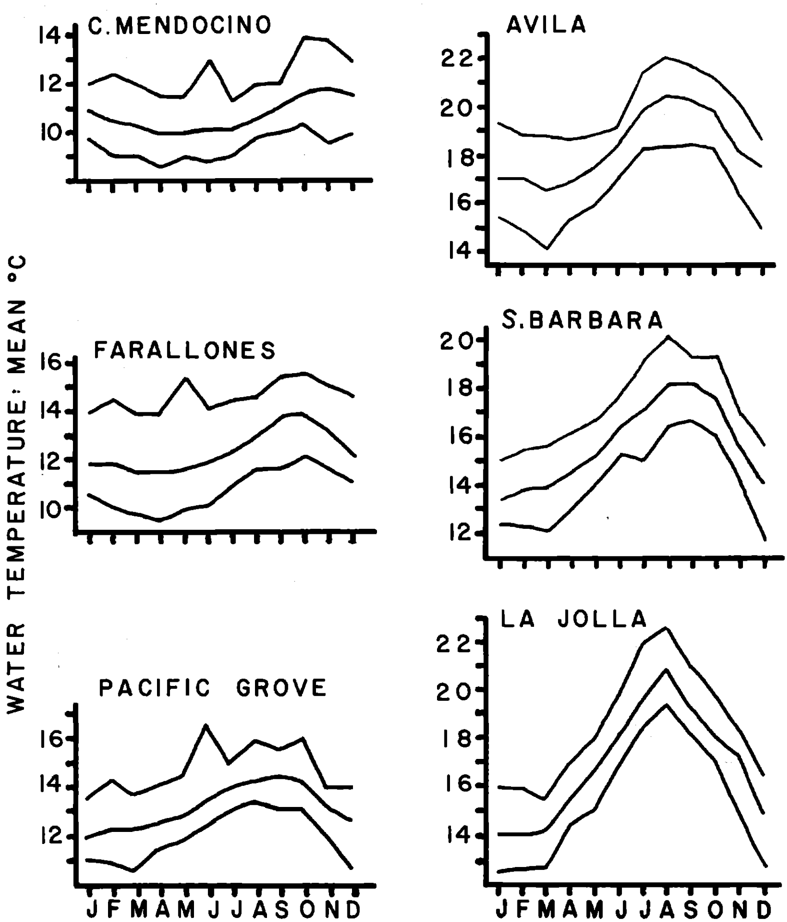


Figure 5. The seasonal pattern of change in water temperature for the different study areas. Shown for a location within each area are the monthly means, mean maxima and mean minima calculated from data collected 1956-1972 (Scripps Institution of Oceanography).

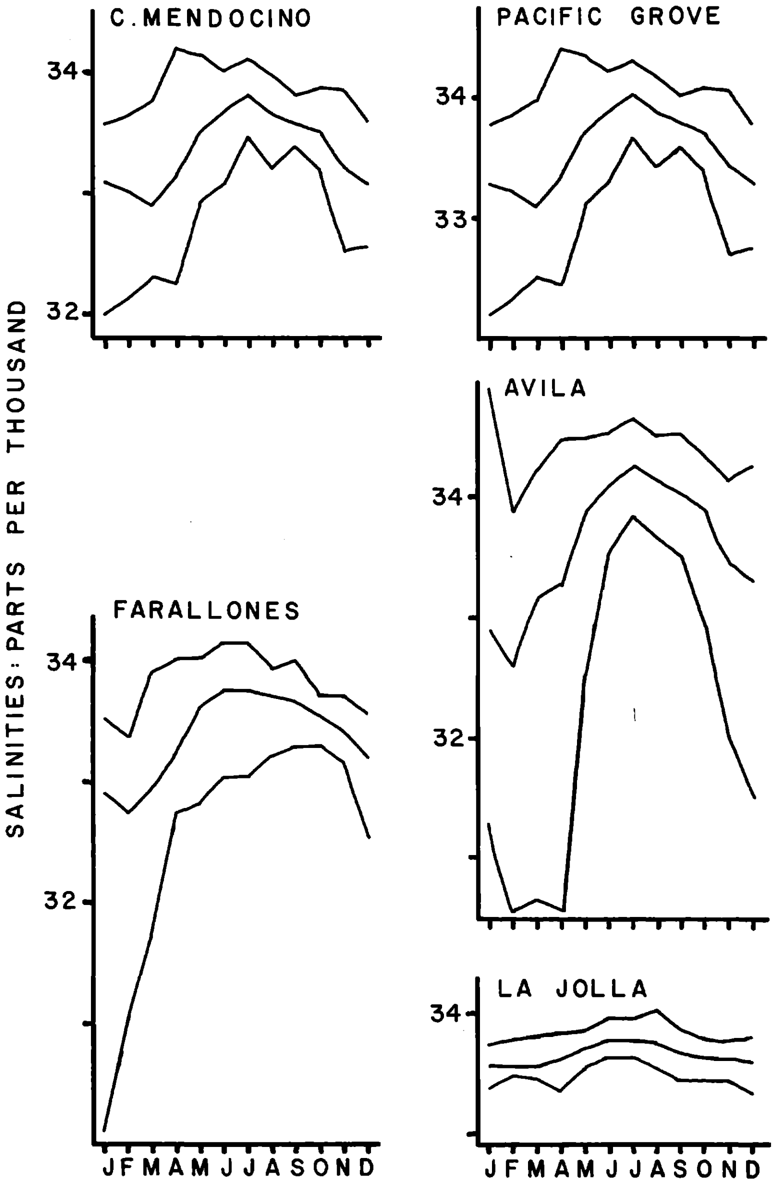


Figure 6. The seasonal pattern of change in water salinity for the different study areas. Shown for a location within each area are the monthly means, mean maxima and mean minima calculated from data collected 1956-1972 (Scripps Institution of Oceanography).

to the coast. Plankton production is low, surface salinities reach the annual low point because of runoff from winter storms, and temperatures begin to decline.

A comparison of the areas in Figure 5 (also see Bakun 1973) reveals the hydrographic cycle occurring later in the year with increasing latitude. For instance, highest temperature (oceanic period) at La Jolla on the average occurs in August, but not until September or October farther north. There is less variation in the salinity cycles latitudinally

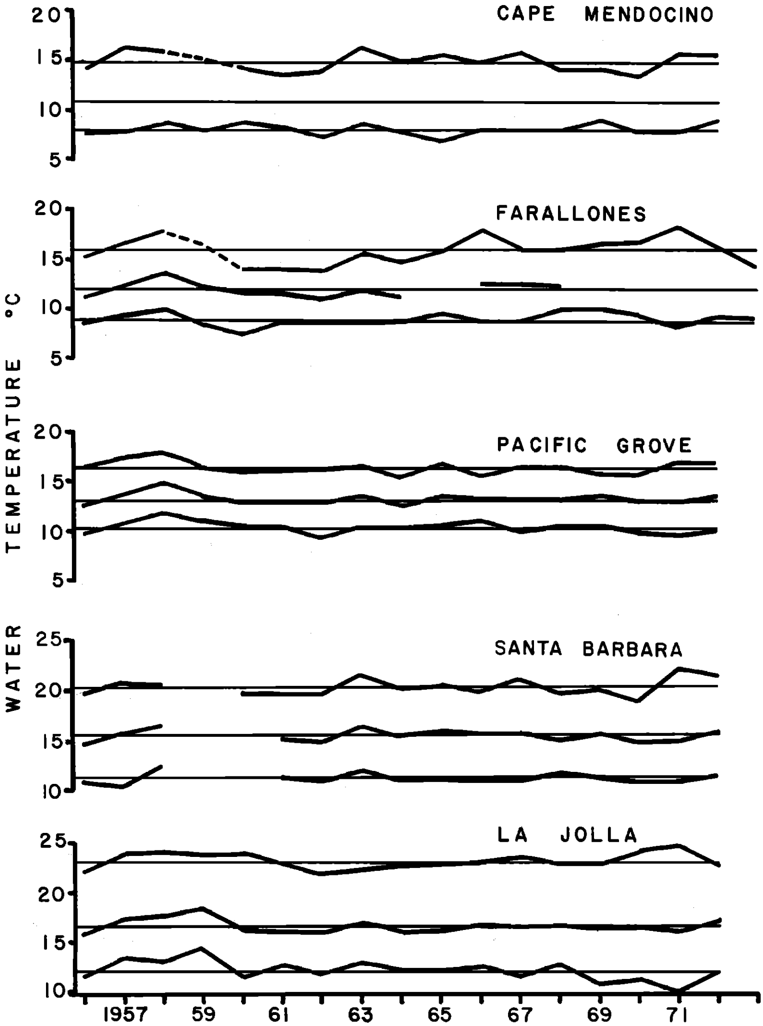


Figure 7. Yearly variations of water temperature around the mean, mean maximum and mean minimum in the study areas, 1956-1973.

(Figure 6). The lowest salinities (Davidson Current period) are reached during January in areas 1 and 2, and in February-March in areas 3-5. This latter phenomenon may be connected with the more frequent and intense winter storms and the resultant river runoff in the northern areas.

Warm ocean temperatures prevailed during 1957, 1958, 1959, 1972, and to a lesser extent in 1963 and early 1973 (Figures 7 and 8). Temperatures during these years were above the mean and the mean maxima and minima for the study period (Figure 8). Values above the mean minima are some indication for poor upwelling, which is suggested also by the low phytoplankton volumes recorded in 1958, 1959 and proposed for 1972 and 1973 (Figure 9). The warm water of 1957 was accompanied by substantial phytoplankton volumes, but the cold waters of the preceding months may have been related to this. Low zooplankton volumes (from Smith 1971) were recorded off California in 1958, 1961, and 1965 (Figure 9). The years 1956, 1961, and 1962 stand out

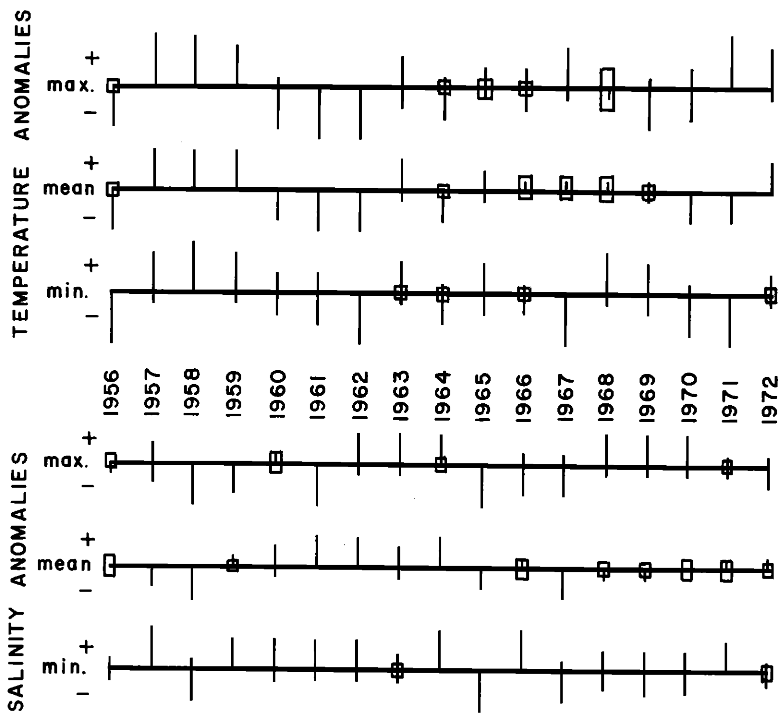


Figure 8. A summary of temperature and salinity anomalies off California, 1956-1972. Vertical lines give a relative indication of the number of study areas having conditions above or below average. Rectangles indicate that conditions are average.

as being particularly cold. The years 1963, 1967, 1970 and 1971 are interesting in that they included temperature extremes at both ends of the scale. In particular, 1971 had temperatures reaching the highest and almost the lowest extremes for the entire study period. In general, phytoplankton volumes were high during years having cold temperatures and low in years when cold temperatures were not recorded. Higher zooplankton volumes also occurred in years having cold temperatures, but the relationship between phyto- and zooplankton volumes is not always a clearly defined one.

The trends in salinity did not closely match those of temperatures (Figure 8). Anomalies in mean salinities matched those in mean minimum salinities, indicating that the amount of rainfall was probably an important factor. The years 1958, 1965, and 1967 had very low salinities. These were years of high or slightly above average temperature anomalies, too, but high salinities occurred in 1962-64 which included both cold and warm years. Salinity anomalies tended toward the high end of the scale during the middle of the study period, while prior to this, anomalies went to both sides of the scale with a high incidence of average conditions. During the period 1968-70, salinities were at the high and low extremes, interestingly, when temperatures were also changing toward extreme values. During the last two warm years, salinities were "normal". The pattern of salinity anomalies had no relationship to changes in phytoplankton volumes. Lowest zooplankton volumes occurred during 1958 and 1965, also years of lowest salinities.

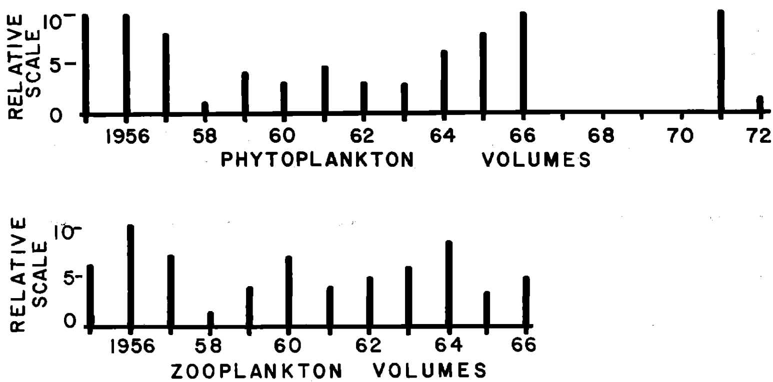


Figure 9. Relative phytoplankton (Monterey Bay only) and zooplankton (all California) volumes for the years 1955-1966. Data were summarized from Bolin and Abbott (1963), Abbott and Albee (1967) and Smith (1971). Phytoplankton volumes for 1971 and 1972 are proposed on the basis of observations made at the Farallones (florimetric analysis; PRBO unpubl.). The Monterey and Farallon data are not precisely comparable but both serve as general indices for the central coast region, and possibly for a much greater region (Bolin and Abbott 1963).

SPECIES ACCOUNTS

BLACK-FOOTED ALBATROSS *(Diomedea nigripes).* Black-footed Albatrosses were observed in all months of the year, but were most abundant June through August, the upwelling period (Figure 2). Numbers increased during late May coincident with departure of adults and fledglings from their nesting islands in the Hawaiian Chain (Rice and Kenyon 1962). Individuals recorded during the winter were presumably prebreeding juveniles (Sanger 1970). Maximum abundance occurred later in the year as latitude decreased: May-July in areas 2 and 3 *vs* August in area 5 (Figure 3). This same trend in the entire eastern Pacific was also observed by Sanger (1974a). South of central California, numbers decreased (Table 3). High counts reached 220 birds off northern areas and 48 during one day's observations off southern California. Low abundance at the Farallones (area 2) compared to areas north and south probably resulted from a rarity of observations beyond the continental shelf. For instance, in April 1972, a few days after a trip reported 3-4 Black-foots near the islands, I observed 150 five km west of there, or about 1 km beyond the edge of the shelf. The species seems to prefer deep waters, as noted also by Miller (1940).

Kuroda (1955) recorded *D. nigripes* where water temperatures ranged 8° to 16°C. This is roughly within the annual temperature range found in northern and central California waters where in the present study they were most abundant. Large numbers of albatrosses occurred during years when temperatures reached low levels earlier in the year before most albatrosses arrived (Figures 4, 7 and 8). The low temperature, as an indication of intense upwelling, suggests the likelihood for abundant food later on. Peak seasonal abundance (June-August) coincided with the non-breeding season, the time of highest plankton volumes (Figures 2 and 9), and the period of rising but not highest temperatures. Interestingly, off Washington *D. nigripes* was more abundant than off California during August when temperatures reached 16-18°C (Sanger 1970), temperatures higher than those usually recorded in northern California (Figure 5). Sanger concluded that, other factors being equal, higher temperatures were conducive to greater abundance of Black-foots. This seems true for California, too, but food abundance seems a rather important "other factor" (Thompson 1951). Excellent summaries on the distribution and occurrence of this species in the entire Pacific Ocean are given by Robbins and Rice (1974) and by Sanger (1974a).

LAYSAN ALBATROSS *(D. immutabilis).* Laysan Albatrosses were rarely seen in the study area, and were not recorded south of area 4 (Table 3). Records occurred February to April and August to October (Figure 3), the two periods described by Sanger (1970, 1974b) and Fisher and Fisher (1972) for presence of this species in the eastern North Pacific. Comparison of records during this study with the species breeding cycle in the Leeward Hawaiian Islands, where adults are tied by nesting duties from November to July, suggests that Laysans observed off California in the spring must be mostly non-breeders (see also Sanger 1970). Late summer visitors probably include some adults as well (Fisher and Fisher 1972).

Kuroda (1955) remarked that Laysans avoid water above 13°C in the western Pacific, and Sanger (1970) noted a similar tendency to avoid high temperatures. This may help explain the dearth of records for southern areas where temperatures are usually above 13°C, and the abundance of records off Washington where waters are usually colder. However, the years since 1955 during which *D. immutabilis* was recorded in this study were all of abnormally warm water: 1958, 1967, 1971 (fall), and 1973 (summer)! Five of these sightings occurred during the spring when temperatures were close to 13°C (warm for California waters at that time of year), but the three fall sightings occurred at or above 16°C (Figures 3 and 4).

Sanger (1970) noted this species avoided water of relatively low salinity (below 32‰), and Fisher and Fisher (1972) noted preference for waters of relatively high salinity. Off California, the species has been seen most often during the early spring when salinities are lowest (but still higher than off Washington; see Sanger 1970), and the four years in which it occurred here had salinities at average or below. Sanger's further observation that oceanic waters far from land are preferred by this species may be more pertinent here. In the four years of record, temperatures were abnormally high, probably a result of altered circulation in the North Pacific (see Sette and Isaacs 1960). Altered circulation patterns, including the inshore movement of oceanic waters, may play a part in bringing Laysans into the study area (see also Holmes 1964).

NORTHERN FULMAR *(Fulmarus glacialis).* Fulmars breed on the Aleutians and on islands and coasts of the Bering Sea (AOU 1957). They were reported throughout the California study area, but south of Point Conception their abundance dropped sharply (Table 3). Scattered individuals were seen during some summers, but usually fulmars were not seen consistently or in any numbers until November. By then all birds had left breeding sites. Peak numbers off California were reached later in the winter as latitude decreased (Figure 2). In the Farallon area they were seen within 8 km of the coast, but were even more abundant westward of the islands. April, the month of arrival at the breeding grounds (Bent 1922), was the first month of their general absence from California waters.

Kuroda (1955) found fulmars commonest in cold waters (3-8°C), temperatures rarely reached off the California coast. Here, they seemed to be low in number during warm years and during the warmest part of the summer; and most abundant during winters of colder waters, 1961 to 1971 (e.g. temperatures averaging near 9°C (Figures 2 and 4). They also were abundant during years of high maximum salinity anomalies, which might suggest an association with more oceanic waters during winter. Relative to temperature, fulmars should have been abundant during the cold year of 1956, but this was apparently not so. Interestingly, salinities were very low that year (Figure 8). Thus fulmars perhaps prefer cold water of high salinity.

FLESH-FOOTED SHEARWATER *(Puffinus carneipes).* Flesh-footed Shearwaters breed on islands near Australia and are uncommon off California; in fact, they seem to be nowhere common at sea (Murphy 1936). They occurred off the California coast from May, just after the fledging period, to early November, the period of arrival and prebreeding activities at the nesting islands (Figure 2; see Serventy et al. 1971). The birds seen September to November are probably on their way southward.

Kuroda (1955) considered this a "warm water species". His sightings in the western Pacific occurred where water temperatures were 11° to 16°C. Flesh-footed Shearwater presence off California seems to agree with Kuroda's observations, as the species is more often seen in the southern regions (warmer waters) than northern ones (Table 3). If a water temperature range of 11-16°C is preferred, California waters should be ideal, for that is the normal temperature range from May to November. Flesh-footed Shearwaters were not seen during years of extremely cold temperature anomalies (1956, 1962, 1967), with the exception of 1971, when warm waters also occurred later in the year (Figures 4, 7 and 8).

PINK-FOOTED SHEARWATER *(P. creatopus).* Pink-footed Shearwaters nest on islands in warmer waters off Chile and spend the interim periods in the eastern North and South Pacific (Murphy 1936). They were common in all parts of the study area from April to November, although sightings were more frequent from August to early October (Figure 2). This is essentially the non-breeding season. They have occurred as far north as Alaska in some years (Murphy 1936), but during this study they were much more abundant in southern regions (Table 3).

There was a direct correlation of yearly abundance to mean maximum temperatures at La Jolla ($P<0.05$, $r=0.62$, $z=2.48$; Spearman Rank Correlation). Thus off California they seem to prefer waters in the upper range of temperatures.

Yearly differences in abundance off California may also be connected to ocean conditions off Peru and Chile, where Pink-foots are known to occur in all seasons (Murphy 1936). The trends in Pink-foot populations off California (Figure 4) are the reverse of seabird population trends, including shearwaters, off Peru (Idyll 1973; Jordan 1967). These Peruvian populations were low during the period 1957-59, were high 1960-64, and have been low ever since. The first depression resulted from a disappearance of anchovies due to oceanographic conditions ("El Niño"; see Murphy 1936), and the second by a disappearance of anchovies apparently caused by human over-fishing. During periods of low anchovy populations, Peruvian seabirds die or disperse farther than usual (Murphy 1925, 1936). During those lean years, *P. creatopus* may move in greater numbers to the California Current region. This may, of course, be speculative.

SOOTY SHEARWATER *(P. griseus).* Sooty Shearwaters at peak abundance were by far the most numerous bird in the study area, and probably numbered more than all other species combined. Those occurring in California waters probably originate from sub-Antarctic islands off both Cape Horn and New Zealand for the following reasons. First, *P. griseus* has been noted from Baja California south to the Peru Current (Loomis 1918; EASTROPAC Prelim. Repts., T. J. Lewis pers. comm.; observations by T. J. Lewis pers. comm.; Jehl 1974). In that area between Peru and California, Sooties were equal in abundance to Short-tailed and Buller's shearwaters, species known to breed only in the New Zealand-Australia area, but cruise tracks perhaps have not intersected the main north-south Sooty Shearwater migratory route. Second, King (1970) recorded Sooties as abundant during migration in the area immediately east of the main Hawaiian Islands. These were presumably birds on their way between New Zealand and the eastern North Pacific. Third, Sooty Shearwaters banded in the New Zealand area have been recovered in California waters (Richdale 1957, Warham 1964). These clues suggest that Sooty Shearwaters off California nest in both the New Zealand-Australia and the southern South America regions. Loomis (1918), Beck (1910) and Murphy (1936) suggested that most, if not all, Sooties seen off California were from South America. They were not aware, however, of the vast numbers of this species nesting in sub-Antarctic New Zealand (see Richdale 1963).

Sooty Shearwaters were most abundant off California from mid-May through September (Figure 2). Highest numbers were present in July and August, the period of maximum productivity in these waters as well as the birds' non-breeding season. Sooties were abundant off southern California only in May (Figure 3). They prefer colder waters (Murphy 1936; Kuroda 1955), and might avoid that area when temperatures begin to rise in following months. Their abundance as early as May, so soon after the nesting season, suggests that many fly directly to California rather than, as Phillips (1963) and others have proposed, by circumnavigating the North Pacific. King (1970) noted they migrate on a broad front across the tropical central Pacific, a fact that supports direct flight to California by at least part of the New Zealand population.

Yearly differences in abundance in this region were not clearly defined, perhaps due to the nature of the data. Most evident was their scarcity during the warm water years of 1957, 1958, 1966-67, and 1972-73 (Figure 4).

SHORT-TAILED SHEARWATER *(P. tenuirostris).* Short-tailed Shearwaters breed on islands in the Australian region and during the non-breeding season inhabit waters of the far northern Pacific (Kuroda 1955, Marshall and Serventy 1956) and Bering Sea (Bartonek and Gibson 1972). They were observed in very small numbers off California mostly during the late fall (peak in mid-November) and winter (Figure 2), but not in all years. Comparison of their pattern here to their nesting cycle suggests that individuals reported off California were mostly non-breeders. After a month or more of pre-breeding activities, they lay eggs over only a three-week period beginning in late November (Serventy et al. 1971). Short-tails seen off California after early November may include those pre-breeding juveniles that visit the nesting grounds during or after egg laying.

Kuroda (1955) found little correlation to water temperature in the occurrence of *P. tenuirostris* off Japan or in the North Pacific. He noted them in waters 3.5° to 12.5°C, the cold end of the scale in California. Greater numbers occurred here when water temperatures were cold during the fall and winter or when upwelling seemed strong earlier in the year, indicating a greater likelihood for abundant food (Figures 4, 7 and 9). A change in occurrence with latitude off California was not apparent (Table 3).

MANX SHEARWATER *(P. puffinus).* Manx Shearwaters breed on islands off the west coast of central Baja California, and many seem to remain in that area the year round (AOU 1957, T. J. Lewis pers. comm.). They became common in the study area during December, which is the midst of the Davidson Current period and the end of their non-breeding season (Figure 2). They occurred abundantly off San Diego and less so as far north as Monterey, but sightings dropped sharply north of there (Table 3). They have been reported rarely as far north as Vancouver (AOU 1957). Greatest yearly abundance and extensive northward movement occurred during years when water temperatures were above average off San Diego, years when temperatures were high farther north as well (Figures 4 and 7). In fact, abundance correlated directly to mean maximum temperatures at La Jolla ($P<0.01$, $r=.71$, $z=2.84$; Spearman Rank Correlation). Such conditions of high winter temperatures indicate strong northerly flow of Davidson Current waters. Manx Shearwaters thus seem to prefer waters 14°C and above the year round.

BULLER'S (NEW ZEALAND) SHEARWATER *(P. bulleri).* Buller's Shearwaters breed on the temperate North Island of New Zealand. They are most numerous off California from early September to early October, the time when adults begin to arrive at nesting areas (Figure 2; Serventy et al. 1971). During their period of greatest numbers off California, birds were often seen in rapid flight, suggesting they were in the midst of migratory movement. Their abundance decreased rapidly south of Monterey (Table 3), and few have been reported in the eastern Pacific south of Baja California (EASTROPAC Prelim. Repts., T. J. Lewis pers. comm.). Birds occurring off California probably turn towards New Zealand at about the latitude of central California.

Kuroda (1955) found them most abundant in the western North Pacific at the boundaries between warm and cold currents. Ocean temperatures were 14.5-16°C, the normal upper range in temperatures for northern California. *P. bulleri* was most abundant off California during three fall periods: 1956, the year preceding an intensive warm water period and a year of strong upwelling and abundant plankton; 1966 and 1967, years of above average fall ocean temperatures, of above average upwelling, and high plankton volumes; and 1970 and 1971, years preceding another warm period and years of above average upwelling and plankton volumes. During the birds' presence, isotherms were closely spaced and close to and parallel to the California coast, indicating that the boundary of cold inshore waters and warm waters was close to the coast also. Occurrence in the study area under these conditions was thus in agreement with Kuroda's observations. Buller's Shearwaters occurring in high numbers off California seem to foretell a period of warm water to follow.

FORK-TAILED STORM-PETREL *(Oceanodroma furcata).* Fork-tailed Storm-Petrels breed on islands from the Aleutians south to northern California (AOU

1957). They were uncommon the year round from central California (area 3) north with no seasonal change in abundance (Figure 2). This may indicate that the birds in the study area were mostly non-breeders. They were present in the southern areas only during the spring and fall, and in area 5 only one bird was seen during the study period (Table 3).

According to Kuroda (1955) and to Martin and Myres (1969) the species inhabits cold waters. Kuroda found them most abundant in waters 3-8°C and saw scattered individuals in warmer waters. The fact that only "scattered individuals" are seen off California is probably related to waters being warmer than 8°C; and rarity of this species in area 5 is probably due to their avoidance of the very warm waters there. Numbers have varied little in the study area, but they were most abundant during the spring of 1970 and 1971 and the fall of 1973, periods of unseasonally cold waters (Figure 4).

LEACH'S STORM-PETREL *(O. leucorhoa).* Leach's Storm-Petrels breed on offshore islands and headlands from Alaska south to central Baja California (AOU 1957). Only white-rumped forms were recorded north of Point Conception, but both these and dark-rumped individuals, with the latter predominating, occurred south of there. Much information has been lost by observers and editors not reporting the two forms separately. Distinguishing dark Leach's from other dark storm-petrels in the eastern North Pacific on the basis of size and color is usually difficult (Crossin 1974), but flight characteristics are distinct between most species, and are particularly evident when mixed species flocks are observed (Stallcup pers. comm.).

They were very abundant off southern California in comparison to areas 1-3 (Table 3). The Farallon population is much smaller (ca. 700 pair; Ainley and Whitt 1973, Ainley and Lewis 1974) than populations both north and south, which helps explain the fewer numbers seen in northern study areas. The fall peak in numbers, especially in northern areas, corresponds well with the fledging period at the Farallones (Ainley, Morrell and Lewis 1974). Birds collected during the fall over the years off central and northern California and deposited in the Museum of Vertebrate Zoology (MVZ) and California Academy of Sciences (CAS), are almost all fledglings, based on characteristics of molt (Ainley, Lewis and Morrell 1976), as were 15 individuals found dead on area 4 beaches during fall 1973 (Ainley unpubl.). Martin and Myres (1969), Ainley et al. (1974) and Sanger (pers. comm.) report that from California north to British Columbia the species prefers warmer oceanic waters, i.e. those westward of the California Current in the California region. This also helps explain low numbers in northern study areas, where warmer waters occur far offshore, and their greater occurrence during the fall when warm oceanic waters move closer to the coast. Fall also is the period for fledglings which may stray from the adult norm (Figure 2). In the western North Pacific, Kuroda (1955) noted *O. leucorhoa* in warmer waters than those preferred by *O. furcata*, a phenomenon also noted by Martin and Myres (1969) and Sanger (pers. comm.) for the eastern North Pacific.

High abundance in the study areas occurred in some years when waters were warm, in some when upwelling was strong earlier, and in others when salinities were low (Figure 4). This last factor, if a result of storms and heavy rain runoff, might indicate that the large numbers in those years represent birds concentrated near the coast by the storms. The 1973 peak did result from such conditions. Fewer Leach's Storm-Petrels were seen during years when ocean temperatures were cool.

ASHY STORM-PETREL *(O. homochroa).* Ashy Storm-Petrels breed from Los Coronados north to the Farallones and Point Reyes (AOU 1957, Ainley and Osborne 1972). They were observed at all times of the year in waters off central California, and peak numbers occurred from September to October when they concentrated in Monterey Bay (Figure 2). This peak coincided with peak fledging at the Farallones, where the 4000 bird breeding population (Ainley and Lewis 1974) probably outnumbers all other of this species' breeding populations combined. Ashys visit the Farallones year round. Fall concentrations in Monterey Bay probably included Farallon breeders, non-breeders, and fledglings along with individuals from southern populations. This would seem likely, judging from the high estimates of birds there (up to 7000). A general northward movement of storm-petrels, including several species, seems to occur each fall in the study area. About half the specimens in MVZ and CAS, collected over the years during the fall in Monterey Bay, are birds-of-the-year. Scattered Ashys in the fall sometime reach as far north as Cape Mendocino (Table 3). Ainley et al. (1974) describe them as being restricted to the coastal area of the California Current from northern Baja California to Cape Mendocino.

Yearly differences in abundance were not analyzed because the fall concentration area in Monterey Bay was discovered a few years ago, and this strongly biases numbers for later years.

BLACK STORM-PETREL *(O. melania).* Black Storm-Petrels breed on islands off the east and west coasts of central and northern Baja California (AOU 1957). They were observed off California during most months, but with increasing latitude, they occurred more frequently in the fall (Figures 2 and 9). North of area 3, *O. melania* was observed very rarely, but several thousand were present in Monterey Bay during the fall of certain years (Table 3). The fall peak, September to October, corresponded to the late fledging and post-fledging periods and to the oceanic period, the time of warmest ocean temperatures. Greatest numbers occurred during years of above average fall ocean temperatures (Figure 4). Yearly abundance correlated directly to mean maximum ocean temperatures at La Jolla ($P<0.05$, $r=.51$, $z=2.04$; Spearman Rank Correlation). A steady increase of fall numbers in Monterey Bay over the past several years relates well to the pattern of rising fall water temperatures there (Figure 7). During years of colder waters, this species was mostly absent from the study area. Black Storm-Petrels thus seem restricted to warmer coastal waters (ca. 16° and above) throughout its annual cycle.

LEAST STORM-PETREL *(Halocyptena microsoma).* Least Storm-Petrels breed on many of the same islands as the previous species (AOU 1957). Their presence off California was restricted to September and October except in area 5 where they also occurred in low numbers during July and August (Figure 2). They were present later in the fall with increasing latitude (Figure 3). North of Point Conception, they were seen rarely (Table 3). During 10 of 19 years in this study, they were not reported even in area 5.

Peak seasonal abundance corresponded to the oceanic period of maximum temperatures. These petrels were reported only during years when temperatures at La Jolla were at or above average maximum (23.1°C). During the periods of their greatest abundance, fall 1970 and 1971, temperatures were the highest recorded for the study period, 24-25°C at La Jolla.

WILSON'S STORM-PETREL *(Oceanites oceanicus).* Wilson's Storm-Petrels occurring in the eastern Pacific breed in the Cape Horn region (Murphy 1936). They were recorded rarely during this study, and all 10 records occurred between mid-August and the first day of November (Figure 2). Adults should have begun visits to the breeding islands by early November, so possibly these 10 birds were pre-breeding juveniles. It may be significant that nine of the records were during years of disruption in fish populations of the Peru Current, where *O. oceanicus* usually winters (Murphy 1936).

MAGNIFICENT FRIGATEBIRD *(Fregata magnificans)*. Magnificent Frigatebirds breed in the tropics (AOU 1957). They occurred off California from late June to early November (Figure 2), suggesting that in comparison with a rather extended period of nest attendance, individuals seen were mostly non-breeders but not fledglings of that year. In other words, breeding adults should still have been attending young when the species occurred in California far from the nearest breeding site (Magdalena Bay, southern Baja California). Most frigates seen in California are indeed juveniles (McCaskie 1970); however, immature plumage is retained for several years (Schreiber pers. comm.). Numbers and frequencies of records decreased sharply with increasing latitude, particularly north of areas 4 and 5 (Table 3). This could be related to increasing distance from nesting areas, but more probably is connected with declining ocean temperatures.

Peak seasonal abundance occurred in July and August, coinciding with the period of maximum water temperatures in southern areas. Frigatebirds were present during years when temperatures were near to or above maximum and were absent in cold or moderate years. Except for one record in 1968, they were seen north of Point Conception only during years of unusually warm conditions, i.e. temperatures 17-18°C or more (Figure 4). The largest numbers occurred during 1972, a year of warm water and a year following one in which breeding success was very high in Baja colonies (D. W. Anderson pers. comm.). These facts suggest frigatebirds move north in sub-tropical conditions, and occurrence off California depends on the presence of these conditions.

BROWN BOOBY *(Sula leucogaster)*. Brown Booby is a sub-tropical and tropical breeder (AOU 1957) which rarely occurs in California. All records were south of Point Conception (Table 3) and were in February, June-September and December. Seasonally, their occurrence generally coincided with warm temperatures, and they occurred in warm years (Figure 4). Three records were apparently of the same individual that visited San Miguel Island during the summers of 1961, 1965 and 1968 (McCaskie 1970).

BLUE-FOOTED BOOBY *(S. nebouxii)*. Blue-footed Booby, another subtropical breeder (AOU 1957), was rare in California. Individuals of both booby species occurring in California probably originate from nesting areas in the Gulf of California or coastal Mexico. All occurrences of Blue-foots were after the fledging period which, along with plumage characters (see McCaskie 1970), indicated young birds (Figure 2). All records were from August to November, the time of highest ocean temperatures. Only in the abnormally warm fall of 1971 did this species reach as far north as Point Conception and Monterey (Table 3; Figure 4).

RED-BILLED TROPICBIRD *(Phaethon aethereus)*. Red-billed Tropicbird, another tropical pelecaniform, probably arrived in California waters from the Revilla Gigedo Islands or islands in the Gulf of California. Sightings of this bird decreased rapidly with increasing latitude (Table 3). They were seen several times in area 5, three times in area 4, and once in area 3 (Monterey Bay region). The species reportedly breeds year-round in the Gulf of California (Palmer 1962), but it occurred off southern California from May through October, with highest numbers present from August to October (Figure 2). The pattern coincided with movement of warmer oceanic waters into the study area. Tropicbirds usually occurred during periods of extreme conditions—years having very cold waters (1956, 1962, 1969, 1970 and 1971) and years of warm waters (1957, 1959, 1971 and 1973). Interestingly, like Buller's Shearwaters, they were most abundant in the study area prior to warm water periods (e.g. 1956, 1968-70), but they became less plentiful during the warm years (Figure 4). They occurred in years of strong upwelling. Occurrence of tropicbirds in California waters may be related to movements of tuna schools with which they are often associated (see Ashmole and Ashmole 1967). Williams (1972) and Fink and Bayliff (1970) described seasonal movements of Skipjack Tuna *(Katsuwonus pelamis)* into the eastern North Pacific. Tuna begin to occur near the Revilla Gigedo Islands in April, move inshore off Baja California during May and June, and reach their northernmost extent off northern Baja and sometimes southern California in September before turning south. There is good agreement between this pattern and that for tropicbirds in the southern study areas. A slightly more northern migration of tuna in certain years would readily bring tropicbirds to our area. In fact, during the eleven years from 1955 through 1965, the greatest tonnage of tuna caught north of 15°N along the Baja Coast was in the four-year period 1956-59 (Joseph and Calkins 1969), a period of many tropicbird records off San Diego (Figure 4).

SOUTH POLAR or CHILEAN SKUA *(Catharacta maccormicki* or *C. chilensis).* Most skuas seen off Japan, according to Kuroda (1955), are South Polar Skuas, and it is generally felt that this species predominates in California waters, too (Devillers MS). It would not be surprising if some off California were Chilean Skuas, since other mobile species of the Peru Current also visit here regularly. Chilean Skuas have been reported as far north as northern Peru (Murphy 1936). Skuas were seen off California during most months, but the majority of records were in September and October (Figure 2). Both species begin egg laying in November (Murphy 1936, Ainley pers. obs.), the South Polar about 2-3 weeks later than the Chilean, and both arrive at the nesting area a month beforehand. Most California records occurred when these birds should have been present at breeding areas, indicating that California birds are non-breeders. South Polar Skuas do not return to nesting areas until age 3 or more (R. C. Wood pers. comm.) but whether or not these juveniles regularly wander the extent of the world's oceans is unknown.

Without exception, highest numbers occurred during years in which phytoplankton volumes were highest ($P<0.01$, $r=.81$, $z=2.83$; Spearman Rank Correlation). Skuas do not eat phytoplankton, thus the exact nature of the relationship is not clear. Low numbers occurred during years of warmest fall temperatures (Figure 4): 1958, 1959, 1966, 1967, 1972 and 1973 (early). There was no well-defined trend in abundance relative to latitude (Table 3).

SABINE'S GULL *(Xema sabini).* Sabine's Gull breeds on the Alaskan tundra, becomes pelagic during its migrations, and winters off Peru (Murphy 1936). In late April and early May, Sabine's Gulls passed through the study area very quickly, as indicated by the well-defined peak in numbers at that time (Figures 2 and 3). The fall passage extended from late August to early October, but most passed south in mid-September. These periods coincide closely with arrival and departure at the breeding grounds (Bent 1921), another indication of fast migration in this species. Yearly differences in abundance could not be analyzed because of insufficient quantitative data. The species was reported most often in area 5 (Table 3).

BLACK-LEGGED KITTIWAKE *(Rissa tridactyla).* Kittiwakes breed on the rocky cliffs of the Aleutian Islands and of islands and headlands further north (AOU 1957). They are pelagic during the winter in our area, with highest numbers reported from Monterey south (Table 3). They were seen earlier in the fall in northern areas, but did not become abundant anywhere in the region until late December, well after the breeding season (Figures 2 and 3). Both these factors indicate a leisurely movement. Peak numbers were present late February to early March, possibly as birds were massing for northward migration, but also possibly because of water temperature (see below). Departure from California was about a month before expected arrival at nesting areas.

Kuroda (1955) found them most abundant where waters were 5-6°C, temperatures far lower than those in California waters. Greatest abundance here did not occur during the coldest months, but when water temperatures were 9-16°C.

During years when winter temperatures were at or below average, kittiwakes were more abundant; and in years of above average winter temperatures, they were few in number (Figure 4).

THICK-BILLED MURRE *(Uria lomvia).* These murres breed on the cliffs of islands and headlands of the high Arctic (AOU 1957). Nine individuals were seen on six scattered occasions in Monterey Bay. No obvious relationship of their occurrence to oceanographic conditions was evident. They could be easily overlooked in area 2 among the thousands of Common Murres *(Uria aalge)* there.

HORNED PUFFIN *(Fratercula corniculata).* These puffins breed on British Columbian, Alaskan and Bering Sea islands (AOU 1957, Drent and Guiguet 1961). Twelve were recorded during six years of the study, within all five areas. Similarly to the juvenile Kittlitz's Murrelet *(Brachyramphus brevirostris),* another Arctic species found at La Jolla on 16 August 1969 (Devillers 1972), Horned Puffins occurred May to August, but mostly during the late summer. That is when oceanic waters move closer to the coast. No other correlations to ocean conditions were apparent. Most puffins, and *U. lomvia,* too, were reported in 1972 and 1973, both years of anomalous conditions. Hamilton (1958) recorded both species as common far south of the Aleutian Islands, and Clapp and Woodward (1968) recorded Horned Puffins in Hawaii! It might well be that these arctic species are much more abundant than suspected in oceanic waters west of the California Current during some years, and that it takes anomalous conditions to bring them coastward.

ANCIENT MURRELET *(Synthliboramphus antiquus).* Ancient Murrelets breed on coastal islands off British Columbia and southeastern Alaska (AOU 1957). They winter throughout the study area, but mostly north of area 3 (Table 3). Greatest abundance occurred from late November to early March, indicating southward movement well after nesting (Figure 2). They may wait for ocean temperatures to cool down here, or for stormy weather to begin farther north. Departure from California occurs suddenly just before arrival at breeding areas.

Kuroda (1955) noted this species twice off Japan at ocean temperatures 4.5-5.5°C. Off California their greater abundance in northern areas and during winters of low water temperatures (near 9°C at the Farallones and 10°C at Pacific Grove; Figure 4) indicates a preference for colder waters.

MARBLED MURRELET *(Brachyramphus marmoratus).* Marbled Murrelets breed along the coast from southeastern Alaska to the northern part of area 3 (AOU 1957). Numbers fell sharply south of Point Conception (Table 3). They were reported year-round except during May and June (Figure 2), when adults are supposedly on eggs or feeding chicks (Sealy 1974). They may be less visible to shore observers during that time, but A. Baldridge and R. Stallcup (pers. comm.) have often observed pairs in breeding plumage during May and June off Pigeon Point (area 3).

XANTUS' MURRELET *(Endomychura hypoleuca).* Xantus' Murrelets breed on islands in study areas 4 and 5, and farther south along the west coast of Baja California (AOU 1957). Occurrence declined gradually with increasing latitude (Table 3). They were present year-round in areas 4 and 5, but only during the spring and fall farther north (Figure 3). With all areas combined, most records were in early March, just before egg laying, and in August, just after the last chicks fledge (Figure 2). Greatest abundance was in years when late summer and fall ocean temperatures were above average maximum (Figure 4); yearly abundance correlated directly to mean maximum temperatures at La Jolla ($P<0.05$, $r=.61$, $z=2.44$; Spearman Rank Correlation). Scott et al. (1971) and Sanger (1973) reported four records of Xantus' Murrelets well off the coasts of Oregon and British Columbia during the late summer and fall, 1969-1972, a period when fall ocean temperatures were rising in the eastern North Pacific. This and their greater abundance in coastal California when the influence of warm oceanic water was strongest, suggests that *E. hypoleuca* seeks warmer oceanic waters during the non-breeding season and move as far north as preferred conditions allow.

CRAVERI'S MURRELET *(E. craveri).* Craveri's Murrelet breeds on islands in the Gulf of California (DeWeese and Anderson MS). They were not recorded north of Monterey Bay during this study, and abundance dropped sharply north of Point Conception (Table 3). They were seen from mid-July to mid-September, but only since the late 1960s have they been looked for in California waters. Occurrence here coincided with the post-fledging season and also with the period of warmest ocean temperatures.

RHINOCEROS AUKLET *(Cerorhinca monocerata).* Rhinoceros Auklets breed in very low numbers at the Farallon Islands, in area 1 and in Oregon, but otherwise mostly on islands from Washington to southeastern Alaska (AOU 1957, Ainley and Whitt 1973, Scott et al. 1974). They winter in large numbers off California, but their abundance in California waters has been underestimated; I suspect because they remain mostly offshore and beyond the continental shelf, as also observed by Sanger (pers. comm.). Peak occurrence was in December and January (Figure 2), well after the breeding season (see Richardson 1961). Most records were from area 3 northward. Like the Ancient Murrelet, *C. monocerata* may wait for cooler temperatures to be reached in California waters or for stormy weather farther north before moving south. Their departure was more gradual than their arrival, but most birds were gone by March.

MARINE BIRDS AND THE ENVIRONMENT

The relationship of marine bird distribution and occurrence off California was most clearly defined relative to ocean temperature, and less clearly so relative to salinity. One factor involved here was that temperature fluctuation was greater and more clearly defined. Murphy (1936) felt that temperature was critically important in any explanation of seabird distribution. Sanger (1970), for certain species off Washington, noted some correlations to salinity, but referred to almost two-fold differences in concentrations, a range not noted in the present study.

Water temperatures relate to bird occurrence in two major ways. First, they are an index to the strength of upwelling of cold, nutrient-rich waters, and hence, an index to food abundance at the base of the food web (see Bolin and Abbott 1963). Good phytoplankton production usually occurs in cold, nutrient-rich upwelled water. After that the relation to marine birds becomes complex and not well understood, except that large numbers of marine birds also occur in productive waters (Murphy 1936, Ashmole 1971). Food abundance, however, is not necessarily the same as food availability, but it too correlates to ocean temperature. For example, Northern Anchovies *(Engraulis mordax),* one of the major food items for California seabirds (PRBO unpubl. data), remain in deep waters when temperatures are warm and thus are not available to seabirds (Frey 1973).

The second way in which temperature affects the numbers and species of seabirds relates to the temperature preferences of the species. In the northern North Pacific each water mass or oceanographic region, defined by physical factors at certain values (Dodimead et al. 1963), has a particular marine bird community associated with it (Sanger 1972). Murphy (1936) discussed this for South American waters. The phenomenon is well established for other California marine biota (e.g., Bolin and Abbott 1963, Hubbs 1963). Hubbs mentioned marine birds in his review of the phenomenon, but observations in the present paper revise his observations. For instance, he discounted the occurrence of boobies off California.

In coastal waters south of Point Conception, where temperatures usually range 13° to 16°C at the spring low and 16.5° to 23°C at the late summer high, the typical marine avifauna includes breeding species as well as visitors. Except for Brown Pelicans (Schreiber and Risebrough 1972) and Double-crested Cormorants *(Phalacrocorax auritus;* Gress et al. 1973), current information on other breeding species exists only for relatively small breeding communities, e.g. offshore rocks (Osborne and Reynolds 1971) and Santa Barbara Island (Hunt and Hunt 1974, PRBO MS). These species at present (AOU 1957, Ainley and Lewis 1974) include three storm-petrels *(O. leucorhoa, melania,* and *homochroa),* pelicans, three cormorants *(P. auritus, penicillatus, pelagicus),* Western Gulls *(Larus occidentalis),* and three alcids *(Cepphus columba, Endomychura hypoleuca,* and *Ptychoramphus aleuticus).* Three of these do not breed north of the point, but four northern breeding species do not presently breed south of the point *(O. furcata, Uria aalge, Lunda cirrhata, Cerorhinca monocerata;* see below).

The usual visiting species in coastal waters south of Point Conception are from spring into the fall: Black-footed Albatross, Flesh-footed, Pink-footed, and Sooty shearwaters, and Black Storm-Petrel. Under particularly warm conditions in the fall, Magnificent Frigatebirds, boobies and Least Storm-Petrels occur, and under cool fall conditions, Short-tailed Shearwaters may occur. The typical winter visitors are Manx Shearwater and Black-legged Kittiwake, but when cooler conditions prevail then fulmars, murres and Ancient Murrelets visit in larger numbers.

In coastal waters north of Point Conception, where temperatures normally range 9° to 14°C at the spring low and 10.5° to 16°C at the fall high, the typical marine avifauna includes the breeding species (see above paragraph, Ainley and Whitt 1973, and Marbled Murrelet account above) as well as several visitors. In spring, summer and early fall these are: Black-footed Albatross, Flesh-footed, Pink-footed, and Sooty shearwaters, and Fork-tailed Storm-Petrel. Buller's Shearwater occurs only in the fall. If upwelling has been poor during early spring, these species do not occur in usual numbers. In late fall and winter the visitors are:

Northern Fulmar, Common Murre (*U. a. inornata* from northern breeding areas; Storer 1952, Smail et al. 1972), Ancient Murrelet, Rhinoceros Auklet (a rare breeder in this area, too), and Black-legged Kittiwake. If winter temperatures are warmer than normal, these species are usually scarce. If fall temperatures are unseasonally cold, Short-tailed Shearwaters occur also. When conditions are unduly warm, species typical of waters south of Point Conception move north. These include, usually, Manx Shearwater, Black Storm-Petrel, frigatebird and Xantus' Murrelet. Under extremely warm conditions boobies and Least Storm-Petrels also move north.

Extensive overlap thus occurs in visiting marine avifaunas of northern and southern California during the upwelling period. The upwelling and southward movement of cold water affects the overlap by unifying marine conditions. When the oceanic period approaches in southern California the extent of overlap decreases and subtropical marine birds occur there. However, if oceanic period temperatures are abnormally warm in northern areas then many of these species move north of Point Conception to again produce extensive overlap. Species composition seems less variable from year to year during the Davidson Current period. If colder temperatures occur during winter, indicating possibly a weak countercurrent (Bolin and Abbott 1963), then northern species move south of Point Conception in greater numbers. A strong countercurrent seems to bring the subtropical Manx Shearwater north.

SEASONAL CHANGES IN NUMBERS AND SPECIES DIVERSITY

The number of marine bird species visiting California's nearshore waters is lowest during March and April, increases to a peak in September, and then declines through the winter (Figure 10). Numbers of individuals follow a similar pattern (Figure 2). Numbers and species diversity begin to increase during the upwelling period, reach their peak just before and during the oceanic period, and then decline during the Davidson Current period. These changes are a function of the breeding seasons of respective species, along with factors such as food availability and climate. That is, when the species from South Pacific nesting areas are passing through in migration (e.g. Buller's and Flesh-footed shearwaters) or are lingering on while food is still apparently available (e.g. Sooty and Pink-footed shearwaters), species from subtropical eastern North Pacific nesting areas are finishing their breeding and waters off California are becoming warm enough to suit them. Thus, demand placed on the resources of coastal California by visiting marine birds increases during the upwelling period and reaches its peak in the early oceanic period.

Demand on the resources of coastal California by *resident breeding* species increases and declines in a pattern timed similarly to the visitors' (Figure 10). An intensive study on this phenomenon is now under way for the central California area (PRBO), and the following points are readily evident. During the upwelling period, breeding adults are raising young as well as feeding themselves; and during the oceanic period or just before it, fledglings go forth on their first month or two of independence, supposedly the most critical in their future chances of survival (see reviews in Lack 1968, 1972). Adults are still present in coastal California then, too. These coinciding patterns of food demand by visiting and resident species are interesting in light of recent statements about the role of interspecific competition in the evolution of feeding adaptations and patterns of food resource exploitation (e.g. Ashmole and Ashmole 1967, Pearson 1968, Scott 1973, Cody 1973). Competition for resources of the ocean among all members of marine bird communities has rarely been considered. If interspecific competition for food among resident species can be so important in shaping the organization of breeding seabird communities, what is the effect on this organization of competition from visiting species? It is potentially of great magnitude (Ainley 1976).

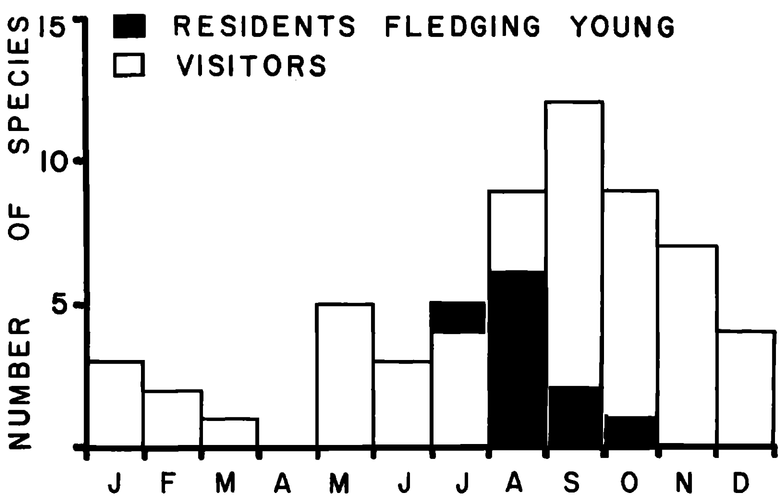


Figure 10. Fledging periods in California breeding seabirds compared to the abundance of visiting species. Visitors were tabulated for months in which their relative abundance exceeded 15 percent of the yearly total (see Figure 2).

SUMMARY

The occurrence and distribution of 28 marine bird species that visit the coastal waters of California was described from data provided in *Audubon Field Notes/American Birds* for the years 1955 to 1973. Where possible, yearly differences in occurrence were related to ocean temperatures, salinities and productivity. Best correlations were derived from water temperatures, especially for such "southern" species as Black Storm-Petrel and Xantus' Murrelet. Marine bird communities north and south of Point Conception, an oceanographic boundary region, were compared, including breeding and visiting species, based on temperature conditions of the two regions. The upwelling of cold water in areas occurring the length of the state effected extensive overlap in breeding avifaunas and in visiting species during the upwelling period. During the oceanic and Davidson Current periods (e.g. fall and winter) there was less overlap in visiting species of the two regions, although abnormally warm conditions in the fall and winter or abnormally cold conditions in the winter caused greater overlap. Peak numbers and species diversity of visiting seabirds occurred during late summer and fall, a period when food resources are supposedly critical for resident species off California.

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