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# Breeding success of Brown Pelicans in 2002 at West Anacapa Island, California, and long-term trends in reproductive performance, 1985-2002

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## INTRODUCTION

West Anacapa Island, part of the Channel Islands National Park, is the site of the largest, most consistent breeding colony of California brown pelicans *(Pelecanus occidentalis californicus)* in the Southern California Bight (SCB) (Gress and Anderson 1983, Anderson and Gress 1983, Gress 2002) (Figure 1). The SCB extends from Point Conception, California, southward to the vicinity of Cabo San Quintín, Baja California Norte, Mexico, and is bounded to the west by the California Current (Southern California Coastal Water Research Project 1973). Currently active colony sites in the SCB include West Anacapa Island, Santa Barbara Island, Islas Los Coronados, and Isla San Martín; the colony at Islas Todos Santos was extirpated in the 1920s (see Jehl 1973, 1984, Gress and Anderson 1983, Gress et al. 1990, Everett and Anderson 1991, Palacios and Mellink 2000, E. Palacios and F.G. unpublished data).

The SCB brown pelican breeding population was nearly extirpated in the decade of the early 1960s to early 1970s from almost total reproductive failure caused by eggshell thinning associated with high levels of *p,p'*-DDE (the principal metabolite of the organochlorine pesticide DDT) (Keith et al. 1971, Risebrough et al. 1971, Blus et al. 1972, Risebrough 1972, Anderson et al. 1975, 1977, Gress 1970, 1995). Over a period of at least 12 years (1962-1973) (see Anderson and Hickey 1970, Gress 1995), and perhaps longer (as early as the mid-1950s; Anderson and Anderson 1976), excessive eggshell thinning likely caused the majority of eggs laid in the SCB brown pelican colonies to be broken or crushed during incubation. Thus, there was very little or no breeding success during those years (see Table 1). In 1970, for example, only one pelican chick fledged from about 550 nests (Gress 1970, 1995). The source of DDT into southern California coastal waters was from contaminated effluent (from a manufacturer in the Los Angeles area) that entered the marine environment through an offshore sewage outfall (see Carry and Redner 1970, MacGregor 1974, Anderson et al. 1975, 1977, Gress and Anderson 1983, Gress 1995). Because of its uncertain future, *P. o. californicus* was given endangered species status by U.S. Fish and Wildlife Service in 1970 and by the State of California in 1971 (see Gress and Anderson 1983); the subspecies is still recognized as endangered.

As DDT input into coastal waters began to decline in the early to mid-1970s, mean DDE levels also decreased in the SCB brown pelican population (Anderson et al. 1975, Gress 1995). Over time, mean eggshell thickness gradually increased, resulting in increased pelican productivity on Anacapa Island beginning in about 1974 (Anderson et al. 1975, reviewed in Gress and Anderson 1983, Gress et al. 2002). Recovery of SCB brown pelicans continued into the early 1980s; with stable, low levels of DDE in coastal ecosystems by the mid-1980s and with mean eggshell thinning also at low levels, breeding success on Anacapa Island showed marked improvement (Gress 1995) (Table 1). In comparison, the mean number of pairs nesting annually during the years 1979-2001 was over an order of magnitude greater than that of 1969-1978 (Gress et al. 2002).

Brown pelican breeding success has been monitored on West Anacapa Island each year since 1970 (with the exception of 1995) (see Table 1). Our initial objective, of course, was to monitor the recovery (or lack of) from the pollutant-related reproductive failures. Once levels of DDE abated, we have since found brown pelicans to be excellent indicators of a variety of environmental fluctuations. We have gathered breeding data from this colony not only to continue monitoring the effects of DDE and other organochlorine contaminants (Anderson et al. 1975, 1997, Gress 1995), but also to look at the effects of oil spills (Anderson et al. 1996), commercial fisheries (Anderson et al. 1980, Sunada et al.1980, Anderson and Gress 1994), decreased food resources (Anderson et al. 1980, 1982), climatic change and ENSO (El Niño Southern Oscillation) conditions (Sydeman et al. 2002), and human disturbance (Anderson 1988, Anderson and Keith 1980, Gress and Anderson 1983).

We have monitored brown pelican reproductive success since 1998 as part of a project (Anacapa Island Restoration Project) to eradicate introduced black rats *(Rattus rattus)* from Anacapa Island. With funding for restoration from litigation related to the *American Trader* oil spill in 1990, the objective of this project is to completely eliminate black rats from all three Anacapa islands (*American Trader* Trustee Council 2001). Eradication of rats from Anacapa Island is expected to restore breeding habitat for Xantus's murrelets *(Synthliboramphus hypoleucus)* and possibly ashy storm-petrels *(Oceanodroma homochroa)*. Gathering breeding data from the Anacapa Island pelican population prior to eradication established a baseline with

which post-eradication data can be compared statistically to ascertain possible detrimental effects on reproductive success and general "health" of the population. Eradication activities on West Anacapa Island took place in November 2002. The last chicks fledged in mid-October and no pelicans were on the island during the helicopter bait-drop (G. Howald, pers. comm.). At that time of year, pelicans are either completely absent from the island or roosting at shoreline level or on offshore rocks at very low numbers. Although there is little probability that brown pelicans would be affected by disturbance from the eradication activities (pelicans were not present), by primary or secondary poisoning, or by some long-term residual effect. Nevertheless, it is essential to monitor future reproductive performance to be certain that the pelican population was not compromised.

Here, our objectives are twofold: (1) to report brown pelican breeding success from West Anacapa Island for 2002; and (2) to present the results of a statistical analysis that will: (a) describe past patterns of change over the years 1985-2002 and determine a baseline for brown pelican breeding success and productivity variables, and (b) determine the power of detecting potential future trends over the years 2001-2012.

## METHODS

### *2002 Breeding Surveys*

Surveys of the 2002 brown pelican breeding effort on West Anacapa Island were conducted approximately monthly throughout the breeding season between April and September using methods developed and utilized by F.G. and D.W.A. over a period of many years (since 1970). Detailed descriptions of field methodology and data handling for brown pelican breeding surveys are given in Gress (1992 and 2002). The methodology described was intended to give sufficient detail so that future monitoring would have an established protocol to follow for reasonably accurate comparisons with past data and as a means for assessing current and future population trends.

Survey dates for Anacapa Island in 2002 were: 30 April to 9 May, 29 May to 5 June, 26 June to 1 July, 12–19 August, and 9-17 September. During the September visit, we conducted post-breeding nest and chick carcass counts in the colony (details of annual post-breeding surveys are given in Gress 2002); except for one relatively isolated area of late nesting (described below), all other pelicans had left the breeding grounds by that time. In addition to our land and boat observations, we were aided (particularly in determining phenology) by monthly aerial surveys from February through August over West Anacapa as part of another study. Nest site locations, new nesting, and shifts in nesting effort were observed, and the relative size of various censusing units was estimated during the aerial surveys. We are attempting to develop a means of monitoring brown pelican nesting using aerial photography; the photographs taken in 2002 are being analyzed as a separate study.

Breeding data were compiled from censuses of "sub-colonies" (see Gochfeld 1980), which are standardized breeding groups that can be compared from year to year. Each canyon and bluff where pelicans nest along the north shore of West Anacapa Island is a distinct sub-colony unit with defined natural boundaries (Figure 2) that remain the same from year to year and can thus be compared. Each sub-colony consists of many smaller sub-units (or "count units") that were censused at regular intervals throughout the breeding season from various distant vantage points overlooking the pelican colony or by boat (about 30 percent of the colony area can be seen only from a boat). Sub-unit boundaries are defined by natural features (such as ravines, vegetative patches, rock outcrops, bluff edges, etc.) and are consistent between censusing intervals; each year we follow the progression of sub-units throughout the breeding season. Data for all sub-units of each sub-colony are compiled and summarized per sub-colony. The actual nesting locations on West Anacapa can vary considerably from year to year and cannot be predicted beforehand; with changes of location, observation points and survey methods shift accordingly.

Human disturbance can have a significant negative impact on brown pelican reproductive success (see Schreiber 1979, Anderson and Keith 1980, Gress and Anderson 1983, Anderson 1988). Brown pelicans are particularly sensitive to disturbance in the early stages of nesting and egg-laying. When disturbed, pelicans may abandon their nests, leaving eggs or small young

vulnerable to gull predation. Because renesting rarely occurs (Schreiber 1979, Gress and Anderson 1983), disturbance resulting in the loss of nest contents will likely end a pair's attempt at nesting for that season. Thus, to avoid disturbance, our surveys were conducted at non-disturbing distances.

Data collected for each census sub-unit on each visit to the colony site consisted of: (1) nests with adults incubating eggs or brooding small young (less than 2 weeks old); (2) abandoned nests; (3) nests containing chicks at least 3 weeks old; (4) number and ages of chicks at least 3 weeks old (both total number and brood counts); (5) number of adults attending nests or roosting in nesting areas; and (6) number of adults and sub-adults roosting in "loafing groups" outside the nesting areas. Our data is derived from a near-total count of nests and visible nest contents (i.e., chicks at least 3 weeks old) in each sub-colony. Most nests are visible from standardized observation points and offshore from a boat, but some are obscured by dense vegetation and/or irregular terrain (e.g., in the bottom of canyons or ravines) and cannot be observed from distant points. The number of obscured nests in each area was estimated from our post-breeding ground surveys of all accessible areas. An estimate of chicks fledged from the unobserved nests was derived from counts in adjacent areas that were censused during the breeding season. By noting the condition of these nests, an estimate could be made of the percentage that most likely produced chicks. The estimated number of chicks fledged from the unobserved nests was then extrapolated from a combination of chicks per successful nest and the observed chick mortality in the adjacent sub-unit that was visible during the breeding season.

***Analysis of Long-term Data, 1985-2002***

Data discussed here were accumulated from 1985 through 2002, representing 18 years of fieldwork on the breeding population of brown pelicans on West Anacapa Island. Only in 1995 did we not survey both nests and chicks throughout the breeding season; we only counted nests that year in a post-breeding season ground survey. Our assessment of this colony began in 1969 (see Table 1). The data gathered during the period 1969-1973 ascertained the status of a failing, nearly extirpated population. The years 1974-1976 in general showed a marked improvement in reproductive rates (albeit, these were still very small colonies) as the SCB breeding population began to recover. The breeding efforts during the 1970s were small, compact, and relatively

synchronous (see Table 1); thus, our periodic surveys could be done mostly from shipboard in a single day (Anderson et al. 1975, 1977, Gress and Anderson 1983). Beginning in the early1970s, we gathered breeding data using standardized methods (see Anderson and Gress 1983, Gress 1992, 2002); these were comparable to methods used in Florida (Schreiber 1979,1980) and in the Gulf of California, Mexico, by D.W.A. Over time, our census techniques became more refined as colony dynamics became more complex in response to substantial increases in breeding numbers beginning in 1979 (Gress 1992, 2002). In addition to continually increased colony size, breeding seasons became lengthier and more asynchronous as the colony spread out over most of the island (Anderson and Gress 1983, Gress 1992, 2002). As a result, breeding surveys became much more complex and involved considerably more time. Nesting surveys in a typical breeding season (usually about 7-9 months long) now generally require 4-6 visits to the island with an average of 7-8 days per visit.

Prior to 1979, the continuing effects of DDE contamination were so dominant that it masked all other factors influencing reproductive rates, including food supply variation (Anderson et al. 1975, Anderson and Gress 1983, Gress 1995). Even though recovery had begun in the mid-1970s, the reproductive rates still continued to be heavily influenced by chronic eggshell thinning into the early 1980s (see Table 1). As DDE levels in the SCB declined progressively through the 1970s, mean eggshell thickness increased and reproductive success gradually improved (Anderson et al. 1975, 1975, Gress 1995). The period of 1979-1984 showed a general trend of increasing colony size as DDE residues began leveling off ; eggshell thinning, while steadily decreasing, did not level off until about 1985 (Gress 1995, F.G. unpublished data). Thus, for the purpose of our statistical analysis of the long-term data set, we used only data gathered after 1984. We believe the breeding data prior to 1985 was still influenced by DDE-induced eggshell thinning and therefore not directly comparable to data gathered since then.

Although our surveys do not represent a true total count, they do approach census completeness; we therefore consider these to be very strong indicators of annual breeding status for Anacapa. Moreover, we believe any annual pattern of change in our observed breeding measures is a strong indicator of change in actual breeding status on the island. Since we conducted complete surveys of breeding sites, rather than a partial survey based on random

breeding sites at random time intervals, we attribute none or negligible variability in the counts to sampling variability. For this reason, we saw no reason to use statistical estimation methods (such as ANOVA) to further estimate breeding intensity over the years. With detailed censuses, we consider our survey counts each year to be highly reliable indices of breeding for that year. To model patterns of change over the years, we used a combination of statistical time series analyses and trend analyses, which we discuss below.

To achieve the first objective of our analysis, we identified several model types characterizing different patterns of change for each of the breeding measures (or model parameters) of brown pelican reproductive success. We separately analyzed each of these measures: (1) number of nest attempts, (2) number of chicks fledged, (3) chicks fledged per nest attempt (productivity), (4) percent nest abandonment, (5) chicks fledged per successful nest, and (6) percent chick mortality. The models anticipate different structures of variation or correlation in the data. For example, the simplest model, the ***mean model***, assumes annual breeding measure is centered about the baseline mean and fluctuates independently from previous or subsequent annual measurements. Another way to think of the mean model is by the following equation: annual observed breeding = baseline mean + annual fluctuation. This is equivalent to the statistical mean model $Y=\mu+\varepsilon$, where Y= annual observed breeding, $\mu$ = the mean, and $\varepsilon$ = random fluctuations from the mean. Annual fluctuation has mean 0 and the baseline mean is constant; mean annual breeding is therefore equivalent to the baseline mean. All other models feature enhancements to the mean model. For example, the *regression model* is similar to the mean model with the exception that the mean is subject to a sustained increase or decrease according to a trend over years. In this case, the mean is linear with year, as represented by $\mu = a + b$*year, and the constants $a$ and $b$ are estimated by regression methods.

Annual fluctuation is positive for years with exceptionally high breeding effort and good productivity and is negative for years with low effort and poor productivity. Often, for certain individual years, unusually low observations of breeding variables coincided with atypical environmental conditions, such as sudden decreases in local food supplies, region-wide effects of ENSO (El Nino Southern Oscillation) events, bright lights utilized by the squid fishery, disease outbreaks, fishery overexploitation, or domoic acid toxicity. Each of these diminishing events

were either very rare (squid fishery, disease, domoic acid toxicity) or not consistently measured (food availability, ENSO effects). We did not formulate models to account for these specific sources of variation because the data were too sparse to adequately represent variation surrounding these relatively rare events. However, variation caused by these conditions is included in the estimate of overall annual variation and is represented collectively as part of the annual fluctuation.

Both the mean and regression models assume that fluctuation each year is independent from other years. We also wanted to consider time series models in which fluctuation in one year could be correlated to fluctuations in a prior year. However, using the time series model was not appropriate for several reasons. First, the sample size (i.e., for the period 1985-2002) is only 18 years, which is arguably inadequate to conduct time series modeling. Second, since the time series model requires observations at every regular interval, we would need to guess the missing values using an interpolation technique, which raises concerns over pseudoreplication. Third, an initial analyses based on a longer series of years, 1979-2002, indicated that time series models did not offer any better fit than the mean or regression models.

For each breeding measure, we fit two model types and evaluated the relative fit by comparing a model-fit statistic, Akaike's Information Criteria (AIC) (Akaike 1973).
We selected the best-fitting model from among the mean and regression models, based on the lowest AIC value. To facilitate the comparison of models, we calculated $\Delta$AIC as the difference in AIC between each model and the lower AIC model. The model with lower AIC has $\Delta$AIC=0, which we would typically designate as the "best model." However, two models can fit the data nearly equally well and have $\Delta$AIC arbitrarily close to 0. Candidate models with $\Delta$AIC<2 are said to be "worthy of consideration" (Burnham and Anderson, 1998). Therefore, whenever two models had $\Delta$AIC<2, we designated the more parsimonious of these (i.e., having the lower AIC value) to be the better model. By using the selected model, we estimated the baseline mean for that breeding measure using a 90 % confidence level and also estimated a range in which we predict future data to occur with 90 percent accuracy.

To achieve our second objective, we used our analyses of the 1985-2002 data to establish an estimate of the baseline for 2001-2002. From this baseline, we projected future changes in means based on ±10%, ±5%, ±2% and 0% annual changes over the 2002 through 2012 time interval. For each projected trend, we conducted 100,000 computer simulations of count data subject to annual fluctuation comparable to that observed for the long-term past period (1985-2002). We performed simulations on the logarithm of the count data, rather than on untransformed data, to facilitate detection of multiplicative changes (i.e., percent per annum changes), and because the count data are subject to different degrees of fluctuation depending on the size of the mean count. In other words, larger counts will fluctuate more widely than small counts. Since simulations are frequently performed subject to a constant degree of fluctuation, this can add complexity to the simulation or pose credibility issues if not addressed. By simulating trends in log(count) with a fixed level of annual fluctuation, we were able to simulate trends in count that followed the appropriate percent per annum changes and had a level of annual fluctuation that corresponded to the magnitude of the mean count.

Since we anticipate that resource agencies will want to consider multiple methods for statistically detecting changes in reproductive rates, we estimated the likelihood of detecting each trend using two popular statistical detection methods. The first method was to use AIC to select between a regression model (indicating trend) and the mean model (indicating no trend). The AIC method gives a conclusion that favors trend when the AIC for the regression model is less than the AIC for the mean model (i.e., when $\Delta AIC = AIC_{mean} - AIC_{trend} > 0$). The second detection method was to use hypothesis testing to select between the hypothesis of a trend model and the null hypothesis (mean model). The hypothesis tests were conducted at both the 0.05 and 0.10 significance levels.

We compared detection ability between the two methods by comparing the probabilities that either method would detect the simulated trends. Both methods are capable of detecting a true trend; however, they are also capable of failing to detect a trend or falsely detecting a trend that does not exist. The two methods are also difficult to compare because they vary according to the type of errors they allow. The agencies will need to decide not only what type of error they are most willing to accept, but also the magnitude of error. The magnitude of error

manifests itself by a critical value in a "decision rule" (i.e., when a statistic calculated from the data reaches the critical value, then rule in favor of a trend).

For hypothesis testing, the critical value is determined by the level of Type I error (probability of detecting a false trend). This is the significance level, which is typically 0.05 although many prefer 0.10 (see Cowles and Davis 1982). The lower and more conservative 0.05 significance level has been widely criticized for being too conservative in wildlife investigations because it involves greater Type II error (probability of failing to detect a true trend), thus compromising power to detect trends (Johnson 1999). The 0.10 level is a common choice for those who prefer better control of Type II errors.

With AIC model selection, the critical value is compared to relative differences in the AIC statistic. Generally, the model with the lower AIC is considered the better fit. When there are just two models being considered (such as the mean model and the trend model in our case), there is a greater than 50 percent weight of evidence for the model with the lower AIC and a less than 50 percent weight for the other model. However, statistics calculated from data are subject to variation because of variation in the data itself, so investigators are typically reluctant to decide in favor of any one model when the evidence is too close to a 50-50 split. As a rule of thumb, the favorable model should not only have the lowest AIC, but it should also have lowest AIC by a margin of 2. When there are just two models being considered, then an AIC difference ($\Delta AIC = AIC_{mean} - AIC_{trend}$) greater than 2 is considered to have over 70 percent weight in favor of the trend model. When $0 < \Delta AIC < 2$, then the mean model is considered to be "worthy of consideration" because it has between 30 to 50 percent weight (Burnham and Anderson 1998). On principles of parsimony, in this case, one could arguably rule in favor of the mean model even though it does not have the lowest AIC. In our analysis, we present probabilities for strong evidence in favor of the trend model ($\Delta AIC > 2$) and also weaker evidence in favor of the trend model ($0 < \Delta AIC < 2$).

We also examined the impact of varying survey intensity on the power of detecting trends. The simulation methods were applied to the 2001-2012 period, which includes actual data from 2001-2002 and simulated data from 2003-2012. Since data for 2001-2002 has already

been collected and 2003 data is already being planned, we included 2001-2003 years as part of all variations on survey intensity. These variations include: (1) all years from 2001 through 2012, (2) 2001-2003 and every odd year after through 2011, (3) 2001-2003 and every third year after through 2012.

All detection methods were performed on each of the 100,000 simulations for each of the trend levels at each level of survey intensity. The power of detecting trend was estimated binomially as the proportion of 100,000 outcomes in favor of the trend model (Zar 1999). With any number of simulations, we anticipate binomial variability in our estimated power. The standard error for a binomial proportion based on 100,000 values is $\sqrt{(1-p)p/100000}$, which maximizes at $p$=1/2. Thus, we anticipate the standard error to be no greater than $\sqrt{(1-0.5)0.5/100000} = .0016$.

## RESULTS AND DISCUSSION

### *2002 Phenology and Breeding Success*

Nesting phenology of brown pelicans on West Anacapa Island for 2002 is summarized in Table 2. The first eggs were laid during the first week of January, which was much earlier than usual. Mean onset of nesting (1970-2001) is mid- to late February (F.G. unpublished data). From 1970 through 2001, the earliest nesting occurred in late December 1985, while the latest onset of nesting was in early May in both 1972 and 1975 (Anderson and Gress 1983, F.G. unpublished data).

Nesting in 2002 began in the Oak Canyon/North Bluff area (Figure 2). The latest areas to be colonized were Ridge Trail East and upper Pelican Canyon, where nesting in both areas began in early June. New nests were built and eggs laid continuously from early January to mid-June (historically, the latest egg-laying date recorded for Anacapa was in mid-July1988; F.G. unpublished data). Nesting occurred in all sub-colony areas from the Amphitheater westward to Big Cliff (Figure 2). With the exception of the 2000 season, this was perhaps the most extensive breeding effort (in terms of how much of the island was utilized) on record for Anacapa (since at least 1970). After an incubation period of 4 weeks, eggs began hatching on about 10 February.

Peak of egg-laying was in early March. In late June there were still about 250 nests containing eggs or very small young; the last eggs laid were hatched in mid-July.

The first chicks to fledge left the colony in early May (brown pelican chicks usually fledge when they are 13-14 weeks old, although some uncommonly may fledge as early as 10 weeks; D.W.A., F.G. unpublished data; see Schreiber 1976, 1980). The last chicks to fledge (58 in the Ridge Trail group and 5 in upper Pelican Canyon; see Figure 2) left the island by mid-October.

On West Anacapa Island for 2002 the total colony size was about 6,440 nests. This was the largest breeding effort on record for Anacapa (Table 1). Colony size has exceeded 6,000 nests in only one other year since at least 1969 (6,330 nests in 1985). The 2002 colony exceeded the mean colony size from 1979 to 2001 (3,660 ± 708; 95% CI) by 43 percent. As discussed previously, we chose1979 as the first year to begin long-term comparisons since it appeared that the SCB breeding population had largely recovered from the acute effects of contaminants by that time (although lower level, more chronic effects were still evident until about 1985; Gress 1995). Also, 1979 appeared to be the beginning of larger breeding efforts (over 1,000 nests per year, except for 1984), progressively increasing number of pairs nesting, and generally more stable reproductive rates. Sub-colonies with the largest number of nests were Three Sisters Bluff (n=645), Summit Canyon Bluff (n=654), and Amphitheater (n=1,123); these areas comprised nearly 40 percent of the total breeding effort (Figure 2; Table 3). Typically, the latter two areas (in most years) have the largest number of nests; Summit Canyon Bluff and Oak Canyon Bluff usually have the highest nest densities (F.G. unpublished data), as they did again in 2002. Three Sisters Bluff is only occasionally colonized (since 1990, it has been active only in 1993 and 2000), but in 2002 had a very large breeding effort. Ridge Trial East, an area in which nesting has never occurred (at least, since 1969), was colonized in 2002 (Figure 2). Initial nest-building in this area occurred very late (in mid-June). Although small in size, this sub-colony was very successful (discussed below).

An estimated 3,220 chicks fledged from Anacapa in 2002 (Table 3). Thus, we calculated a productivity rate of 0.50 chicks fledged per nest attempt (see Anderson and Gress 1983 and

Gress and Anderson 1983 for discussion of productivity). Despite the low productivity figure, the number of chicks fledged in 2002 was still 27 percent higher than the 1979-2001 mean of 2,440 (± 652; 95% CI). Productivity for 2002 at 0.50 was 25 percent lower than the long-term mean (0.67 ± 0.10; 95% CI). This is the lowest productivity figure since 1994.

The nest abandonment rate at 54 percent in 2002 was also higher than usual. Nest abandonment has not exceeded 50 percent since 1994 (Table 1); the 2002 rate was 8 percent above the long-term mean (49.6 ± 6.6; 95% CI). There is high variability in the nest abandonment data, with both very high and very low rates reported in previous years. The highest rate since 1976 (when we first began recording nest abandonment annually) was 93 percent in 1978; the lowest was 22 percent in 1985 (F.G. unpublished data). It was not coincidental that productivity in 1976 was a very low 0.18, while in 1985 it was a robust 1.24, the highest we have ever recorded (Table 1).

The number of young fledged per nest attempt (yf/sn) in 2002 at 1.08 (Table 3) was very low and about 19 percent below the long-term mean of 1.33 ± 0.063 (95% CI). The 2002 yf/sn rate was one of the lowest on record; 1.07 and 1.08 were recorded in 1983 and 1996, respectively (Table 1). Such low success was attributed to the very high chick mortality rate and high nest abandonment rate observed in 2002 (see discussion below). In contrast, the two highest yf/sn rates were 1.64 and 1.59, recorded in 1984 and 1985, respectively (see discussion in Gress 2002).

Brown pelican chick mortality in 2002 was an extraordinary 53.6 percent (Table 3), the highest rate recorded since we began collecting mortality data in 1980 (Table 1); this was more than twice the long-term mean of 21.3 ± 5.9 (95% CI). The previous highest rate was 49.3 percent in 1997, a year in which El Niño events heavily influenced breeding success. Like nest abandonment, there is a great deal of variability in mean mortality data (see Table 1). The lowest mortality rate recorded on Anacapa was 0.44 percent in 1984. Most of the mortality observed in 2002 apparently occurred in late April; we conducted aerial surveys over Anacapa on 5 March and again on 7 April and saw no evidence of widespread chick mortality at that time. Our first land survey of the colony was during the first week of May, and at that time the colony was littered with at least 1,500 pelican chick carcasses. During this same time period, high mortality

of adult and sub-adult brown pelicans was observed along the mainland coast between approximately Santa Barbara and Los Angeles; carcasses of other seabird species and California sea lions *(Zalophus californianus)* were also reported. On 23 April, carcasses of about 30 adult brown pelicans were found around Anacapa Island by National Park Service personnel. Acute mortality continued for several more weeks. We estimated a minimum of 100 pelican adult and sub-adult carcasses were found on the water surface, in intertidal areas and kelp beds, and on shore at Anacapa from 23 April to 10 June; mortality seemed to have abated by mid-June. Adult mortality on or around Anacapa during the breeding season is rarely seen; most of the mortality we encounter there is due to monofilament entanglement or fishing tackle injury.

The apparent cause of death was domoic acid toxicity (presence of domoic acid was confirmed from analysis of 12 brown pelican carcasses; F. Van Dolah, NOAA, pers. comm.). In 1991 unusually high mortality reported in brown pelicans and Brandt's cormorants *(Phalacrocorax penicillatus)* in Santa Cruz, California, was attributed to domoic acid, a neurotoxin produced by blooms of a pennate diatom *Pseudonitzschia australis* (Work et al. 1993). In that study, high levels of domoic acid (an excitatory amino acid) were found in the viscera of northern anchovies *(Engraulis mordax),* the principal prey item of brown pelicans (Anderson et al. 1980, 1982, Gress et al. 1980, Gress and Anderson 1983), which acted as a vector for the toxin. We speculate that pelican nestlings in 2002 were fed prey items harboring domoic acid and succumbed to the toxin; pelican chicks may have a lower tolerance for the toxin than adults. From our carcass count in the post-breeding survey, we estimated that at least 3,720 chicks had died on Anacapa in 2002. We also estimated that approximately 80 percent of the mortality occurred in late April and May, the apparent height of the domoic acid event. Later breeding efforts on Anacapa appeared to be unaffected; there was very little or no chick mortality among late nesters (see Table 3; note that the "Ridge Trail East" sub-colony, comprised wholly of late nesters, had no chick mortality).

***Analysis of Long-term Breeding Data, 1985-2002***

We found that the best model for each of the breeding measures (nest attempts, chicks fledged, productivity, percent abandoned nests, and percent mortality) was the mean model (Table 4). Although the mean model did not have the lower AIC for chicks per successful nest,

the AIC was sufficiently close to the trend model ($\Delta AIC<2$) to be "worthy of consideration". On principle of parsimony, we modeled these breeding measures using the mean model. However, the trend model had a substantially lower AIC value than the mean model for chicks fledged and mortality; we therefore modeled these measures using the trend model.

The mean number of nest attempts over the period 1985-2002 was 4,443 (Table 5). The standard error of this value as an estimate of the true underlying mean was 355. This leads to a 90 % confidence that the true mean lies within the range (3,825 - 5,061). As we have previously discussed, the number of nests for individual years can vary considerably. The standard deviation of a single year's nest count was 1,507, leading to a 90 % prediction interval (PI) of the range (1,964 - 6,921). Therefore, over a 10-year period of no change, we expect about 90 percent of those years (or 9 years) to have a number of nests ranging between 1,964 and 6,921. The coefficient of variation (CV), or standard deviation divided by mean, was 34 percent.

For all breeding measures, CV's ranged from 34 to 65 percent, with the exception of number of chicks per successful nest which had a relatively low CV of 11 percent (Table 5). Thus, the estimation and prediction accuracy is highest for number of chicks per successful nest, which we would expect since this parameter is the most limited (i.e., a brown pelican's maximum clutch size is 3 eggs). The estimated mean number of chicks per successful nest was 1.32, with 90 % confidence intervals (CI) ranging from 1.26 to 1.38 and 90 % PI from 1.08 to 1.55. The values cannot be less than 1 nor more than 3; these are the limits of this measure. In comparing the other breeding measures, the estimated mean number of chicks fledged was 2,935, with 90 % CI range of 2,289 - 3,580 and 90 % PI of 427-5,443. Estimated productivity, or mean number of fledglings per nesting attempt, was 0.66 (90 % CI range of 0.54-0.77 and 90 % PI range of 0.21-1.11). Mean percent abandoned nests is 50 % (90 % CI range of 43-58 % and 90 % PI range of 21-80 %), and mean percent chick mortality is 24 % (90 % CI range of 17-31 % and 90 % PI range of 0-50 %).

The power of detecting trends varied widely depending on multiple factors, including the amount of trend in the population, the amount of data collected, and the method for detecting it in the data analysis. Decreasing trends are more likely to be detected than increasing trends of

the same magnitude. For example, assuming the maximum survey effort (every year), a 10 percent decrease in nest attempts had a 85 percent chance of detection using the hypothesis test at the 0.05 significance level, compared with a 10 percent increase which had only a 72 percent chance of detection (Table 6). A 2% and 5% per annum increase had very poor chance of being detected (<10%; Tables 6-7; Figures 3-4). For all trends between –5% to +5%, the hypothesis tests had more than 50 percent chance of failure of detecting the trend. For the less conservative 0.10 significance level, the probability of detecting a –10% or +10% trend was better than 50 percent for all levels of survey effort. However, 80 percent (rather than 50 percent) is more widely regarded as the benchmark indicating sufficient power. We were able to achieve 80 percent power only for nest attempts, and then only for a severe trend (–10% or +10%) and with maximum survey effort (every year) (Tables 6-7; Figures 3-4).

The probability of detecting trends using AIC model selection criterion was comparable to that using the hypothesis test. The probability of detecting a trend was higher for negative trends than with positive trends, with the highest probability of detection generally occurring with a –10% or +10% trend. However, using a critical value of 2, indicating greater than 70 percent weight of evidence for the trend model, the probability of detecting the trend reached 80 percent only for nest attempts, and only for a severe decline (-10%) and with maximum survey effort (again, every year) (Tables 8-9; Figures 5-6). With the critical value for $\Delta$AIC of 0, indicating greater than 50 percent weight of evidence, the probability of detecting a trend exceeded 80 percent for all survey efforts when detecting a ±10 percent change in nest attempts and chicks fledged (Tables 8-9; Figures 5-6).

Monitoring brown pelican breeding activity cannot be any more complete than a total count. Our surveys have been near-total counts, falling short because some nests are out of view during in-season breeding surveys. As previously mentioned, some nests are not observable from either land-based vantage points or offshore by boat because they are obscured by features of the landscape or dense vegetation. We obtain relatively accurate counts of these nests in post-breeding surveys conducted in the colony area after the last chicks fledge and all birds have left the colony. We therefore could probably not improve much on coverage and accuracy in our current monitoring scheme. We believe our survey data can be treated as the most reliable index

possible of annual breeding activity on the island and not suited to any further statistical enhancements. However, if any reduction in the survey is employed, such as random sub-sampling, then statistical estimation of breeding activity will be needed for the reduced survey to be comparable to our surveys during the years 1985-2002. We do not recommend sub-sampling for (at least) 2 reasons. First, brown pelican breeding activity does not fall naturally into discernible breeding location units that could be used as sampling units. Second, breeding activity is already subject to large annual variation, and a partial sample survey would only contribute sampling variation, making the detection of trends even more difficult.

With complete surveys of breeding activity, annual fluctuation has been large relative to the mean, with coefficients of variation for nest attempts near 35 percent and over 50 percent for chicks fledged. Environmental variables and/or perturbations, such as the effects of an El Niño, food availability, disease, human disturbance, domoic acid, fishery exploitation, etc., all contribute to dramatic variability in breeding activity from year to year. For this reason, underlying sustained trends in breeding activity of up to 10 percent per annum could easily be masked by annual fluctuations. Statistical trend detection using either hypothesis testing or AIC model selection has less than a 50 percent chance of detecting trends in the –5% to +5% range. Only "dramatic" changes, such as a –10% per annum decline, have greater than a 50 percent chance of detection and typically only when surveys are conducted every year. In considering the results of the power analysis, it is clear that annual surveys provide by far the best ability to detect significant change.

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project. Their cooperation and participation have made this project possible, and we thank them for their willingness to help, for their tolerance, and for the many friendships developed over the years. Thanks also to our pilots, Larry Heitz, Robert Morgan, and Wayne Burnett of the California Department of Fish and Game, for their expertise and the success of our aerial surveys. Our special thanks to the agencies and the many people who have provided us with support, advice, and assistance over the years.

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## CAPTIONS TO FIGURES

**Figure 1**. Map of the Southern California Bight (SCB) showing locations of past and present major breeding colonies of California Brown Pelicans. Colonies on West Anacapa Island, Santa Barbara Island (SBI), Islas Los Coronados, and Isla San Martín are all currently active. San Martín was inactive from 1974 to1999, but now a small number of nests are found there. The Islas Todos Santos colony was extirpated in the 1920s. The Brown Pelican breeding range in the SCB extends from the northern California Channel Islands southward to Isla San Martín, near Cabo San Quintín, Baja California Norte, Mexico. The narrow arrows indicate generalized circulation patterns of the Oceanic Phase of the California Current (map adapted from Anderson and Gress 1983).

**Figure 2.** Brown Pelican nesting areas on West Anacapa Island, California, showing locations of the various sub-colonies given in Table 3 and described in the text.

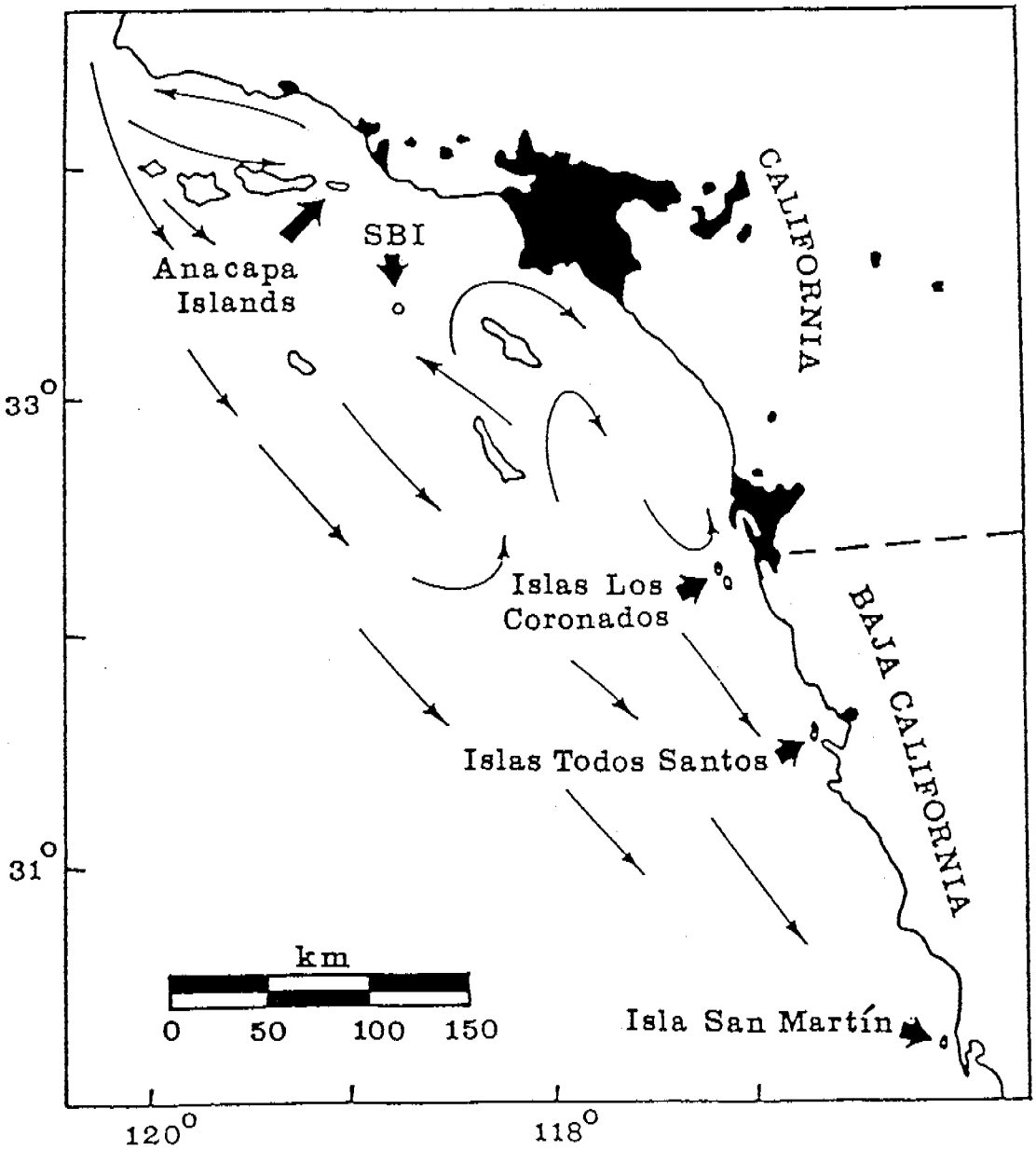
**Figure 3.** Power of detecting trend in Brown Pelican *nest attempt counts* using hypothesis test at the 0.05 and 0.10 significance level for the years 2001-2012. Power is the probablity of detecting trend and was calculated for three scenarios of survey effort: (1) every year in 2001-2012; (2) each year 2001-2003, then every odd year until 2012; and (3) each year 2001-2003, then every third year until 2012.

**Figure 4.** Power of detecting trend in Brown Pelican *fledged young counts* using hypothesis test at the 0.05 and 0.10 significance level for the years 2001-2012. Power is the probablity of detecting trend, and is calculated for three scenarios of survey effort: (1) every year 2001-2012; (2) each year 2001-2003, then every odd year until 2012; and (3) each year 2001-2003, then every third year until 2012.

**Figure 5.** Probability of detecting trend in Brown Pelican *nest attempt counts* using AIC model selection criterion. Probabilities are calculated for three scenarios of survey effort: (1) every year 2001-2012; (2) each year 2001-2003, then every odd year until 2011; and (3) each year 2001-2003, then every third year until 2012. Probabilities are calculated for strong evidence favoring the trend model ($\Delta AIC>2$), weaker evidence favoring the trend model ($0<\Delta AIC<2$), and no evidence favoring the trend model.

**Figure 6.** Probability of detecting trend in Brown Pelican *fledged young counts* using AIC model selection criterion. Probabilities are calculated for three scenarios of survey effort: (1) every year 2001-2012; (2) each year 2001-2003, then every odd year until 2011; and (3) each year 2001-2003, then every third year until 2012. Probabilities are calculated for strong evidence favoring the trend model ($\Delta AIC>2$), weaker evidence favoring the trend model ($0<\Delta AIC<2$), and no evidence favoring the trend model.

Figure 1.


CALIFORNIA
SBI
Anacapa
Islands
33°
Islas Los
Coronados
BAJA CALIFORNIA
Islas Todos Santos
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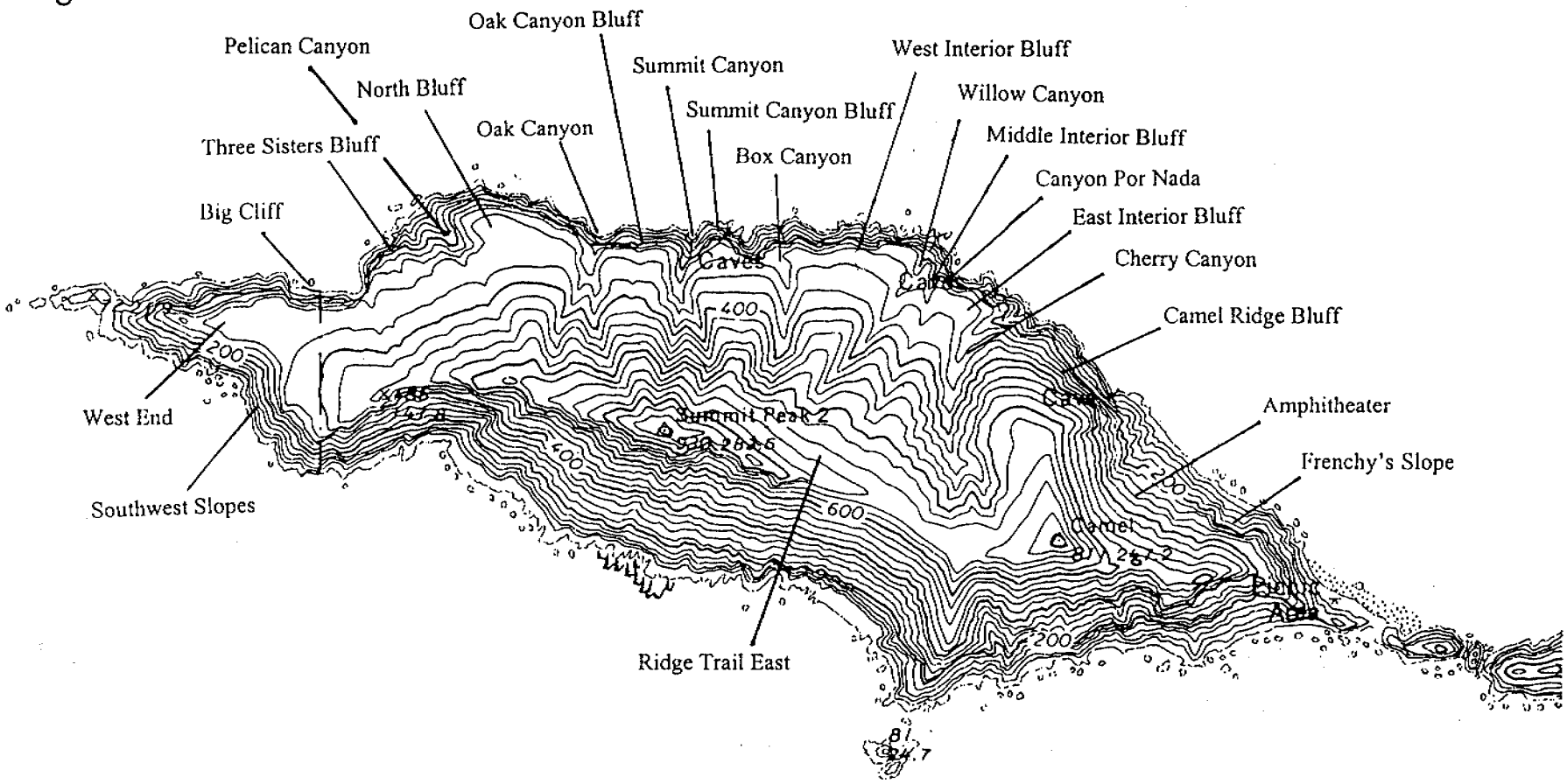
150
Isla San Martín
120°
118°

Figure 2.




# West Anacapa Island

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Figure 3

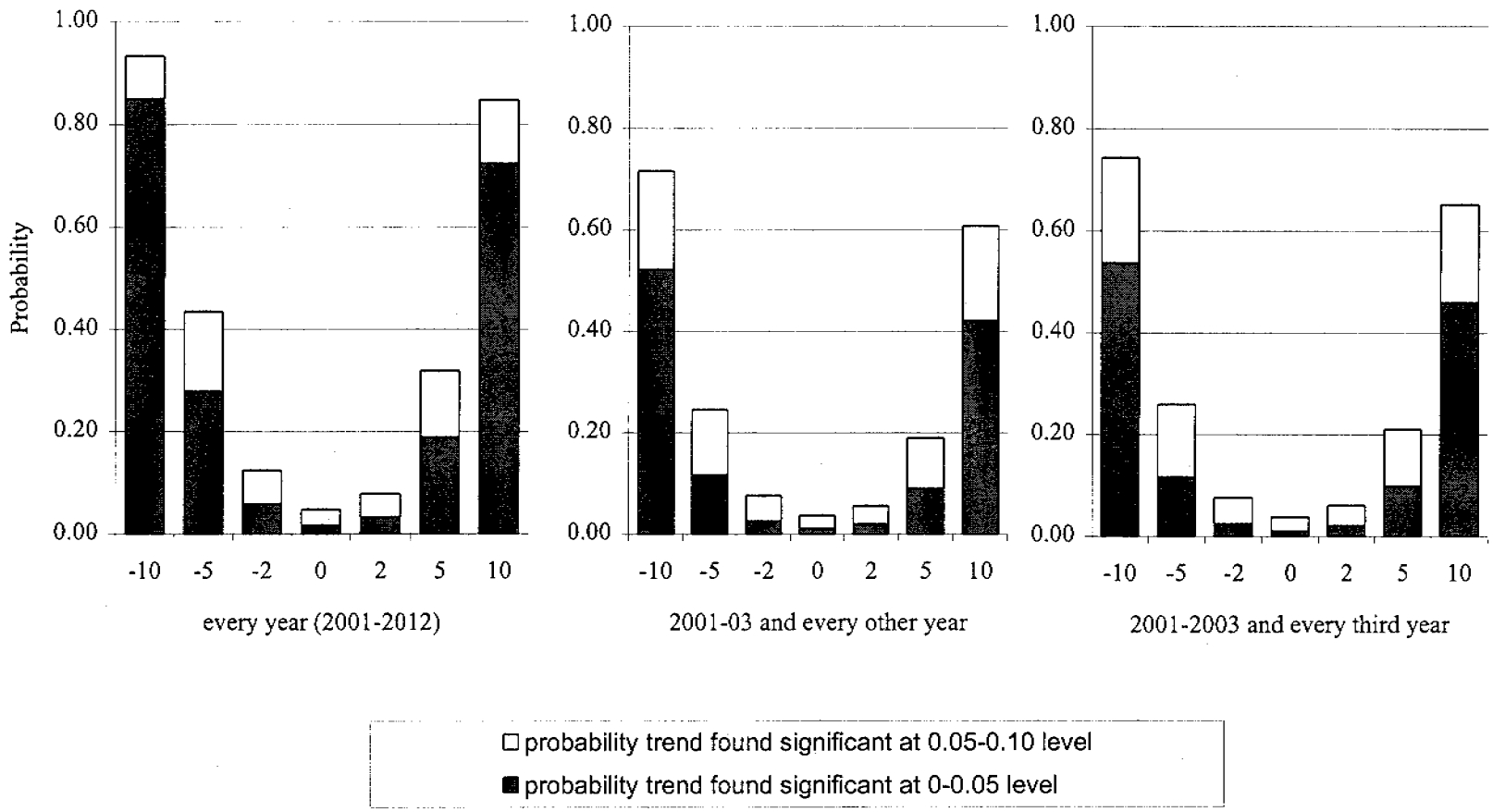
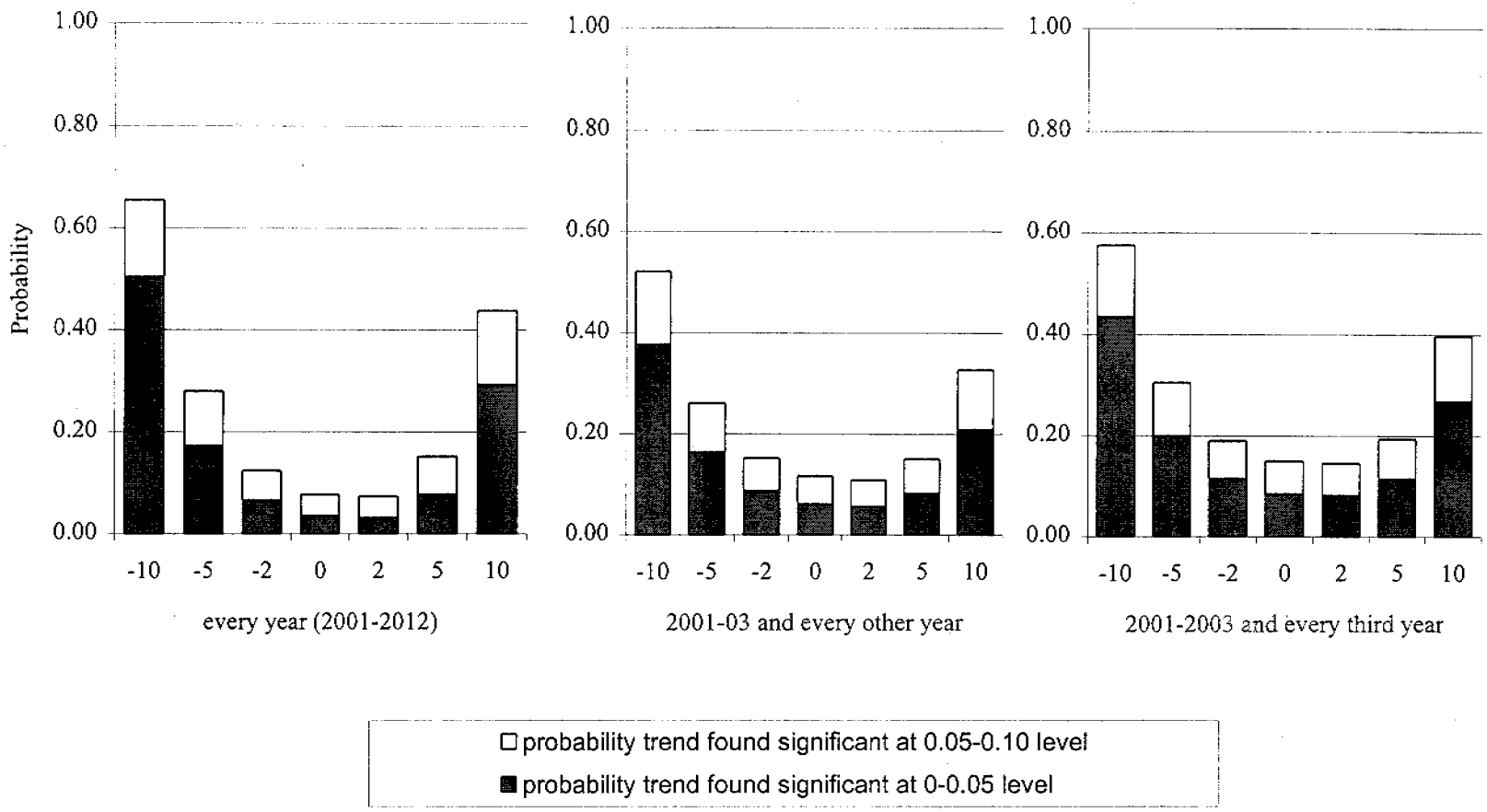

Probability
1.00
0.80
0.60
0.40
0.20
0.00
-10 -5 -2 0 2 5 10
every year (2001-2012)
2001-03 and every other year
2001-2003 and every third year
probability trend found significant at 0.05-0.10 level
probability trend found significant at 0-0.05 level

Figure 4


Probability
1.00
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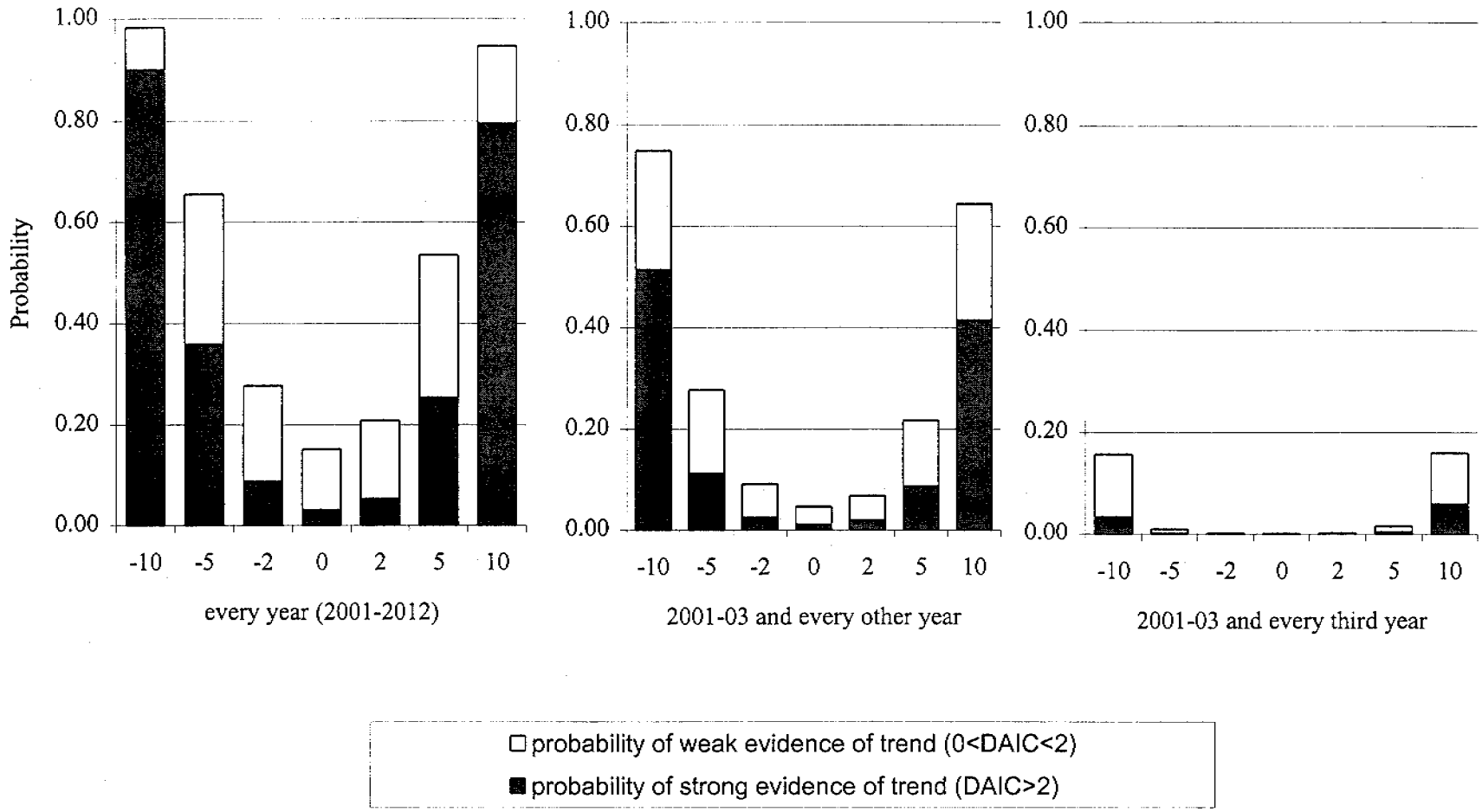
every year (2001-2012)
2001-03 and every other year
2001-2003 and every third year
probability trend found significant at 0.05-0.10 level
probability trend found significant at 0-0.05 level

Figure 5


Probability
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every year (2001-2012)
2001-03 and every other year
2001-03 and every third year
probability of weak evidence of trend (0<DAIC<2)
probability of strong evidence of trend (DAIC>2)

Figure 6

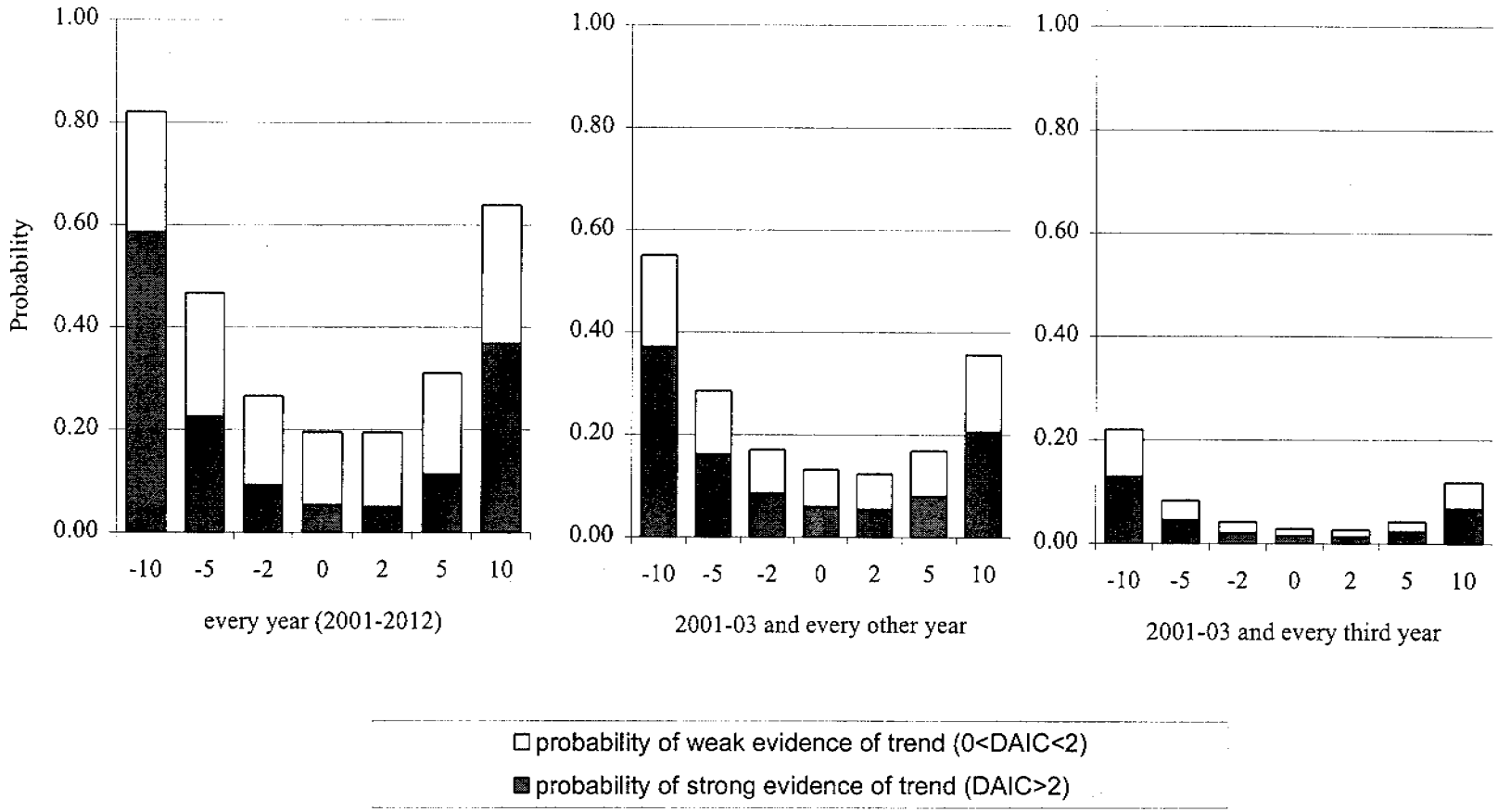

Probability
1.00
0.80
0.60
0.40
0.20
0.00
-10 -5 -2 0 2 5 10
every year (2001-2012)
2001-03 and every other year
2001-03 and every third year
probability of weak evidence of trend (0<DAIC<2)
probability of strong evidence of trend (DAIC>2)

Table 1. Annual mean breeding data for California Brown Pelicans nesting in the Anacapa Island area (West Anacapa Island and Scorpion Rock), California, 1969-2002. (a)

| Year | Nest Attempts (b) | Young Fledged | Productivity (c) | Percent Abandoned Nests | Young / Successful Nest | Percent Chick Mortality |
|---|---|---|---|---|---|---|
| 1969 | 750 | 4 | 0.005 | nd | nd | nd |
| 1970 | 552 | 1 | 0.002 | nd | nd | nd |
| 1971 | 540 | 7 | 0.013 | nd | nd | nd |
| 1972 (d) | 261 | 57 | 0.22 | nd | nd | nd |
| 1973 | 247 | 34 | 0.14 | nd | nd | nd |
| 1974 (d) | 416 | 305 | 0.73 | nd | nd | nd |
| 1975 (d) | 292 | 256 | 0.88 | nd | nd | nd |
| 1976 | 417 | 279 | 0.67 | 53.5 | 1.44 | nd |
| 1977 | 76 | 39 | 0.51 | 55.0 | 1.14 | nd |
| 1978 (e) | 210 | 37 | 0.18 | 88.1 | 1.48 | nd |
| 1979 | 1260 | 980 | 0.78 | 41.5 | 1.33 | nd |
| 1980 | 2150 | 1440 | 0.67 | 44.2 | 1.20 | 5.8 |
| 1981 | 2950 | 1810 | 0.61 | 52.4 | 1.29 | 20.5 |
| 1982 | 1860 | 1180 | 0.63 | 56.5 | 1.46 | 27.2 |
| 1983 | 1860 | 1150 | 0.62 | 42.2 | 1.07 | 39.0 |
| 1984 | 628 | 530 | 0.84 | 48.5 | 1.64 | 0.4 |
| 1985 | 5150 | 6390 | 1.24 | 22.0 | 1.59 | 12.7 |
| 1986 | 5910 | 3990 | 0.68 | 53.1 | 1.44 | 40.7 |
| 1987 | 6330 | 4060 | 0.64 | 52.8 | 1.36 | 33.6 |
| 1988 | 2720 | 2470 | 0.91 | 25.6 | 1.22 | 10.6 |
| 1989 | 4990 | 2880 | 0.58 | 59.6 | 1.43 | 8.6 |
| 1990 | 2200 | 650 | 0.30 | 78.7 | 1.39 | 27.1 |
| 1991 | 5770 | 1600 | 0.28 | 79.0 | 1.32 | 9.5 |
| 1992 | 1490 | 372 | 0.25 | 77.7 | 1.12 | 33.7 |
| 1993 | 3640 | 2390 | 0.66 | 48.7 | 1.28 | 16.4 |
| 1994 | 4910 | 1930 | 0.39 | 68.6 | 1.25 | 33.9 |
| 1995 (f) | 4800 | nd | nd | nd | nd | nd |
| 1996 | 5440 | 5530 | 1.02 | 32.2 | 1.50 | 17.0 |
| 1997 | 5500 | 3320 | 0.60 | 47.0 | 1.14 | 49.3 |
| 1998 | 2540 | 2210 | 0.87 | 40.0 | 1.45 | 3.4 |
| 1999 | 5290 | 3020 | 0.57 | 47.1 | 1.08 | 35.0 |
| 2000 | 3670 | 3310 | 0.90 | 33.2 | 1.35 | 6.2 |
| 2001 | 3180 | 2550 | 0.80 | 40.2 | 1.34 | 17.4 |
| 2002 | 6440 | 3220 | 0.50 | 53.7 | 1.08 | 53.6 |

nd = no data

(see next page for footnotes)

(a) Data from Anderson et al. 1975, 1977, Anderson and Gress 1983, Gress and Anderson 1983, Gress 1995, Gress et al., unpubl. data.

(b) Estimates of numbers of pairs nesting represent a compromise between maximum numbers present, numbers of nests constructed, reproductive behavior, and appearance of secondary sexual characteristics.

(c) Productivity defined as number of young fledged per nest attempt.

(d) Nesting occurred on Scorpion Rock in 1972 (112 nests; 31 fledged), 1974 (105 nests; 75 fledged), and 1975 (80 nests; 74 fledged); Scorpion Rock is located off northwestern Santa Cruz Island approximately 6 nautical miles west of West Anacapa Island.

(e) Probable renesting in 1978; 210 pairs built 340 nests.

(f) Based on nest counts at end of breeding season; young not censused in 1995.

Table 2. Nesting phenology of Brown Pelicans on West Anacapa Island, Channel Islands National Park, California, in 2002.

| Event | Date |
|---|---|
| First egg-laying | Early January |
| First hatching | Early February |
| Peak egg-laying | Early March |
| First fledging | Early May |
| Late egg-laying | Mid-June |
| Last hatching | Mid-July |
| Last fledging | Mid-October |
| Length of breeding season * | 10.5 months |

(* From onset of nesting to last fledging)

Table 3. Summary of California Brown Pelican reproduction by sub-colony on West Anacapa Island, California, in 2002.

| Subcolony | Nest Attempts | Young Fledged | (a) Produc-tivity | (b) % Aban. Nests | (c) Young Fledged/ Succ.Nest | (d) % Chick Mort-ality |
|---|---|---|---|---|---|---|
| 3 Sisters Bluffs | 645 | 137 | 0.21 | 81.4 | 1.14 | 66.7 |
| North Bluff | 578 | 398 | 0.69 | 33.0 | 1.03 | 35.9 |
| Oak Canyon | 317 | 152 | 0.48 | 55.8 | 1.09 | 40.1 |
| Oak Canyon Bluff | 577 | 298 | 0.52 | 50.3 | 1.04 | 54.8 |
| Summit Canyon | 194 | 109 | 0.56 | 47.9 | 1.08 | 46.3 |
| Summit Cyn. Bluff | 654 | 322 | 0.49 | 53.1 | 1.05 | 66.4 |
| Box Canyon | 165 | 85 | 0.52 | 53.3 | 1.10 | 60.1 |
| West Interior Bluff | 434 | 278 | 0.64 | 37.1 | 1.02 | 54.3 |
| Willow Canyon | 69 | 34 | 0.49 | 56.5 | 1.13 | 58.5 |
| Middle Interior Bluff | 313 | 196 | 0.63 | 45.0 | 1.14 | 59.3 |
| Canyon por Nada | 270 | 94 | 0.35 | 70.0 | 1.16 | 35.2 |
| East Interior Bluff | 344 | 196 | 0.57 | 45.9 | 1.05 | 47.6 |
| Ridge Trail East | 165 | 58 | 0.35 | 68.5 | 1.12 | 0 |
| Cherry Canyon | 483 | 216 | 0.45 | 62.9 | 1.21 | 52.9 |
| Camel Ridge Bluff | 106 | 55 | 0.52 | 52.8 | 1.10 | 42.7 |
| Amphitheater | 1123 | 591 | 0.53 | 52.0 | 1.10 | 48.8 |
| TOTALS | 6,437 | 3,219 | 0.50 | 53.7 | 1.08 | 53.6 |

(a) Productivity is defined as the number of young fledged per nesting attempt.

(b) Percent abandoned nests.

(c) Young fledged per successful nest
(successful nests are those from which young have fledged).

(d) Chick mortality is based on end-of-season ground counts of carcasses in each sub-colony area.

Table 4. Fit statistics, AIC and ΔAIC, for each model type for all breeding measures for Brown Pelicans nesting on West Anacapa Island, CA, 1985-2002.

| | AIC | | | | | |
|---|---|---|---|---|---|---|
| Model | Nest Attempts | Young Fledged | Productivity | Abandoned nests (%) | Young per successful nest | Chick Mortality (%) |
| Mean | 315.50 | 315.26 | 4.57 | 154.69 | -17.83 | 149.77 |
| Trend | 317.45 | 316.93 | 6.55 | 156.46 | -18.78 | 151.42 |
| | ΔAIC | | | | | |
| Model | Nest Attempts | Young Fledged | Productivity | Abandoned nests (%) | Young per successful nest | Chick Mortality (%) |
| Mean | 0.00 | 0.00 | 0.00 | 0.00 | 0.95 | 0.00 |
| Trend | 1.95 | 1.67 | 1.98 | 1.77 | 0.00 | 1.65 |

Table 5. Summary statistics describing the baseline mean and variation in breeding measures of Brown Pelicans nesting on West Anacapa Island, CA, 1985-2002.

| | Summary statistics | | | | | |
|---|---|---|---|---|---|---|
| Model | Nest Attempts | Young Fledged | Productivity | Abandoned nests (%) | Young per successful nest | Chick Mortality (%) |
| Sample size | 18 | 17 | 17 | 17 | 17 | 17 |
| Mean | 4443 | 2935 | 0.66 | 50 | 1.32 | 24 |
| Standard error | 355 | 370 | 0.07 | 4.3 | 0.03 | 3.8 |
| 90% Confidence limits | 3825-5061 | 2289-3580 | 0.54-0.77 | 43-58 | 1.26-1.38 | 17-31 |
| Standard deviation | 1507 | 1525 | 0.27 | 18 | 0.14 | 16 |
| 90% Prediction interval | 1964-6921 | 427-5443 | 0.21-1.11 | 21-80 | 1.08-1.55 | 0-50 |
| Coefficient of variation (%) | 34 | 52 | 42 | 35 | 11 | 65 |

Table 6. Power of detecting trend in Brown Pelican *nest attempt counts* using hypothesis test at the 0.05 and 0.10 significance level for the years 2001-2012. Power is the probability of detecting trend, and is calculated for three scenarios of survey effort: (1) every year 2001-2012; (2) each year 2001-2003, then every odd year until 2011;and (3) each year 2001-2003, then every third year until 2012.

| | | Probability trend found significant | | |
|---|---|---|---|---|
| Effort | Trend (% per annum) | 0-0.05 level | 0.05-0.10 level | 0-0.10 level |
| Every year | -10 | 0.85 | 0.08 | 0.93 |
| | -5 | 0.28 | 0.16 | 0.43 |
| | -2 | 0.06 | 0.07 | 0.12 |
| | 0 | 0.02 | 0.03 | 0.05 |
| | 2 | 0.03 | 0.05 | 0.08 |
| | 5 | 0.19 | 0.13 | 0.32 |
| | 10 | 0.72 | 0.12 | 0.85 |
| Every odd year | -10 | 0.52 | 0.19 | 0.72 |
| | -5 | 0.12 | 0.13 | 0.25 |
| | -2 | 0.03 | 0.05 | 0.08 |
| | 0 | 0.01 | 0.03 | 0.04 |
| | 2 | 0.02 | 0.04 | 0.06 |
| | 5 | 0.09 | 0.10 | 0.19 |
| | 10 | 0.42 | 0.19 | 0.61 |
| Every third year | -10 | 0.54 | 0.21 | 0.74 |
| | -5 | 0.12 | 0.14 | 0.26 |
| | -2 | 0.02 | 0.05 | 0.08 |
| | 0 | 0.01 | 0.03 | 0.04 |
| | 2 | 0.02 | 0.04 | 0.06 |
| | 5 | 0.10 | 0.11 | 0.21 |
| | 10 | 0.46 | 0.19 | 0.65 |

Table 7. Power of detecting trend in Brown Pelican *fledged young counts* using hypothesis test at the 0.05 and 0.10 significance level for the years 2001-2012. Power is the probability of detecting trend, and is calculated for three scenarios of survey effort: (1) every year 2001-2012; (2) each year 2001-2003, then every odd year until 2011; and (3) each year 2001-2003, then every third year until 2012.

| | | Probability trend found significant | | |
|---|---|---|---|---|
| Effort | Trend (% per annum) | 0-0.05 level | 0.05-0.10 level | 0-0.10 level |
| Every year | -10 | 0.50 | 0.15 | 0.65 |
| | -5 | 0.17 | 0.11 | 0.28 |
| | -2 | 0.06 | 0.06 | 0.12 |
| | 0 | 0.03 | 0.04 | 0.08 |
| | 2 | 0.03 | 0.04 | 0.07 |
| | 5 | 0.08 | 0.07 | 0.15 |
| | 10 | 0.29 | 0.15 | 0.44 |
| Every odd year | -10 | 0.38 | 0.14 | 0.52 |
| | -5 | 0.16 | 0.10 | 0.26 |
| | -2 | 0.09 | 0.07 | 0.15 |
| | 0 | 0.06 | 0.06 | 0.12 |
| | 2 | 0.05 | 0.05 | 0.11 |
| | 5 | 0.08 | 0.07 | 0.15 |
| | 10 | 0.21 | 0.12 | 0.33 |
| Every third year | -10 | 0.43 | 0.14 | 0.58 |
| | -5 | 0.20 | 0.11 | 0.31 |
| | -2 | 0.11 | 0.08 | 0.19 |
| | 0 | 0.08 | 0.07 | 0.15 |
| | 2 | 0.08 | 0.06 | 0.14 |
| | 5 | 0.11 | 0.08 | 0.19 |
| | 10 | 0.27 | 0.13 | 0.40 |

Table 8. Probability of detecting trend in Brown Pelican *nest attempt counts* using AIC model selection criterion. Probabilities are calculated for three scenarios of survey effort: (1) every year 2001-2012; (2) each year 2001-2003, then every odd year until 2011; and (3) each year 2001-2003, then every third year until 2012. Probabilities are calculated for strong evidence favoring the trend model ($\Delta AIC>2$), weak evidence favoring the trend model ($0<\Delta AIC<2$), and no evidence favoring the trend model.

| | | Probability of evidence of trend, based on AIC | | |
|---|---|---|---|---|
| Effort | Trend (% per annum) | strong evidence ($\Delta AIC>2$) | weak evidence ($0<\Delta AIC<2$) | no evidence |
| Every year | -10 | 0.90 | 0.08 | 0.02 |
| | -5 | 0.36 | 0.30 | 0.34 |
| | -2 | 0.09 | 0.19 | 0.72 |
| | 0 | 0.03 | 0.12 | 0.85 |
| | 2 | 0.05 | 0.16 | 0.79 |
| | 5 | 0.25 | 0.28 | 0.46 |
| | 10 | 0.79 | 0.15 | 0.05 |
| Every odd year | -10 | 0.51 | 0.24 | 0.25 |
| | -5 | 0.11 | 0.17 | 0.72 |
| | -2 | 0.02 | 0.07 | 0.91 |
| | 0 | 0.01 | 0.04 | 0.95 |
| | 2 | 0.02 | 0.05 | 0.93 |
| | 5 | 0.09 | 0.13 | 0.78 |
| | 10 | 0.41 | 0.23 | 0.36 |
| Every third year | -10 | 0.03 | 0.12 | 0.84 |
| | -5 | 0.00 | 0.01 | 0.99 |
| | -2 | 0.00 | 0.00 | 1.00 |
| | 0 | 0.00 | 0.00 | 1.00 |
| | 2 | 0.00 | 0.00 | 1.00 |
| | 5 | 0.00 | 0.01 | 0.98 |
| | 10 | 0.06 | 0.10 | 0.84 |

Table 9. Probability of detecting trend in Brown Pelican *fledged young counts* using AIC model selection criterion. Probabilities are calculated for three scenarios of survey effort: (1) every year 2001-2012; (2) each year 2001-2003, then every odd year until 2011; and (3) 2001-2003 followed by every third year until 2012. Probabilities are calculated for strong evidence favoring the trend model ($\Delta$AIC>2), weak evidence favoring the trend model (0<$\Delta$AIC<2), and no evidence favoring the trend model.

| | | Probability of evidence of trend, based on AIC | | |
|---|---|---|---|---|
| Effort | Trend (% per annum) | strong evidence ($\Delta$AIC>2) | weak evidence (0<$\Delta$AIC<2) | no evidence |
| Every year | -10 | 0.58 | 0.24 | 0.18 |
| | -5 | 0.22 | 0.24 | 0.53 |
| | -2 | 0.09 | 0.17 | 0.73 |
| | 0 | 0.05 | 0.14 | 0.80 |
| | 2 | 0.05 | 0.14 | 0.81 |
| | 5 | 0.11 | 0.20 | 0.69 |
| | 10 | 0.37 | 0.27 | 0.36 |
| Every odd year | -10 | 0.37 | 0.18 | 0.45 |
| | -5 | 0.16 | 0.13 | 0.71 |
| | -2 | 0.08 | 0.09 | 0.83 |
| | 0 | 0.06 | 0.07 | 0.87 |
| | 2 | 0.05 | 0.07 | 0.88 |
| | 5 | 0.08 | 0.09 | 0.83 |
| | 10 | 0.20 | 0.15 | 0.64 |
| Every third year | -10 | 0.13 | 0.09 | 0.78 |
| | -5 | 0.04 | 0.04 | 0.92 |
| | -2 | 0.02 | 0.02 | 0.96 |
| | 0 | 0.01 | 0.01 | 0.97 |
| | 2 | 0.01 | 0.01 | 0.97 |
| | 5 | 0.02 | 0.02 | 0.96 |
| | 10 | 0.07 | 0.05 | 0.88 |

APPENDIX G: Jaques, D.L. and D.W. Anderson. 1988. Brown Pelican use of the Moss Landing Wildlife Management Area. California Department of Fish and Game Nongame Bird and Mammal Section Report. 58 pages.

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME
WILDLIFE MANAGEMENT DIVISION
NONGAME BIRD AND MAMMAL SECTION

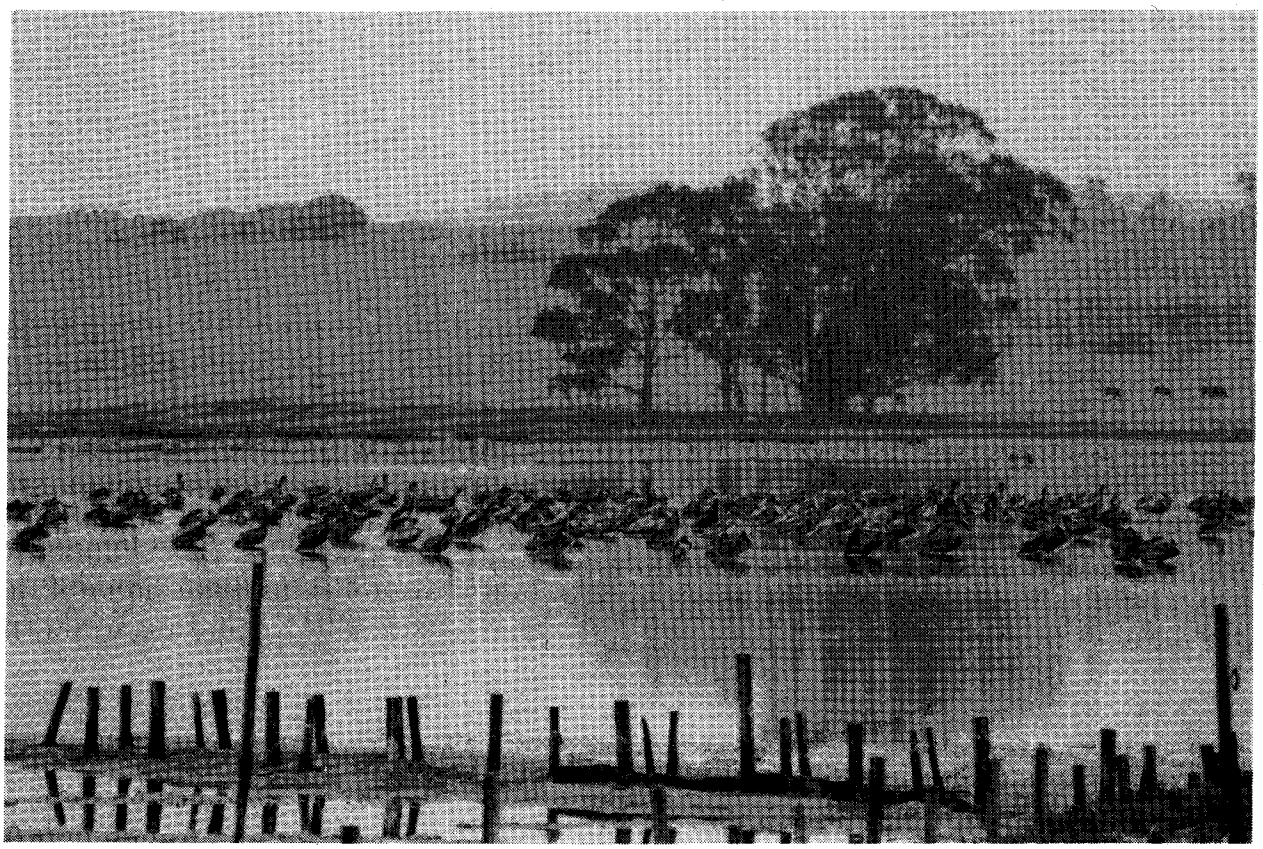
# BROWN PELICAN USE OF THE MOSS LANDING WILDLIFE MANAGEMENT AREA

## Roosting Behavior, Habitat Use, and Interactions with Humans

by

Deborah L. Jaques and Daniel W. Anderson

1988



**Cover photograph of California Brown Pelicans in a salt pond at Moss Landing Wildlife Management Area by Deborah Jaques**

STATE OF CALIFORNIA
THE RESOURCES AGENCY
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# BROWN PELICAN USE OF THE MOSS LANDING WILDLIFE MANAGEMENT AREA

## Roosting Behavior, Habitat Use, and Interactions with Humans

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July 1988

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ABSTRACT

The deteriorating salt evaporation ponds at the Moss Landing Wildlife Management Area served as a communal roost site for thousands of Brown Pelicans (Pelecanus occidentalis californicus) during this study--July through December 1987. The peak high count was obtained in late July when a minimum of 4355 pelicans were present during a morning census. Roosting populations declined greatly soon after this and were relatively low through the expected peak in fall. The habitat of the study site was unusual relative to other night roosts used by pelicans on the U.S. Pacific coast. The roosting patterns and management problems we observed were also unique and complex. Brown Pelican seasonal and diurnal patterns of occupation, within-roost habitat use, and frequency of disturbance at the salt ponds suggest that the quality of the roost has decreased since 1982 and will continue to do so unless active management to enhance the security of the site takes place. The salt ponds roost should be designated and treated as critical nonbreeding habitat for Brown Pelicans.

**ACKNOWLEDGEMENTS**

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We would like to thank the following persons: all the CDFG pilots, Bob Cole, Larry Heitz, Ron VanBenthuysen, Kevin McBride, and Rich Anthes for their excellent cooperation and flying skills; David Harlow from the U.S. Fish and Wildlife Service (USFWS) Endangered Species Office, Sacramento, for contributing the USFWS vehicle and gasoline which enabled us to conduct pelican surveys of the U.S. Pacific coast over the last two years; Bruce Elliot from the CDFG office in Monterey for his help on the study site and for arranging accommodations adjacent to the MLWMA which were invaluable to this research.

We would like to thank David Packard for use of the guest house on the Elkhorn Ranch and providing these ideal living conditions. We are grateful to ranch managers Clarence and Patty Tighe for the same, as well as their warm hospitality and friendship. Mark Silberstein and Ken Moore (Elkhorn Slough National Estuarine Research Reserve/CDFG) also provided a great deal of support with their interest in the study, and helped organize volunteers to assist in conducting pelican censuses at the ESNERR and surrounding areas. We would like to thank all of these volunteers, particularly Jane Olsen and Joe Ferreira (CDFG). Special thanks go to Craig Strong for conducting early morning censuses at Moss Landing when we could not be there, and for assistance in preparation of this report.

Point Reyes Bird Observatory and San Francisco Bay National Wildlife Refuge made time on Southeast Farallon Island possible and Long Marine Lab, UCSC, did the same for Año Nuevo Island. We appreciated assistance during aerial surveys from Sid Englund, Kim Heinemeyer, Chris Depkin, Mathew Klope, John Scholl (CDFG), Lisa Stewart, Oodvin Lund, and Dawn Breese. We also appreciated help from Lawrence Laurent (CDFG) which included boat censuses of Morro Bay. Thanks to Brian Knave for reviewing parts of this manuscript and to Alan Baldridge, Gregg Calliet, and Ken Briggs for their interest and ideas regarding this study. The California Department of Parks and Recreation and the Pebble Beach Company provided access to State Park and private lands.

## TABLE OF CONTENTS


ABSTRACT ..... i

ACKNOWLEDGEMENTS ..... ii

INTRODUCTION ..... 1

STUDY AREA ..... 5

METHODS ..... 7

Censuses at MLWMA ..... 7

Habitat Use ..... 7

Disturbance ..... 7

Aerial Surveys ..... 8

Ground Surveys ..... 8

RESULTS AND DISCUSSION ..... 8

Central California Population Trends ..... 8

Population Trends at MLWMA ..... 14

Roosts Associated with MLWMA ..... 17

MLWMA Daily Use Patterns ..... 20

Habitat Use at MLWMA ..... 28

Human Disturbances ..... 34

Natural Disturbance ..... 39

Impacts of Disturbance ..... 42

Hunting in the Salt Ponds ..... 44

DISCUSSION OF PROPOSED LEVEE ..... 52

SUMMARY AND RECOMMENDATIONS ..... 54

LITERATURE CITED ..... 58

APPENDIX ..... A-1

## INTRODUCTION

Recognition of the importance of specific habitats used by birds during the nonbreeding season has increased in recent years. Identification and protection of essential roosting habitat was listed among the primary objectives of the recovery plan for the California Brown Pelican (Pelecanus occidentalis californicus)(USFWS 1983). Basic requirements for communal night roosts used by Brown Pelicans are inflexible, and birds in these aggregations are highly sensitive to human disturbances. This study was initiated out of concern for a site which has been considered one of the largest, most important pelican roosts on the U.S. Pacific coast--the abandoned salt evaporation ponds in Elkhorn Slough. The salt ponds have been purchased by the state of California and are now part of the Moss Landing Wildlife Management Area (MLWMA). The preservation of this roost presents a challenge to wildlife managers and to the concept of protecting critical nonbreeding habitat for an endangered coastal seabird.

During late summer and fall thousands of Brown Pelicans from breeding colonies in the Southern California Bight (SCB), west coast of Baja California, and the Gulf of California innundate the California coast (Anderson and Anderson 1976). The central coast (Pt. Conception to Bodega Bay) and the offshore islands in the SCB comprise the "heart" of the U.S. nonbreeding range for this subspecies (Briggs et al. 1983). Brown pelicans range in smaller numbers as far north as British Columbia and as far south as Central America. Dispersal to Oregon and Washington during the fall has increased greatly in recent years (Jaques and Anderson, in prep). The number of pelicans along the California coast varies annually, along with breeding success and migratory patterns. Aerial shoreline surveys and at-sea transects yielded estimates of 83,000 to 100,000 Brown Pelicans present in California in October 1980 (Briggs et al. 1983).

Suitable communal roost sites in proximity to foraging areas are essential to Brown Pelicans away from breeding colonies. Brown Pelicans utilize a relatively wide range of habitats and sites for loafing during the day, but at night gather onto a fewer number of more secure communal roosts. Three essential requirements for night roosts are as follows: (1) they must occur within energetically efficient distances from foraging areas, (2) they must be buffered from mammalian predators and human disturbances, and (3) they must provide shelter from strong winds and surf spray (USFWS 1983). Day roosts are often less secure from mammalian predators, more accessible to humans, more exposed to wind and waves, and physically smaller than night roosts.

Where abundant, reliable food resources and favorable roosting habitat occur in the same area, large traditional roosts exist. These roosts may be occupied throughout the season and attract up to several thousand pelicans on a given night. Pelicans are found less regularly in other areas, where food resources are more ephemeral and/or roost habitat is of lower quality. Dispersion of roost sites may be a key factor governing pelican distribution (Briggs et al. 1983), and thus their ability to exploit food resources. The overall energy budgets of pelicans are likely influenced greatly by quality and distribution of roosts, but we will not discuss this further here.

The five most important night roosts in central California from south to north are as follows: (1) the nearshore rocks at Pismo Beach, (2) the coastal rocks in the vicinity of Diablo Canyon, (3) the abandoned salt evaporation ponds at Moss Landing, (4) Año Nuevo Island, and (5) Southeast Farallon Island (Fig.1). Each of these major roosts is associated with waters south of upwelling points (Pt. Buchon, Pt. Año Nuevo, and Pt. Reyes), and gulfs or embayments of known high productivity.

Among the five major roosts in central California, the salt pond site at Moss Landing is the most unique. It is the only artificial or man-made roost and the only site that is inland. It is relatively accessible to mammalian predators and people, and at low tide does not offer true "island" habitat. While food is abundant in Monterey Bay, offshore rocks or islands, the preferred roosting habitat for Brown Pelicans, are lacking in the Bay.

We suspect that natural habitats suitable for night roosting were available to pelicans in the Bay area prior to intensive human settlement and coastal development. For example, there may have been large sandbars and much greater volumes of water at the mouths of rivers, such as the Pajaro and the Salinas, providing secure night roost sites. The nature of both of these river mouths and Elkhorn Slough itself have changed dramatically during the 19th century. Flows out of the Salinas River have been reduced by agricultural practices and the channel has been re-routed near the river mouth. Condominiums were constructed a few hundred yards from a former pelican roost at the Pajaro River in the early 1970's. Elkhorn Slough habitats were severely altered early in the century when the sand dune was artificially breached to create the harbor at Moss Landing.

The Moss Landing salt evaporation ponds, constructed in 1910, have served as the primary pelican roost within Monterey Bay perhaps since the 1930's (in Baldridge 1973) and at least since the early 1970's (B. Ramer, unpublished data). During salt production, and later brine shrimp harvesting operations, the interior levees were surrounded by shallow water and infrequently

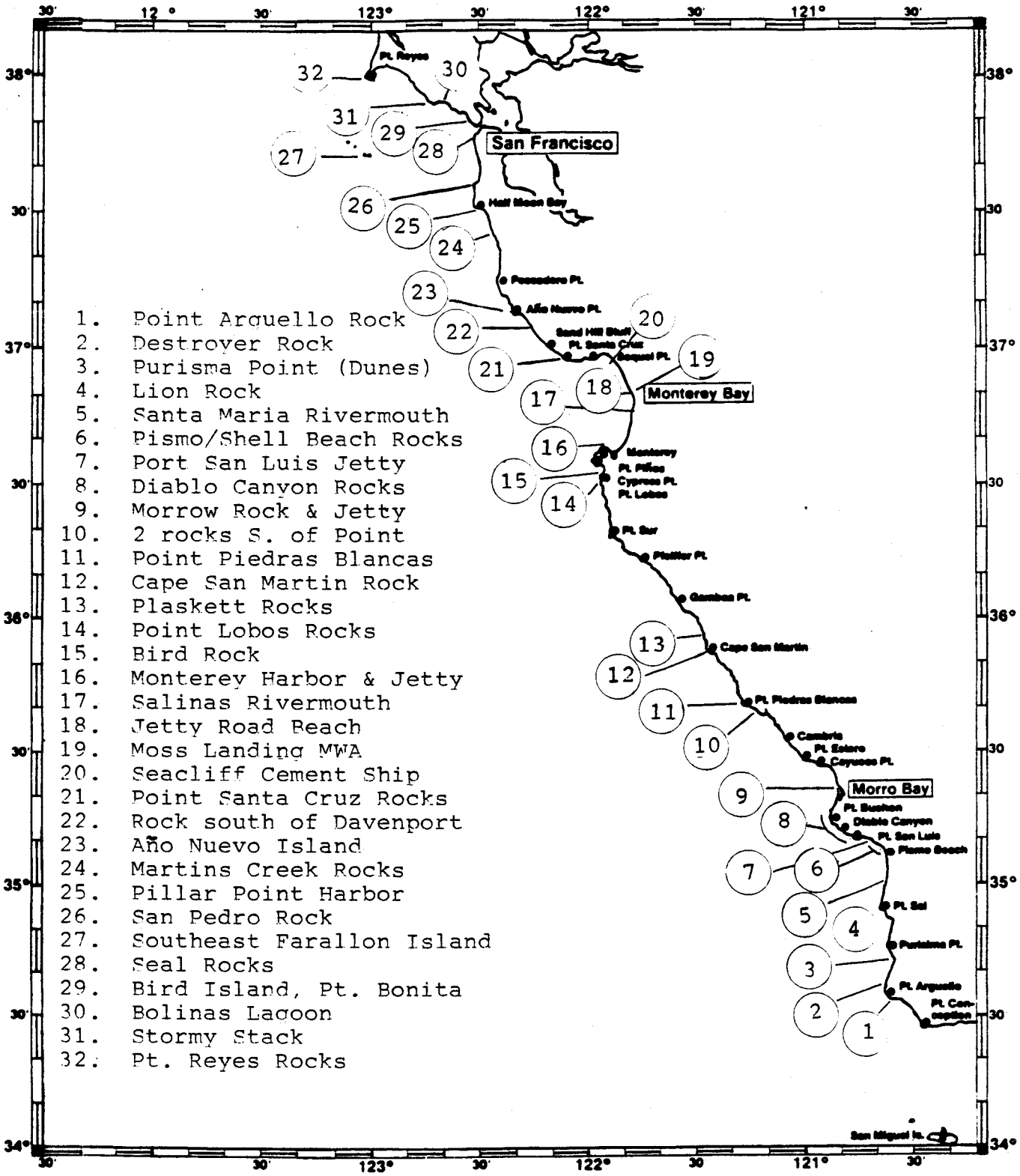


Figure 1. Locations of important Brown Pelican roosting and loafing sites along the Central California coastline.

accessed by humans. These inner levees functioned as islands and fulfilled the basic requirements for night roosting habitat. The security of the habitat was evidenced by the fact that the levees were used for nesting by gulls, terns, and shorebirds. Human access to the ponds was so restricted by the salt company that surveys of Brown Pelicans in the early 1970's were often conducted from Highway 1 (DWA field notes). Counts of pelicans roosting at the salt ponds in 1981 approached 5,300 birds, making this the largest known single aggregation of nonbreeding pelicans in the U.S. (Briggs et al. 1983).

Since the early 1980's the salt pond roost has changed rapidly. In 1982, the main levee was breached at the eastern end of the complex. The interior levees then eroded rapidly, exposing the entire area to tidal flux. The salt ponds have thus become increasingly vulnerable to mammalian predators during low to medium tides. To compound the problem, populations of non-native Red Foxes seem to have exploded along regions of the central coast through the 1980's. Foxes are sighted regularly in the Elkhorn Slough area during daylight hours. Finally, there has been an increase in human activity and access at the salt ponds since acquisition of the property by the California Department of Fish and Game (CDFG) in 1984. Trails have been constructed into and around the ponds, observations blinds have been installed, and the area has been opened to the public for waterfowl hunting.

Questions regarding pelican use patterns and the potential impact of human activities on the roost arose early in the planning stages for management of the MLWMA. In January 1987, CDFG biologists and the United States Fish and Wildlife Service (USFWS) Endangered Species Office agreed that data on seasonal abundance of Brown Pelicans, habitat use, and responses to disturbances were needed before firm management plans, especially concerning waterfowl hunting, could be established for the area.

Unfortunately, this study was initiated when it was too late for collection of baseline data on a "healthy" roost. The patterns of occupation we observed in 1987 suggest that some of the changes which have occurred since 1982 have made the site less attractive to pelicans. It is difficult to assess the impact of accelerated levee deterioration, increased public access, and waterfowl hunting at the roost, since these variables cannot be isolated. We recognize also, that in the context of a one-year study it is often impossible to separate such influences from natural seasonal and annual variation. Comparison of attendance patterns, within-roost habitat use, and frequency of disturbance relative to other large roosts on the central coast, however, aid in the evaluation of the MLWMA site.

In this report we summarize findings on Brown Pelican use of the MLWMA from July to December 1987. This is the most detailed

account of communal roosting behavior in Brown Pelicans to date. Results of our 1986 and 1987 aerial surveys and observations at other central California roosts are also included, to help place the importance and problems of the MLWMA roost in perspective. This results of this study provide a basis for future management decisions at MLWMA, and we hope that the information will be applied towards a management plan which will preserve and perhaps enhance roosting habitat for this endangered species.

## STUDY AREA

The MLWMA extends along most of the north bank of Elkhorn Slough, just inside the shoreline midway between the north and south limits of Monterey Bay (Fig 1). The salt pond portion of the 550-acre wetland complex is 1.0 km from the ocean, covers 270 acres and consists of six remnant salt evaporation ponds and their associated eroded levees (Fig. 2). A thorough description of the area and its history is provided in the CDFG management plan; only the features most relevant to pelicans will be presented here.

The entire salt ponds complex is subject to tidal inundation due to erosion of the outer levees. The main breach is at the the east end of the area. This region (pond 6) is subject to the greatest tidal flux. During most tidal stages the east end is characterized by extensive mudflat and saltmarsh habitat riddled with channels of shallow water and one deeper channel. During high tides above 5.0 ft. the entire area is flooded and the water in all of the ponds except the north end of pond 1 becomes too deep for pelicans to stand in. Portions of the deteriorated levees, primarily in the central area of the complex, have broken up into small island mounds (area 5d, 4d, 1d). During low tides, only two permanent ponds (1 and 4) at the western edge of the complex persisted throughout this study. The remainder of the area was essentially mudflat at medium to low tides.

A parking lot, trail system, and two observation blinds were incorporated into the area by the CDFG during 1986 and 1987 (Fig. 2). Temporary hunting blinds were constructed in locations A and B during the salt ponds waterfowl season in December 1987. The adjacent private landowner, David Packard, has provided an easement to allow the sloughside trail and parking lot on the Elkhorn Ranch for the benefit of non-consumptive users. The Elkhorn Ranch is a conservation-restoration project which has as one of its goals the provision of freshwater waterfowl habitat along the edges of the slough. Several freshwater ponds have been established adjacent to the MLWMA during the last three years.

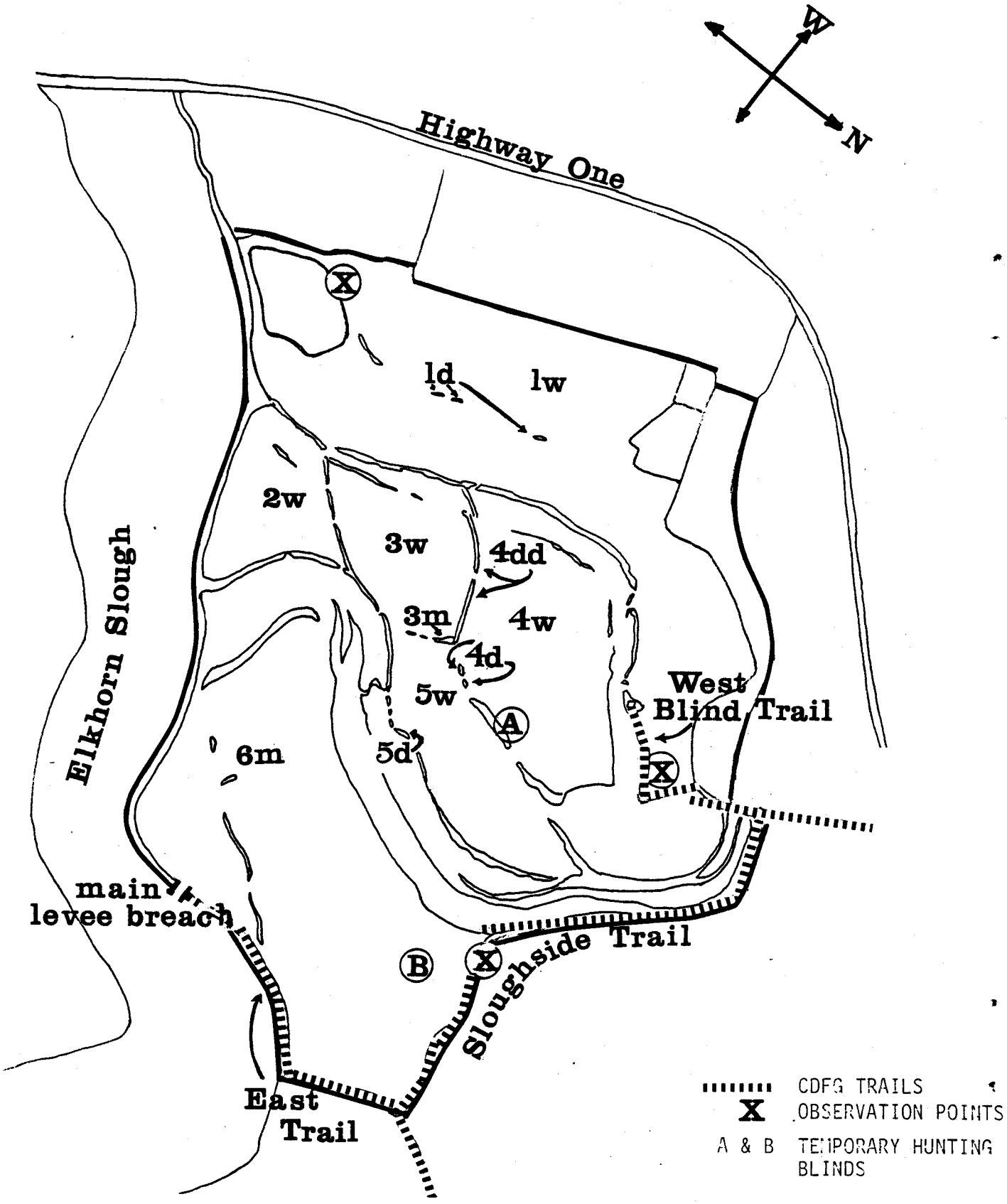


Figure 2. Diagram of the remnant salt evaporation ponds at Moss Landing Wildlife Management Area showing primary ponds, CDFG trails, and observation point used during this study. Letters next to pond numbers indicate substrate within each pond utilized by Brown Pelicans: w=water, m=mudflat or tidal regions, d=dry areas not inundated by high tides.

## METHODS

### Censuses at MLWMA

We conducted observations at the salt ponds during 63 days from 11 July to 15 December. Census periods included dawn (approx. 30 min before sunrise), morning (two hours after sunrise), midday, evening (two hours before sunset), and dark (approx. 30 min post-sunset). The dawn censuses were conducted by counting numbers of birds departing the roost (against the sky at twilight), grouping time in 10-minute departure intervals. At two hours post-sunrise the remaining pelicans were counted. To determine predawn numbers, all departures were added to this morning census, and all arrivals were subtracted. Post-sunset counts were obtained similarly, by conducting an evening census and then monitoring arrivals and departures until dark.

This census method provided the best means of obtaining representative counts of numbers of pelicans using the roost at night. Standard instantaneous counts of the roost at dawn and dusk were not used because: (1) pelican movements in and out of the roost often took place when intensity of light was too low to count birds against the ground, (2) departures or arrivals of several hundred pelicans might occur before a census of the group could be completed, and (3) birds were often too clumped and abundant at these times of day to be counted accurately without a high vantage point. The method we employed also provided data on patterns of arrivals and departures at the roost during periods of greatest movement.

Observations generally took place from a distance of 275+ meters to the nearest bird in three primary locations (Fig. 2), depending on position of roosting groups. During the December hunting season, evening observations were conducted at 500+ meters in the evening and at distances of about 300 meters in the morning.

### Habitat Use

Pelican location in the roost and substrate on which they were standing (i.e., dry, water, or mudflat) were documented at each census. Significant movements from one part of the roost to another were also noted. Wooden stakes were placed in the ponds in some areas to help quantify water cover, water depth, and as a reference for distance measurement.

### Data Collection on Disturbances

Disturbances were classified as anything that caused the roosting group (or portion of it) to flush rapidly and fly away from an obvious disturbance source, or circle around the roost in a confused fashion. When possible, we documented time and cause of disturbance, as well as percent of pelicans that flushed, relocated, returned, and departed. We estimated distances between human disturbance sources and pelicans using various

known measures in the study area and satellite photographs of the salt ponds.

**Aerial Surveys**

We conducted aerial surveys in CDFG aircraft from July to December 1987 (and August to December 1986) as part of a larger study on wintering Brown Pelicans (see table 1 for exact dates). Three sets of surveys were scheduled in 1987 (and four in 1986). Regions covered included the entire California coastline and perimeter of the eight offshore islands in the Southern California Bight. We documented total numbers of Brown Pelicans observed within 1-2 km from the shore, their activity (roosting, flying, feeding, sitting on water), and roosting location and substrate. Flight speed was held at approximately 90 knots and altitude at 70-90 meters. Results of 1987 central California surveys are included in this report, along with basic comparisons to 1986. The shoreline surveys serve as an index to the total population present in the region. Detailed descriptions of 1986 aerial censuses are provided in Jaques and Anderson 1987 (unpubl. rep). Statewide surveys for 1987 will be provided in a subsequent manuscript.

**Ground Surveys**

We conducted ground surveys of roosting Brown Pelicans from the Mexican Border to the Olympic Peninsula as part of the larger study; however, most effort was concentrated in central California. Accessible roosts along the central coast were surveyed approximately once a month. Southeast Farallon Island (SEFI) was visited for two one-week periods in 1987 (August and October) and one week in 1986 (October). Pelicans at Año Nuevo Island were observed over one three-day period in 1987 (November) and during two similar visits in 1986 (August and September). A total of 21 days were spent at Pismo Beach in the two years. Daytime roosts in the Moss Landing area, particularly the Salinas River mouth and Jetty Road Beach, were observed as often as possible in 1987. Data collection at all sites included total numbers of pelicans, age ratio, responses to disturbances, and position within the roost in relation to wind, sun, and sea conditions. Information on age ratios and details on specific use of roosts other than MLWMA will be provided in a separate report.

## RESULTS

### POPULATION TRENDS IN CENTRAL CALIFORNIA: AERIAL SURVEYS

Brown Pelicans arrived in large numbers relatively early in 1987 and were most abundant at California coastal roosts during the July 1987 aerial survey (Table 1). Numbers in Central California were reduced by about half (53%) in early October and declined again slightly in November. Populations were higher and

Table 1. California Brown Pelican aerial survey results for central California showing census dates and pelican activity in 1986 and 1987.

| Survey Date | Total | Number Roosting | Number Active |
|---|---|---|---|
| 20 AUG 1986 | 11,800 | 9,700 | 2,100 |
| 9 SEP 1986 | 12,850 | 12,180 | 670 |
| 17 NOV 1986 | 9,390 | 6,550 | 2,840 |
| 7 JUL 1987 | 13,950 | 13,130 | 820 |
| 1 OCT 1987 | 6,800 | 6,030 | 770 |
| 24 NOV 1987 | 6,550 | 6,135 | 415 |

more stable in this region throughout summer and fall 1986.

The population indices from our aerial surveys of pelicans between Point Conception and the Oregon border can be compared to the shoreline surveys conducted from 1980-82 by Briggs et al. (1983). This comparison supports our impression that numbers of pelicans in central and northern California during the 1987 fall survey were unusually low. Our estimate of 15,000 pelicans in September 1986 was very similar to the 1980 and 1982 fall counts (15,000 and 16,000 respectively). However, our October 1987 count (8,600) was 44% lower than the average of these three fall counts (1980, 1982, and 1987). The 1981 count for this region (24,000) is the highest on record, and is 36% higher than the three-year mean used above. On the other hand, the estimate we obtained in July 1987 (17,100) was higher than any midsummer pelican count on record. It exceeded the 1980 and 1982 surveys by more than double, and the 1981 count by only 1,600 birds.

High numbers of pelicans unusually early in the season are typical of years in which there is substantial breeding failure in the Gulf of California, Mexico (Anderson and Anderson 1976). Inspection of several large colonies in the Gulf revealed widespread failure of early nest attempts in 1987 (DWA field notes). Second nesting or late nesting attempts at some Mexican colonies late in the season were evidently very successful, however. Large numbers of adults and newly fledged young were seen in the Gulf in August by DWA. The near absence of young of the year and the relatively low fall pelican population in southern and central California in 1987 indicate that these late nesting Mexican birds did not migrate to the California coast following breeding and fledging.

Two distinct pelican concentration areas were apparent in all aerial surveys of the central coast during 1986 and 1987 (Fig. 3). One zone of heavy pelican-use was between Pt. Sal (34°50'N) and Pt. Buchon (35°15'N); the other was between Pt. Lobos (36°30'N) and Pt. Año Nuevo (37°06'N). These areas also stand out as important in the 1980-82 surveys (Briggs et al. 1983). The Gulf of the Farallones and Southeast Farallon Island (37°41'N) comprise a third major pelican concentration area on the central coast (Ainley 1972, Briggs et al. 1983, PRBO unpublished data). We were unable to survey the offshore island roost from the air, thus the importance of the area is not represented in Figure 3. The relative importance of various roosts and regions in central California varies seasonally and among years; thus it is difficult to rank which among the three regions is most important without a long-term database covering all sites. The Big Sur region (36°00' - 36°30'N) consistently harbored the fewest numbers of pelicans in central California in 1986-87 and 1980-82 (Briggs et al. 1983).

Several large roosts occurred in the region of pelican

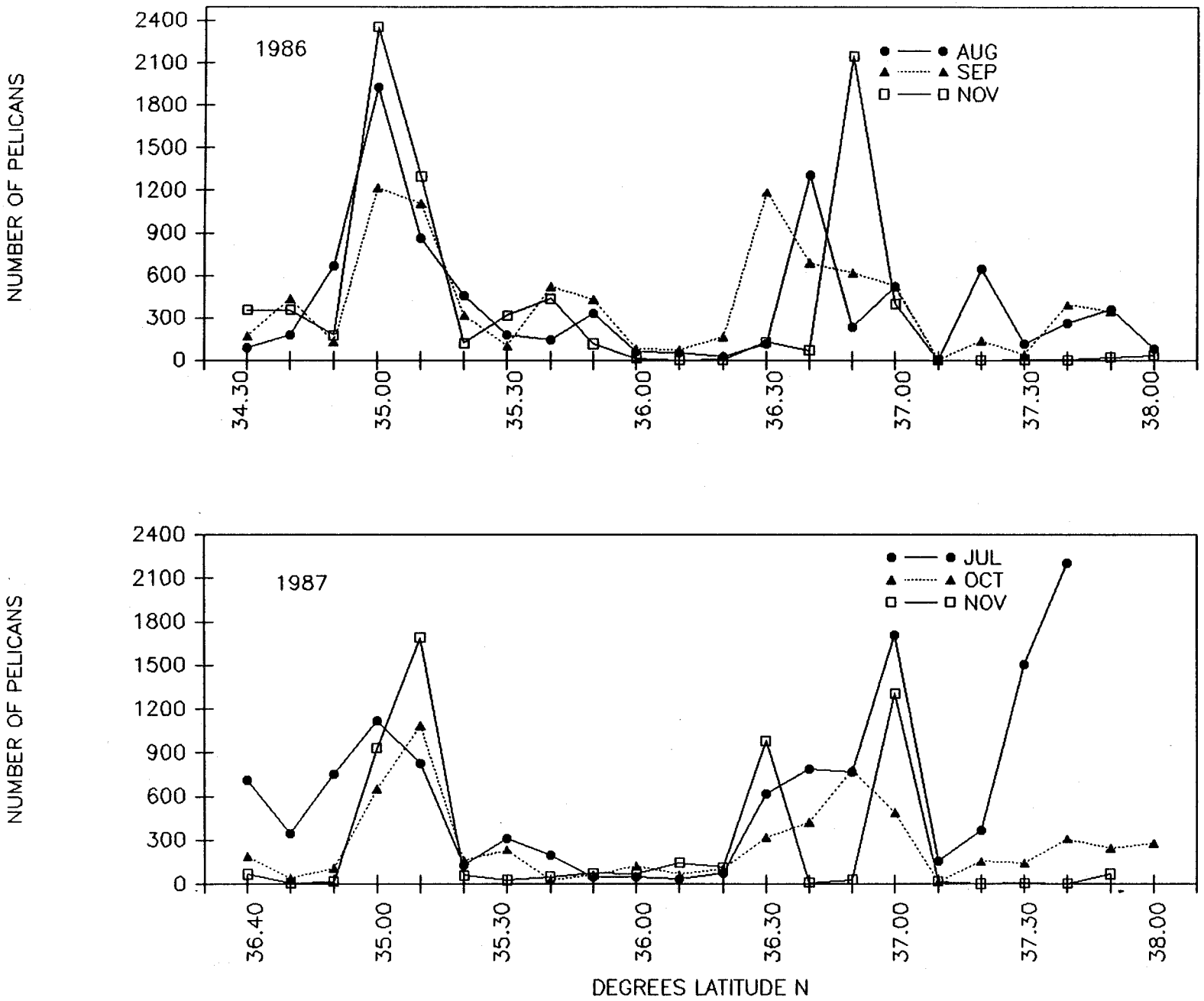


**Figure 3. Distribution and abundance of Brown Pelicans along the Central California coastline (Pt. Conception - Pt. Reyes) during three aerial surveys in 1986 and 1987.**

concentration between Pt. Buchon and Pt. Sal, including the rocks off Diablo Canyon, the Pismo/Shell Beach Rocks, the Santa Maria Rivermouth, and Lion Rock (see Fig. 1). The largest roosting aggregations were consistently found in either the Pismo/Shell Beach area or on the rocks along the Diablo Canyon shoreline. Feeding flocks containing hundreds of pelicans were observed in the immediate vicinity of these roosts on 20 August 1986, 1 October 1987, and during ground visits in early September 1987.

Pelican distribution in the greater Monterey region (between Pt. Lobos and Pt. Año Nuevo) during the three flights in 1987 will be presented in detail since it incorporates the MLWMA and applies closely to this study. The location of large roosting populations betweeen Point Lobos and Año Nuevo shifted seasonally. Counts at individual roosts area provided in Table 2. The importance of the MLWMA roost was clearly not represented by these midday aerial surveys.

During the 7 July census, numbers at Año Nuevo Island comprised more than half of the pelicans in the greater Monterey region (Table 2). Feeding flocks occurred both north and south of the island, from 36°50′-37°10′ N. Pelicans in the Moss Landing area were found in a large loafing and bathing group at the mouth of the Salinas River, only 18 were present at the salt ponds. Repeated observations from the ground confirmed that the Salinas River is used by pelicans during the daytime only, and the majority of pelicans found there appear to roost at the MLWMA overnight. Up to 1200 pelicans utilized the MLWMA salt ponds for night roosting during the same week of the July aerial survey.

Pelicans were not concentrated at any of the large night roosts in the vicinity of Monterey Bay on 1 October, but instead were primarily dispersed on day roosts. The region between Moss Landing and Pt. Año Nuevo supported the greatest numbers of loafing and feeding pelicans (1050 birds). Small feeding flocks were most common just south of Santa Cruz. The largest aggregation in the Moss Landing area (150 pelicans) was at the day roost in Moss Landing Harbor directly adjacent to the salt ponds, "Jetty Road Beach." Pelicans had also begun to gather in Monterey Harbor by this date.

On 24 November 1987 Brown Pelicans aggregated in three areas on the central coast and were virtually absent anywhere else. These areas were as follows: (1) Año Nuevo Island, (2) Monterey Harbor to Pt. Lobos, and (3) Diablo Canyon to Pismo Beach. A similar phenomenon of clustering around the major night roosts occurred in 1986. Cohesive large groups may be a characteristic of Brown Pelican social behavior during southward migratory movement.

Distribution of pelicans in the Monterey Bay region during the November 1987 aerial survey was very different than that

Table 2. 1987 Aerial survey results of Brown Pelican roost sites from Pt. Lobos (36 30' N) to Ano Nuevo Island (37 06' N).

| | Survey Date | | |
|---|---|---|---|
| Roost Location | 7 July | 1 Oct | 28 Nov |
| Pt. Lobos | 250 | 37 | 540 |
| Bird & Seal Rocks (Carmel Bay) | 150 | 35 | 30 |
| Pt Pinos & Hopkins Rocks | 40 | 53 | 35 |
| Monterey Harbor | 60 | 150 | 325 |
| Salinas Rivermouth | 1100 | 150 | 0 |
| MLWMA | 18 | 60 | 5 |
| Elkhorn Slough NERR | * | 0 | 0 |
| Pajaro Rivermouth | * | 90 | 0 |
| Cement ship pier (Aptos) | 50 | 100 | 0 |
| Capitola | 0 | 250 | 0 |
| Santa Cruz Rocks | 30 | 120 | 8 |
| Rocks North of Santa Cruz | 385 | 310 | 76 |
| Año Nuevo Island | 2,060 | 150 | 1,200 |

* Not counted.

observed from the air in 1986; 1987 was distinguished by a lack of feeding flocks, lower numbers at MLWMA, and much higher numbers of pelicans in Monterey Harbor. In November 1986, an assemblage of 1200 pelicans actively foraging near the Santa Cruz Harbor accounted for peak numbers in the region. Ground-based counts two days later revealed that several hundred pelicans, arriving from the north, roosted at the MLWMA at night. No large flocks of birds feeding on fish schools were observed anywhere on the central coast during the November 1987 flight. Instead, birds were divided among the following three places: (1) a large inactive group at Año Nuevo Island, (2) several hundred scavenging pelicans in Monterey Harbor, and (3) a roosting group at Pt. Lobos. The MLWMA roost was utilized by few pelicans during the entire month of November.

The build up of Brown Pelicans in Monterey Harbor in 1987 was unprecedented both in terms of numbers and duration of stay throughout the winter. Peak numbers occurred in mid-November and exceeded 600 individuals. Ground observations revealed that pelicans were scavenging heavily on offal from commercial and sport fishing activities as well as bait fish offered by tourists. Between October and February 1988 an estimated 500-1000 pelicans died near Monterey. A bacterial infection, Erisypelas, which spread among the population was suspected to be an important cause of mortality. The investigation of that die-off was tied into this study, but details will be published in a separate report (Hunter et al. in prep.).

**POPULATION TRENDS AT MLWMA**

In correspondence with the seasonal trend observed for central California, numbers of pelicans roosting at the MLWMA salt ponds were greatest in July 1987 and dropped throughout the fall. A peak count of 4355 birds was made at the roost on the morning of 28 July (Fig. 4, Table 3). Within six days, counts declined by nearly one-half (45%) and use of the MLWMA continued to drop sharply through August. Monthly means then declined fairly gradually from September to December, although brief and relatively minor influxes of pelicans occurred at least once during each month. The index used here, "monthly mean", is the average of the daily high counts obtained during each month.

The decrease in use of the MLWMA roost from July to October was greater than the decline in the pelican population on the central coast during this time period. A 78% decline in numbers of pelicans roosting at MLWMA occurred from July ($\bar{X}$ = 2316 pelicans) to October ($\bar{X}$ = 500). A comparison of the July and October aerial surveys in central California indicates a 53% decrease in pelican abundance from mid-summer to mid-fall.

Daily fluctuations in numbers of pelicans at the salt-pond

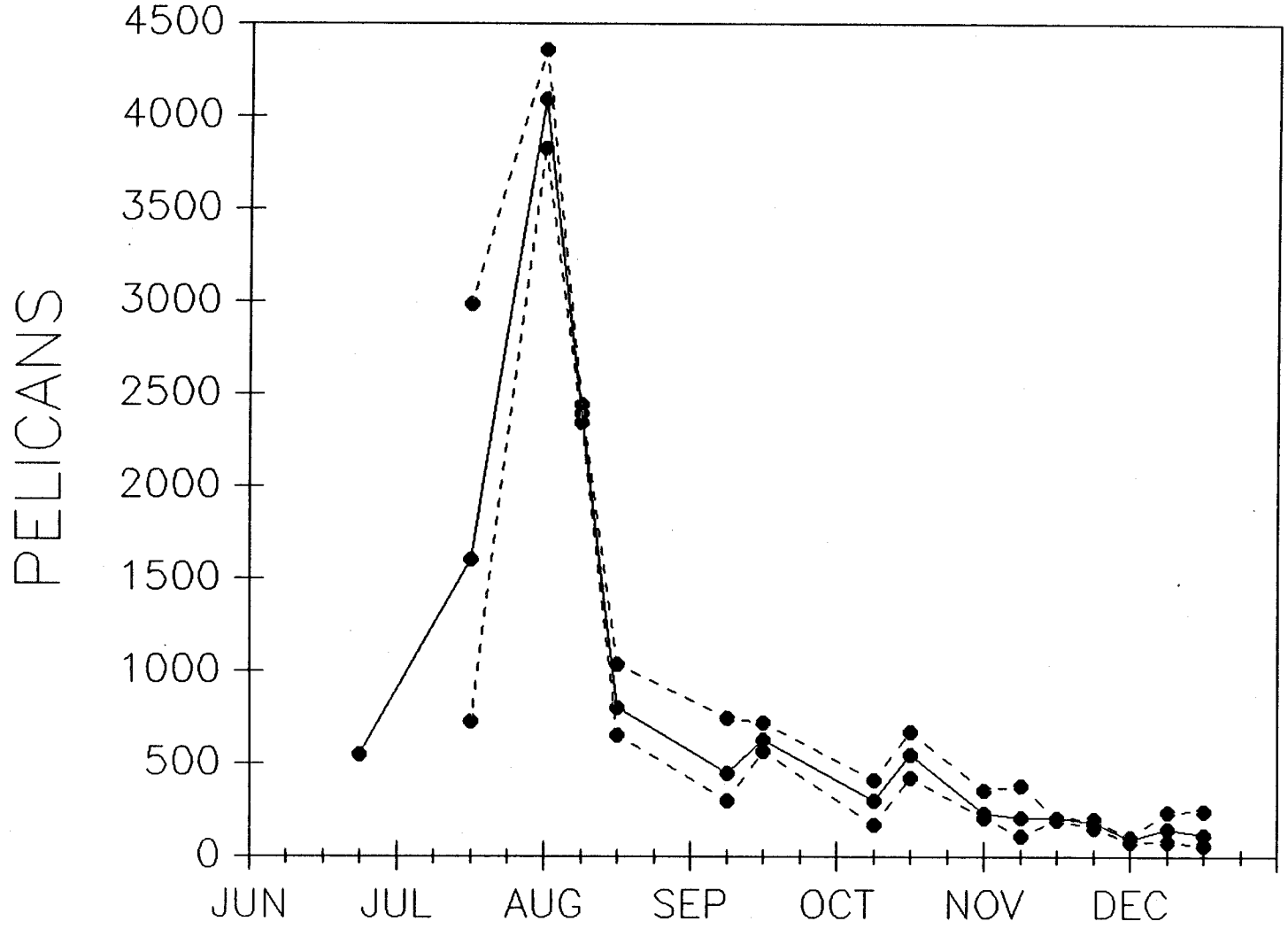


**Figure 4. Weekly mean, minimum, and maximum counts of Brown Pelicans at MLWMA from June to December 1987.**

Table 3. Counts of Brown Pelicans at MLWMA from July to December, 1987. Numbers shown are morning or late evening high counts.

| | | | | | |
|---|---|---|---|---|---|
| JULY | $\bar{x}$ = 2,316 | SEPTEMBER (CON'T) | | NOVEMBER (CON'T) | |
| 11 | 2,085 | 14 | 565 | 9 | 199 |
| 12 | 2,988 | 15 | 567 | 12 | 210 |
| 13 | 729 | 16 | 664 | 16 | 202 |
| 14 | 1,022 | OCTOBER | $\bar{x}$ = 314 | 17 | 151 |
| 15 | 1,209 | 4 | 309 | 18 | 230 |
| 27 | 3,823 | 5 | 175 | 20 | 163 |
| 28 | 4,355 | 6 | 414 | 24 | 79 |
| AUGUST | $\bar{x}$ = 1,324 | 7 | 424 | 28 | 97 |
| 4 | 2,345 | 9 | 675 | 29 | 102 |
| 5 | 2,441 | 18 | 203 | 30 | 89 |
| 11 | 654 | 28 | 131 | DECEMBER | $\bar{x}$ = 132 |
| 12 | 1,036 | 29 | 357 | 1 | 108 |
| 13 | 724 | 30 | 238 | 2 | 80 |
| 31 | 744 | 31 | 210 | 3 | 127 |
| SEPTEMBER | $\bar{x}$ = 491 | NOVEMBER | $\bar{x}$ = 187 | 4 | 189 |
| 1 | 372 | 1 | 382 | 5 | 242 |
| 2 | 367 | 2 | 235 | 10 | 246 |
| 3 | 520 | 3 | 230 | 12 | 116 |
| 4 | 345 | 4 | 279 | 13 | 61 |
| 5 | 300 | 5 | 210 | 14 | 82 |
| 6 | 494 | 7 | 112 | 15 | 71 |
| 12 | 719 | 8 | 212 | | |

roost were greatest in July. The most extreme variation between days occurred in mid-July when the roosting population increased by 900 pelicans from 11-12 July, and then decreased by 2259 pelicans from 12-13 July. In contrast, the greatest difference between counts on consecutive days in November was a decrease of 147 pelicans from 1-2 November. Table 3 lists daily maximum counts obtained throughout the season.

**DAY ROOSTS ASSOCIATED WITH MLWMA**

Population trends at the two primary satellite day roosts in the area, Jetty Road Beach and the Salinas River mouth, followed a pattern similar to MLWMA (Figs. 5 and 6). Pelicans were not seen at the Jetty Road Beach site until August, perhaps due to heavy use by summer recreationists. Zero counts were common at this sandbar throughout the study, as occupation by beachwalkers, clammers, windsurfers, kayakers, etc., often precluded use by pelicans. Sandbar formation at the mouth of the Salinas River provided an attractive roost for pelicans in 1987. Pelicans also used the river mouth for bathing and pouch-washing. The site became virtually unusable, however, once hunting blinds were established on the bar and waterfowl shooting began in late October. One day when no pelicans were resting at the Salinas River, for example, we observed two hunters wading back and forth across the river mouth, crouching down on the exact locations where pelicans would normally roost. Another time, a group of people were shooting out into the water towards nongame bird species.

Other less important day roosts in the Moss Landing vicinity included the mouth of the Pajaro River and the Elkhorn Slough National Estuarine Research Reserve (ESNERR). Maximum numbers observed at the Pajaro River during this study did not exceed 100 pelicans. With the road and condominiums only a few hundred yards away, the roost area is immediately accessible to humans and dogs during low water levels. In late fall, pelicans made infrequent use of the site.

The maximum count documented at the ESNERR was 48 pelicans in mid-October. Through November the high count was eight individuals. Early morning censuses confirmed that this area was not used as a night roost in 1987, at least during late fall or at low population levels in the slough. Use of the ESNERR was surely higher in mid- to late summer, but we do not have data adequate to determine relative use during this time. The area has been recently restored to wetland habitat and includes a series of artificial islands. Use of the area by pelicans is likely to increase in the future but its ability to serve as a large night roost is questionable. It is located about 4 km inland and the construction of the islands does not appear to offer a high degree of security from mammalian predators.

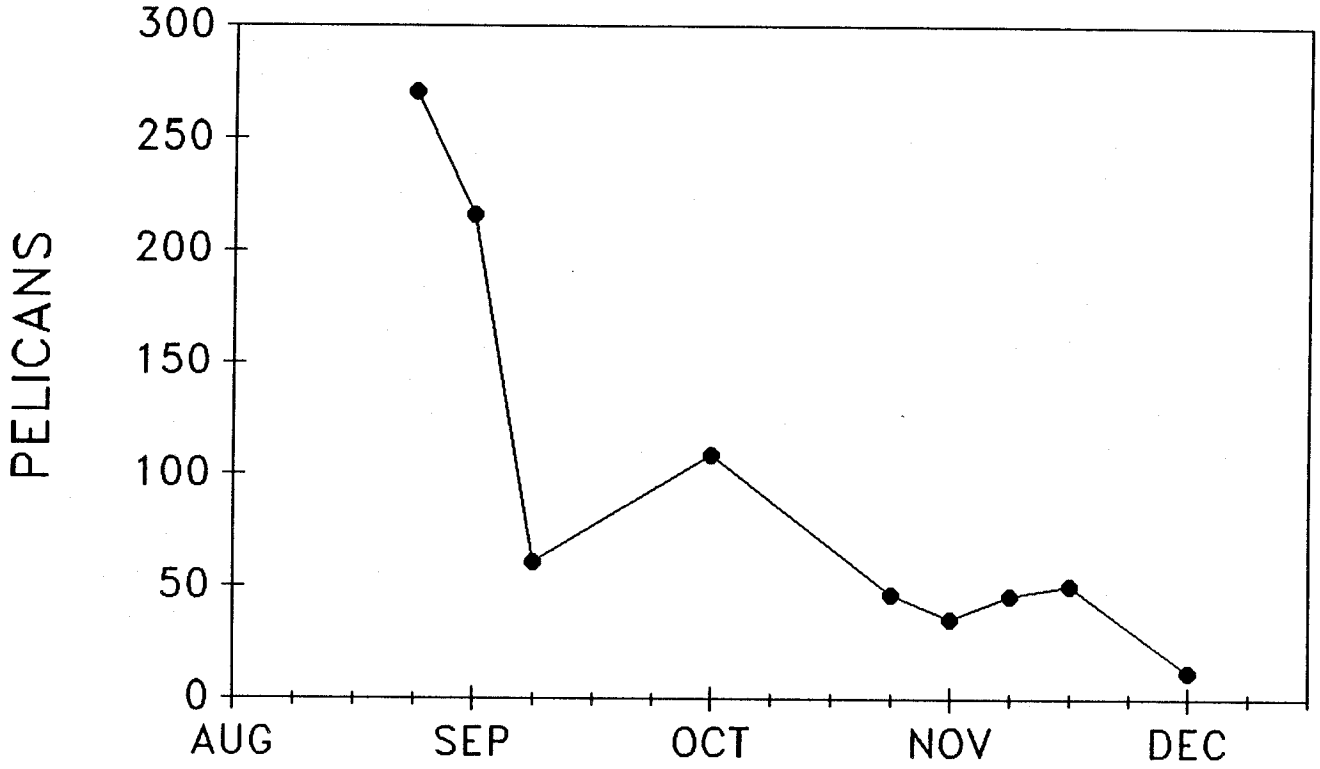


Figure 5. Numbers of Brown Pelicans at the Jetty Road Beach loafing site in Moss Landing Harbor, August - December, 1987. Points represent weekly high counts.

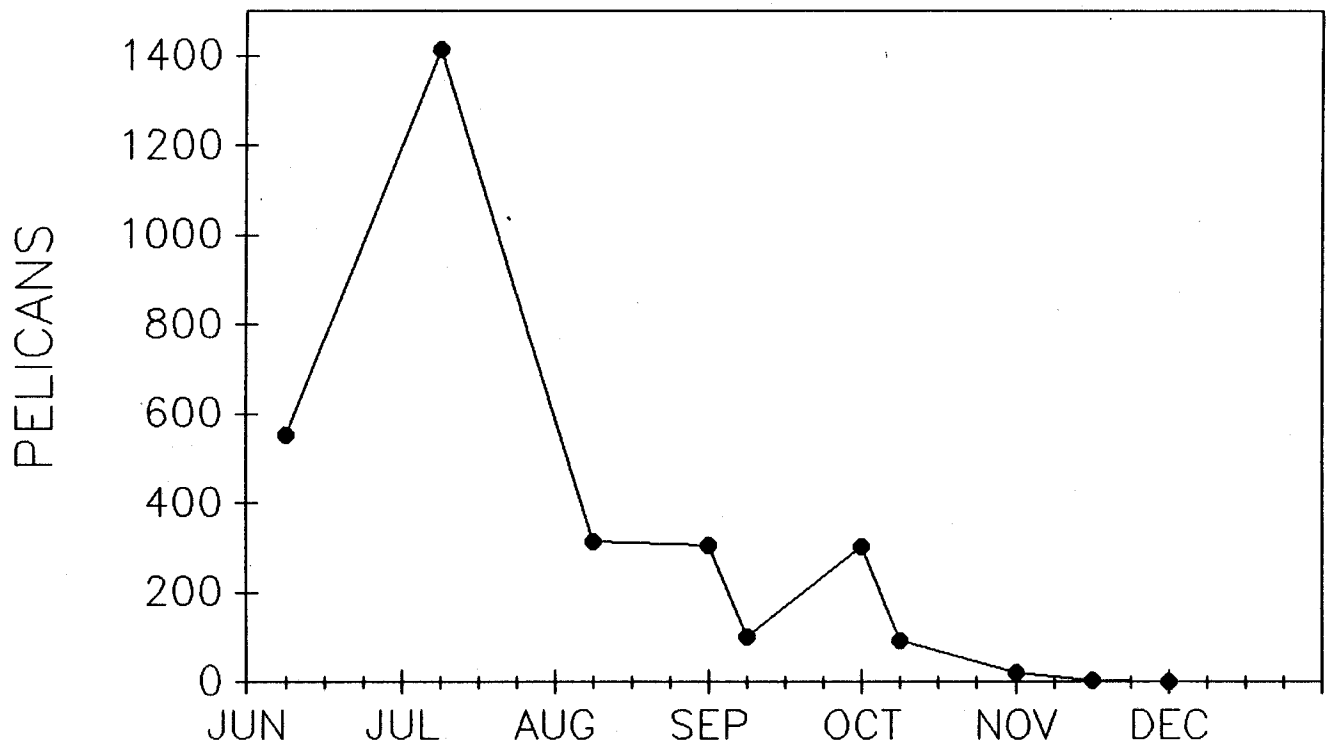


Figure 6. Numbers of Brown Pelicans at the Salinas River mouth, June-December, 1987. Points represent weekly high counts.

## DAILY PATTERNS OF OCCUPATION AT THE MLWMA ROOST

Numbers of pelicans were highest at MLWMA during early morning or late evening censuses (Fig. 7). Populations generally increased towards sunset and declined within the first few hours after sunrise. From July through early October, roosting pelicans could be found in the salt ponds at all times, however. At least 1700 pelicans were present throughout the day on 28 July. The pattern changed abruptly in late October when pelicans abandoned the salt ponds during the middle part of the day. Their absence became more pronounced in November and December, when all birds generally departed before the standard morning census and did not return until close to sunset (after the standard evening census).

Unique to December is the low percentage of pelicans present at late evening censuses. During this time only 32% of the birds counted in early morning censuses were present at dark the previous night. Disturbance from waterfowl hunting in the evening during the first week in December was directly related to the low numbers of pelicans settling by dark (see Hunting in the Salt Ponds).

Comparisons of attendance patterns at other major roosts indicate that absence during most of the daylight hours in late fall is not a seasonal phenomenon characteristic of the species. The roost at Southeast Farallon Island was attended by large numbers of pelicans during six days of observations in late October 1987. Midday counts were lowest, averaging 25.7% of the daily highcount; morning censuses averaged 63.0 % of the daily high. The Año Nuevo Island roost was also well attended throughout the day on 22 November 1987. Here, the midday count of 1030 pelicans was 90.7% of the early morning count. Few birds utilized the Pismo Beach roost during ground observations in late November 1987. On 29 November 1986, however, the midday count (542) was actually the highest count of the day and pelicans were present at all hours.

Previous censuses conducted at the salt ponds roost in late fall, further suggest that the complete absence of pelicans in the MLWMA roost during the day late in 1987 was atypical. On 26 October and 6 November 1980, 1070 and 110 pelicans were counted in the salt ponds at midday (D. Croll, unpub. report). Several of the changes that have occurred in the salt ponds environment from 1980 to 1987 could influence this difference in use pattern. Deterioration of secure roosting habitat will be discussed in the sections on Habitat Use, Human Disturbances, and Hunting.

Two possible explanations for the absence of pelicans during the daytime in November and December compared with July through

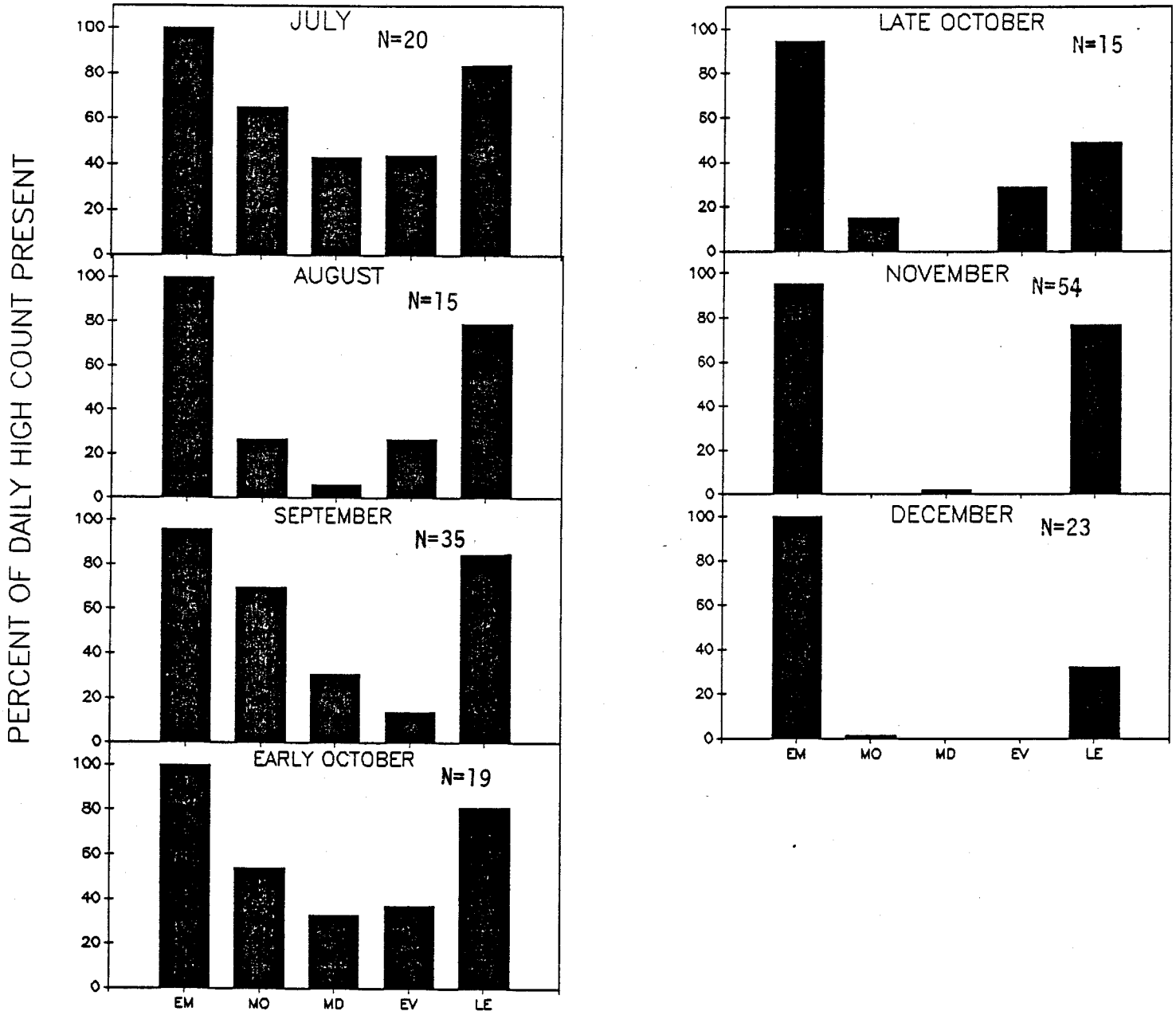


Figure 7. Percentage of Brown Pelicans present at the MLWMA roost at 5 time periods during the day, July - December. EM = early morning (30-60 minutes before sunrise); MO = morning (2 hours after sunrise); MD = midday; EV = late evening (2 hours before sunset). Percent = proportion of highest count obtained for each date, summed and averaged by month.

October 1987 are as follows: (1) that the quality of roosting habitat at MLWMA deteriorated during the season, either physically or in terms of disturbance level, making alternative sites more attractive for daytime loafing, or; (2) that food availability was so reduced in the Moss Landing area in late fall that pelicans were forced to spend more time traveling greater distances to feed, subsequently using distant loafing areas during the day. We did not see an increase in use of nearby loafing areas in late fall. However, the Salinas River mouth was open to waterfowl hunting during this time.

**Mean Arrival and Departure Times**

A great deal of variation occurred in mean arrival and departure times of roosting pelicans during this study. The mean used here is the time at which either 50% of the total roosting population had arrived in the evening or had departed in the morning. Pelicans generally arrived later and departed the roost earlier as day length grew shorter. In addition to season, stage of the moon and disturbances appeared to influence timing of movements into and out of the roost.

Analysis of weekly mean patterns showed that pelicans arrived at the roost progressively later in the evening from July through November (Fig. 8A). But in December, mean arrival time shifted abruptly and became so late that the actual December mean could not be calculated (as more than 50% of the birds settled in to the roost after dark). Average timing of morning departure from the roost was similar from July through mid-October. However, in late October, pelicans began to leave the roost much earlier relative to the rest of the season (Fig. 8b). Following this change, pelicans departed from the roost progressively earlier in the morning. By mid-December, 50% of pelicans present departed the roost by an average of eight minutes before sunrise.

We obtained data on complete morning departures during November and December, since all pelicans left the roost during the two-hour observation period. Figure 9 shows the percent of the population departing in each ten-minute interval for a given morning, averaged for five days during the indicated week. The overall weekly pattern of departures was similar from early November to mid-December (Fig. 9). Departure curves became more skewed towards pre-sunrise periods as the season progressed, however. Pelicans tended to remain in the roost longer in the morning early in November as compared to later weeks, and peak departures were centered around sunrise as opposed to pre-sunrise periods. Greater clumping of departures in the first week of December was associated with disturbances from hunting activities on two days. Examples of aberrant morning departure patterns resulting from disturbances are presented in the Human Disturbance section.

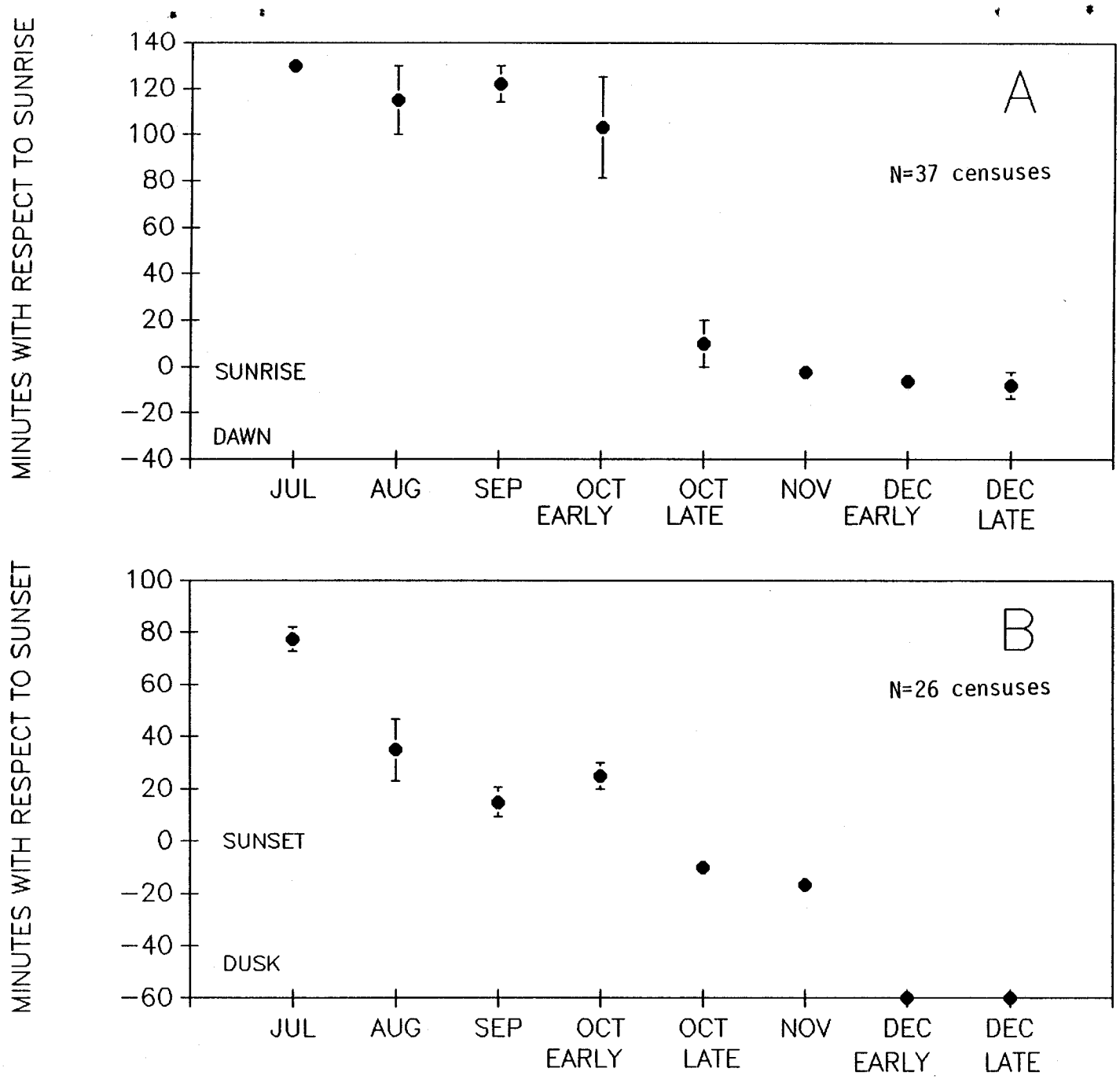


**Figure 8. Mean morning departures (A) and evening arrival times (B) for Brown Pelicans using the MLWMA roost with respect to time of sunrise and sunset. Negative numbers are pre-sunrise (A) and post-sunset (B).**

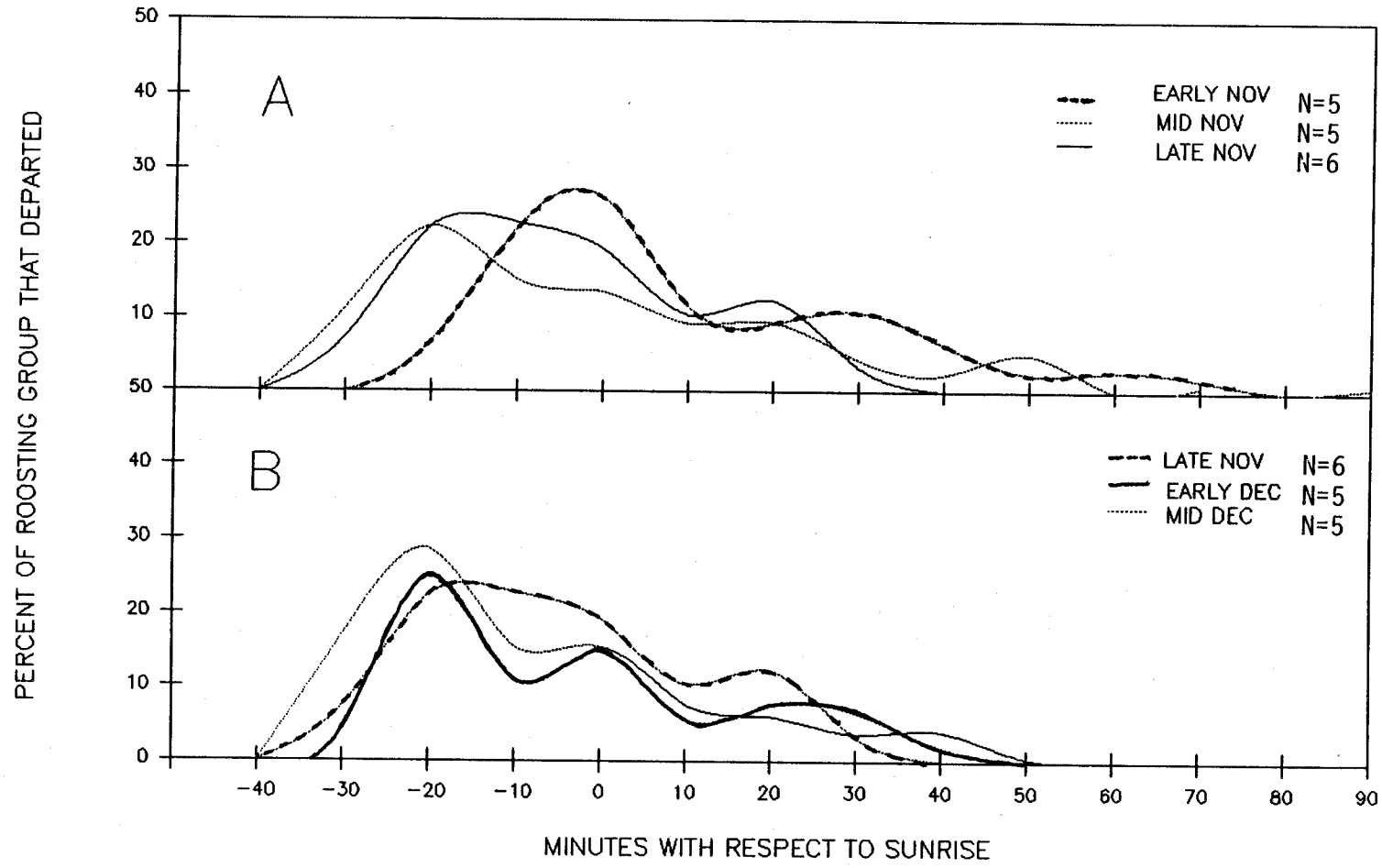


Figure 9. Weekly mean pattern of morning departures from the MLWMA roost; (A) during 3 weeks in November, and (B) the week of hunting in the salt ponds (early December) and the 2 weeks before and after hunting.

**Evening Departures from the Roost**

Brown Pelicans are considered to be a diurnal species, and as we have described, they generally settle into communal roosts at night. On certain evenings, however, we observed significant departures from roosts as darkness approached. This occurred at MLWMA on six evenings. The most extreme case was on 5 October, when 35% of all birds enumerated (those present at start + all arrivers until dark) departed the roost during the 2 hour evening census period. The average percentage of pelicans that departed the roost during evening observations sessions throughout the study was 7.8% (N=21).

Three variables we considered as influencing unusual numbers of departures included evening high tides, high population levels (both of which would implicate habitat limitation - see Habitat Use), and full moon nights. Of these, high numbers at the roost did not correlate with evening departures (Fig. 10B), whereas full moon nights showed a strong relationship to departures (Fig. 10A). Four of the six instances where departures were greater than the mean occurred on or within a few days of full moons. We suspect that pelicans are able to forage at night under bright moons, and perhaps when there is phosphorescence in the ocean. Nocturnal migration is another consideration; however, on these four occasions subsequent population levels did not suggest movement out of the area. In fact, some full moon nights were followed by unusual numbers of arrivals to the roost early the following morning.

Reasons for departures during the two other occasions are unexplained, but did correspond with disturbance events and crowded conditions. Movement out of the area was indicated on 13 July, when populations at the roost declined progressively throughout the day, continued to fall towards sunset (20.2% of those counted in the evening departed), and did not recover by morning. At least one severe human disturbance event and three natural disturbances occurred on this date (see Human Disturbance).

The final case was on 27 July when significant evening departures (10.9%) corresponded with peak population levels. Departures did not seem to be an immediate result of overcrowding, however. Most departures occurred gradually, in the 30 minutes before sunset whereas arrivals were numerous after sunset (Fig. 11). Numbers continued to build throught the night (and birds that had departed may have returned). An additional 532 pelicans were found in the subsequent early morning census. On this date the MLWMA proved its capacity to hold at least 4355 pelicans on a given night.

The rapid decline in numbers and relatively low populations following the July peak raises concern about the attractiveness of the area to large numbers of pelicans over a longer time,

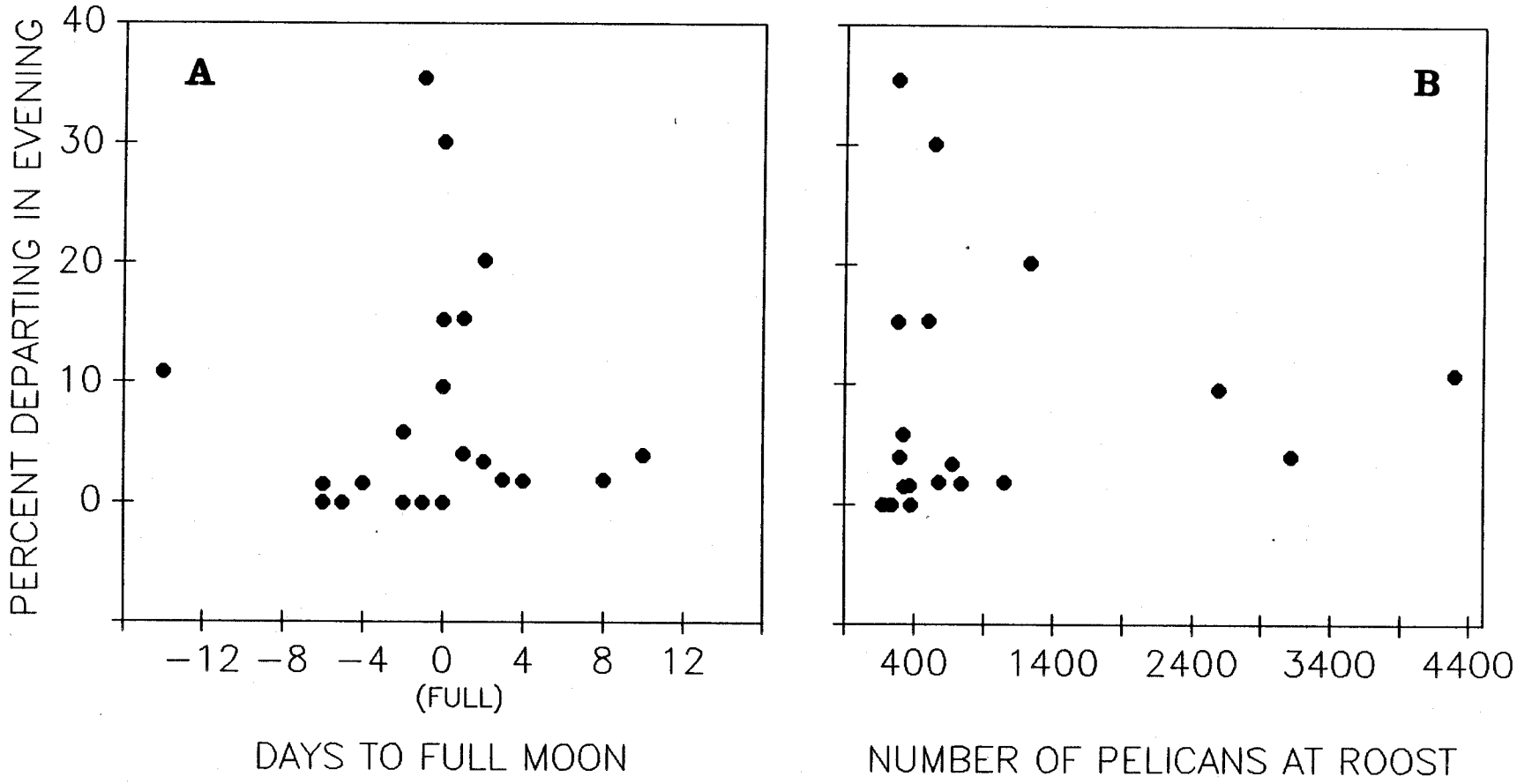


Figure 10. The percentage of pelicans departing from the MLWMA roost in the evening in relation to full moons (A) and total numbers of pelicans present at the roost (B).

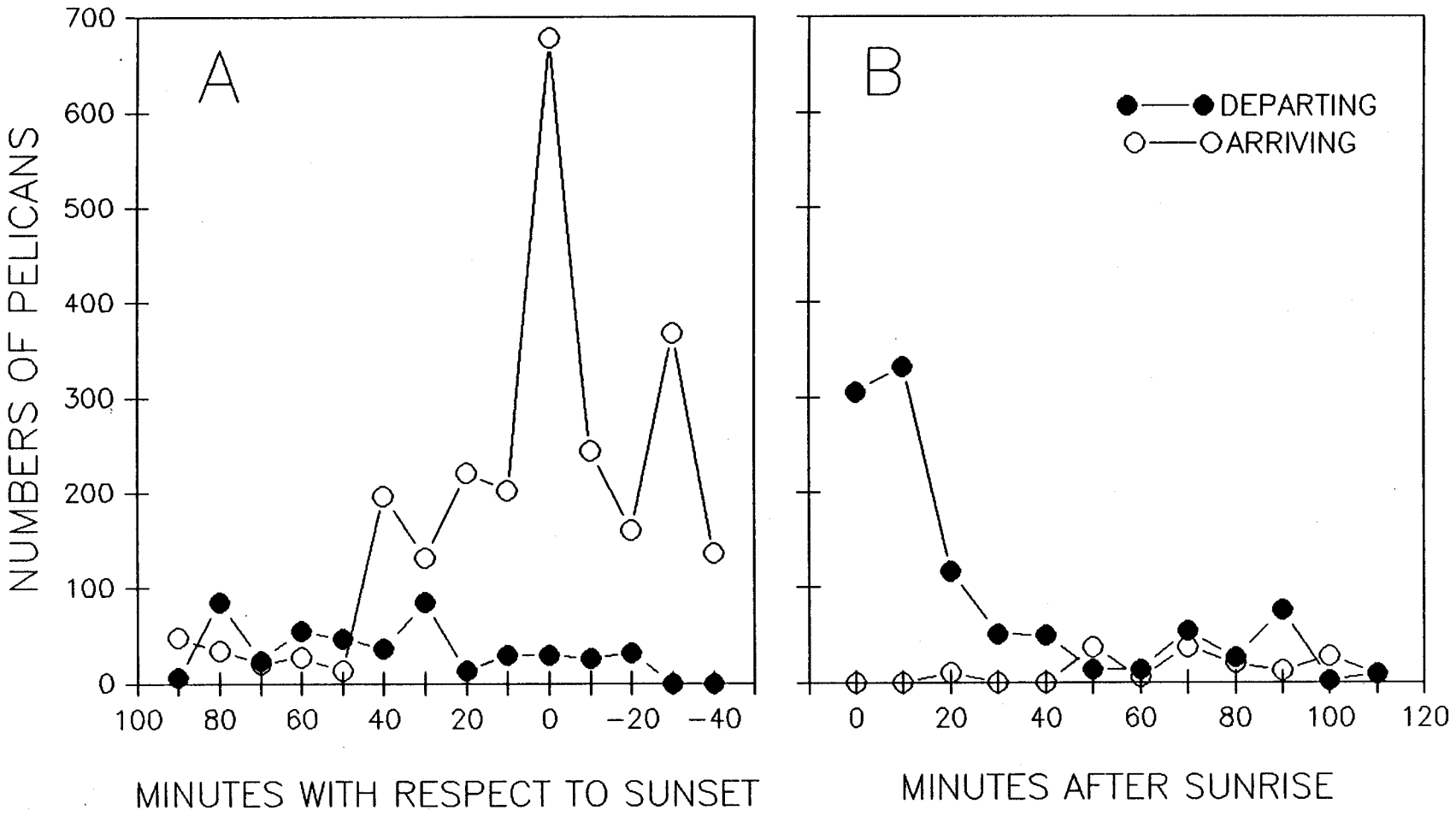


**Figure 11. Numbers of pelicans arriving and departing at MLWMA during peak levels of occupation in July, 1987; (A) = evening arrivals and departures on 27 July, (B) = morning departures and arrivals on 28 July.**

however. Stressful conditions may occur when high tides induce crowding, but immediate departures from the roost were not observed under these circumstances in 1987. High-tide crowding is described in the section on Habitat Use.

Southeast Farallon Island (SEFI) was the only other location where it was possible to monitor arrivals and departures as we did at MLWMA. The sample from both 1986 and 1987 is not spread out across the season, but is based on three one-week periods. Evening departures were more frequent at SEFI than at MLWMA. An average of 25.1%. (range = 2.6% - 46.7%) of the roosting group departed during evening census periods (N = 11) in August and October.

Of five evenings when the percent of pelicans departing the SEFI roost was greater than 35% of the total enumerated during the 2 hour observation period, three corresponded with a full moon period in August 1987. Hundreds of pelicans streamed out from the roost around sunset during this time and subsequent mornings were characterized by unusual numbers of arrivals to the roost. Population levels changed little during the week. Squid spawning occurs in the Gulf of the Farallones in late summer, and with bright moonlight or light from bioluminescence, pelicans may be able to seize squid (or other food items) from the surface at night. During the two other evenings of unusually high departure levels, we observed large streams of pelicans fly out from the roost to scavenge from large commercial fishing boats emptying their nets.

Whatever their activity, Brown Pelicans are obviously able to move and navigate at night. The comparsion of SEFI with MLWMA lends confidence to our impression that evening departures from the roost at MLWMA (prior to the hunting season) were not due to inadequate roosting conditions. SEFI had the greatest capacity of any roost on the central coast and was the least disturbed, so in this case it served as a good control, probably representing ideal roosting habitat.

**HABITAT USE AT MLWMA**

Pelicans always chose positions within the salt ponds roost that provided a buffer from mammals and trails frequented by people. Time of day, tidal height, and numbers of pelicans present also strongly influenced habitat use at MLWMA. During periods of peak abundance, the birds spread out (during daylight hours) in up to seven groups and occupied the greatest number of locations in the roost (Fig. 12). Site use became more specific and predictable when fewer pelicans were present and they roosted as one group. Favored locations and the strong attraction to conspecifics thus became especially apparent late in the season.

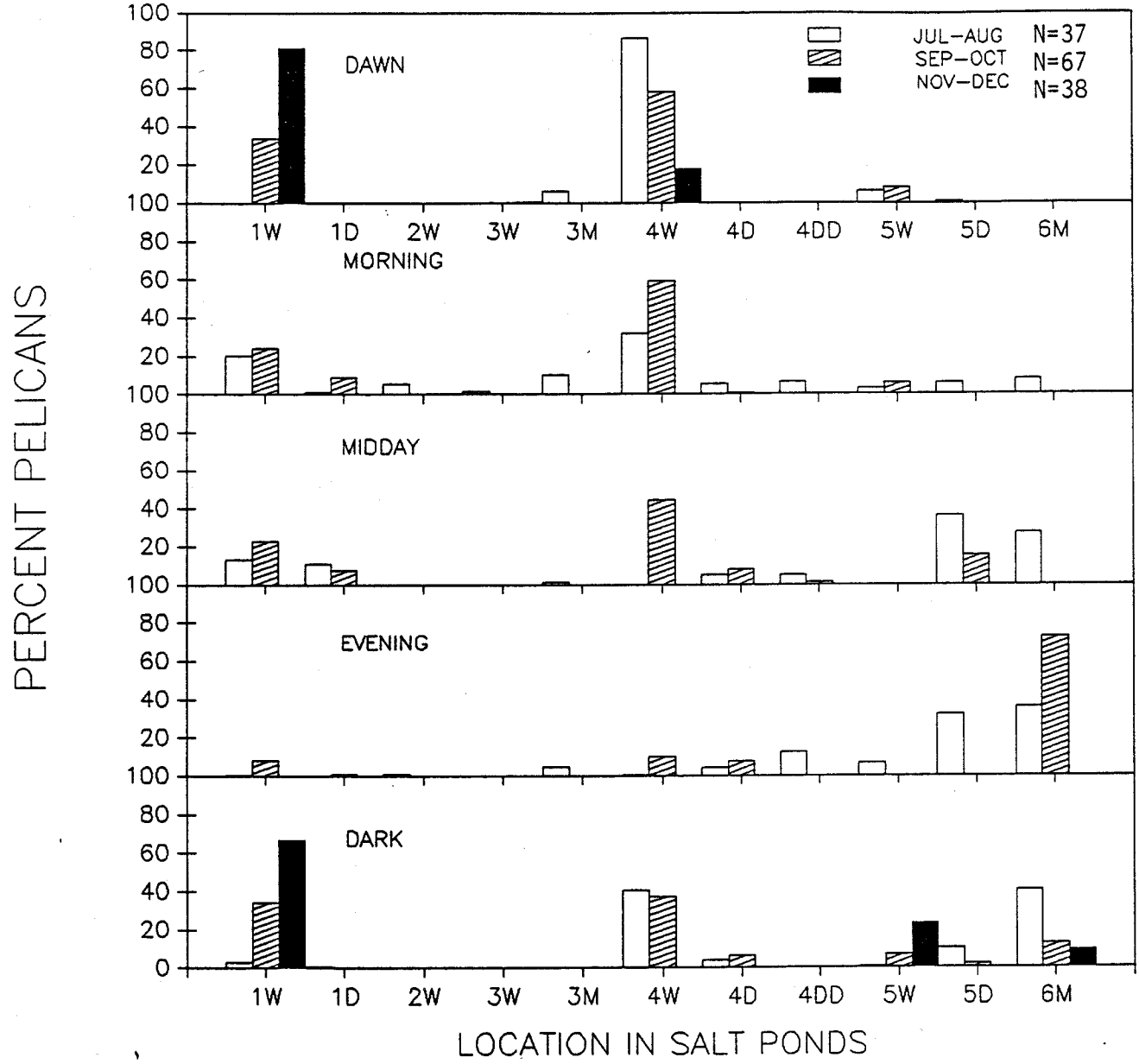


Figure 12. Distribution of pelicans among 11 sites at MLWMA by season and time of day. Numbers in site names refer to site locations (see fig. 2); letters refer to substrates: W=water, M=mudflat, D and DD=permanently dry areas.

**Roosting Substrates**

The most important finding regarding habitat use at MLWMA was that while pelicans utilized portions of the deteriorated inner levee and mudlats during the day, they always spent the night standing in the water of permanent ponds (Fig. 13) unless the water was too deep (see High Tides at Dark). Being surrounded by water at night is obviously an important adaptation for secure roosting in this species. When standing in the center of permanent ponds, the pelican group becomes an effective island. During the daylight, when approaching predators can be detected visually, habitat use is more flexible.

In July and August, pelicans in concentrated night groups relocated and spread out in the roost as dawn progressed (Fig. 12). We interpret this response as a preference for dry substrates and more inter-individual space for preening. Pelicans at Pismo Beach, Año Nuevo Island, and SEFI also tended to clump together at night and spread out by day. In September and October, however, pelicans generally remained in the water of the permanent ponds at MLWMA through morning and midday unless high tides occurred. Three sets of mounds preferred for high tide roosting were 1d, 4d and 5d (Fig. 2).

**High Tides at Dark**

Spring high tides occurring during the dark hours limited the amount of night roosting habitat available at the salt ponds. Evening observations under these circumstances revealed that all areas except the northern end of pond 1 became too deep for pelicans to stand in without getting their plumage wet. Pelicans either moved to the northeast edge of pond 1, stood on the mounds at 5d or 4d, (Fig. 2) or ended up floating and swimming on the water at dark as water levels rose.

In some instances, pelicans exhibited a strong motivation to inhabit the islands on high tide nights, but at the same time, were reluctant to be the first to occupy them. They milled in the air over the mounds and touched down briefly several times before finally settling. Once an island was occupied by a nuclear group of pelicans, others moved in rapidly. Sometimes there was not enough room on those islands the birds chose to use, and aggressive interactions and displacements followed. Birds unable to gain access to the mounds sometimes remained swimming around the periphery of the islands at dark.

The only time we observed aggressive behavior between pelicans at MLWMA was under crowded conditions on mounds. Aggressive interactions were common during evening arrivals to the rocks at Pismo Beach when densities were high, but such encounters were never seen at SEFI, which was essentially an unlimited-space roost.

In each instance when pelicans were present on islands at

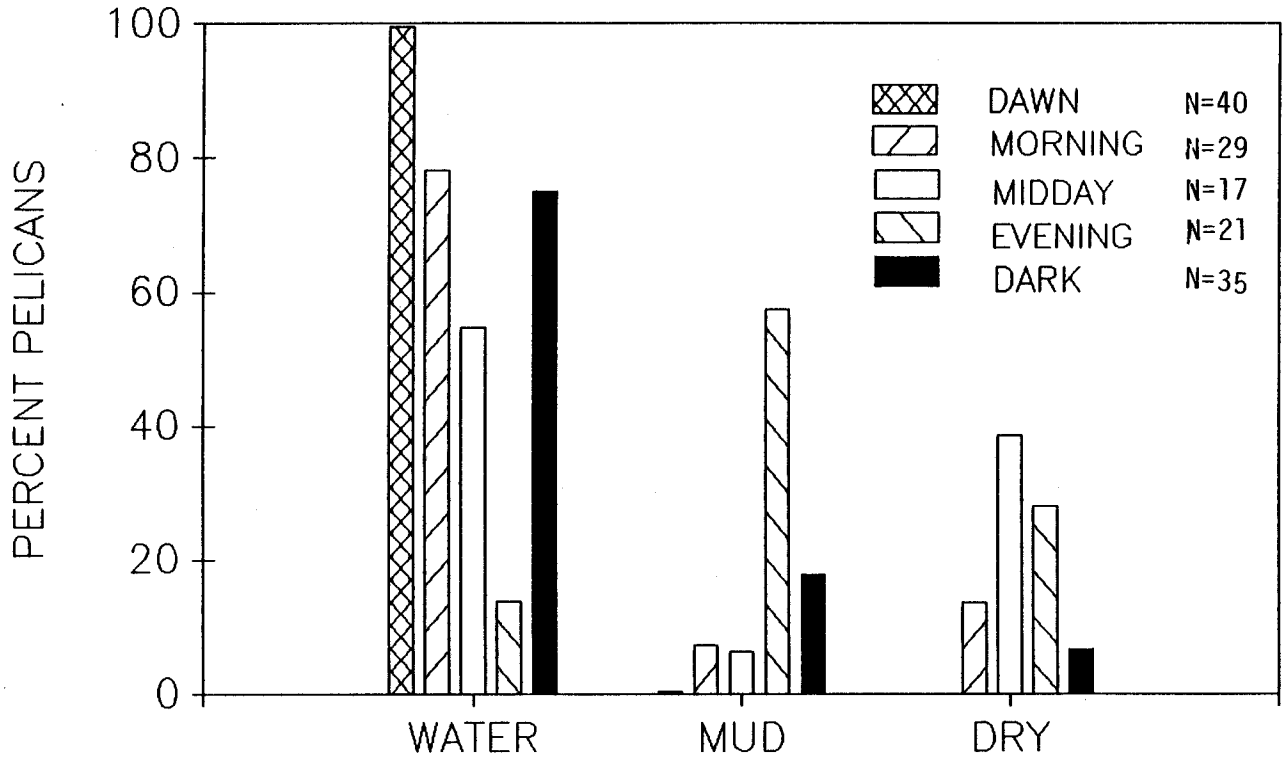


Figure 13. Distribution of pelicans on three substrate types by time of day at the MLWMA roost. N=142 censuses.

dark, by early morning they were back standing in the permanent ponds (Fig 12). Movement off the mounds as the tide levels dropped during the night was not surprising because as they became surrounded by mudflat, the mounds were no longer islands.

**Regions of Greatest Importance and the Evening Exodus**

Night roost locations receiving the greatest use by pelicans were ponds 4 and 1 (Fig. 2). In terms of a numerical index of utilization (Fig. 14), pond 4 stands out as most important. This was the most commonly used night roost during the early season peak abundance period. Use patterns shifted seasonally. Pond 4 became less important as the season progressed and pond 1 became the primary night roost in November and December.

Use of the mudflat region in the southern portion of pond 6 became especially interesting in September, when pelicans adopted a distinct evening pattern that carried over through the rest of the season. This mudflat region was slightly raised and most of it was more often dry than inundated. Birds arrived (or relocated) to the mudflat in pond 6 (Fig. 2), and used this a form of staging area before movement into the permanent ponds at dark.

While on the mudflat of pond 6, pelicans generally remained alert and preened actively, sometimes walking around, rather than settling into a resting posture. At the approach of darkness, the birds tended to spread out and flap their wings, sometimes stepping off raised areas into shallow water. A few "scouts" would typically then depart and move west, circling over the permanent ponds. Occasionally they soon returned to join the roosting group on the mudflat, particularly when no conspecifics or gulls were present in the western ponds. At other times, they did settle into the permanent ponds, forming a roosting nucleus. Birds arriving from the sea then joined this group directly, and a major movement of pelicans from the mudflat soon followed. The average time elapsed between the first "scout movement" and relocation of the rest of the group was 7 minutes (N = 21).

The first time we observed this type of coordinated mass exodus from the east to the western ponds was 28 July, the fifth night of our observations. This movement became extremely synchronous and orderly by 14 September. On several nights, the pelicans could be counted against the sky as they flew across the salt ponds in single file in near darkness. They were often accompanied by gulls, but it was not clear which species initiated the movement. Gulls vocalized loudly before moving, as did some of the large shorebirds which also exhibited evening migrations within the study area and utilized water night roosts in the western ponds.

Mean relocation time for Brown Pelicans was 25 minutes after

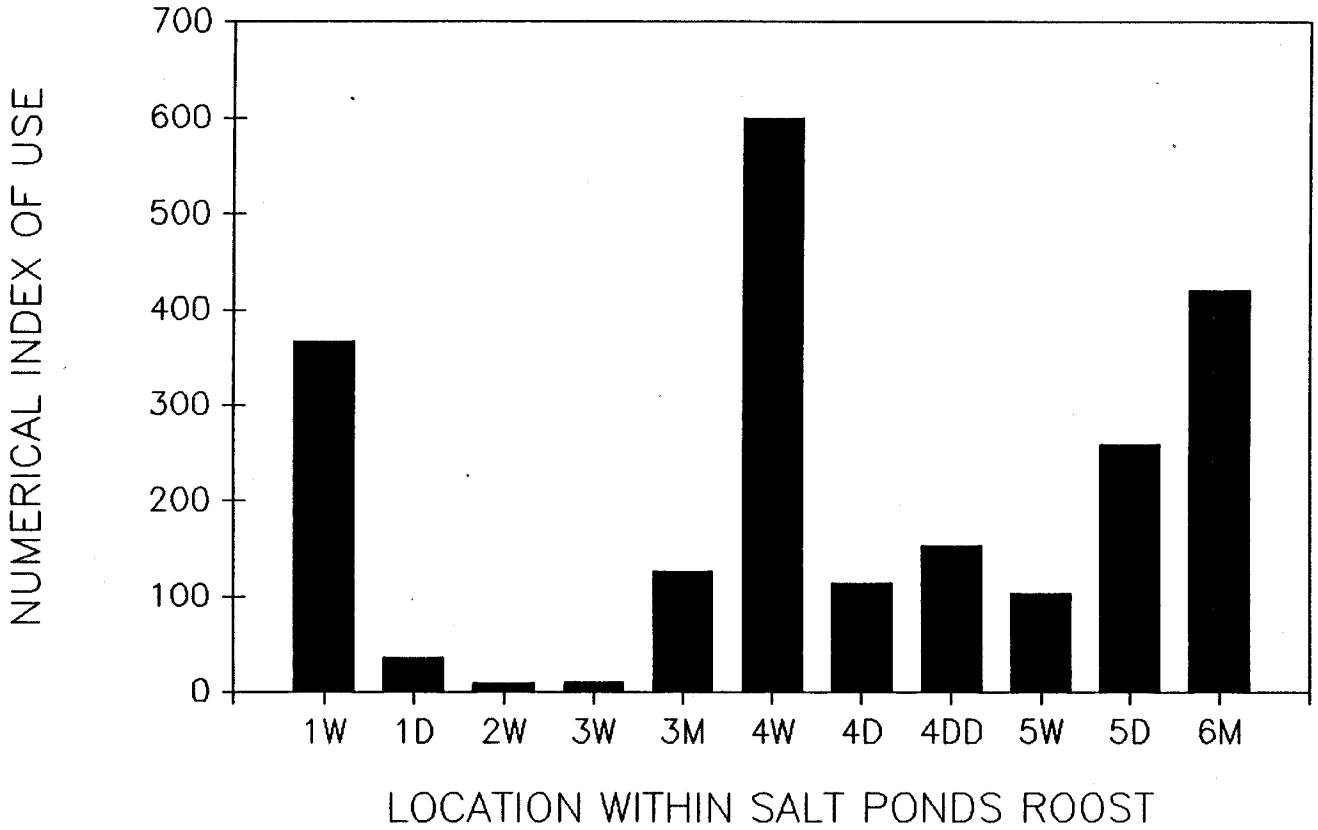


Figure 14. Numerical index of location-use in the MLWMA roost by Brown Pelicans. Bars represent the sum of the total number of pelicans found in each location at each census, divided by the total number of censuses through the 1987 season. N=146 censuses; 56,112 pelicans counted.

sunset through early and mid-season periods (July-August, September-October: N=12), but was delayed to an average of 49 minutes post sunset in November (N=6). Later than average movements often corresponded with clear nights (higher light levels) and dates when the mudflat at pond 6 was shallowly inundated in the evening. In fact, when water in pond 6 was at desirable levels, pelicans sometimes remained there at dark, moving later as the tide changed.

## HUMAN DISTURBANCES

### Location and Cause of Disturbances

We documented 21 cases of human-related disturbances from July to November 1987 (disturbances associated with December waterfowl hunting in the salt ponds will be described in a later section of this report.) Only those incidences which caused pelicans to take flight or "flush" are included as "disturbances" for this analysis.

Much of our data on human disturbance (apart from the hunting season) were obtained from flushing reactions caused in the process of conducting this research. It became apparent early in the study that pelicans were sensitive to our approach on certain areas of the newly installed CDFG trails leading into and surrounding the salt ponds. Controlled disturbances were not a part of our study plan; however, we were encouraged by CDFG personnel to continue using the trails for census purposes. Because we never saw visitors using these sections of the trails when pelicans were present in the associated sensitive roosts, our own limited use of these trails was the only means we had of assessing the potential impact of public access.

The approach of persons on trails within or surrounding the salt ponds caused the most (16 of 21) flushing events. Thirteen of these were research-induced (61% of 21) and three were the result of public use (Table 4). Research induced disturbances in areas other than the designated CDFG trial system (five instances) were unintentional. Those on the CDFG trails (seven) were not deliberate but were occasionally allowed to proceed when it was apparent that the birds were getting nervous. The frequency of disturbance on each trail system is as follows:

| CDFG TRAILS | | INNER LEVEES | | OUTER LEVEE | |
|---|---|---|---|---|---|
| West Blind Trail | 5 | Between pond 4 & 1 | 3 | South end | 3 |
| East Trail | 2 | Pauls Island | 1 | | |
| Sloughside Trail | 1 | (Pond 4) | 1 | | |
| TOTAL | 8 | | 5 | | 3 |

Our approach along the West Blind trail, or presence in front of the observations blind recently installed there, often instigated flushing reactions from pelicans roosting in pond 4.

Table 4. Human related activities at MLWMA which caused disturbance (flushing) in Brown Pelicans during 1987 observations.

| | | -----DISTURBANCE----- | | ----------PELICAN---------- | | | |
|---|---|---|---|---|---|---|---|
| DATE | TIME | TYPE | LOCATION | LOCATION[a] | NO. FLUSH | NO. DEPART | FLUSH DIST. |
| 11 JUL | 0652 | DOG | BENNET [b] | BENNET [b] | 93 | 83 | 50 M |
| 12 JUL | 1340 | RESEARCH | OUTER LEVEE | #6 M | 120 | 9 | 180 |
| 13 JUL | 1100 | BIRDERS | OUTER LEVEE | #6 M | 600+ | 50 | 190 |
| 15 JUL | 0757 | RESEARCH | INNER LEVEE | #4 W | 280 | 0 | 200 |
| 15 JUL | 1540 | RESEARCH | #4 POND | #1 W | 24 | 0 | 300 |
| 28 JUL | 1415 | RESEARCH | EAST TRAIL | *[c] | 30 | 30 | 160 |
| 5 AUG | 1018 | FISHERMEN | OUTER LEVEE | #6 M | 2400 | ? | 600 |
| 11 AUG | 1200 | RESEARCH | INNER LEVEE | #1 W | 9 | 4 | 150 |
| 13 AUG | 0620 | RESEARCH | W.BLIND TRAIL | #4 W | 20 | 20 | 180 |
| 31 AUG | 0750 | RESEARCH | W.BLIND TRAIL | #4 W | 321 | 321 | 150 |
| 2 SEP | 0910 | RESEARCH | W.BLIND TRAIL | #4 W | 10 | 10 | 180 |
| 2 SEP | 1710 | RESEARCH | EAST TRAIL | #6 M | 50 | ? | 160 |
| 3 SEP | 0640 | RESEARCH | W.BLIND TRAIL | #4 W | 105 | 77 | 200 |
| 6 SEP | 0630 | RESEARCH | INNER LEVEE | #1 W | 57 | 0 | 100 |
| 13 SEP | 0810 | RESEARCH | W.BLIND TRAIL | #4 W | 46 | 22 | 280 |
| 16 SEP | 1430 | RESEARCH | PAUL'S ISLAND | #1 W | 14 | 0 | 260 |
| 7 OCT | 1754 | HELICOPTER | OVER PONDS | ? | 200 | 0 | --- |
| 29 OCT | 1718 | GUNSHOT | SLOUGHSIDE TR. | #6 M | --- | --- | --- |
| 30 OCT | 0655 | GUNSHOT | MAIN SLOUGH | #4 W | 45 | 45 | --- |
| 1 NOV | 1813 | HUNTER | SLOUGHSIDE TR. | #6 M | --- | --- | --- |
| 20 NOV | 0700 | PG & E | POWERPLANT | #1 W | 30 | 30 | --- |

a See fig. 2 for location abbreviations.
b Bennet Slough, along the North margin of the salt ponds.
c Salt marsh to the east of the salt ponds.

Birds in pond 1 were never disturbed from any of the designated public trails but flushed when approached along the levee between pond 4 and 1. Pelicans standing on the mudflat of pond 6 were susceptible to disturbance by persons walking on the CDFG trail on the east border of the salt ponds by the main breach, and from the south outer levee along the slough. In each case of pedestrian disturbance, pelicans were flushed from one of the three primary use areas mentioned above (pond 4, 1, or 6). The frequency of disturbance at each site is as follows: Pond 4 - seven times, Pond 6 - five times, Pond 1 - five times.

**Reaction to Disturbance**

The most common reaction to disturbance in the pelicans was an initial heads-up, alert posture followed by wing flapping and rapid flushing of all or a portion of the birds. Of 17 disturbance events, all flushed birds departed the MLWMA area on five occasions, all relocated within the salt ponds in five other cases, and a portion of the birds departed in seven cases. On average, half (49%) of the flushed birds departed and half relocated within the salt ponds (n=17).

Time of day and persistence of the disturbance were among the factors which influenced type and degree of pelican response. Birds disturbed in the early morning were more likely to depart the roost ($\bar{x}$ = 77% departed, n = 6). This is not surprising, since the tendency is to leave the roost in the morning eventually. Early morning departures caused by disturbances stood out against the undisturbed pattern of departures, even when data are presented in 10-minute intervals (Fig. 15). Over one half (57%) of all human-induced flushing incidents occurred in the morning hours (n = 21).

Our data on reactions of disturbed pelicans may not be representative of the reaction to disturbance by the average nonconsumptive user. More than half of the flushing reactions analyzed here were caused in the process of research and our behavior in this situation was probably different than that of the average visitor to the salt ponds. In most cases we backed off from a disturbance point as soon as the first pelicans began to flush. Thus, in the majority of disturbance events for which we have data, the source of disturbance was present for only a short duration, i.e., the disturbance source was non-persistent.

Two of the three occasions when the pedestrian disturbance was caused by the public deserve further detail here as these disturbances are probably more typical of visitor use. In both cases the disturbance point was on the south outer levee along the slough. This was not a designated CDFG trail at the time of the study, but one that has been accessed for years by small numbers of fishermen and birdwatchers. Most people do not travel as far east along the trail as was observed in these cases, however.

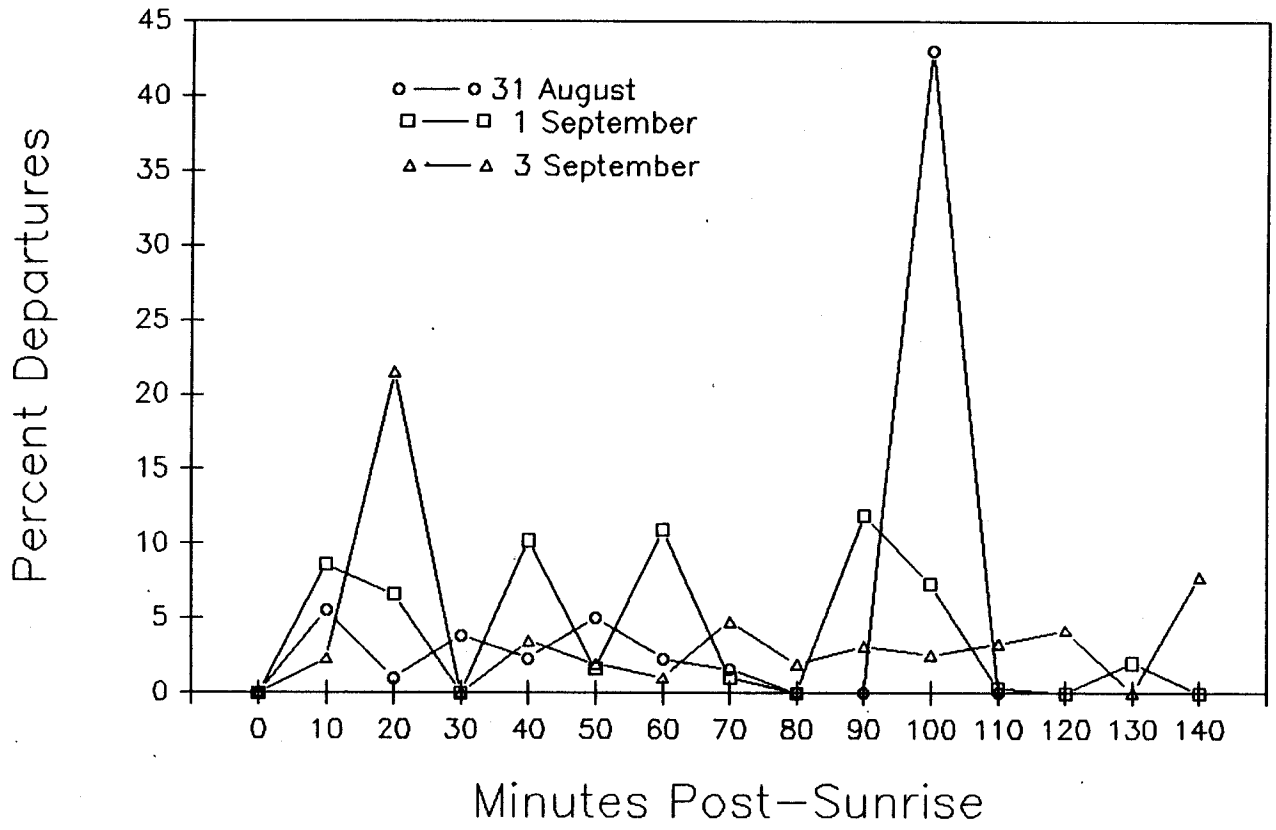


Figure 15. Morning departures of pelicans at the MLWMA roost for 3 days in 1987, showing 2 anomalous peaks of departing birds following disturbances on 31 August and 3 September. Percent departing is in relation to the total number present at dawn.

In the first case the disturbance was more persistant than any others witnessed and had a longer lasting effect on pelicans. Two birdwatchers, stopping and going, approached and passed a roosting pelican group in pond 6 at a distance of 140 meters. The visitors remained within 500 meters of the pelicans for a period of 30 minutes, then passed by the group a second time on their exit from the area. Throughout this 30 minute period all pelicans remained alert, about 600 pelicans gradually relocated to join another group in the center of the ponds (pond 5), and 50 departed toward the harbor. The small flock of birds remaining after the second encounter continued to relocate even after the birdwatchers had left the area.

The second occasion was different in terms of the immediacy of both the disturbance and response, and had a surprisingly widespread influence on the roost. This occurred when two fishermen walked this same levy at a quicker pace, directly approaching 158 pelicans on the same mudflat of pond 6. This group of birds flushed rapidly, instigating panic throughout the roost. Within one minute 2400 pelicans from ponds 4,3,5, and 6 had flushed and were circling over the salt ponds in a huge gyre. The fishermen turned around and headed back toward the harbor and the pelicans settled into one tight group, again in the center of the roost (primarily pond 5).

**Flushing Distances**

Flushing distances ranged from 110 - 600 M and averaged 220 meters (N = 15). On occasion we were able to approach resting pelicans closer than 200 meters without inducing flushing, however, and sometimes disturbance events could be aborted by backing off as soon as pelicans became visibly nervous. For example, on three occasions the birds went through the initial phases of disturbance (heads up and alert, spreading out, facing away, wing flapping) when we approached slowly at distances of 100, 180, and 170 meters. Following our immediate retreat, they resumed normal resting postures and preening activities within a few minutes. A number of variables no doubt influence flushing distance and without repeated controlled disturbances (which we feel would be a risky experiment at this site), influences of such factors could not be quantified.

The extent that flushing distance can be situation-specific is illustrated by the following example. On three dates (two at MLWMA), DLJ was standing, observing relaxed pelicans for a period of at least 20 minutes. But upon bending down at the same location, the pelican group alarmed and flushed. Thus, flushing distance is not fixed, even within the same roosting group, and can be influenced by subtle parameters, such as a change in human posture.

It is clear that the security of the habitat, i.e., the

effectiveness of barriers to mammalian predators and human disturbance, is a key factor determining flight response in pelicans (Jaques and Anderson 1987). When roosting at MLWMA, Brown Pelicans are more nervous and less approachable than at any other roost we have had the opportunity to observe. Pelicans at Año Nuevo Island, for example, can be approached within 50 meters without inducing any discernable reaction. Pelicans scavenging at fish-cleaning stations and piers are in an entirely different category than large roosting groups.

**Habituation**

Most human disturbances occurred early in the fall season (76% occurred before 17 September). Four factors most likely account for this trend are as follows: (1) Pelicans were new to the area early in the year and may have exhibited a type of migratory nervousness (this has been documented in other roosting groups by DWA and DLJ). (2) The birds remained in the salt ponds all day through September, allowing more time for disturbances. (3) Group size was larger, thus there was more opportunity for one individual to alarm the flock. 4) Our observations were conducted from greater distances later in the season.

Flushing distances varied independent of season and gave no indication of habituation to human presence as the study progressed. Since the pelican population at MLWMA is obviously not a stable resident population throughout most of the season (as evidenced by the constant variation in numbers) the possibility for habituation, of individual pelicans and the population as a whole, to human disturbance is low.

**NATURAL DISTURBANCE**

We documented 17 cases of nonhuman disturbances during the study period (Table 5). Four of these were due to unkown factors, but were presumed natural since no humans were in sight. Raptors flying overhead or pursuing shorebirds were the most common cause of flushing and accounted for half (48%) of all natural disturbance events. The raptors which elicited the greatest response were Red-Tailed Hawks (*Buteo jamaicensis*), Golden Eagles (*Aquila chrysaetos*), and Peregrine Falcons (*Falco peregrinus*). Peregrine Falcons were seen several times in the study area in 1986 but only once in 1987. On average 16% of the pelicans flushed due to a natural disturbance departed the roost (N = 14). In 10 of 14 cases no pelicans departed.

The primary differences between natural and human disturbances were that, in natural disturbances, (1) generally the whole group of pelicans responded by flushing, as opposed to a portion of the group nearest the disturbance, and (2) most pelicans did not relocate or depart, but rather circled the area briefly (less than one minute) and settled in the same region of

Table 5. Disturbance to Brown Pelicans from nonhuman sources at MLWMA in 1987.

| DATE | TIME | DISTURB. TYPE | PEL LOC | NO. FLUSH | NO. DEPART |
|---|---|---|---|---|---|
| 12 JUL | 1150 | UNKNOWN | 4DD | 500 | 0 |
| 13 JUL | 1259 | RAPTOR | 6,5,4,1 | 600 | 0 |
| 14 JUL | 0749 | RAPTOR | 6,4,3 | 200 | 20 |
| 15 JUL | | PELICANS | 6 | 150 | 0 |
| 27 JUL | 1830 | RAPT(x3) | 6,4 | ? | ? |
| 28 JUL | 1300 | RAPTOR | 6,5 | 1900 | 0 |
| 13 AUG | 2015 | UNKNOWN | 5D,4DD,3 | 300 | 0 |
| 31 AUG | 1951 | PELICANS | 6 | --- | 0 |
| 1 SEP | 1457 | GB HERON | 4 | 275 | 275 |
| 2 SEP | 1230 | FOX | 4 | 120 | 120 |
| 5 SEP | 1735 | UNKNOWN | | 300 | 0 |
| 6 OCT | 0908 | RAPTOR | 5 | 300 | 0 |
| 6 OCT | 0911 | GB HERON | 5 | 300 | 30 |
| 7 OCT | 1326 | UNKNOWN | 4D | 74 | 0 |
| 1 NOV | 1725 | RAPTOR | 6 | | 0 |

the roost rather than relocating.

These differences are evidently related to the time available for the pelicans to evaluate the disturbance source and the severity of the threat. Flushing of the whole group seems to be a response to sudden alarms, such as are induced by raptors, in contrast to the relatively slow approach by humans which are generally detected in advance. Pelicans soon resettle following disturbance by raptors or other birds, since they generally do not pose a real threat to pelicans. The approach of humans evidently does threaten the security of roosting pelicans.

Two natural disturbances stand out against the others, in terms of their impact and parallels to specific human disturbances. The response to a Golden Eagle flying over the salt ponds was strikingly similar to the disturbance from the rapidly approaching fishermen. The eagle did not appear to be hunting but elicited immediate alarm in Western Gulls (Larus occidentalis), which vocalized loudly, mobbed the bird, and chased it out of the area. Meanwhile, 1900 pelicans flushed from all areas of the salt ponds, circled over the roost in a large gyre, then settled in the center of the salt ponds in one continous flock. No departures were observed. Perhaps this widespread reaction and subsequent central grouping results when the alarm is intense, cued into by particular alarm calls of gulls, and the disturbance source is not readily assessed. On the other hand, since Golden Eagles sometimes harass Brown Pelicans during overland migration in Mexico (DWA field notes), the presence of these birds may actually threaten pelicans.

The reactions to Great Blue Herons (Ardea herodias) landing in with the pelican roosting groups on two occasions seemed peculiar; however, we have noted this species causing pelicans to flush on three other instances at different roosts. During the middle of the day on 1 September 1987, a Great Blue Heron landing nearby caused all pelicans in pond 4 to vacate the roost (275 birds) and head north up the coast. On the previous morning, 31 August, a research-induced disturbance at pond 4 had caused the same unusually severe response, i.e., total departure from the roost (321 birds). Great Blue Herons were present in the salt ponds every day and usually instigated no reaction in pelicans.

Brown Pelicans flushed on two occasions when large numbers of conspecifics attempted to land among birds already present. This happened during one evening of concentrated arrivals and one morning when birds were flushed by human disturbance from one location to another.

The "natural" disturbance factor having the greatest impact on the roost at MLWMA may be the non-native Red Fox (Vulpes vulpes). These animals could be partly responsible for the unusually large flushing distance and wariness we have observed at this site. Red Foxes were seen in the roost on two dates

during this study, once by us and once by volunteers with the ESNERR (Bernadette Ramer, field notes). A fox in the center of the salt ponds (levee near pond 5) on 2 September caused pelicans in pond 4 to vacate the roost entirely and immediately. Non-native red foxes have become established in the Monterey Bay area and have spread rapidly. They are a special concern due to their boldness and activity throughout the day. The problem at the salt ponds has been compounded since the levee breached in 1982. The area has become more accessible to mammalian predators (at low tides) and the Red Fox population has increased.

**IMPACTS OF DISTURBANCE**

Repeated disturbances may have influenced a change in habitat use, a decline in numbers throughout the season, and a strong attraction for roosting with gulls when pelican numbers were low. Pelicans changed their primary night roost location in late fall from pond 4 to to an area that was not accessible by trails in pond 1. Pond 4 served as the primary night roost from July to August; an average 87% of all birds observed were located there in early morning. Six human disturbances accounted for in this study occurred at pond 4 prior to 14 September and use of the site declined during that month. On 31 October there was essentially a total change in use from pond 4 to pond 1. This switch also correlated with the start of waterfowl hunting in the slough (28 October), however. Hunting took place off the trail at the east end of the salt ponds, and pond 1 was farther from the shooting activity than pond 4. No changes in water levels or differences in habitat between the ponds were noted throughout the season.

Determination of the effect that disturbances had on numbers of pelicans using the MLWMA is problematic. A relatively high turnover of individuals at the roost was likely and undetectable without marked birds. There was, however, a statistically significant inverse correlation between change in daily pelican numbers and percent flushed by a disturbance on the previous day ($Rs = -0.48$, $p = 0.01$, $N = 20$. Fig. 16). We analyzed data only for days in which we had consecutive peak counts, and included both natural and human disturbance events as well as days when no disturbances were observed.

Frequency of disturbances at MLWMA were higher than at other night roosts due to the accessibility of the habitat and perhaps the species composition of roosting associates. In the 52 days prior to the December hunt we observed an average of 0.73 flushes per day at MLWMA. This compares to 0.08 flushes per day ($N = 20$ days) observed at SEFI. Brown pelican roosts do not exist, or are infrequently occupied, in areas which experience chronic, intense disturbance (Jaques and Anderson 1987); MLWMA would not be placed in this category. Some pelicans are evidently more

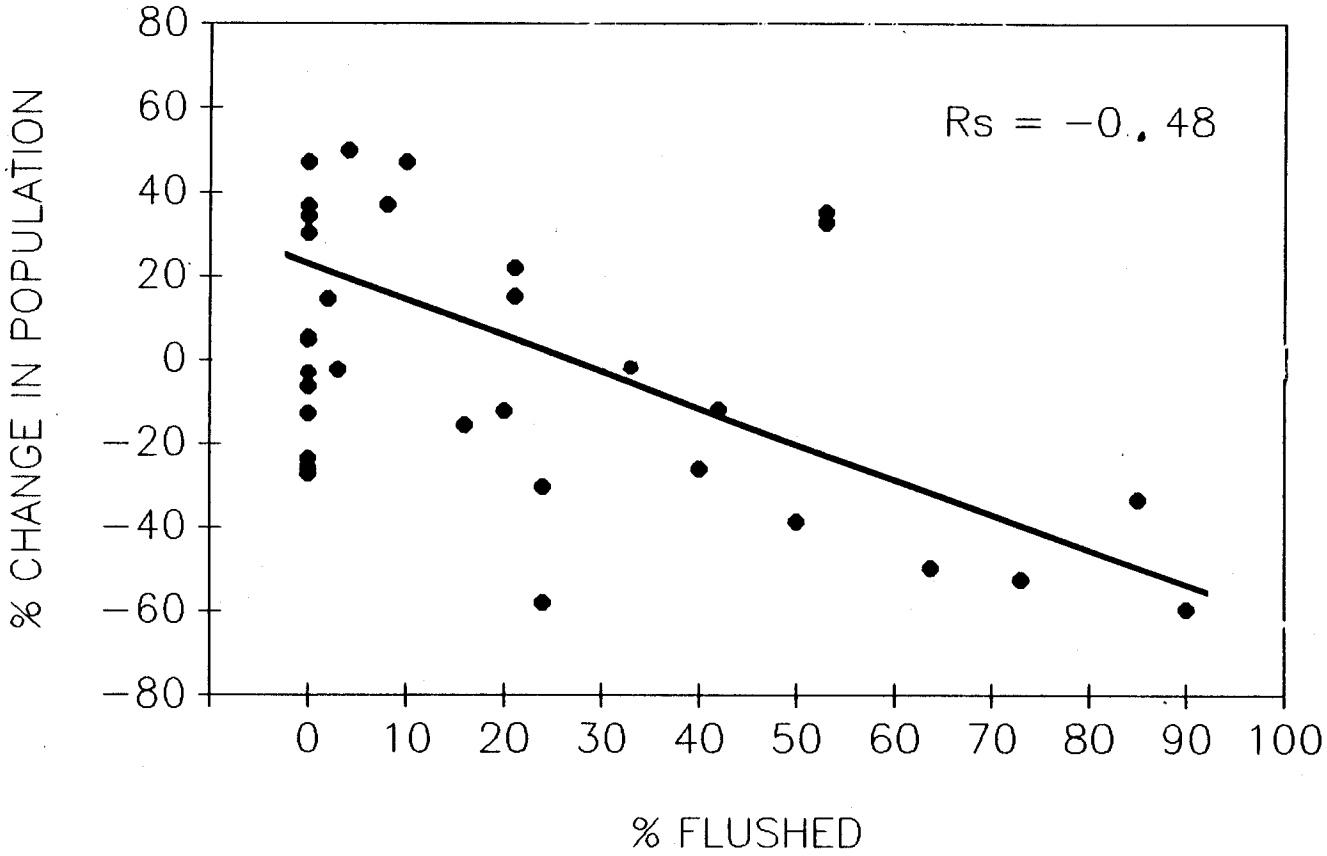


Figure 16. Change in the number of pelicans at MLWMA from one day to the next related to the percent flushed by a disturbance on the first day. Points represent percent increase/decrease from the count of the previous day for all (July-November) 1987 disturbances with successive daily high counts. Percent flushed are in response to natural or human disturbance events; 0 percent = no disturbance.

sensitive to disturbance than others (Anderson 1988, in press), and the level of disturbance at the salt ponds may have been above the threshold for segements of the population.

Pelicans exhibited a large degree of insecurity about roosting at the MLWMA at night late in the season, and sought association with gulls. When pelican numbers were low in late November and December, arriving birds were reluctant to be the first individuals or group to land in the salt ponds. The first arrivals would circle the salt ponds in the evening, evidently searching for conspecifics or gulls. When gulls were not present, the pelicans did not land, and continued circling around the salt ponds or departed out towards the harbor. The vocal alarms of disturbed gulls may provide a sense of security to pelicans resting in the dark. Shorebirds and egrets were evidently not suitable sentinels, as pelicans arriving to the roost in the evening would often circle low over them, but depart after inspection of the group. The importance of gulls as a roosting nucleus became most evident during the December hunt, described in the following section.

**HUNTING IN THE SALT PONDS**

Waterfowl hunting in the salt ponds opened on 1 December 1987. An interagency agreement between the CDFG and the USFWS stated that hunting would commence on this date if numbers of pelicans were below 100. On 30 November, 89 pelicans were counted; however, 102 and 108 were counted on 29 November and 1 December, respectively. Numbers declined to 80 pelicans after the first day of hunting, but on the third day began to increase and climbed to 242 by 5 December. The waterfowl season was temporarily closed on 4 December, due to this influx of pelicans. Following the official closure, the salt ponds continued to be hunted through at least the morning of 6 December by presumably uninformed hunters.

Although observations of hunter/pelican interactions were limited due to the short duration of the season, it was clear that hunting in the salt ponds was disruptive to roosting pelicans and was the single most severe source of disturbance observed during the study. Shooting and intrusion of humans and dogs into the roost resulted in high rates of flushing, inability of pelicans to utilize specific required habitats, extended periods of milling and circling around the roost, and delayed evening arrival times.

During the five-day period (1-5 December), we documented 17 obvious disturbance events (flushing of roosting pelicans); 10 were in the evening and seven were in the morning hours. This compares to a total of 38 flushing incidences observed in 52 days prior to the hunt (two of these related to hunting outside the

salt ponds). The average number of flushes/hour of observation (hours in which pelicans were present) were as follows:

| | | |
|---|---|---|
| prehunt: | 0.1 flushes/hour | (n=312 hours) |
| morning hunt: | 1.3 flushes/hour | (n=4.5) |
| evening hunt: | 3.3 flushes/hour | (n=3.7) |
| total hunt: | 2.1 flushes/hour | (n=8.2) |

Morning hunting affected pelicans less than did evening hunting. The two primary reasons for the difference are as follows: (1) Roosting birds and hunters were generally separated by a greater distance in the morning; therefore disturbances were less frequent. (2) The degree of conflict in pelican response was less; pelicans readily responded to morning disturbance by departing the roost. The duration of disturbance events was, therefore, shorter than at night when pelicans had a stronger motivation to remain in the roost. Detailed descriptions of the different situations arising from morning and evening hunting follow.

**Morning Hunt**

Pelicans and hunters were generally separated by about 1200 meters on nearly opposite sides of the salt ponds in the morning. Hunters favored the northeast end of the salt ponds and established a temporary hunting blind in that area. Most duck flights were to and from a freshwater pond immediately adjacent to the salt ponds on the Elkhorn Ranch. Pelicans maintained their established pattern of roosting in Pond 1 (with one exception), but shifted to the south end (further from most shooting activity) as opposed to the central and northern portions of the pond. Shooting in the northeast region of pond 6 did not flush pelicans in pond 1. The average pattern of morning departures for this first week in December was similar to the previous week in November and later dates in December (Fig. 9), but morning disturbances did stand out in the pattern of departures for individual days.

Morning disturbances and flushing-induced departures occurred when the distance between hunters and pelicans was closer than about 600 meters. Pelicans in pond 1 were flushed by gunshots on 3 December when hunting took place from the center mounds in pond 5. On 5 December pelicans present in ponds 4 and 3 were flushed by gunshots from pond 6. December 5 was the only morning during the entire study that pelicans were observed in ponds 3 and 4, and corresponds with the presence of a hunter in pond 1 the previous night. In all morning cases, flushing resulted in only partial departures of the flock, rather than total abandonment of the roost.

Hunters were present on the trails as early as one hour before sunrise and began shooting as early as 18 minutes before sunrise. The first morning shot occurred at a mean time of five

minutes after sunrise (n=5).

**Evening Hunt**

In the evenings, pelicans and hunters had similar habitat preferences, creating conflict for the pelicans. As described previously, pelicans and gulls had established a pattern of gathering on a raised region in the southern portion of pond 6 before moving to the western ponds at dark (see Habitat Use). The birds thus utilized both ends of the salt ponds each night. The greatest numbers of hunters were generally present in the evenings (maximum = eight on 1 December) and they occupied a greater number of areas, including both ends and the center of the salt ponds. Hunters also tended to roam the levees in the evening, as opposed to sitting in the blinds.

Two nights which presented the greatest conflict were 1 and 3 December, when hunters occupied the staging area in pond 6 and were present near pond 1. Pelicans showed very little flexibility in habitat use and did not elect to land in suboptimal regions of the roost. Instead, they demonstrated that the regions normally selected were actually required, not simply preferred.

On the evening of opening day, essentially all regions of the salt ponds were occupied by hunters. Gulls initially landed on the staging area but were soon flushed after detecting a hunter crouched on the mudflat. At least five groups of pelicans arrived, circled around the east end, and departed without landing. After the hunter left the mudflat, several hundred gulls and 19 pelicans finally did land (16 minutes after sunset), but they were immediately flushed by gunshots nearby. During the evening observation period, pelicans spent a period of eight minutes on land (from the time they arrived until it was too dark to see), were flushed twice, and spent 26 minutes milling and circling around the salt ponds. Birds appeared to be settling in at pond 1 at last light.

The evening of 3 December seemed to be one of mass confusion for thousands of gulls and between 68 and 100 pelicans. A hunter and dog present in the roosting area at pond 6 triggered the evening scenario, which was compounded by another hunter remaining at pond 1 until well after dark. Four groups of pelicans arrived and departed the salt ponds before any landed. It is impossible to know if these early arrivals, which initially rejected the salt ponds, returned or not. The birds that finally landed were nervous and flushed wherever they did land. Only one shot was fired from pond 1, but the obvious awareness of this person by gulls and pelicans, coupled with a strong tradition and necessity for roosting in this pond, was enough to create havoc in the roost. These factors kept thousands of gulls milling over the area at dark and forced movements of pelicans and gulls back and forth across the salt ponds, and out to the Bay and back, for

the duration of the evening observations. Throughout the brief period that pelicans were on land, a minimum of five flushing incidences occurred. The actual number of flushes was difficult to determine as the pelican group broke up in the confusion, and flushing continued in various locations until at least one hour after sunset (when we could no longer see the birds).

On 4 December, the locations of hunters did not impact pelicans as severely. People were not present in the portion of pond 6 used by pelicans. Gulls were able to form a nuclear roosting group and arriving pelicans settled directly. However, after the birds initiated their evening exodus from pond 6 to pond 1, a gunshot was fired from one of the western ponds. This startled the birds, aborted the movement, and resulted in a horizon full of gulls and pelicans as in the previous night. This time the pelicans relocated fairly quickly to pond 5 and stood on the mound for a few minutes, then walked off into the water at last light. The next morning they were found in ponds 4 and 3 where they were disturbed by morning hunters.

On 5 December, after the official temporary closing of the hunt, no hunters were seen in the salt ponds in the evening and we did not hear shooting. Pelicans and gulls staged in pond 6 but were nervous and flushed several times. They did successfully complete their evening exodus to pond 1 at 30 minutes post-sunset. The following table provides a comparison of roosting activities for the four evenings detailed above.

PELICANS:

| Date | First Arrival | First Landing | Number Flushes | Minutes Milling | Minutes on Land |
|---|---|---|---|---|---|
| 1 Dec | 6 | -16 | 2 | 26 | 8 |
| 3 Dec | 8 | - 1 | 5 | 29 | 35 |
| 4 Dec | 50 | 50 | 1 | 3 | 92 |
| 5 Dec | 46 | 46 | 2 | 4 | 76 |

GULLS:

| | | | | | |
|---|---|---|---|---|---|
| 1 Dec | 16 | 16 | 3 | 42 | 18 |
| 3 Dec | 8 | 8 | 5 | 33 | 31 |
| 4 Dec | 50 | 50 | 2 | 5 | 90 |
| 5 Dec | 60 | 60 | 2 | 5 | 90 |

Numbers for First Arrival and First Landing are minutes with respect to sunset. Negative numbers = minutes post sunset.

**Hunting Pressure**

Twelve individual hunters were counted in the salt ponds on

opening day, seven hunters worked the area on 2 December, and numbers declined after that. The heaviest shooting pressure probably occurred on opening day. Three morning hunters were present and fired a total of four shots during the time pelicans were present. Shooting increased throughout the day, and exceeded 93 shots by dark (Fig 17). One individual continued to shoot until 26 minutes post-sunset. The average number of shots fired per hour on December 1 was as follows:

| | | |
|---|---|---|
| morning hunt: | 3 shots/hour | (0656-0904) |
| midday hunt: | 12 shots/hour | (1100-1600) |
| evening hunt: | 28 shots/hour | (1600-dark) |

After opening day, gunshots were monitored only during morning and evening observations. Number of gunshots ranged from 2 to 19 in the morning when pelicans were present. The number of shots was not nearly as critical as the location of hunters within the salt ponds in relation to pelicans.

**Other Observations Related to Hunting**

Pelicans were sometimes secondarily affected by hunting from the alarm response of other birds. Shots outside the salt ponds twice induced disturbance of Brown Pelicans due to the flight and alarm of other species flushing into the salt ponds. This occurred when a flock of Pintail (Anas acuta) rushed over the levee into pond 6, and another time when gulls screaming alarm calls descended upon the pelicans following a gunshot in the nearby marsh.

The effect of waterfowl hunting on other species at the salt ponds was not quantified, but the following are examples of the types of changes we noted. We observed disturbance and departure of Harbor Seals (Phoca vitulina), which were hauled out in pond 6 by the main levee breach, on two dates when hunters and dogs approached on the mudflat. Foraging shorebirds were practically eliminated from the east end of the salt ponds on one afternoon when a dog was allowed to run freely through pond 6 while its owner sat by the blind. The presence of hunters on the center mounds (5d) eliminated use of this site for roosting by gulls and shorebirds. This was noted as a favored daytime high tide loafing area prior to the hunt. Snowy and Great Egrets (Egretta thula and Casmerodius albus) utilized a set of wooden posts in pond 6 for roosting on most nights during the study. When hunters were present in the immediate area, egrets were not.

Many species besides pelicans utilized pond 1 for night roosting in December (see Table 6). The potential for disruption of the entire roosting commnuity is great if ducks, and consequently hunters, find the western ponds more attractive in the future. Data on roosting and foraging habits of shorebirds and waders, and the impact of hunting on these groups of birds, should be collected if shooting is to continue in the salt ponds.

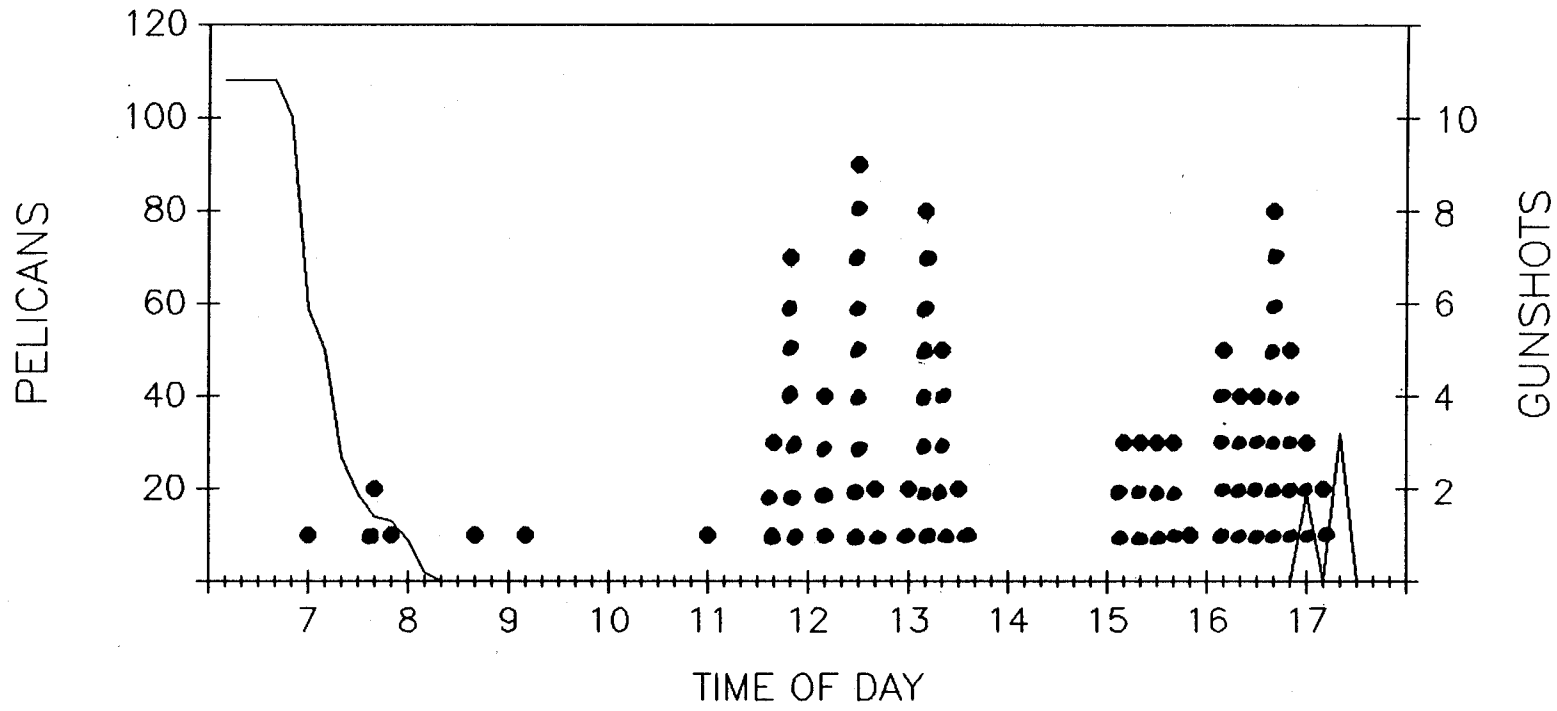


Figure 17. Number of pelicans (represented by line) and number of gunshots (points) during opening day at MLWMA, 1 December, 1987.

Table 6. Morning counts of birds roosting at pond 1 adjacent to or associated with Brown Pelicans in December.

| | DATE (1987) | | | |
|---|---|---|---|---|
| SPECIES GROUP | 2 Dec. | 4 Dec. | 5 Dec. | 10 Dec. |
| Brown Pelican | 80 | 189 | 242 | 246 |
| Gulls | 2,000 | 3,470 | 4,665 | 2,595 |
| American Avocet | 190 | 190 | * | * |
| Black Necked Stilt | 31 | 52 | * | * |
| Dowitchers | 60 | 200 | * | * |
| Long Billed Curlew | 3 | - | * | * |
| Marbled Godwit | 410 | 100 | * | * |
| Sandpipers | 6.000 | 4,000 | * | * |
| Willet | 240 | - | * | * |
| Great Blue Heron | - | 3 | * | * |
| TOTAL COUNT | 9,014 | 8,204 | * | * |

* not counted.

Such data are also needed in order to determine impacts of habitat changes as a result of proposed improvements (see Management Recomendations).

**Impact of Hunting**

The above descriptions provide an indication of the immediate reactions of pelicans and other non-game species to a very short (five-day) period of hunting in the salt ponds. Observations such as on the night of 3 December (pg. 39) reveal the conflicts presented to pelicans (and other roosting species) when as few as one hunter is present in a critical area. The actual "costs" to individuals roosting at MLWMA, or to populations, are not easily quantified.

Turnover of individuals during the period of expected southward migration probably masked the impact of hunting on numbers of pelicans using the roost in December. Pelicans remained in Oregon and Washington in unusually high numbers through November in 1987 (Roy Lowe, USFWS, pers. comm.) and we suspect that the small and brief December influx at MLWMA was due to birds "stopping over" at this traditional roost. (A larger influx of pelicans was observed in mid-November 1986.) We were generally unable to detect marked birds at MLWMA due to their limited number, large observation distances, and the fact that pelicans mostly stood in the water. Thus it was impossible to know if birds that were disturbed by hunting ever returned.

The most obvious cost incurred to pelicans during the hunt was an increased energy expenditure (more flying time) and less time resting during periods of milling and flushing at the roost. Flapping flight is a costly activity for pelicans due to their relatively high wing loading (Pennycuick 1972). These birds have evolved behavioral adaptations such as flying in formation, gliding low against cushions of air in wave troughs, and spending large proportions of the day inactive on roosts (Croll et al. 1986) to minimize energy expediture. Chronic disturbance and flushing could feasibly have a large impact on the condition of individuals already stressed from late season food shortages, migratory movements, cold weather, and feather molt.

Finally, the winter residence of several hundred pelicans in Monterey Harbor and subsequent spread of disease, deaths and mutilations of birds, nuisance to wharf businessess, and potential human health hazards, cannot be dismissed as being totally unrelated to occurrences at the salt ponds. It is possible that pelicans disturbed from the salt ponds may have been attracted to the next nearest aggregation of birds to the south. In using roosting sites at the harbor, more pelicans may have gotten "hooked" into a scavenging and begging mode, which in some cases, cost lives of birds. Hunting activities at the salt ponds may have discouraged Brown Pelicans wintering in Monterey Bay from roosting at the MLWMA.

Strictly from the standpoint of roost protection, promoting activities which obviously decrease the attractiveness of the MLWMA roost to pelicans, even through the winter, seems to be ill-advised management of critical Endangered Species habitat, and in direct conflict with the goals of the Brown Pelican Recovery Plan (USFWS 1983).

## DISCUSSION OF PROPOSED LEVEE

The CDFG has proposed construction of a levee in the remnant salt ponds to allow management of water levels in the western ponds (1-4) and enhancement of habitat for a variety of resident and migratory species (Army Corps of Engineers, Public Notice No. 17316S27, 2 March 1988). The proposed levee is six feet high and twelve feet wide and would essentially bisect the area from northeast to southwest. This construction could potentially provide great benefits for roosting Brown Pelicans if water levels and human access on the levee are managed appropriately.

Appropriate management for Brown Pelicans would have to take into consideration the water levels in the night roosting ponds. If the water is too deep (above four inches), pelicans would either be forced to swim all night, or more likely, abandon use of the area. If the water is drained out or surface cover is minimized during the time when pelicans are present, roosting conditions would likewise be inadequate.

Construction of the levee would eliminate both of the sites most frequently used by pelicans during high tides (4d and 5d); thus the loss of these high tide sites should be mitigated by the construction of islands in the salt ponds. Pelicans may roost on the new levee itself if it is not frequently traversed by people or foxes and dogs. Whether or not the birds use the levee, island habitat should be provided which is suitable for use by pelicans during all tidal conditions, times of day, and intended public activities.

The best place to construct islands would be in central locations of the salt ponds, as far as possible from the influences of human and other terrestrial disturbance sources. The island should be surrounded by a radius of at least 100 meters of open water and a 250-meter radius that is off limits to both consumptive and non-consumptive users. We have arrived at these figures through observations of pelican position in the night roosting ponds and flushing distances. The depth of the water around the islands would not be as important as the horizontal barrier, but deeper water would provide better isolation from mammals. Pelicans seem to prefer water/land interfaces; therefore a maximum amount of edge in the design would be encouraged over a circular shape.

The "island" proposed by the CDFG in pond 6 would provide an excellent high tide roosting site but would be unsuitable throughout the night under most tidal regimes. We suspect it would not be used at all as a night roost by pelicans. Pond 6 does not hold water for very long; it drains out rapidly during ebb tides, and tides below four feet do not fill the area. In contrast, island construction where water can be retained may serve as needed nesting substrate for resident birds as well as a permanent roost site which can be used by pelicans and other species at all times of day and at all tidal heights. We suggest island construction in the southwest region of pond 4.

The provision of dry substrates suitable for use at all tides is highly recommended. This would enable pelicans to get out of the water. The MLWMA is the only "wet roost" we know of. Before the main levee breached, the birds evidently were never seen standing in the water and roosted on central portions of the inner levee system (DWA field notes; B. Ramer and D. Croll, pers. comm.). Secure dry islands are the normal night roosting substrate for Brown Pelicans, but the lack of roosting security due to habitat changes at MLWMA since levee breaching has evidently forced pelicans to roost in the water. A pelican roosting in shallow water, as opposed to dry land, may suffer from several disadvantages. During cold temperatures, pelicans may incur heat loss through their legs and large feet while standing in the water. Preening activities may be inhibited somewhat while in the water, since pelicans appear to strive to keep their plumage dry while roosting. We noticed that pelicans lifting their feet out of the water often left large marks of mud on their heads when preening or scratching with the foot.

The single most important recommendation we have regarding the new levee is that human access be severely restricted during periods when pelicans are present or when resident birds are nesting. A person merely walking along the levee could potentially disturb all but one of the pelican roosting areas used in 1987. If chronic human disturbances were to occur on this levee, and pelicans continued to use the same general sites that they did in 1987, only pond 1 (where there is currently no public access) would remain unaffected. We do not know if there are plans to retain water in pond 1, however, or what future disturbances might result if the adjacent property west of MLWMA (Paul's Island) is acquired by the CDFG.

In summary, we feel that levee construction and subsequent ability to control water levels could substantially improve the security and attractiveness of the MLWMA roost for pelicans. On the other hand, under present conditions, inappropriate management of water levels and public access to the new levee would be risking the loss of the entire roost.

## SUMMARY AND RECOMMENDATIONS

Large numbers of Brown Pelicans occur along the central California coast during the nonbreeding season and require suitable communal roosting sites in proximity to food resources. The roost at the remnant salt evaporation ponds at Moss Landing is among the largest and most important roost sites on the U.S. Pacific coast. The area is now owned and managed by the CDFG and is an integral part of the Moss Landing Wildlife Management Area (MLWMA). Due to the unusual nature of the habitat, the MLWMA roost has special problems. It is more susceptible to both human and natural disturbances than most other night roosts, which are typically located on offshore rocks and islands. The potential to actively manage the salt-ponds roost to maintain and enhance the security of the site for Brown Pelicans, as well as for other species, was made possible with its acquisition by the CDFG in 1984. Financial support by the CDFG of this study on pelican use of the MLWMA roost constitutes another step toward management of the salt ponds for pelicans.

The nonbreeding season of 1987 (July-December) was characterized by early arrivals to the central coast due to breeding failure in the Gulf of California. Populations of Brown Pelicans were highest in July and declined to relatively low levels from September through December. Three pelican concentration areas were observed on the central coast, one of which was the greater Monterey Bay area (Pt. Lobos to Año Nuevo Island), which includes the MLWMA.

The MLWMA sheltered the largest single roosting aggregation observed on the U.S. Pacific coast during this study, with a peak count of 4355 pelicans in late July. Average numbers of pelicans roosting at MLWMA declined from midsummer to fall more than central coast populations declined as a whole. Day roosts in the Monterey Bay area followed the same population trend as the salt ponds.

Numbers of pelicans varied throughout the day at MLWMA and were highest late in the evening (post-sunset) and early in the morning (pre-sunrise). The most accurate method used to census night roosting populations was to begin counting pelicans flying out of the roost as soon as they were visible overhead in the morning. A count of the remaining group could be conducted when light levels, movements, and position of pelicans were conducive to obtaining accurate counts.

Pelicans spent more time roosting at the salt ponds throughout the day early in the season than they did as the fall progressed. During November and December,pelicans largely abandoned the site during the day, departing soon after sunrise and not returning until near sunset. This pattern of daytime absence was not seen at other large roosts; these sites were

occupied continuously by a percentage of birds. Pelicans occasionally departed the MLWMA in the evening, but we did not believe this to be a consequence of inadequate roosting conditions.

Brown Pelicans at MLWMA roosted in areas least accessible to humans and mammalian predators. Habitat use was also strongly influenced by time of day and tidal stage. Roosting location was more flexible during daylight hours than it was at night. Raised mounds or mudflats were favored during the day. At night pelicans were forced to roost in the water of permanent ponds since dry substrates did not provide secure habitat in the dark. When high tides occurred in the evenings, the water in the permanent ponds became too deep for pelicans to stand in. In this case, the birds generally crowded onto small centrally located island mounds. These mounds were not big enough to hold all the pelicans present on some evenings, and some birds remained swimming around the perimeter of the islands at dark. Pelicans moved off the mounds and back into the ponds as water receded during the night.

Brown Pelicans were highly sensitive to the presence of people in the salt ponds. The newly constructed CDFG trails were close enough to major roost locations to cause pelicans to flush (in some instances) when persons approached on certain portions of the trails. The greatest problem area was the end of the trail leading to the West Blind. Pelican reactions to such disturbances were highly situation-specific, but documentation of mean flushing distances provides a basis for further management decisions. The study species did not appear to habituate to use of the trails or other human disturbances throughout the season.

Nonhuman disturbances also occurred at MLWMA and were primarily due to predator-prey interactions between raptors and shorebirds and the alarm of roosting associates such as gulls. Red Foxes were observed in the salt ponds and may be an important cause of the increased sensitivity of pelicans in this area to disturbances.

Impacts of disturbances were difficult to assess beyond the immediate responses of pelicans, but may have resulted in a change in choice of night roosting location, decline in numbers using the site throughout the season, and increased association with gulls when pelican populations were low.

The five-day December waterfowl hunting season in the salt ponds was the single most severe source of human disturbance to the roost. Gunshots fired within 600 meters of pelicans in the morning instigated flushing and accelerated departures from the roost. The greatest impact occurred in the evening when hunters occupied staging areas and night roost locations used by pelicans. Pelicans and gulls spent extended periods circling

around the roost and were flushed frequently on three nights when hunters occupied critical sites. The majority of pelicans did not settle into the roost until after dark in December.

The actual cost of the hunting season to pelicans was difficult to determine in such a short period and with rapid population turnover. The presence of hunters in the roost, at the very least, resulted in increased energy expenditure when pelicans were unable to land in the roost in the evening. Decisions regarding the future of the hunt in relation to its impact on roosting pelicans will have to take place based on the information provided in this report of further study. Promotion of activities which has a negative influence on the roost would be unwise management of critical endangered species habitat.

Proposed levee construction in the salt ponds could potentially provide great benefits for Brown Pelicans as well as many other species. The roosting situation at MLWMA is complex, and management of water levels and human access will be of primary importance in any endeavor to enhance habitat for the study species. The project could work against Brown Pelicans, and feasibly eliminate them from the site, if management is not appropriate to their needs. Construction of islands in permanent water bodies is our highest recommendation for improving habitat and increasing the security of the roost for Brown Pelicans.

The MLWMA may still be the single most important location for roosting pelicans north of Point Conception in terms of the numbers of birds it serves throughout the nonbreeding season. The availability of this roost may strongly influence the ability of pelicans to exploit the food resources of Monterey Bay. With recent acquisition of the property and subsequent management capabilities, the CDFG is the primary agency responsible for ensuring that Brown Pelicans passing through or overwintering in this region, are provided a secure roost for many years to come.

Our recommendations, then, for management of the MLWMA to conserve and enhance Brown Pelican roosting habitat are as follows:

1. Reduce or eliminate human disturbances to roosting pelicans, by doing the following:

    A. Do not construct additional trails into or around the periphery of the salt ponds. Most importantly, do not allow public access on the proposed levee that bisects the area. Do not construct a trail along the western border of Paul's Island if this piece of property is acquired.
    B. Discourage further public use of the south outer levee along Elkhorn Slough.
    C. Remove the West Blind from the interior of the salt ponds and close the last portion of the trail near pond 4.
    D. Educate the public. Provide information on the

sensitivity of Brown Pelicans to disturbance in the general brochures describing the MLWMA.

2. If the proposed levee is approved, conduct major construction during late winter and early spring, when pelicans are least likely to be present.

3. If the proposed levee is constructed, manage water levels so that pelicans continue to have at least one appropriate shallow water area (depth = four inches or less) available for roosting. The pond should provide at least 100 meters of water surrounding all sides of a roosting group and allow for a distance of at least 250 meters between public access points and pelicans. We suggest that pond 1 be maintained as shallow water habitat.

4. Construct an island in a permanent body of water that would serve as a secure dry roost for large numbers of pelicans at all times of day. We suggest that the central-southwest portions of pond 4 should be the location for such an island, perhaps deepening the area around the island. The shape of the island should provide a maximum degree of land-water interface. It should be buffered from disturbance by the same degree of water and space as suggested above. Island construction would be desirable regardless of levee construction.

5. Close the salt ponds to waterfowl hunting at all times of year, to reduce disturbance problems in the following ways:

   A. People would no longer have free access to all parts of the salt ponds in the critical early morning and late evening periods.
   B. Disturbance from dogs would be largely eliminated.
   C. Disturbance from gunshots and hunting-related alarm of other species would be significantly reduced. Complete closure of the salt ponds to hunting is especially important if pelicans continue to winter in the Monterey area.

6. Continue monitoring numbers of pelicans and their use pattern at the salt ponds, particularly if habitat manipulations proceed and waterfowl hunting continues. Use the early morning census technique described in this paper to most accurately assess night roosting populations. Conduct observations and counts during morning, midday, and evening at least one time per month during the non-breeding season until conditions at the MLWMA have stabilized or the roost is abandoned.

7. Consider the Salinas River mouth and Jetty Road Beach sites as satellite day roosts to the MLWMA and respond to proposals or problems that may negatively affect the quality of roosting habitat to Brown Pelicans at those locations.

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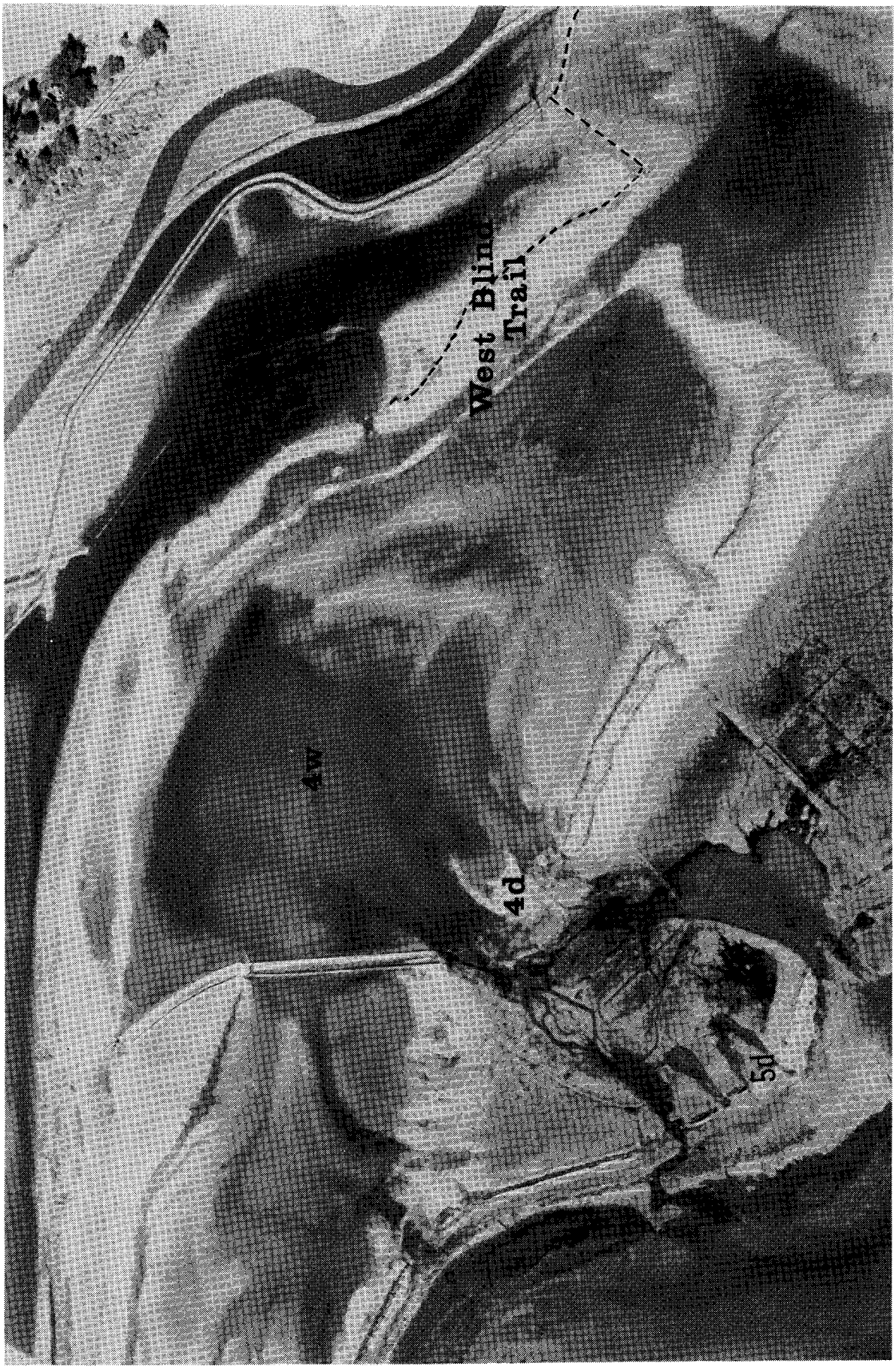
# APPENDIX

Appendix Figure A. Aerial photograph of the remnant salt evaporation ponds at Moss Landing Wildlife Management Area, showing primary ponds and CDFG trails. (See Figure 2, page 6, for definition of W, D, & M).

West
Blind Trail
4W
4DD
4D
5
5D
3W
East Trail
6M
1W

Appendix Figure B. Aerial photograph of MLWMA ponds 3 (unnumbered, upper left), 4, and 5 (unnumbered, lower central). (Compare with Figure 2, page 6).


West Blind
Trail
4w
4d
5b

Appendix Figure C. Aerial photograph of MLWMA pond 6, with Elkhorn Slough at extreme right outside of levee. (Compare with Figure 2, page 6).

6m

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APPENDIX H: Jaques, D.L., C.S. Strong, and T.W. Keeney. 1996. Brown Pelican roosting patterns and responses to disturbance at Mugu lagoon and other non-breeding sites in the Southern California Bight. USDI NBS, Cooperative Studies Unit Technical Report 54. Tucson, AZ. 62 pages.

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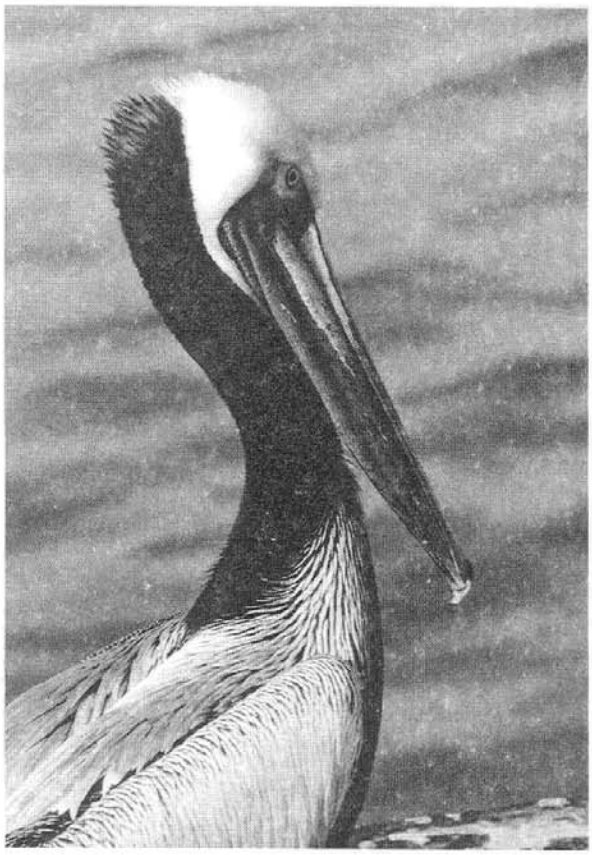
**Technical Report No. 54**



United States Department of the Interior
National Biological Service
Cooperative Park Studies Unit
The University of Arizona ♦ Tucson, Arizona

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## Dedication

Aerial surveys have become a critically important tool in many studies of seabird ecology. When flying at slow speed at relatively low elevations over rugged marine coastlines, researchers usually choose to leave the flying to the most experienced pilots. By doing so, the investigators are free to focus full concentration on their research efforts. This was the case with our research on the roosting behavioral ecology of brown pelicans and the seabird ecology of the Southern California Bight.

John Michael Drust was a meticulous pilot and navigator, inquisitive friend, and a wonderful supporter of our seabird research. John was born on 14 July 1948 in Ventura, California. He was a graduate of Ventura High School and San Diego State University and a member of the Reserve Officer Training Corps. John was a pilot in the U.S. Air Force for 10 years and became one of their top instructors. His experience ranged from flying C-141 transports to T-37 and T-38 trainers. When he left the Air Force, John worked for Omohundro Company in Costa Mesa, California, as quality engineering project manager. During that 5-year period, he and a partner founded Precision Aircraft and designed, built, and flew an ultralight aircraft. John went back to flying full time and for the past 6 years was chief pilot for Aspen Helicopters, Inc. John died 9 January 1996 when a plane he was piloting crashed 15 miles off the coast of Santa Monica, California.

John's death is a tragic loss to those of us in the seabird and marine mammal research community. John was in flight to San Diego to pick up marine mammal researchers for a trip to Baja California when the accident occurred. John was keenly interested in all the aspects of ecological research that presented opportunities to exercise his outstanding flying ability and other talents and knowledge. To help us perform the best data collection possible, John probed us for information to maximize the performance capabilities of his aircraft during our flights.

The cadre of seabird ecologists from the Department of Defense Naval Air Weapons Station Point Mugu, Department of the Interior National Biological Service and U.S. Fish and Wildlife Service, and Crescent Coastal Research trusted John's flying and navigational abilities, enjoyed his dry wit, and embraced his kind heart. There is no doubt in any of our minds that the seabird data collected during our research efforts would have been of lesser caliber without John Michael Drust. We dedicate this report to him.

Thomas W. Keeney, Harry Carter, Deborah Jaques, Craig Strong, Gerry McChesney, Darrell Whitworth, Jean Takekawa, and Mike Parker

# Contents

Dedication ..... iii

List of Figures ..... vi

List of Tables ..... vii

Acknowledgments ..... viii

Abstract ..... ix

Introduction ..... 1
- Literature Review and Background ..... 3

Methods ..... 7
- Naval Air Weapons Station Point Mugu ..... 7
- Point Mugu Vicinity Surveys ..... 14
- Aerial Surveys ..... 14

Results ..... 16
- Mugu Lagoon ..... 16
- Disturbance ..... 26
- Southern California Bight ..... 38

Discussion ..... 51
- Seasonal Abundance at Mugu Lagoon ..... 51
- Factors Influencing Large-scale Annual and Seasonal Variation ..... 51

Conclusion and Management Recommendations ..... 57

Literature Cited ..... 59

## Figures

Figure 1. Southern California Brown Pelican Study Area .....2

Figure 2. Naval Air Weapons Station Point Mugu, Mugu Lagoon, and Wetland Areas .....8

Figure 3. Mugu Lagoon Central Basin Sandbar Configuration and Roost Locations Prior to Flooding .....9

Figure 4. Mugu Lagoon Central Basin Sandbar Configuration and Roost Locations Following Flooding .....10

Figure 5. California Brown Pelican Abundance in the Mugu Lagoon Central Basin .....17

Figure 6. Average Percent of Immature Pelicans Using Mugu Lagoon .....18

Figure 7. Diurnal Pattern of California Brown Pelican Use of the Mugu Lagoon Central Basin .....19

Figure 8. Counts of Pelicans at Dusk and Dawn in the Mugu Lagoon Central Basin .....21

Figure 9. Impact of Disturbance Sources on California Brown Pelicans at Mugu Lagoon .....34

Figure 10. Number of Disturbances to California Brown Pelicans at Mugu Lagoon .....35

Figure 11. Percent of Immature California Brown Pelicans Observed at Nonbreeding Sites in the Southern California Bight .....42

Figure 12. Habitat Types Used by Roosting California Brown Pelicans on the Southern California Mainland Coast .....45

Figure 13. Numbers of California Brown Pelicans Roosting at Marina Del Rey Breakwater and Mugu Lagoon.....49

# Tables

Table 1. Summary of Previous California Brown Pelican Use and Survey Efforts at Mugu Lagoon ....6

Table 2. Summary of Field Effort ....11

Table 3. Numbers of California Brown Pelicans Counted by Ground Survey at Naval Air Weapons Station Point Mugu ....23

Table 4. Average Percent Use of Daytime and Night Roost Locations in Mugu Lagoon Central Basin ....24

Table 5. Summary of Disturbance Events at Mugu Lagoon ....27

Table 6. Events Causing Disturbance to California Brown Pelicans at Naval Air Weapons Station Point Mugu ....28

Table 7. Number of Potential Disturbance Events at Mugu Lagoon, and Their Effect on Pelicans ....37

Table 8. Numbers of California Brown Pelicans Observed by Aerial Survey in 5 Coastal Counties in Southern California ....39

Table 9. Numbers of California Brown Pelicans Counted by Aerial Survey on the Channel Islands ....40

Table 10. Counts of California Brown Pelicans at Mainland Roost Sites ....43

Table 11. California Brown Pelican Roosts along the Southern California Mainland ....44

Table 12. Ground Censuses of California Brown Pelicans at Roosts in the Vicinity of Naval Air Weapons Station Point Mugu in 1991-1992 ....47

Table 13. Ground Censuses of California Brown Pelicans at Roosts in the Vicinity of Naval Air Weapons Station Point Mugu in 1992-1993 ....48

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# Abstract

We studied California brown pelican *(Pelecanus occidentalis califomicus)* roosting behavior at Mugu Lagoon (an estuary within the Naval Air Weapons Station Point Mugu) from October 1991 to 1993 to evaluate seasonal use, habitat selection, diurnal attendance patterns, and effects of human disturbances. We also conducted air and ground surveys of other pelican roosts in the Southern California Bight (SCB) to evaluate the relative importance of Mugu Lagoon. El Niño-Southern Oscillation conditions-caused major differences in pelican distribution and abundance in the SCB between the 2 years of the study. Peak numbers of roosting pelicans at Mugu Lagoon occurred in June each year, with a record count of 1,404 birds in 1992. Most roosting at Mugu Lagoon took place on sandbars and mudflats surrounding the central basin and estuary mouth. Shifts in the configuration of the central basin due to flooding and erosion of sandspits caused shifts in use of roost sites. Pelicans consistently used the lagoon as a night roost, but numbers were higher during the day. Pelicans were flushed from their roosts at Mugu Lagoon by various disturbance sources an average of once every 2.5 hr (133 disturbances/323 hr observation). Using a disturbance index, we found that waterfowl hunting and other recreational activities caused the greatest amount of disturbance, while air operations caused relatively little disturbance. Mugu Lagoon was the most important estuarine roost site in the SCB and one of the most consistently used large roosts overall. Other large roosts along the mainland occurred primarily on man-made structures in association with harbors. Offshore, greatest numbers of pelicans occurred at East Anacapa and Santa Cruz Islands. Mugu Lagoon was the closest large mainland roost to the major breeding colony and night roost at Anacapa Island, and served as a staging area for birds moving to and from the island. Mugu Lagoon represented a relatively secure roost site due to restricted public access and current navy management policies. In contrast, many other roosts along the southern California coast were not formally protected and remain vulnerable to changes that could result in loss of essential nonbreeding habitat for the California brown pelican.

# Introduction

The California brown pelican *(Pelecanus occidentalis californicus)* is a coastal seabird that requires terrestrial habitat for communal roosting throughout its range (U.S. Fish and Wildlife Service 1983). Brown pelicans breed on the Channel Islands and are present in southern California year-round. Their numbers swell seasonally with the inundation of thousands of post-breeding migrants from Mexico (Anderson and Anderson 1976; Briggs et al. 1981, 1983). Appropriate roosting habitat for these birds is limited, particularly along the highly developed southern California coastline. The California brown pelican is a state and federally listed endangered subspecies (Federal Register 16047, 13 October 1970). Assessment and protection of major roost sites was included among the primary objectives of the *California Brown Pelican Recovery Plan (U.S.* Fish and Wildlife Service 1983). Protection of roosting areas has become an increasingly important management issue in California, as awareness of the potential impact of human disturbance and habitat alteration has grown.

Coastal estuaries comprise a unique and important component of brown pelican nonbreeding habitat. Pelicans are attracted to estuaries by 3 primary features. First, estuaries usually provide a location where birds can roost on land and be at least partly surrounded by water, thus protected or buffered from human disturbances and mammalian predators. Second, estuaries are often associated with high concentrations of young fish. Brown pelicans prey primarily on small surface-schooling fish (Anderson et al. 1980). Third, pelicans seem to prefer brackish waters for bathing. Freshwater may reduce salt-water adapted parasites in the gular pouch and esophageal region of these seabirds, although this hypothesis remains to be tested (D. W. Anderson, pers. comm. 1988). Estuaries in which pelicans can engage in all three of the above activities (foraging, bathing and roosting) provide an energetically ideal situation. Birds may rest and dry their plumage on shore at a secure communal roost following heavy feeding or vigorous bathing, rather than fly (heavy with undigested food or wet plumage) to another location.
Many coastal estuaries in California have been severely altered or lost due to development (Ferren et al. 1995). Sensitive wildlife species are generally vulnerable to a high level of disturbance from human recreational activities in remaining California coastal wetlands (Harms 1981; Jaques and Anderson 1988; Josselyn et al. 1989).

Mugu Lagoon is one of the largest, most natural estuaries remaining in southern California, and it is regularly used by pelicans as both a roost site and feeding area (Briggs et al. 1981; Onuf 1987). The U.S. Navy has operated a naval base at Mugu Lagoon since 1946 and has generally preserved estuarine habitat. Restricted access to the lagoon has limited human disturbance from the general public. The value of Mugu Lagoon to pelicans is increased by its close proximity to Anacapa Island (Fig. 1), the largest breeding colony of brown pelicans on the U.S. Pacific coast (Anderson and Gress 1983). Schooling fishes in the lagoon attain peak abundance in summer (Onuf 1987), providing forage for pelicans fledging from local colonies as well as for migrants arriving in California from breeding grounds in Mexico (Anderson and Anderson 1976). Pelicans banded both on Anacapa Island and in Mexico frequent the lagoon (D. W. Anderson, unpubl. data).

In this report, we summarize findings of 2 years of research (October 1991-October 1993) on the roosting ecology of brown pelicans at Mugu Lagoon, within the Naval Area Weapons Station

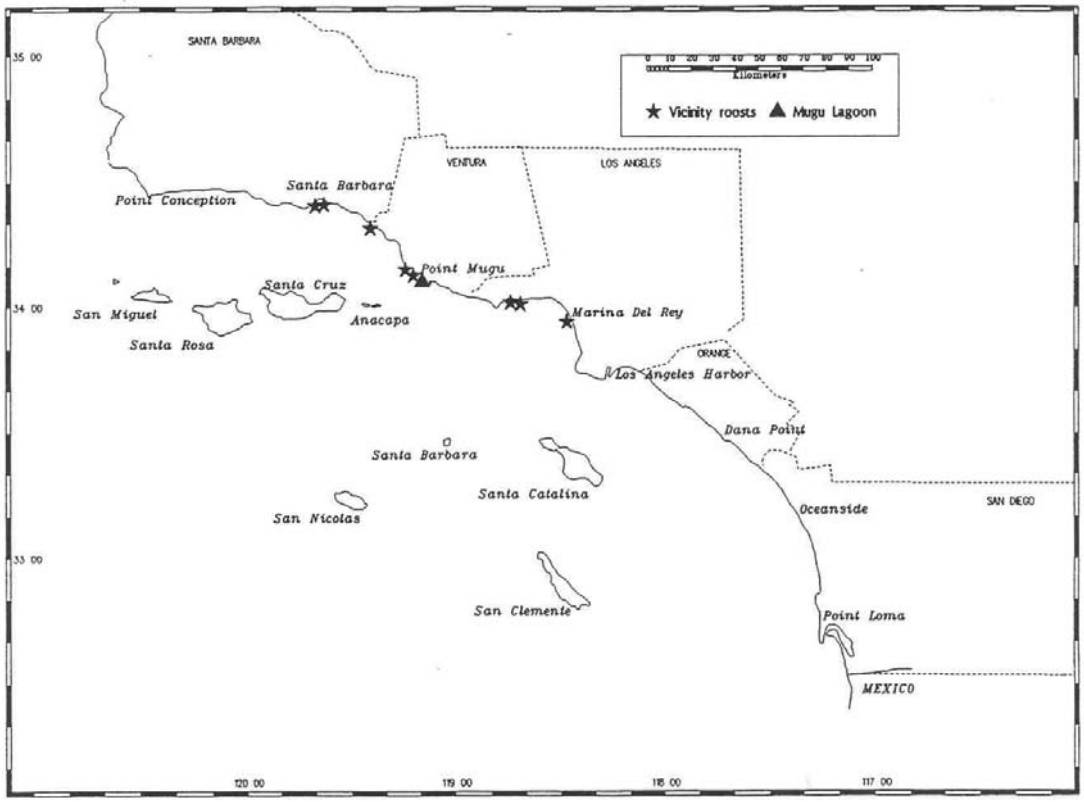



Figure 1. Southern California brown pelican *(Pelecanus occidentalis)* study area showing aerial survey region (Point Conception to the Mexican border and all island perimeters), vicinity roost locations (stars), and location of Naval Air Weapons Station Point Mugu (triangle).

(NAWS) Point Mugu, in Ventura County, California. The need for this study arose from questions regarding the effects of human activities, including waterfowl hunting, on pelicans. This study was designed to achieve an understanding of the use of Mugu Lagoon by brown pelicans so that the effects of human disturbance, current management practices, and physical characteristics of the lagoon could be evaluated. Protection of communal pelican roosts in southern California is important to the health of the California brown pelican population.

This is the first focused study of brown pelicans at Mugu Lagoon and the only detailed study of any roost in southern California. We examined seasonal abundance, habitat use, diurnal patterns of occupation, and responses to disturbance at Mugu Lagoon. To evaluate the relative importance and role of the lagoon within a larger region, we conducted ground surveys of mainland roosts within an 80-km radius of Point Mugu, and conducted 6 aerial surveys of brown pelicans in the Southern California Bight (SCB). Aerial surveys included the mainland coast from Point Conception to the U.S.-Mexico border and the perimeters of the 8 California Channel Islands.

The primary questions that we addressed for this study were:

1. How many brown pelicans occur at Mugu Lagoon, and how does abundance vary seasonally?

2. What is the diurnal pattern of pelican use? Do numbers tend to peak at a particular time of day? Is Mugu Lagoon used for roosting overnight?

3. Which habitats and sites within the lagoon are most important to roosting pelicans?

4. What kinds of human activities disturb pelicans, and how is use of the study area affected by disturbance events?

5. How important is the roost at Mugu Lagoon in the greater context of the southern California mainland coast and offshore islands in the SCB?

## Literature Review and Background

### *Seasonal Occurrence*

Regular censuses of California brown pelicans, both on the breeding grounds and at communal roosts away from nesting areas, began in the early 1970s, soon after the discovery that the subspecies was experiencing severe reproductive failure (see Risebrough et al. 1971; Jehl 1973; Anderson and Gress 1983). Anderson and Anderson (1976) clearly established that there was a great seasonal flux in the numbers of pelicans on the California coast. A large segment of the Mexican breeding population from the Gulf of California and western Baja peninsula migrates northward into California Current waters after nesting. These birds mix with birds from breeding colonies in the SCB and disperse along the Pacific coast as far north as southern British Columbia. Peak pelican populations in California have generally occurred in the fall (Anderson and Anderson 1976; Briggs et al. 1981, 1983). By late December, most migrants retreat to breeding areas, leaving a relatively small breeding population in the SCB. Lowest numbers of pelicans in the SCB have occurred in spring.

## *Communal Roosting*

The importance of roosting habitat became apparent soon after comprehensive surveys of brown pelicans were initiated (Keith and Anderson, unpubl. data; U.S. Fish and Wildlife Service 1983). Basic requirements for pelican roosts include (1) terrestrial substrates where pelicans can keep their bodies dry while resting and maintaining their plumage (preening, drying, bathing, etc.); (2) a buffer from mammalian predators and human disturbances; and (3) presence of prey resources within energetically efficient distances.

Communal roosting in pelicans, as well as many other birds, serves energetic and social functions. Terrestrial roosts are required because pelicans have "wettable" plumage and will eventually become soaked to the skin, and thus unable to thermoregulate, if they remain in the water (Rijke 1970; Schreiber and Schreiber 1982). By occupying protected microhabitats within a roost and/or flocking close together during cold and windy weather, pelicans can further preserve body heat. Pelicans select roost habitats that will minimize the chance of predation and energy expenditure resulting from alarm flight. Avoidance of disturbance is particularly important to pelicans, as they are among the earth's heaviest flying birds and flapping flight is energetically expensive (Pennycuick 1972). Increases in the size of roosting groups may increase predator detection but may also increase flushing frequency due to false alarms. Social facilitation of food finding can be another function of communal roosts for birds preying on ephemeral resources such as schooling fishes (Ward and Zahavi 1973; Bayer 1982).

Pelican roost sites are theoretically selected to maximize the possibilities of successful foraging with minimum energy expenditure for commuting (Briggs et al. 1981; U.S. Fish and Wildlife Service 1983). Traditional roosts occur in regions where both seasonally abundant food resources and quality roost habitats are available. Availability and dispersion of appropriate roost sites may limit the ability of pelicans to exploit prey. Briggs et al. (1983) suggested that distance to the nearest large roost may be the most important factor governing pelican distribution during the nonbreeding season in the California Current system. Shifts in the distribution of fish schools no doubt influence the occupation of given roosts on daily and seasonal bases.

## *Human Disturbance*

The effects of human disturbance on colonially-nesting seabirds has been fairly well documented and can be measured directly by reduced reproductive success (Manuwal 1978; Anderson and Keith 1980). Disturbance effects on nonbreeding birds are more difficult to quantify but have been measured in terms of changes in behavior, habitat use and distribution, total numbers, heartbeat rate, and physiological condition (Stalmaster and Newman 1978; Burger 1981 a, b; Jaques and Anderson 1988; Josselyn et al 1989; Culik et al. 1990; Gaston 1991; Klein 1993).

The flight response is the most commonly used measure of disturbance to nonbreeding birds. There have been no studies to date that quantify the costs of disturbance at the population level resulting from effects such as increased energy expended in flight, altered behavior, and exclusion from preferred feeding or resting sites. Repeated disturbances will negatively affect the energy budget of birds and compound other physiological stresses from migration, breeding, food shortages, and heavy contaminant loads (Josselyn et al. 1989). The frequency and nature of disturbances degrades the quality of roost sites. Sites with chronic disturbance may undergo long-term abandonment.

Prior to this study, only 3 other brown pelican _roost sites had been studied and described in any detail in California. Regular censuses offshore at the major roost on the South Farallon Islands have provided long-term data on seasonal and annual variation in numbers (Ainley 1972; Point Reyes Bird Observatory, unpubl. data). This roost site is off limits to human activities with few exceptions. Two other well-known roosts occur in estuarine habitats at Morro Bay (Harms 1981) and the former salt ponds at Elkhorn Slough (Jaques and Anderson 1988) in central California. At Morro Bay, human disturbance, largely from water-based recreation, has influenced habitat use, age ratios, and numbers of pelicans. At Elkhorn Slough, pelicans were unusually wary of humans due to lack of a deep water buffer, coupled with recent development of a public trail system, waterfowl hunting within the roost, and the invasion of nonnative red foxes (*Vulpes fulva).* Portions of this roost used for nocturnal roosting were highly specific and limited, in contrast to the many roosting areas used during daylight hours.

### *Previous Censuses at Mugu Lagoon*

Censuses of brown pelicans at Mugu Lagoon were first conducted by the U.S. Fish and Wildlife Service (USFWS) in 1971 (D. W. Anderson, field notes) when breeding populations in the SCB were at extreme low levels. Since then, pelican counts have been documented as part of various projects, providing information on abundance and seasonal occurrence in the lagoon (Table 1). Of 14 southern California beach sections surveyed by Briggs et al. (1981), the Mugu Lagoon area harbored the greatest average number of birds. Monthly surveys (1975-1978) revealed peak counts in fall (September-November).

Ecologists at NAWS Point Mugu completed a preliminary study on disturbance to pelicans and Pacific harbor seals *(Phoca vitulina richardsi)* in fall 1990. These data demonstrated that waterfowl hunting displaced both pelicans and seals from resting areas and prompted the initiation of the present study (Keeney and Smith, unpubl. data).

Table 1. Summary of previous California brown pelican *(Pelecanus occidentalis californicus)* use and survey efforts at Mugu Lagoon, California, 1971–1990. The acronym USFWS denotes U.S. Fish and Wildlife Service.

| Year | Month | Reference | Sampling | Number of pelicans | Type |
|---|---|---|---|---|---|
| 1971 | September | Anderson (field notes) | irregular | 120 | high count |
| 1975–1977 | all | Briggs et al. 1981 | monthly | 68 | 3-year mean |
| 1975–1977 | October | Briggs et al. 1981 | monthly | 271 | mean October count |
| 1977–1982 | all | Onuf 1987 | 20-day intervals | 41 | 5-year mean |
| 1986 | September | Jaques (unpubl. data) | irregular fall | 668 | high count |
| 1987 | September | Jaques (unpubl. data) | irregular fall | 1,110 | high count |
| 1989 | all | USFWS Laguna Nigel (unpubl.) | monthly | 39 | annual mean |
| 1989 | September | USFWS Laguna Nigel (unpubl.) | monthly | 162 | high count |
| 1990 | all | USFWS Laguna Nigel (unpubl.) | monthly | 48 | annual mean |
| 1990 | August | USFWS Laguna Nigel (unpubl.) | monthly | 198 | high count |
| 1990 | October–December | Keeney (unpubl.) | hunting periods | 43 | mean |
| 1990 | October–December | Keeney (unpubl.) | hunting periods | 240 | high count |

# Methods

## Naval Air Weapons Station (NAWS) Point Mugu

### *Site Description*

The Mugu Lagoon study area included all wetland habitat and beaches within the NAWS Point Mugu property (Fig. 2). The water area of the lagoon is approximately 130 ha and consists of 2 long arms projecting out from a larger central basin (Onuf 1987). The military installation surrounding the lagoon includes a large airfield, a resident population of several thousand people, and a number of highly restricted areas associated with radar facilities and weapons testing. The open water area of the central basin has decreased in surface area and depth over the past 2 decades due to accelerated inland soil erosion in the Calleguas Creek watershed and particularly heavy sedimentation during major storms (Onuf 1987).

Our observations were focused on the central basin where the great majority of pelicans occurred. Winter storms caused a major change in the configuration of the outer sandbars of the central basin during January 1992 (Figs. 3, 4). Heavy flows from Calleguas Creek eroded the west spit of the lagoon, allowing the creek to drain directly out to sea, rather than meandering to the east. The sandbars continued to change gradually throughout the study period, but the overall configuration remained as in Figure 4.

### *Abundance, Diurnal Patterns, and Habitat Use*

Data on seasonal abundance, diurnal patterns, and habitat and site use in the central basin were obtained by a series of censuses taken throughout the day over 3- to 5-day periods. Monthly surveys were conducted from October to December 1991. During 1992, censuses were made each month from June to December (fledging and migratory period), and every other month from January through May. In 1993, censuses were conducted in January, February, April, June, July, and September (Table 2). A total of 93 census days were completed between 25 October 1991 and 1 October 1993. The western wetland areas of NAWS Point Mugu (Fig. 2) were surveyed for pelicans 44 times over the 2 years.

### *Census Procedures*

Counts were made using a 15-40X zoom spotting scope from the radar calibration parking area at the west spit (Figs. 3, 4). Observations took place from platforms of existing towers or from ground level, depending on circumstances. The area surveyed in these censuses extended from the east end of NAWS property adjacent to Pt. Mugu State Beach, to Laguna Road. Data recorded at each census included:

1. Time of start and end of observation;
2. Weather, wind direction and velocity, cloud cover and type; 3. Tidal height and direction;
4. Number of pelicans at each location (locations recorded as shown in Figs. 3 and 4);
5. Age class of pelicans, categorized as adult (white-headed birds) and immature (brown-headed birds); and
6. Disturbance data (see Measures of Disturbance).

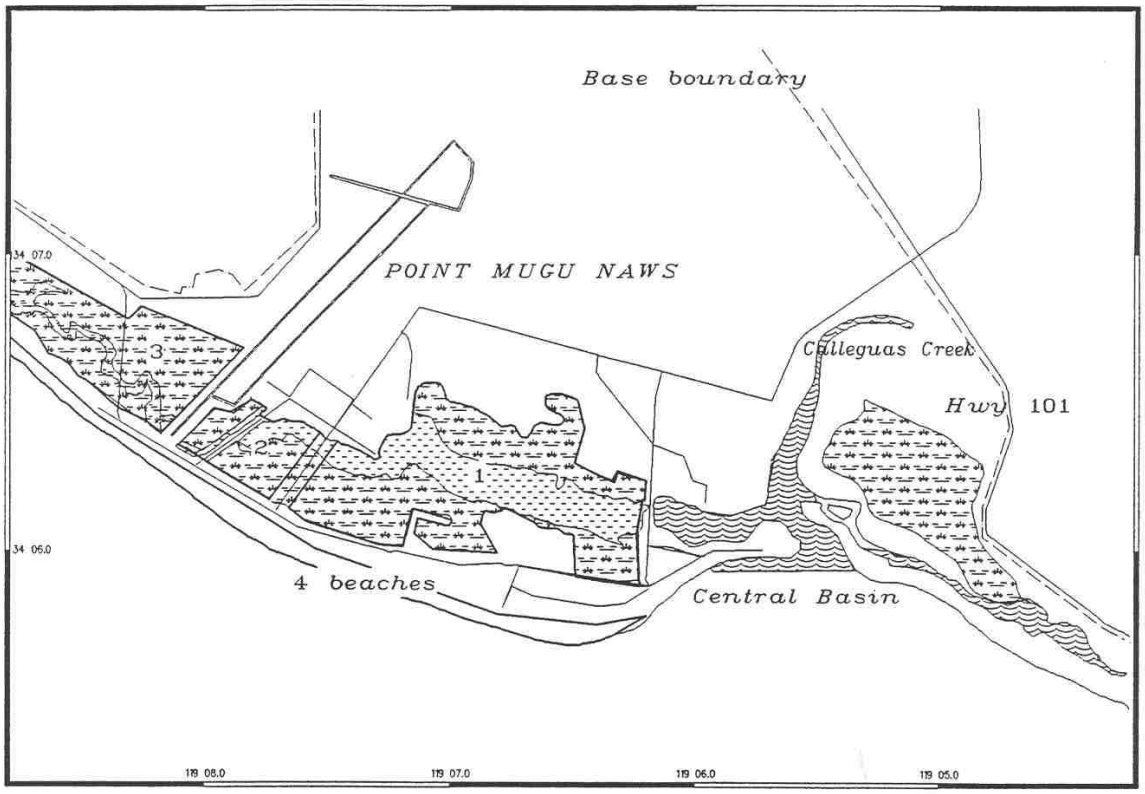



Figure 2. Naval Air Weapons Station Point Mugu, Mugu Lagoon, California, and wetland areas. Numbers on figure refer to western areas (see text).

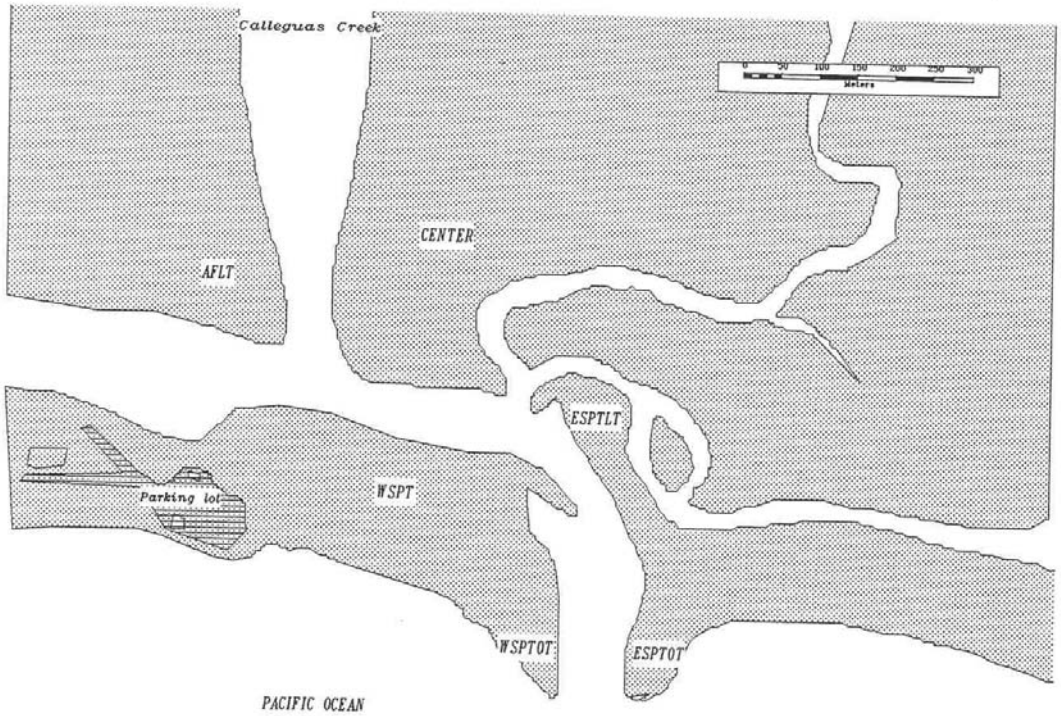



Figure 3. Central basin of Mugu Lagoon, California, showing approximate sandbar configuration and roost location names from October 1991 to January 1992, prior to flooding. Locations are coded as follows: WSPT (West Spit), WSPTOT (West Spit Ocean Tip), ESPTLT (East Spit Lagoon Tip), ESPTOT (East Spit Ocean Tip), CENTER (Center Mudflats), and AFLT ("A" Hunting Blind Mudflat).

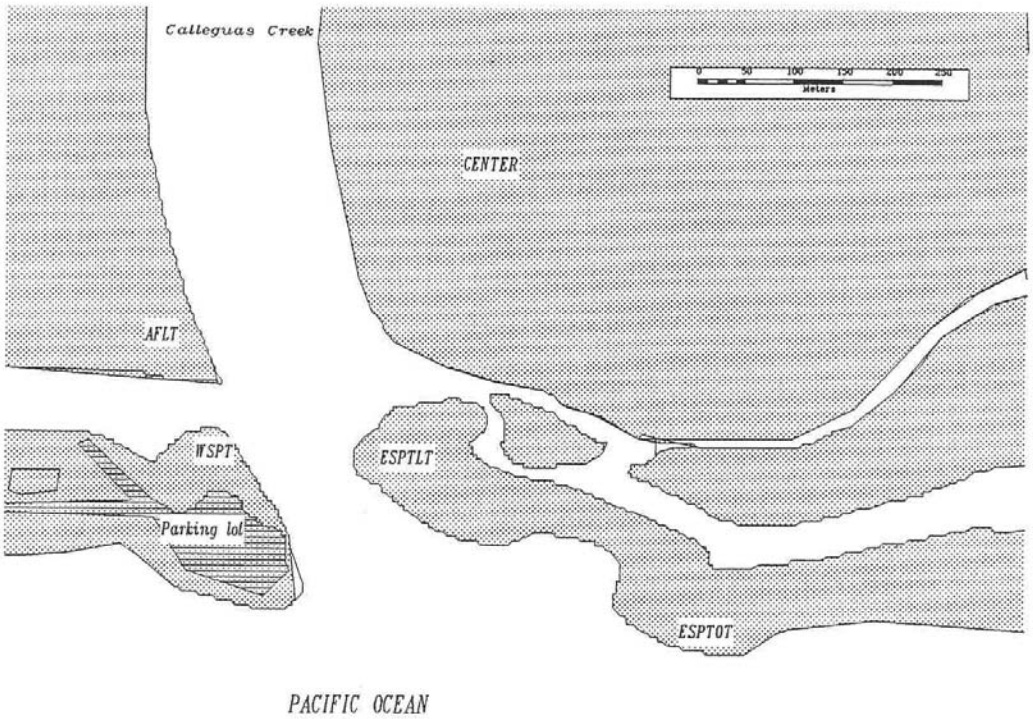



Figure 4. Central basin of Mugu Lagoon, California, showing approximate sandbar configuration and roost locations following winter 1992 flooding. The sandbars continued to shift throughout the study period, but remained approximately as above (drawn from aerial photographs taken in June 1993). Locations are coded as follows: WSPT (West Spit), WSPTOT (West Spit Ocean Tip), ESPTLT (East Spit Lagoon Tip), ESPTOT (East Spit Ocean Tip), CENTER (Center Mudflats), and AFLT ("A" Hunting Blind Mudflat).

Table 2. Dates of California brown pelican *(Pelecanus occidentalis californicus)* ground and aerial surveys at Mugu Lagoon and other southern California roosts, October 1991 to October 1993.

| | Census area coverage | | |
|---|---|---|---|
| Dates | Mugu Lagoon | Vicinity roosts | Aerial surveys |
| *1991* | | | |
| 24–31 October | X | X | |
| 9–16 November | X | X | |
| 19–22 December | X | X | |
| *1992* | | | |
| 31 January–5 February | X | X | |
| 8–15 April | X | X | |
| 5–12 June | X | X | X |
| 22–30 July | X | X | X[1] |
| 18–23 August | X | X | X |
| 21–26 September | X | X | X |
| 22–27 October | X | X | |
| 10–15 November | X | X | X[2] |
| 4–6 December | X | | |
| *1993* | | | |
| 8–10, 27–28 January | X | | |
| 21–26 February | X | X | |
| 8–12 April | X | X | |
| 9–12, 24–26 June | X | X | X |
| 18–22 July | X | X | |
| 20 September–1 October | X | X | X |
| Number of surveys | 18 | 16 | 7 |

[1] These survey data were not used.
[2] Mainland survey only.

To measure diurnal changes in pelican numbers, censuses were conducted within 7 designated time periods. Ideal times to conduct each census within each time period were as follows:

1. Dawn (30-50 min pre-sunrise, see below) 2. Early morning (1 hr after sunrise)
3. Morning (2 hr after sunrise)
4. Midday (the midpoint between sunrise and sunset) 5. Afternoon (2 hr before sunset)
6. Evening (1 hr before sunset)
7. Dusk (40-50 min after sunset, see below)

Dawn and dusk counts represented the numbers of pelicans at the roost at first light and last light, respectively. These counts were indicative of overnight roosting numbers, because few birds appeared to arrive or leave in full darkness. For the dawn count, pelicans were counted as silhouettes against the sky as they departed the roost in the morning (beginning at 30-40 min before sunrise). When light levels were adequate to obtain an accurate count of the group, a count was made and birds that departed from or arrived at the roost prior to the count were added or subtracted. This method was used in reverse for the late evening (dusk) count, beginning 1 hr before sunset and continuing until birds could no longer be seen against the sky (usually 40-50 min after sunset). Numbers of other species in association with roosting pelicans were recorded on some occasions. These data are not presented in this report.

### *Measures of Disturbance*

Data on disturbance were collected concurrently with standard censuses and during longer observation periods. The basic measure of disturbance was observation of a group of pelicans abruptly taking flight (flushing) from the roost, usually in response to an obvious stimulus. Frequency of disturbance was calculated by the number of disturbance events that occurred divided by duration of observation in hours. Types of disturbance (disturbance sources) were categorized as follows:

1. Waterfowl hunting
   a. Physical presence of hunters
   b. Presence of dogs
   c. Shooting

2. Aerial operations and aircraft
   a. Large helicopters
   b. Small helicopters
   c. Jet fighter planes
   d. Cargo planes
   e. Light aircraft
   e. Towing aircraft
   g. Blimp

3. Recreational activities
   a. Beach walking
   b. Walking with dog(s), or dog alone
   c. Fishing from shore

d. Clamming
e. Jogging
f. Birdwatching

4. Recreational trespassers
   a. Surfers
   b. Boats
   c. Beachwalking in restricted areas

5. Natural sources
   a. Raptors
   b. Sudden flights of other species
   c. Unknown source

6. Other human sources
   a. Headlights or activities at parking lot
   b. Research activities
   c. Construction or base operations

The presence of any of the above sources in the area used by pelicans was recorded, and the estimated distance to pelicans noted. In this way, potential disturbance sources were quantified, whether a disturbance resulted or not. If a disturbance occurred, the location, distance between pelicans and source (if possible), and number of birds flushed were recorded. The response of the flushed birds was noted as follows: (1) number of birds that departed the lagoon; (2) number that relocated to a different location within the lagoon; and (3) number that relanded at the original site. The response of disturbed birds was also used as an estimator of the severity of the disturbance event, both in terms of the probable alarm state of the birds and in the probable energy expended responding to the disturbance. We assumed that departing the lagoon was the most severe response, relocating within the lagoon was a less severe response, and relanding at the same site was the least severe response of those measured. More subtle measures of disturbance (i.e., alert posture, stretching, wings out or flapping) were not quantified for this study.

### *Disturbance Index*

We developed the following disturbance index "D" to compare the impact, or severity, of the various disturbance sources above:

$$D = \frac{N((n\ \text{depart} * 3) + (n\ \text{relocate} * 2) + (n\ \text{reland} * 1))}{\text{hours of observation}}$$

where N = number of disturbances attributed to the source and n = number of pelicans exhibiting each response (depart, relocate, reland).

The multipliers were used to give some weight to pelican response in order of severity. However, we did not gather specific data to determine if these weightings were representative of relative

energetic costs.. It is possible that severe disturbance (i.e., depart) should be weighed more heavily than it was in our model.

## Point Mugu Vicinity Surveys

To evaluate the relative importance of pelican roosts at NAWS Point Mugu in comparison to other coastal roosts in this area of the SCB, we conducted ground censuses of roost sites between Marina del Rey and Santa Barbara (approximately 80 and 65 km south and north, Fig. 1), including the following sites:

1. Marina del Rey breakwater
2. Bait barge off Malibu
3. Malibu Lagoon
4. Channel Islands Harbor and breakwater
5. Ventura Harbor and breakwater
6. Mussel Shoals oil pier
7. Santa Barbara Harbor

Ground censuses were made from nearby vantage points using a 15-40X zoom spotting scope. Time of beginning and end of observation, weather, number of adult and immature pelicans, and disturbance notes were recorded at each site. Most sites were visited at dawn or dusk at least once during the year to determine if they were used as night roosts. Fifteen surveys of vicinity roosts were conducted during the study period.

## Aerial Surveys

To obtain a perspective on pelican use of roost sites in the entire SCB region, 6 aerial surveys were flown during June, July, August, September, and November 1992, and June and September 1993. Problems with coverage and photo quality precluded use of the July 1992 survey results. In most cases, we were able to survey the entire coastline from the Mexican border to Point Conception and the perimeter of the 8 offshore Channel Islands in the SCB (Fig. 1). However, fog and military operations precluded surveys of relatively small coastal sections during several flights.

The aircraft used was a Partanavia twin engine wing-over plane from a private charter service, with the exception of the September 1993 survey when the California Department of Fish and Game provided air time for the mainland coast in a similar aircraft. Four persons were usually employed on air surveys: two manned cameras; one determined roost locations on a map and visually estimated numbers of roosting birds; and one recorded data, labeled film and scanned the ocean on the seaward side of the plane for pelicans away from roosts. Photographs of all roosts with more than 5 birds were taken using a hand-held 35 mm camera with a 70-210 mm zoom or a 300 mm lens. Flight speed was held at approximately 90 mph and altitude near the mainland was maintained at about 90 m. Around the perimeter of the Channel Islands, we flew at 120-150 m to avoid disturbance to nesting seabirds and at approximately 300 m over areas with special resource-based restrictions. Permits were granted by the National Oceanic and Atmospheric Administration (National Marine Sanctuary) for overflights around 5 Channel Islands.

Photo transparencies were later projected on large paper sheets, and pelicans were counted using a pen to dot their positions so as not to double-count birds and to provide archived materials for roost counts. This method has been used extensively in surveys of nesting seabirds in California (Takekawa et al. 1990; Carter et al. 1992), and was used by Jaques et al. (1994) for counts of pelicans in north and central California.

# Results

## Mugu Lagoon

### *Seasonal Abundance*

Pelicans roosted at Mugu Lagoon during each day of our study (n = 93 days). Greatest numbers were present from summer through early fall (June-September) in both 1992 and 1993 (Fig. 5). In 1991, there was also heavy use of the lagoon through late fall (October-November). The highest count occurred on 6 June 1992, with 1,404 birds in the central basin. The peak count in 1993 also occurred in June, but was much lower (260 birds). Overall, there was a far greater level of use of the lagoon during the summer and fall in 1992 compared to 1993. The mean daily high count during June-September was 461 birds (n = 20 days) in 1992 vs. 150 birds (n = 18) in 1993. In both years there was an increase in numbers of pelicans in September, following a late summer (August) decline. Use of the lagoon was lowest in winter (December-February) (Fig. 5). Daily peak counts during winter and spring ranged from 16 to 157 birds.

Exceptionally high numbers of pelicans in the lagoon occurred episodically. While more than 1,400 pelicans were present on the first day of our June 1992 survey period, numbers declined sharply over the next 4 days, suggesting that birds had moved out of the area. More than 1,000 birds were also present at Mugu Lagoon just prior to the start of this study in September 1991 (Jaques and Strong, unpubl. data), but by October numbers were in the hundreds and decreasing. Our observations suggest that the presence of more than 1,000 pelicans at Mugu Lagoon can occur at irregular intervals in summer and fall in response to local feeding opportunities or large-scale movements along the coast.

### *Age Ratios*

Mugu Lagoon was used predominantly by pelicans in adult plumage (3 yr and older) during this study. Of all pelicans aged during censuses, 92% were adult (n = 50,5 10). Immatures occurred in greatest numbers during October 1991, with up to 519 immatures (28% of the flock) present at a given census. Although total numbers were lower, the mean proportion of immatures was greatest during late summer and fall 1993 (16-18%; Fig. 6). In contrast, there was no increase in immatures during the post-breeding period in 1992. Rather, a general decline occurred through the summer and fall, reflecting local reproductive failure that year. Numbers of young birds at the lagoon were lowest during winter and spring, comprising less than 5% of monthly averages from December through April.

#### ***Diurnal Pattern***

Brown pelicans used Mugu Lagoon as both a day and night roost, but it was most heavily used during daylight hours. The general diurnal pattern at the lagoon was one of relatively low numbers at dawn, building gradually to a peak late in the day, and dropping rapidly just before dark (Fig. 7). Average peak numbers were highest in the afternoon or evening during all seasons, but this pattern did not hold true every day. Peak counts were obtained during each of the designated time periods. Thus, one could not be assured of observing peak numbers by conducting censuses of the roost only in the afternoon or evening.

Counts of pelicans at the lagoon were often highly variable within a given day and from one day to the next. For example, numbers ranged from 35 birds in early morning to 716 birds by evening

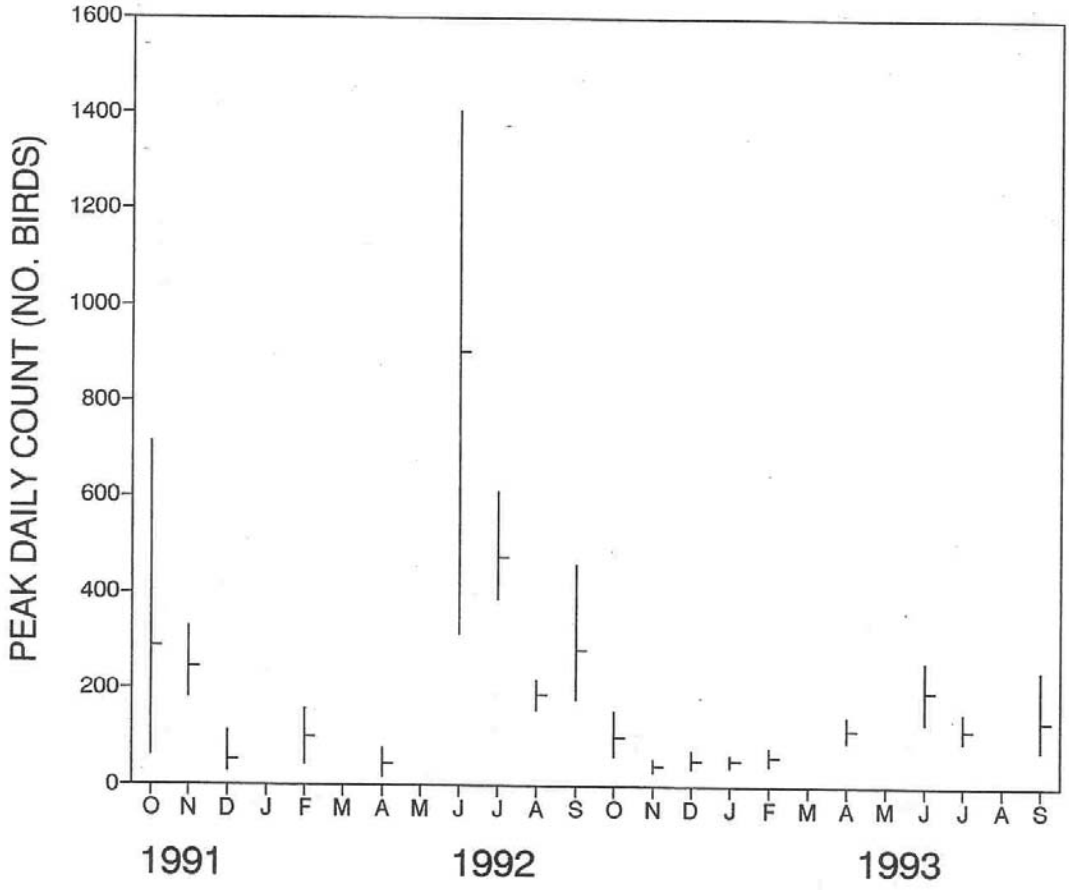



Figure 5. California Brown pelican *(Pelecanus occidentalis californicus)* abundance in the Mugu Lagoon central basin, California, between 24 October 1991 and 29 September 1993. Values shown are the mean (horizontal line) and range (vertical line) of the daily high count over 3- to 6-day survey periods in each month of observation.

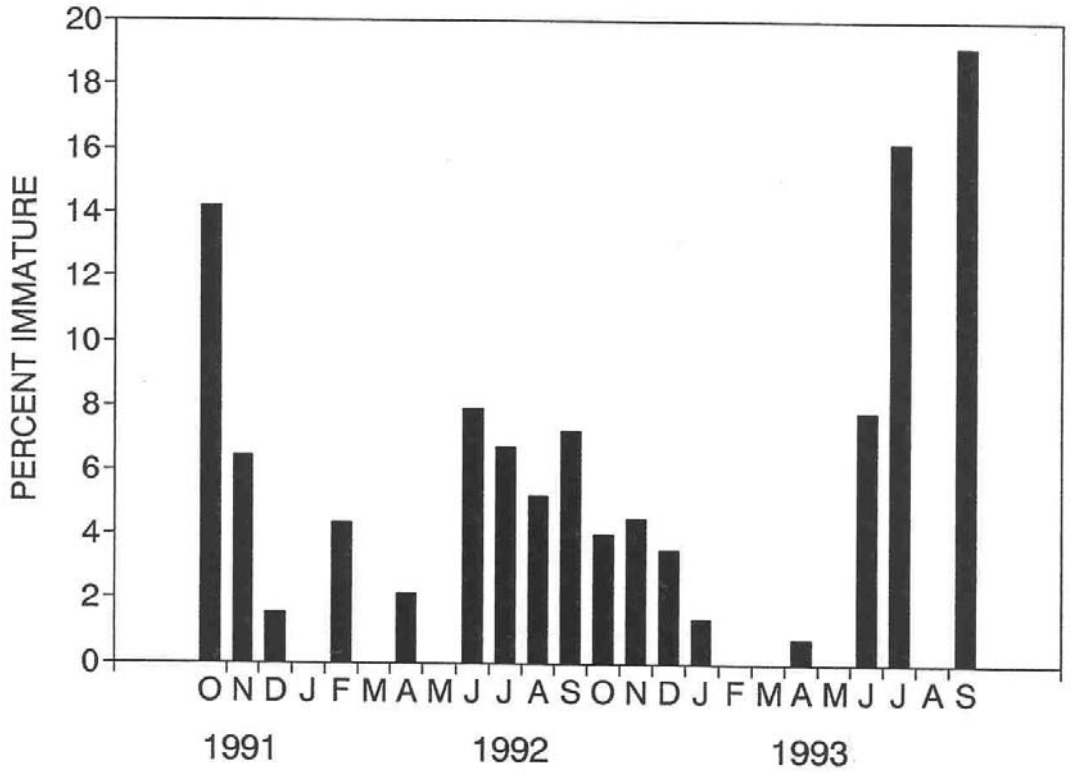



Figure 6. Average percent of immature California brown pelicans (*Pelecanus occidentalis californicus)* using Mugu Lagoon, California, in 3- to 6-day observation periods from October 1991 to October 1993.

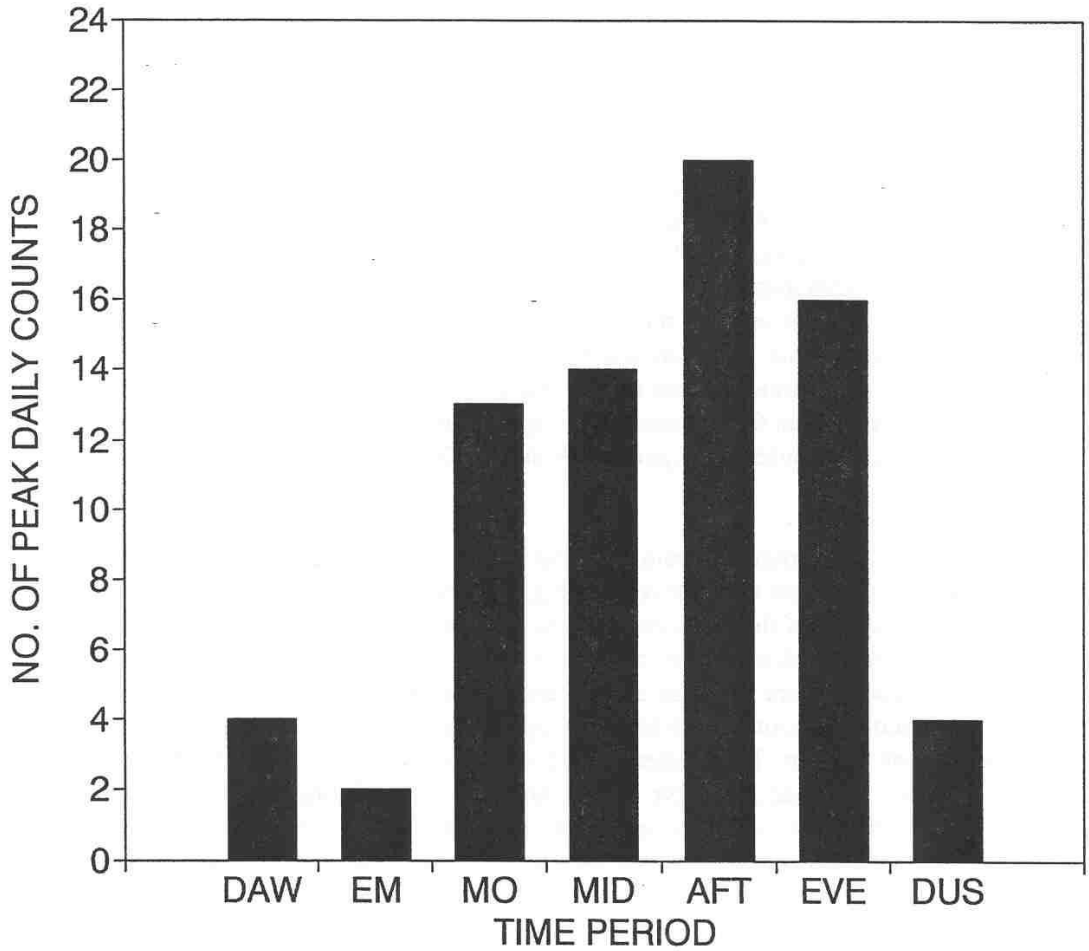



Figure 7. Diurnal pattern of California brown pelican *(Pelecanus occidentalis californicus)* use of the Mugu Lagoon central basin, California. The number of times the peak count occurred in each of 7 time periods through the day, for all days of observation (October 1991–October 1993) are shown.

Time periods:

| | |
|---|---|
| DAW | Dawn (30–50 minutes pre-sunrise) |
| EM | Early morning (60 minutes after sunrise) |
| MO | Morning (2 hours after sunrise) |
| MID | Midday (the midpoint between sunrise and sunset) |
| AFT | Afternoon (2 hours before sunset) |
| EVE | Evening (60 minutes before sunset) |
| DUS | Dusk (40–50 minutes after sunset) |

on 25 October 1991. A single count early on 25 October would have revealed only 5 percent of the peak for that day. Counts in June 1992 were the most variable and ranged from 50 to 1,404 birds over a 4-day period (Jaques et al. 1993).

Overnight roosting by pelicans took place during 83 of 87 nights of observation. Average numbers roosting overnight followed nearly the same seasonal pattern as did peak day counts, but at lower levels (Figs. 5 and 8). Periods of heaviest use during the day corresponded with the greatest numbers of birds remaining overnight. The highest night roost count was 883 birds on 6 June 1992. The period of least use was during February and April 1992, when there were less than 10 birds present most nights. This low-use period may have been related to recent flooding and changes in lagoon configuration, rather than seasonal factors. Night counts in February 1993 were comparatively higher, even though use of the lagoon during the day was lower than in 1992. Zero counts at night occurred once per month during December 1991, February and April 1992, and June 1993.

On some dates, arrivals and departures from the roost during hours of darkness were evident due to disparities in consecutive dusk to dawn counts (Fig. 8). Roost counts were higher at dawn than at the preceding dusk in 35% of the cases analyzed ($n = 34$, $x = 20.4$ pelicans, $s = 30.97$). Counts were lower at dawn than at dusk in 53% of cases ($x = 48.8$, $s = 68.4$). No movement was detected in 12% of cases (i.e., counts were the same at dusk and dawn). Small differences in numbers may have been due to difficulty in counting birds in low light levels, but large differences revealed nocturnal movement of pelicans. The greatest increase from dusk to dawn was 107 birds on the night of 26-27 October 1991 and may have been related to nocturnal foraging (see Foraging and Bathing). Large numbers of pelicans departed the lagoon after dark on the nights of 6 and 7 June 1992 (266 and 140 birds). This departure corresponded to a period of rapidly falling counts at the lagoon (Jaques et al. 1993) and may have represented nocturnal migration during the northward dispersal period.

High tides (more than 1.5 m) completely inundated the main night roost at night in September 1992. Many pelicans evidently departed the roost entirely during the night through this period (Fig. 8; see also Habitat Use).

Pelicans cycled in and out of the lagoon area throughout the day. Periods of greatest pelican movement were in the early morning and late evening. Departures and arrivals generally began about 30 min before sunrise and subsided by 20-30 min after sunset.

Throughout the study period, Mugu lagoon served as an evening staging area for birds commuting to other local night roost locations. Nearly all flocks that departed the lagoon in the evening flew west out to sea in the direction of Anacapa Island (about 19 km across the water). Pelicans may have flown to any of the Channel Islands, but we suspect that the majority gathered at East Anacapa, the nearest island roost site in the SCB. During the summer, birds probably commuted regularly between West Anacapa Island, the primary breeding colony in the SCB, and Mugu Lagoon, the nearest large mainland roost. Likewise, most pelicans arriving at the lagoon in the early morning came from the direction of the Anacapa and the northern Channel Islands, rather than from up or down the mainland coast. An overnight visit to East Anacapa Island on

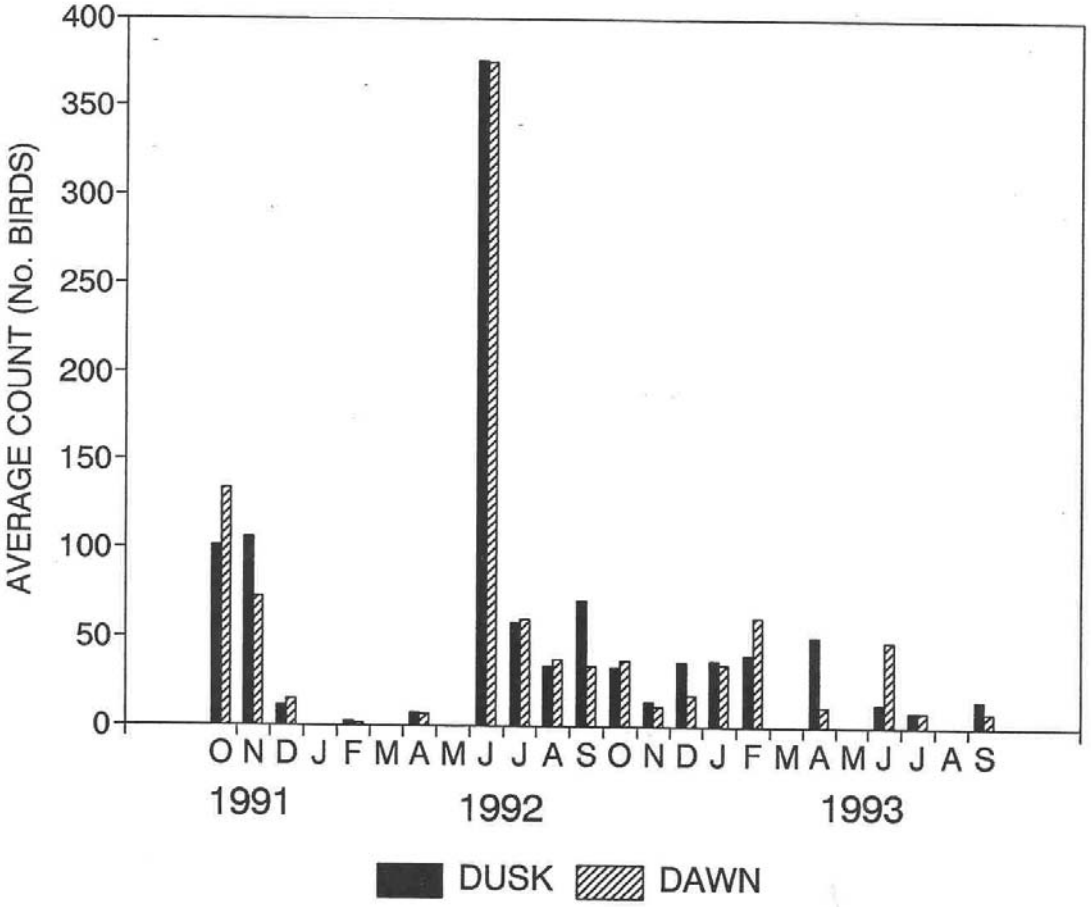



Figure 8. Counts of California brown pelicans *(Pelecanus occidentalis californicus)* at dusk and at dawn in Mugu Lagoon central basin, California, averaged over 3- to 6-day study periods from October 1991 to October 1993.

11-12 November 1992 revealed that numbers on the island did indeed swell at sunset. We recorded 1,058 pelicans at the roost at dawn on 12 November.

### *Habitat Use and Roosting Behavior* -

Pelican activities at Mugu Lagoon were focused around the mouth of the lagoon in the central basin where all large roosting groups gathered and all night roosting took place. The western region of Mugu Lagoon (west of Laguna Road) was used consistently but by very few pelicans (usually less than 10; Table 3).

Birds sighted in the western region of Mugu Lagoon were primarily flying or foraging solitarily. The most frequently used roost site in the west lagoon was a dilapidated pier structure over shallow open water in area 2 between L and M roads (Fig. 2). Up to 12 pelicans were seen on this structure by day, but it was apparently not used as a night roost (based on 3 after-dark visits). Of the 4 western areas surveyed, area 2 was used by the greatest average number of pelicans. During spring and early summer, small numbers of pelicans regularly foraged near the culvert just west of the Laguna Road bridge and rested on nearby mudflats (area 1). The western-most portion of the estuarine complex (area 3) was used least.

Roosting groups formed sporadically on the outer coastal beaches west of the central basin when human activity was low or restricted. The largest aggregation on the beaches was about 40 birds observed from the air in June 1993. The beach east of the central basin (near the eastern border of the NAWS and adjacent to the firing range) was used more often, and on some occasions groups of more than 100 pelicans formed there.

Within the central basin, daytime roosting locations were more numerous than night roost sites (Table 4). During daylight hours, pelicans usually roosted on sand or mud near the edge of the water in 5 general areas (Figs. 3, 4). Site-use was affected by the winter 1992 shift in lagoon configuration and by disturbance associated with the hunting seasons.

During fall 1991, the central mudflat (CENTER) region inside the lagoon was the most preferred roost site (Table 4, Fig. 3). This area was primarily mudflat but also included a raised sandbar that became an island at high tides. Use of the four other areas was nearly equal. On hunting days, there was a reduction in use of the inner portions of the lagoon-"A" mudflat (AFLT) and CENTER-and an increase in use of the 2 outer east and west spits (ESPT and WSPT). Hunting blinds were located inside the lagoon, nearest to the AFLT and CENTER roost sites. On nonhunt days the majority of pelicans roosted on mudflats inside the lagoon (60%), while on hunt days the majority (66%) roosted on the outer sandbars of the lagoon (ESPT and WSPT).

Winter storms and flooding in January and February 1992 caused the mouth of Calleguas Creek to drain out directly into the ocean, breaking through the west spit (WSPT, Fig. 4). The former tip of the spit temporarily became an island within the mouth of the lagoon but by April 1992 it had eroded away. Subsequently, the WSPT was reduced to a small beach at the base of the parking lot, which later extended inward to within 30 m of AFLT. The inner arm of the east spit (ESPT) gradually grew towards the west and extended inward toward the center of the creek mouth forming east spit lagoon tip (ESPTLT).

Table 3. Numbers of California brown pelicans *(Pelecanus occidentalis californicus)* counted at Naval Air Weapons Station Point Mugu, California, during ground surveys west of the central basin; n = the number of surveys during each survey period. Survey areas are shown in Figure 2.

| | | Survey area | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | | 2 | | 3 | | 4 | |
| Survey Period | n | Average | Range | Average | Range | Average | Range | Average | Range |
| *1991* | | | | | | | | | |
| 27–31 October | 5 | 0.8 | 0-3 | 2.5 | 0-5 | 0.4 | 0-1 | 0.2 | 0-1 |
| 13–16 November | 5 | 0.6 | 0-2 | 0.4 | 0-2 | 1.2 | 0-5 | 0.2 | 0-2 |
| 19–22 December | 4 | | 0 | | 0 | | 0 | 0.2 | 0-2 |
| *1992* | | | | | | | | | |
| 31 January–3 February | 3 | | 0 | 0.3 | 0-1 | | 0 | 0.3 | 0-1 |
| 10–14 April | 3 | 4.3 | 3-6 | 0.3 | 0-1 | | 0 | | 0 |
| 25–29 July | 3 | 1.3 | 1-3 | 7.3 | 0-14 | 0.3 | 0-1 | 2.7 | 0-8 |
| 21–24 August | 4 | 0.8 | 1-3 | 2.0 | 1-4 | 0.5 | 0-2 | 8.8 | 0-35 |
| 22–26 September | 2 | 1.5 | 1-2 | 1.0 | 0-2 | | 0 | | 0 |
| 22–26 October | 5 | 0.6 | 0-2 | 4.4 | 1-10 | | 0 | | 0 |
| 12–15 November | 1 | | 0 | 1.0 | | | 0 | | 0 |
| *1993* | | | | | | | | | |
| 22–24 February | 3 | | 0 | | 0 | | 0 | | 0 |
| 8–10 April | 3 | | 0 | 0.3 | 0-1 | | 0 | 0.3 | 0-1 |
| 24–28 June | 2 | 1.0 | 0 | 0.5 | 0-1 | 0.5 | 0-1 | | 0 |
| 27 September–1 October | 1 | 1.0 | | 14.0 | | 3.0 | | | 0 |
| All periods | 44 | 1.0 | 0-6 | 2.2 | 0-14 | 0.3 | 0-5 | 1.2 | 0-35 |

Table 4. Average percent use by California brown pelicans *(Pelecanus occidentalis californicus)* of daytime and night roost locations in Mugu Lagoon central basin, California, during 6 study periods from fall 1991 to fall 1993. Roost use during fall was divided between hunting and non-hunting days within the same (October–December) time period for both years. Habitat changes due to flooding occurred in January 1992. Locations are coded as follows: AFLT ("A" Hunting Blind Mudflat), CENTER (Center Mudflats), ESPTLT (East Spit Lagoon Tip), ESPTOT (East Spit Ocean Tip), and WSPT (West Spit).

| | | Roost Area | | | | |
|---|---|---|---|---|---|---|
| Time Period | No. of days | AFLT | CENTER | ESPTLT | ESPTOT | WSPT |
| *Day Roosts* | | | | | | |
| Fall 1991 non-hunt | 12 | 12.6 | 53.9 | 10.4 | 9.4 | 13.7 |
| Fall 19 91 hunt | 4 | 4.1 | 36.1 | 7.9 | 21.6 | 30.3 |
| 1992 off-season | 28 | 3.9 | 12.4 | 37.0 | 37.2 | 9.5 |
| Fall 1992 non-hunt | 10 | 16.7 | 6.5 | 57.6 | 10.5 | 8.9 |
| Fall 1992 hunt | 5 | 0.1 | 4.5 | 81.8 | 12.6 | 1.0 |
| 1993 off-season | 23 | 15.6 | 7.0 | 33.8 | 19.3 | 24.3 |
| *Night roosts* | | | | | | |
| Fall 1991 non-hunt | 10 | 100.0 | | | | |
| Fall 1991 hunt | 3 | 100.0 | | | | |
| 1992 off-season | 25 | 64.1 | 2.9 | 30.5 | 2.5 | |
| Fall 1992 non-hunt | 19 | 89.5 | 10.5 | | | |
| Fall 1992 hunt | | 87.5 | 12.5 | | | |
| 1993 off season | 19 | 41.7 | 58.3 | | | |

The temporary (WSPT) island was the most preferred roost site while it existed. Following its erosion, use of the WSPT was low until June 1993 (Table 4). Use increased- as the spit extended into the lagoon. Closure of the west spit to beachwalkers (in an effort to protect harbor seals pupping on AFLT) may have also affected increased use of the spit, although people frequently trespassed on the closure zone. The inner tip of ESPTLT adjacent to the main channel became the most important roost site overall after the lagoon mouth shifted. It was used increasingly as the sandspit extended into the center of the lagoon through fall 1992. Changes in the lagoon after flooding also corresponded to a major decline in use of the CENTER mudflat area. During hunt days in 1992, pelicans essentially abandoned use of AFLT, CENTER, and the WSPT and 95% of all roosting took place on the ESPT.

Pelicans were faithful to a single night roost site from October 1991 through February 1992, but night roosting behavior and habitat use became less predictable following the floods and change in lagoon configuration (Table 4). Pelicans consistently spent the night on AFLT before the winter floods. They would often gather or "stage" in other areas of the lagoon, such as the ESPT, and then in the last minutes of twilight move in unison over to AFLT. The birds generally stood in very shallow water at the edge of the mudflat at dark, and may have remained standing in the water through the dark hours on most nights. Most pelicans relocated rapidly onto dry substrates with increasing light in the morning. When high tides made it impossible for pelicans to stand in the water over AFLT at dusk without getting their feathers wet, they either floated over the site, landed briefly in other locations, or departed the lagoon roost entirely after circling several times over the area.

In spring 1992, pelicans began to roost overnight on the east spit and CENTER sandbar, but AFLT continued to be the most important night roost site throughout the study (Table 4). Night roosting birds split into 2 groups for the first time in June 1992, when 883 birds occupied AFLT at dusk and 45 birds remained on the center bar (CENTER). The inner tip of the east sandspit (ESPTLT) became an important night roost site in July 1992. The CENTER area became a relatively more important night roost towards the end of the study for the relatively few birds that remained overnight during this time.

### *Foraging and Bathing*

Small numbers of pelicans often foraged in the shallow waters of the lagoon and in the nearshore waters just off the lagoon mouth; a few major feeding events were also observed during this study. Large feeding flocks occurred offshore (within 3 km of the mouth) during October 1991 and June 1992 and corresponded to periods of peak pelican abundance at the lagoon. Only 1 major feeding event within the lagoon was observed during this study, but intensive foraging within the central basin and eastern arm has been noted on other occasions (D. L. Jaques, unpubl. data).

In addition to providing a place to rest after foraging, the roost at Mugu Lagoon also served as a center from which pelican groups could detect and pursue prey. For example, streams of pelicans departed the roost at sunset each night during October 1991 and formed scattered feeding flocks extending from very near shore to several kilometers out to sea. Foraging took place in association with brightly lit squid fishing boats present in the area at the time. Increases in the numbers of pelicans from dusk to dawn (as high as 107 birds) indicated that some of the same

pelicans probably returned to Mugu Lagoon to roost after foraging at night. On numerous occasions during June and September 1992, pelicans standing on the ocean tip of the east spit detected mixed-species feeding flocks a few kilometers offshore. Pelicans, along with Heermann's and western gulls *(Larus heermanni* and *occidentalis),* flew directly out from the roost (sometimes by the hundreds) to forage among passing shearwaters and dolphins. Many birds typically returned to the east spit after feeding, but maintained alert posture towards the sea. A brief intense feeding event occurred just inside the mouth of the lagoon, when about 300 pelicans that had been roosting on the sandbars joined double-crested cormorants *(Phalacrocorax auritus)* in pursuing small schooling fish.

Pelicans often bathed in the waters of the Calleguas Creek mouth, especially upon arrival to the lagoon. After bathing, wet birds usually swam or flew a short distance to preen on sandbars or mudflats of the lagoon. Bathing was more common on an outgoing tide when water would be less saline.

## Disturbance

We observed 133 disturbance events during 322.5 hr of pelican observations at the central basin in Mugu Lagoon (Table 5, 6). Of these, 100 were caused by human activities and 33 were attributed to natural or undetermined sources. There were 6 primary sources of disturbance. Direct disturbance from waterfowl hunting caused the greatest number of disturbances, followed by recreational activities on the west spit. Pelicans were most often flushed from roost sites on the outer sandspits. Hunting was the primary source of disturbance to pelicans inside the lagoon. The level of disturbance was greatest during the first 3 months of the study when there was an average 0.79 flushing events per hour (n = 68.4 hr). During the remainder of the study, the rate was 0.31 (n = 254.1 hr), yielding an overall disturbance rate of 0.41 events per hour. The first 3 months corresponded with the 1991 waterfowl season and regular use of the west spit roost site by pelicans. Specific effects from different disturbance sources are described below.

### *Waterfowl Hunting*

Waterfowl hunting occurred from 3 designated blinds in the upper portion of the central basin. Hunters gained access to these areas either by wading or use of small boats. Most shooting occurred in the early morning and evening. We observed pelican responses to hunting activities during 9 days, which included all of the hunt days allowed in the central basin during the 1991 and 1992 hunting seasons (October-January).

Hunting activities caused 24.8% of all flushing events during this study although hunting only occurred on 9 of 93 observation days. We recorded 16 disturbance events from hunting activities during the 1991 season (4 days) and 17 events during the 1992 season (5 days). Most were due to gunshots (Table 6).

Though the number of disturbance events was similar, the impact of hunting was less in 1992 than 1991 as measured by the index "D" (Fig. 9). This result occurred because the measured frequency of disturbance was lower and fewer birds were present to be disturbed.
Most hunt-related disturbances occurred prior to sunrise with the first few volleys of shots (Table 6, Fig. 10). In both years, the first shots on hunt days flushed pelicans from their night roosts on AFLT and CENTER. The majority of these pelicans departed the roost entirely (Table 6). Later

Table 5. Summary of disturbance events at Mugu Lagoon, California, showing number of disturbances by category and location where pelicans flushed. Locations are coded as follows: WSPT (West Spit), ESPT (East Spit), AFLT ("A" Hunting Blind Mudflat), and CENTER (Center Mudflats).

| | Location of disturbance | | | | |
|---|---|---|---|---|---|
| Disturbance source | WSPT | ESPT | AFLT | CENTER | Total |
| Waterfowl hunt | 0 | 7 | 13 | 13 | 33 |
| Aircraft | 4 | 7 | 3 | 2 | 16 |
| Recreation | 19 | 3 | 4 | 1 | 27 |
| Trespassing | 0 | 14 | 0 | 0 | 14 |
| Other human | 6 | 1 | 3 | 0 | 10 |
| Natural/unknown | 4 | 17 | 6 | 6 | 33 |
| Total | 33 | 49 | 29 | 22 | 133 |

Table 6. Events causing disturbance to California brown pelicans *(Pelecanus occidentalis californicus)* at Naval Air Weapons Station Point Mugu, California, during 93 days of observation between October 1991 and October 1993.

| | | | | Number of pelicans | | | |
|---|---|---|---|---|---|---|---|
| Disturbance events | Date | Time | % Flush | Flush | Depart | Relocate | Reland |
| *Waterfowl hunt* | | | | | | | |
| gunshot | 10/26/91 | 0547 | 100 | 92 | 92 | | |
| gunshot | 10/26/91 | 0558 | 100 | 3 | 3 | | |
| gunshot | 10/26/91 | 0617 | 100 | 1 | 1 | | |
| gunshot | 10/26/91 | 1626 | 100 | 250 | 13 | 1 | 236 |
| presence | 11/09/91 | dawn | 100 | 11 | 11 | | |
| set decoy | 11/16/91 | 0603 | 100 | 36 | 2 | | 34 |
| gunshot | 11/16/91 | 0607 | 100 | 34 | 34 | | |
| gunshot | 11/16/91 | 0621 | 100 | 4 | 4 | | |
| gunshot | 11/16/91 | 0622 | 100 | 2 | 2 | | |
| gunshot | 11/16/91 | 0658 | 100 | 5 | 5 | | |
| gunshot | 11/16/91 | 0822 | 100 | 7 | 7 | | |
| gunshot | 11/16/91 | 1030 | 18 | 9 | 3 | 6 | |
| walking | 11/16/91 | 1405 | 100 | 246 | 1 | | 245 |
| gunshot | 12/21/91 | 0638 | 100 | 18 | 12 | 6 | |
| walking | 12/21/91 | 0731 | 100 | 1 | 1 | | |
| gunshot | 12/21/91 | 0905 | 100 | 6 | 5 | 1 | |
| gunshot | 10/24/92 | 0647 | 100 | 53 | 13 | | 40 |
| gunshot | 10/24/92 | 0649 | 100 | 40 | 13 | | 27 |
| gunshot | 10/24/92 | 0756 | 100 | 2 | | 2 | |
| walk | 10/24/92 | 1600 | 82 | 5 | 5 | | |
| gunshot | 10/25/92 | 0545 | 44 | 11 | 9 | 2 | |
| gunshot | 10/25/92 | 0549 | 8 | 2 | 1 | 1 | |
| gunshot | 10/25/92 | 0554 | 100 | 24 | 2 | 22 | |
| gunshot | 11/14/92 | 0601 | 100 | 4 | 4 | | |

Table 6—continued.

| Disturbance events | Date | Time | % Flush | Number of pelicans | | | |
|---|---|---|---|---|---|---|---|
| | | | | Flush | Depart | Relocate | Reland |
| gunshot | 11/14/92 | 0715 | 100 | 12 | 12 | | |
| gunshot | 12/05/92 | 0616 | 31 | 9 | 4 | 5 | |
| gunshot | 12/05/92 | 0621 | 21 | 5 | 5 | | |
| gunshot | 12/05/92 | 0629 | 60 | 9 | 9 | | |
| gunshot | 12/05/92 | 0638 | 100 | 4 | 2 | | 2 |
| gunshot | 12/05/92 | 0640 | 100 | 2 | | 2 | |
| gunshot | 12/05/92 | 0652 | 100 | 19 | 1 | 18 | |
| gunshot | 12/05/92 | 1300 | 2 | 1 | 1 | | |
| gunshot | 01/09/93 | 0640 | 16 | 6 | 6 | | |
| Hunt subtotal | | | | 933 | 283 | 66 | 584 |
| *Air traffic* | | | | | | | |
| Navy helicopter | 10/25/91 | 0632 | 100 | 12 | | | 12 |
| helicopter | 10/26/91 | 1740 | 100 | 64 | | 30 | 34 |
| helicopter | 10/26/91 | 1740 | 100 | 41 | | 20 | 21 |
| helicopter | 10/28/91 | 1125 | 100 | 51 | | | 51 |
| blimp | 11/13/91 | 1230 | 100 | 151 | | | 151 |
| Navy jet | 01/31/92 | 1510 | 37 | 18 | | | 18 |
| Navy cargo | 02/01/92 | 1200 | 5 | 2 | | 2 | |
| helicopter | 02/03/92 | 1000 | 16 | 3 | | | 3 |
| Navy jet | 07/28/92 | 1228 | 12 | 22 | | 22 | |
| Navy jet | 07/28/92 | 1231 | 2 | 3 | | | 3 |
| Navy cargo | 09/23/92 | 0950 | 72 | 92 | | | 92 |
| blimp | 11/13/92 | 1153 | 100 | 46 | 46 | | |
| ultralight | 01/09/93 | 0830 | 100 | 28 | 11 | | 17 |
| Navy jet | 02/24/93 | 1200 | 20 | 3 | | | 3 |
| Navy helicopter | 04/08/93 | 1350 | 16 | 20 | | | 20 |
| helicopter | 06/28/93 | 1317 | 2 | 3 | | 2 | 1 |
| Air traffic subtotal | | | | 559 | 57 | 76 | 426 |

Table 6—continued.

| Disturbance events | Date | Time | % Flush | Number of pelicans | | | |
|---|---|---|---|---|---|---|---|
| | | | | Flush | Depart | Relocate | Reland |
| *Recreation* | | | | | | | |
| clam | 10/26/91 | 0629 | 100 | 44 | 1 | 43 | |
| clam | 10/26/91 | 0635 | 100 | 43 | | 43 | |
| walk/dogs | 10/26/91 | 0725 | 100 | 66 | 31 | | 35 |
| walk | 10/26/91 | 1550 | 100 | 61 | | 61 | |
| fish | 10/27/91 | 0815 | 100 | 134 | 50 | 2 | 82 |
| walk/dog | 10/27/91 | 0834 | 100 | 105 | | 105 | |
| jog | 10/27/91 | 1247 | 100 | 7 | 7 | | |
| walk | 11/14/91 | 0812 | 100 | 114 | 10 | 104 | |
| walk | 11/14/91 | 0815 | 100 | 104 | | 104 | |
| walk | 11/15/91 | 0855 | 100 | 35 | | 35 | |
| fish | 11/16/91 | 1038 | 75 | 18 | 18 | | |
| walk | 11/16/91 | 1054 | 100 | 6 | 6 | | |
| walk | 11/16/91 | 1108 | 100 | 86 | 4 | 82 | |
| walk | 11/16/91 | 1312 | 100 | 6 | 6 | | |
| walk | 12/21/91 | 1140 | 100 | 19 | 14 | 5 | |
| walk | 12/21/91 | 1444 | 100 | 4 | 4 | | |
| walk | 06/06/92 | 1318 | 41 | 115 | | 115 | |
| walk/dog | 06/07/92 | 0840 | 100 | 25 | | 25 | |
| walk/dog | 06/07/92 | 0843 | 100 | 225 | 10 | 215 | |
| walk/dog | 06/07/92 | 0913 | 100 | 203 | 6 | 197 | |
| walk/dog | 06/07/92 | 0918 | 100 | 18 | | 18 | |
| walk/dog | 06/07/92 | 0920 | 51 | 36 | | 36 | |
| walk | 10/25/92 | 0710 | 100 | 14 | | 14 | |
| walk | 12/05/92 | 0825 | 100 | 7 | 7 | | |
| walk/dog | 04/10/93 | 0647 | 100 | 1 | | 1 | |
| jog/dog | 04/10/93 | 1914 | 100 | 69 | 30 | 39 | |

Table 6—continued.

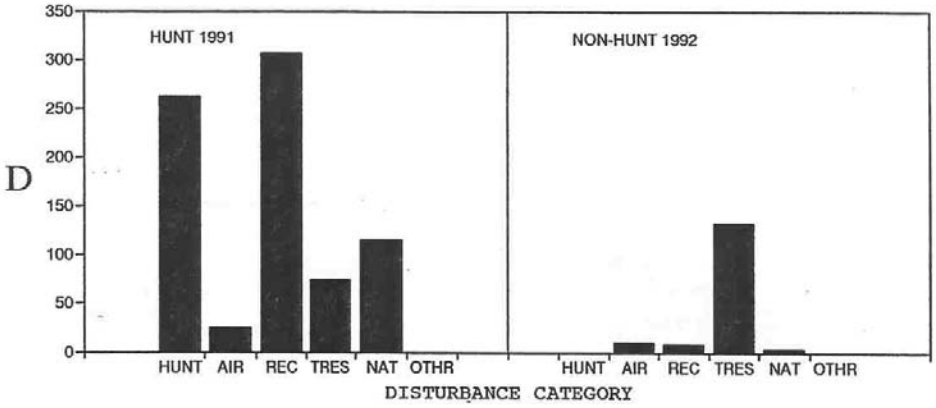
| | | | | Number of pelicans | | | |
|---|---|---|---|---|---|---|---|
| Disturbance events | Date | Time | % Flush | Flush | Depart | Relocate | Reland |
| walk | 06/28/93 | 1140 | 1 | 1 | 1 | | |
| run | 06/28/93 | 1218 | 100 | 81 | | 81 | |
| walk | 09/30/93 | 1000 | 100 | 17 | 8 | 9 | |
| walk | 10/01/93 | 1208 | 100 | 42 | 12 | 2 | 28 |
| Recreation subtotal | | | | 1,706 | 225 | 1,336 | 145 |
| *Trespass recreation* | | | | | | | |
| dog loose | 11/09/91 | 1500 | 100 | 77 | 77 | | |
| surf | 11/16/91 | 0818 | 100 | 27 | 27 | | |
| surf | 11/16/91 | 0821 | 100 | 7 | 7 | | |
| surf | 11/16/91 | 1032 | 100 | 8 | 8 | | |
| walk/dog | 11/16/91 | 1157 | 100 | 150 | 150 | | |
| walk | 12/19/91 | 1327 | 27 | 20 | 14 | 6 | |
| surf | 04/12/92 | 1910 | 100 | 1 | 1 | | |
| surf | 06/06/92 | 1820 | 100 | 128 | | 128 | |
| walk/dog | 06/07/92 | 0835 | 100 | 400 | 15 | | 385 |
| surf | 0726/92 | 1745 | 60 | 41 | 5 | 36 | |
| surf | 09/26/92 | 1709 | 76 | 228 | 138 | 90 | |
| Trespass recreation subtotal | | | | 1,087 | 442 | 260 | 385 |
| *Natural/unidentified* | | | | | | | |
| unknown | 10/27/91 | 1000 | 100 | 35 | | | 35 |
| northern harrier | 10/27/91 | 1509 | 100 | 5 | | 5 | |
| unknown | 10/27/91 | 1628 | 100 | 98 | 2 | | 96 |
| unknown | 11/09/91 | 1400 | 100 | 190 | | | 190 |
| unknown | 11/14/91 | 0935 | 100 | 25 | | 25 | |
| bald eagle | 11/15/91 | 0653 | 100 | 78 | 31 | 6 | 41 |
| bald eagle | 11/15/91 | 0658 | 100 | 40 | | 40 | |

Table 6—continued.

| Disturbance events | Date | Time | % Flush | Number of pelicans | | | |
|---|---|---|---|---|---|---|---|
| | | | | Flush | Depart | Relocate | Reland |
| unknown | 11/15/91 | 0704 | 300 | 37 | 18 | | 19 |
| bald eagle | 11/15/91 | 0750 | 100 | 35 | 3 | | 32 |
| unknown | 11/16/91 | 1052 | 96 | 76 | | 76 | |
| unknown | 12/19/91 | 1648 | 41 | 9 | 4 | 5 | |
| unknown | 02/02/92 | 1000 | 100 | 42 | | | 42 |
| gull/fishline | 02/02/92 | 1820 | 100 | 2 | 2 | | |
| unknown | 04/12/92 | 0624 | 100 | 3 | 1 | | 2 |
| other species | 04/13/92 | 0610 | 100 | 12 | 7 | 5 | |
| northern harrier | 09/25/92 | 0940 | 7 | 12 | | | 12 |
| unknown | 10/22/92 | 1750 | 2 | 2 | | | 2 |
| unknown | 10/25/92 | 0730 | 100 | 88 | 3 | | 85 |
| unknown | 10/25/92 | 0800 | 100 | 104 | 2 | | 102 |
| peregrine falcon | 11/13/92 | 0820 | 100 | 5 | | | 5 |
| peregrine falcon | 11/13/92 | 1508 | 14 | 5 | | | 5 |
| peregrine falcon | 11/13/92 | 1513 | 100 | 33 | 18 | 15 | |
| peregrine falcon | 11/15/92 | 1232 | 100 | 55 | 24 | | 31 |
| peregrine falcon | 11/15/92 | 1600 | 72 | 16 | 5 | | 11 |
| unknown | 12/05/92 | 0725 | 100 | 4 | 2 | 1 | 1 |
| peregrine falcon | 01/09/93 | 1030 | 100 | 26 | | | 26 |
| raptor | 02/24/93 | 0652 | 34 | 4 | | | 4 |
| peregrine falcon | 02/24/93 | 1700 | 100 | 38 | | | 38 |
| peregrine falcon | 04/08/93 | 1740 | 100 | 85 | 3 | | 82 |
| raptor | 06/27/93 | 2040 | 100 | 16 | 15 | | 1 |
| pelican w/line | 07/19/93 | 0556 | 100 | 30 | | | 30 |
| unknown | 07/21/93 | 2031 | 100 | 4 | | | 4 |
| unknown | 09/21/93 | 0645 | 100 | 12 | | 12 | |
| Natural/unidentified subtotal | | | | 1,226 | 140 | 190 | 896 |

Table 6—continued.

| Disturbance events | Date | Time | % Flush | Number of pelicans | | | |
|---|---|---|---|---|---|---|---|
| | | | | Flush | Depart | Relocate | Reland |
| *Other disturbance* | | | | | | | |
| firing range | 01/31/92 | 1110 | 4 | 4 | 4 | | |
| security light | 10/25/92 | 1750 | 10 | 6 | 6 | | |
| research | 11/10/92 | 1738 | 100 | 44 | 5 | | 39 |
| radar operations | 01/08/93 | 0727 | 6 | 3 | | 3 | |
| research | 01/10/93 | 0650 | 9 | 1 | | 1 | |
| radar operations | 02/23/93 | 0734 | 33 | 11 | 2 | | 9 |
| radar operations | 06/10/93 | 1545 | 20 | 38 | 38 | | |
| headlights | 06/24/93 | 2100 | 100 | 21 | 20 | | 1 |
| research | 06/25/93 | 1230 | 8 | 20 | 17 | | 3 |
| research | 09/30/93 | 1415 | 100 | 200 | 37 | 108 | 55 |
| Other disturbance subtotal | | | | 348 | 129 | 112 | 107 |
| All disturbances total | | | | 5,859 | 1,276 | 2,040 | 2,543 |



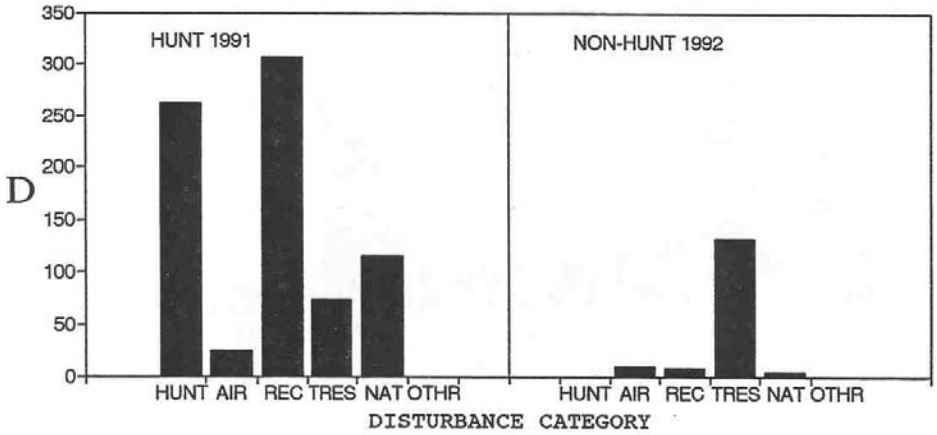




Figure 9. Impact of 6 disturbance sources measured by the "D" index of disturbance (see text) on California brown pelicans *(Pelecanus occidentalis californicus)* at Mugu Lagoon, California, during 4 periods: waterfowl hunt 1991 (October–December), non-hunt 1992 (February–September 1992), hunting 1992 (October–January 1992), and non-hunting 1993 (February–October 1993).

Disturbance categories:

| | |
|---|---|
| HUNT | waterfowl hunting activity |
| AIR | aircraft overflights |
| REC | recreational activities by persons at Naval Air Weapons Station (NAWS) Pt. Mugu |
| TRES | recreational activities by civilian trespassers on NAWS property |
| NAT | natural or undetermined |
| OTHR | base activities occurring at the west spit parking lot |

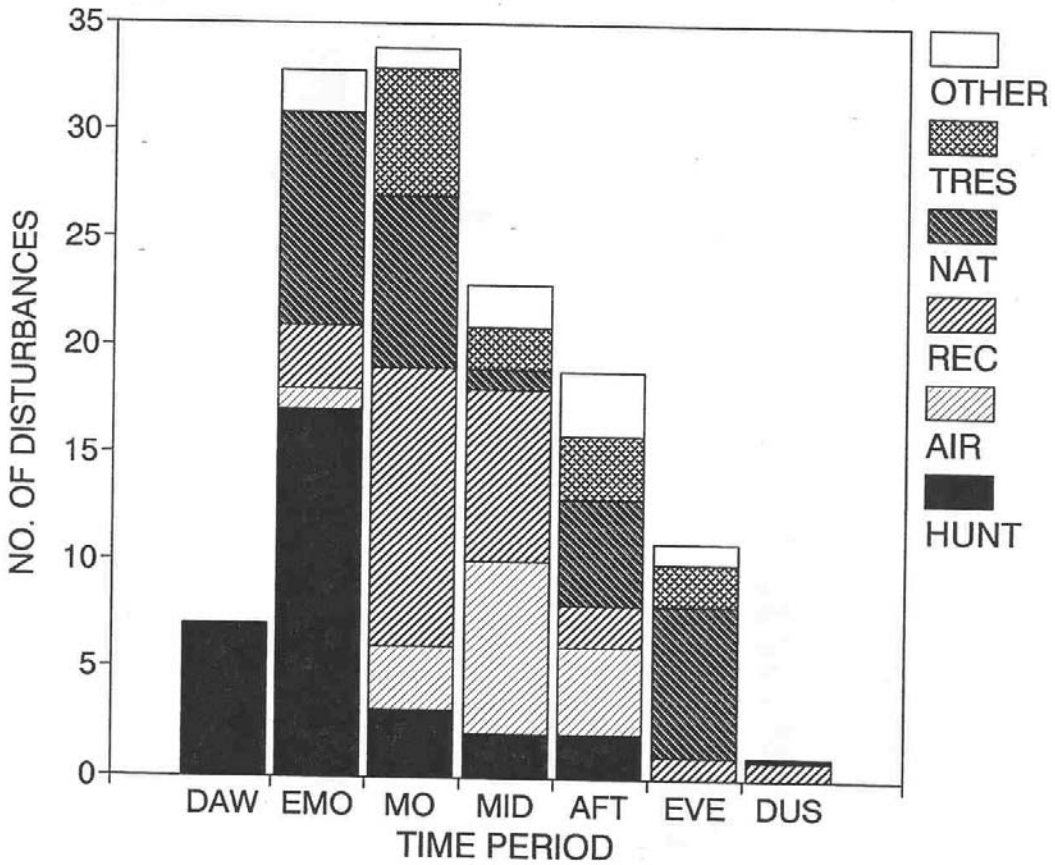



Figure 10. Number of disturbances to California brown pelicans *(Pelecanus occidentalis californicus)* at Mugu Lagoon, California, caused by 6 disturbance sources in 7 time periods through the day.

Time periods:

| | |
|---|---|
| DAW | Dawn (30–50 minutes pre-sunrise) |
| EM | Early morning (60 minutes after sunrise) |
| MO | Morning (2 hours after sunrise) |
| MID | Midday (the midpoint between sunrise and sunset) |
| AFT | Afternoon (2 hours before sunset) |
| EVE | Evening (60 minutes before sunset) |
| DUS | Dusk (40–50 minutes after sunset) |

in the day, pelicans flushed by gunshots were more likely to remain in the lagoon. Hunting primarily affected pelicans roosting on inner lagoon mudflats. However, in 1992, the roost site on the inner tip (ESPTLT) was also disturbed by gunshots (Table 5). There was a decrease in the use of roost sites inside the lagoon on hunt days and an increase in use of the outer sandspits (see Habitat Use).

Additional disturbances were probably indirectly related to hunting because hunters often prevented pelicans from using interior roost sites. Pelicans roosting on the outer sandspits were more vulnerable to disturbance from pedestrian recreational activities. Increased use of the west spit by displaced pelicans in 1991 may have contributed to the relatively high impact of recreational disturbance that fall (see Fig. 9). During the 1991 hunting season, the frequency of disturbance from all sources was 1.27 events per hour (27.6 hr obs.), compared to 0.62 events/hr on 5 hunt days in 1992 (35.5 hr obs.). The overall disturbance rate on the 9 hunt days was 0.90 events per hour (63.1 hr obs.), far higher than the 0.24 disturbance events per hour recorded on 25 non-hunt days during both hunt seasons (91.3 hr obs.).
Significantly fewer pelicans used Mugu Lagoon during hunt days than on the day prior to the hunt (Wilcoxin paired rank test, $p < 0.05$). Numbers remained depressed (i.e., they did not increase significantly) the day after the hunt ($p > 0.05$).

## *Air Traffic*

Air traffic, mainly from Navy Operations, accounted for only 12% of all disturbances (Table 6), although air operations occurred each day of the study. Pelicans that flushed from overflights of aircraft usually relanded quickly in the same location, resulting in a relatively low rank in the disturbance impact index (Fig. 9). Helicopters caused the greatest number of disturbances.

Though air traffic was a frequent potential cause of disturbance, birds seldom flushed from the many aircraft of all types passing over the central lagoon (Table 7). Changes in regulations at NAWS Point Mugu governing air traffic patterns and altitude over the central lagoon have probably reduced the amount of disturbance caused to pelicans by aircraft in recent years. Also, pelicans seemed to be generally habituated to overflights of loud aircraft at Mugu Lagoon. Overflights at other roosts in California, particularly from helicopters, have caused flushing more readily (Jaques and Strong, unpubl. data).

### *Recreation and Trespassing*

Recreational activities on the west spit, mostly beachwalking or walking with dogs, caused the greatest total number of birds to flush (1,706, Table 6), however nearly 80% of flushed birds relocated to another roost site in the central basin. Recreation caused the same number of disturbances (16) as did hunting prior to the erosion of the west spit and ranked highest in the disturbance index during the 1991 hunting season (Fig. 9). In contrast, during 1992, legal recreational activities had very little impact on roosting pelicans (Fig. 9), largely because pelicans infrequently used the remnant west spit (Table 4). Recreation disturbance on the west spit increased again in 1993 as pelicans renewed a higher level of use of that site (Fig. 9, Table 4).

Table 7. Number of events with the potential to disturb California brown pelicans *(Pelecanus occidentalis californicus)* at Mugu Lagoon, California, between October 1991 and October 1993. Response effects are noted as flush (disturbance), alert, or no response.

| Event | | Total no. events | Effect on pelicans | | |
|---|---|---|---|---|---|
| Category | Description | | Flush | Alert | No response |
| *Hunt* | | | | | |
| | gunshots | 37 | 26 | 5 | 6 |
| | walking | 12 | 5 | 0 | 7 |
| | Total | 49 | 31 | 5 | 13 |
| *Air traffic* | | | | | |
| | cargo plane | 38 | 2 | 1 | 35 |
| | jet fighter | 39 | 4 | 6 | 29 |
| | large helicopter | 20 | 2 | 7 | 11 |
| | other helicopter | 36 | 5 | 5 | 26 |
| | light plane | 10 | 0 | 0 | 10 |
| | blimp/towplane | 5 | 3 | 2 | 0 |
| | Total | 148 | 16 | 21 | 111 |
| *Firing range* | | | | | |
| | gunshots | 18 | 1 | 2 | 15 |
| | Total | 18 | 1 | 2 | 15 |
| *Recreation* | | | | | |
| | walk | 76 | 15 | 3 | 58 |
| | walk/dog | 28 | 6 | 3 | 19 |
| | jog | 2 | 2 | 0 | 0 |
| | fish | 12 | 4 | 0 | 8 |
| | kite/toy plane | 6 | 0 | 0 | 6 |
| | Total | 124 | 27 | 6 | 91 |
| *Trespass recreation* | | | | | |
| | surf | 28 | 7 | 1 | 20 |
| | walk | 3 | 1 | 0 | 2 |
| | walk/dog | 5 | 5 | 0 | |
| | Total | 36 | 13 | 1 | 22 |
| *Natural/ unidentified* | | | | | |
| | raptor | 26 | 15 | 5 | 6 |
| | other/unidentified | 15 | 15 | | |
| | Total | 41 | 30 | 5 | 6 |

In 1991, recreational activities only disturbed pelicans roosting on the west spit. However, as the west spit tip migrated inward during 1992, pelicans across the water on AFLT, ESPTLT, and CENTER were flushed by people walking with dogs on the west spit. Some dogs entered the water and swam towards pelicans.

During the non-hunting season in 1992, most disturbance in the central basin was caused by illegal recreation, i.e., trespassers walking on the east spit or surfers crossing the eastern arm of the lagoon (Table 6, Fig. 9). Enforcement of laws against trespassing on the east spit increased in 1992 and may have contributed to the overall decrease in disturbance from trespassers later in the study.

### *Natural Disturbance*

The most common natural source of disturbance was the presence of raptors (Table 6). Many disturbances from unidentified sources may have been due to raptors. While pelicans are too large to be physically threatened by most raptor species, they reacted to alarm calls and flushing responses by gulls, shorebirds, and waterfowl. Raptors inducing pelicans to flush included peregrine falcon *(Falco peregrinus),* northern harrier (*Circus cyaneus),* and bald eagle *(Haliaeetus leucocephalus).* Raptor disturbance occurred mostly in early morning or evening (Fig. 10).

### *Other Disturbance*

Other disturbance events were caused by activities in the parking lot at the base of the west spit. Construction and maintenance, movements of researchers, and headlights from security or visitor vehicles caused 10 disturbances from this area. Heavy equipment operation and rip-rap installation to control erosion of the north side of the parking lot was not seen to cause disturbance in January 1993, even though pelicans were within 100 m of the operation at the time.

## Southern California Bight

### *Pelican Abundance During Summer and Fall*

Annual peaks in pelican abundance in the SCB were recorded in summer (June) 1992 and in fall (September) 1993. Numbers of pelicans counted during aerial surveys of the mainland and island shorelines ranged from about 11,500 birds in June 1992 to 3,400 birds in June 1993 (Tables 8, 9). September counts were more similar than June counts, varying by less than 2,000 birds. Pelican abundance along the mainland was more variable than on offshore islands.
Very high numbers of pelicans counted along the mainland coast in June 1992 (Table 8), corresponded to severe nesting failure and abandonment of Channel Islands breeding colonies due to El Nino-Southern Oscillation (ENSO) conditions (Gress et al. 1995). By August, numbers of pelicans along the mainland had decreased to 35% of the June peak. Populations then increased again gradually through the fall. In contrast, during 1993, low numbers of pelicans encountered during the June air survey (Tables 8, 9) corresponded to a very good breeding year in southern California (Gress et al. 1995). Pelicans were concentrated at nest sites in the SCB (and Mexico), which were not included in our surveys. More pelicans were present in the SCB in September 1993 than in September 1992.

Table 8. Numbers of California brown pelicans *(Pelecanus occidentalis californicus)* observed in 5 coastal counties in southern California during aerial surveys of the mainland coast from Mexico to Point Conception in 1992 and 1993.

| | 1992 | | | | 1993 | |
|---|---|---|---|---|---|---|
| | June | August | September | November | June | September |
| San Diego | 837 | 642 | 808 | 393 | 143 | 900 |
| Orange | 910 | 258 | 170 | 475 | 111 | 141 |
| Los Angeles | 2,562 | 1,044 | 659 | 1,372 | 1,248 | 1,720 |
| Ventura | 1,663 | 546 | 611 | 1,035 | 269 | 589 |
| Santa Barbara | 2,279 | 374* | 895 | 490* | 253* | 1,532 |
| Total mainland | 8,251 | 2,864 | 3,143 | 3,765 | 2,024 | 4,882 |

* Point Conception not surveyed.

Table 9. Numbers of California brown pelicans *(Pelecanus occidentalis californicus)* counted on the Channel Islands, California, during 5 aerial surveys in 1992 and 1993.

| | 1992 | | | 1993 | | 1992–93 |
|---|---|---|---|---|---|---|
| | June | August | September | June | September | Average |
| *Southern Channel Islands* | | | | | | |
| San Clemente | 335 | 92 | 348 | 96 | 185 | 211 |
| Santa Catalina | 467 | 412 | 269 | 248 | 733 | 426 |
| San Nicolas | 532 | 329 | 591 | 88 | 167 | 341 |
| Santa Barbara | 111 | 381 | 318 | 159 | 348 | 263 |
| Subtotal | 1,445 | 1,214 | 1,526 | 591 | 1,433 | 1,241 |
| *Northern Channel Islands* | | | | | | |
| Anacapa | 618 | 347 | 1,071 | 303 | 445 | 557 |
| Santa Cruz | 751 | 811 | 901 | 457 | 1,856 | 955 |
| Santa Rosa | 190 | 239 | 138 | 17 | 197 | 157 |
| San Miguel | 231 | 498 | 482 | 13 | 249 | 295 |
| Subtotal | 1,790 | 1,895 | 2,592 | 790 | 2,747 | 1,964 |
| Total | 3,235 | 3,109 | 4,118 | 1,381 | 4,180 | 3,205 |

The ratio of immature to adult pelicans increased from June to September each year, and was greatest in September 1993 (Fig. 11). The percent immature along the mainland was higher than on offshore island shores during all air surveys, as noted previously by Briggs et al. (1981). Mugu Lagoon was used by a lower percentage of immatures than were recorded along the mainland as a whole.

### *Distribution and Habitat Use*

Aerial surveys indicated that northern regions of the SCB were used more heavily by pelicans during summer and fall than were southern regions (Table 8, 9). The northern Channel Islands, particularly Anacapa and Santa Cruz, were especially important in September each year (Table 9). In June, distribution was less skewed to the northern islands. Along the mainland, the 3 north-most counties received greatest use overall (Table 8). Los Angeles, Ventura, and the southern half of Santa Barbara counties averaged 11.2 pelicans per kilometer of shoreline (total = 285 km), while San Diego and Orange counties averaged 5 pelicans per km (total = 190 km). Los Angeles County harbored more pelicans than any other county during 5 of 6 air surveys.

Twenty roosts occurred along the southern California mainland that were used by more than 100 pelicans on a given air survey (Table 10). Eight occurred on natural substrates and 12 were artificial structures (Table 11). The 2 lowest-ranking "large" roosts occurred on public beaches only in June 1992 when those parks were closed to the public due to sewage pollution. Of the remaining 6 natural roost sites, 3 were estuarine habitats and 3 were located on cliffs. Mugu Lagoon was by far the most important estuarine site. Its high rank (6th overall) and low coefficient of variation demonstrated consistent use by large numbers of birds. The cliffs at Point Conception ranked as the largest natural roost overall. Three of the 6 natural sites were on military bases, where access by the public is restricted.

Artificial structures and restricted-access military installations together accounted for 15 of the 20 largest roosts (Table 11). Two breakwaters in Los Angeles County provided reliable, high-capacity roosts that were largely responsible for consistently high counts of pelicans. Only two of the regularly used large roost sites are managed by resource-based (state) agencies: Malibu Lagoon-Department of Parks and Recreation, and Batiquitos Lagoon-Department of Fish and Game.

Dependence on artificial structures for roosting along the mainland, and relative lack of undisturbed natural sites, was further exemplified by analysis of total percentages of pelicans using various substrates during the 4 most complete aerial surveys (Fig. 12). About 65% of all pelicans roosted on artificial structures, mainly associated with harbors. Beaches used by pelicans occurred primarily along inaccessible stretches of the Santa Barbara coastline between Gaviota and Point Conception. Many of the reefs and offshore rocks along the coast could only used for roosting during low tides due to their low relief and small size. Most of the coastal roost rocks occurred in 2 regions: (1) between Palos Verdes-Long Beach and (2) Newport Bay-Dana Point. Although a few artificial structures exist around_ the Channel Islands (e.g., shipwrecks, jetties, abandoned piers), pelicans almost exclusively chose natural substrates there.

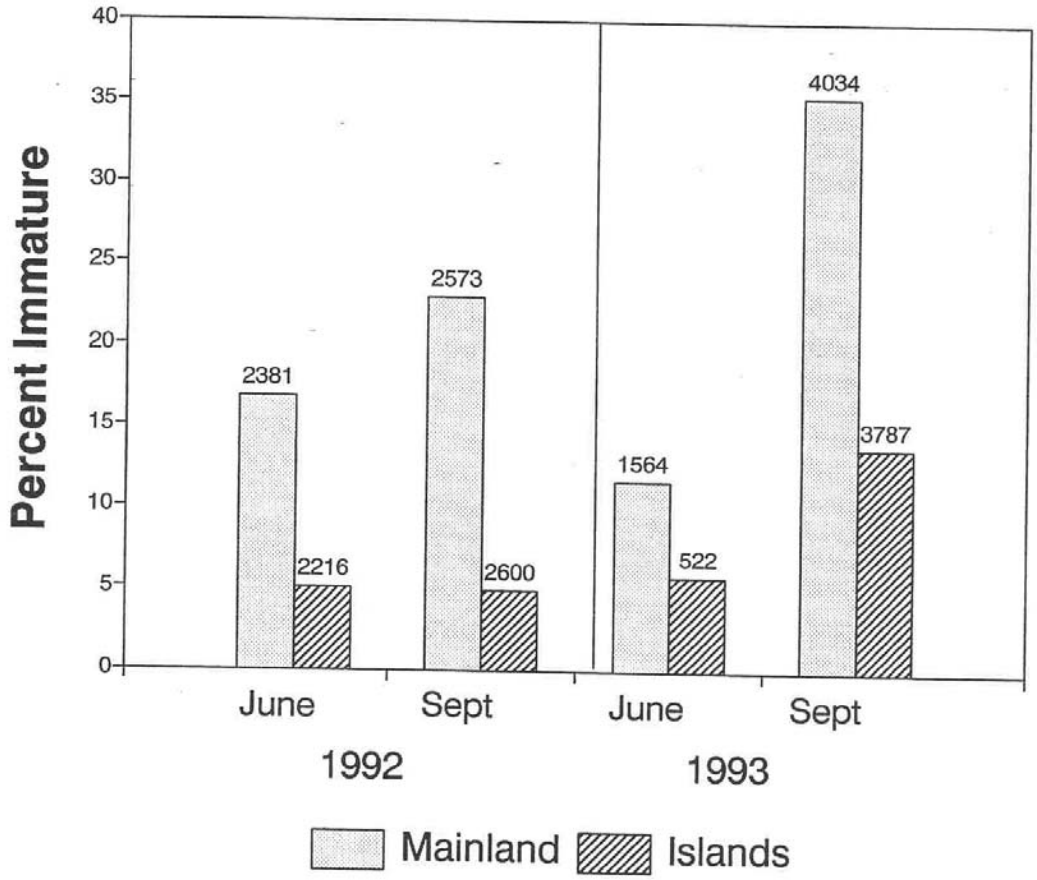



Figure 11. Percent of immature California brown pelicans *(Pelecanus occidentalis californicus)* observed at nonbreeding sites in the Southern California Bight during air surveys in 1992 and 1993. Immatures included all pelicans with brown heads and white bellies (hatch-year and young of previous year). Numbers at tops of bars are sample sizes.

Table 10. Counts of California brown pelicans *(Pelecanus occidentalis californicus)* at mainland roost sites with more than 100 birds present on 1 or more aerial surveys; ND indicates when a roost site was not surveyed. Counties are abbreviated as follows: SD = San Diego, OR = Orange, LA = Los Angeles, VN = Ventura, SB = Santa Barbara.

| | | 1992 | | | | 1993 | | 1992–93 |
|---|---|---|---|---|---|---|---|---|
| Location | Co. | June | August | September | November | June | September | Average |
| Crown Cove Marina | SD | 0 | 17 | 0 | 20 | 9 | 130 | 29 |
| Zuniga Point | SD | ND | 100 | 165 | 120 | 26 | 123 | 107 |
| Navy Electronics Lab | SD | 2 | 155 | 25 | 24 | 0 | 6 | 35 |
| La Jolla | SD | 155 | 6 | 0 | 35 | 8 | 60 | 44 |
| Oceanside Harbor | SD | 284 | 0 | 73 | 54 | 22 | 122 | 93 |
| Batiquitos Lagoon | SD | 4 | 7 | 362 | 0 | 0 | 102 | 79 |
| Dana Point Harbor | OR | 17 | 97 | 70 | 341 | 40 | 52 | 103 |
| Bolsa Chica Lagoon | OR | 214 | 0 | 0 | 2 | 9 | 0 | 38 |
| Anaheim Bay | OR | 250 | 102 | 55 | 45 | 13 | 136 | 100 |
| Los Angeles Harbor | LA | 615 | 442 | 374 | 441 | 732 | 868 | 579 |
| King Harbor | LA | 55 | 195 | 231 | 48 | 20 | 95 | 107 |
| Marina del Rey | LA | 195 | 350 | 118 | 640 | 405 | 585 | 382 |
| Malibu Lagoon | LA | 216 | 7 | 12 | 7 | 30 | 0 | 45 |
| Will Rogers State Beach | LA | 506 | 0 | 0 | 0 | 0 | 0 | 84 |
| Naval Air Weapons Station Point Mugu | VN | 272 | 209 | 233 | 49 | 181 | 65 | 168 |
| Ventura Harbor | VN | 60 | 23 | 7 | 33 | 32 | 125 | 47 |
| Mussel Shoals | VN | 505 | 190 | 293 | 739 | 1 | 226 | 326 |
| Punta Gorda | VN | 301 | 52 | 8 | 102 | 15 | 1 | 80 |
| Outer Santa Barbara Harbor | SB | 1,480 | 112 | 265 | 152 | 47 | 3 | 343 |
| Point Conception | SB | 104 | ND | 283 | ND | 75 | 679 | 285 |

Table 11. California Brown pelican *(Pelecanus occidentalis californicus)* roosts along the southern California mainland with more than 100 birds present during aerial surveys in 1992 and 1993. Mean rank is the average rank of abundance among these roosts from 6 aerial surveys; CV is the coefficient of variation.

| Location | Roost type | Management entity | Mean rank | Mean count | CV (s/x) |
|---|---|---|---|---|---|
| Los Angeles Harbor | Breakwater | U.S. Army Corps of Engineers | 1.8 | 579 | 0.33 |
| Marina del Rey | Breakwater | Army Corps | 4.8 | 382 | 0.54 |
| Mussel Shoals | Oil Pier | Private Industry | 5.5 | 326 | 0.80 |
| Point Conception | Cliff | U.S. Navy | 5.8 | 285 | 0.98 |
| Outer Santa Barbara Harbor | Boats | Private Industry | 6.5 | 343 | 1.64 |
| Naval Air Weapons Station Point Mugu | Estuary/ Beach | U.S. Navy | 6.7 | 168 | 0.54 |
| Zuniga Point | Jetty | U.S. Navy & Army Corps | 8.0 | 107 | 0.49 |
| Anaheim Bay | Jetty | U.S. Navy & Army Corps | 9.5 | 100 | 0.85 |
| King Harbor | Jetty | Army Corps | 9.7 | 107 | 0.80 |
| Oceanside | Jetty | Army Corps | 9.8 | 93 | 1.11 |
| Dana Point | Jetty | Army Corps | 10.2 | 103 | 1.16 |
| Punta Gorda | Jetty | Private Industry | 11.2 | 80 | 1.44 |
| Ventura Harbor | Breakwater | Army Corps | 11.5 | 47 | 0.90 |
| Malibu Lagoon | Estuary | Calif. Dept. of Parks & Recreation | 11.5 | 45 | 1.86 |
| Batiquitos Lagoon | Estuary | Calif. Dept. of Fish & Game | 13.0 | 44 | 1.80 |
| Navy Electronics Laboratory | Cliff | U.S. Navy | 13.8 | 35 | 1.69 |
| La Jolla | Cliff | City | 14.0 | 44 | 1.34 |
| Crown Cove Marina | Buoys etc. | Private | 14.0 | 29 | 1.70 |
| Will Rogers SB | Beach | Calif. Dept. of Parks & Recreation | 14.8 | 84 | 2.45 |
| Bolsa Chica SB | Beach | Calif. Dept. of Parks & Recreation | 15.3 | 38 | 2.31 |

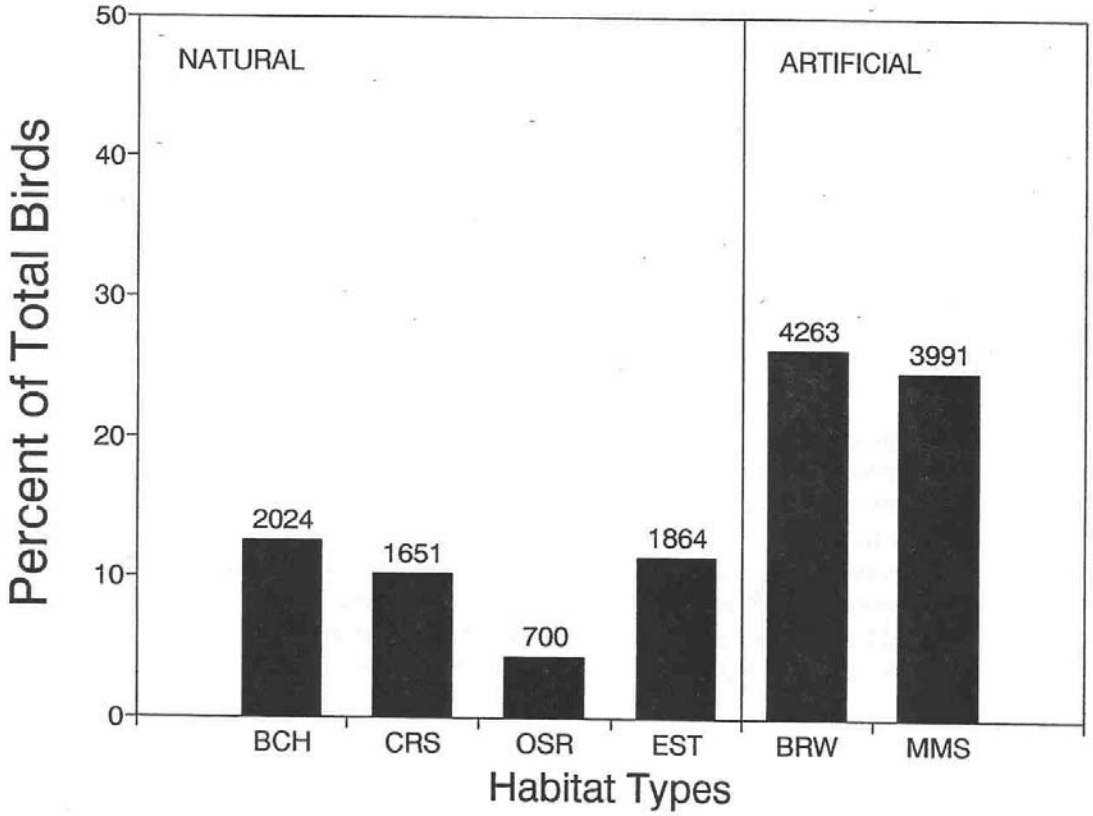



Figure 12. Habitat types used by roosting California brown pelicans *(Pelecanus occidentalis californicus)* on the southern California mainland coast from June and September 1992 and 1993 aerial surveys.

Habitat codes:

| | |
|---|---|
| BCH | beach |
| CRS | cliff or rocky shoreline |
| OSR | offshore islet |
| EST | lagoon / estuary |
| BRW | harbor breakwaters and jetties |
| MMS | Other man-made structures |

### *Roosts in the Vicinity of Mugu Lagoon*

Data collected from ground surveys of 12 mainland roosts within a 160-km radius of Mugu Lagoon (see Fig. 1) reflected the different seasonal trend between the 2 years of this study. Numbers were higher in summer than fall in 1992 and higher in fall than summer in 1993 (Tables 12, 13). However, peaks in abundance were variable between roosts, and no single site mirrored the large-scale pattern. Three of the largest roosts along the southern California mainland (determined from aerial surveys, Table 11) occurred within the range of our ground surveys. These sites were (1) the Marina del Rey Breakwater in Santa Monica Bay; (2) the oil pier at Mussel Shoals; and (3) a large, temporarily abandoned barge moored in the outer harbor at Santa Barbara.

Mugu Lagoon ranked second in average numerical abundance of pelicans from ground counts in this 160-km stretch of coastline, following the Marina del Rey Breakwater. However, both the oil pier and the barge ranked higher than Mugu Lagoon from aerial survey data. While it is likely that some birds on these structures were not visible from ground vantage points, the difference in counts is probably due to inconsistent use. The pier and barge were private industrial properties, and disturbance from operations probably contributed to variable counts. During summer and early fall 1992, when the barge was inoperative, it attracted large numbers of roosting pelicans. More than 1,300 pelicans were recorded there during the June 1992 flight. When it was put back in operation in late fall 1992 (and presumably chronically disturbed), the roost site was essentially lost. No more than 200 pelicans were counted in the entire Santa Barbara Harbor area once the barge was reclaimed by a mariculture business. The oil pier was gated off to public access but was subject to disturbance from normal working operations. The barge and the industrial pier, along with the Marina del Rey Breakwater and an abandoned houseboat, were the only other night roosts found in the Mugu Lagoon vicinity.

The Marina del Rey Breakwater roost was more consistently used as a night roost by large numbers of pelicans than was Mugu Lagoon. Hundreds of pelicans typically flew in around sunset to join others already on the breakwater. We conducted most of our censuses of that roost at dawn or dusk to obtain peak counts. Numbers exceeded 1,000 during each survey from December 1991 to June 1992 and peaked at 1,640 birds (Table 12). Seasonal use of Marina del Rey Breakwater did not follow the same pattern as at Mugu Lagoon. Numbers at the breakwater peaked in the winter and spring months in contrast to the summer and fall peaks at Mugu Lagoon (Fig. 13). Pelicans may have been centered farther south in the winter, nearer to the Santa Monica Bay-area than the Santa Barbara Channel region.

Numbers of pelicans using other roost sites in the Mugu Lagoon vicinity were variable but relatively low. Counts appeared to be influenced more by local conditions affecting roost quality (e.g., swell height, human disturbance, changes in lagoon configuration) and scavenging opportunities, rather than by large-scale seasonal phenomena.

### *Disturbance Levels at Vicinity Roosts*

We spent 52 hr conducting observations from the ground at roosts in the vicinity of Mugu Lagoon (listed in Tables 12). During observations, 22 disturbance events (0.42 events/hr) were observed, of which at least 21 were caused by people. The disturbance level was higher in estuaries (1.33 events/hr) than in harbors (0.29 events/hr). For example, there were nearly 2

Table 12. Ground censuses of California brown pelicans *(Pelecanus occidentalis californicus)* at roosts along the California coast in the vicinity of Naval Air Weapons Station, Point Mugu, in 1991–1992. Numbers for Mugu Lagoon represent the mean daily peak count; ND indicates no observations made.

| Location | October | December | February | April | June | July | August | September |
|---|---|---|---|---|---|---|---|---|
| King Harbor | ND | ND | 54 | ND | ND | ND | ND | 178 |
| Marina Del Rey Harbor | ND | 1,642 | 1,009 | 1,115 | 1,106 | 654 | 347 | 365 |
| Malibu barge | 32 | 44 | 48 | 8 | 16 | 0 | ND | 6 |
| Malibu Lagoon | ND | 0 | 123 | 31 | 115 | 5 | ND | 9 |
| Mugu Lagoon | 290 | 52 | 99 | 45 | 904 | 474 | 181 | 280 |
| Channel Islands Harbor breakwater | ND | 57 | 16 | 4 | 81 | 102 | 89 | 11 |
| Channel Islands Harbor inner | ND | 49 | 28 | 9 | 19 | 29 | 26 | 74 |
| Santa Clara River | 18 | 32 | 0 | 24 | 118 | 48 | 6 | 21 |
| Ventura Harbor breakwater | 190 | 130 | 0 | 0 | 15 | 19 | 0 | 13 |
| Ventura Harbor inner | 3 | 20 | ND | 12 | 15 | 19 | 0 | 13 |
| Mussel Shoals pier | ND | 111 | 77 | 118 | ND | 191 | 59 | 50 |
| Santa Barbara East | ND | 29 | 65 | 147 | ND | ND | 76 | ND |
| Santa Barbara Harbor | ND | 37 | 86 | 20 | ND | ND | 45 | ND |

Table 13. Ground censuses of California brown pelicans *(Pelecanus occidentalis californicus)* at roosts along the coast in the vicinity of Naval Air Weapons Station, Point Mugu, California, in 1992–1993. Numbers for Mugu Lagoon represent the mean daily peak count.

| Location | October | November | February | April | June | July | September |
|---|---|---|---|---|---|---|---|
| Marina Del Rey breakwater | 368 | 636 | 616 | 321 | 405 | 342 | 261 |
| Malibu bait barge | 2 | ND | 5 | 3 | 29 | ND | ND |
| Malibu Lagoon | 12 | ND | 0 | 31 | 20 | ND | 0 |
| Mugu Lagoon | 100 | 41 | 61 | 116 | 197 | 117 | 137 |
| Channel Islands Harbor breakwater | 52 | 11 | 1 | 23 | 6 | 8 | 80 |
| Channel Islands Harbor inner | 44 | 11 | 16 | 21 | 13 | 12 | 9 |
| Santa Clara River | 74 | 8 | 3 | 87 | 74 | 86 | 1 |
| Ventura Harbor breakwater | 35 | 48 | 10 | 0 | 13 | 43 | 190 |
| Ventura Harbor inner | 14 | 16 | 6 | 7 | 9 | 1 | 4 |
| Mussel Shoals pier | 51 | 211 | 154 | 122 | 40 | 75 | 122 |
| Santa Barbara East | 114 | 160 | 52 | 29 | ND | 4 | 6 |
| Santa Barbara Harbor | 42 | 23 | 29 | 29 | ND | 24 | 30 |

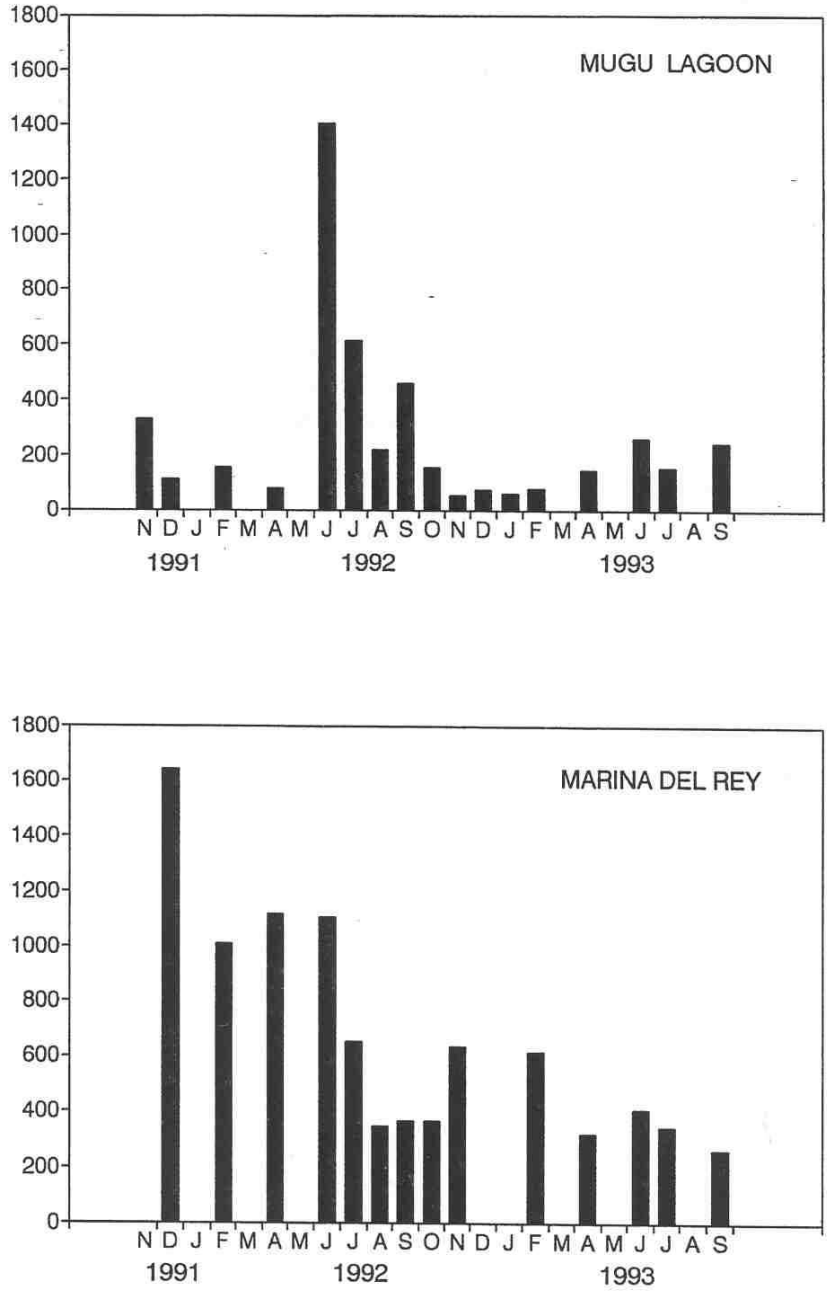



Figure 13. Numbers of California brown pelicans *(Pelecanus occidentalis californicus)* roosting at Marina Del Rey breakwater and Mugu Lagoon, California, from October 1991 to September 1993, based on ground censuses.

disturbances/hr at the Santa Clara River mouth (McGrath State Beach) compared to an average of 1 disturbance every 4 hr at the Marina del Rey Breakwater. These differences were related primarily to accessibility of roost sites to the public. Most roost sites in harbors were effective islands (e.g., detached breakwaters) buffered from human disturbance by deep water barriers. In contrast, pelicans roosting at small estuaries were vulnerable to disturbance from people and dogs on foot.

# Discussion

## Seasonal Abundance at Mugu Lagoon

In this study, we have established that abundance peaks of up to several thousand birds can occur at Mugu Lagoon any time from June through October. The annual peak in pelican use of the roost occurred during early summer in both 1992 and 1993. During 1990, the U.S. Fish and Wildlife Service (Laguna Nigul office, unpubl. data) also recorded peak numbers of pelicans in summer (June-August), but in 1989 the peak count was obtained in September. Briggs et al. (1981) recorded peak numbers at Mugu Lagoon in October during 3 years of study (1975-1977).

Pelican use of Mugu Lagoon in summer has definitely increased since the 1970s, but use in the fall may have declined. Briggs et al. (1981) counted all pelicans visible (flying, on the water, and on shore) from a 4.8-km section of shoreline at NAWS Point Mugu, including the Mugu Lagoon central basin. Monthly means from June to August ranged from 16.5 to 78 pelicans. Our mean counts for the same months, including only birds roosting in and around the central basin, ranged from about 150 to 900 pelicans (Fig. 5). The average of our fall mean counts, however, was lower than obtained by Briggs et al. (1981; Table 1). Increased use of the lagoon in summer is probably directly related to the recovery of the breeding population at Anacapa and Santa Barbara islands (Gress and Lewis 1988). Mugu Lagoon appeared to be heavily used as a staging area and roost site by birds commuting between Anacapa and the mainland. Mugu Lagoon is the closest mainland location where large numbers of pelicans roost, relative to Anacapa Island.

Pelican numbers at Mugu Lagoon reflected large-scale shifts in abundance in southern California (as observed during summer and fall aerial surveys) in many but not all respects. The most intense use of the lagoon corresponded to the period of peak pelican influx along the mainland coast during June 1992. Along with other nonbreeding areas, overall numbers at Mugu Lagoon were much lower in June 1993. However, differences between abundance patterns at Mugu Lagoon and the greater southern California region were noted: (1) peak use of the lagoon in 1993 occurred in June rather than in September; (2) numbers were higher in September 1992 than 1993, and (3) use of Mugu Lagoon declined from September to November 1992, whereas the population along the mainland increased.

## Factors Influencing Large-scale Annual and Seasonal Variation

Interannual variation in summer and fall counts of brown pelicans throughout the SCB appeared to be strongly influenced by differences in ocean conditions and local breeding success in 1992 and 1993. Ocean temperatures in the SCB were anomalously warm from about spring 1992 to early fall 1993 during persistent ENSO conditions (Hayward 1993; Kerr 1993).

Strong ENSO events affect the distribution and abundance of primary prey species such as the northern anchovy (*Engraulis mordax*) and Pacific sardine (*Sardinops sagax*) (Radovich 1961; Anderson et al. 1980, 1982; MacCall 1984, Pearcy et al. 1985; Fiedler et al. 1986). California brown pelicans have responded to periods of low food availability caused by ENSO conditions with a reduction in nesting attempts, high rate of breeding failure, early dispersal away from nesting colonies, and early migration to northern regions of the nonbreeding range (Anderson and Anderson 1976; Ainley et al. 1988; Jaques et al. 1994).

Brown pelicans experienced severe breeding failure in the SCB (Gress et al. 1995) and southern Gulf of California (D. W. Anderson, pers. comm. 1992) during 1992, presumably due to food shortages. Productivity at Anacapa and Santa Barbara Islands in 1992 was the lowest recorded since 1978 (Gress and Lewis 1988). Only about 1,750 nest attempts were made, and less than 400 fledglings were produced (Gress et al. 1995). Food shortages near Channel Islands nesting areas were evidently more severe than during the 1982-1983 ENSO, when an estimated 1,160 pelicans survived to fledging age. In Mexico, some colonies in the northern region of the Gulf of California were successful in 1992 despite ENSO conditions, while more southerly colonies were essentially deserted during the breeding season (D. W. Anderson, pers. comm. 1992).

Productivity at the California Channel Islands rebounded during the 1993 breeding season, when approximately 4,750 nest attempts were made and 3,225 young fledged. Although water temperatures were still above normal, collections of regurgitated fish indicated that Pacific sardine were locally abundant near Anacapa Island, and contributed to the successful breeding season in 1993 (F. Gress, pers. comm. 1993).

The very high numbers of pelicans at Mugu Lagoon and other roosts throughout southern California in June 1992 were probably composed largely of failed breeders and non-breeders dispersing from nesting islands early and emigrating north up the coast. The sharp drop in numbers by late August indicated that pelicans moved rapidly through the SCB to regions north of Point Conception during the summer. Evidence of a severe food shortage included a large-scale die-off of hundreds of pelicans between Santa Barbara and San Diego counties in June (Ingram and Jory 1993), apparently due to starvation. The brief, high peak in numbers of pelicans at Mugu Lagoon demonstrated use of the area as a stopover point during large-scale movement of birds along the coast.

In 1993, relatively low numbers of pelicans were observed at southern California roosts during summer, and counts peaked during the fall. This pattern may be more typical of most years, since it was associated with a more "normal" breeding season in relation to oceanographic conditions (Gress et al. 1995; Anderson and Anderson 1976; Briggs et al. 1981). Higher numbers of pelicans in the SCB in fall 1993 compared to 1992 probably reflected greater availability of prey resources, longer residence time of post-breeding birds, and greater production of fledglings.

### *Long-term Changes in Pelican Abundance and Seasonality in the SCB*

The early summer peak in pelican numbers during 1992 was unusual relative to studies conducted in California during the 1970s and early 1980s. Anderson and Anderson (1976) and Briggs et al. (1981, 1983) observed population peaks in California during the fall (September-October), even during ENSO years. The California Channel Islands breeding population increased greatly after 1984 (Gress and Lewis 1988; Carter et al. 1992), and the local contribution to the overall population has become more significant. High numbers of pelicans along the southern California mainland in early summer during ENSO years may consist largely of failed breeders from nearby colonies, mobilizing in advance of migrants from Mexico. During the 1987 ENSO event, Jaques and Anderson (1988) documented peak pelican numbers in central California in summer (July) rather than fall. The timing and severity of ENSO events, no doubt, has significant effects on pelican responses as well.

Overall shifts in pelican distribution within the SCB may also have occurred. Although comparable data is limited, it appears that use of the southern California coastal mainland by pelicans has increased while use of offshore island roosts has decreased. The first fall aerial survey of pelicans along the southern California mainland took place in September 1972, when 1,871 pelicans were counted (D. W. Anderson, unpubl. data). Fall (ground-based) estimates by Briggs et al. (1981) peaked at 800 birds during 1975-1978. Jaques et al. (1994) counted 3,005 and 856 pelicans from aerial surveys along the mainland in fall 1986 and 1987, respectively. The June 1992 count (8,250 pelicans) was clearly a large departure from earlier reference data. The September 1993 count (4,882 birds) also represented the highest fall count recorded for the southern California mainland. In contrast, estimates of pelicans offshore at the Channel Islands were highest during the mid-1970s. Using both shipboard and aerial censuses, Briggs et al. (1981) recorded fall peaks ranging from 5,500 to 10,500 birds along island shores. Estimates made in fall 1986 and 1987 (3,200 and 3,600 birds; Jaques 1994) and those obtained during this study (Table 9) were all at least 50% lower than the peak count obtained in 1977. Unfortunately, differences between survey techniques make some of the counts not directly comparable.

Long-term changes in the distribution and abundance of prey and northern range expansion of the brown pelican have probably affected pelican use patterns in the SCB. Since 1976, there has been a decline in the central stock of northern anchovies that spawn offshore in the SCB and a general northward shift in several stocks of small pelagic fishes (MacCall et al. 1985; Methot and Lo 1987; MacCall and Prager 1988). Pacific sardines are increasing in the California Current following a population crash in the 1950s, but their center of distribution has historically been north of the SCB (Barnes et al. 1992). Since about 1982, brown pelicans have expanded their range northward into Washington where they have found rich foraging areas and favorable roosting habitats associated with large, relatively undisturbed estuaries (Jaques et al. 1994). Pelican distribution in Oregon and Washington suggests that the northern stock of northern anchovy is a key prey item in that region. Thousands of post-breeding pelicans now migrate north of California in fall, whereas prior to 1982, numbers in Oregon and Washington were relatively insignificant (Briggs et al. 1983). Many post-breeding pelicans migrating north may now bypass offshore foraging areas and Channel Islands roosts, rely more on nearshore fishes while in the SCB, and move more rapidly through southern California to the new portions of the range. These 2 factors (shifts in the prey base and pelican range expansion) are probably linked, and ultimately related to long-term fluctuation in ocean climate and a series of strong ENSOs and other warm-water years (reviewed in Jaques et al. 1994). Additional data are needed to evaluate long-term changes in seasonal patterns of pelican abundance and distribution in California following the recovery of local breeding populations and ecological change in the marine environment.

### *Relative Importance of Mugu Lagoon*

Aerial surveys of daytime roosts revealed that Mugu Lagoon was one of the most important southern California mainland sites, both in terms of numerical abundance of pelicans and in the unique habitat that it offered (Tables 10, 11). Mugu Lagoon clearly contained the most important estuarine roosting habitat for pelicans between Point Conception and the Mexican border during this study. Our peak count of 1,404 pelicans at Mugu Lagoon represented the third largest roosting aggregation observed, following East Anacapa Island and the Marina del Rey breakwater. This peak was also the greatest number of pelicans ever documented in Mugu

Lagoon. Mugu Lagoon was one of only 3 major roosts along the mainland coast that existed as a natural habitat. It provided adequate roosting substrates, partial protection from humanrelated disturbances, foraging opportunities both within and just outside the lagoon, and a mainland staging area adjacent to the breeding colony and major night roost at Anacapa Island.

The majority of roosting pelicans in southern California occurred in harbors on man-made structures. Presence of these birds in harbors increases the chances for contact with oil and other contaminants, injuries from fishing hooks and entanglement in monofilament.fishing lines, as well as intentional harm by humans. Pelicans roosting at more natural sites such as Mugu Lagoon generally do not become a nuisance to fishermen or property owners and are less exposed to hazards associated with the highly developed southern California coastline. Furthermore, most southern California roosts are not secure (i.e., they are generally not managed for their wildlife value and may cease to exist depending.on changes in human use or habitat alteration). One example is the loss of the barge roost at Santa Barbara when the barge was put back into commercial operation.

### *Habitat Use and Diurnal Pattern at Mugu Lagoon*

The Mugu Lagoon central basin and associated mudflats, sandbars, and sandspits were the areas used most consistently and heavily by pelicans within the NAWS Point Mugu property. Pelicans probably selected the central basin as their primary roost location because (1) it was the largest body of open water in closest proximity to the ocean, (2) it provided vegetation free terrestrial substrates relatively isolated from potential land-based sources of disturbance, and (3) it offered advantages in terms of detection of and proximity to fish schools. Pelicans roosted on islands, peninsulae, or edges of land that were largely surrounded by water and relatively inaccessible to people and potential predators. These birds evidently recognize that deep water provides a buffer to disturbances. "Safe" roosts theoretically allow pelicans to maximize time spent resting and preening and minimize the amount of time spent in vigilance or flushing behavior.

Night roosts selected by pelicans at Mugu Lagoon appeared to offer the greatest amount of predator protection. Aerial photographs from 1990 show that the primary night roost site (AFLT) is isolated from the mainland by a tidal creek. Photographs from 1971 to 1983 (Onuf 1987) reveal that this tidal creek was formerly the western edge of the open water area before sedimentary filling created the mudflat. The exclusive use of this quasi-island mudflat for night roosting during most of the study suggests that it was perceived by pelicans as the area least accessible to dogs, coyotes, foxes, and so forth. As the east spit extended further into the open water area of the central basin, it became an adequate alternate location for night roosting.

Most night roosts in California occur on dry substrates completely surrounded by deep ocean water, including offshore rocks, islands, and breakwaters (Jaques and Anderson 1988). Both very high and very low tides diminished the effective island habitat at inner sandbar and mudflat roosts ("AFLT" and "CENTER"). The lack of permanent island habitat and deep water buffers within the lagoon probably led to reduced use and quality as a night roost for pelicans, compared to daylight use, when approaching threats could be seen. Although Mugu Lagoon was used for nocturnal roosting nearly every night of observations, higher numbers consistently occurred during the day.

Brown pelicans appear to rely on Mugu Lagoon most heavily during the day as a place to rest in association with nearshore foraging, and move offshore to more desirable roosts on the Channel Islands at night. The typical early morning arrival of large numbers of pelicans and predictable evening exodus reflected use of the lagoon as a staging area. It probably served regularly as a first and last stop for birds commuting between the mainland and Channel Islands roosts.

### *Disturbance at Mugu Lagoon*

The frequency and severity of disturbance to pelicans at Mugu Lagoon were highly variable, but the following general statements can be made:

1. Waterfowl hunting caused the greatest amount of disturbance of all human activities that took place at the lagoon. This source of disturbance was limited, however, to 9 days during 2 years. Gunshots from blinds in the interior of the estuary caused pelicans to flush from and depart from their night roosts prior to sunrise. Shooting activity throughout the day generally prohibited use of roosts inside the lagoon by pelicans. Pelicans roosting on the outer sandspits near the mouth of the lagoon were rarely affected directly by hunting activities.

2. Recreational activities on the west spit and trespassing on the east spit (mostly by surfers) resulted in a relatively chronic, year-round source of disturbance. Most disturbance to pelicans occurred on the outer sandspits. Persons walking with dogs caused pelicans to flush more readily that did persons without dogs. Most pelicans flushed by pedestrians or dogs relocated a short distance to other roost sites within the central basin.

3. Aerial operations were probably the most frequent potential source of disturbance, but their impact on pelicans appeared to be low. Most pelicans that flushed in response to aircraft spent a brief period in flight and relanded at the same roost site. The response to aircraft was most similar to response to raptors and other natural disturbances. These sources of disturbance generally did not preclude pelicans from roosting at a particular location in the lagoon, unlike hunting and recreation disturbance. Birds that used the lagoon regularly may have become habituated to aerial operations.

4. Overall disturbance levels decreased at Mugu Lagoon during the study, partly due to changes in lagoon configuration. After extensive erosion of the west spit, the relatively remote roost at the former tip was lost. The remnant west spit was small and frequently occupied by people, which precluded pelicans from landing there. Thus, the frequency of encounters on the west spit was reduced. Enforcement of trespassing laws may have decreased disturbance by surfers using the east spit. Overall pelican use of the lagoon also decreased during the study (presumably due to natural factors) and resulted in lower disturbance index values.

The pelican roost at Mugu Lagoon was consistently used at the current observed level of disturbance. The overall frequency of disturbance during all non-hunt days (0.196 events/hr) was higher than the non-hunt rate at Elkhorn Slough (0.1 events/hr), located in Monterey Bay in central California (Jaques and Anderson 1988). The disturbance rate was less at Mugu Lagoon on hunt dates (0.903 events/hr), where hunters are restricted to blinds, than at Elkhorn Slough (2.1 events/hr) where hunters were allowed to stalk the entire area.

Overall, Mugu Lagoon had a lower rate of disturbance than the combined value for other roosts sampled in the vicinity. Whether long-term use of the Mugu Lagoon roost might increase with a decrease in disturbance frequency is unknown. Threshold levels of disturbance that would affect traditional use of a pelican roost have not been determined. However, it is apparent that habitats used by sensitive birds will be avoided or abandoned if disturbance becomes too chronic or intense (Burger 1981 a, b; Stalmaster and Newman 1978). Resident birds may habituate to certain kinds of activity, while migrant pelicans using the site for a short time may not habituate. In addition, there are many other factors that may act in concert or separately to affect roost site use (e.g., prey conditions, breeding success, habitat changes, etc.).

## Conclusion and Management Recommendations

Mugu Lagoon is a key roost for both resident and migrating brown pelicans in the SCB. The roost site appears to be in good status due to the combination of adequate water buffers surrounding appropriate terrestrial substrates and highly restricted human access to the central basin wetlands.

Several existing management policies at NAWS Point Mugu serve to limit disturbance to pelicans (and other wildlife species) in the central basin: (1) waterfowl hunting in the central basin has been reduced to 4 days of the year and is limited to 2 blinds; (2) flight paths for helicopter operations have been altered and all aircraft have been directed to remain above 275 m altitude over the lagoon; (3) public access to the area is limited by tight entry restrictions on the base; and (4) no activities other than waterfowl hunting and research are allowed within the lagoon wetlands. In 1992, the Environmental Division required the waterfowl blind near the AFLT roost to be relocated further away from the lagoon mouth. This measure may have decreased, but did not prevent hunting-related disturbances to brown pelicans.

Disturbances to pelicans could be further reduced without affecting normal operations of the base by placing additional restrictions on recreational activities and increasing enforcement of existing regulations. For example, people might be prohibited from walking on the west spit during hunting days. This would help to ensure that alternate roost sites near the mouth of the lagoon are available when pelicans are flushed from inner areas of the central basin. The leash law for dogs on the west spit should be strictly enforced at all times. Additional fencing, surveillance, and prosecution of trespassers may be necessary to reduce disturbance from surfers, and others who access the lagoon from the highway or state beach border.

Since the physical configuration of the central lagoon basin is dynamic (Onuf 1987), pelican use-patterns and management problems. also will change. Pedestrian access and vulnerability of roost sites to disturbance will vary with the lagoon. Any processes that create or increase the integrity of islands within the central basin will reduce disturbance and may increase use of the lagoon as a night roost. Potential habitat changes associated with sedimentary filling of the lagoon, such as deterioration of island habitat or loss of deep-water buffers, could be the greatest detriment to long-term use of the roost. Physical enhancement of the night roost on AFLT might be achieved by dredging the tidal creek that separates the mudflat from the mainland and piling the spoils on the mudflat near the center of the basin.

The estuarine roost at Elkhorn Slough in central California has been abandoned since 1989 due to habitat alterations that eliminated an adequate water buffer between pelicans and disturbance sources (Jaques and Strong, unpubl. data). At Elkhorn Slough, water was drained from the night roost ponds, and human and predator access was increased by creation of a levee through the center of the area by the California Department of Fish and Game as part of a multi-species habitat restoration project.

Some degree of continued pelican monitoring should take place at Mugu Lagoon so that specific management guidelines remain relevant to current scenarios. The NAWS Point Mugu has demonstrated a long-standing concern and commitment for maintaining Mugu Lagoon as quality

wildlife habitat, which includes the most important pelican roost site of the remaining southern California estuaries.

Increased awareness of other important roost sites in the SCB is needed. Policies regarding pelican roosts on other government lands should be formulated. Active management to reduce disturbance and otherwise preserve or enhance roosts may be necessary. Further assessment of given sites may be needed. Management agencies should engage in discussions with private entities that host roosting pelicans on their property. At some sites, large groups of pelicans may be incompatible with the intended use of the property. Loss of roosts on artificial structures in southern California could be mitigated by setting aside or creating other appropriate artificial roost sites.

The distribution and abundance of brown pelicans along the Pacific Coast will vary with both short and long-term changes in ocean climate and fisheries. Dispersion of quality roost habitat throughout the nonbreeding range will have a positive influence on energy budgets of pelicans responding to both natural and human-induced changes in the coastal environment. Broadscale cataloguing and protection of major roost sites is one objective of the California Brown Pelican Recovery Plan (U.S. Fish and Wildlife Service 1983) that has not yet been met.

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