Brown Pelican Roosting Patterns and Responses to Disturbance at Mugu Lagoon and Other Nonbreeding Sites in The Southern California Bight

Deborah L. Jaques, Craig S. Strong, and Thomas W. Keeney

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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The Cooperative Park Studies Unit at The University of Arizona (CPSU/UA) was established 16 August 1973 as a unit in the National Park Service (NPS). By action of Secretary of the Interior Bruce Babbitt, the research function of NPS and several other Interior agencies was transferred to a newly created agency, the National Biological Service (NBS), on 12 November 1993. At that time, the CPSU/UA and unit personnel were transferred to the new agency.

The CPSU/UA provides a multidisciplinary approach to studies in natural and cultural sciences. The unit conducts and coordinates research that is funded by various agencies. Principal Arizona cooperators include the School of Renewable Natural Resources and the Department of Ecology and Evolutionary Biology of The University of Arizona. The Western Archeological and Conservation Center (NPS) and the School of Renewable Natural Resources (UA) provide administrative assistance. Unit scientists hold faculty or research associate appointments at the university.

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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

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The Channel Islands National Marine Sanctuary (LCDR Steve Jamieson and John Miller) granted permission for aerial surveys over Santa Barbara, Anacapa, Santa Cruz, Santa Rosa, and San Miguel Islands (under permits CINMS-04-92 and CINMS-05-92). We are grateful to Paul Valovich and S. Laughter, commanding officers at NAWS Point Mugu, and Barry Winkle, officer-in-charge of San Nicolas Island. We also thank the Naval Warfare Center, Weapons Division, for scheduling our time in the Outer Sea Test Range. We appreciate the cooperation and services of Aspen Helicopters, Inc. of Oxnard (Charlie McLaughlin, president) and the excellent piloting by John Drust during aerial surveys. The California Department of Fish and Game provided flight time on their aircraft for certain surveys.

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Abstract

We studied California brown pelican (*Pelecanus occidentalis californicus)* 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

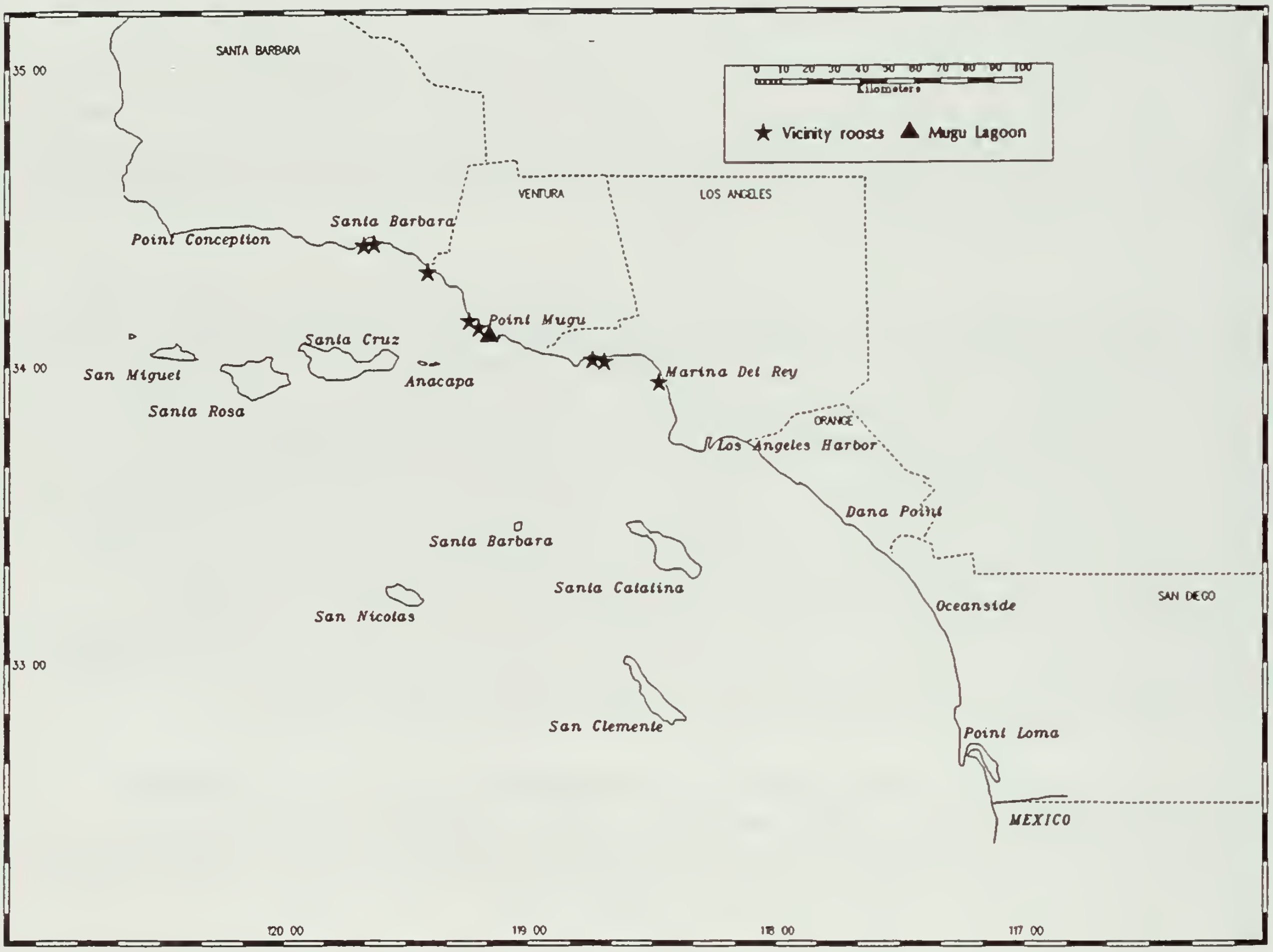


Figure 1. Southern California brown pelican *(Pelecanus occidentalis)* study area showing aerial survey region (Point Conception to the Mexican border and all island perimeters), vicinity roost locations (stars), and location of Naval Air Weapons Station Point Mugu (triangle).

anded both on Anacapa Island and in Mexico frequent the lagoon (D. W. Anderson, unpubl. ata).

n this report, we summarize findings of 2 years of research (October 1991–October 1993) on the oosting ecology of brown pelicans at Mugu Lagoon, within the Naval Area Weapons Station NAWS) Point Mugu, in Ventura County, California. The need for this study arose from uestions regarding the effects of human activities, including waterfowl hunting, on pelicans. 'his study was designed to achieve an understanding of the use of Mugu Lagoon by brown elicans so that the effects of human disturbance, current management practices, and physical haracteristics of the lagoon could be evaluated. Protection of communal pelican roosts in outhern California is important to the health of the California brown pelican population.

'his is the first focused study of brown pelicans at Mugu Lagoon and the only detailed study of ny roost in southern California. We examined seasonal abundance, habitat use, diurnal patterns f occupation, and responses to disturbance at Mugu Lagoon. To evaluate the relative importance nd role of the lagoon within a larger region, we conducted ground surveys of mainland roosts vithin an 80-km radius of Point Mugu, and conducted 6 aerial surveys of brown pelicans in the outhern 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.

'he 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 1981a, 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).

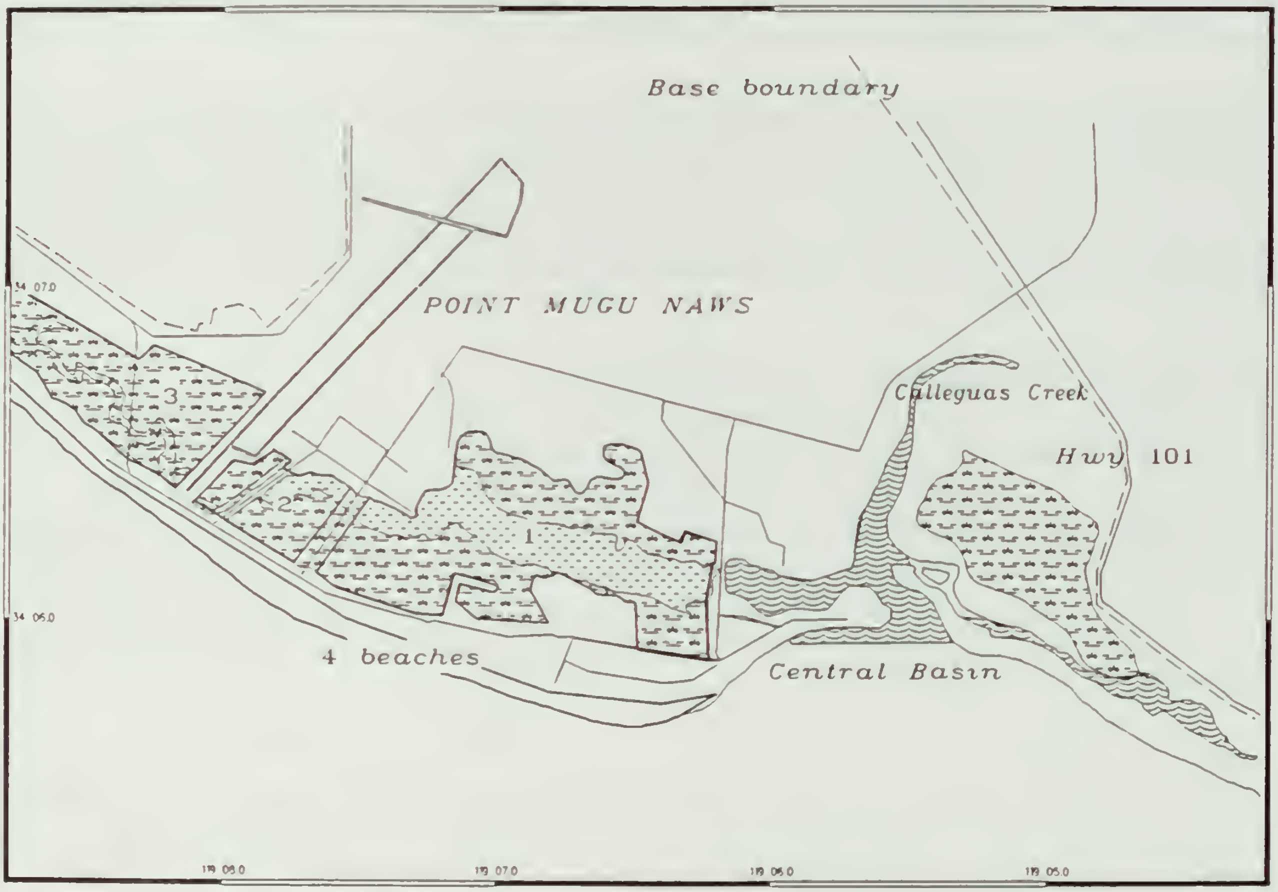


Figure 2. Naval Air Weapons Station Point Mugu, Mugu Lagoon, California, and wetland areas. Numbers on figure refer to western areas (see text).

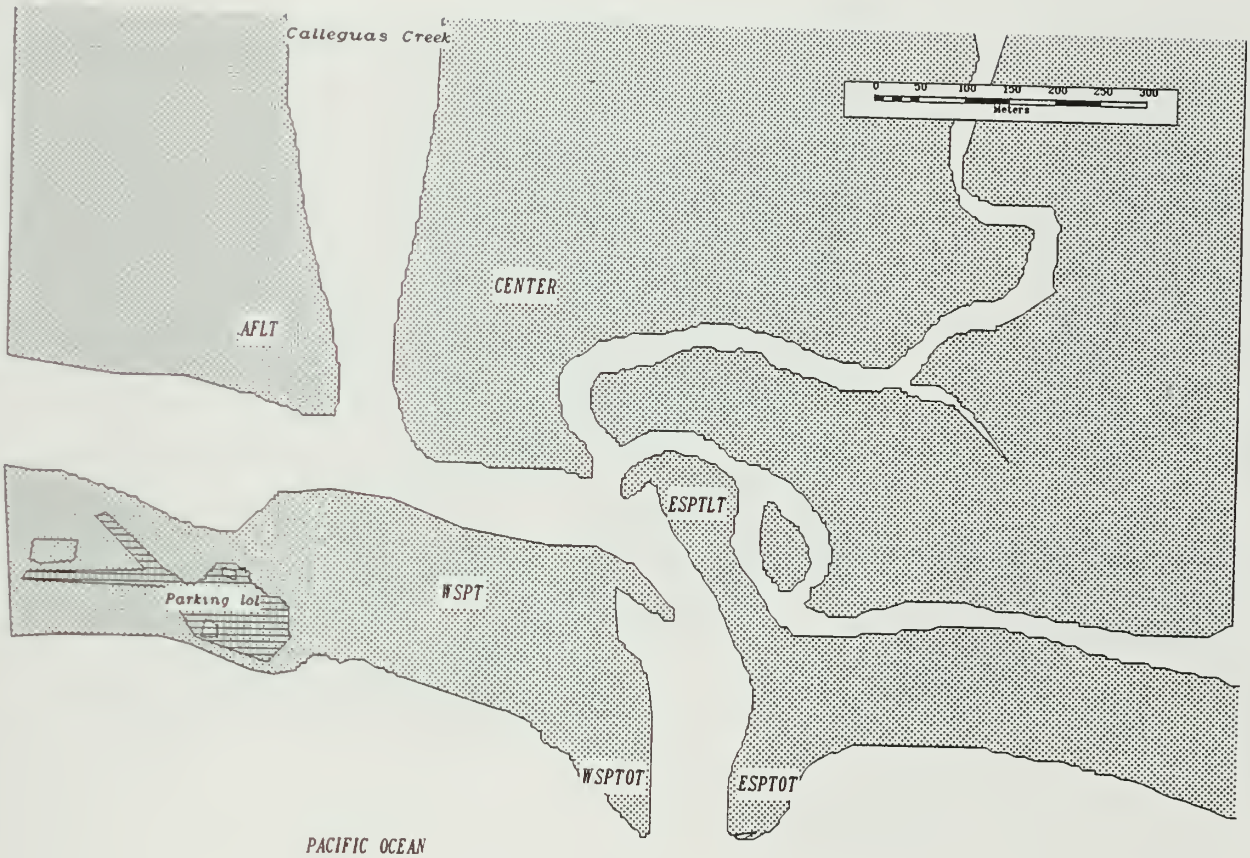


Figure 3. Central basin of Mugu Lagoon, California, showing approximate sandbar configuration and roost location names from October 1991 to January 1992, prior to flooding. Locations are coded as follows: WSPT (West Spit), WSPTOT (West Spit Ocean Tip), ESPTLT (East Spit Lagoon Tip), ESPTOT (East Spit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

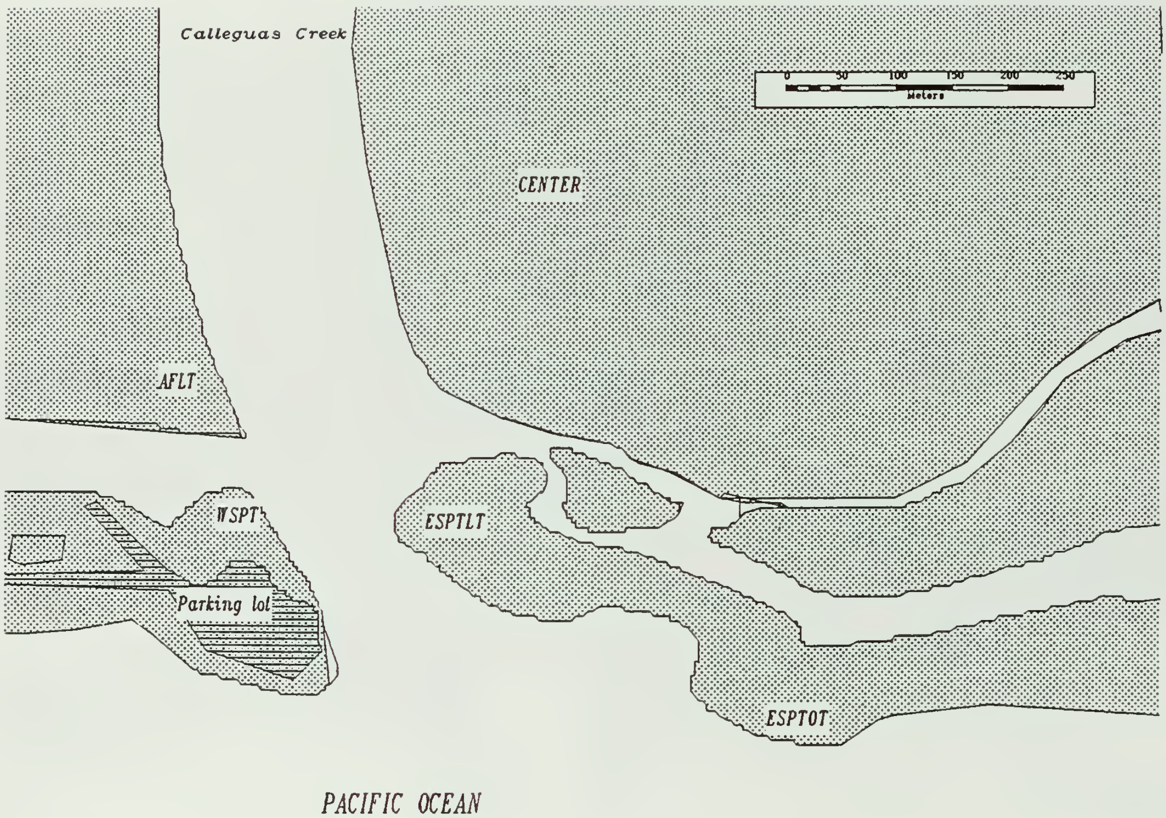


Figure 4. Central basin of Mugu Lagoon, California, showing approximate sandbar configuration and roost locations following winter 1992 flooding. The sandbars continued to shift throughout the study period, but remained approximately as above (drawn from aerial photographs taken in June 1993). Locations 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
   f. 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 = 50,510). 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.

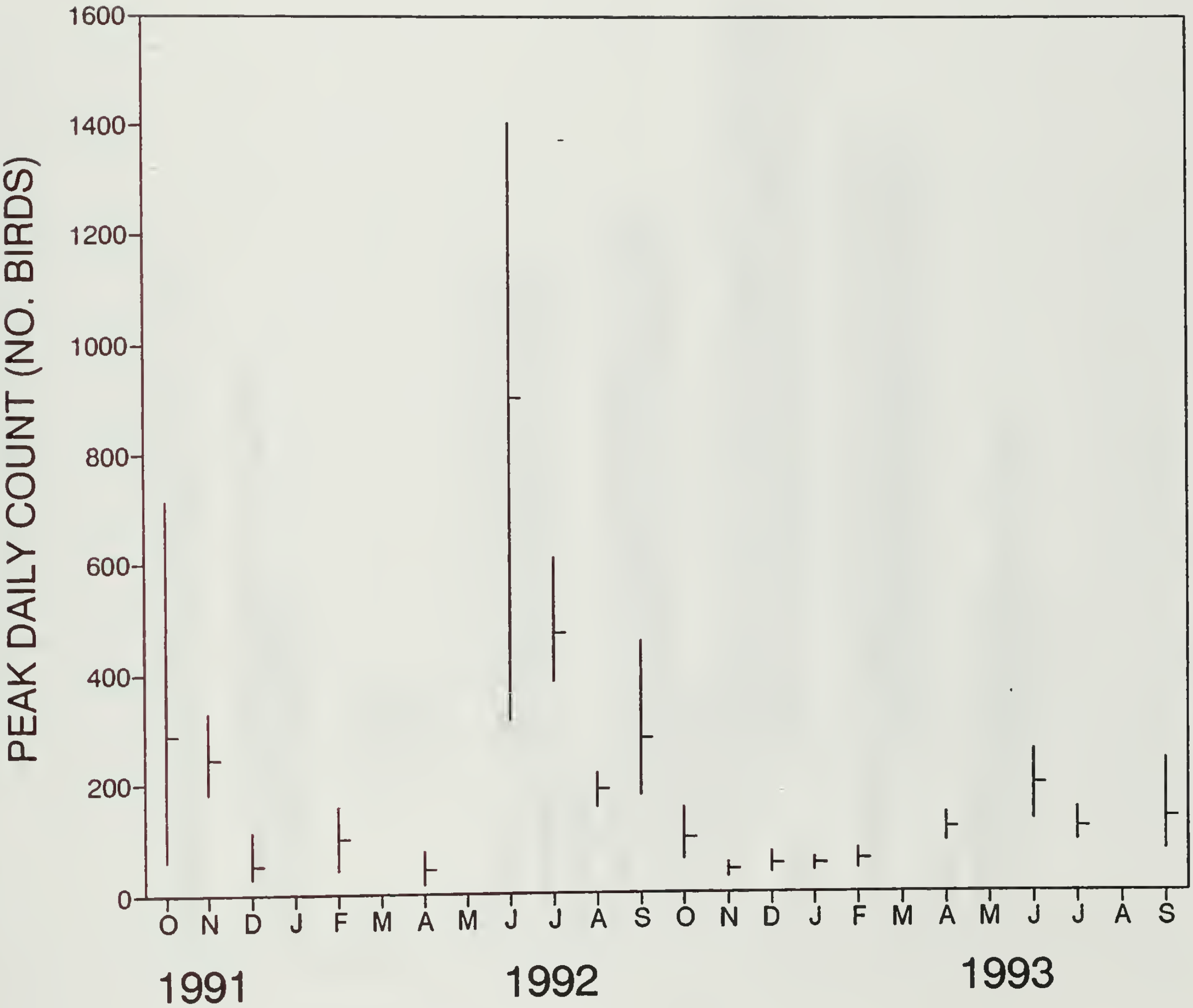


Figure 5. California Brown pelican *(Pelecanus occidentalis californicus)* abundance in the Mugu Lagoon central basin, California, between 24 October 1991 and 29 September 1993. Values shown are the mean (horizontal line) and range (vertical line) of the daily high count over 3- to 6-day survey periods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

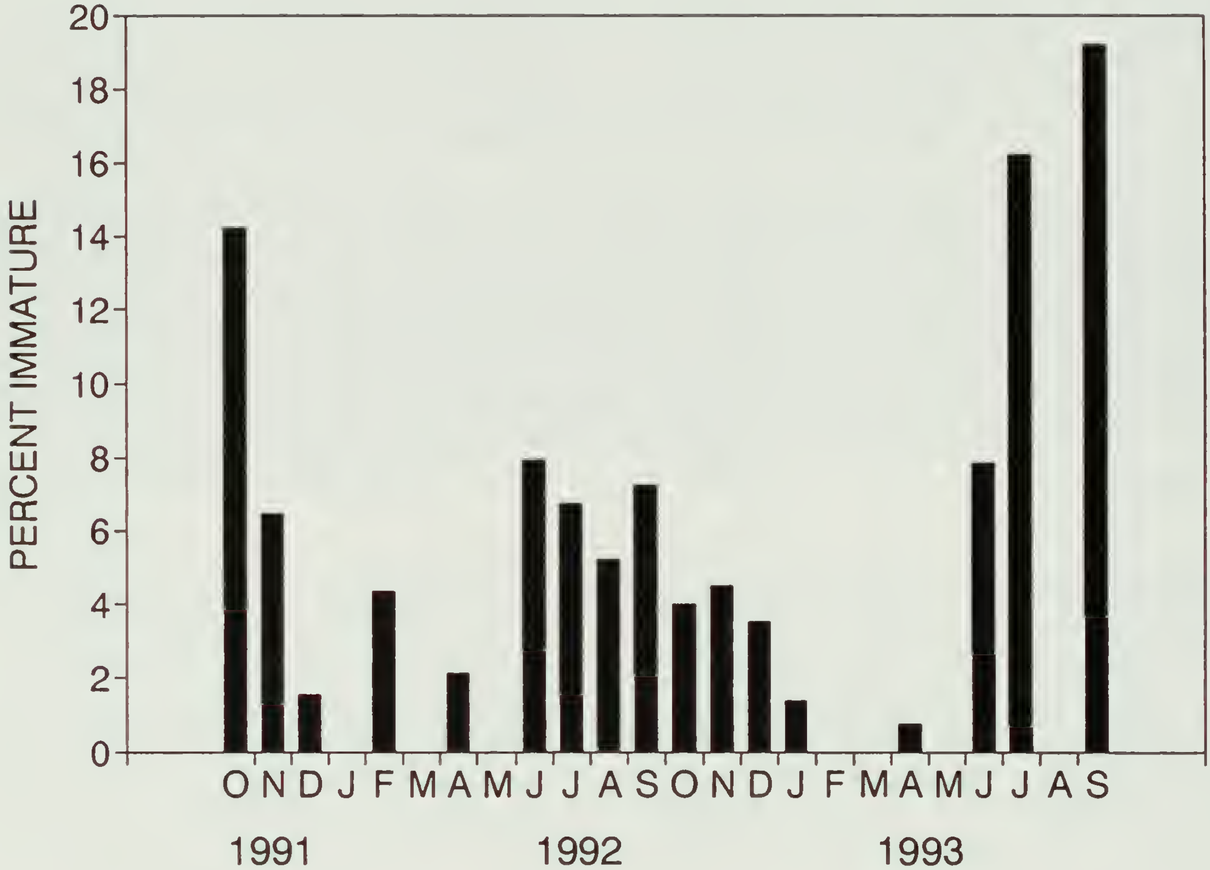


Figure 6. Average percent of immature California brown pelicans (*Pelecanus occidentalis californicus)* using Mugu Lagoon, California, in 3- to 6-day observation periods from October 1991 to October 1993.

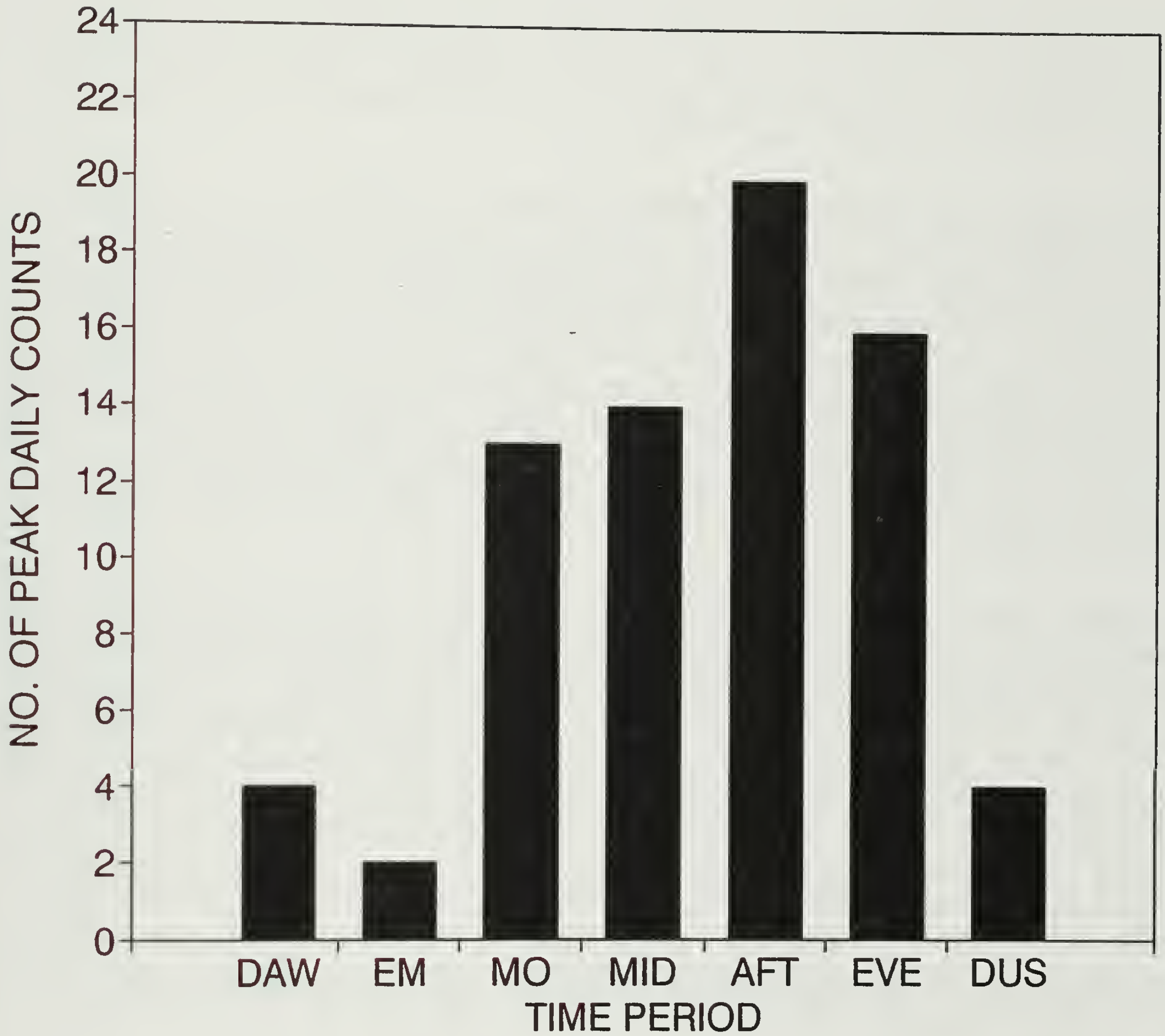


Figure 7. Diurnal pattern of California brown pelican *(Pelecanus occidentalis californicus)* use of the Mugu Lagoon central basin, California. The number of times the peak count occurred in each of 7 time periods through the day, for all days of observation (October 1991–October 1993) are shown.

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)

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 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

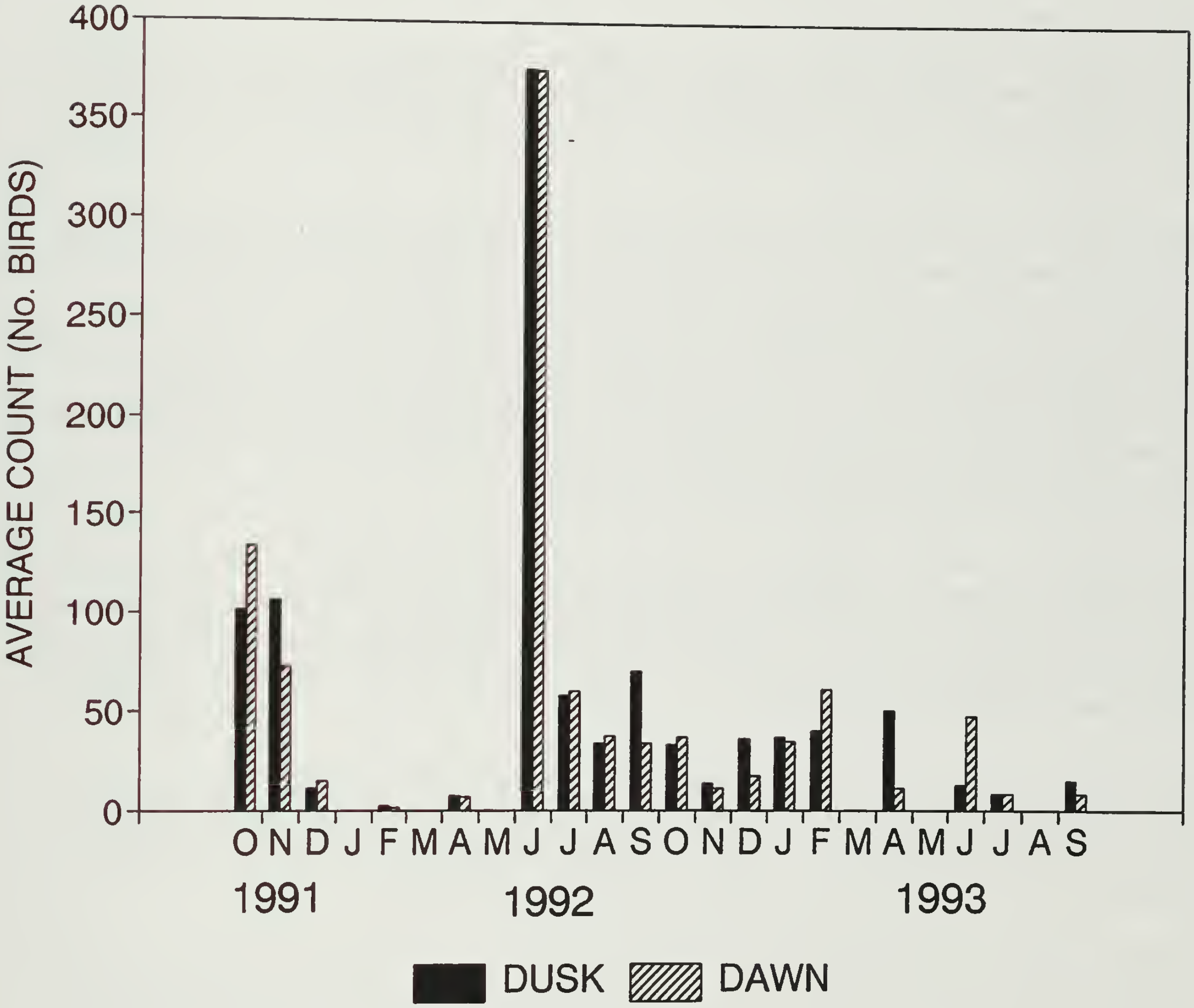


Figure 8. Counts of California brown pelicans *(Pelecanus occidentalis californicus)* at dusk and at dawn in Mugu Lagoon central basin, California, averaged over 3- to 6-day study periods from October 1991 to October 1993.

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 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 non-hunt 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

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).

Time Period	No. of days	Roost Area				
		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			

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).

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).

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

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 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).

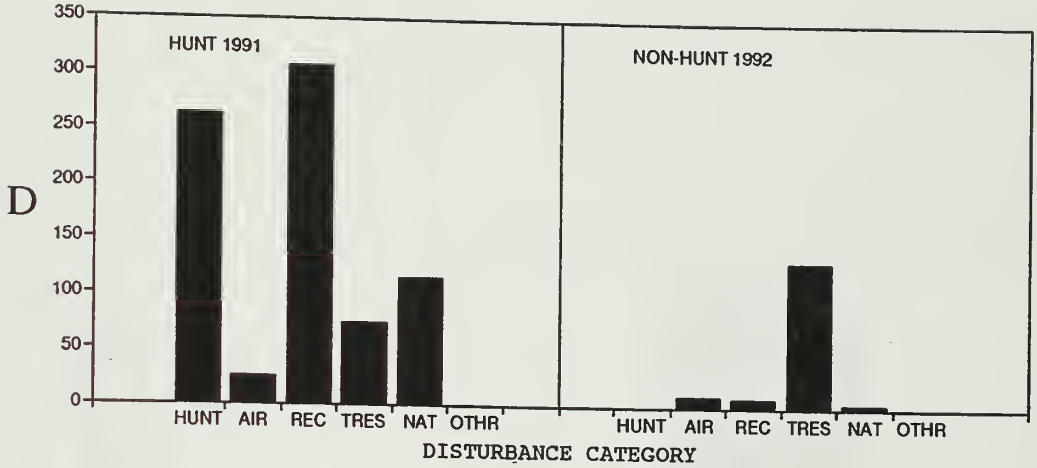
Additional disturbances were probably indirectly related to hunting because hunters often prevented pelicans from using interior roost sites. Pelicans roosting on the outer sandspits were more vulnerable to disturbance from pedestrian recreational activities. Increased use of the west spit by displaced 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.



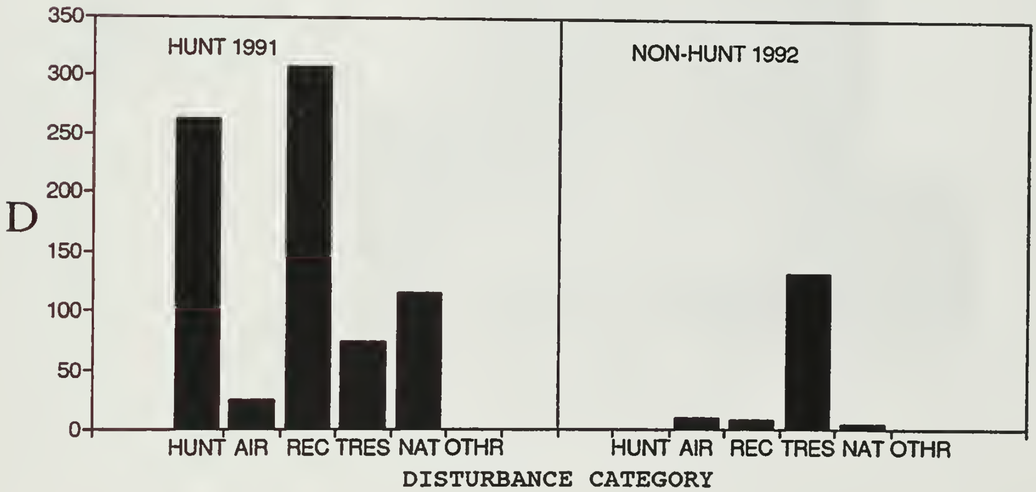


Figure 9. Impact of 6 disturbance sources measured by the "D" index of disturbance (see text) on California brown pelicans *(Pelecanus occidentalis californicus)* at Mugu Lagoon, California, during 4 periods: waterfowl hunt 1991 (October–December), non-hunt 1992 (February–September 1992), hunting 1992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

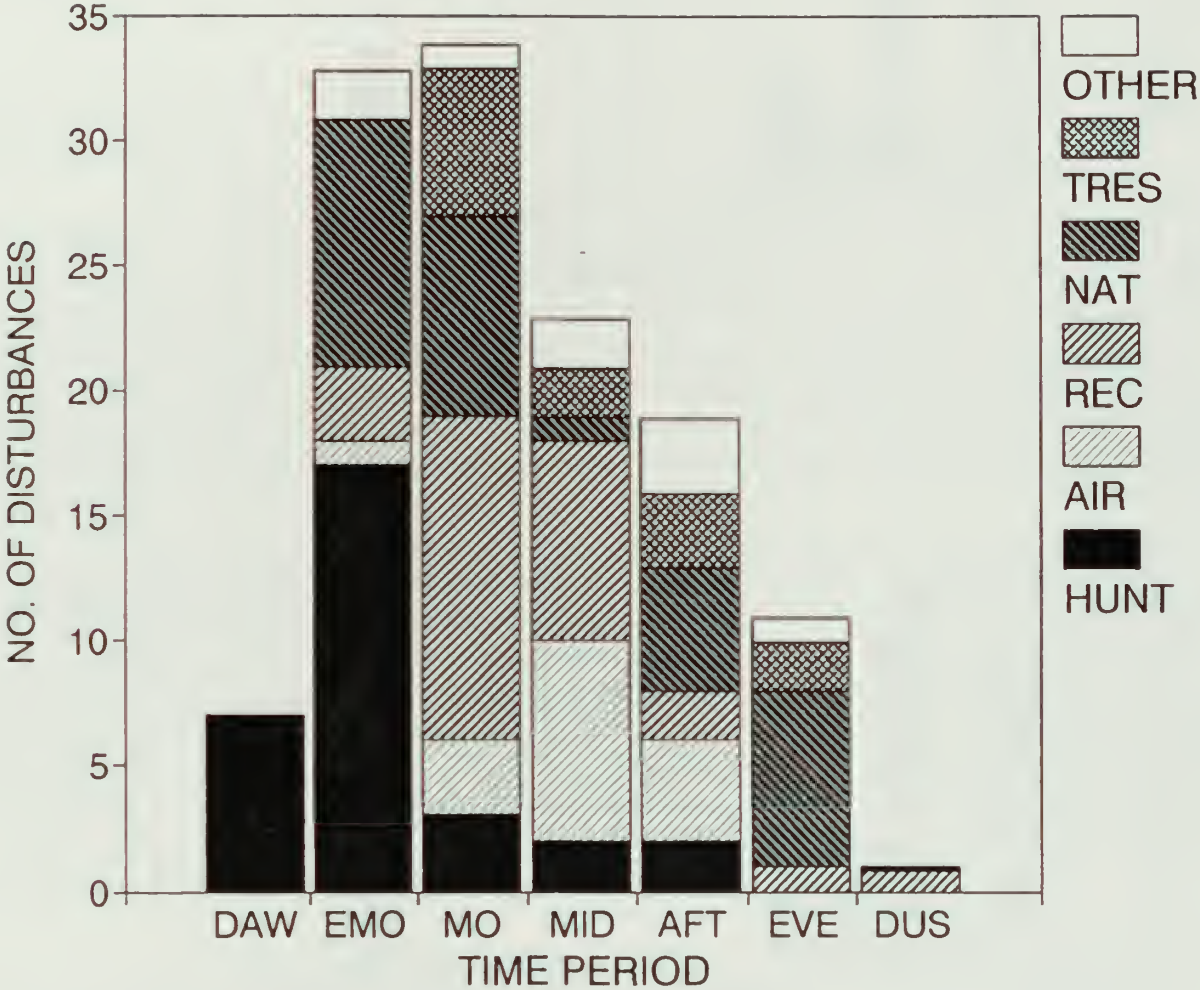


Figure 10. Number of disturbances to California brown pelicans *(Pelecanus occidentalis californicus)* at Mugu Lagoon, California, caused by 6 disturbance sources in 7 time periods through the day.

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)

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

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).

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 Niño-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.

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.

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

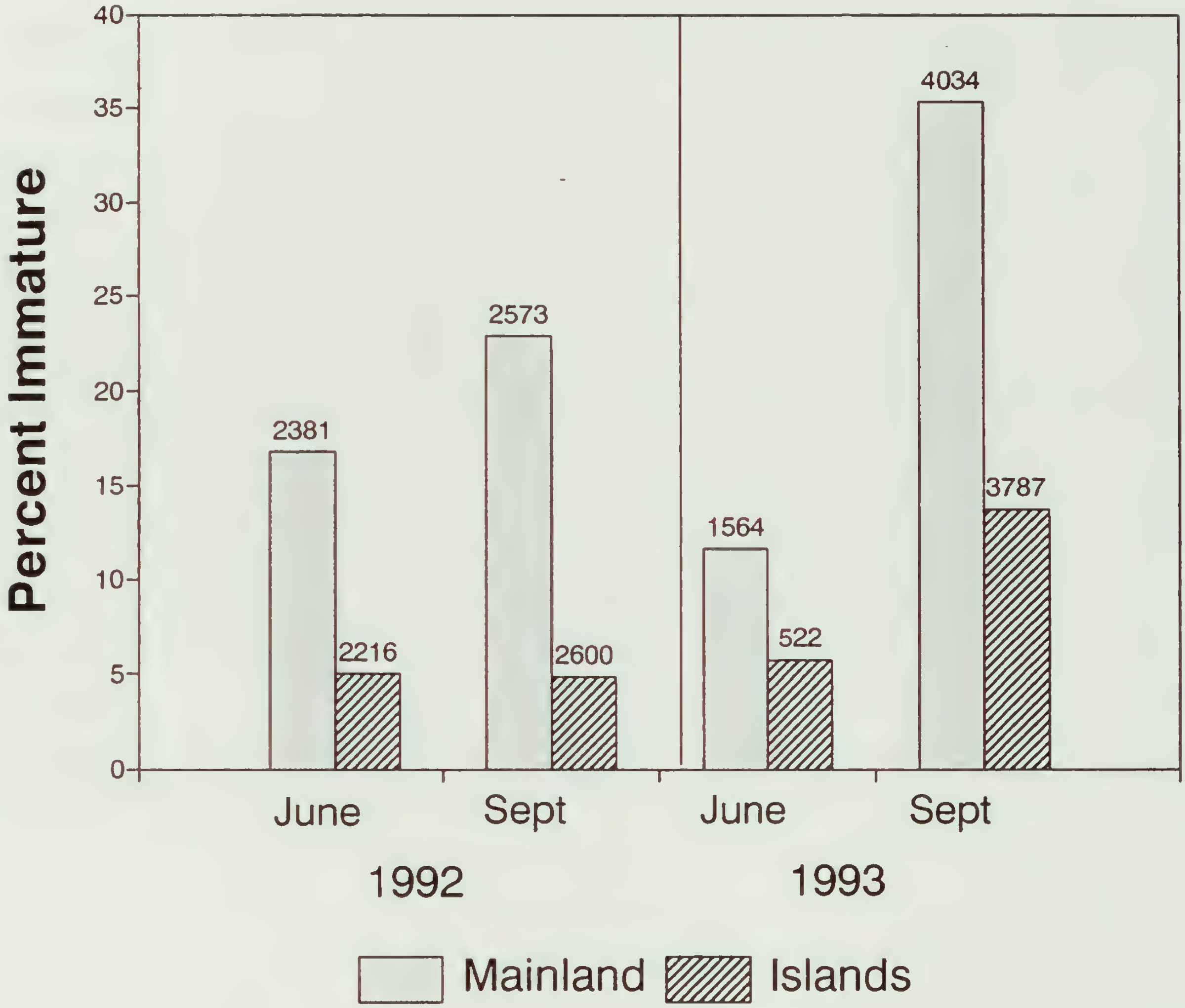


Figure 11. Percent of immature California brown pelicans *(Pelecanus occidentalis californicus)* observed at nonbreeding sites in the Southern California Bight during air surveys in 1992 and 1993. Immatures included all pelicans with brown heads and white bellies (hatch-year and young of previous year).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

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.

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.

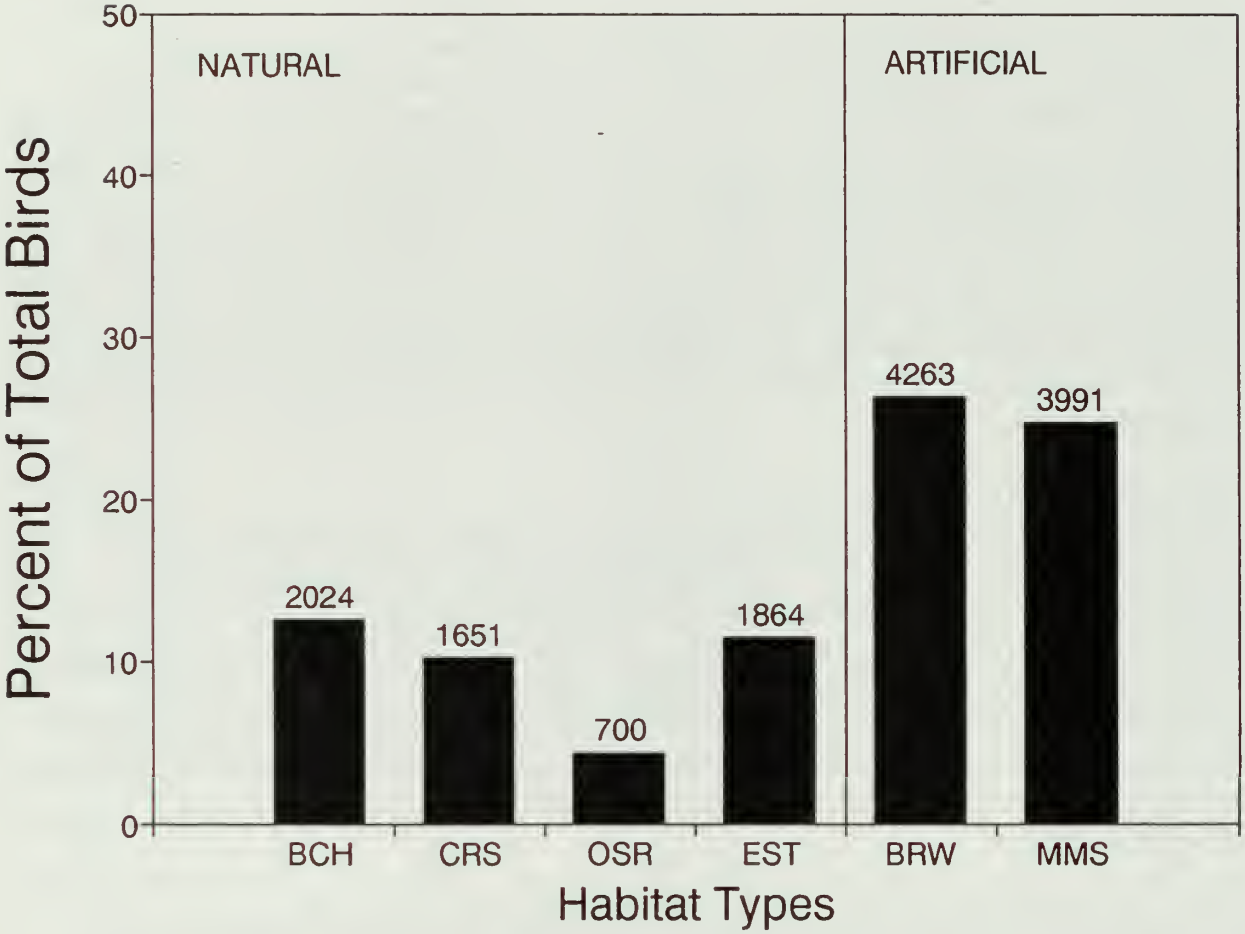


Figure 12. Habitat types used by roosting California brown pelicans *(Pelecanus occidentalis californicus)* on the southern California mainland coast from June and September 1992 and 1993 aerial surveys.

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

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.

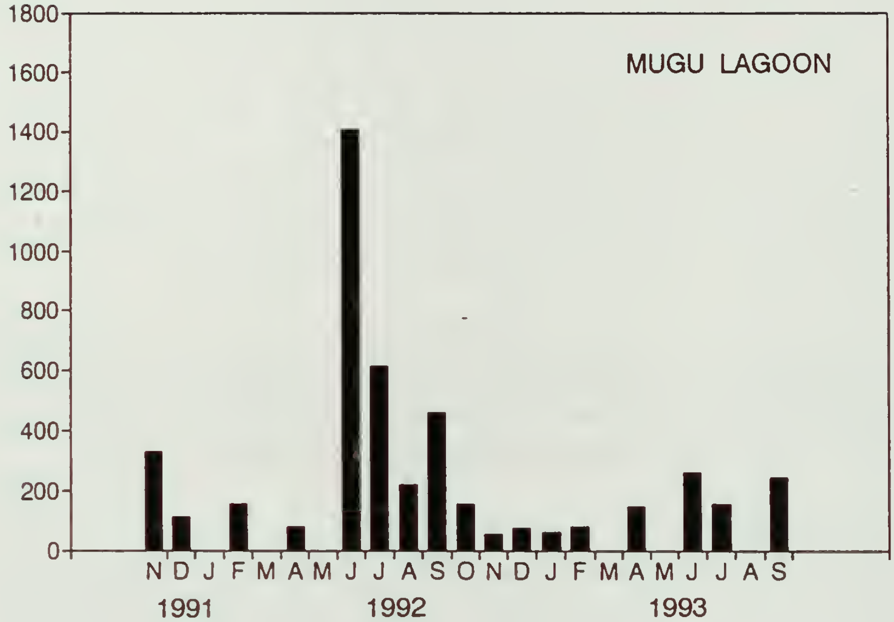
Location	October	November	February	April	June	July	September
Marina Del Rey breakwater	368	636	616	321	405	342	261
Malibu bait barge	2	ND	5	3	29	ND	ND
Malibu Lagoon	12	ND	0	31	20	ND	0
Mugu Lagoon	100	41	61	116	197	117	137
Channel Islands Harbor breakwater	52	11	1	23	6	8	80
Channel Islands Harbor inner	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

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 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.



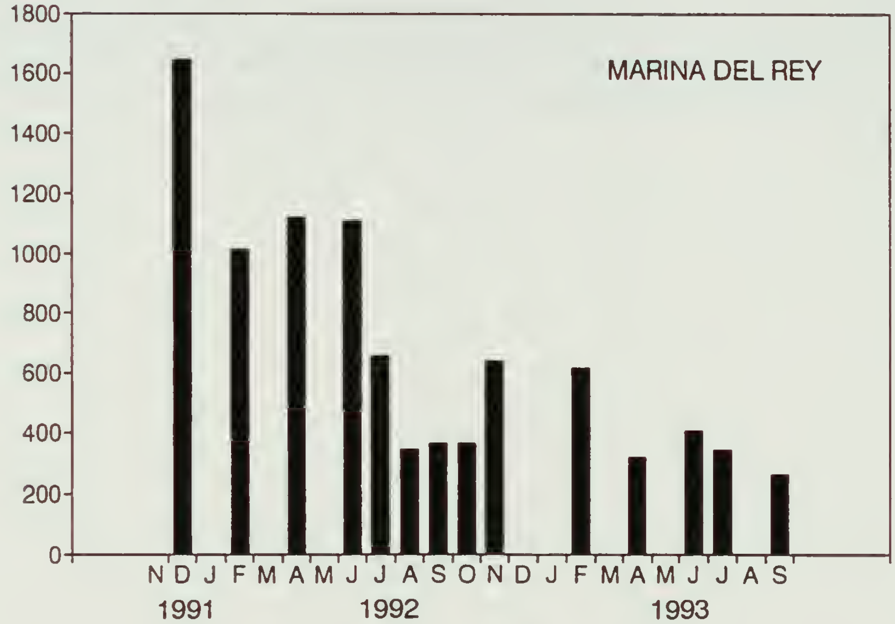


Figure 13. Numbers of California brown pelicans *(Pelecanus occidentalis californicus)* roosting at Marina Del Rey breakwater and Mugu Lagoon, California, from October 1991 to September 1993, based on ground censuses.

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 human-related 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 1981a, 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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As the nation's principal conservation agency, the U.S. Department of the Interior has responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting fish, wildlife and plants, preserving the environmental and cultural values of national parks and historic places, and providing for enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.