SEABIRD MORTALITY IN CALIFORNIA AS WITNESSED THROUGH 14 YEARS OF BEACHED BIRD CENSUSES

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ABSTRACT

Between June 1971 and May 1985, volunteer censusers surveyed 91 beaches in California. Periods of coverage varied between beaches but several beaches, in the Gulf of the Farallones, on Monterey Bay, and in San Luis Obispo County, were surveyed monthly for over 8 years. Survey coverage was more extensive in these regions than to the north or south.

Censusers found 39,444 dead or dying marine birds. The most commonly found species were Common Murre from Monterey Bay north, Common Murre and Western/Clark's grebes in San Luis Obispo County, Sooty Shearwater, Western/Clark's grebes, and Common Murre in the Santa Barbara Channel region, and Northern Fulmar, Sooty Shearwater, and Western Gull from Los Angeles to San Diego counties. Carcass densities (birds/km walked) were highest in the Monterey Bay region for 15 taxa but for no more than 7 taxa in any other region of the coast. Carcass densities were lower south than north of Point Conception. Carcass densities were high enough to examine seasonal trends and annual variation for 19 species or taxa. For most of these taxa, seasonal trends in carcass density north of Point Conception generally tracked live bird occurrence. However, south of Point Conception seasonally highest carcass densities for some species coincided with spring and early summer periods when live bird population sizes were lowest in the area. The period of highest overall carcass densities in the Gulf of the Farallones was July through September, the post-breeding period for local resident species. On Monterey Bay and San Luis Obispo County beaches, carcass density peaks occurred throughout the year. South of Point conception highest carcass densities occurred from March through June. Years of above average carcass densities coincided mostly with El Niño-Southern Oscillation episodes, other warm water periods, and a period of intensive gill net fishing in Monterey Bay and the Gulf of the Farallones.

Suspected causes of death that could be identified were almost entirely due to humans. Censusers ascribed a probable cause of death to 4713 (11.9%) of the carcasses. At least an additional 2.4% of the carcasses were obvious gill net casualties. Of the 4713 "known-cause" carcasses, 83.0% were oiled. Oiling rates varied between regions, between beaches, and between species groups. Highest rates of oiling were from beaches south of Point Conception. Among beaches with several years of coverage in the Gulf of the Farallones, highest oiling rates were from Ocean and Cronkhite beaches, near the Golden Gate entrance. Entanglement in fishing gear was the next most commonly implicated cause of death.

The impact of the T/V Puerto Rican oil spill was most severe for the Common Murre but also among the worst events since 1971 for the loons and Western/Clark's grebes. For the Common Murre, daily carcass deposition rates on eight beaches were estimated to be from 15 to 110 times greater than usual for the 3 to 5 initial days of the spill. Daily carcass deposition rates for the loon were 2.5 to 33 times greater than usual. Rates for Western/Clark's grebes were 2.5 to 10 times greater than usual.

INTRODUCTION

In January 1971 two oil tankers collided in the Golden Gate entrance of San Francisco Bay. The resulting spill of 840,000 gallons of crude oil spread quickly along the outer coast from southern San Mateo County to Point Reyes as well as inside the mouth of San Francisco Bay. In the days following the spill 4600-6000 oiled birds were taken to cleaning stations while uncounted numbers of birds that died were discarded during beach clean up efforts (Smail et al. 1972). One of the obvious questions that arose from the spill was how the mortality caused by such a catastrophic event compared to normal. At the time, nothing was known about normal patterns of mortality on the central California coast, although accounts of catastrophic mortality from the last major oil spill in the area in March 1937 were available (Aldrich 1938, Moffitt and Orr 1938).

It is not possible to directly measure the number of seabirds that die in our coastal waters. However, it is possible to monitor some portion of the mortality by regularly counting seabirds that are found dead or dying on the shoreline. Such counts were begun in England by the Royal Society for the Protection of Birds in 1952, with a major goal of monitoring mortality due to oil pollution (Barclay-Smith 1956). After the 1971 spill, Point Reyes Bird Observatory (PRBO) initiated a study for California similar to the English monitoring project. Both studies used volunteer observers to count beached carcasses.

The goal of the California beached bird project was to monitor oiling and other causes of death in seabirds under non-catastrophic conditions, and to determine the "normal" numbers of carcasses that wash onto beaches. In particular, we wanted to know how these numbers varied in different regions of the state, in different seasons, and in different years. Variation between years was of particular interest because of another major PRBO research project, which was seeking to understand fluctuations in breeding population size and success of seabirds on Southeast Farallon Island. This seabird breeding colony, the largest in the 48 contiguous states (Sowls et al. 1980, Ainley and Boekelheide ms in prep.), is located 42 km west of the Golden Gate. The possibility of relating oceanographic conditions in different years in central California to breeding success from the Farallones and mortality data from the beached bird project provided PRBO with an unparalleled opportunity to interpret some major features of seabird ecology.

The number of seabird carcasses that wash onto a beach each day (i.e., the daily deposition rate) is a function of the number of live seabirds in the adjacent ocean, their distribution at sea, mortality rates, the birds' behavioral responses to impairment, and the net effectiveness of onshore deposition forces against factors that cause carcass loss at sea. Further, the number of carcasses found on a survey is a function of the daily deposition rate, the time since the previous survey, and the rate of carcass loss from the beach. We will discuss these factors in more detail in the report but mention here that we distinguish the number of carcasses found on a survey from actual mortality by referring to the former as carcass density.

Oil pollution of the sea was recognized as a threat to seabird populations as early as 1872 (Stowe 1982) and interest in monitoring its effects on birds has risen with increased oil exploration and development at sea. Beached bird survey projects in Great Britain (Hope Jones 1980, Stowe 1982 and references cited therein, Heubeck 1987), in northern Europe (Joensen 1972a,b; Gorski et al. 1976; Joensen and Hansen 1977; Kuyken 1978), on the east coast of North America (Piatt et al. 1985, Simons 1985), on the Great Lakes (Lambert and Risley 1979, Lambert 1982), in Washington state (Wahl et al. 1981, Speich and Wahl 1986), and in New Zealand (Powlesland 1986) provide valuable perspective on carcass densities and oiling rates under non-catastrophic conditions. Reports on the numbers of birds killed during oil spills (e.g. Hawkes 1961, Bourne et al. 1967, Bourne 1968, Tanis and Mörzer-Bruyns 1968, Greenwood 1969, Hope Jones et al. 1970, Smail et al. 1972, Brown et al. 1973, Bibby and Bourne 1974, Dunnet 1974, Hope Jones et al. 1978, Powers and Rumage 1978, Barrett 1979, Heubeck and Richardson 1980, Pfister 1980, RSPB 1981, Baillie and Mead 1982, reviewed in Bourne 1969 and Stowe and Underwood 1984) provide disaster data complementary to the survey projects, although previously no attempt has been made to reconcile the carcass density data from these two sources of information on seabird mortality.

One of the most formidable barriers to a comparison of these two sources of data is the differing methods in which the data are collected. Beached bird surveys are usually conducted at regular or semi-regular intervals during which carcasses deposit on and disappear from beaches. In contrast, during oil spills or other catastrophic mortality episodes, birds usually are removed from beaches daily (or more often) and little carcass turnover likely occurs between counts. In this report, we propose a method to compare beached bird survey data with thorough bird counts done for oil spills by comparing daily deposition rates for individual beaches. We use this method to estimate the relative magnitude of the 1984 T/V Puerto Rican oil spill in the Gulf of the Farallones (PRBO 1985).

In this report, we also provide a detailed data base on carcass numbers for beaches surveyed in the Gulf of the Farallones and Monterey Bay.

STUDY AREA, REGIONAL DEFINITIONS, AND SEASONAL DEFINITIONS

The study area included 82 shoreline segments along the outer coast of California, 8 segments on two of the Channel Islands off southern California, and a shoreline segment on the northeast side of Tomales Bay, Marin County. California's emergent coastline is mostly backed by cliffs of varying height, but is interrupted occasionally by pocket beaches at the mouths of creeks, sand spits at large river mouths, and large dune systems at a few locations. Sites surveyed for bird carcasses included bluff-backed rocky to sandy segments of coastline, pocket beaches, dune-backed beaches, and sandspits. We refer to all survey sites as beaches throughout this report. Due to predictable seasonal patterns of beach building and erosion (Bascom 1964), the extent of the beach zone suitable for carcass deposition varies seasonally on the different beach types. In general, beaches backed by bluffs lose most of their deposition zone due to beach erosion that usually begins with the first winter storms in October or November and extends through February or March. Beaches of other types also lose depositional area, but usually not to the same extent as beaches backed by vertical bluffs. During the beach building period, which begins in March or April, high tide depositional areas are typically reëstablished on all types of beaches.

We divided the outer coast into six regions to examine geographic variation in marine bird mortality .

Region 1, **Northern California**, included Del Norte, Humboldt, Mendocino and Sonoma counties. This region was relatively sparsely-populated by humans, except in the vicinity of Humboldt Bay, and there were no onshore or offshore oil facilities.

Region 2, the **Gulf of the Farallones**, included Marin, San Francisco, and San Mateo counties. Most urban development in this heavily-populated region was away from the outer coast. The mouth of San Francisco Bay, the most prominent coastline feature, was the destination for much of the outer coast shipping traffic, including vessels serving the oil refineries within San Francisco Bay. There were no offshore oil facilities. The largest breeding seabird population along the North American west coast, south of western Alaska, occurs in the section.

Region 3, **Monterey Bay**, included Santa Cruz County and Monterey County north of the Big Sur coast. This region was less heavily populated than the Gulf of the Farallones, although much of the urban development present here was along the shore. On the central Monterey Bay shoreline was an oil-burning power plant fueled from an offshore oil unloading facility for tankers. There were no other oil-related facilities in the region.

Region 4, **Estero Bay**, included San Luis Obispo County and Santa Barbara County north of Point Conception, a relatively sparsely populated region of the coast. There were no offshore oil facilities but an oil well facility at the mouth of the Santa Maria River in southern San Luis Obispo County was in operation for the entire period of our study.

Region 5, **Santa Barbara Channel**, included mainland Santa Barbara County south of Point Conception, mainland Ventura County, Santa Cruz Island, and San Nicolas Island. There were 18 natural oil seeps located along the Santa Barbara county coastline from Point Conception east to Carpentaria, 1 off San Miguel Island, 2 off Santa Cruz Island, and 1 off Anacapa Island (Ventura and Wintz 1971). Numerous mainland onshore and offshore oil facilities existed in this heavily-populated region. Santa Cruz Island is located about 40 km south of the mainland coast and well within the influence of shipping and oil development in the channel. San Nicolas Island is located about 80 km south of Santa Cruz Island and 110 km southwest of the nearest mainland coast in Los Angeles County, well away from most of the human activity associated with the coastline.

Region 6, **Southern California**, included Los Angeles, Orange, and San Diego counties. This heavily populated region had much urban development along the coast. Natural oil seeps known from this region were two on the northwest side of the Palos Verdes Peninsula in Los Angeles County, one in San Pedro Channel between the peninsula and Santa Catalina Island, and two off Santa Catalina Island (Ventura and

Wintz 1971). Numerous onshore and offshore oil facilities occurred in Los Angeles and Orange counties.

The beach on Tomales Bay, Marin County, was not used in any of the regional, seasonal, or annual comparisons. However, to present the data on coverage, species composition, and carcass densities from this beach, Tomales Bay is labeled as a region in Tables 1, 2, 3, and 4.

To summarize and present the data, we defined study years from 1 June to 31 May and divided each study year into three seasons: "fall" from June through October, "winter" from November through February, and "spring" from March through May. These periods roughly correspond to some of the major regional oceanographic events and marine bird activities.

Spring encompassed the beginning of the upwelling period in central California, when northwesterly winds are usually strongest (Lynn 1967, Schwartzlose and Reid 1972). Marine birds breeding locally lay and incubate eggs at this time, and species breeding to the north migrate through the area.

Fall encompassed the end of the upwelling period from June through August, and the warm-water, low-wind period in September and October (Bolin and Abbott 1963). This period included the fall migration of some species breeding to the north, the fledging period of most locally breeding marine species, the time during which species breeding in Mexico and on islands off the southern California coast migrate or disperse north, and the main period of occurrence for several procellariforms that breed in the Southern Hemisphere.

Winter encompassed the period during which the Davidson Current flows northward along the coast, displacing the SE flowing California Current over 80 km offshore (Lynn 1967, Schwartzlose and Reid 1972); this is also the period of intermittent storms. Many locally breeding seabirds and species that breed to the north overwinter during these months.

The study period included several distinct oceanic events, a period of high gill net fishing mortality in two regions, and one major oil spill. From about June 1972 through fall of 1973, from June through December of 1976, and from about June 1982 through February 1984 warm surface water, associated with El Nino-Southern Oscillations, resided along the coast causing anomalous weather patterns and changes in the birds' food resources (Ainley and Boekelheide ms in prep.). From March through June of 1978, warm water encroached into the study area from the Aleutian region, with similar changes in the oceanic resources (Ainley and Boekelheide ms in prep., McLain and Thomas 1983). From spring 1980 through 1983 in Monterey Bay, and in the falls of 1982 to 1985 in the Gulf of the Farallones, a gill net fishery exacted a high mortality in marine birds, many of which washed onto beaches (Wild 1984, 1986; Carter in Appendix B, Heneman in Appendix C). On 31 October 1984, the oil tanker T/V Puerto Rican exploded just outside the Golden Gate. In the subsequent days, the tanker was towed to a point about 17 km south of Southeast Farallon Island, where it broke in half and released approximately 1.5 million gallons of petrochemicals. The ensuing slick moved north to Point Reyes, the Bodega Bay area, and eventually broke up off the Mendocino coast.

METHODS

Field Work

Data were collected from 91 beaches on the California coast between June 1971 and May 1985 (Table 1). The surveys were coordinated by the Point Reyes Bird Observatory (PRBO). Volunteer observers selected beaches for coverage, conducted the surveys, and submitted their results to PRBO. Observers were instructed to select a beach or segment of beach that they would walk once a month. For each beach walk they recorded the date and the extent of oil or tar found on the beach. As they walked the beach, they searched for carcasses or ailing beached marine birds. For each bird found they recorded the species, degree of decomposition, any evidence of cause of death, presence of oil on the plumage, age, sex, color phase, and subspecific identity, if known. Identifications of carcasses were facilitated by a manual prepared specifically for that purpose (Ainley et al. 1980), but before it was available observers used standard avian field guides to birds (eg. Peterson 1961) for common species and sent difficult-to-identify specimens to PRBO for verification. We suspect some misidentifications of common species such as small loons, small grebes, large cormorants, and large gulls occurred, particularly in early years of the study. Accordingly, we have combined these species in some analyses. Carcasses were removed from the beaches or marked distinctively so that they would not be counted again on subsequent surveys.

Survey frequency varied on different beaches, although censusers were urged to cover their beaches once each calendar month. In cases

Table 1. Summary of total coverage on beaches in California.

REGION=NORTHERN CALIFORNIA

BEACH	COUNTY	KMS WALKED	SURVEYS	MONTHS COVERED	YEARS COVERED
BIG LAGOON	HUMBOLDT	39.2	17	17	3
CENTERVILLE	HUMBOLDT	40.0	15	15	3
CLAM	HUMBOLDT	169.6	53	42	6
DORAN	SONOMA	272.0	80	75	10
GOAT ROCK	SONOMA	25.6	16	16	2
GOLD BLUFF	HUMBOLDT	234.6	23	23	4
JUGHANDLE	MENDOCINO	3.1	31	26	4
MACKERRICHER	MENDOCINO	33.6	21	21	4
MAD RIVER, NORTH	HUMBOLDT	58.4	37	37	5
MAD RIVER, SOUTH	HUMBOLDT	48.0	30	30	4
MANCHESTER	MENDOCINO	68.6	74	68	9
PELICAN	DEL NORTE	86.4	27	24	3
SALMON CREEK	SONOMA	221.1	62	56	9
SONOMA COAST (GUALALA)	SONOMA	53.2	38	38	5
TRINIDAD	HUMBOLDT	5.2	4	4	1
WRIGHTS	SONOMA	35.2	16	16	2

REGION=GULF OF THE FARALLONES

BEACH	COUNTY	KMS WALKED	SURVEYS	MONTHS COVERED	YEARS COVERED
ANO NUEVO	SAN MATEO	208.8	29	10	3
BOLINAS	MARIN	318.6	118	93	13
CRONKHITE	MARIN	144.0	160	151	14
DILLON	MARIN	202.4	92	83	11
DOUBLE POINT	MARIN	297.5	85	71	8
DRAKES	MARIN	81.6	34	23	5
EDGEMAR	SAN MATEO	29.9	23	20	3
FORT POINT	SAN FRANCISCO	102.4	64	62	8
HALF MOON BAY, NORTH	SAN MATEO	259.2	81	75	11
HALF MOON BAY, SOUTH	SAN MATEO	117.1	32	31	5
LIMANTOUR	MARIN	860.7	151	120	13
LINDA MAR	SAN MATEO	20.8	16	12	3
MONTARA	SAN MATEO	33.6	21	16	3
MUIR	MARIN	137.0	274	160	15
OCEAN	SAN FRANCISCO	480.0	150	146	14
PESCADERO	SAN MATEO	111.6	62	50	8
POINT REYES, A	MARIN	331.8	79	64	10
POINT REYES, B	MARIN	79.3	13	11	3
POINT REYES, C	MARIN	42.0	14	13	3
POINT REYES, D	MARIN	59.8	13	12	3
RCA	MARIN	686.8	194	133	15
SEADRIFT	MARIN	744.9	191	151	15
SHARP PARK	SAN MATEO	64.5	43	40	9
STINSON	MARIN	25.2	18	18	2
THORNTON	SAN MATEO	238.8	110	97	12

Table 1, continued (page 2 of 3).

REGION=TOMALES BAY

BEACH	COUNTY	KMS WALKED	SURVEYS	MONTHS COVERED	YEARS COVERED
CYPRESS GROVE	MARIN	88.5	59	55	8

REGION=MONTEREY BAY

BEACH	COUNTY	KMS WALKED	SURVEYS	MONTHS COVERED	YEARS COVERED
DAVENPORT, EAST	SANTA CRUZ	51.5	103	87	8
DAVENPORT, WEST	SANTA CRUZ	5.0	10	9	1
DEL MONTE	MONTEREY	225.6	141	116	12
JETTY	MONTEREY	173.6	109	103	11
LAGUNA CREEK	SANTA CRUZ	109.2	156	93	8
MAJORS CREEK	SANTA CRUZ	78.8	99	81	8
MARINA	MONTEREY	381.1	59	59	9
PAJARO DUNES	SANTA CRUZ	364.0	182	162	14
RIO DEL MAR	SANTA CRUZ	176.0	88	86	8
SALINAS RIVER	MONTEREY	8.0	4	4	1
SCOTT CREEK	SANTA CRUZ	44.8	28	13	2
SEASCAPE-APTOS	SANTA CRUZ	98.4	82	81	10
SEASIDE	MONTEREY	56.6	50	50	5
SUNSET	SANTA CRUZ	271.2	113	64	6
WILDER	SANTA CRUZ	83.2	104	61	6
YELLOW BANK CREEK	SANTA CRUZ	82.6	118	90	8
ZMUDOWSKI	MONTEREY	57.6	32	31	5

REGION=ESTERO BAY

BEACH	COUNTY	KMS WALKED	SURVEYS	MONTHS COVERED	YEARS COVERED
ATASCADERO	SAN LUIS OBISPO	84.6	94	90	10
CAMBRIA	SAN LUIS OBISPO	271.8	151	151	14
HAZARD CREEK	SAN LUIS OBISPO	253.5	96	93	11
MORRO BAY	SAN LUIS OBISPO	201.4	38	38	5
PURISIMA POINT	SANTA BARBARA	158.4	22	22	6
SAN SIMEON	SAN LUIS OBISPO	46.8	26	16	3

REGION=SANTA BARBARA CHANNEL

BEACH	COUNTY	KMS WALKED	SURVEYS	MONTHS COVERED	YEARS COVERED
ARROYO BURRO	SANTA BARBARA	124.8	78	64	6
DEVERAUX	SANTA BARBARA	121.9	53	40	4
LAS VARAS RANCH	SANTA BARBARA	118.4	37	33	4
MCGRATH	VENTURA	134.4	28	28	5
MUGU ROCK	VENTURA	120.0	25	25	3
PITAS POINT (FARIA)	VENTURA	54.4	32	29	4
POINT MUGU	VENTURA	134.4	24	24	3

Table 1, continued (page 3 of 3).

REGION=SANTA BARBARA CHANNEL

BEACH	COUNTY	KMS WALKED	SURVEYS	MONTHS COVERED	YEARS COVERED
SAN NICHOLAS I, SN 1B	SANTA BARBARA	20.7	23	23	3
SAN NICHOLAS I, SN 4B	SANTA BARBARA	27.6	23	23	3
SAN NICHOLAS I, SN 6B	SANTA BARBARA	14.7	21	21	3
SAN NICHOLAS I, SN 8B	SANTA BARBARA	62.4	24	24	3
SAN NICHOLAS I, SN13B	SANTA BARBARA	22.5	23	23	3
SANTA CRUZ I, SC-NORTH	SANTA BARBARA	82.8	23	23	3
SANTA CRUZ I, SC-SOUTH	SANTA BARBARA	94.0	20	20	3
SANTA CRUZ I, SC-WEST	SANTA BARBARA	81.6	24	24	3

REGION=SOUTHERN CALIFORNIA

BEACH	COUNTY	KMS WALKED	SURVEYS	MONTHS COVERED	YEARS COVERED
BOLSA CHICA	ORANGE	216.0	48	40	5
BORDER FIELD	SAN DIEGO	104.0	40	40	6
CAMP PENDLETON	SAN DIEGO	382.4	27	23	4
CRYSTAL COVE	ORANGE	72.8	28	25	3
HERMOSA	LOS ANGELES	76.7	59	53	5
HUNTINGTON BEACH	ORANGE	48.3	21	21	2
LEUCADIA	SAN DIEGO	52.8	22	22	2
REDONDO	LOS ANGELES	15.0	5	5	3
SAN ONOFRE BLUFFS	SAN DIEGO	299.7	37	31	3
SILVER STRAND	SAN DIEGO	92.0	23	22	2
TORRANCE	LOS ANGELES	827.0	207	101	9

when a month was missed but two surveys were conducted in either the previous or next month, we assigned the closest of the latter surveys to the month missed. The "assigned" month (in most cases, this was the actual month of the survey) was used in analyses. We defined the coverage on a given beach in a given year to be complete for fall if at least one survey was conducted in (or assigned to) at least four of the five fall months, to be complete for winter if at least one survey was conducted during each of the four winter months, and to be complete for spring if at least one survey was conducted in each of the three spring months.

During the 1984 Puerto Rican oil spill (PROS), biologists and volunteers of PRBO counted and removed all dead birds and any live birds that could be captured, from Marin County beaches between 7 and 11 November 1984. Included among the beaches for which we had daily counts during the PROS were eight beaches with prior data from the 1971-1985 survey project: Bolinas, RCA, Limantour, Drakes, and Point Reyes A, B, C, and D.

Treatment of the Survey Data

We were most interested in examining how seasonal trends, variation between regions, variation between beaches, and variation between years affected the number of carcasses found and the percent of carcasses oiled. However, beached bird data typically are not suited to the standard linear model approach due to the preponderance of zero counts and conspicuous outliers. Further, because of great variability in the coverage of beaches, we were concerned with the potential of confounding the effect of beach with season or year. Given these limitations and the observational nature of the data, we approached the analysis in an exploratory spirit, which is reflected in our presentation of the results. We used rank statistics (medians, 25^{th} and 75^{th} percentiles, maximums, often conditioned on non-zero values), and percent occurrence for most data description. To examine variation in the number of carcasses, we used carcass density, the total number of carcasses (of the species or group in question)/total kms walked.

Differences between regions and between beaches in carcass densities were examined using the entire data set. Comparisons between beaches in the Gulf of the Farallones and Monterey Bay were drawn by examining the proportion of surveys on which taxa were found and, conditional on their occurrence, the median monthly carcass density for each season (see Appendix A).

Seasonal trends, from June through May, in carcass rates were plotted for species that were sufficiently abundant for comparison. For seasonal trends, we compared the total carcasses found/total kms walked each month, using only beaches with complete years of data. Regional differences in seasonal trends were examined by combining the Santa Barbara Channel and Southern California regions (called southern coast on the histograms), combining Estero Bay and Monterey Bay (south-central coast), and presenting the Gulf of the Farallones (Gulf/Farallones) alone; data from the Northern California region were too sparse to plot.

We examined annual variation in carcass densities on beaches north of Point Conception, for those species sufficiently abundant for comparison. Annual comparisons were made by season, using only beaches with complete coverage. For each beach, we calculated the total carcasses/total kms walked for each eligible season and year. The data were presented as box and whisker plots. These plot are designed to display the central 50% of the data within vertically oriented boxes. The remainder of the data appear as whiskers extending vertically from the boxes, with outlying values shown as isolated asterisks. The bottom of the box indicates the 25^{th} percentile; the top, the 75^{th} percentile; and the horizontal midline, the median of the data. The distance between the top and bottom of the box is the inter-quartile range, Q. A distance, 1.5 x Q, above the 75^{th} percentile, the upper fence, is indicated by five dots above the boxes. The upper fence indicates the boundary between the main portion of the data and those values considered outliers. Vertical whiskers extend from the smallest value of the data to the 25^{th} percentile and from the 75^{th} percentile to the largest value of the data less than the upper fence. Data greater than the upper fence are plotted as isolated asterisks.

The location, spread, symmetry, and general shape of the data can be seen from these plots, as well as the approximate proportion of the data comprising zeroes. When a box rests on the horizontal axis, at least 25% of the data are zeroes. When such a box also lacks a median midline, at least 50% of the data are zeroes. When no box is shown, at least 75% of the data are zeroes.

Sample sizes for the box plots tended to be lower prior to 1975-76 than in later years. The number of beaches in fall samples were 3 in 1971, 8 in 1972, 11 in 1973, 7 in 1974, 17 in 1975, 18 in 1976, 21 in

1977, 27 in 1978, 20 in 1979, 29 in 1980, 22 in 1981, 29 in 1982, 30 in 1983, and 18 in 1984. The number of beaches in winter samples were 4 in 1971-72, 9 in 1972-73, 11 in 1973-74, 7 in 1974-75, 16 in 1975-76, 18 in 1976-77, 22 in 1977-78, 20 in 1978-79, 35 in 1979-80, 32 in 1980-81, 18 in 1981-82, 18 in 1982-83, 17 in 1983-84, and 18 in 1984-85. The number of beaches in spring samples were 5 in 1972, 9 in 1973, 12 in 1974, 13 in 1975, 19 in 1976, 17 in 1977, 25 in 1978, 19 in 1979, 30 in 1980, 24 in 1981, 24 in 1982, 23 in 1983, 16 in 1984 and 13 in 1985.

In three cases we altered the values of the maximum densities in order to maintain reasonable scale to the plots. For the plot of all birds in fall 1983 the density 118.0 is plotted as 30.0. For the Red Phalarope in winter 1976-77 the density 11.7 is plotted as 6.0. For the Common Murre in fall 1983 the density 114.8 is plotted as 30.0.

For each taxon or age class found on at least 25% of the beaches surveyed (non-zero 75th percentiles in box plots) in at least 8 of the 14 years (8 taxa in fall, 11 in winter, and 9 in spring) we ranked annual carcass densities by medians and 75th percentiles. Within each season, we then used the maximum, minimum, and median ranks of each year to identify years of higher or lower than usual carcass deposition.

We examined variation in oiling rates (the percent of carcasses oiled) in different regions and on different beaches. We compared beach oiling rates in the six outer coast regions. For each beach, the percent of carcasses that were oiled was calculated for each year in which at least 11 carcasses were found; the median percent for each beach was plotted. Comparisons between selected beaches in the Gulf of the Farallones and Monterey Bay in the percent of carcasses oiled were made for beaches on which at least 11 carcasses were found during completely-covered falls or winters. Data for both comparisons were presented as boxplots.

Comparison of the PROS Results with the Survey Data

We used two estimates of the number of beached birds resulting from the PROS: 1) birds that were visibly oiled, and 2) visibly-oiled plus non-visibly oiled birds. The latter approach seemed justified because we suspected that at least some of the large number of seemingly non-oiled birds, beaching with the visibly oiled ones were disabled or killed after ingesting oil or were so thinly coated with lighter lube oil or dispersant that censusers could not detect it. The latter case is supported by the comments of censusers who reported difficulty in detecting a thin coating of light oil on some birds. We subtracted 7 Common Murres and 2 Western Grebes found on 8 November because either their state of decomposition was too great for them to have died recently or because they obviously had been killed by other causes. We included live oiled and non-oiled birds that were not removed from beaches in descriptions of daily beaching numbers but excluded them from the total number of birds beached between 7 and 11 November, unless they could not be accounted for in the numbers of birds found on the next day on the same or adjacent beaches.

We compared the magnitude of mortality from the PROS with previous, 1971 to 1983, levels for each species on each beach by dividing the mean daily carcass rate during the early phase of the PROS by daily deposition rates for prior years. We compared PROS daily rates for each beach with usual levels (median ratios) using median daily deposition rates from the previous surveys, and with other high deposition periods (maximum ratios) using maximum daily deposition rates. Median and maximum rates of 0.00 were assigned rates of 0.05 in these ratios. To estimate the number of days of deposition that would have been required under "usual" conditions to account for the number of birds that beached in the initial five days of the PROS, we multiplied the median of the median ratios by five, for each species.

For the PROS, the daily rate was calculated as the total number of beached birds of each taxa divided by the number of days that censuses were conducted on a specific beach after birds started coming ashore (7 November for Common Murres and 8 November for loons and Western/Clark's Grebes). PROS rates were calculated only for Common Murre, loons, and Western/Clark's grebes, the most numerous bird taxa found on beaches during the PROS (PRBO 1985). The loons included Common, Arctic, Red-throated and unidentified loons.

To obtain daily deposition estimates from the monthly data collected between 1971 and 1983 we used a model of carcass deposition and disappearance. This model assumes that birds are deposited on beaches between surveys at a random but constant rate (a) and disappear from those beaches at a rate proportional to the number present (bN). If N is the number of carcasses present on a beach then $dN/dt = a - bN$. If carcasses are removed from beaches at the time of each survey and t is measured from the time of the previous survey, then, by solving the above differential equation for t and rearranging:

$$a = (bN) / (1 - \exp(-bt)),$$

where a = the daily deposition rate since the previous survey,

b = the carcass disappearance rate,

N = the number of carcasses found on the current survey,

and t = the number of days since the previous survey.

We used estimates of b from data collected on daily beached bird surveys on Seadrift and Limantour (Marin County) beaches 5 October-3 November 1979, on Seadrift Beach 24 October-23 November 1978 and 23 November-22 December 1977, and from RCA Beach (Marin County) 23 October-21 November 1978, and 31 October-5 December 1980 (Page et al. 1982, unpubl. data). Values for N and t were taken from the 1971-1983 October and November surveys.

RESULTS PART I: 14 YEAR SURVEY PROJECT

Beach Coverage

Coverage varied considerably among the 6 regions and 14 years of study. North of Point Conception coverage was sparsest from 1971-72 to 1974-75, but each year afterwards there were at least 8 beaches with full-year coverage, 17 beaches with complete fall coverage, 16 beaches with complete winter coverage, and 13 beaches with complete spring coverage (Table 2). Overall, coverage peaked in 1979-80 and 1980-81, when there were up to 19 beaches with full-year, 29 with complete fall, 35 with complete winter, and 30 with complete spring coverage; most of those beaches were from the Gulf of the Farallones and Monterey Bay.

No beach in the Northern California region received more than 2 complete years or 12 complete seasons of coverage. The beaches with the greatest coverage were Manchester, Doran, and Salmon Creek (Table 2). There were more than two beaches with complete fall coverage only from 1976 to 1979 and in 1982 and 1983, with complete winter coverage only from 1976-77 to 1980-81, and with complete spring coverage only in 1977, 1978, 1981, and 1983.

In the Gulf of the Farallones, several beaches had at least 3 complete years of coverage: Cronkhite (9), Limantour (3), Muir (11), Ocean (6), RCA (5), and Seadrift (8). Six additional beaches received at least 12 complete seasons of data. The years of highest coverage varied between seasons, although in 1975-76, 1976-77, and 1980-81 at least eight beaches received complete coverage every season. At least eight beaches also received complete fall coverage in 1977,

Table 2. Survey coverage of beaches on the California coast, by year. F indicates complete fall coverage; W, complete winter coverage; S, complete spring coverage; three periods, surveys were conducted but no season completely covered; single period, no surveys conducted.

REGION=NORTHERN CALIFORNIA

BEACH	71-72	72-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85
BIG LAGOON	.	.	.	.	.	.	.	..S	F..	F..	.	.	.	.
CENTERVILLE	.	.	.	.	.	.	.	...	FW.	...	.	.	.	.
CLAM	.	.	.	.	.	.WS	...	FW.	FW.	...	...	.	.	.
DORAN	.	.	.	.	...	FWS	..S	FW.	.W.	.W.	...	..S	F.S	...
GOAT ROCK	.	.	.	.	.	.	.WS	.W.	.	.	.	.	.	.
GOLD BLUFF	.	.	.	.	.	.	.	.	.	...	...	...	...	.
JUGHANDLE	.	..S	FWS	F.S	...	.	.	.	.	.	.	.	.	.
MACKERRICHER	.	.	.	..S	FWS	.	.	.	.	.W.	...	.	.	.
MAD RIVER, NORTH	.	.	.	.	.	.	.	.	.W.	.WS	.W.	F.S	F..	.
MAD RIVER, SOUTH	.	.	.	.	.	.	.	.	.	.WS	.W.	F.S	F..	.
MANCHESTER	.	.	.	.	...	.W.	.W.	F..	FWS	F..	..S	FWS	F..	.
PELICAN	.	.	.	.	.	.	FWS	FW.	.	...	.	.	.	.
SALMON CREEK	..S	F..	.	.	...	FWS	F..	.	.	.WS	F.S	F..	.	...
SONOMA COAST (GUALALA)	.	.	.	.	..S	F.S	FWS	F.S	...	.	.	.	.	.
TRINIDAD	.	.	.	.	.	.	..S	.	.	.	.	.	.	.
WRIGHTS	.	.	.	.	.	.	.WS	F..	.	.	.	.	.	.

REGION=GULF OF THE FARALLONES

BEACH	71-72	72-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85
ANO NUEVO	.	.	.	.	.	...	...	F..	.	.	.	.	.	.
BOLINAS	F..	.	.W.	F..	.WS	.WS	.WS	.	...	FWS	..S	FW.	...	F..
CHONKHITE	..S	FWS	FWS	.WS	FWS	.WS	FWS	FWS	FWS	FWS	FWS	F.S	FW.	FWS
DILLON	.	.	..S	FWS	FW.	.W.	..S	.W.	.WS	FWS	FW.	...	.	...
DOUBLE POINT	.	.	.	.	.	.	.WS	..S	.W.	.WS	F.S	FW.	F.S	..S
DRAKES	.	.	.	.	.	.	.	.	.WS	.W.	.	...	...	...
EDGEMAR	.	F..	FWS	...	.	.	.	.	.	.	.	.	.	.
FORT POINT	.	.	.	.	.	.	..S	F..	FW.	F..	..S	F..	FW.	FWS
HALF MOON BAY, NORTH	...	FWS	...	.WS	..S	FW.	...	.	.	...	.	.WS	FWS	...
HALF MOON BAY, SOUTH	.	.	.	.	.	.	F..	.	.	...	.	.WS	F..	...
LIMANTOUR	.	...	FWS	F.S	FWS	F.S	.WS	F.S	.WS	FWS	..S	.W.	F.S	.WS
LINDA MAR	.	.	.	.	.	.	.	.	...	F..	.	.	...	.
MONTARA	.	.	.	.	.	.	.	.	.	.	.	...	F..	..S
MUIR	FW.	.WS	.WS	FWS	FWS	FWS	FWS	FWS	FWS	FWS	FWS	FWS	FWS	FWS
OCEAN	..S	.WS	FWS	.WS	F.S	F.S	FW.	FWS	FWS	FWS	FWS	F.S	FWS	FW.
PESCADERO	...	...	F..	...	FWS	FWS	F.S	F..	.	.	.	.	.	.
POINT REYES, A	.	.	.	.	.WS	F.S	FW.	.W.	.WS	...	...	F..	...	...
POINT REYES, B	.	.	.	.	.	.	.	.	.WS	...	.	.	.	...
POINT REYES, C	.	.	.	.	.	.	.	.	.WS	...	.	.	.	...
POINT REYES, D	.	.	.	.	.	.	.	.	.WS	...	.	.	.	...
RCA	FW.	FWS	FWS	...	FWS	.W.	...	F.S	FWS	FWS	.WS	F..	...	...
SEACLIFF	.W.	FWS	FWS	...	FWS	F..	F.S	FW.	FWS	FWS	FWS	FW.	FWS	FWS
SHARP PARK	.	.	.	.	..S	FW.	...	...	...	...	.	...	...	...
STINSON	.	.	.	.	.	.	.	.	.WS	FWS	.	.	.	.
THORNTON	.	.	..S	...	.W.	FWS	F.S	F..	.WS	...	..S	F.S	FW.	.W.

REGION=TOMALES BAY

BEACH	71-72	72-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85

Table 2, continued (page 2 of 3).

REGION=MONTEREY BAY

BEACH	71-72	72-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85
DAVENPORT, EAST	.	.	.	.	.	.	FWS	FWS	FWS	FWS	FW.	F.S	FWS	.W.
DAVENPORT, WEST	.	.	.	.	.	.	FW.	.	.	.	.	.	.	.
DEL MONTE	.	.W.	.W.	.	FWS	FWS	FWS	F.S	FWS	FW.	F..	FW.	FW.	FW.
JETTY	.	.	.	..S	F.S	F.S	FW.	F.S	.WS	FWS	FWS	F.S	FW.	F..
LAGUNA CREEK	.	.	.	.	.	.	FWS	FWS	FWS	FWS	FW.	FWS	FW.	FW.
MAJORS CREEK	.	.	.	.	.	.	FWS	FWS	FWS	FWS	F.S	F.S	...	.W.
MARINA	.	...	F..	..S	FWS	.W.	.W.	FW.	...	.W.	.	.	.	.
PAJARO DUNES	.WS	FWS	FWS	FWS	FWS	FWS	FWS	FWS	FWS	FWS	FWS	FWS	FW.	FW.
RIO DEL MAR	.	.	.	.	.	.	..S	FWS	FWS	FWS	FWS	F.S	FWS	FWS
SALINAS RIVER	.	.	.	.	.	.	.	.	.	.W.	.	.	.	.
SCOTT CREEK	.	.	.	.	.	.	.	.	.WS	F..	.	.	.	.
SEASCAPE-APTOS	.	.	.	.	F..	F..	...	.WS	FWS	FWS	FWS	F..	F..	..S
SEASIDE	.	.	.	.	.	.	.	.	.	.W.	FWS	FW.	F..	F.S
SUNSET	.	.	.	.	.	.	.	.	.WS	FW.	F.S	FWS	FWS	FWS
WILDER	.	.	.	.	.	.	.	.	...	FWS	FWS	FWS	FWS	FWS
YELLOW BANK CREEK	.	.	.	.	.	.	FWS	FWS	FWS	FW.	FWS	F.S	..S	FWS
ZMUDOWSKI	.	.	...	...	FWS	.W.	...	.	.	.	.	.	.	.

REGION=ESTERO BAY

BEACH	71-72	72-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85
ATASCADERO	.	.	.	.	...	F.S	..S	FWS	FWS	F..	..S	F.S	FWS	F..
CAMBRIA	..S	FWS	F.S	FWS	FWS	FWS	FWS	FWS	FWS	FWS	FWS	FWS	F..	.W.
HAZARD CREEK	.	.	.	..S	F..	...	F..	...	..S	FWS	F.S	FWS	F.S	FW.
MORRO BAY	.	.	.	.	.	.	.	.	.	..S	F..	.WS	FWS	F..
PURISIMA POINT	.	.	.	.	.	.	.	.	...	...	...	.W.	F.S	...
SAN SIMEON	.	.	.	.	.	.	.	.	.WS	F..	.	.	.	...

REGION=SANTA BARBARA CHANNEL

BEACH	71-72	72-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85
ARROYO BURRO	.	.	.	.	FWS	FWS	FWS	FWS	F..	F.S	.	.	.	.
DEVERAUX	.	.	.	.	FW.	FWS	F..	F..	.	.	.	.	.	.
LAS VARAS RANCH	.	.	.	...	FW.	FWS	FW.	.	.	.	.	.	.	.
MCGRATH	.	.	.	.	...	FWS	F..	F..	...	.	.	.	.	.
MUGU ROCK	.	.	.	.	.	F.S	F.S	F..	.	.	.	.	.	.
PITAS POINT (FARIA)	.	.	.	...	F.S	FWS	F..	.	.	.	.	.	.	.
POINT MUGU	.	.	.	.	.	F.S	FW.	F..	.	.	.	.	.	.
SAN NICHOLAS I, SN 1B	.	.	.	.	..S	.WS	FW.	.	.	.	.	.	.	.
SAN NICHOLAS I, SN 4B	.	.	.	.	..S	.WS	FW.	.	.	.	.	.	.	.
SAN NICHOLAS I, SN 6B	.	.	.	.	..	.WS	FW.	.	.	.	.	.	.	.
SAN NICHOLAS I, SN 8B	.	.	.	.	..S	FWS	FW.	.	.	.	.	.	.	.
SAN NICHOLAS I, SN13B	.	.	.	.	..S	.WS	FW.	.	.	.	.	.	.	.
SANTA CRUZ I, SC-NORTH	.	.	.	.	...	FWS	FW.	.	.	.	.	.	.	.
SANTA CRUZ I, SC-SOUTH	.	.	.	.	...	FWS	F..	.	.	.	.	.	.	.

Table 2, continued (page 3 of 3).

REGION=SOUTHERN CALIFORNIA

BEACH	71-72	72-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85
BOLSA CHICA	.	.	..S	..S	.WS	FWS	FW.	.	.	.	.	.	.	.
BORDER FIELD	.	.	.	.	.	FWS	F..	.	...	F..	...	...	.	.
CAMP PENDLETON	.	.	.	.	..S	FWS	...	...	.	.	.	.	.	.
CRYSTAL COVE	.	.	.	.	..S	FWS	FW.	.	.	.	.	.	.	.
HERMOSA	.	.	.	.	.	F..	FWS	FW.	FW.	F..	.	.	.	.
HUNTINGTON BEACH	.	.	.	.	.	FWS	FW.	.	.	.	.	.	.	.
LEUCADIA	.	.	.	.	.	FWS	FW.	.	.	.	.	.	.	.
REDONDO	.	.	.	.	.	...	...	.	...	.	.	.	.	.
SAN ONOFRE BLUFFS	.	.	.	.	.WS	FWS	FW.	.	.	.	.	.	.	.
SILVER STRAND	.	.	.	.	.	FWS	FW.	.	.	.	.	.	.	.
TORRANCE	.	.	.	FWS	FWS	FWS	FW.	.WS	FWS	FWS	FWS	FWS	.	.

1978, 1982, and 1983; complete winter coverage in 1973-74 and 1979-80; and complete spring coverage in 1974, 1978, 1980, and 1982 (Table 2).

In Monterey Bay, Pajaro Dunes received 11, Rio Del Mar 6, East Davenport, Laguna Creek, Wilder, and Yellow Bank Creek 5, Del Monte and Majors Creek 4, and Seascape-Aptos and Sunset 3 complete years of surveys. All other beaches were surveyed for 2 or fewer complete years (Table 2). Between 1977-78 and 1984-85 there were at least eight beaches with complete fall, six with complete winter, and five with complete spring coverage (Table 2).

In the Estero Bay region, Cambria received 10 and all other beaches 3 or fewer complete years of coverage. Years in which four or more beaches received complete fall coverage were 1980 and 1983; complete winter coverage, 1982-83; and complete spring coverage 1980, 1983, and 1984 (Table 2).

The only southern coast beaches with more than 1 complete year of coverage were Arroyo Burro (Santa Barbara Channel) with 4 and Torrance (Southern California) with 7 years. In 1976-77 there were 18 beaches with full-year coverage, 21 beaches with complete fall coverage, 22 beaches with complete winter coverage, and 24 beaches with complete spring coverage. Complete fall and winter coverage were similarly high in 1977-78 but in all other years was considerably lower (Table 2).

Total Numbers of Carcasses Found

There were 39444 carcasses found during the study, two thirds of which came from the Gulf of the Farallones and Monterey Bay. If we examine the entire data set without making any adjustments for higher north of than south of Point Conception, and higher in Monterey Bay than in the other northern California regions. The total number of carcasses/km walked was 2.9 in each of Northern California, the Gulf of the Farallones, and Estero Bay, 4.5 in Monterey Bay, 1.8 in Santa Barbara Channel, and 1.5 in Southern California. Thus, total carcass density for Monterey Bay was about 1.5 times greater than that of any other region north of Point Conception and almost 3 times greater than regions to the south.

Within regions, total carcass densities for individual beaches in single months varied as shown on page 1 of Appendix A. Using beaches with sample sizes (N) of at least 10, conditional median densities (zero censuses not included) for the Gulf of the Farallones ranged from 0.6 (Fort Point) to 9.3 (Sharp Park) in fall, 0.8 (RCA) to 5.2 (Dillon) in winter, and 0.6 (Double Point) to 4.0 (Muir) in spring (Appendix A, page 1). Similarly, on Monterey Bay conditional median rates ranged from 1.2 (Wilder) to 10.6 (Seaside) in fall, 0.5 (Rio del Mar) to 13.4 (Del Monte) in winter, and 1.0 (Rio del Mar) to 18.8 (Del Monte) in spring. The medians of these medians were highest in both regions in fall (3.2 in the Gulf, 3.8 on Monterey Bay), and lower in winter (2.3 in the Gulf, 2.2 on Monterey Bay) and in spring (1.7 in the Gulf, 2.0 on Monterey Bay).

Regional densities of total birds varied seasonally. Highest total densities of birds occurred during fall in the Gulf of the Farallones, intermittently throughout the year in Monterey and Estero bays (south-central coast), and March through July in the regions south of Point Conception (Fig. 1). High fall densities in the Gulf of the Farallones were related to the timing of highest Common Murre carcass densities central coast), and March through July in the regions south of Point Conception (Fig. 1). High fall densities in the Gulf of the Farallones were related to the timing of highest Common Murre carcass densities there. The intermittent timing of peaks on the south-central coast was related to the large number of species that appeared to prefer Monterey Bay, as discussed below. A possible explanation for the seasonal trend on the southern coast, which we propose below in the species accounts, is that birds in that area that remain behind after the spring exodus experience high mortality.

Carcass densities varied between years on beaches north of Point Conception. In fall, highest median densities occurred in pairs of years: 1972 and 1973; 1975 and 1976; 1980 and 1981; and 1982 and 1983 (Fig. 2). All but the third pair spanned ENSO episodes. High densities in the third pair of years may have been due, in part, to the first years of intense gill net fishing in the Monterey Bay area (Heneman in Appendix C). Years with the highest medians also appeared to be more variable than years with lower medians (except 1971). This indicated that in years of greater deposition, the upward shift of carcass density occurred on only some beaches (Fig. 2). Only in years of lowest density (1979, 1984) were there beaches with full fall coverage on which no birds were found in any month of the fall. Years of high or low winter carcass densities were more difficult to identify than those for fall. Median densities appeared higher in 1971-72, 1975-76, and 1982-83 but lower in 1974-75 than in some other years (Fig. 3). Of these, only the 1982-83 winter was part of an ENSO episode; the other two high density winters preceded ENSO episodes that

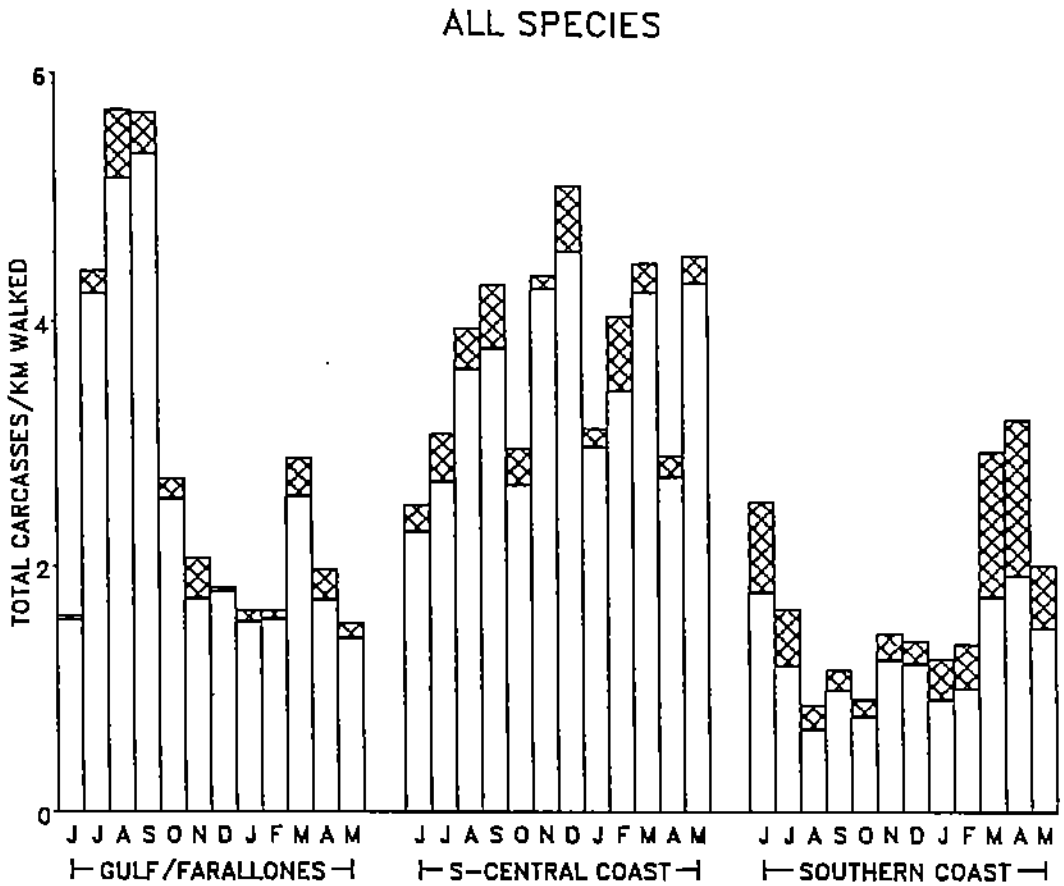

Fig. 1. Monthly (June to May) total carcass densities. Oiled carcasses indicated by cross-hatched portions of bars. See methods for details.

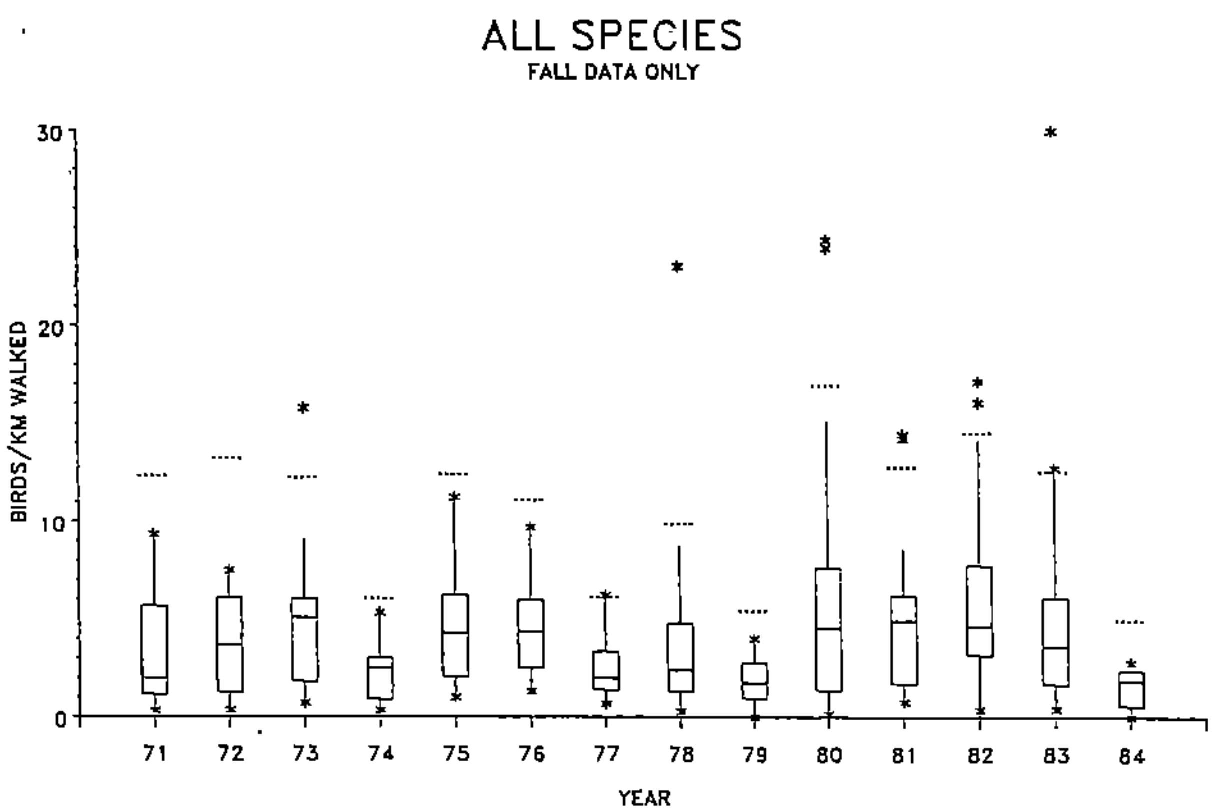

Fig. 2. Annual variation in carcass densities north of Point Conception. See methods for details.

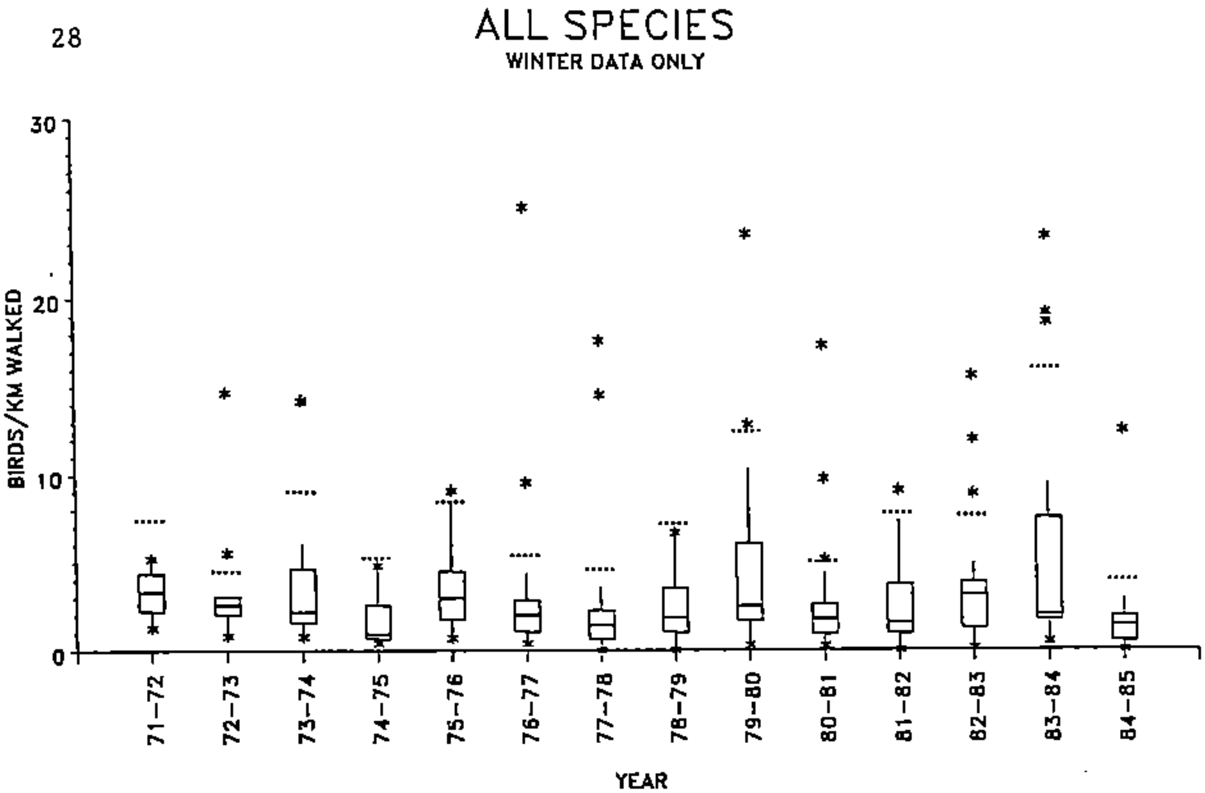

Fig. 3. Annual variation in carcass densities north of Point Conception. See methods for details.

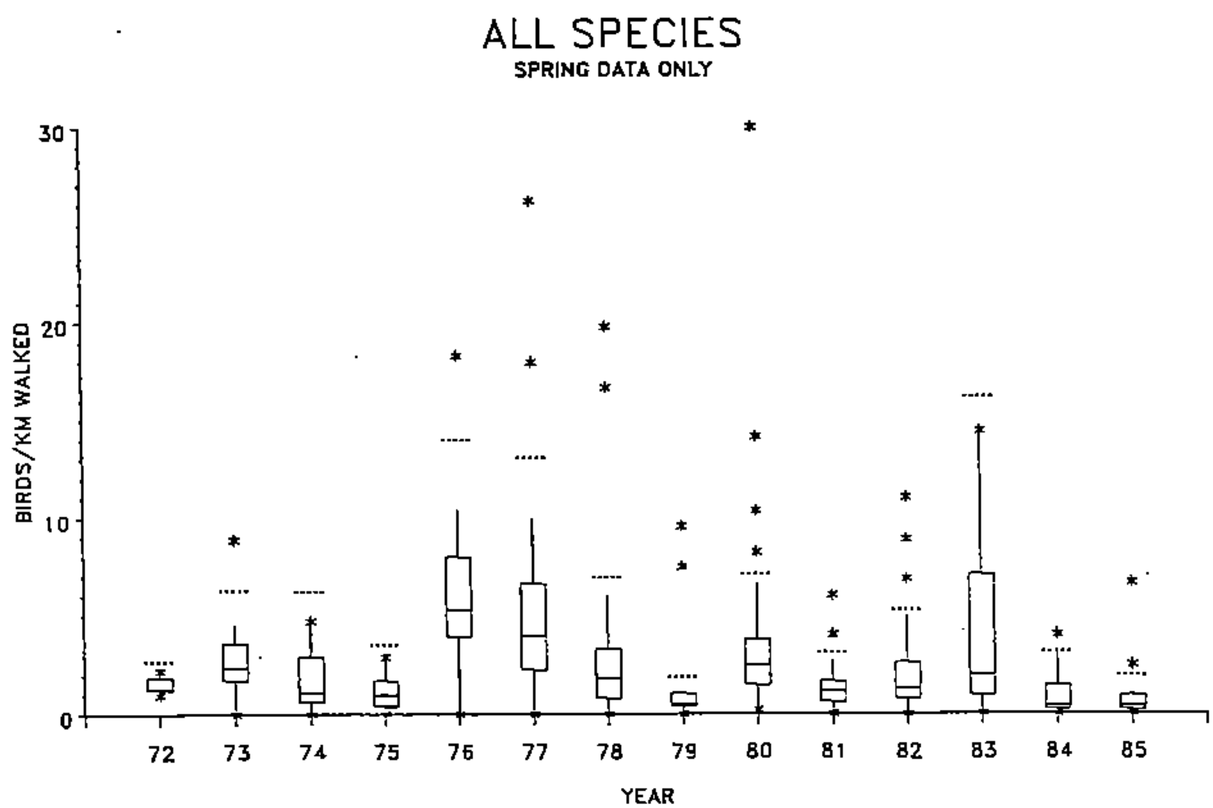

Fig. 4. Annual variation in carcass densities north of Point Conception. See methods for details.

began the following Junes. Carcass densities in spring were highly variable between years. In 1976 and 1977 median densities were noticeably higher than in other years; for these years, and 1983, the variability of densities was greater than in others (Fig. 4). Years of relatively low median density were 1979, 1984, and 1985 (Fig. 4).

Species Composition

Species composition varied among regions, shifting from large alcids and gulls in the north toward large tubenoses and gulls in the south. In Northern California and the Gulf of the Farallones at least half of the carcasses comprised large alcids and gulls (Table 3). In Tomales Bay, the only shoreline surveyed within an enclosed bay, over half of the carcasses were scoters (Table 3). In Monterey Bay at least half of the carcasses were large alcids, large tubenoses, and gulls; in Estero Bay at least half were large alcids, large grebes, cormorants, large tubenoses, and gulls (Table 3). At least half of the carcasses in the Santa Barbara Channel region comprised large tubenoses, gulls, and large alcids, and in the Southern California region large tubenoses and gulls (Table 3).

Of the 20 commonest species, the regions with the highest densities for each species included Northern California for 3, the Gulf of the Farallones for 4, Monterey Bay for 15, Estero Bay for 7, Santa Barbara Channel for 1, and Southern California for 3 species. Thus, high total carcass density in Monterey Bay is caused by higher densities for many rather than a few species. Highest overall densities of White-winged Scoter occurred in Northern California; Common Murre and Western Gull,

Table 3. Species group composition of the outer coast regions and Tomales Bay. See species account for species composition of the groups. Pct is percent.

	NORTHERN CALIFORNIA		GULF OF THE FARALLONES		TOMALES BAY		MONTEREY BAY		ESTERO BAY		SANTA BARBARA CHANNEL		SOUTHERN CALIFORNIA	
	REGIONAL TOTAL	PCT OF REGION	REGIONAL TOTAL	PCT OF REGION	REGIONAL TOTAL	PCT OF REGION	REGIONAL TOTAL	PCT OF REGION	REGIONAL TOTAL	PCT OF REGION	REGIONAL TOTAL	PCT OF REGION	REGIONAL TOTAL	PCT OF REGION
LOONS	171	4.2	453	2.8	18	7.1	485	4.7	275	9.3	194	8.7	200	6.2
LARGE GREBES	401	9.8	1271	7.7	22	8.7	861	8.4	510	17.2	274	12.3	234	7.3
SMALL GREBES	60	1.5	136	0.8	1	0.4	173	1.7	96	3.2	106	4.8	129	4.0
LARGE TUBENOSES	325	7.9	1322	8.0	.	.	1516	14.8	302	10.2	491	22.1	1062	33.1
STORM PETRELS	16	0.4	34	0.2	.	.	38	0.4	2	0.1	1	0.0	7	0.2
CORMORANTS	259	6.3	1806	11.0	12	4.7	1079	10.5	317	10.7	249	11.2	135	4.2
PELICANS	8	0.2	64	0.4	1	0.4	119	1.2	59	2.0	38	1.7	27	0.8
HERONS & EGRETS	5	0.1	5	0.0	1	0.4	2	0.0	6	0.2	2	0.1	1	0.0
SCOTERS	371	9.1	682	4.1	141	55.5	686	6.7	245	8.3	65	2.9	74	2.3
OTHER WATERFOWL	21	0.5	163	1.0	12	4.7	35	0.3	15	0.5	50	2.3	17	0.5
RAILS & COOTS	15	0.4	89	0.5	3	1.2	13	0.1	3	0.1	10	0.5	4	0.1
PHALAROPES	124	3.0	254	1.5	2	0.8	455	4.4	62	2.1	24	1.1	69	2.2
OTHER SHOREBIRDS	42	1.0	90	0.5	1	0.4	53	0.5	42	1.4	60	2.7	25	0.8
JAEGERS & SKUAS	1	0.0	8	0.0	.	.	5	0.0	2	0.1	1	0.0	8	0.2
GULLS	597	14.6	2328	14.2	19	7.5	1418	13.8	301	10.2	346	15.6	893	27.8
TERNS	4	0.1	7	0.0	1	0.4	11	0.1	2	0.1	3	0.1	5	0.2
LARGE ALCIDS	1606	39.2	7272	44.2	20	7.9	3099	30.2	645	21.8	289	13.0	258	8.0
SMALL ALCIDS	70	1.7	454	2.8	.	.	215	2.1	79	2.7	18	0.8	61	1.9

from Northern California to Monterey Bay; Brandt's Cormorant, in the Gulf of the Farallones and Monterey Bay; Cassin's Auklet, from the Gulf of the Farallones to Estero Bay; Northern Fulmar, Pelagic Cormorant, Surf Scoter, Red Phalarope, California Gull, and Pigeon Guillemot, in Monterey Bay; Arctic Loon, Common Loon, and Brown Pelican, in Monterey and Estero bays; Sooty Shearwater, in Monterey Bay, Santa Barbara Channel, and Southern California; Red-throated Loon and Western/Clark's grebes, in Estero Bay; and Eared Grebe and Black-legged Kittiwake, in Southern California (Table 4).

Species Group Accounts

Below we briefly discuss patterns of carcass occurrence for different species. In Table 4 we present densities, totals, and months of occurrence for all carcasses by region, without adjusting for irregular coverage on some beaches. Regional comparisons are only made for the six outer coast regions, although we do include in some tables data from the one beach on Tomales Bay for completeness. Using only beaches with full years of coverage we present seasonal patterns for the most common species. These patterns are compared to the species' general occurrences in California as derived from Cogswell (1977), Roberson (1980), Garrett and Dunn (1981), Harrison (1983), and Shuford et al. (ms in prep.). We also examine annual densities for the most common species from the beaches with complete coverage in the seasons in which they were most abundant on beaches. Because carcass densities for some species on some beaches are consistently low, it is possible to underestimate carcass densities in years that the sample sizes of

Table 4. Summary of occurrence for all specifically identified carcasses found during the study, by region. Max is maximum number found on any beach in any single month. Months (actual, not assigned; see methods) in which one or more carcasses were found during study indicated by dashed line; double line for Gulf of the Farallones and Monterey Bay added for emphasis.

	Region	Total	Total Birds/km Walked	Max	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Red-throated Loon	N. California	22	0.02	5	-				-	-	-		-	-	-	-
	Gulf/Farallones	112	0.02	4	=	=	=	=		=	=	=	=	=	=	=
	Monterey Bay	78	0.03	5	=		=			=	=	=	=	=	=	=
	Estero Bay	73	0.07	20	-		-			-	-	-	-	-	-	
	S.B. Channel	54	0.04	10	-	-				-	-	-	-	-	-	-
	S. California	56	0.03	8	-	-				-	-	-	-	-	-	-
	Tomales Bay	6	0.07	2								-			-	
Arctic Loon	N. California	87	0.06	7	-	-	-	-	-	-	-	-	-	-	-	-
	Gulf/Farallones	229	0.04	8	=	=	=	=	=	=	=	=	=	=	=	=
	Monterey Bay	246	0.11	14	=	=	=	=	=	=	=	=	=	=	=	=
	Estero Bay	130	0.13	23	-	-	-	-	-	-	-	-	-	-	-	-
	S.B. Channel	86	0.07	8	-	-	-			-	-	-	-	-	-	-
	S. California	115	0.05	33						-	-	-	-	-	-	-
	Tomales Bay	3	0.03	1								-	-		-	
Common Loon	N. California	48	0.03	5	-	-	-		-	-	-	-	-	-	-	-
	Gulf/Farallones	83	0.01	9	=	=	=	=	=	=	=	=	=	=	=	=
	Monterey Bay	152	0.07	8	=	=	=	=	=	=	=	=	=	=	=	=
	Estero Bay	63	0.06	9	-	-			-	-	-	-	-	-	-	-
	S.B. Channel	43	0.02	2	-	-				-	-	-	-	-	-	-
	S. California	25	0.01	3						-	-	-	-	-	-	-
	Tomales Bay	9	0.10	2		-				-	-	-			-	
Yellow-billed Loon	N. California	2	*	1							-	-				
Pied-billed Grebe	Gulf/Farallones	1	*	1					=							
	Monterey Bay	4	*	1						=			=	=	=	
	Estero Bay	1	*	1									-			
	S.B. Channel	3	*	1		-		-		-						
Horned Grebe	N. California	36	0.03	11		-		-		-	-		-	-	-	-
	Gulf/Farallones	55	0.01	5		=				=	=	=	=	=	=	=
	Monterey Bay	33	0.01	2			=	=	=	=	=	=	=	=	=	
	Estero Bay	13	0.01	2	-		-	-	-	-	-		-	-	-	-
	S.B. Channel	12	0.01	2				-			-	-	-	-		-
	S. California	3	*	1						-		-	-			
Red-necked Grebe	N. California	3	*	1		-			-						-	
	Gulf/Farallones	5	*	1						=		=	=			
	Monterey Bay	1	*	1				=								
	Estero Bay	2	*	1							-				-	
Eared Grebe	N. California	9	0.01	3							-	-	-	-	-	
	Gulf/Farallones	40	0.01	5				=	=	=	=	=	=	=	=	
	Monterey Bay	127	0.06	6		=	=	=	=	=	=	=	=	=	=	=
	Estero Bay	74	0.07	9			-	-	-	-	-	-	-	-	-	-
	S.B. Channel	69	0.06	4	-			-	-	-	-	-	-	-	-	-
	S. California	124	0.11	30	-	-		-	-	-	-	-	-	-	-	-

Table 4, continued (page 2 of 11).

	Region	Total	Total Birds/km Walked	Max	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Western/Clark's Grebe	N. California	389	0.28	20	—	—	—	—	—	—	—	—	—	—	—	—
	Gulf/Farallones	1256	0.22	22	—	—	—	—	—	—	—	—	—	—	—	—
	Monterey Bay	860	0.38	20	—	—	—	—	—	—	—	—	—	—	—	—
	Estero Bay	504	0.50	42	—	—	—	—	—	—	—	—	—	—	—	—
	S.B. Channel	273	0.22	12	—	—		—	—	—	—	—	—	—	—	—
	S. California	231	0.11	14	—	—	—		—	—	—	—	—	—	—	—
	Tomales Bay	22	0.25	2	—			—	—	—	—	—	—	—	—	—
Black-footed Albatross	N. California	9	0.01	2	—		—	—							—	
	Gulf/Farallones	13	*	1	—	—	—	—							—	—
	Monterey Bay	6	*	2	—			—								—
Laysan Albatross	N. California	2	*	1				—								—
Northern Fulmar	N. California	275	0.20	50	—		—	—	—	—	—	—	—	—	—	—
	Gulf/Farallones	966	0.17	98	—	—	—	—	—	—	—	—	—	—	—	—
	Monterey Bay	725	0.32	59	—	—	—	—	—	—	—	—	—	—	—	—
	Estero Bay	190	0.19	21	—	—	—	—	—	—	—	—	—	—	—	—
	S.B. Channel	161	0.13	8	—	—	—			—	—	—	—	—	—	—
	S. California	546	0.25	59	—	—	—	—	—	—	—	—	—	—	—	—
Mottled Petrel	Estero Bay	1	*	1										—		
Pink-footed Shearwater	Gulf/Farallones	3	*	1	—		—									—
	Monterey Bay	17	0.01	5	—	—	—		—	—						—
	Estero Bay	3	*	1			—	—		—						
	S.B. Channel	3	*	2			—	—								
	S. California	8	*	2	—	—	—							—		
Buller's Shearwater	N. California	1	*	1					—							
	Gulf/Farallones	1	*	1			—									
	Monterey Bay	3	*	1				—	—				—			
Sooty Shearwater	N. California	35	0.03	3		—	—	—	—	—	—			—	—	—
	Gulf/Farallones	331	0.06	14	—	—	—	—	—	—	—	—	—	—	—	—
	Monterey Bay	740	0.33	35	—	—	—	—	—	—	—	—	—	—	—	—
	Estero Bay	94	0.09	9	—	—	—	—	—	—	—			—		—
	S.B. Channel	313	0.26	36	—	—	—	—	—	—	—	—		—		—
	S. California	502	0.23	66	—	—	—	—	—	—	—	—	—	—	—	—
Short-tailed Shearwater	N. California	2	*	1				—			—					
	Gulf/Farallones	1	*	1						—						
	Monterey Bay	15	0.01	2		—		—		—	—	—	—			—
	Estero Bay	5	*	4							—		—			
Manx Shearwater	Gulf/Farallones	2	*	1	—	—										
	Monterey Bay	1	*	1					—							
	Estero Bay	3	*	3				—								
	S.B. Channel	1	*	1					—							
	S. California	2	*	1				—			—					

Table 4, continued (page 3 of 11).

	Region	Total	Total Birds/km Walked	Max	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Fork-tailed Storm-Petrel	N. California	8	0.01	2												
	Gulf/Farallones	11	*	2												
	Monterey Bay	20	0.01	6												
Leach's Storm-Petrel	N. California	3	*	1												
	Gulf/Farallones	10	*	5												
	Monterey Bay	4	*	1												
	Estero Bay	1	*	1												
	S. California	2	*	1												
Ashy Storm-Petrel	N. California	3	0.01	1												
	Gulf/Farallones	8	*	1												
	Monterey Bay	9	*	3												
	S.B. Channel	1	*	1												
	S. California	1	*	1												
Black Storm-Petrel	Gulf/Farallones	1	*	1												
	Monterey Bay	2	*	1												
	S. California	4	*	1												
Brown Pelican	N. California	8	0.01	1												
	Gulf/Farallones	64	0.01	3												
	Monterey Bay	119	0.05	11												
	Estero Bay	59	0.06	5												
	S.B. Channel	38	0.03	2												
	S. California	27	0.01	2												
	Tomales Bay	1	0.01	1												
Double-crested Cormorant	N. California	30	0.02	3												
	Gulf/Farallones	56	0.01	7												
	Monterey Bay	53	0.02	13												
	Estero Bay	43	0.04	7												
	S.B. Channel	24	0.02	2												
	S. California	32	0.01	5												
	Tomales Bay	2	0.02	2												
Brandt's Cormorant	N. California	132	0.09	10												
	Gulf/Farallones	1360	0.24	33												
	Monterey Bay	736	0.32	44												
	Estero Bay	167	0.16	8												
	S.B. Channel	174	0.17	10												
	S. California	68	0.03	9												
	Tomales Bay	9	0.10	2												
Pelagic Cormorant	N. California	79	0.06	4												
	Gulf/Farallones	299	0.05	7												
	Monterey Bay	263	0.12	23												
	Estero Bay	76	0.07	4												
	S.B. Channel	24	0.02	2												
	S. California	17	0.01	2												

Table 4, continued (page 4 of 11).

	Region	Total	Total Birds/km Walked	Max	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Great Blue Heron	N. California	4	*	2		—	—		—							
	Gulf/Farallones	1	*	1												—
	Estero Bay	4	*	1					—		—	—	—			
	S.B. Channel	2	*	1									—			—
Snowy Egret	Monterey Bay	1	*	1		—										
Cattle Egret	S. California	1	*	1						—						
Black-crowned Night Heron	N. California	1	*	1												—
	Gulf/Farallones	4	*	1			—					—	—			
	Monterey Bay	1	*	1								—				
	Estero Bay	2	*	1			—						—			
	Tomales Bay	1	0.01	1							—					
Tundra Swan	Gulf/Farallones	1	*	1								—				
White-fronted Goose	Gulf/Farallones	1	*	1								—				
Brant	Gulf/Farallones	2	*	1						—					—	
	Monterey Bay	1	*	1								—				
	Estero Bay	4	*	1						—			—	—	—	
	S.B. Channel	1	*	1						—						
	S. California	1	*	1										—		
Green-winged Teal	N. California	1	*	1						—						
	Gulf/Farallones	8	*	4								—	—			
	S.B. Channel	6	*	2				—		—	—	—				
Mallard	Gulf/Farallones	8	*	1			—	—		—	—	—		—		
	Monterey Bay	2	*	1							—			—		
	S. California	1	*	1												—
	Tomales Bay	1	0.01	1						—						
Northern Pintail	N. California	1	*	1												—
	Gulf/Farallones	17	*	3				—	—	—		—		—		
	Monterey Bay	4	*	1				—	—		—		—			
	S.B. Channel	21	0.02	4					—	—	—	—	—			
	S. California	4	*	1					—	—	—			—		
Blue-winged Teal	Monterey Bay	1	*	1					—							
Cinnamon Teal	Gulf/Farallones	1	*	1									—			
	Estero Bay	1	*	1									—			
	S. California	2	*	1			—					—				
Northern Shoveler	Gulf/Farallones	1	*	1								—				
	Monterey Bay	2	*	1								—		—		
	S.B. Channel	7	0.01	2						—	—	—	—			
Gadwall	Gulf/Farallones	1	*	1								—				
	Monterey Bay	1	*	1							—					
	S. California	1	*	1	—											

Table 4, continued (page 5 of 11).

	Region	Total	Total Birds/km Walked	Max	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
American Wigeon	Gulf/Farallones	9	*	1						—	—	—	—			
	Monterey Bay	1	*	1									—			
	Estero Bay	2	*	1								—	—			
	S.B. Channel	2	*	2								—				
Canvasback	N. California	1	*	1					—							
	Gulf/Farallones	7	*	1							—	—	—			
	S.B. Channel	2	*	1						—		—				
Greater Scaup	N. California	2	*	1			—								—	
	Gulf/Farallones	26	*	2							—	—	—	—	—	
	Estero Bay	1	*	1										—		
	Tomales Bay	1	0.01	1									—			
Lesser Scaup	Gulf/Farallones	17	*	2						—	—	—	—	—	—	
	Monterey Bay	1	*	1							—					
	Tomales Bay	2	0.02	2										—		
Oldsquaw	Estero Bay	1	*	1								—				
Black Scoter	N. California	5	*	2								—		—		—
	Gulf/Farallones	10	*	1							—	—	—	—	—	
	Monterey Bay	11	*	2					—			—	—	—	—	—
	Estero Bay	6	0.01	4						—				—	—	
	S. California	2	*	1					—			—				
Surf Scoter	N. California	188	0.13	7	—	—	—	—	—	—	—	—	—	—	—	—
	Gulf/Farallones	452	0.08	22	—	—	—	—	—	—	—	—	—	—	—	—
	Monterey Bay	458	0.20	19	—	—	—		—	—	—	—	—	—	—	—
	Estero Bay	161	0.16	27	—		—		—	—	—	—	—	—	—	—
	S.B. Channel	58	0.05	6	—	—	—		—	—	—	—	—	—	—	—
	S. California	64	0.03	3	—	—			—	—	—	—	—	—	—	—
	Tomales Bay	109	1.23	81						—	—	—	—		—	—
White-winged Scoter	N. California	174	0.12	7	—	—	—	—	—	—	—	—	—	—	—	—
	Gulf/Farallones	179	0.03	5	—	—	—	—	—	—	—	—	—	—	—	—
	Monterey Bay	203	0.09	10	—	—	—	—	—	—	—	—	—	—	—	—
	Estero Bay	71	0.07	9	—	—			—	—	—	—	—	—	—	—
	S.B. Channel	5	*	1					—	—	—	—		—		
	S. California	6	*	2							—	—	—	—		
	Tomales Bay	28	0.32	7					—	—	—	—	—	—	—	
Common Goldeneye	Gulf/Farallones	3	*	1								—	—	—		
Bufflehead	N. Calfornia	2	*	1								—			—	
	Gulf/Farallones	13	*	2							—	—	—			—
	Estero Bay	1	*	1							—					
	Tomales Bay	6	0.07	2								—	—	—		

Table 4, continued (page 6 of 11).

	Region	Total	Total Birds/km Walked	Max	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Red-breasted Merganser	N. California	3	*	1						—	—				—	
	Gulf/Farallones	4	*	1		—					—				—	
	Monterey Bay	10	*	2					—		—			—		
	Estero Bay	2	*	1							—				—	
	S.B. Channel	1	*	1										—		
	S. California	2	*	1					—							—
Ruddy Duck	N. California	5	*	1				—			—	—		—		
	Gulf/Farallones	32	0.01	7					—	—	—	—	—	—	—	—
	Monterey Bay	12	0.01	1					—	—	—	—	—	—		—
	Estero Bay	1	*	1								—				
	S.B. Channel	8	0.01	2					—	—		—		—		
	S. California	4	*	1					—	—						
Virginia Rail	Monterey Bay	1	*	1			—									
Common Moorhen	Monterey Bay	1	*	1									—			
	S. California	1	*	1				—								
American Coot	N. California	15	0.01	4						—	—	—		—		
	Gulf/Farallones	89	0.02	36				—	—	—	—	—	—	—	—	—
	Monterey Bay	11	*	3					—	—	—	—			—	
	Estero Bay	3	*	1						—				—		
	S.B. Channel	10	0.01	2		—		—	—	—		—				
	S. California	3	*	1					—				—		—	
	Tomales Bay	3	0.03	1		—								—	—	
Black-bellied Plover	N. California	3	*	1						—		—	—			
	Gulf/Farallones	8	*	3			—	—		—				—	—	
	Monterey Bay	5	*	1			—		—				—	—		
	Estero Bay	1	*	1									—			
	S.B. Channel	8	0.01	1				—			—	—	—			—
	S. California	1	*	1						—						
Snowy Plover	Gulf/Farallones	1	*	1			—									
	S.B. Channel	2	*	1				—								—
	S. California	1	*	1		—										
Killdeer	Gulf/Farallones	3	*	1		—						—				—
	Monterey Bay	2	*	1								—	—			
	Estero Bay	2	*	1								—			—	
	S.B. Channel	1	*	1				—								
	S. California	2	*	1					—						—	
Black Oystercatcher	Gulf/Farallones	3	*	1		—	—									
	Estero Bay	1	*	1												—
	S.B. Channel	4	*	1		—	—	—						—		
Black-necked Stilt	Monterey Bay	2	*	1									—	—		
American Avocet	Gulf/Farallones	1	*	1										—		

Table 4, continued (page 7 of 11).

	Region	Total	Total Birds/km Walked	Max	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Greater Yellowlegs	S. California	1	*	1											—	
Lesser Yellowlegs	Gulf/Farallones	1	*	1			—									
Willet	N. California	7	0.01	2				—	—		—				—	
	Gulf/Farallones	36	0.01	2			—	—	—	—	—	—	—	—	—	—
	Monterey Bay	15	0.01	3	—		—		—	—	—		—	—		
	Estero Bay	16	0.02	2		—		—	—	—	—	—	—	—	—	
	S.B. Channel	10	0.01	1			—	—	—	—	—	—		—	—	
	S. California	7	*	1					—		—	—		—		
Wandering Tattler	Estero Bay	1	*	1			—									
	S. California	1	*	1						—						
Whimbrel	Monterey Bay	1	*	1		—										
	Estero Bay	1	*	1											—	
Long-billed Curlew	Estero Bay	1	*	1					—							
Marbled Godwit	N. California	3	*	1					—		—		—			
	Gulf/Farallones	10	*	1				—	—	—	—			—		
	Monterey Bay	9	*	2			—			—	—	—	—			—
	Estero Bay	4	*	2						—		—	—			—
	S.B. Channel	2	*	1				—				—				
	S. California	2	*	1						—	—					
	Tomales Bay	1	0.01	1								—				
Ruddy Turnstone	N. California	1	*	1										—		
	Monterey Bay	2	*	1				—								—
Black Turnstone	N. California	1	*	1									—			
	Gulf/Farallones	2	*	1			—							—		
	Monterey Bay	1	*	1								—				
	Estero Bay	2	*	1			—		—							
	S.B. Channel	1	*	1	—											
Surfbird	Gulf/Farallones	1	*	1											—	
Sanderling	N. California	13	0.01	3				—			—					
	Gulf/Farallones	16	*	3				—	—	—	—	—		—	—	
	Monterey Bay	14	0.01	4				—	—	—		—	—	—		
	Estero Bay	6	0.01	2				—		—	—	—	—			
	S.B. Channel	27	0.02	4		—		—	—	—	—	—	—	—		—
	S. Califonia	9	*	2			—	—		—	—	—	—	—		
Western Sandpiper	N. California	2	*	1					—					—		
	Gulf/Farallones	1	*	1					—							
	Monterey Bay	1	*	1											—	
	Estero Bay	3	*	1					—						—	
	S.B. Channel	1	*	1								—				
	S. California	1	*	1												—

Table 4, continued (page 8 of 11).

	Region	Total	Total Birds/km Walked	Max	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Least Sandpiper	N. California	1	*	1									—			
	Gulf/Farallones	1	*	1	—											
Dunlin	N. California	3	*	2											—	—
	Gulf/Farallones	1	*	1							—					
Short-billed Dowitcher	Monterey Bay	1	*	1			—									
	S.B. Channel	1	*	1										—		
Long-billed Dowitcher	S.B. Channel	1	*	1										—		
Wilson's Phalarope	S.B. Channel	1	*	1												—
Red-necked Phalarope	N. California	9	0.01	2				—	—	—	—					—
	Gulf/Farallones	18	0.01	4				—		—	—				—	—
	Monterey Bay	23	0.01	2		—	—	—	—	—	—	—	—		—	—
	Estero Bay	6	0.01	3		—		—		—					—	
	S.B. Channel	8	0.01	2			—	—	—	—	—	—				
	S. California	16	0.01	3		—	—	—	—	—	—					
Red Phalarope	N. California	114	0.08	69					—	—	—	—				—
	Gulf/Farallones	231	0.04	18	—	—		—	—	—	—	—	—			—
	Monterey Bay	390	0.17	126	—	—			—	—	—	—	—	—	—	—
	Estero Bay	55	0.05	18		—			—	—	—	—			—	—
	S.B. Channel	13	0.01	2	—					—	—	—			—	—
	S. California	49	0.02	16			—		—	—	—	—		—	—	—
	Tomales Bay	2	0.02	2					—							
Pomarine Jaeger	Gulf/Farallones	3	*	1								—	—			—
	Monterey Bay	2	*	1	—						—					
	Estero Bay	1	*	1				—								
	S. California	2	*	1						—					—	
Parasitic Jaeger	N. California	1	*	1				—								
	Monterey Bay	1	*	1											—	
	Estero Bay	1	*	1						—						
	S. California	5	*	1					—	—			—			—
Long-tailed Jaeger	Gulf/Farallones	2	*	1				—								
	Monterey Bay	1	*	1				—								
South Polar Skua	Gulf/Farallones	1	*	1				—								
Bonaparte's Gull	N. California	4	*	1		—										—
	Gulf/Farallones	21	*	1	—			—		—	—	—		—	—	—
	Monterey Bay	51	0.02	3	—				—	—	—	—		—	—	—
	Estero Bay	5	*	1						—	—			—		—
	S.B. Channel	8	0.01	1	—					—		—	—	—		
	S. California	25	0.01	2					—	—	—	—	—	—	—	—

Table 4, continued (page 9 of 11).

	Region	Total	Total Birds/km Walked	Max	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Heermann's Gull	N. California	30	0.02	5												
	Gulf/Farallones	131	0.02	5												
	Monterey Bay	97	0.04	11												
	Estero Bay	42	0.04	8												
	S.B. Channel	23	0.02	2												
	S. California	51	0.02	2												
Mew Gull	N. California	15	0.01	3												
	Gulf/Farallones	37	0.01	7												
	Monterey Bay	44	0.02	3												
	Estero Bay	3	*	1												
	S.B. Channel	2	*	1												
	S. California	2	*	1												
	Tomales Bay	2	0.02	2												
Ring-billed Gull	N. California	6	*	1												
	Gulf/Farallones	29	0.01	2												
	Monterey Bay	39	0.02	3												
	Estero Bay	11	0.01	1												
	S.B. Channel	7	0.01	2												
	S. California	40	0.02	3												
California Gull	N. California	42	0.03	4												
	Gulf/Farallones	140	0.02	4												
	Monterey Bay	242	0.11	8												
	Estero Bay	16	0.02	2												
	S.B. Channel	20	0.02	2												
	S. California	112	0.05	5												
	Tomales Bay	1	0.01	1												
Western Gull	N. California	262	0.19	14												
	Gulf/Farallones	1191	0.21	11												
	Monterey Bay	560	0.25	11												
	Estero Bay	145	0.14	8												
	S.B. Channel	170	0.14	6												
	S. California	301	0.14	9												
	Tomales Bay	2	0.02	1												
Glaucous-winged Gull	N. California	40	0.03	4												
	Gulf/Farallones	167	0.03	4												
	Monterey Bay	55	0.02	5												
	Estero Bay	12	0.01	3												
	S.B. Channel	4	*	1												
	S. California	2	*	1												
	Tomales Bay	3	0.03	1												
Glaucous Gull	Gulf/Farallones	1	*	1												
	Monterey Bay	1	*	1												

Table 4, continued (page 10 of 11).

	Region	Total	Total Birds/km Walked	Max	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Black-legged Kittiwake	N. California	57	0.04	10												
	Gulf/Farallones	238	0.04	40												
	Monterey Bay	98	0.04	29												
	Estero Bay	29	0.03	8												
	S.B. Channel	81	0.07	6												
	S. California	288	0.13	32												
Sabine's Gull	Monterey Bay	1	*	1												
Caspian Tern	N. California	2	*	1												
	Gulf/Farallones	3	*	1												
	Monterey Bay	2	*	1												
	S.B. Channel	1	*	1												
	Tomales Bay	1	0.01	1												
Elegant Tern	Monterey Bay	1	*	1												
	S. California	1	*	1												
Common Tern	Monterey Bay	1	*	1												
	S. California	1	*	1												
Arctic Tern	Monterey Bay	1	*	1												
Forster's Tern	Gulf/Farallones	4	*	1												
	Monterey Bay	4	*	1												
	S.B. Channel	1	*	1												
	S. California	3	*	1												
Black Tern	N. California	1	*	1												
Common Murre	N. California	1502	1.08	81												
	Gulf/Farallones	6951	1.22	918												
	Monterey Bay	2756	1.22	50												
	Estero Bay	506	0.50	21												
	S.B. Channel	226	0.19	14												
	S. California	209	0.10	57												
	Tomales Bay	18	0.20	4												
Thick-billed Murre	Monterey Bay	2	*	1												
Pigeon Guillemot	N. California	87	0.06	9												
	Gulf/Farallones	228	0.04	5												
	Monterey Bay	186	0.08	14												
	Estero Bay	53	0.05	6												
	S.B. Channel	7	0.01	2												
	S. California	4	*	1												
	Tomales Bay	1	0.01	1												

Table 4, continued (page 11 of 11).

	Region	Total	Total Birds/km Walked	Max
Marbled Murrelet	N. California	7	0.01	3
	Gulf/Farallones	4	*	1
	Monterey Bay	6	*	3
	Estero Bay	5	*	2
	S.B. Channel	1	*	1
Xantus' Murrelet	Monterey Bay	5	*	1
	Estero Bay	3	*	1
	S.B. Channel	4	*	1
	S. California	12	0.01	3
Craveri's Murrelet	Estero Bay	1	*	1
Ancient Murrelet	N. California	5	*	2
	Gulf/Farallones	101	0.02	14
	Monterey Bay	29	0.01	8
	Estero Bay	1	*	1
	S.B. Channel	3	*	1
	S. California	6	*	2
Cassin's Auklet	N. California	41	0.03	5
	Gulf/Farallones	323	0.06	26
	Monterey Bay	164	0.07	17
	Estero Bay	62	0.06	13
	S.B. Channel	9	0.01	3
	S. California	35	0.02	4
Parakeet Auklet	Monterey Bay	2	*	2
Rhinoceros Auklet	N. California	16	0.01	2
	Gulf/Farallones	77	0.01	7
	Monterey Bay	148	0.07	14
	Estero Bay	85	0.08	12
	S.B. Channel	56	0.05	5
	S. California	43	0.02	8
	Tomales Bay	1	0.01	1
Tufted Puffin	N. California	1	*	1
	Gulf/Farallones	8	*	1
	Monterey Bay	2	*	1
	S. California	1	*	1
Horned Puffin	Gulf/Farallones	8	*	1
	Monterey Bay	5	*	1
	Estero Bay	1	*	1
	S. California	1	*	1

beaches are small. Such small sample sizes prevented us from identifying years of particularly low densities that might have occurred from 1971-72 to 1974-75.

Gaviiforms

Loons, found year round on the surveys, comprised four species, three of which were common. Of those identified, Arctic Loons were the most common in all regions, making up about one half of the total identified loons in each area (Table 4). Using only full years of data, Common and Arctic/Red-throated Loons occurred at greatest frequency on beaches of the south-central coast region, and at least frequency on beaches of the Gulf of the Farallones (Figs. 5, 6). The only two Yellow-billed Loons found on the surveys, from Centerville Beach in November 1979 and Clam Beach in January 1980, (Table 4) are consistent with the October to May occurrence of this species in California (Remsen and Binford 1975).

At least two strong seasonal peaks for the three common loon species were apparent in each region. North of Point Conception, the highest peak usually was in December and the next highest between April and June (Figs. 5, 6). Both of these peaks correspond with the known periods of maximum migratory movement and occurrence along the California coast. Loons are known to winter in California and Mexico waters from November through March, a residency reflected as well by the occurrence of beached carcasses. A third peak in July for Common Loons in the Gulf and possibly on the southern coast occurred when numbers of loons offshore are low. We hypothesize that it represented

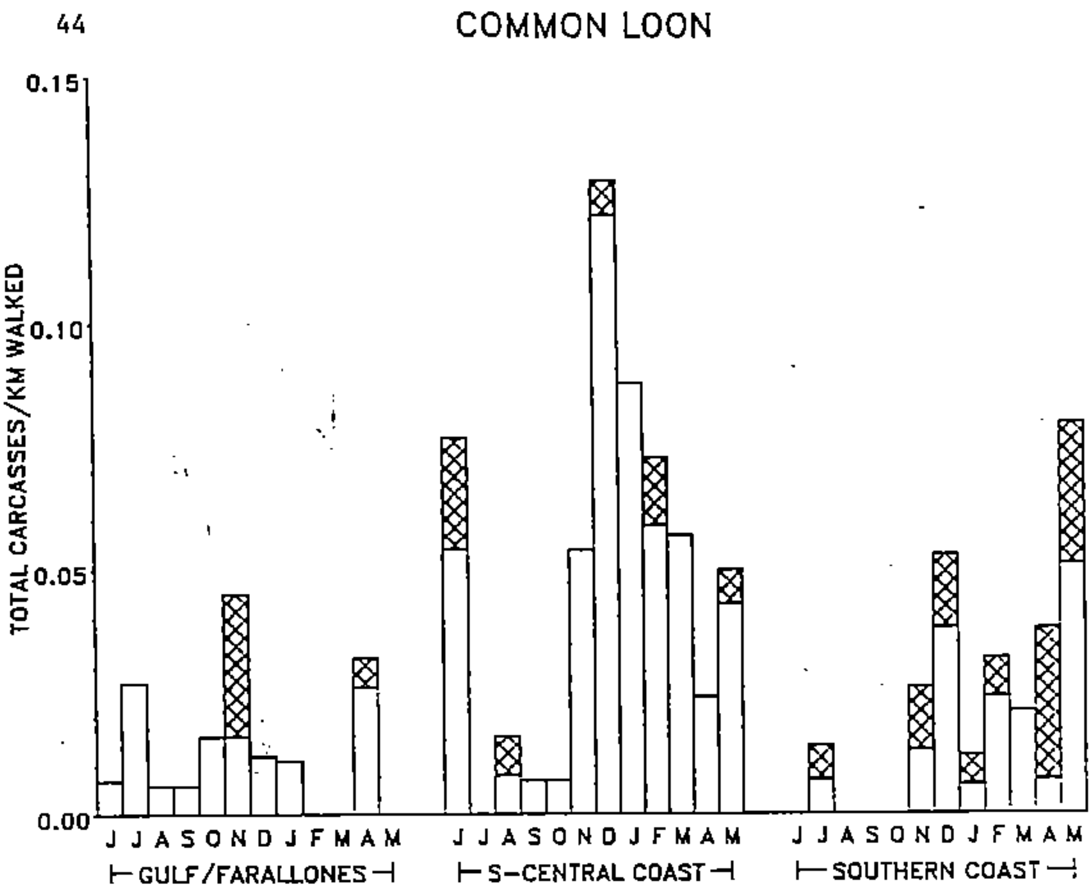

Fig. 5. Monthly (June to May) total carcass densities. Oiled carcasses indicated by cross-hatched portions of bars. See methods for details.

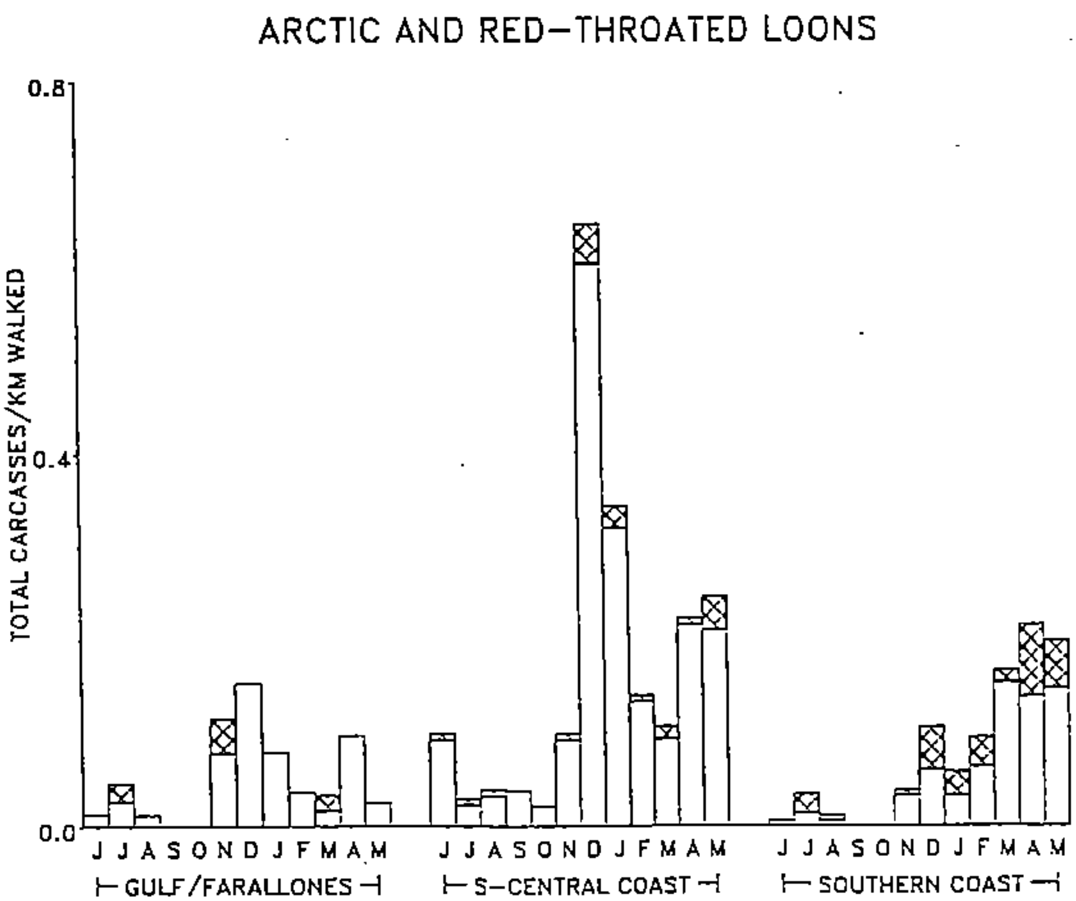

Fig. 6. Monthly (June to May) total carcass densities. Oiled carcasses indicated by cross-hatched portions of bars. See methods for details.

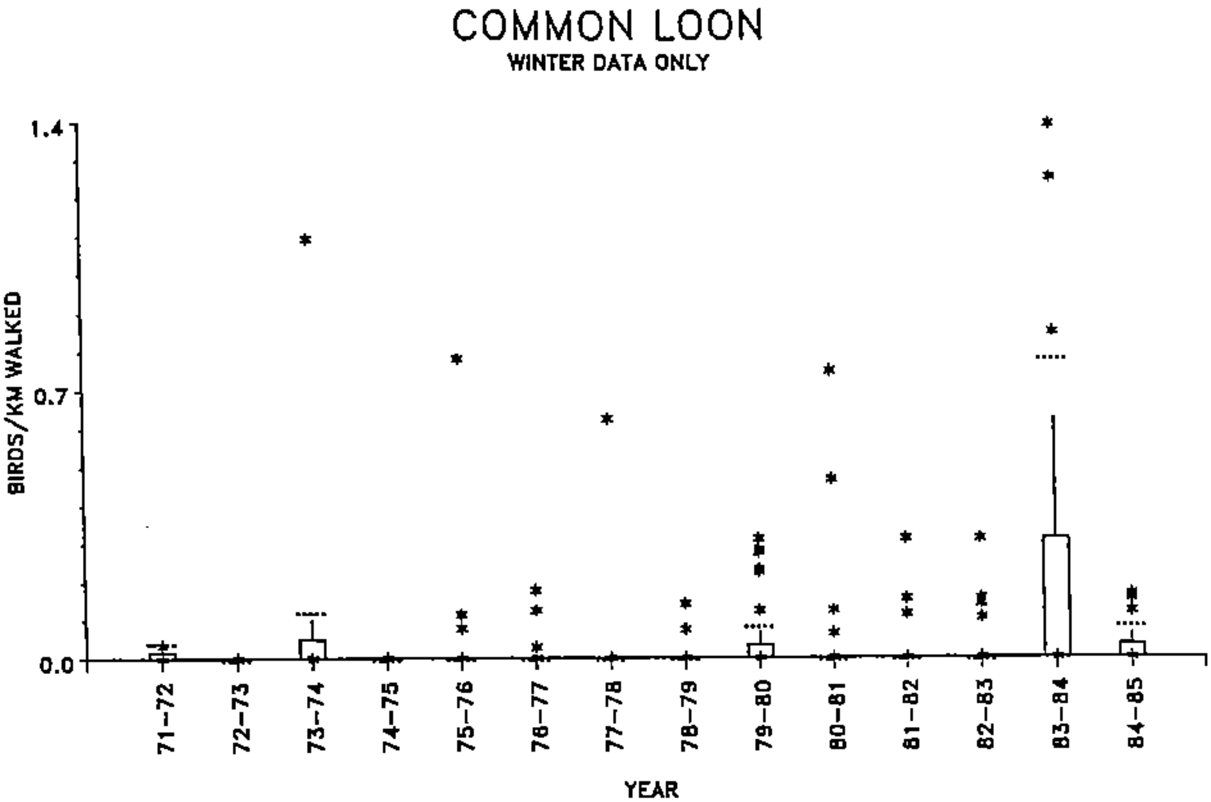

Fig. 7. Annual variation in carcass densities north of Point Conception. See methods for details.

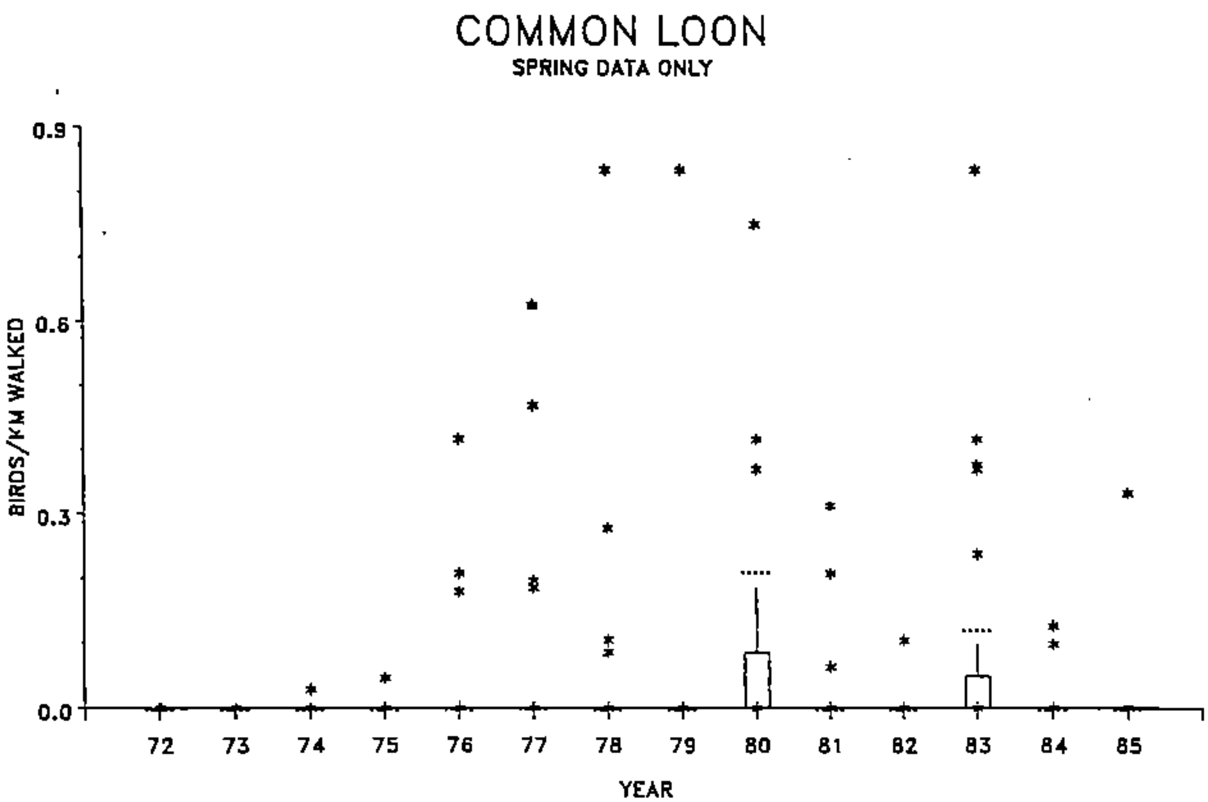

Fig. 8. Annual variation in carcass densities north of Point Conception. See methods for details.

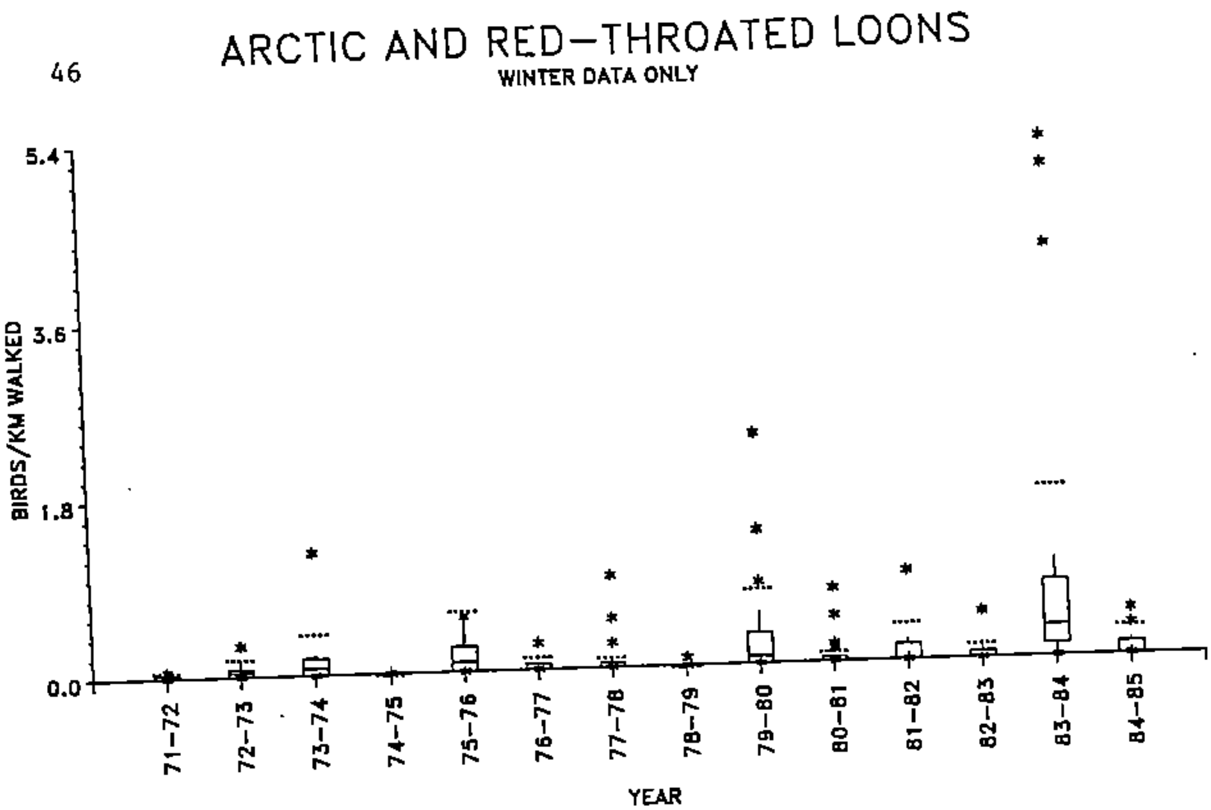

Fig. 9. Annual variation in carcass densities north of Point Conception. See methods for details.

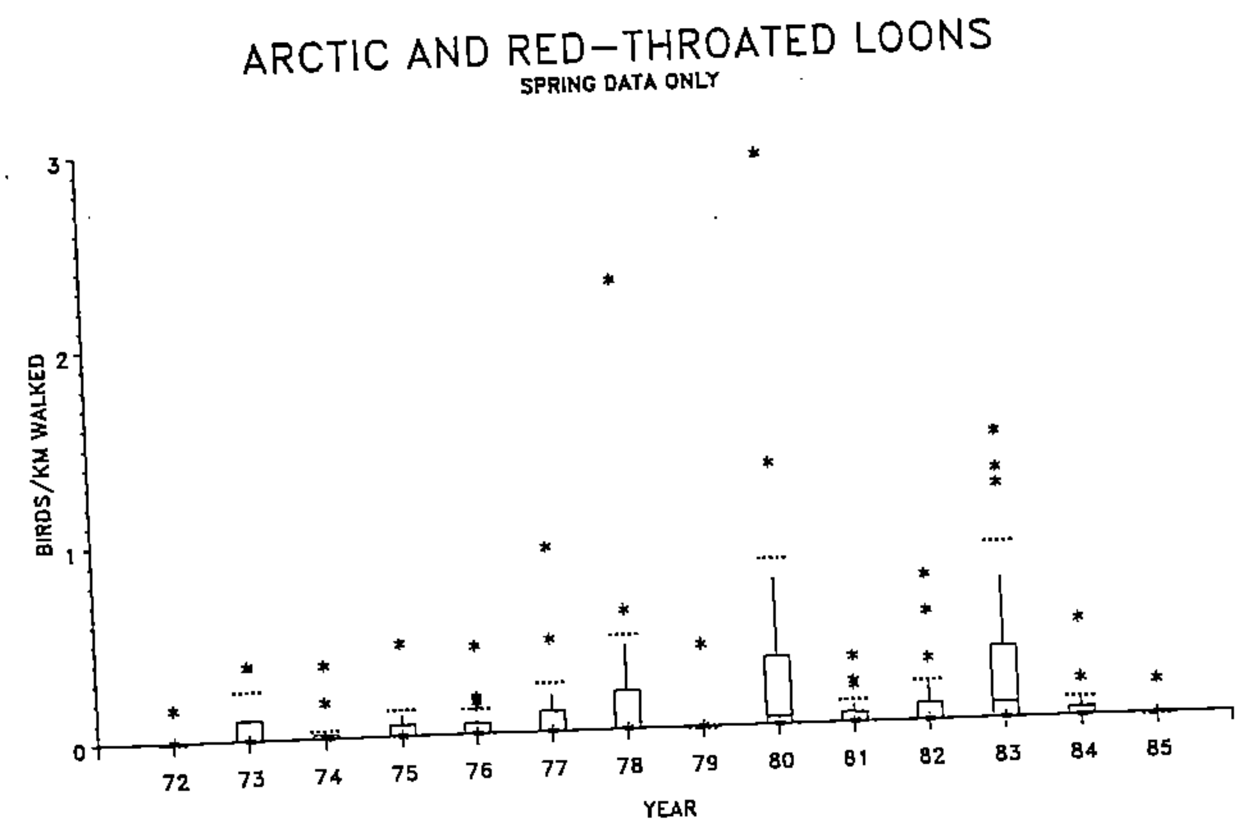

Fig. 10. Annual variation in carcass densities north of Point Conception. See methods for details.

weakened individuals which had remained behind after the spring exodus and subsequently died.

Even in the seasons of highest occurrence, winter and spring, Common Loons were frequently not found on beaches; in no winter or spring did they occur on even half of the beaches with complete coverage (note that median densities were zero in all years in Figs. 7, 8). However, carcasses were more common on beaches in some years than in others (see those years in Figs. 7 and 8 with boxes, indicating occurrence on at least 25% of the beachs). Higher densities in spring 1983 and winter 1983-84 corresponded to the end of the 1982-84 ENSO; higher densities in winter 1973-74 occurred just after the 1972-73 ENSO. It is possible that the prolonged ENSO episodes may claim a higher mortality in the Common Loon. Higher densities in winter 1979-80 and spring 1980 were inexplicable, even though intensive gill netting in Monterey Bay began in that spring. Were gill netting the cause, one would expect most of the non-zero densities to be from Monterey Bay beaches. However, three of the nine beaches with non-zero densities were in Estero Bay and four were from the Gulf of the Farallones, where gill netting was not a problem in spring 1980. The five non-zero densities in winter 1984-85 were from beaches affected by the T/V Puerto Rican oil spill. Years of low apparent mortality could also be identified in winter 1977-78 and spring 1979, 1982, and 1985.

Arctic and Red-throated loon densities were high in the same years that Common Loon densities were highest, but since the former species were more common, it was also possible to identify other years of high density (Figs. 9, 10). In winter, median Arctic and Red-throated loon

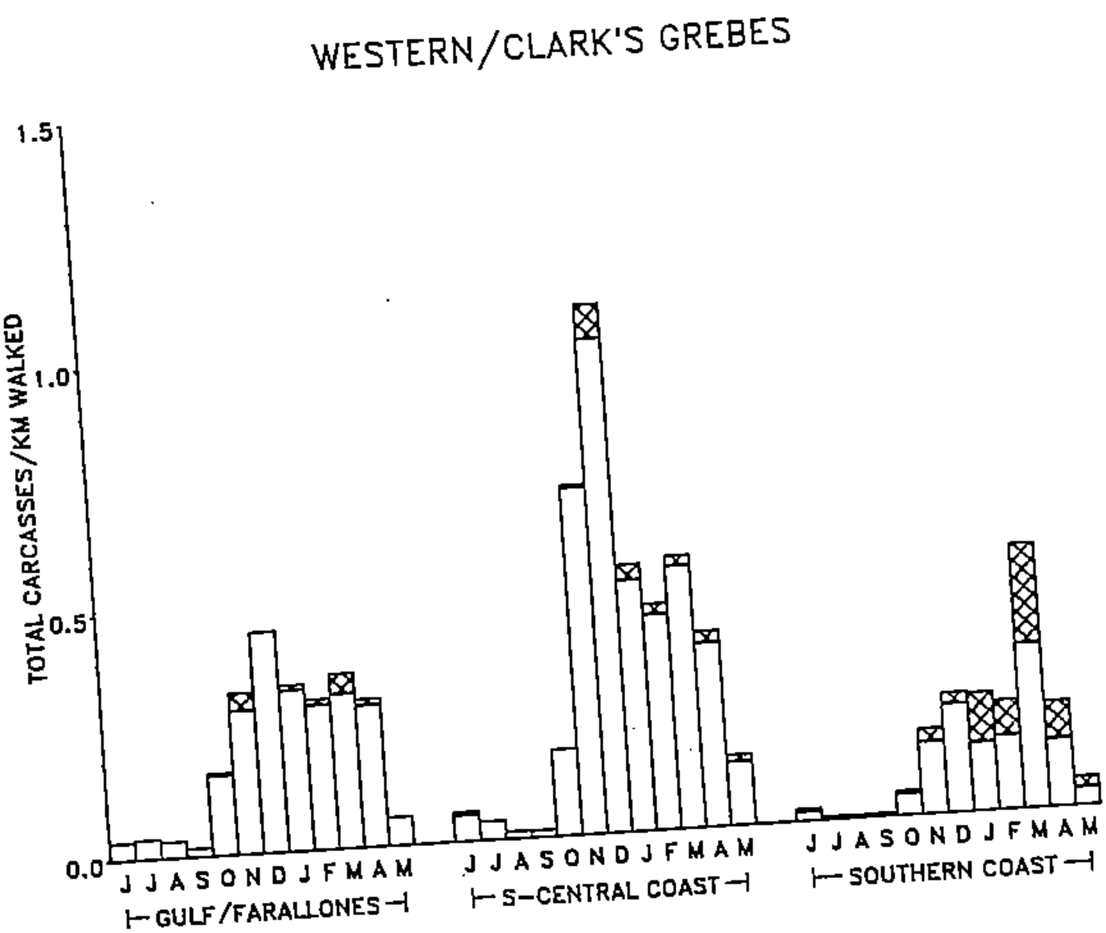

Fig. 11. Monthly (June to May) total carcass densities. Oiled carcasses indicated by cross-hatched portions of bars. See methods for details.

densities were greater than zero in five years (Fig. 9). Densities were highest in 1983-84, as for Common Loons, but as high in 1975-76 as in 1979-80. Densities in 1973-74 and 1972-73 were lower than in the other three high years. Low winter densities occurred in 1978-79. In spring, 1983 and 1980 were the only years in which medians were greater than zero; densities in 1978, during the Aleutian warm-water period, may have been somewhat greater than in other years. Low spring densities occurred in 1979 and 1985.

Podicipediforms

Large grebes, comprising Red-necked Grebes, Western Grebes, and Clark's Grebes, occurred throughout the year in most regions. Only 11 Red-necked Grebes were found on the surveys, all north of Point Conception (Table 4); this is consistent with their known distribution and abundance. Although some observers separated Western and Clark's Grebe (as light and dark phase Western Grebes) before they were distinguished as separate species in 1985 (A.O.U. 1985), the identified proportion is too small to allow us to separate these two species in analyses. From the relative abundance of the live birds and from the identifications of those observers that separated these species on surveys, we know that Western Grebes were much more common than Clark's Grebes on the surveys. Together, the two species made up over 99% of the large grebes found.

Seasonal patterns of occurrence for the Western/Clark's grebes were clear and consistent with their live occurrence. Using only full years of data, Western/Clark's grebes occurred primarily from November through April in all regions; they were encountered with greatest frequency in the south-central region (Fig. 11). Peaks in carcass density occurred on the south-central coast in November and December and on the southern coast in March, but not in the Gulf of the Farallones (Fig. 11). Shuford et al. (ms in prep.) found live Western and Clark's grebes exhibiting migratory peaks at one location but not at another nearby site.

Annual variation in densities during the Western/Clark's grebes' two seasons of greatest abundance was relatively high (Figs. 12, 13). Densities in several winters appeared higher than in others. In the winters of 1971-72, 1972-73, and 1975-76 Western/Clark's grebes were found on every beach with complete coverage and median densities were among those of the highest four years (Fig. 12). In 1983-84 the densities were highly skewed, as indicated by the spread above the median which was much greater than in any other year. Although the median density in 1982-83 was among those of the highest four years, Western/Clark's grebes were absent from at least 25% of the beaches with complete coverage that winter. Densities in 1977-78, 1978-79, and 1984-85 were the lowest of the 14 years. In spring, the location, spread, and symmetry of the densities were quite variable (Fig. 13). In 1973 and 1980, these grebes were found on at least 75% of the beaches and median densities were among those of the highest five years. Median densities were also among those of the highest five years in 1977 and 1983 when these grebes were found on at least 50% of the beaches with complete coverage. Particularly low occurrence was indicated in spring 1979 when they were absent from at least 75% of the

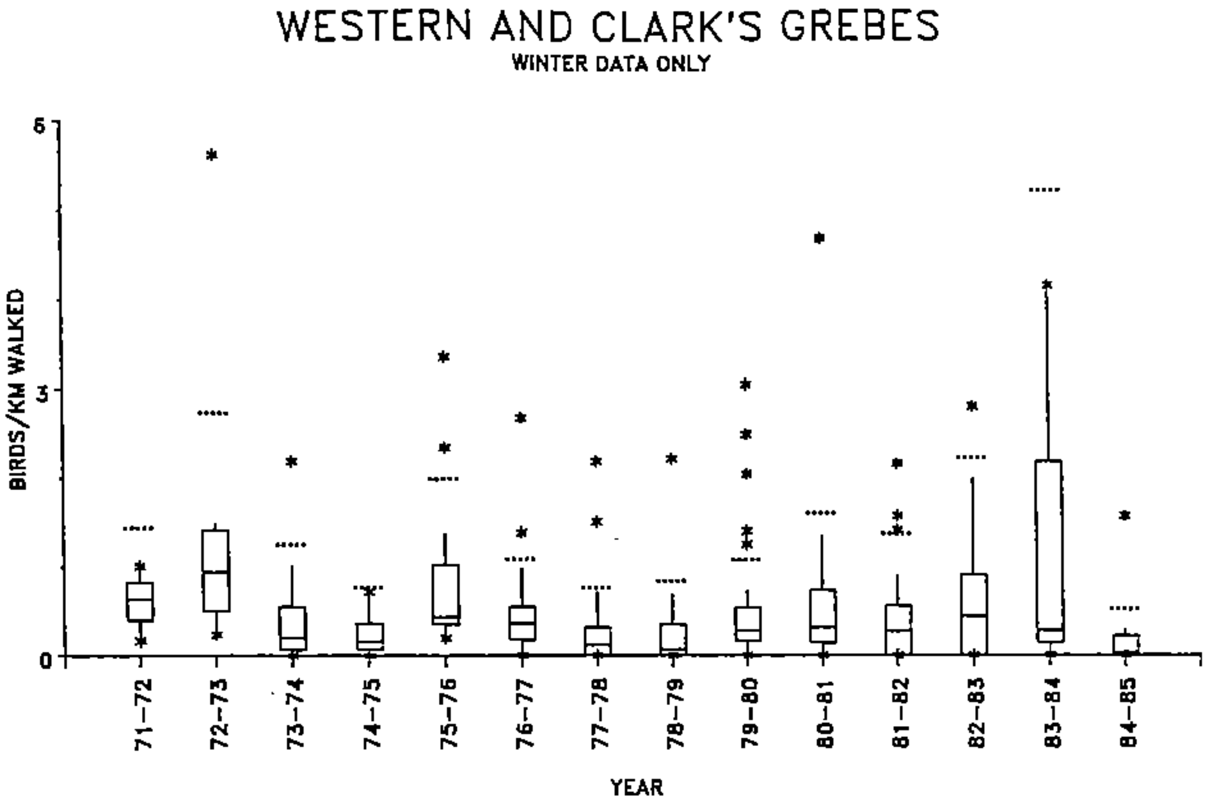

Fig. 12. Annual variation in carcass densities north of Point Conception. See methods for details.

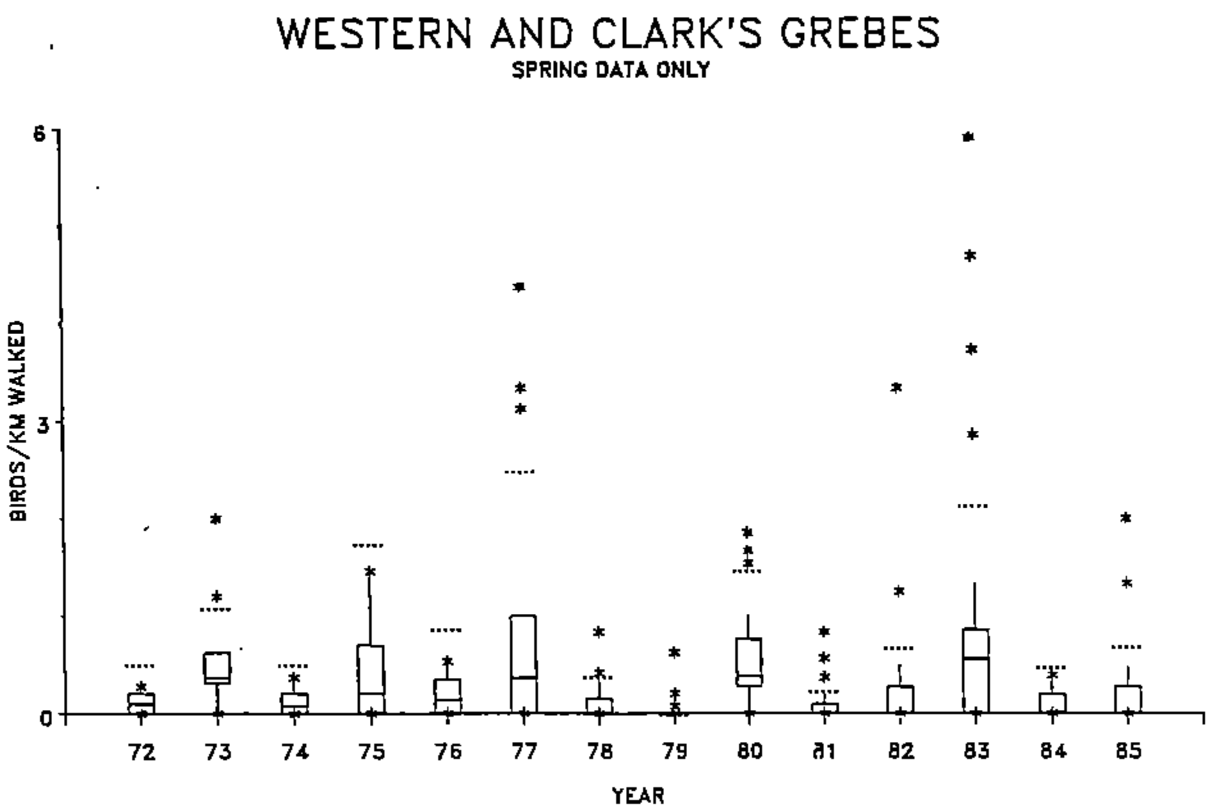

Fig. 13. Annual variation in carcass densities north of Point Conception. See methods for details.

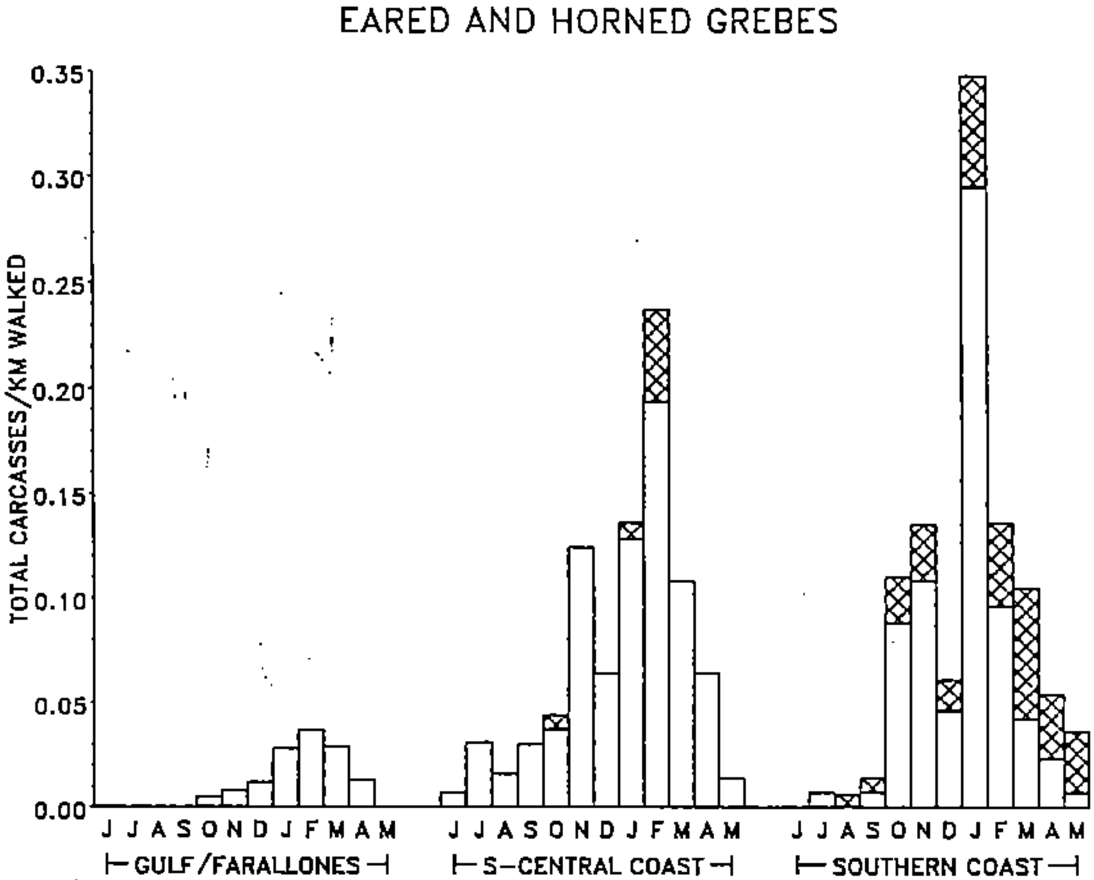

Fig. 14. Monthly (June to May) total carcass densities. Oiled carcasses indicated by cross-hatched portions of bars. See methods for details.

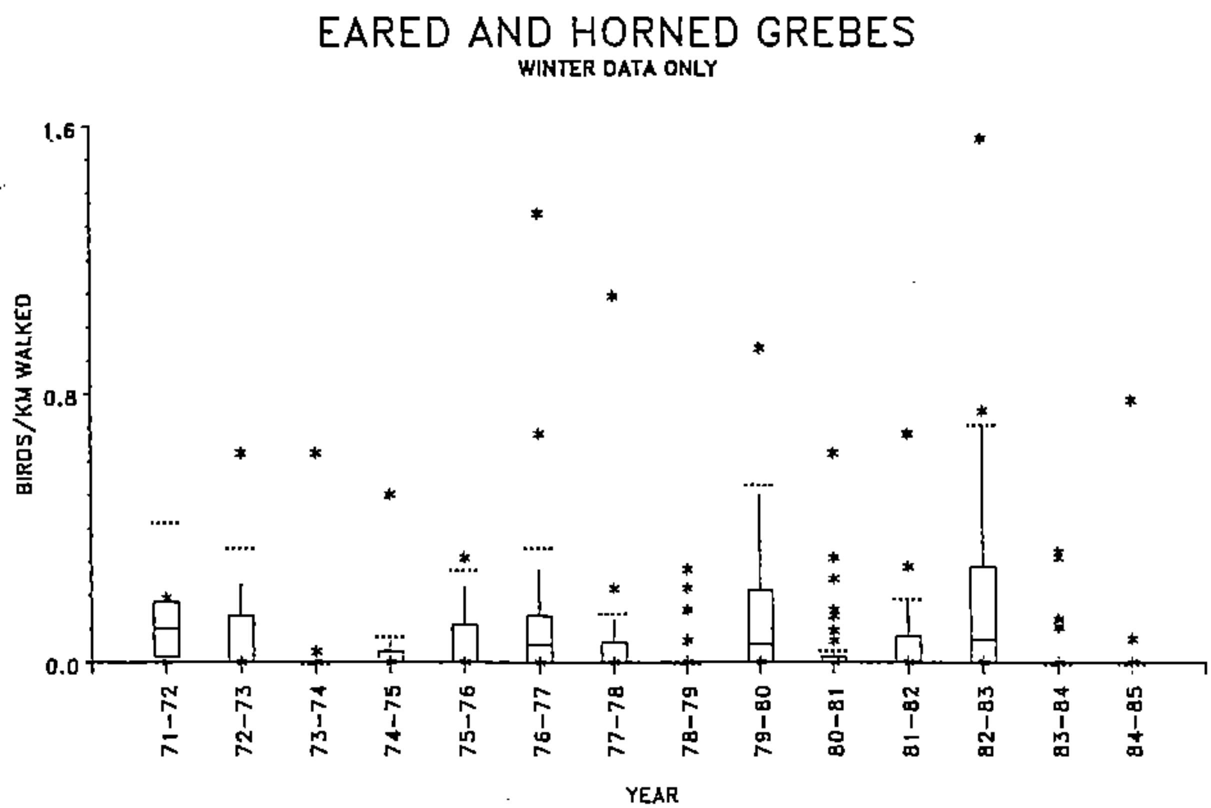

Fig. 15. Annual variation in carcass densities north of Point Conception. See methods for details.

beaches with complete coverage.

Small grebes comprised Pied-billed, Horned, and Eared grebes. Only nine Pied-billed Grebes were found, all between the Gulf of the Farallones and Santa Barbara Channel (Table 4). Almost three quarters of the identified small grebes were Eareds; they were the most common small grebe from Monterey Bay south (Table 4). About one quarter of the identified small grebes were Horneds; they were the most common small grebe in Northern California but were only slightly more common in the Gulf of the Farallones than the Eared Grebe (Table 4). Only Eared and Horned grebes are included in the small grebe graphs.

Since Horned and Eared grebes can be difficult to distinguish, particularly if the head is missing or damaged, we combined these species for seasonal and annual analyses. Using only full years of data, Eared and Horned grebes occurred from October through April in the Gulf of the Farallones, primarily from November through April on the south-central coast, and primarily from October through March on the southern coast (Fig. 14). A depression in density in December, apparent both on the south-central coast and on the southern coast, is suggestive of the passage of two groups of birds (possibly the two species) through those regions.

Annual variability in small grebe densities on beaches with complete coverage was apparent in winter and spring. Densities in the winters of 1971-72, 1976-77, 1979-80, and 1982-83 appeared higher and in 1978-79, 1983-84, 1984-85 lower than other years (Fig. 15). In spring, only 1977 densities were notably high; in all other years except 1980 these grebes were absent from at least 75% of the beaches with complete coverage (Fig. 16).

Procellariiforms

Large tubenoses comprised albatrosses, Northern Fulmar, Mottled Petrel, and shearwaters. Fulmars and Sooty Shearwater made up 98% of the identified large tubenoses. Fulmars were more common than Sooty Shearwaters in Northern California, Gulf of the Farallones, and Estero Bay; Sooty Shearwaters more common than fulmars south of Point Conception; and the two species were about equally common in Monterey Bay (Table 4).

Northern Fulmars occurred on beaches primarily from November to March in the Gulf and on the south-central coast, and in November, December, and from February to July on the southern coast (Fig. 17). The occurrence period on southern coast beaches likely reflect a lesser degree of residence of this species in that region than in the others. As with the loon pattern, we believe the summer peak in June and July on the southern coast is a consequence of higher mortality rates among weak individuals, which remained behind after the exodus north. The large majority of these summer-occurring fulmars had exceedingly abraded and faded plumage, giving the impression to the uneducated eye that they were light color morphs. Densities in the winters of 1971-72, 1975-76, 1976-77, and 1983-84 appeared notably higher and in 1978-79 and 1982-83 lower than in other years (Fig. 18). The extreme March peak in the Gulf and south-central coast regions (Fig. 17) was an artifact of a spectacular die-off of this species during 1976 (Fig. 19, Harrington-Tweit 1979). Other years in which spring densities were

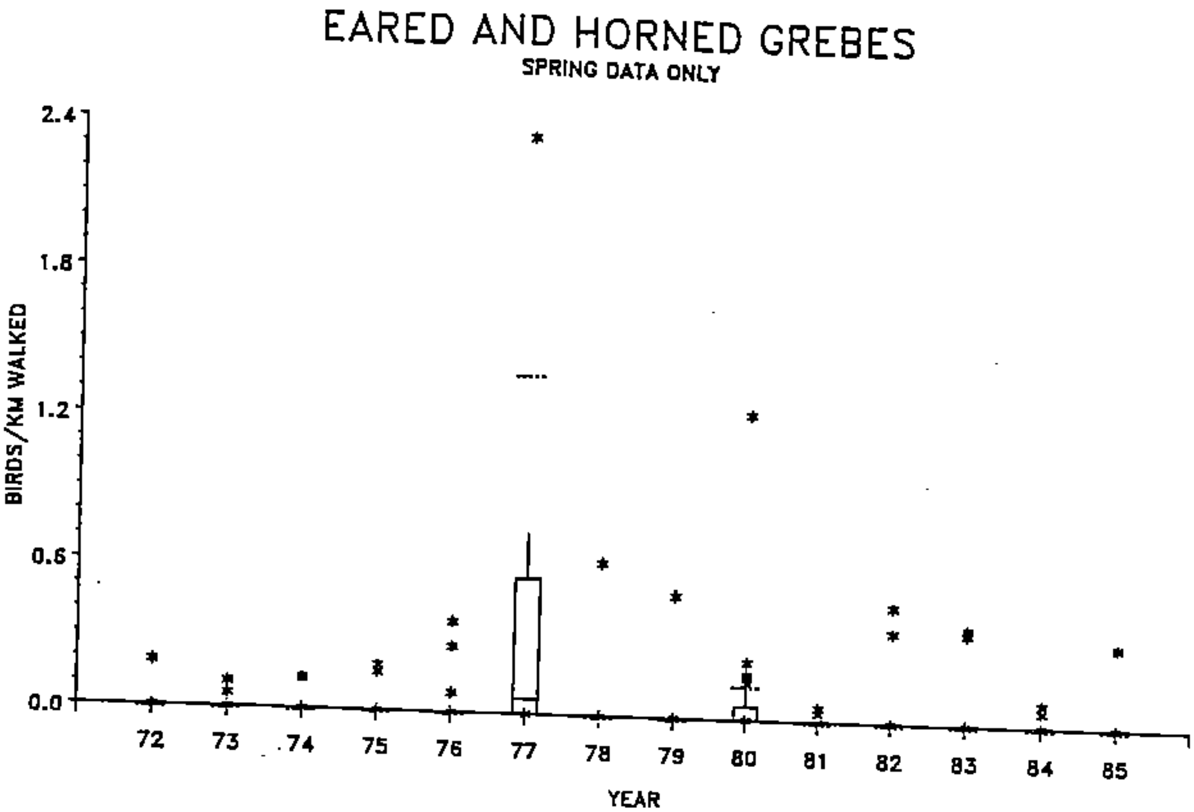

Fig. 16. Annual variation in carcass densities north of Point Conception. See methods for details.

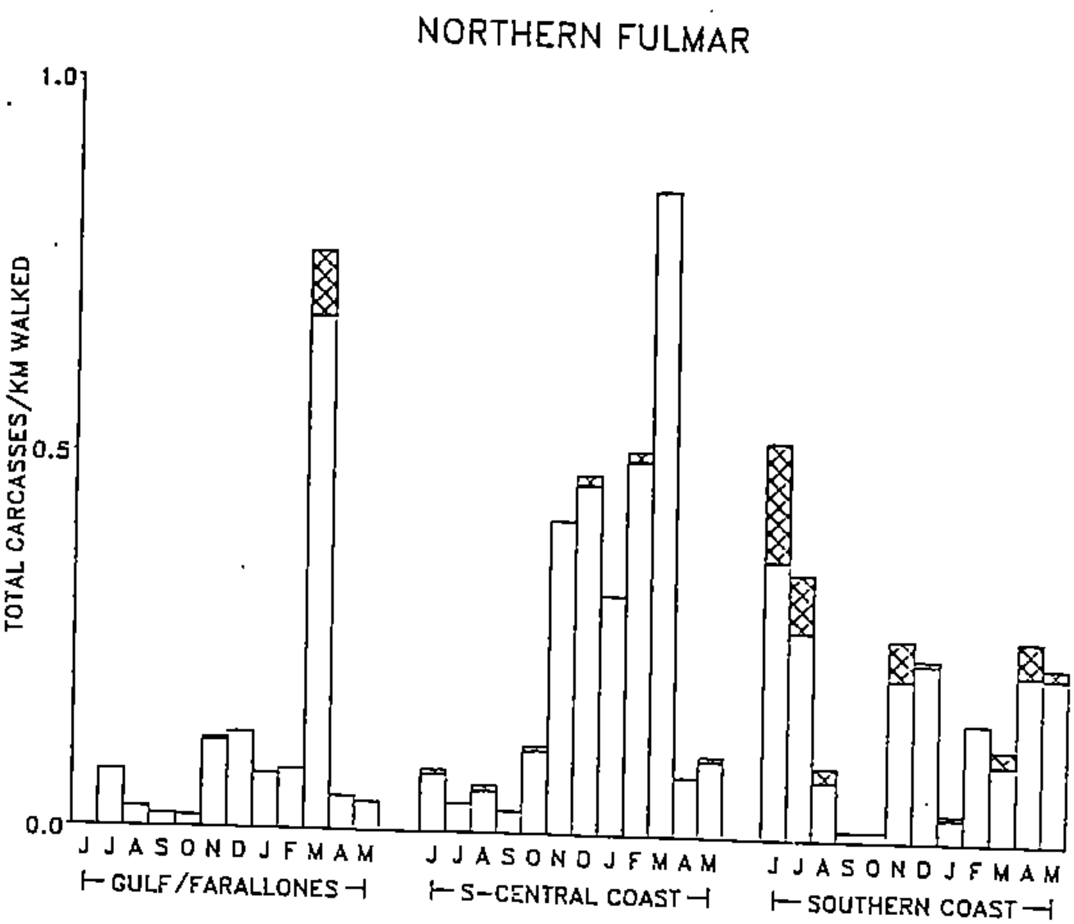

Fig. 17. Monthly (June to May) total carcass densities. Oiled carcasses indicated by cross-hatched portions of bars. See methods for details.

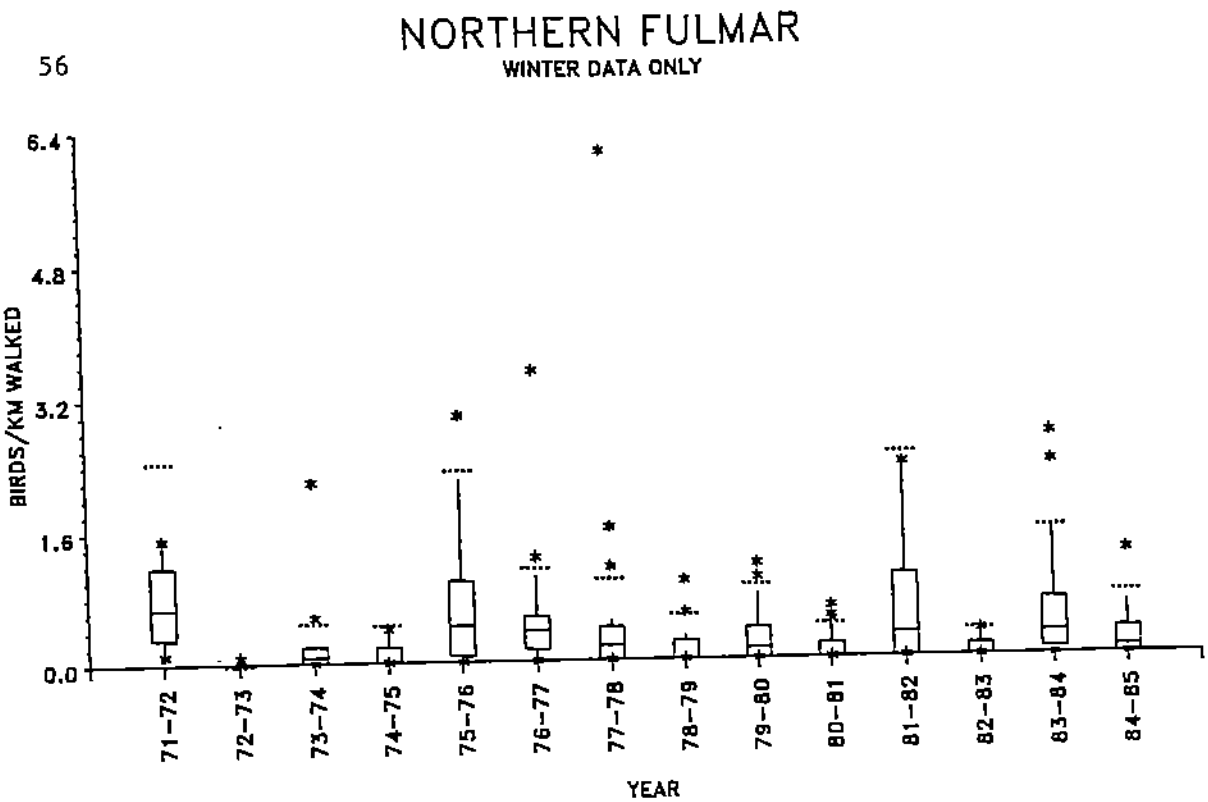

Fig. 18. Annual variation in carcass densities north of Point Conception. See methods for details.

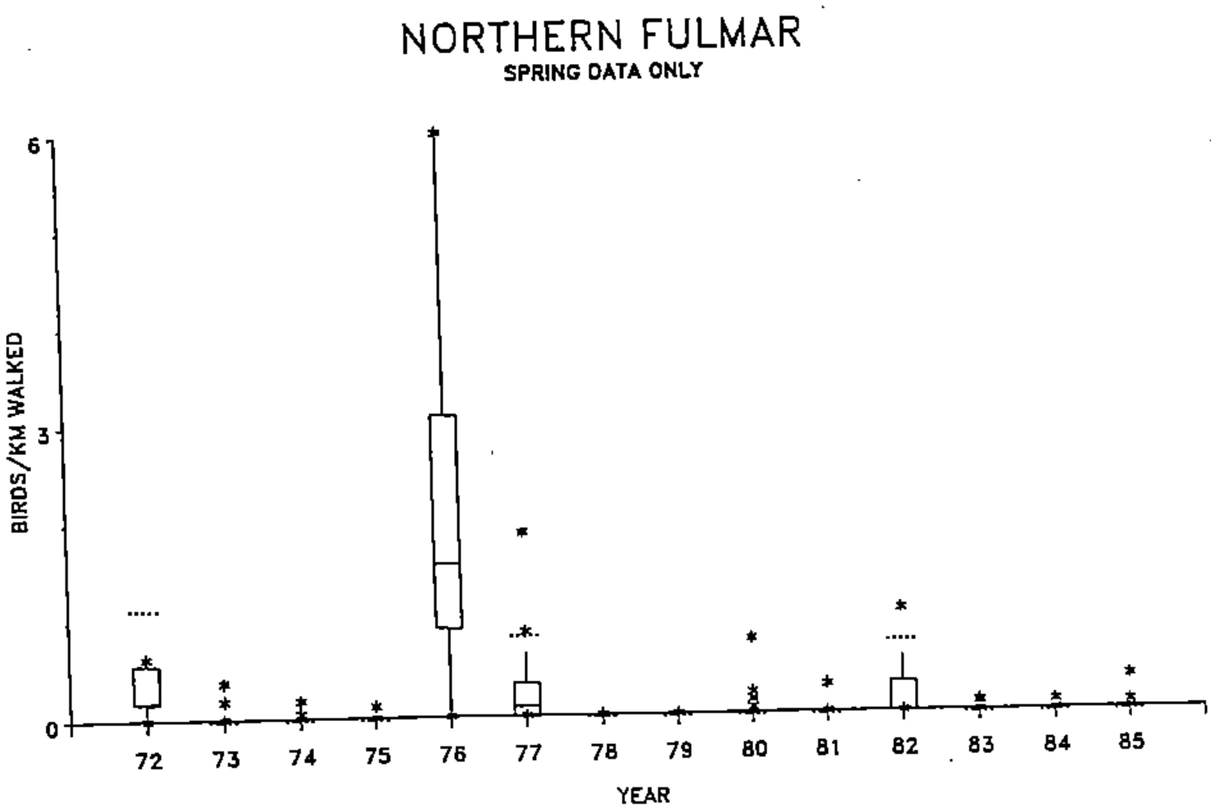

Fig. 19. Annual variation in carcass densities north of Point Conception. See methods for details.

particularly high were 1972, 1977, and 1982 (Fig. 19).

Sooty Shearwaters are most common on California beaches from May through September (Fig. 20). It was surprising that Sooty Shearwater densities on the southern coast were about as high as those on the south-central coast (Fig. 20) since Briggs et al. (1983a) note that the species is especially attracted to waters of the latter areas. The seemingly large peak on the southern coast, when gauged against what is known of this species occurrence, suggests either greater mortality or an at-sea distribution that is closer to shore in the south. The later spring arrival of this species in the Gulf compared to the other two areas (Fig. 20) is consistent with known occurrence patterns of live individuals. During fall, densities were higher in 1972, 1973, 1975 and, to a lesser degree, in 1981, 1982, and 1984 than in other years (Fig. 21).

Other shearwaters, albatross, and large petrels breed primarily in the south, central and west Pacific. Their sporadic occurrences on beaches during this study are consistent with their low frequency of occurrence off the California coast. Between April and September, 28 Black-footed Albatross were found from Northern California to Monterey Bay (Table 4). Two Laysan Albatross were found on Centerville Beach in September 1979 and on South Mad River Beach in May 1983 (Table 4). A Mottled Petrel was found on Cambria Beach in March 1976 (Table 4); this species occurs in California offshore waters during March and April on its migration northward (Ainley and Manolis 1979). Pink-footed Shearwaters were found from the Gulf of the Farallones south between March and November (Table 4) consistent with known occurrence (Ainley

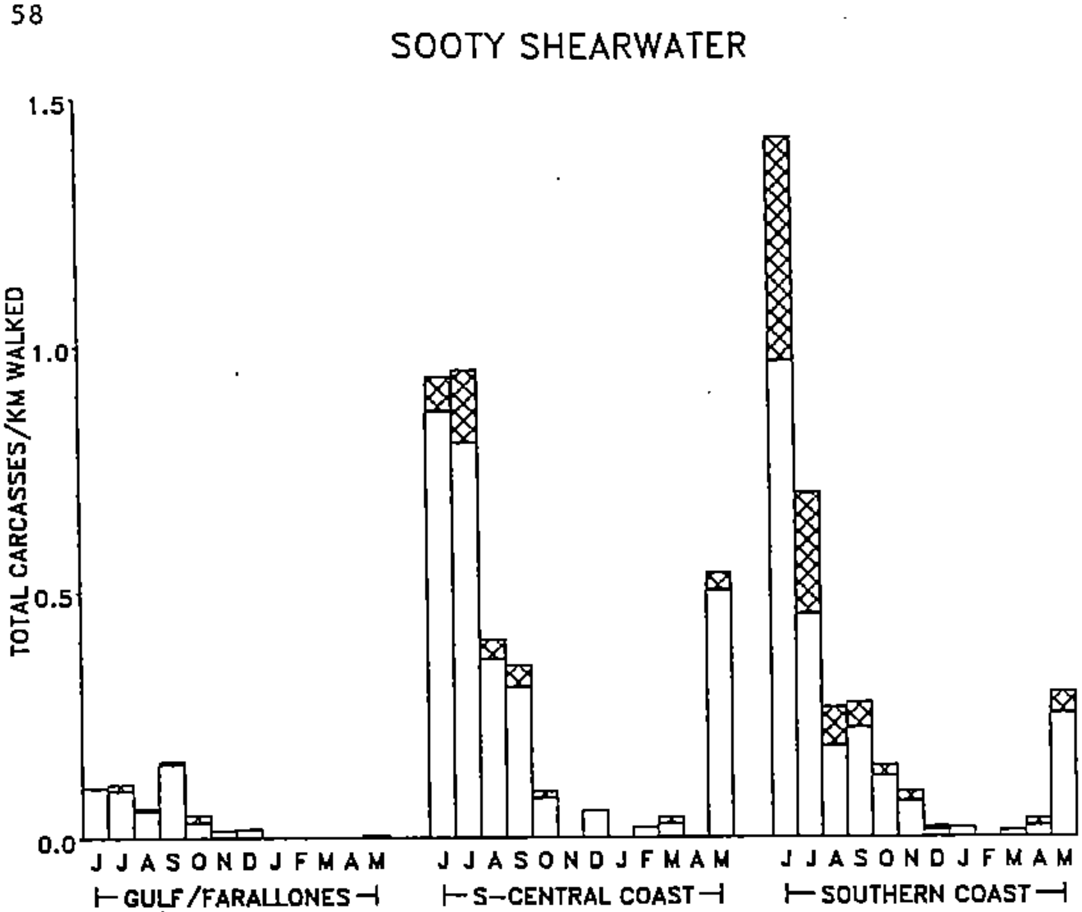

Fig. 20. Monthly (June to May) total carcass densities. Oiled carcasses indicated by cross-hatched portions of bars. See methods for details.

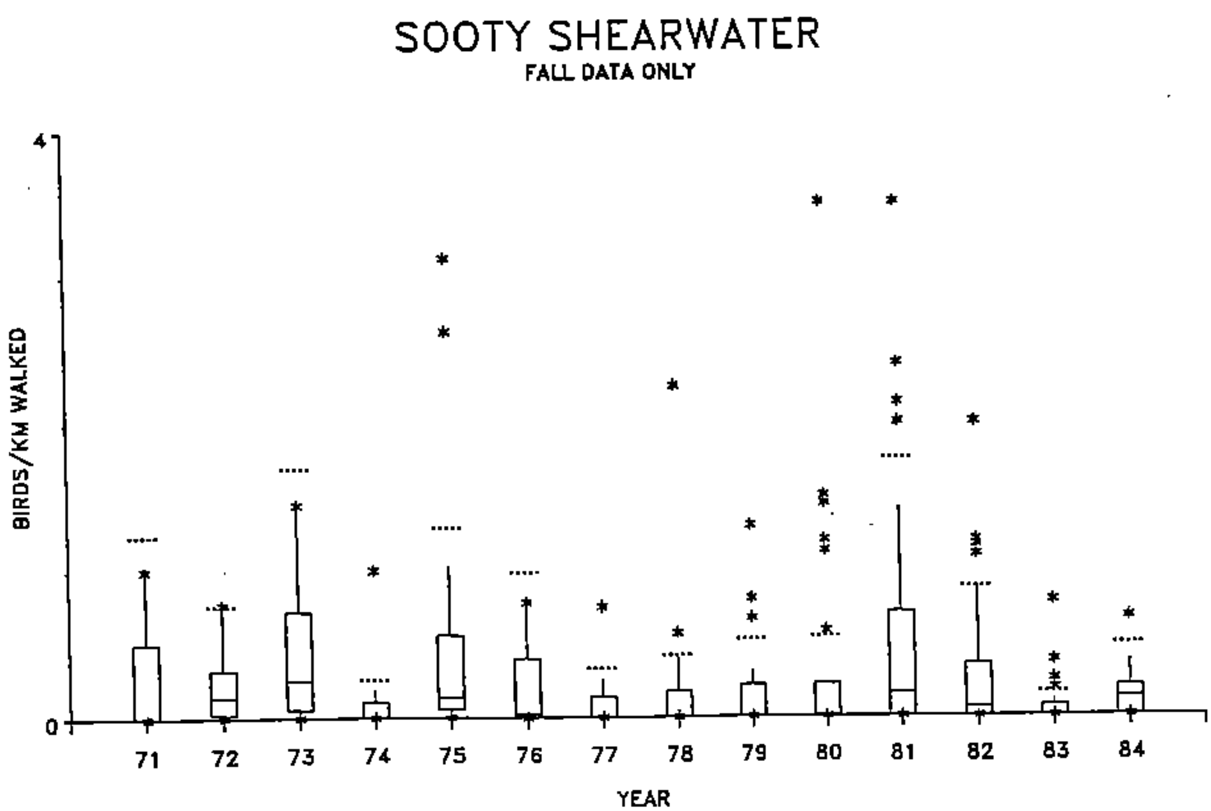

Fig. 21. Annual variation in carcass densities north of Point Conception. See methods for details.

1976, Briggs et al. 1983a). Buller's Shearwaters were found on Marina and Del Monte beaches in February, September, and October 1976, on Thornton Beach in August 1976, and on Clam Beach in October 1977 (Table 4); only the February record is outside of the fall period when the species usually occurs. Twenty-three Short-tailed Shearwaters were found in May, July, and September and between November and February north of Point Conception; the May to September records fall outside of the usual winter occurrence periods. Black-vented (Manx) Shearwaters were found in June, July, September, October, and December from the Gulf of the Farallones south.

Four species of storm-petrel were found on the surveys. Although none were very common, on several instances from two to six individuals were found on single surveys (Table 4). Fork-tailed Storm-Petrels were found from Monterey Bay north throughout the year (Table 4). Leach's Storm-Petrels were found in all regions except Santa Barbara Channel, between June and August and between November and February (Table 4). Ashy Storm-Petrels were found from Monterey Bay north from June through October and from February through April and on the southern coast in May and in July (Table 4). Black Storm-Petrels were found at Muir Beach in September 1983, Pajaro Dunes in August, Zmudowski Beach in October 1974, Torrance Beach in September 1975 and 1979 and October 1974, and Border Field Beach in June 1977 (Table 4).

All four storm-petrels breed in California. Their rare occurrence on beach surveys may be explained by their pelagic feeding habits, their small body size (making them more susceptible to scavenging and disintegration), and small population sizes in areas where most surveys