RESTORATION OF COMMON MURRE COLONIES IN CENTRAL CALIFORNIA: ANNUAL REPORT 1998

FINAL REPORT TO THE *APEX HOUSTON* TRUSTEE COUNCIL

FINAL

by

Michael W. Parker[1], Jennifer A. Boyce[1,2], Emilie N. Craig[1,2], Holly Gellerman[1,2], David A. Nothhelfer[1,2], Richard J. Young[1,2], Stephen W. Kress[3], Harry R. Carter[4,2], and Genie A. Moore[1]

[1] U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex, P.O. Box 524, Newark, CA 94560
[2] Humboldt State University, Department of Wildlife, Arcata, CA 95521.
[3] National Audubon Society, 159 Sapsucker Road, Ithaca, NY 14850
[4] U.S. Geological Survey, Biological Resources Division, 6924 Tremont Road, Dixon, CA 95620

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RESTORATION OF COMMON MURRE COLONIES ON THE CENTRAL CALIFORNIA COAST: ANNUAL REPORT 1998

EXECUTIVE SUMMARY

The 1986 *Apex Houston* oil spill killed approximately 9,000 seabirds, including 6,000 Common Murres (*Uria aalge*), in central California. The case was settled in August 1994 and a trustee council, comprised of representatives from U.S. Fish and Wildlife Service, California Department of Fish and Game, and National Oceanic and Atmospheric Administration, was established to oversee implementation of restoration actions for natural resources injured by the spill. Three projects have been approved to date: 1) the Common Murre Restoration Project; 2) the Marbled Murrelet (*Brachyramphus marmoratus*) Nesting Habitat Acquisition Project; and 3) Island habitat restoration activities at Southeast Farallon Island (Farallon National Wildlife Refuge).

The Trustee Council selected the U.S. Fish and Wildlife Service (San Francisco Bay National Wildlife Refuge Complex; hereafter "Refuge") to lead the Common Murre Restoration Project. Following preparation of a publicly reviewed restoration plan, the Refuge established Scientific and Environmental Education programs, within the Common Murre Restoration Project. Field work for the Scientific Program is being conducted by biologists from the Refuge in collaboration with the U.S. Fish and Wildlife Service (Ecological Services), Humboldt State University, National Audubon Society, U.S. Geological Survey (Biological Resources Division), and Point Reyes Bird Observatory. Additional collaboration has been provided by: National Park Service (Point Reyes National Seashore), Gulf of the Farallones and Monterey Bay National Marine Sanctuaries, California Department of Fish and Game, and California Department of Parks and Recreation. In addition, the Environmental Education Program is being implemented by the Refuge. This report summarizes results for year 3 (Federal Fiscal Year 1998) of the Common Murre Restoration Project's Scientific and Environmental Education programs.

Efforts to restore the Common Murre colony at Devil's Slide Rock in central California continued in 1998 with the deployment of social attraction equipment on 5 March. Murre decoys (384 adult, 36 chick, and 48 egg), 12 three-sided mirror boxes, and two independent sound systems were deployed as elements of a social attraction design. Decoys were removed and the sound system was turned off on 11 August after the murres left the rock for the fall.

Efforts to restore Common Murre colonies in central California expanded during 1998 when social attraction equipment was placed on San Pedro Rock, San Mateo County, California (approximately 1 mile north of Devil's Slide Rock). Murre decoys (353 adult decoys) and two independent sound systems were placed on the central

portion of San Pedro Rock on 10 April. Decoys were removed and the sound system was turned off on 12 August after the murres left the rock for the fall.

In addition to the social attraction work and monitoring at Devil's Slide and San Pedro rocks, Common Murres were monitored extensively at the Point Reyes National Seashore headlands and along the Big Sur Coast at Castle and Hurricane Point rocks. The information collected will be used to help evaluate and refine restoration efforts at Devil's Slide and San Pedro rocks and other colonies in central California where social attraction techniques may be employed in the future. Parameters monitored included: colony and subcolony populations, reproductive success, behavior, phenology, attendance patterns, and chick diet. Anthropogenic factors (e.g., boat disturbance, aircraft overflights, oiling) and natural factors (e.g., predation) that may affect the success of recolonization efforts were also monitored.

Efforts of the Scientific Program resulted in fourteen pairs of murres nesting and six chicks successfully fledging from Devil's Slide Rock. In addition, a peak of 80 and 26 murres were recorded on Devil's Slide and San Pedro rocks, respectively. This represents a 100% increase from 1997 in the peak number of murres attending Devil's Slide Rock and the first murres observed attending San Pedro Rock since 1972 (murres have not been documented nesting at San Pedro Rock since 1908). These increases are especially encouraging given the unfavorable breeding conditions seabirds experienced at other colonies during 1998 due to the El Niño-Southern Oscillation event. Murres continued to utilize the "aisles" within our decoy plots as well as open space close to the decoys and mirrors. With continued efforts over the next several years, we expect that breeding will continue at DSR and the colony will grow to a much larger breeding population size. At SPR, we expect breeding within a few years and eventual growth to a much larger colony size. In addition, extensive information collected from other nearshore and offshore colonies will aid in refining restoration techniques.

The Environmental Education Program continued was implemented for a third year in 1998. Since 1996, twenty teachers and nearly 1,700 elementary and middle school children from 6 coastal San Mateo County schools and one school in the City of Fremont participated. The program focused on teaching students about: 1) seabirds of the central coast of California; 2) human impacts on seabirds from the early 1900s to the present; 3) efforts to restore seabirds; and 4) ways students can help protect and restore seabirds. In addition, the program provided students with the opportunity to directly participate in the restoration project at Devil's Slide Rock by repainting the murre decoys prior to their re-deployment. The Education Program continues to education students about seabirds and conservation, involving over 700 students in a hands-on project that occurs in their own backyard.

PROJECT ADMINISTRATION

TRUSTEE COUNCIL

U.S. Fish and Wildlife Service

Dan Welsh, Primary Representative, Sacramento Fish and Wildlife Office

Joelle Buffa, Alternate Representative, San Francisco Bay National Wildlife Refuge Complex

National Oceanic and Atmospheric Administration

Ed Ueber, Primary Representative, Gulf of the Farallones National Marine Sanctuary

Beth Mitchell, Alternate Representative, NOAA General Counsel

California Department of Fish and Game, Office of Spill Prevention and Response

Don Lollock, Primary Representative, Sacramento Office

Paul Kelly, Alternate Representative, Sacramento Office

SAN FRANCISCO BAY NATIONAL WILDLIFE REFUGE COMPLEX

Margaret Kolar, Refuge Manager

Humboldt State University

Dr. Rick Golightly, Department of Wildlife, Cooperative Agreement Administrator

James Hamby, Humboldt State University Foundation Administrator

INTRODUCTION

Common Murre (*Uria aalge*) colonies in central California occur on nearshore rocks and adjacent mainland points between Marin and Monterey counties as well as at the North and South Farallon Islands, 20-40 kilometers offshore (Sowls et al. 1980; Briggs et al. 1983,1987; Carter et al. 1992). Trends in the population size of Common Murres at all colonies have been well documented since 1979 (Ainley and Boekelheide 1990; Takekawa et al. 1990; Sydeman et al. 1997; McChesney et al. 1998; Manuwal et al., in press). A steep decline in the population occurred between 1982 and 1986 due to mortality associated with an intensive, nearshore gillnet fishery, a severe El Niño-Southern Oscillation (ENSO) event in 1982-83, and several oil spills, including the 1986 *Apex Houston* oil spill (Page et al. 1990; Takekawa et al. 1990; Carter et al. 1992; Sydeman et al. 1997; Carter et al., in press; Manuwal et al., in press).

The *Apex Houston* Oil Spill

Between 28 January and 4 February 1986, the barge *Apex Houston* discharged approximately 20,000 gallons of San Joaquin Valley crude oil while in transit from San Francisco Bay to the Long Beach Harbor. Between Sonoma and Monterey counties, an estimated 9,000 seabirds were killed, including approximately 6,000 Common Murres. Due to the efforts of biologists from the Point Reyes Bird Observatory and Ecological Consulting Inc., seabird mortality resulting from the *Apex Houston* oil spill was well documented (Ford et al. 1987; Page et al. 1990; Carter et al., in press). Several seabird breeding sites were impacted and the Common Murre colony at Devil's Slide Rock (DSR) was abandoned (Takekawa et al. 1990; Carter et al. 1992, in press; Swartzman 1996; Manuwal et al. in press).

State and federal natural resources trustees commenced litigation against potentially responsible parties in 1988 (Carter et al. in press). In August 1994, the case was settled in a Consent Decree for a total of $6,400,000. A Trustee Council comprised of representatives from the California Department of Fish and Game, National Oceanic and Atmospheric Administration, and the U.S. Fish and Wildlife Service was established to review, select, and oversee implementation of restoration actions for natural resources injured by the spill. Two projects were approved in 1995: 1) the allocation of $500,000 to the California Department of Fish and Game (Office of Oil Spill Prevention and Response) for the acquisition of nesting habitat for the Marbled Murrelet, a state endangered and federally threatened species that was impacted by the spill; and 2) the Common Murre Restoration Project, led by the U.S. Fish and Wildlife Service, to which $4,916,430 has been allocated over a ten year period. In 1998, the Trustee Council also approved funds for habitat restoration at the Southeast Farallon Island (Farallon

National Wildlife Refuge) which will be supervised by the U.S. Fish and Wildlife Service (San Francisco Bay National Wildlife Refuge Complex).

The Common Murre Restoration Project

The *Apex Houston* Trustee Council developed a restoration plan consisting of a Scientific Program for the Common Murre Restoration Project (USFWS 1995a; Carter et al., in press). Field work for the Scientific Program is being conducted by the U.S. Fish and Wildlife Service (San Francisco Bay National Wildlife Refuge Complex; hereafter "Refuge") in collaboration with the U.S. Fish and Wildlife Service (Ecological Services-Sacramento Field Office), Humboldt State University, National Audubon Society, U.S. Geological Survey (Biological Resources Division), and Point Reyes Bird Observatory. Additional assistance has been provided by National Park Service (Point Reyes National Seashore), Gulf of the Farallones and Monterey Bay National Marine Sanctuaries, California Department of Fish and Game and California Department of Parks and Recreation. In addition, an Environmental Education Program was developed and implemented by the Refuge with the approval of the *Apex Houston* Trustee Council (Parker et al. 1997).

The primary goal of the Scientific Program is the restoration of extirpated Common Murre colonies at Devil's Slide Rock (DSR) and San Pedro Rock (SPR)(Figure 1). Social attraction was selected as the methodology to be used to recolonize DSR and SPR. This technique uses decoys, recorded vocalizations, and mirrors to mimic an active seabird colony with the purpose of encouraging live birds to visit the area. If visiting birds remain long enough to encounter other live birds, they may begin to attend regularly, select nest sites, obtain mates, and breed. Depending on the target species, birds with prior experience at a colony (i.e., having hatched, attended, or previously bred there) are most likely to be attracted during the early stages of recolonization. Subadult birds prospecting for a nest site are also likely to be attracted to the restoration site.

Increasing evidence demonstrates that social attraction is an effective management tool for encouraging seabirds to recolonize extirpated colonies. Social attraction has been used to successfully recolonize: Common (*Sterna hirundo*), Arctic (*S. paradisaea*), Roseate (*S. dougallii*), Sandwich (*S. sandvicensis*), and Least Terns (*S. albifrons*); Black Skimmers (*Rynchops niger*); Leach's Storm-petrels (*Oceanodroma leucorhoa*); Dark-rumped Petrels (*Pterodroma phaeopygia*); and Laysan Albatross (*Diomedea immutabilis*) (Podolsky 1985; Podolsky and Kress 1989; Podolsky and Kress 1991). It has also been utilized to attract Common Murres to former breeding colonies in Maine and Japan (Schubel 1993; Watanuki and Terasawa 1995).

On 12 January 1996, social attraction equipment consisting of murre decoys, mirror boxes, and two sound systems was deployed on DSR (Parker et al. 1997). Less than 24 hours following deployment, one murre was observed visiting the former colony and 4 murres were present within 48 hours. Thereafter, murre attendance was constant (6 pairs laid eggs) until August 1996, when they departed for the fall. In 1997, a similar pattern occurred with more birds laying eggs. Social attraction techniques continue to be used at DSR. Decoys are deployed in a similar manner each season. Deploying decoys in similar manners prevents displacing murres that have established territorial or breeding sites at DSR. However, as the colonies grow, decoys may be gradually removed to provide additional breeding space and to eventually phase out social attractants over time.

Social attraction techniques were initiated in April 1998 at SPR. Three hundred forty-five adult decoys were deployed on the rock with two independent sound systems. Observations conducted after deploying decoys identified murres attending SPR, with a peak count of 26 murres. No murres were detected at SPR during ground and boat observations or aerial surveys conducted in 1996 and 1997 and none were seen during early 1998 prior to the deployment of social attraction equipment.

In order to provide reference information by which we can determine if murres at DSR are behaving in a manner consistent with an established nearshore breeding colony, information on population size, attendance patterns, phenology, behavior, productivity, and chick diet was collected from murre colonies at the Point Reyes Headlands (PRH) located within Point Reyes National Seashore (Figure 2). At Southeast Farallon Island, data on population size, attendance patterns, phenology, and productivity were also collected. Data from PRH and Southeast Farallon Island provide a measure by which to evaluate the success of our recolonization efforts at DSR.

We also collected similar data from Common Murre colonies at Castle Rocks and Mainland (CRM), Hurricane Point Rocks (HPR), and BM227X Rocks (located 0.75 miles North of CRM), all located on the Big Sur coastline in Monterey County (Figure 3). The CRM and HPR colonies were heavily impacted by the *Apex Houston* spill and declined afterwards. Information from these colonies will allow us to assess the necessity of using social attraction at these colonies as well as examine aspects of breeding biology that may vary at these disjunct, southernmost colonies.

The Environmental Education Program is geared towards elementary and middle school children from schools located in coastal San Mateo County. The program focuses on teaching students about: 1) seabirds of the central coast of California; 2) anthropogenic impacts on seabirds from the early 1900's to the present; 3) efforts to restore seabirds; and 4) ways in which students can help protect and restore seabirds. Students also play a direct role in the restoration project by repainting the murre decoys once they have been removed from DSR.

This report summarizes monitoring efforts conducted at DSR, SPR, PRH, CRM, HPR, and BM227X in 1998, the third year of the Common Murre Restoration Project. Activities conducted as part of the Education Program also are summarized. Data collected on Southeast Farallon Island, historic use of colonies at the PRH and CRM and HPR, and additional studies at Drake's Bay colonies will be summarized in separate reports provided to the *Apex Houston* Trustee Council.

SCIENTIFIC PROGRAM

METHODS

Social Attraction

Devil's Slide Rock
In 1998, 384 life-sized adult murre decoys were deployed at DSR to artificially create the appearance of an active Common Murre colony. The decoys consisted of 288 wooden standing-posture decoys and 96 polyethylene (plastic) incubating-posture decoys. Adult decoys were painted with an exterior latex paint that closely resembles the plumage color of adult murres. A 1/4" hole in the underside of each decoy accepted a metal rod that was placed into a 1/4" diameter hole drilled 3"-4" into the rock.

We developed a project design that would allow assessment and adjustment of social attraction techniques without jeopardizing our management objectives. A randomized-block design was used to establish 4 blocks possessing similar micro-habitat characteristics on DSR (Figure 4). Each block was divided into 4 equal-sized plots (averaging 102cm x 170cm in size) with the following characteristics:

a. A vertical rock ledge between 5 and 20 cm high at the front of the plot.
b. Level rock (or guano covered surface) with no more than a 10° slope.

Within each block, the plots were randomly assigned one of four decoy density treatments as follows:

a. <u>High density decoy plots</u>: contain 40 standing decoys, 13 incubating decoys, and one mirror box.
b. <u>Medium density decoy plots</u>: contain 20 standing decoys, 7 incubating decoys, and one mirror box.
c. <u>Low density decoy plot</u>: contain 12 standing decoys, 4 incubating decoys, and one mirror box.
d. <u>Control plots</u>: without decoys or mirrors.

Each of the 4 randomized blocks contained a high, medium, and low density plot as well as a control plot, resulting in a total of 16 plots. Within all plots, space was provided for live birds that may choose to nest among the decoys.

Plots were re-established as they occurred during the 1997 field season, to the greatest extent possible, in order to prevent displacement of murres with established territorial and breeding sites. This was accomplished by re-using existing holes already drilled into DSR and comparing photographs of the plots taken after decoys were deployed in 1997.

In order to determine preferred areas of use within the plots, each decoy plot was sub-divided into four areas: front line, aisle, edge, and interior (Figure 5). Each area was defined with the following conditions:

> Front line: Area adjacent to the vertical rock ledge. This area was approximately 30cm deep x 1m wide. In medium and high density plots, the front line contained 7 (3 incubating and 4 standing) and 13 (7 incubating and 6 standing) decoys, respectively, and the decoys were arranged in two rows. Low density plots contained one row of 4 decoys (2 incubating and 2 standing).
>
> Aisle: Area separating the front line and the main group of decoys. This area was approximately 30cm deep x 1m wide and was without decoys.
>
> Main Group: Area behind the front line and aisle. This area is approximately 140cm deep x 1m wide. It has the highest concentration of decoys. Two areas occur within the main group of decoys. They are:
>
> > A. Interior: Area inside the main group of decoys. A live murre was considered to be in this area if its body was surrounded by decoys on all sides.
> >
> > B. Edge: Area surrounding the main group of decoys, excluding the aisle and the front line. A live bird was considered in this area if it was within one murre standing body width (~15cm) of the main group of decoys.

In addition to the decoys, one three-sided mirror display box was placed in each of the 12 decoy plots. Mirror boxes were constructed with a peaked roof to prevent cormorants and gulls from roosting on them. Mirrors were approximately 20cm wide x 40cm high. Including the roof and the plywood base, the boxes stand approximately 64cm in height. Mirrors were placed 0.33 m from the front ledge on the left side of each decoy plot.

To provide the sound of an active murre colony, two identical but independent sound systems broadcast murre vocalizations continuously from 4 speakers arranged at regular intervals along the main ridge of the island. Each sound system consisted of a portable CD player, 50 W amplifier and two weatherproof speakers. Speakers were placed approximately four meters apart and secured to the rock with expandable bolts. Power was supplied to the system by three 12 volt deep cycle sealed batteries which were recharged by two 60 W photovoltaic panels. All equipment was housed in a fiber-glassed wood box that fit securely under the solar panel stand. Murre vocalizations played at DSR were recorded by Parker and McLaren at the South Farallon Islands (Farallon National Wildlife Refuge) in May 1995.

All adult decoys (standing and incubating postures) were deployed on 5 and 6 March 1998. To further create the illusion of an active colony, 48 wooden egg and 36 wooden chick decoys were placed among the adult decoys on 20 March. Chick decoys were prepared with a polyester cloth material (black cloth on the back and white cloth on the breast) that resembled down feathers and the faces were painted with black and white exterior latex paints. Decoy eggs were painted with exterior latex paint mixed to resemble the large variety of colors and patterns that occur in murre eggs. Two of the 4 plots within each density group received egg and chick decoys and two remained as adult only plots. In total, 6 decoy plots received egg and chick decoys. High density plots received 10 chick and 12 egg decoys, medium density plots received 5 chick and 8 egg decoys, and low density received 3 chick and 4 egg decoys. Instead of hiding eggs and chicks under adult decoys (i.e., mimicking natural conditions), eggs and chicks were placed in the open beside decoys where they were more conspicuous and further attract murres to the rock.

After Common Murres departed DSR for the season, decoys were removed on 11 August 1998 for cleaning and repairs. To prepare the decoys for repainting, dried guano was scraped off and then decoys were soaked for at least one day in a solution of Biz laundry detergent and water. The decoys were then washed with a pressurized power washer, scrubbed, and repainted.

San Pedro Rock

In 1998, the first year of social attraction efforts at SPR, 345 life-sized adult murre decoys were used to artificially create the appearance of an active Common Murre colony. Adult decoys were deployed on 10, 15, and 16 April 1998. The decoys consisted of 265 standing posture decoys and 80 incubating posture decoys. Decoys were painted and anchored to SPR in the same manner as at DSR (see above).

We developed a project design that utilized information obtained from social attraction activities at DSR and data collected at other nearshore colonies during the previous two season to increase our chances of meeting our management objectives. Decoys were positioned on the south side near the center of the rock. This area is characterized by a steep slope (>45°) with multiple ledges. The ledges are characterized by vertical rock walls (between 30cm and 230cm high) and level horizontal rock (between 25cm and 210cm wide) with no more than 10° slope. The combination of the steep slope and multiple ledges gives the area a stair-step appearance. This area was selected as having the best suitable nesting habitat for large numbers of murres on SPR, based on reconnaissance trips in 1996 and 1997. We suspect that these are former nesting habitats used prior to 1908.

Four ledges were selected to receive decoys. The selection of ledges were based on:

a. Ability to view the ledge from the mainland or boat;
b. Highest quality murre nesting habitat in the area (as judged in comparison to high-quality murre nesting habitat at other California colonies);
c. Ability to accommodate our decoy plot designs and;
d. Probable historic nesting habitat of SPR murre colony (Ray 1909)

Ten decoy plots were established on the four selected ledges. Each plot was approximately 2m x 1m; as space on the ledge allowed. The plots were randomly assigned two decoy density treatments as follows:

a. <u>High density decoy plots</u>: contained 40 standing decoys and 13 incubating decoys;
b. <u>Low density decoy plots</u>: contained 12 standing decoys and 4 incubating decoys.

Eight of ten decoy plots (4 high and 4 low) utilized a plot design similar to DSR (Figure 5). However, on one ledge two plots were modified to utilize the vertical ledges that occurred at the front and back of the ledge (Figure 6). In this plot design, decoys were arranged along the vertical ledges creating a front and back line of decoys. Both front and back line decoys faced the nearest vertical ledge. This plot design created open space between the front and back line decoys, similar to the aisle area created in the decoys plots utilized on DSR. Both a high density and low density plot were established on this "U-shaped" ledge.

To provide the sound of an active murre colony, two identical but independent sound systems were established on SPR. These sound systems were identical to the systems used on DSR. After Common Murres departed SPR for the season, decoys were removed on 12 August 1998 for cleaning and repairs.

Behavior

Devil's Slide Rock

Observations at DSR were conducted approximately four days per week from January to early August. Observations were conducted from a roadway pullout located along Highway 1 overlooking DSR. Observers were positioned approximately 300m from the colony at an elevation of approximately 100 m. Each observation day consisted of two three-hour shifts, weather permitting. The first shift began 0.5 hours after sunrise and the second shift began on a rotating schedule throughout the day (i.e., all parts of the day were surveyed at least once per week). The colony was scanned each ten minute period using a Questar telescope (65X-130X). On 26 June, scan lengths were increased and scan frequencies reduced to twenty minute periods to increase available time to record data due to higher number of attending birds. For each murre observation, we recorded: the bird's presence either outside or within a decoy plot; location within the plot; behavior; and proximity to mirror or speaker. If a murre was observed in the same specific location on a regular basis (e.g., three consecutive days), the location was considered to be a potential territorial/breeding site. The site was then mapped and given a number. Thereafter, occupied sites were noted along with the other data collected during scans.

At the end of the season, occupied sites where murres were observed on greater than 15% of our observation days were considered to be actual territorial sites. Territorial sites are identified as an additional measure of colonization and as an indicator of possible future colony growth. For analyses, behaviors were categorized as either breeding or non-breeding (Table 1).

San Pedro Rock

Due to the great distance from the observation points to SPR detailed behavioral observations were unobtainable (for details see Attendance Patterns - San Pedro Rock below).

Castle Rocks and Mainland and Point Reyes Headlands

At the CRM and PRH colonies, behavioral observations were conducted every second day at individual subcolonies during three-hour shifts rotated daily throughout the study period to provide coverage of all daylight hours. Using a Questar telescope (65X-130X), a scan was made every 10 minutes along an imaginary transect line spanning the breadth of the subcolony, thereby sampling both edge and interior birds. Every fifth murre was noted for behavior at the instant of sighting until a total of 60 birds were studied. When less than 60 murres were in attendance, the behavior of each bird present was recorded. Observation shifts were conducted at all observable subcolonies (i.e., those close enough to permit observations of murre behavior) for comparison.

Attendance Patterns

Devil's Slide Rock

At DSR, seasonal attendance patterns of Common Murres were determined from daily high counts (i.e., the highest number of murres observed on DSR during any behavior scan conducted on each observation day) obtained during behavior scans conducted from 10 December 1997 to 30 July 1998. Diurnal attendance patterns were determined by calculating the mean number of murres present during each 10 minute interval from 0.5 hours to 13 hours after sunrise. Diurnal attendance patterns were divided into pre-breeding (13 January - 13 May 1998) and breeding (14 May - 30 July 1998) seasons. Attendance patterns were not monitored after 30 July 1998 when the murres left the island for the fall.

San Pedro Rock

At SPR, seasonal attendance patterns of Common Murres were determined from single daily counts conducted between 9 December 1997 and 19 May 1998 combined with more detailed observations between 20 May and 8 August 1998 when observations at SPR were conducted approximately four days per week. Each observation day consisted of one two-hour shift, weather permitting. The observation shifts were conducted from both viewing sites located along Highway 1 with one hour of observations conducted at each site. Observers were positioned approximately 1,300 m and 1,700 m from the colony at an elevation of about 200 m. Four two-hour time shifts (0620-0820, 0720-0920, 0820-1020, 0920-1120) were established and observation shifts occurred on a rotating schedule throughout the morning (i.e., all parts of the morning were surveyed at least once per week). The colony was scanned at the start of each five minute period using a Questar telescope (65X-130X). For each murre observation, we recorded: the bird's presence either outside or within a decoy plot; location within the plot, and proximity to a speaker.

Point Reyes Headlands, Castle Rock and Mainland, Hurricane Point Rocks, and BM227X

Seasonal attendance patterns were determined for 5 sub-colonies at PRH and 12 subcolonies at CRM, HPR, and BM227X. All subcolonies were counted three times and a mean was then calculated. Counts were conducted between 0800 and 1100 hours during the pre-breeding season and between 1000 and 1400 hours during the breeding season. At PRH, the pre-breeding and breeding seasons were from 20 February to 3 June 1998 and 4 June to 24 July 1998, respectively. At CRM, HPR, and BM227X the pre-breeding and breeding seasons were from 14 April to 21 May 1998 and 22 May to 4 August 1998, respectively.

At PRH, "Type II" index plots were established at Lighthouse, Boulder, and Cone rocks because these subcolonies were too large to be counted accurately in their entirety (see Birkhead and Nettleship 1980). These plots were delineated by natural features of the rock. We also photographed and mapped the plots to ensure our accuracy in counting within plot boundaries. At the Lighthouse Rock Subcolony (~12,000 birds), three index plots were used for counting (Ledge plot, ~240 birds; Dugout plot, ~200 birds; Edge plot, ~100 birds). At the Cone Rock (~2,000 birds) and Boulder Rock (~1,300 birds) subcolonies, one index plot (~300 birds) at each rock was established. Because of the smaller size of subcolonies at CRM, HPR, and BM227X, index plots were not deemed necessary and all visible birds were counted.

Diurnal attendance during the breeding season was monitored at the Ledge and Edge plots and Wishbone Point Subcolony at PRH and at a "Type I" plot (see Birkhead and Nettleship 1980) established on CRM subcolony 04. At PRH, all-day counts were conducted between 4 June and 24 July 1998. At CRM, 11 all-day counts were conducted between 22 May and 4 August 1998. During all-day counts (06:00-18:00 hours), plots were counted 3 times at 10 minute intervals. A mean number of attending murres was then calculated for each 10 minute interval. Ten-minute means for each all-day count were then averaged in order to determine diurnal attendance patterns during the height of the breeding season (see Takekawa et al. 1990).

Productivity - Common Murres

Devil's Slide Rock

We conducted checks of all potential breeding sites, prior to or following our daily behavior observations, in order to monitor breeding productivity. The status of each potential nest site (i.e., presence or absence of eggs or chicks) was recorded on every day of observation between 1 May and 31 July 1998 using a Questar telescope (65X-130X). We utilized bird postures (e.g., incubating and brooding positions) in order to determine approximate lay and hatch dates when eggs and chicks were not initially observed. In order to better view nest contents, we periodically conducted observations from pull-outs located 0.5-1.0 km north of our "main" observation pull-out along Highway 1. Observer distance from DSR was between 300-400 m depending on pull-outs utilized. Nests were checked until all chicks had fledged.

Point Reyes Headlands and Castle Rock and Mainland Point Reyes Lighthouse Plots

Productivity of Common Murres was monitored for a third year at PRH. The Ledge and Edge plots, established in 1996, were monitored in a manner consistent with "Type I" plots (see Birkhead and Nettleship 1980). Because Lighthouse Rock is relatively large, we selected plots both at the center and on the edge of the subcolony, in order to allow for differences in reproductive success that may occur due to location (Birkhead 1977). The Ledge plot, our primary study plot, typically consists of approximately 120 breeding sites and is located on a small ledge near the center of the colony. The Edge plot is located on the northeast edge of the subcolony and typically consists of greater than 30 breeding sites. Although the Edge plot has fewer sites than an ideal "Type 1" study plot, we were limited to utilizing areas in which we could view the eggs and chicks at sites. Observations of both plots were conducted from within or just outside of a small room in the Lighthouse Powerhouse building, located almost directly above the colony at a distance of approximately 100 m. Both Questar telescopes (65X-130X) and Kowa (20X) spotting scopes were used for observations.

Wishbone Subcolony

Productivity was also monitored at Wishbone Point (WBP), a small subcolony at PRH where breeding has occurred in two (1996, 1998) of the three years (1996-1998) we have been monitoring at PRH. Because of the small size of this subcolony in 1998, it was not necessary to establish a plot. Approximately 25-30 breeding sites are monitored from a mainland bluff located approximately 75 m from the subcolony. Both Questar (65X-130X) and Kowa (20X) spotting scopes were used for observations.

Castle Rock 04 Plot

We continued to monitor productivity at the study plot established in 1996 at CRM subcolony 04. This plot was monitored in a manner consistent with "Type I" plots (see Birkhead and Nettleship 1980). Approximately 80 breeding sites are monitored in a typical year. Observations of the plot were conducted with a telescope (65X-130X) from a pull-out located on Highway 1, approximately 300 m from the rock.

Common Murre breeding productivity at PRH and CRM was monitored every two days beginning when the first eggs were observed. We identified sites in the plots based on 1997 site maps. New sites in 1998 were numbered sequentially and added to existing maps. Sites were checked for presence or absence of eggs and chicks. Although observations were conducted at varying times of day, we focused our efforts in the morning hours. At this time, birds were most active and nest status could be more easily determined. We monitored all egg-laying sites until the nests failed or chicks fledged.

Common Murre Chick Diet

We conducted observations of diet items brought to chicks in the PRH Wishbone Point Subcolony and CRM 04 plot. Observations of prey items were conducted with Questar telescopes (65X-130X). Common Murre chick diet could not be determined at DSR because distance prohibited identification of diet items. In addition, chick diet was not determined at the PRH Ledge Plot as a consequence of poor reproductive success at this site. All fish observed were identified to the lowest possible taxonomic level, and the size of the prey items were measured relative to the length of the adult's bill. Bill length was based on gape or the distance from the corner of the opened bill to the tip. We attempted to conduct these observations for a period of 2 hours every two days during the chick rearing period. However, weather conditions (e.g. fog) often prevented complete observations.

Productivity- Brandt's Cormorants

Brandt's Cormorant breeding productivity has been monitored during the past three seasons to aid in understanding the communal relationship between breeding Brandt's Cormorants and Common Murres. Several instances of formation of new murre subcolonies has been observed in central California, within existing Brandt's Cormorant colonies, possibly because these locations provided greater protection from gull predation or indicated suitable nesting habitat (Ainley and Boekelheide 1990, McChesney et al. 1998; Manuwal et al., in press). Common Murres and Brandt's Cormorants also nest together at several colonies along the coasts of California and Oregon (Sowls et al. 1980; Carter et al. 1992; R. Lowe pers. comm.).

Brandt's Cormorant Colonies at DSR and Mainland, CRM/HPR, and PRH were monitored to determine breeding productivity and nesting phenology. Nests were observed from points along the mainland and observations were made using a Questar telescope (65X-130X) or Kowa (20x) spotting scope. Once nests were identified, they were numbered and mapped. Timing of laying and the number of eggs per nest were determined from our observations. Once eggs began hatching, the nests were checked approximately every 5 days to determine the status of the chicks. Due to the difficulty of following individual chicks once they begin to wander and variation in the age of first wandering between nests and years, productivity calculations were based on the number of chicks recorded in each nest prior to the chicks beginning to wander (see Ainley and Boekelheide 1990; Carter and Hobson 1988).

RESULTS

Social Attraction

Devil's Slide Rock
We began conducting observations of DSR on 9 December 1997, prior to deployment of the decoys. No murres were observed until 8 January when 15 murres were present (Figure 7). The deployment of the social attraction equipment was delayed this season due to severe storms. We conducted 96 days of observation (57 days of behavioral observations days and 39 days of productivity monitoring) between 9 December 1997 and 30 July 1998, after which murres ceased attendance for the breeding season. Numbers of murres on DSR were consistently higher than numbers in 1996 and 1997 (Figure 8). A high count of 80 murres was recorded on 8 July.

High attraction to decoys plots was best demonstrated by comparing the number of murre observations recorded in plots with decoys to the number recorded in the control plots and out of plot during 1998. In total, 57.6% of murre observations occurred within plots with decoys, less than 0.1% of observations occurred within control plots, and 42.0% occurred outside of plots. However, numbers of murre observations were not directly related to plot decoy density: 34.3%, 19.3% and 4.0% occurred in low, high, and medium density plots, respectively (Figure 9). The results of the Block 1 manipulation showed some differences in the percentage of murre observations between high and medium density plots (55.1% and 40.2%, respectively). The low density plot had only 4.7% of observations in this block during 1998.

Total number of murre observations in decoy plots varied greatly, ranging from a low of 4 (Plot 11) to a high of 8124 (Plot 9) (Figure 10). Within all decoy plots, 56.1% of murre observations occurred within the aisle (Figure 11). Other areas (i.e., front line, edge and interior) comprised 23.4%, 11.7% and 8.9%, respectively.

High attraction to mirrors was best demonstrated by comparing the number of murre observations inside and outside the mirror zone. We defined the mirror zone as the small area extending 4 murre body widths (60 cm) from the mirror. At these short distances, reflected images may be clearer and more obvious to a passing bird. In total, 33.5% of murre observations occurred within the mirror zone versus 66.5% of observations outside the mirror zone (Figure 12). We examined distance of the birds from the mirrors within the mirror zone. The highest number of observations (32.5%) was recorded within three murre body widths from the mirror, followed by 30.2%, 25.4%, and 11.7% within two, one and four body widths, respectively.

Good measures of successful social attraction are the establishment of "territorial" sites and "egg-laying" sites by murres at DSR. However, since breeding and colony attendance have occurred in 1996 and 1997, prior experience also plays a role in the establishment of sites at DSR. In 1998, 24 sites (including 14 egg-laying sites and 10 territorial sites) were established on DSR (Figure 13). Seven of the breeding sites (46%) were established outside of decoy plots. Other egg-laying sites were established in Plot 9 (n=5), Plot 6 (n=1), and Plot 1 (n=1). Nine (90%) of the territorial sites were established in Plot 9 (n=4), Plot 6 (n=3) and Plot 8 (n=2). Only one territorial site occurred outside of decoy plots. Eleven of the 24 sites (46%) were established within the mirror zone (5 egg-laying and 6 territorial). While it is difficult to ascertain how all interacting factors affected site establishment, it is likely that social attractants, prior experience and use of nearby areas by other murres influenced site establishment on DSR in 1998.

San Pedro Rock

Between 9 December 1997 and 19 May 1998, no murres were noted at SPR (even after deployment of social attractants on 10-16 April), based on low observation effort. Higher effort began on 20 May and the first murre was observed landing amongst the decoys on 2 June 1998. Due to the distance of observations, it was not possible to fully examine how murres reacted to social attractants at SPR. No egg-laying or territorial sites were noted but may have occurred without detection.

Behavior

Devil's Slide Rock

A total of 203 hours of behavioral observations (1,122 scans) were conducted at DSR between 13 January and 30 July 1998. From these scans, a total of 24,986 observations of individual murres were obtained.

The most prevalent behavior exhibited by murres at DSR this season was standing at rest (36.0%), followed by standing alert (12.9%), preening (12.8%), allopreening (7.3%), and incubating (6.0%). These accounted for 75.0% of all observed behaviors. Head bobbing, a behavior often indicating disturbance in a natural colony, comprised 1.3% of all behavioral observations. Breeding behaviors comprised 16.1% of the total behaviors observed over the course of the season. The most frequently observed breeding-related behaviors were allopreening (7.3%) and incubating (6.0%).

We also analyzed our behavioral information in relation to changes between pre-breeding and breeding seasons. The most prominent behavior observed during the pre-breeding season was standing at rest, followed by preening, standing alert, and allopreening (Figure 14). During the breeding season standing at rest behavior declined 39.5% and incubating rose 14.3%. Breeding-related behaviors constituted 10.5% during the pre-breeding season rising to 23.6% during the breeding season. Unlike the two previous years, there was no post-breeding season at DSR this year. All murres departed from the rock on the same day the last chick fledged. This was perhaps due to the delayed breeding season.

Point Reyes Headlands

A total of 248 hours of observations (1,488 behavioral scans) were conducted between 20 February and 24 July 1998. From these scans, a total of 89,584 behavioral point samples were obtained. Our behavior monitoring was primarily focused on Lighthouse Rock and Wishbone Point subcolonies. Face Rock, Sloppy Joe, Cone Rock, and Upper Cone subcolonies were monitored to a lesser extent. Fewer behavioral observations were collected at Cone Rock this year due to consistent disturbance by sea lions, resulting in too few murres for sampling.

Standing at rest was the most frequently observed behavior (29.1%), followed by standing alert (19.5%), preening (15.1%), sleeping (7.2%), sitting (6.7%), allopreening (4.8%), and incubating (3.1%). These behaviors accounted for 75.5% of all observed behaviors. Head bobbing, a disturbance related behavior, comprised 1.6% of observed behaviors. Breeding related behaviors comprised just 9.3% of all observed behaviors during the entire season. This is a notable decline from last season likely due to the pressures of the ENSO event.

We also analyzed our behavioral information in relation to changes between the pre-breeding and breeding seasons (Figure 15). The most prominent behaviors observed during the pre-breeding season were standing at rest, standing alert, preening, sleeping, sitting, and allopreening. There were no significant changes in behaviors during the breeding season, except for incubating which rose from 0.4% to 5.8%, breeding-related behaviors constituted 8.3% of behaviors during the pre-breeding season rising to 11.6% in the breeding season.

Castle Rocks and Mainland

A total of 253 hours of observations (1,517 behavioral scans) were conducted at CRM between 14 April and 4 August 1998. From these scans, 92,831 behavioral point samples were obtained. Our behavioral observations were focused on CRM Subcolony 04, however, some behavioral observations were also conducted at CRM Subcolony 07.

The primary behavior exhibited by murres this season was standing at rest (31.7%), followed by preening (18.6%), standing alert (13.7%), and sleeping (6.9%). These behaviors accounted for 70.9% of all observed behaviors. Head bobbing comprised 0.8% of observed behaviors. Breeding related behaviors comprised 11.1% of the total behaviors observed over the course of the season.

As at DSR and PRH, we divided the season at CRM into the pre-breeding and breeding seasons (Figure 16). Our initial behavioral observations did not begin until 14 April, because we were unable to access our observation points for extended periods of time due to storm induced road closures and repairs along Highway 1. The most prominent behaviors observed during the pre-breeding season were standing at rest, preening, standing alert, and sleeping (Figure 16). During the breeding season notable changes included: increased incubation (from 0% to 8.9%) and decreased standing alert (down 38.8%). Breeding-related behaviors rose from 5.6% of the total observed behaviors in the pre-breeding season to 14.3% during the breeding season.

Attendance Patterns

Devil's Slide Rock

Murres were recorded on 6 of 15 observation days (40%) prior to decoy deployment and 76 of 78 observation days (97.4%) after decoy deployment. During the pre-breeding season, daily high counts of the number of murres on DSR were variable (see Figure 7). A peak count of 80 birds was recorded on 8 July. The mean peak number of murres attending DSR during the pre-breeding season was 4.6. During the breeding season, the mean peak number of murres observed was 34.6 and attendance was much more consistent during the breeding season. A low count during the breeding season of 11 birds occurred on 8 June. Murres stopped attending the rock on 31 July.

Diurnal attendance patterns of murres varied slightly (Figure 17). During the pre-breeding season, numbers of murres were more stable in the early morning and late afternoon. During the breeding season, numbers were variable in the early morning, stabilized by mid-day, and were variable in late afternoon.

San Pedro Rock

Daily high counts of the number of murres on SPR were variable. No murres were seen on SPR prior to the deployment of decoys. Subsequent to decoy deployment, murres were observed on the rock 36.6% of observation days (14 of 41 days). In addition, murres were observed on the rock 15 of 22 days (68.2%) after the first murre was observed. A peak count of 26 murres occurred on 16 June 1998 (Figure 18). The mean peak number of murres attending SPR post decoy deployment was 3.2 birds.

Point Reyes Headlands

Seasonal attendance was recorded at several additional areas this field season including Aalge Ledge, Boulder, Miwok, and Chip rocks (Figures 19-22). These areas were counted only later in the season when murres began attending the site regularly (e.g. Aalge Ledge, Miwok, and Chip rocks) or a suitable observation site was found on the mainland (e.g. Boulder Rock). We also began collecting seasonal attendance data at the Elephant Seal Cove Subcolonies, previously studied by Point Reyes Bird Observatory (PRBO) and Point Reyes National Seashore staff in 1996 and 1997 (Thayer et al. 1998).

We began recording pre-breeding attendance at PRH on 9 December 1997. The first murres were recorded attending LHR on 16 December 1997. Murres did not begin attending other subcolonies at PRH until March 1998. Attendance at most of the subcolonies remained very sporadic through May. Murres were absent from all subcolonies on at least 1 day in the month of May except for the Elephant Seal Cove subcolonies. Attendance at most of the subcolonies became much more regular during the breeding season (4 June -24 July). The sporadic seasonal attendance at Lower Cone Rock and the LHR index plots can be attributed to disturbances caused by sea lions (see Disturbance and Predation).

The Elephant Seal Cove Subcolonies and Boulder Rock had the most consistent attendance. Disturbances by sea lions were never recorded at these subcolonies. Wishbone Point and Arch Rock had a peak in attendance towards the end of the breeding season. Attendance at SJ Mainland and Cone Rock Shoulder was last recorded in late June (see Disturbance and Predation). Aalge Ledge is a historical subcolony; murres were last recorded in 1994 from aerial photos (McChesney et al. 1998). Though not graphed, small numbers of murres were recorded on Miwok Rock on three days and Chip Rock on six days.

Diurnal attendance at PRH was analyzed during the pre-breeding and breeding seasons at two plots on LHR and during the breeding season at the Wishbone Point (see Figures 23-25). Pre-breeding attendance at the Ledge and Edge plots was more variable than breeding attendance. This may be due to disturbances occurring during the all day counts in the pre-breeding season but not during the breeding season.

During the pre-breeding season, diurnal attendance at the Ledge plot increased until around 08:00 when numbers peaked. After this peak, numbers slowly declined until about 15:00 when a slight increase occurred. Numbers then remained consistent until 18:00. The breeding season attendance on the Ledge plot showed very little fluctuation. At the Ledge Plot, numbers increased until 08:00, then remained constant until 18:00. It should be noted that although no disturbances were recorded while collecting data for our diurnal attendance patterns (3 days), disturbances were recorded on many days during the breeding season.

During the pre-breeding season at the Edge Plot, diurnal attendance peaked within the first hour of counts and then dropped until 15:00. Numbers increased again and remained consistent from 15:00 to 17:00 and then showed a sharp decline from 17:00 to 18:00. During the breeding season, numbers were lowest in the early morning, increased until about 09:00, remained constant until 16:00, and then slowly declined until 18:00. Diurnal attendance at the Edge Plot was more erratic than at the Ledge Plot. This difference in attendance is possibly related to the location of the Edge Plot on the periphery of the colony where exposure to sea lion disturbances is greater.

Diurnal attendance at Wishbone increased until 07:00 when attendance peaked. The numbers then remained constant until 9:00, slowly decreased until 15:00 and slightly increased until 18:00.

Castle Rock and Mainland, Hurricane Point Rocks, Bench Mark 227-X
Seasonal attendance of Common Murres at CRM, HPR and BM227X were determined from colony counts conducted between 9 December 1997 and 4 August 1998 (Figure 26-27). We were unable to count the colonies from 1 February to 7 April due to road closures caused by winter storms. Counts of BM227X "Slea Stack", a newly attended rock, were conducted from the first day birds were observed on 24 May to 4 August 1998. During the pre-breeding season, attendance at all monitored CRM subcolonies was sporadic. As the season progressed, attendance became more regular. Murres were present in moderate numbers at CRM Subcolony 03 West until 5 June when birds abandoned the subcolony. Numbers of murres at CRM Subcolony 05 continued to increase throughout the season until reaching a peak of 49 birds on 29 July. Peak numbers of murres occurred in late July for many of the subcolonies. Numbers of murres at CRM Subcolony 06 was consistently between 35-40 birds until reaching a peak of 100 birds on 15 July. After the peak, numbers dropped to below 20 birds before attendance ceased for the year.

Patterns at the HPR subcolonies were similar to CRM subcolonies. Sporadic attendance occurred during the pre-breeding season until mid-May, just prior to observing first eggs. Attendance remained consistent after mid-May until mid to late July when peak numbers of murres were recorded on HPR Subcolony 01 and Subcolony 02 - Hump. Murres attendance ceased approximately 2 weeks after this peak.

The first count of murres on BM227X Slea Stack subcolony equaled 47 murres. Numbers of murres were irregular after that peak until the birds left the subcolony on 15 July. At the nearby Esselen Rock Subcolony, attendance was extremely erratic. No Common Murres were observed attending the rock until 25 April when 79 murres were counted. A peak of 81 murres was observed on 2 May. Murres were not observed during ground observations on the rock after 2 May until 7 murres were seen on the rock on 20 June. No murres were seen on the rock after 22 June. Murres were first observed on Esselen Rock in 1996 and were first documented breeding on the rock in 1997.

Diurnal attendance at the CRM 04 plot during the pre-breeding season was irregular with peak numbers occurring at sunrise (Figure 28). Numbers decreased throughout the day until stabilizing in the late afternoon. Diurnal attendance during the breeding season was lowest at sunrise, increasing until approximately 09:00 hours. After 09:00 hours, numbers in this plot showed little fluctuation throughout the day until approximately 15:00 hours when numbers increased before stabilizing.

Productivity - Common Murres

Devil's Slide Rock

The first Common Murre egg was seen at DSR on 14 May 1998. In total, 13 pairs of murres were observed to have laid eggs on DSR in 1998. During the removal of decoys on 11 August, we found four unhatched murre eggs. One egg was found in Plot one. As this plot is isolated from the other egg-laying sites, we can definitively state that this egg represents an additional breeding site. The other three eggs were found in close proximity to other breeding sites. We can not distinguish these eggs from eggs lost at our monitored sites. As such, we estimate a minimum of 14-17 eggs were laid on DSR in 1998 (Table 2).

Hatching dates ranged from 15 June to 29 July. Nine eggs (52.9%) laid on DSR hatched successfully. Six of the nine hatched chicks (66.7%) fledged successfully. We estimate chicks fledged per pair ranged from 0.35 to 0.43, based on 14 and 17 breeding pairs, respectively. Chicks remained on the rock for approximately 21.5 days after hatch, similar to the average of 23.5 days recorded at the South Farallon Islands (Ainley and Boekelheide 1990).

Point Reyes Headlands

The first eggs appeared in our "Type 1" monitored plots at PRH on 4 June 1998. This late date may have been due to the impact of ENSO. In the Ledge plot, 121 sites (i.e., egg-laying and territorial sites) were monitored (Table 2). A total of 72 eggs (including 6 replacement eggs) were laid at 66 egg-laying sites. In addition, a total of 55 territorial sites (without egg laid) were recorded. None of the eggs that were laid resulted in hatched chicks. A disturbance by California Sea Lions on 3 July resulted in the flushing of all murres from the Ledge Plot (see Disturbance and Predation). While the murres were off the colony, Common Ravens (*Corvus corax*) and Western Gulls (*Larus occidentalis*) depredated all exposed eggs. At this time, 15 of our monitored sites had been recorded incubating or in incubating posture for several days. Based on our previous data, birds in incubating posture most likely had laid eggs but, due to difficulty in observing these sites, we were unable to confirm all egg-laying sites before the 3 July disturbance event. Although some eggs were observed being taken from the study plot, site numbers and exact number of eggs taken could not be determined. Therefore, our estimate of the number of eggs laid on the Ledge Plot is probably an underestimate.

Murres also were unsuccessful at producing chicks on the Edge Plot. Of a total of 41 sites monitored, eggs were laid at 13 egg-laying sites and birds attended 28 territorial sites. No replacement eggs were laid. Disturbance by California Sea Lions (*Zalophus californianus*) and subsequent predation by Western Gulls and Common Ravens resulted in the loss of all the eggs in this study plot.

A total of 42 sites were monitored at the Wishbone Point Subcolony (Table 2). Twenty-two eggs (including one replacement egg) were laid at 21 egg-laying sites. In addition, 21 territorial sites were recorded. Of 22 eggs, 18 (81.8%) hatched successfully (i.e., 85.7% of the 21 nest sites hatched successfully). None of these chicks survived to fledgling age. The majority of the chicks disappeared at 1-3 days old. Four chicks survived to at least 11 days before disappearing.

Other subcolonies at the PRH had better reproductive success than our monitored plots. On 29 July at Boulder Rock, nine chicks with ages estimated at close to 15 days were observed. At the Elephant Seal Cove Colonies, 18, 1, and 2 fledging-aged chicks were observed on Flattop, Middle and East rocks, respectively. On the same day at the Lighthouse Rock, 2 fledging-aged chicks were observed in areas outside of our plots. On 30 July, five chicks were observed fledging from Boulder Rock. Finally, on 2 August, 10 fledging-aged chicks were observed on Lighthouse Rock in areas other than our plots. These sub-colonies and other areas did not experience disturbance by sea lions as did our monitored plots. As such, the murres were able to incubate eggs and raise chicks without the depredation that resulted from sea lion disturbances. Other subcolonies, such as Lower Cone Rock and Face Rock, experienced disturbances by sea lions and subsequent depredation of their eggs and chicks by Common Ravens and Western Gulls. These disturbances resulted in greatly reduced productivity at these subcolonies (see Disturbance and Predation).

Castle Rock and Mainland

The first eggs were seen at the CRM 04 plot on 22 May 1998. Seventy-seven sites were monitored (Table 2). A total of 41 eggs (including 4 replacement eggs) were laid at 37 egg-laying sites. In addition, 40 territorial sites were recorded. Of the 41 eggs laid, 24 (58.5%) hatched successfully (i.e., 64.8% of the 37 egg-laying sites hatched successfully). Seventeen of the chicks (70.8%) survived to fledging, resulting in 0.46 chicks fledged per breeding pair (N=37) (Table 2).

Disturbance and Predation

Devil's Slide Rock and Mainland and San Pedro Rock

There were three documented predation/disturbance events on Devil's Slide Rock in 1998. On 9 July, a Western Gull was observed eating a Common Murre chick on DSR. It was unclear from our observations whether the gull killed the chick or was scavenging a dead chick. On 15 July, a Brown Pelican flushed 20 murres from the rock. None of the brooding murres flushed from the rock and productivity did not appear to be impacted by this event. There was no predation observed at San Pedro Rock.

Planes and helicopters were frequently observed flying over DSR and SPR during the year. In most cases at DSR, the aircraft did not cause murres to flush from the rock. However, on 23 July a Coast Guard helicopter, flying a search and rescue mission, flushed two murres and 10 Brandt's Cormorants from the rock. This same aircraft flew over SPR causing two murres, 50 Brown Pelican, and 100 Brandt's Cormorants to flush from the rock. In addition, two murres were seen approaching the decoy area on SPR when the helicopter made one of its many passes over the rock. These birds did not land on SPR. This Coast Guard search and rescue operation was centered near SPR and continued for two days. During this time, the helicopters may have kept murres from landing on the rock.

Common Ravens and Peregrine Falcons (*Falco peregrenis*) were recorded several times on SPR although no direct predation or disturbance by these two species were observed. In addition, a Common Raven nest was located on SPR, however the nest did not appear to be utilized during 1998.

On 15 June, a Common Murre was observed flying into the top a mirror box while attempting to land on DSR. As a result of the collision, the murres leg was caught between a ¼" support rod and the wooden mirror box. The murre was unable to free its leg and died within a few hours of being entangled. To prevent this unusual event from happening again, the mirror boxes were redesigned immediately following the breeding season.

Point Reyes Headlands

There was a substantial increase in the number of disturbances observed at Point Reyes during the 1998 breeding season. Specifically, California sea lions were observed flushing murres on 36 separate occasions, Western Gulls flushed murres 8 times, Common Ravens 7 times, and Brown Pelican 5 times. Although Peregrine Falcons were observed on several occasions at PRH, we never observed them flushing murres.

Although Common Ravens and Western Gulls flushed murres on several occasions, flushing events occurred mostly in the pre-breeding season when murres were more prone to take flight. Flushing events that occurred during the breeding season had a limited impact on murres because incubating or brooding murres were unlikely to flush due to the presence of a raven or gull. However, Common Ravens and Western Gulls, both year-round residents of Point Reyes, are known to prey on murre eggs and chicks. Direct depredation by ravens and gulls was observed on three separate occasions. All direct depredation events involved the taking of an egg from an incubating adult murre. Opportunistic depredation of exposed murre eggs by gulls and ravens when incubating murres were flushed by sea lions or Brown Pelicans was most commonly observed. At LHR, Western Gulls were observed taking murre eggs and/or chicks every time gulls were present when incubating murres were flushed (N=6). Similarly, ravens took murre eggs and/or chicks 4 of 5 times when ravens were present on LHR during a disturbance event.

Sea lions caused murres to flush on 26 of 37 days (70.27%) that sea lions were observed on LHR. As mentioned in the productivity section, these disturbance/depredation events were responsible for complete breeding failure on the LHR productivity plots. However, a few chicks of fledging age were observed on other areas of LHR, mostly on narrow ledges inaccessible to sea lions. Sea lion disturbance was not limited to LHR and were observed causing disturbances on 4 of the 5 murre subcolonies that sea lions were observed on (Cone Rock Shoulder, Face Rock, Lower Cone Rock and Lighthouse Rock). On Lower Cone Rock, sea lions caused murres to flush on 8 of 18 days (44.44%) that sea lions were observed hauled out on this rock. Some disturbances were quite significant. On 23 May, 90% of the incubating birds on Lower Cone Rock were flushed off eggs by a sea lion. Gulls and ravens took many of the exposed eggs. Lower Cone Rock, a subcolony consisting of approximately 2,000 murres, produced no chicks due to sea lion disturbances and resulting depredation.

On 2 July, a sea lion moved through the Face Rock subcolony, flushing most incubating and brooding murres. Soon after, Western Gulls arrived and depredated most of the exposed eggs and one of two exposed chicks. Although productivity was not monitored at Face Rock, no eggs or chicks were observed after this disturbance. On 15 June, Cone Rock Shoulder was not attended by murres, after a nearby sea lion had apparently flushed the entire subcolony. This disturbance probably had a large impact as murres were only observed twice again before they ceased to attend Cone Rock Shoulder.

Wishbone Point is one of the smallest and newly-formed murre subcolonies at Point Reyes. Though sea lions were never observed on Wishbone Point, Common Ravens were observed on ten separate occasions. Ravens flushed murres off Wishbone on three separate occasions. Although Wishbone did produce chicks, none were old enough to fledge before they disappeared. We believe depredation was likely the cause of their disappearance.

In addition, Brown Pelicans routinely caused disturbances when they landed within a murre subcolony. Brown Pelicans were observed on LHR on 15 of our observation days. Similar to sea lion disturbances, Brown Pelicans flushed murres and allowed ravens and gulls easy access to murre eggs and chicks.

Only one notable disturbance caused by vessels or aircraft was observed. On 25 April, murres were flushed by a helicopter off Wishbone Point, SJ Mainland, and Lower Cone Rock. This event occurred prior to eggs being laid.

Other possible signs of predation at PRH were items found on the mainland while conducting observations: 3 murre heads, 2 sets of murre wings, and fragments of 6 murre eggs. In addition, a raven was observed along the PRH with a downy chick in its mouth.

Castle Rocks and Mainland, Hurricane Point Rocks, and BM227X
Few instances of predation were at CRM, HPR, and BM227x in 1998. A Peregrine Falcon was observed near the CRM colonies on 21 separate days but only one actual disturbance by a Peregrine Falcon was documented. On 28 July, a Peregrine was observed flushing over 100 murres from CR07 and over 40 murres from CR04. The Peregrine was not observed taking any murres. Brown Pelicans were observed flushing murres from CRM subcolonies on four separate occasions. Western Gulls were observed in our study plot twice but no predation was observed.

Disturbance to colonies by aircraft was observed frequently in 1998 (Table 3). Nineteen separate disturbance events by aircraft or helicopter were documented. Impacts to colonies ranged from head bobbing to the flushing of large numbers of murres from the subcolonies. On 20 July, a Coast Guard Helicopter repeatedly flushed murres from the subcolonies. Only two murres were counted on Subcolony 06 on 21 July and the subcolony was abandoned by 28 July.

Chick Diet

Devil's Slide Rock and San Pedro Rock
Data on chick diet at DSR and San Pedro Rock was unobtainable due to the distance of the colony from our mainland observation point (i.e., observers could not identify species of most fish being fed to murre chicks).

Point Reyes Headlands
Our observations of diet items fed to chicks at the PRH was greatly limited this year due to the poor productivity experienced. We were not able to conduct diet observations at our plots on Lighthouse Rock since no chicks were produced. We were able to conduct limited monitoring of the chicks on Wishbone Point. We conducted six hours of observations between 16 July and 24 July. A total of 31 prey items were observed including: Northern Anchovy (*Engraulis mordax*)/Pacific Sardine (*Sardinops sagax*) (70.9%), Salmon (*Onchorhynchus* sp)(26.1%) and Short-bellied Rockfish (*Sebastes jordani*)(16.1%). We grouped Northern Anchovy and Pacific Sardine into one classification because of the difficulty in distinguishing between these two species from a distance.

Castle Rocks and Mainland
A total of 320 prey items were fed to chicks during 26 hours of observations between 17 and 31 July (Figure 29). Major identified prey were: Anchovy/Sardine (30.0%), Short-bellied Rockfish (18.8%) and Flatfish (Familes Cynoglossidae, Bothidae and Pleuronectidae) and Squid (probably *Lologo opalescens*)(10%). We were unable to identify 40.6% of prey items fed to chicks.

Productivity - Brandt's Cormorants

Devil's Slide Rock and Mainland
Brandt's Cormorants bred on DSR and Turtlehead (an east facing slope on a mainland point just south of the Devil's Slide promontory) in 1998. First eggs occurred on 3 May at DSR and 20 May at Turtlehead. First chicks were observed on 16 June and 11 June, respectively. DSR produced 10 chicks from 7 active nests (1.43 chicks per pair) while Turtlehead produced 24 chicks from 24 active nests (1.00 chicks per pair).

Point Reyes Headlands
In 1998, Brandt's Cormorants bred at the following PRH areas: Upper Cone Rock, Upper Cone Shoulder, Miwok Rock, Face Rock, Chip Rock, Lion Point and Lion Rock. We monitored Miwok Rock and a plot representing about half the number of nests on Upper Cone Rock to determine productivity. First eggs were laid prior to 18 May and the first chick hatched on 30 May at Miwok Rock and on 14 June at Upper Cone Rock. Miwok Rock produced 22 chicks from 9 nests (2.44 chicks per pair) while Upper Cone produced 97 chicks from 46 nests (2.11 chicks per pair).

Castle Rocks and Mainland
In 1998, Brandt's Cormorants bred on Jen's Rock (located between HPR Subcolony 02 and the mainland), Boyce Point (a mainland point adjacent and slightly south of HPR Subcolony 02), and CRM 03 East. Jen's Rock was monitored to determine productivity. The first egg was laid on 18 May and the first chick hatched on 17 June. Eleven chicks were produced from 26 nests (0.42 chicks per pair).

DISCUSSION

Social attraction efforts continued to be successful in the third year of the recolonization project at DSR, despite impacts of the 1997-1998 ENSO event. Common Murres returned to DSR in higher numbers than in 1997 and attendance increased throughout the year. In addition, we strongly suspect that several of the same pairs of birds that bred in 1996 and 1997 returned to breed in 1998, based on strong nest and site fidelity of Common Murres (Birkhead 1977; Halley et al. 1995; Harris et al. 1996) and our field observations. If so, we have now established 3 years of successful breeding by pairs that have elected to continue to breed at Devil's Slide Rock. Such behavior would indicate the development of a strong association to DSR which should greatly assist our recolonization efforts in future years. However, we could not fully establish the degree of continued breeding due to a lack of banded birds.

In order to refine social attraction as a restoration technique at DSR and elsewhere, we continued to monitor and evaluate the effects of decoy density, plot use, and mirror effectiveness. However, our analysis of the importance of decoy density in two prior years was confused by the consistent presence of birds attending egg-laying and territorial sites (i.e., live birds are probably a stronger attractant than decoys). In 1998, we continued to monitor the use of decoy plots within treatment Block 1 because Block 1 is "visually isolated" (i.e., by a standing murre) from the majority of DSR (including all territorial and egg-laying sites). Block 1 provides us with an opportunity to test the effects of decoy density on murre behavior without the confounding presence of sites and nests. We found that the pattern of murre observations documented in this block during 1998 did match the pattern observed in 1997. This pattern suggests that prospecting birds (without an established territorial site) may be more attracted to plots with a higher density of decoys. Further data analysis on the effect of decoy density will be needed in order to elucidate this trend.

Within plots with decoys, murres preferred aisles, as observed in 1996 and 1997. This area of the plot, although relatively small, provides open, high quality habitat in the center of the decoy group for murres that are establishing territorial sites, obtaining mates, and breeding (i.e., displaying breeding behaviors). The aisle also occurs behind the frontline of decoys which is aligned against a small rock ledge. This area may contain preferred microhabitat for site establishment. Similar to the aisle, the mirror zone represents just a small fraction of the DSR nesting habitat, yet comprised 33.5% of the area in which all murre observations occurred. A greater percentage of our murre observations occurred outside the mirror zone (66.5%) than in previous years (54.7% in 1996 and 45.6% in 1997). This resulted from the increased number of pairs that established territorial and breeding sites between Plot 8 and Plot 9. In this area, murres are establishing sites along a small vertical ridge (<20 cm) that occurs in an area of open space between the decoys and sites established previously (during 1996 and 1997) in plots 8 and 9.

Eleven of 24 sites (5 egg-laying and 6 territorial sites) were established in the mirror zone. Mirrors may be attractive for several reasons: 1) they provide an element of image movement that attracts and retains live murres into the area; 2) they reflect the decoys and thus make the area appear more populated; 3) they provide a vertical surface which murres might nest against or near affording protection from predators and/or shelter from winds; and 4) mirrors are located at the edge of every decoy plot and may be visited as a result of attraction to decoys or by walking around plots. We believe that the combined use of decoys, recorded Common Murre vocalizations, and mirrors has resulted in significant continued progress toward the long-term re-establishment of a natural colony at Devil's Slide Rock.

At SPR, the late season attendance may be due to the presence of immature birds which often visit future breeding sites late in the nesting season or may represent attendance by murres that either abandoned or did not lay eggs at established colonies due to ENSO conditions in 1998. Ainley and Boekelheide et al. (1990) found that murres moved inshore during ENSO years. Large congregations of murres (up to 5,000) were regularly seen on the water near SPR (USFWS, unpubl.. data). However, due to the distance from our observation point to SPR, murres may not have been easily distinguished from decoys unless they were moving or near decoys which had accumulated guano.

Similar social attraction methods used at DSR, where breeding had occurred until 1986, resulted in attendance in less than 24 hours and breeding in the first season of the project (Parker et al. 1997). The quick response of the murres and the fact that breeding occurred in the first year suggests that birds with prior experience at DSR returned to the colony. However, murres with prior experience at SPR do not exist. Since young murres often return to natal colonies and have strong nest site fidelity, we would expect sporadic attendance by immatures during the first season of social attraction use at SPR. However, sporadic attendance by failed breeding adults from other colonies also might be expected under ENSO conditions. Furthermore, there was concern about initiating a new social attraction project close to our original site at DSR. It was suggested that social attraction work at SPR might negatively impact DSR. We did not observe such an effect as murre numbers and breeding sites at DSR in 1998 were the highest recorded since the restoration project began.

Given the length of time since murres have last bred at SPR, it may take longer to establish consistent attendance and eventual recolonization by murres without prior experience at SPR. Our observations mark the first time murres have been recorded attending SPR on a regular basis in over 90 years. We consider attendance soon after the implementation of social attraction techniques a positive step towards the eventual recolonization of this historic colony.

The behaviors of murres observed at DSR, CRM, and PRH were very similar. At all three colonies, standing at rest, standing alert, and preening were the most prominent behaviors. At PRH, the fourth most prominent behavior was sitting while at DSR and CRM it was incubating. This difference in behaviors reflected egg lost by murres at PRH due to the high levels of sea lion disturbance and subsequent depredation. Even so, murres recolonizing DSR behaved similarly to other established nearshore colonies in central California during the 1997-1998 ENSO event.

In 1998, spatial differences in seasonal attendance patterns of Common Murres apparently reflected the frequency and magnitude of disturbance, as well as changes in breeding effort. At all monitored colonies, murres were first observed in December and early January and attendance fluctuated greatly during the pre-breeding season. At DSR, murres were present daily after decoy deployment, and attendance stabilized between late April through mid-June. Thereafter, murre numbers increased through late July until murres departed the rock for the fall. At CRM and HPR (subcolonies CRM 02, CRM 04 , CRM 07, HPR 01, HPR 02 Hump, and HPR 02 Ledge), sporadic attendance occurred through April, numbers stabilized in May and June, and then numbers increased slightly in July before murres departed the rocks for the season. These subcolonies had similar attendance patterns in 1996 and 1997 (Parker et al. 1997, 1998). However, a few subcolonies within the CRM complex had seasonal attendance patterns that varied markedly from this pattern. For example, CRM Subcolony 03 West had sporadic attendance throughout the end of May and birds were last observed on the rock on 9 June 1998. In contrast, CRM Subcolony 05 was the antithesis of CRM 03 West with murre numbers increasing through out the season until a peak of 49 murres was observed on 29 July 1998. No stable period was observed.

At PRH, seasonal attendance patterns varied at individual subcolonies. In general, colonies that received high levels of disturbance from sea lions (e.g., Lighthouse, Cone, and Face rocks) had low, fluctuating attendance through May with a more stable attendance pattern through June and July. The occurrence of murres on Aalge Ledge, Chip Rock, Miwok Rock, and to a lesser extent Upper Cone may be due to displacement of murres caused by disturbances at established nearby subcolonies. In contrast, subcolonies that received little or no disturbance by sea lions (e.g. East, Flattop, Middle, and Boulder Rocks) had seasonal attendance patterns typical of 1996 and 1997 (Parker et al. 1997, 1998). In past years, our study sites experienced a small peak in attendance in late June and early July. Late season peaks may be attributed partly to younger subadults visiting colonies more often at this time (Birkhead and Hudson 1977, Gaston and Nettleship 1981, Halley et al. 1995). However, timing of breeding, foraging patterns, and chick feeding frequency by breeding adults can also contribute to such peaks.

At DSR, murres began attending the colony on 8 January, prior to decoy deployment and about the same time murres began attending the HPR and CRM subcolonies, and the PRH Lighthouse Subcolony. Before decoys were deployed, murres attended the colony on 40.0% of observation days whereas, after decoys were deployed, murres were present on 100.0% of observation days. In addition, attendance during the pre-breeding season (after decoy deployment) was more constant at DSR than at PRH, CRM, and HPR. These observations support one of our main hypotheses that social attraction aids in keeping live birds at the recolonization site, thus influencing additional murres that land and stay at the colony.

Unlike the seasonal attendance patterns, diurnal attendance patterns varied little between monitored locations at nearshore colonies during the 1998 breeding season. Murre numbers increased gradually throughout the morning (0600-1000), slightly decreased until late afternoon (1000-1500), increased again in the early evening (1500-1600), and declined gradually before dusk. In 1996 and 1997 a stable period occurred in late morning to early afternoon (1000-1500). The 1998 pattern varied considerably from that observed in past years at the South Farallon Island and at nearshore coastal colonies in central California (Ainley and Boekelheide 1990; Takekawa et al. 1990; Fairman and Sydeman 1996; Hester and Sydeman 1997; Parker et al. 1997, 1998), even though diurnal attendance patterns can vary greatly from day to day (Hatch and Hatch 1989; Hester and Sydeman 1997). However, this atypical pattern also was observed at the CRM Subcolony 04 in 1996 and 1997 (Parker et al. 1997, 1998). In 1996, we speculated that nocturnal or pre-dawn activity by avian predators (e.g., Peregrine Falcons, Great Horned Owls *(Bubo virginianus)*) may have been disrupting murre attendance early in the day. However, no direct evidence of disturbance by owls or falcons has been observed over the three years of the project. Information from this season suggests that other factors (e.g., environmental factors) may be the main cause of this particular diurnal attendance pattern and such environmental factors may be experienced on a regular basis at the southern most colonies (CRM, HPR, BM227X). Further analyses may assist in identifying the cause and importance of diurnal attendance patterns observed in 1998.

Productivity of Common Murres varied considerably between monitored locations at nearshore colonies. For example, at PRH, reproductive success at all three "Type I" plots were 0.00 chicks/pair (Ledge plot, Edge Plot, and Wishbone Point subcolony) while DSR and CRM 04 Plot produced 0.35-0.43 and 0.46 chicks/pair, respectively. This difference in productivity was largely due to the disturbance and subsequent predation events that occurred at PRH. The ENSO event may have been a factor in directly reducing numbers of murres that attempted breeding as most of our monitored sites experienced a decrease of approximately 50% in the number of egg-laying sites in 1988 compared to 1997. The exceptions were DSR and the PRH Wishbone Point subcolony. Although fewer murres attempted to breed, the ENSO event was not severe enough to stop adult murres from breeding entirely. Furthermore, we documented murres at 11 sites replacing lost eggs; 7 of 11 replacement eggs occurred at the PRH. This suggested that at least some adult murres were in adequate physiological condition. In addition, murres at PRH may have produced more eggs and fledged more chicks if their breeding (attendance and egg loss) had not been disrupted so severely by sea lion activities. Although we were unable to collect detailed productivity data at other PRH subcolonies, successful breeding was documented at several subcolonies. Chicks successfully fledged from several subcolonies at PRH where sea lion disturbance was not documented (e.g., Boulder, Flattop, East, and Middle). Murre chicks of fledging age (based on chick size and behavior) were documented on PRH Lighthouse Rock in areas (e.g., cliff ledges) where sea lion disturbance did not occur. Overall, data collected at the nearshore colonies (i.e., number of egg-laying sites, hatching success, fledging success, chicks fledged/pair, disturbance information, and anecdotal fledging observations) suggested that, without sea lion disturbances, murres successfully fledged chicks during this ENSO event, although breeding effort and success were reduced compared to previous years (Parker et al. 1997, 1998).

Productivity at DSR decreased from 0.55-0.67 chicks/pair in 1997 to 0.35-0.43 chicks/pair in 1998. Reduced productivity may have been due to eggs lost by young inexperienced breeders as indicated by the decrease from 0.78 to 0.64 eggs hatched/pair while the number of egg laying sites increased from 9 to 14-17 between 1997 and 1998, respectively. New egg-laying sites at DSR may be established by young murres that have not bred before (Harris et al. 1996). However, ENSO conditions may have prompted movements by a few experienced breeders from other colonies to DSR. Use of a new egg laying site by an experienced pair (or experienced/inexperienced pair) also may result in lower breeding success. At DSR, hatching and fledging success were 52.9% and 85.7% in 1998, respectively. This was higher than hatching success (31.7% and 25.0%) and fledging success (15.0% and 8.0%) experienced during the 1983 and 1992 ENSO events at the South Farallon Islands, respectively (Ainley and Boekelheide 1990, McLaren et al. 1992). However, such comparisons are difficult to make due to differences in the timing and impacts of ENSO events, especially on different colonies with different prey resources. Currently, productivity at DSR appears to be as good or better than what one might expect for a small colony based on information from other nearshore colonies in central California. Assuming the DSR colony will continue to grow in size over the next few years, we expect that the reproductive success of murres will improve slightly as young breeders gain experience, older breeders with higher success increase in percentage, and breeding success improves with higher densities of breeding birds. However, reproductive success may also be affected by the eventual die-out of older experienced breeders with past experience that probably initiated recolonization of DSR in 1996 and 1997.

Our ability to collect data on chick diet was impaired by the reduced hatching success that occurred during 1998. In addition, our observations were hindered due to the distances between our observation points and the colonies as many chick diet items were not identifiable. For this same reason, we were unable to obtain any data on chick diet at DSR. Even with reduced number of observations, percentages of fish species fed to murre chicks were similar to past years (Parker et al. 1997, 1998).

We believe that anthropogenic and natural disturbance events continue to be a factor impacting the growth and recovery of nearshore murre colonies in central California. Anthropogenic disturbance events are mostly associated with aircraft, particularly helicopters. Many of the disturbance events this past season involved law enforcement agencies conducting routine patrol, specific search and rescue missions, or patrolling of special events (i.e., Big Sur Marathon). We continue to work with these law enforcement agencies, regulatory agencies, and event organizers to reduce disturbances in the future. Although some of these disturbances can be eliminated, search and rescue operations can not. These types of operations can have significant impacts on the breeding success of murres as observed at PRH (McChesney et al. 1998, Thayer et al., in press). One particular Coast Guard search and rescue operation occurred at the SPR colony. Coast Guard helicopters conducted flights over this new restoration site for two days. Although murres did attend the rock after the operations ceased, we believe that this disturbance event may have reduced visitation at this restoration site for the remainder of the year. We will continue to evaluate impacts during the 1999 field season. We have not attempted in this report to consider how continued mortality from gill-net fishing and oil spills is affecting murres at nearshore colonies in central California. In particular, the 1997-1998 Point Reyes Tarball Events resulted in substantial mortality of Common Murres and likely affected breeding murres in 1998 (S. Allen and J. Roletto, pers. comm.). Assessments of impacts will be conducted separately. However, it should be noted that such mortality can be significant and likely contributes to lower populations sizes and breeding success in central California (Sydeman et al. 1997; McChesney et al. 1998; Forney and Benson 1999; Manuwal et al., in press).

At PRH, a number of disturbance events caused by sea lions were documented. It appears that an increased number of sick and emaciated sea lions were hauling-out higher on the rocks and in greater numbers than in 1996 and 1997. Sea lions would haul out into the murre breeding areas and displace attending murres. Sea lions often appeared emaciated, as their rib cages and pelvic bones could easily be seen. We believe that disturbance events were so frequent at Lighthouse and Cone rocks that murres abandoned the breeding colonies and moved to higher/safer adjacent locations due to extensive egg depredation by Common Ravens and Western Gulls. For example, shortly after several disturbance events occurred at the Lower Cone Rock area, murres began to appear at Upper Cone amongst a Brandt's Cormorant colony. Several murres laid eggs in this area but no eggs hatched. Murres also began to attend Aalge Ledge, a mainland cliff site immediately adjacent to Lighthouse Rock, soon after several disturbance events occurred. As more disturbances occurred, fewer murres attended Lighthouse Rock and more murres attended Aalge Ledge. These disturbance events had significant impacts on the productivity of murres at PRH.

Although high rates of disturbance and predation were seen at PRH, very little disturbance and predation were observed at DSR. One pair of Western Gulls bred on DSR in 1998. This year was the first that gulls were observed regularly interacting with the murres. In most cases, it appeared the gulls were attempting kleptoparasitism as they tried to steal fish that adult murres were bringing to chicks. However, we never observed a gull successfully stealing the fish. On one occasion, a gull was seen eating a murre chick. The murre chick may have died for some other reason (e.g. starved) and the gull may simply have been scavenging the chick. Gulls are rarely seen on the part of DSR where the murres are currently breeding, partly due to nesting Brandt's Cormorants that tend to keep gulls outside of the plots and nearer to the periphery of the colony. No Common Ravens or Peregrine Falcons have been observed on DSR in the three years of the project even though both species are observed regularly along the Devil's Slide mainland area and at SPR. While aircraft overflights occur regularly at DSR (due to the proximity of the Half Moon Bay Airport), most are at or close to an altitude of 1000 feet. At present, these overflights do not appear to present a problem as flushing of murres has not been witnessed. However, head bobbing, a murre behavior related to disturbance, was routinely observed during overflights.

Increases in the number of murres, territorial sites, and egg-laying sites documented at DSR in 1998 reaffirms the feasibility of applying direct seabird restoration techniques to assist with the restoration of extirpated seabird colonies. Furthermore, the fact that several territorial sites from 1997 developed into breeding sites in 1998 suggests that young prospecting murres are establishing future egg-laying sites at DSR which should contribute to a larger breeding population. The rapid and sustained response by murres to social attraction techniques at DSR and SPR, as well as the establishment of numerous breeding pairs at DSR, bodes well for the permanent reestablishment of these extirpated murre colonies in central California.

Overview

The Seabird Restoration Education Program began in Fall 1996. Twenty-two teachers and nearly 1,700 students in Montara, Pacifica, Half Moon Bay, El Granada, and Fremont have participated over the past three years. During the 1998-1999 school year, seven schools, twenty-two teachers, and 742 elementary school children (grades 1-6) on the Central San Mateo Coast and in the City of Fremont participated. The education program focused on: 1) seabirds of the central coast of California; 2) the negative effects of egg collecting in the early 1900's, gill-net fishing, oil spills, and disturbance; 3) efforts to restore seabirds, including the restoration project at Devil's Slide Rock and San Pedro Rock; and 4) ways for students to help protect and restore seabirds. The education program was coordinated by Genie Moore and Fran McTamaney, Environmental Education Specialists at San Francisco Bay National Wildlife Refuge Complex (Refuge).

Participants

Cabrillo Unified School District

Farallone View Elementary School

Diana Purucker, 4th / 5th grade, 30 students
Linda Carroll, 4th / 5th grade, 32 students

Hatch Elementary School

Lyn Kelly, 5th grade, 32 students
Ann Margel, 4th / 5th grade, 32 students
George Nuttall, 5th grade, 32 students
Leslie McBride, 5th grade, 32 students

El Granada Elementary School

Jennifer Austin, 3rd grade, 20 students

Laguna Salada School District

Linda Mar Elementary School

Gretchen Delman, 5th grade, 31 students
Sandi Jaramillo, 5th grade, 30 students
Tom Mann, 4th grade, 31 students
Nora Chickhale, 3rd grade, 18 students
Betty Hayward, 3rd grade, 19 students

Vallemar Elementary School

Natalie Taylor, 1st grade, 31 students
Jenny Hansen, 5th grade, 30 students
Doreen Barnes, 5th grade, 32 students
Pat Ladner, 3rd grade, 30 students
Jan Willson, 3rd grade, 20 students
Carol Taylor, 3rd grade, 20 students

Sharp Park Elementary School

Sharron Walker, 3rd / 4th grade, 30 students
Kris Elvander, 4th / 5th grade, 30 students

Fremont Union School District

Warwick Elementary School

Ann Trammal, 5 classes of 3rd, 4th, and 5th graders, 30 students in each class

Katie Johnson, 6th grade, 30 students

Methods

Learn About Seabirds Workshop

On 12 September 1998, a workshop was conducted for the teachers involved in the education program. The workshop served as an introduction to the Common Murre Restoration Project for new teachers and as a refresher for continuing teachers. The workshop provided background information about seabird biology, reasons for seabird declines, and restoration techniques (specifically the Common Murre Restoration Project). Jennifer Boyce spoke about the Common Murre Restoration Project. New participants were supplied with educational materials to use in their classrooms (continuing participants already received these materials) including:

1) *Learn About Seabirds* Curriculum Guide, (U.S. Fish and Wildlife Service 1995b); 2)Project Puffin (Kress and Salmansohn, 1997); 3) Zoobooks: Seabirds, (Burst 1995); 4) Plastics Eliminators: Protecting California's Shorelines, California Aquatic Science Education Consortium, University of California, Santa Barbara (English and Spanish) (Shinkle and Copeland); 5)Video footage from Common Murre Restoration Project biologists, KRON, KPIX, and CNN; 6)Pre and Post Unit Assessments.

Classroom Presentations

Refuge staff, restoration biologists, and volunteers gave classroom presentations to each class during September and early October. The 45-minute presentations began with an introduction to seabirds and their ocean environment. A photo collage of seabirds was used to stimulate student discussion about the behavior and adaptations of seabirds. Ocean food webs were discussed. The students participated in a hands-on activity by building a Common Murre food pyramid. A short slide show was given to show pictures of Devil's Slide Rock and San Pedro Rock. The use of mirrors, decoys, and recordings of a murre colony used to attract the Common Murre to the restoration sites were discussed. There were also pictures of the biologists setting up the decoys and mirrors on the restoration sites. Students passed around adult murre, egg, and chick decoys. The presentation concluded with an explanation of the students role in the restoration project. The students also had the opportunity to ask questions about the restoration project.

Decoy Painting

After the decoys were removed from the rock and cleaned, the repainting project began. Wooden stands with metal rods were used to hold decoys while the students painted. Decoys, painting supplies, and decoy stands were taken to the schools during October and early November. One school was visited per day, with one to four classes painting at a time. Refuge staff, restoration biologists, and volunteers demonstrated how to paint the decoys and assisted students with the painting. Teachers and parents also assisted the students. A question and answer session was held after the painting was completed. The newly painted decoys stayed overnight at the schools to dry.

Classroom Activities

The teachers have used the curriculum material to conduct a number of activities and projects. Teachers and students have expanded the education project in various ways, creating paper mache murres and eggs, writing letters, reports, news articles, talking with local reporters, and many other activities and projects.

Data

The participating classes will be sent bi-weekly updates of the number of murres on Devil's Slide Rock and San Pedro Rock. The students keep track of the number of murres on Devil's Slide Rock and San Pedro Rock by using a data chart that is located on their classroom wall. Classes also are notified of eggs and chicks on the sites.

Conclusion

The third year of the Common Murre Restoration Project's Education Program included numerous activities and involved a large number of students in a hands-on action project. The project grew to include approximately 200 more students than last year. This is due to the increase in the number of decoys that were put on Devil's Slide Rock and San Pedro Rock. This project offered an opportunity for students to participate in an exciting natural resource project occurring in their own community. Students demonstrated a strong interest in and knowledge of the murre restoration project. The project would not have been so successful without the work and cooperative nature of the teachers, parents, students, refuge volunteers, environmental education staff, and restoration biologists.

OTHER FUNDED TASKS

A. Murre Studies at the South Farallon Islands

During Federal Fiscal Year 1996, funding was provided by the *Apex Houston* Trustee Council (AHTC) to the Point Reyes Bird Observatory (PRBO) to provide information from two PRBO studies of murres at the South Farallon Islands (Farallon National Wildlife Refuge) that: 1) will assist the refinement of social attraction techniques at DSR and SPR; and 2) will assist with determination of Common Murre breeding population estimates and assessment of population trends in central California. A description of work conducted is provided below.

Project A. Colony Formation and Nest Site Selection of Common Murres on Southeast Farallon Island, California

This work involved a retrospective analysis of existing PRBO data on site occupancy from 1986 through 1997 for the Upper Shubrick Point and Upper Upper murre colonies. Specifically, PRBO described changes in murre numbers, habitat selection and patterns of recruitment in relation to physical and social features of populations within the Shubrick and Upper Upper study plots (Sydeman et al. 1998). A final report has been provided to the San Francisco Bay National Wildlife Refuge Complex and the Apex Houston Trustee Council. Copies of the report can be obtained by contacting the Refuge.

Project B. Plot Attendance Patterns and Development of Correction Factors Used to Estimate Common Murre Breeding Population Size.

Diurnal and seasonal patterns of egg laying and attendance were examined to assess the most appropriate time to conduct aerial surveys of Common Murre colonies at the South Farallon Islands. In addition, K correction factors for converting numbers of individuals counted from aerial surveys into breeding pairs were examined. Data were collected from two Type I study plots (Upper Shubrick Point and Upper Upper) on the Southeast Farallon Island in 1996, 1997, and 1998. A draft report on the three-year project is due to the San Francisco Bay National Wildlife Refuge Complex in May 1999.

Aerial surveys in previous years have generally been conducted between 1000 and 1400 hours after the majority of eggs have been laid. Preliminary results from data collected at Upper Shubrick Point on Southeast Farallon Island in 1996 and 1997 indicate that diurnal and seasonal attendance of murres were least variable during this period (Hester and Sydeman 1997).

B. 1998 Aerial Surveys of Common Murre Colonies in California

In 1998, aerial surveys of central California Common Murre colonies were conducted on 14-15 May, 26-29 May, 1-2 June, and 18-19 June. Northern California surveys were conducted on 1-2 June. All other survey days were focused on conducting the annual and replicate surveys in central California. Surveys were conducted using similar method to Takekawa et al. (1990) and Carter et al. (1992, 1996). A slight modification was made as colonies were photographed out a 2'x3' opening located in the bottom of the plane. Previous photos were taken out the side windows of the plane. Surveys were flown at 50-90 knots (depending on wind speed) from a twin engine, wing-over Partenavia aircraft at altitudes above 500 feet. Colonies were photographed by two photographers, each using a 35 mm camera set at rapid shutter speeds, a 300mm telephoto lens, and color slide film (ASA 100 or 400). Overview photos also were taken using a 50 mm lens and color slide film (ASA 64 or 100). The airplane passed directly overhead to minimize oblique photographs. Cliffs and caves were photographed by flying slightly off the colony with a slight bank (<20°) allowing the colony to be viewed through the opening in the bottom of the plane.

A complete report on numbers of murres attending colonies, breeding population estimates and replicate survey work for 1996-1998 is expect by Fall 1999 or Spring 2000.

C. Subcolony Use and Population Trends at Point Reyes Headlands and Castle-Hurricane Colony Complexes, 1979-1995

During Federal Fiscal Year 1997, funding was provided by the AHTC to Humboldt State University (HSU) to provide and summarize detailed information from past aerial photographic surveys of Point Reyes Headlands and Castle-Hurricane Colony Complexes from 1979-1995 which will assist: 1) the refinement of social attraction techniques at DSR, SPR, and possibly in the future at the Castle-Hurricane Colony Complex; 2) determination of Common Murre breeding population estimates and assessment of population trends at these and other colonies in central California; and 3) analyses of subcolony attendance patterns studied by the Scientific Program since 1996. A final HSU report on the Point Reyes Headlands Colony Complex has been completed (McChesney et al. 1998). A draft report on the Castle-Hurricane Colony Complex has been completed and is currently being revised (McChesney et al., in prep.).

D. Marbled Murrelet Habitat Acquisition

In 1998, This project was completed under leadership of the California Department of Fish and Game with oversight by the *Apex Houston* Trustee Council. The AHTC contributed $500,000 toward the $1,450,000 purchase of 111 acres of forest habitat in the Gazos Creek Watershed of southern San Mateo County. This partnership with the Sempervirens Fund protects residual old growth redwood and Douglas fir stands that provide nesting habitat for Marbled Murrelets. The property will eventually become part of Butano State Park. An additional $60,000 of AHTC funds will pay for development of a management plan and continued monitoring of Marbled Murrelet occupancy of the acquired property.

E. Seabird Habitat Restoration

In Federal Fiscal Year 1998, funding has been provided by the AHTC to U.S. Fish and Wildlife Service - San Francisco Bay National Wildlife Refuge Complex for seabird habitat restoration at Southeast Farallon Islands. A total of $30,000 was provided to protect and enhance seabird nesting habitat by: 1) Reconstructing the system of wooden walkways and installing new walkways in heavily traveled areas and 2) restoring native plant communities through the control and eradication of invasive non-native plansts (e.g., New Zealand Spinach).

PLANS FOR 1999

Devil's Slide Rock
Decoys will be deployed during the winter-spring of 1999. The decoy arrangement will remain unchanged from the 1998 season. The batteries, CD players, amplifiers, and speakers will be replaced in each sound system.

San Pedro Rock
Decoys will be re-deployed on SPR in winter-spring 1999. Efforts will be concentrated on the central portion of SPR. The decoy arrangement will remain unchanged from 1998. Monitoring will be conducted by mainland, boat observations, and aerial overflights.

Castle Rocks and Mainland and Hurricane Point Rocks
Information on Common Murre attendance (diurnal and seasonal), behavior, breeding success, and chick diet will continue to be collected similar to the 1998 season. A recommendation about whether or not to deploy social attraction equipment at Castle Rocks and Mainland and Hurricane Point Rocks for breeding season year 2000 will be made at the end of the 1999 breeding season.

Point Reyes National Seashore (Point Reyes Headlands)
Information on Common Murre attendance (diurnal and seasonal), behavior, breeding success, and chick diet will continue to be collected using methods similar to those used in 1998.

Aerial Surveys/Population Estimates
Aerial surveys will be conducted to monitor breeding populations of Common Murres, Brandt's Cormorants, and Double-crested cormorants in central and northern California in May and June 1999.

Environmental Education
The environmental education program will continue to be conducted in San Mateo County and City of Fremont schools. Approximately sixteen teachers and 1000 students will be involved with the program.

LITERATURE CITED

Ainley, D.G. and R.J Boekelheide (editors). 1990. Seabirds of the Farallon Islands: Ecology, dynamics, and structure of an upwelling-system community. Stanford University Press, Stanford, California. 450 pp.

Birkhead, T.R. 1977. The effect of habitat and density on breeding success in the Common Guillemot (*Uria aalge*). Journal of Animal Ecology. 46:751-764.

Birkhead, T.R. and P.J. Hudson. 1977. Population parameters for the Common Guillemot (*Uria aalge*). Ornis. Scand. 8:145-154.

Birkhead, T.R. and D.N. Nettleship. 1980. Census methods for murres, *Uria* species: a unified approach. Canadian Wildlife Service Occasional Papers. Paper Number 43. 25pp.

Briggs, K.T., W.B. Tyler, D.B. Lewis, and K.F. Dettman. 1983. Seabirds of central and northern California, 1980-1983: status, abundance, and distribution. Unpubl. report, Center for Coastal Marine Studies, University of California, Santa Cruz, California.

Briggs, K.T., W.B. Tyler, D.B. Lewis, and D.R. Carlson. 1987. Bird communities at sea off California: 1975-1983. Studies in Avian Biology No. 11.

Burst, B.W. 1995. Zoobooks: Seabirds. Wildlife Education Ltd. San Diego, California.

Carter, H.R., and K.A. Hobson. 1988. Creching behavior of Brandt's Cormorant chicks. Condor 90:395-400.

Carter, H.R., G.J. McChesney, D.L. Jaques, C.S. Strong, M.W. , J.E. Takekawa, D.L. Jory, and D.L. Whitworth. 1992. Breeding populations of seabirds in California, 1989-1991. Vols. 1 and 2. Unpublished draft report, U.S. Fish and Wildlife Service, Northern Prairie Wildlife Research Center, Dixon, California.

Carter, H. R., G.J. McChesney, J.E. Takekawa, L.K. Ochikubo, D.L. Whitworth, T.W. Keeney, W.R. McIver, and C.S. Strong. 1996. Population monitoring of seabirds in California: 1993-1995 aerial photographic surveys of breeding colonies of Common Murres, Brandt's Cormorants, and Double-crested Cormorants. Unpublished final report, U.S. Geological Survey, Biological Resources Division, California Science Center, Dixon, California. 213 pp.

Carter, H.R., V.A. Lee, G.W. Page, M.W. Parker, R.G. Ford, G. Swartzman, S.W. Kress, B.R.Siskin, S.W. Singer, and D.M. Fry. In press. The 1986 *Apex Houston* oil spill in central California: seabird mortality and population impacts, injury assessments, litigation process, and initial restoration efforts. *In* J.A. Wiens and M.L. Tasker (Eds.). Seabirds and oil pollution. Cambridge University Press.

Fairman, N.P. and W.J. Sydeman. 1996. Attendance patterns, productivity, and effects of disturbance to Common Murre (*Uria aalge*) and Brandt's Cormorants (*Phalacrocorax penicillatus*) populations at Point Reyes National Seashore, California, 1995-1996. Unpublished report, Point Reyes Bird Observatory, Stinson Beach, California. 43 pp.

Ford, R.G., G.W. Page, and H.R. Carter. 1987. Estimating mortality of seabirds from oil spills. Pp. 547-551 *In* Proc. 1987 Oil Spill Conference, American Petroleum Institute, Washington D.C.

Forney, K.A. and S.R. Benson. 1999. Set gillnet effort and seabird bycatch in the Monterey Bay region, California, 1990-1997. Presentation at Pacific Seabird Group Annual Meeting. Blaine, Washington.

Gaston, A.J. and D.N. Nettleship. 1981. The Thick-billed Murres of Prince Leopold Island. Canadian Wildlife Service Monograph Series Number 6. 350pp.

Halley, D.J., M.P. Harris, and S. Wanless. 1995. Colony attendance patterns and recruitment in immature Common Murres (*Uria aalge*). The Auk 112(4):947-957.

Harris, M.P., D.J. Halley, and S. Wanless. 1996. Philopatry in the Common Guillemot *Uria aalge*. Bird Study 43:134-137.

Hatch, S.A. and M.A. Hatch. 1989. Attendance patterns of murres at breeding sites: implications for monitoring. J. Wildlife Management. 53:483-493.

Hester, M.M. and W.J. Sydeman. 1997. Attendance patterns and correction factors used to estimate breeding population size of Common Murres at Southeast Farallon Island, California - 1996. Unpubl. progress report, Point Reyes Bird Observatory, Stinson Beach, California.

Kress, S.W. and P. Salmansohn. 1997. Project Puffin: How we brought puffins back to Egg Rock. National Audubon Society. Tilbury House, Publishers, Garner, Maine.

Manuwal, D.A., H.R. Carter, and T. Zimmerman (Eds.). In press. Assessment of the biology, population status and conservation of the Common Murre *(Uria aalge californica)* in California, Oregon, Washington, and British Columbia. Chapters 1 and 2: Natural History and Population Trends. U.S. Geological Survey.

McChesney, G.J., H.R. Carter, M.W. Parker, J.E. Takekawa and J.L. Yee. 1998. Population trends and subcolony use of Common Murres and Brandt's Cormorants at Point Reyes Headlands, California, 1979-1997. Unpubl. report, U.S. Geological Survey, Biological Resources Division, Western Ecological Research Center, Dixon, California; Humboldt State University, Department of Wildlife, Arcata, California; and U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex, Newark, California.

McLaren, E.B., W.J. Sydeman, and P. Pyle. 1992. Population size and reproductive success of seabirds on Southeast Farallon Island, 1992. Unpubl. report, Point Reyes Bird Observatory, Stinson Beach, California (for U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex).

Page, G.W., H.R. Carter, and R.G. Ford. 1990. Numbers of seabirds killed or debilitated in the 1986 Apex Houston oil spill in central California. Studies in Avian Biology 14:164-174.

Parker, M.W., E.B. McLaren, S.E. Schubel, J.A. Boyce, P.J. Capitolo, M.A. Ortwerth, S.W. Kress, H.R. Carter, and A. Hutzel. 1997. Restoration of Common Murre Colonies in Central California: Annual Report 1996. Unpublished Report, U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex, Newark, California (prepared for the *Apex Houston* Trustee Council).

Parker, M.W., E.B. McLaren, J.A. Boyce, V. Collins, D.A. Nothhelfer, R.J. Young, S.W. Kress, H.R. Carter, and A.M. Hutzel. 1998. Restoration of Common Murre Colonies in Central Coastal California: Annual Report 1997. Unpublished Report, U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex, Newark, California (prepared for the *Apex Houston* Trustee Council).

Podolsky, R.H. 1985. Colony formation and attraction of the Laysan Albatross and Leach's Storm-Petrel. Unpubl. Ph.D. dissertation, University of Michigan, Ann Arbor, Michigan.

Podolsky, R.H., and S.W. Kress. 1989. Factors affecting colony formation in Leach's Storm-Petrel. Auk 106(2):332-336.

Podolsky, R.H., and S.W. Kress. 1991. Attraction of the endangered dark-rumped petrel to recorded vocalizations in the Galapagos Islands. Condor 94:448-453.

Ray, M.S. 1909. The passing of Pedro Island sea-bird rookery. Condor 11:94-96.

Schubel, S.E. 1993. A Common Murre attraction project on a Maine island. Unpubl. report, National Audubon Society, Ithaca, New York.

Shinkle, J. and W.D. Copeland. Plastics Eliminators: Protecting California's Shorelines. California Aquatic Science Education Consortium. Graduate School of Education, University of California, Santa Barbara, California.

Sowls, A.L., A.R. Degange, J.W. Nelson, and G.S. Lester. 1980. Catalog of California seabird colonies. U.S. Department of Interior, Fish and Wildl. Serv., Biol. Serv. Prog. FWS/OBS 37/80.

Swartzman, G. 1996. Resource modeling moves into the courtroom. Ecological Modeling 92: 277-288.

Sydeman, W.J., H.R. Carter, J.E. Takekawa, and N. Nur. 1997. Common Murre *Uria aalge* population trends at the South Farallon Islands, California, 1985-1995. Unpublished report, Point Reyes Bird Observatory, Stinson Beach, California; U.S. Geological Survey, Dixon, California; and U.S. Fish and Wildlife Service, Newark, California.

Takekawa, J.E., H.R. Carter, and T.E. Harvey. 1990. Decline of the Common Murre in Central California 1980-1986. Studies in Avian Biology 14:149-163.

Thayer, J.A., W.J. Sydeman, N.P. Fairman, S.G. Allen. In press. Attendance and Effects of Disturbance on Coastal Common Murre Colonies on Point Reyes, California.

U.S. Fish and Wildlife Service. 1995a. Restoration of nearshore breeding seabird colonies on the central California coast: Final Plan. Federal Register 60:81.

U.S. Fish and Wildlife Service. 1995b. Learn About Seabirds: A Curriculum Teacher's Guide. Second Printing

Watanuki Y. and T. Terasawa. 1995. Status and conservation of seabirds at Teuri Island, Japan. Unpublished Report. 13pp.

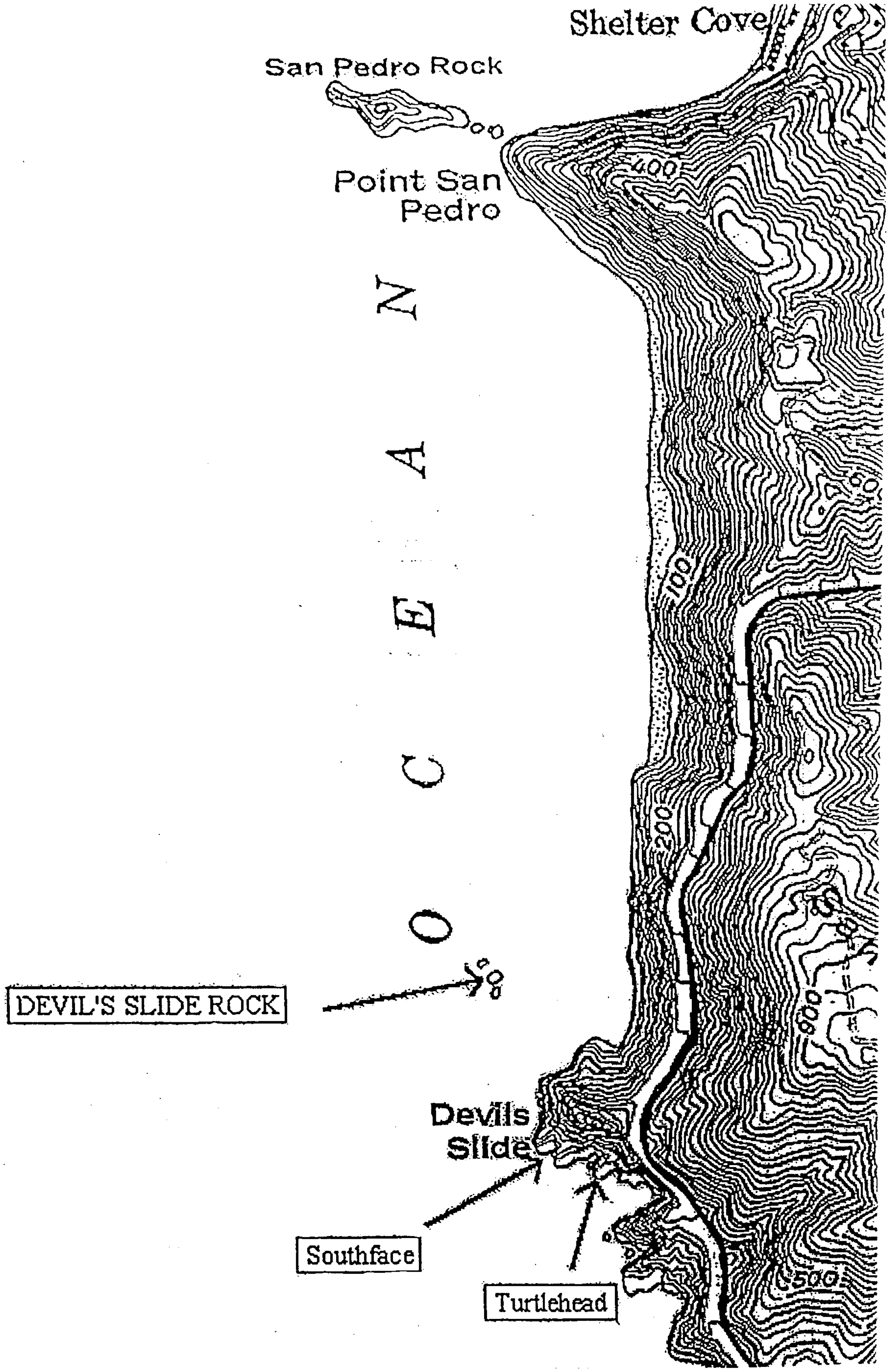

Figure 1. Map of Devil's Slide Rock and Mainland and San Pedro Rock, San Mateo County, California (Map created with TOPO!™© 1996 Wildflower Productions, www.top.com).

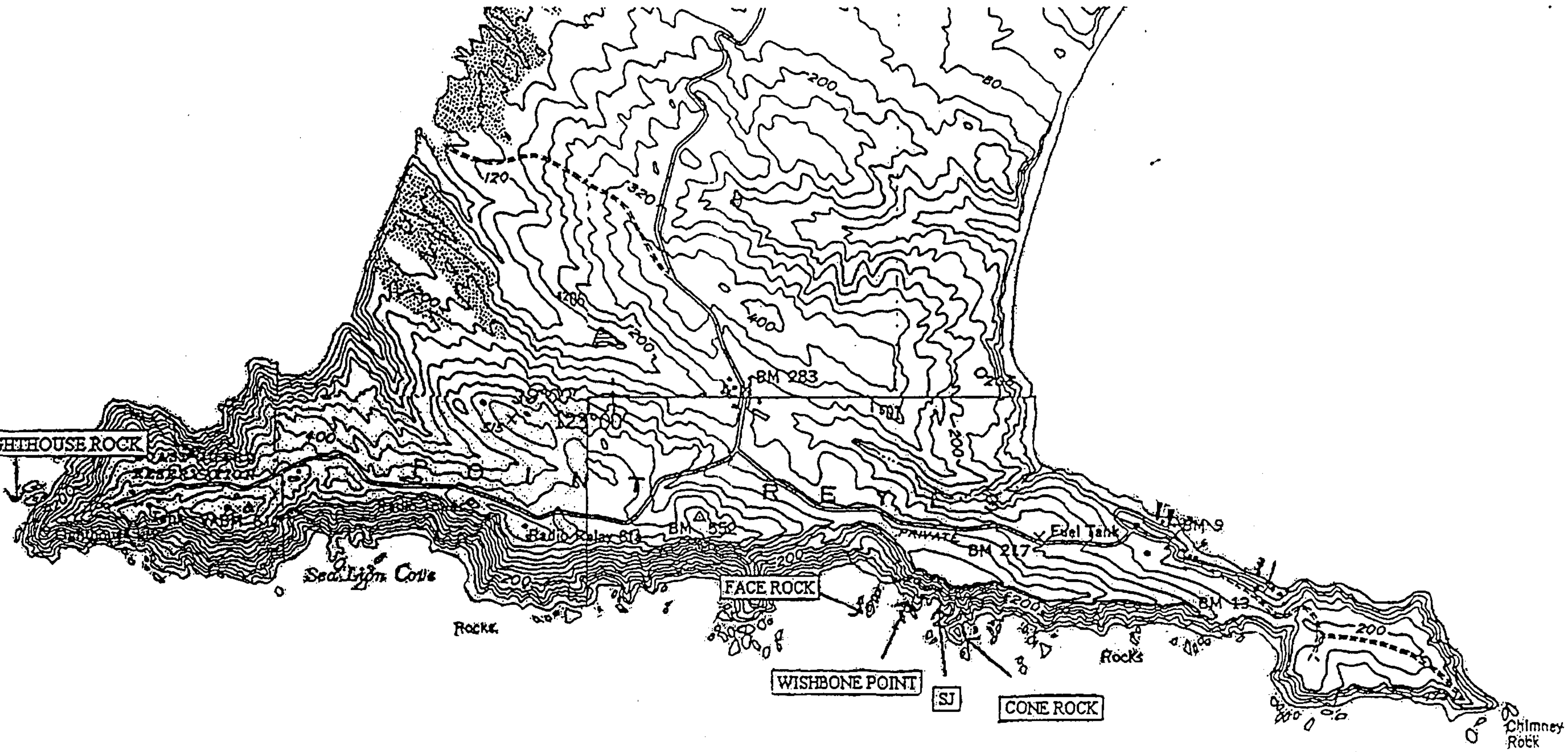

Figure 2. Map of monitored colonies at the Point Reyes Headlands, Point Reyes National Seashore, Marin County, California (Map created with TOPO!™©1996 Wildflower Productions, www.top.com).

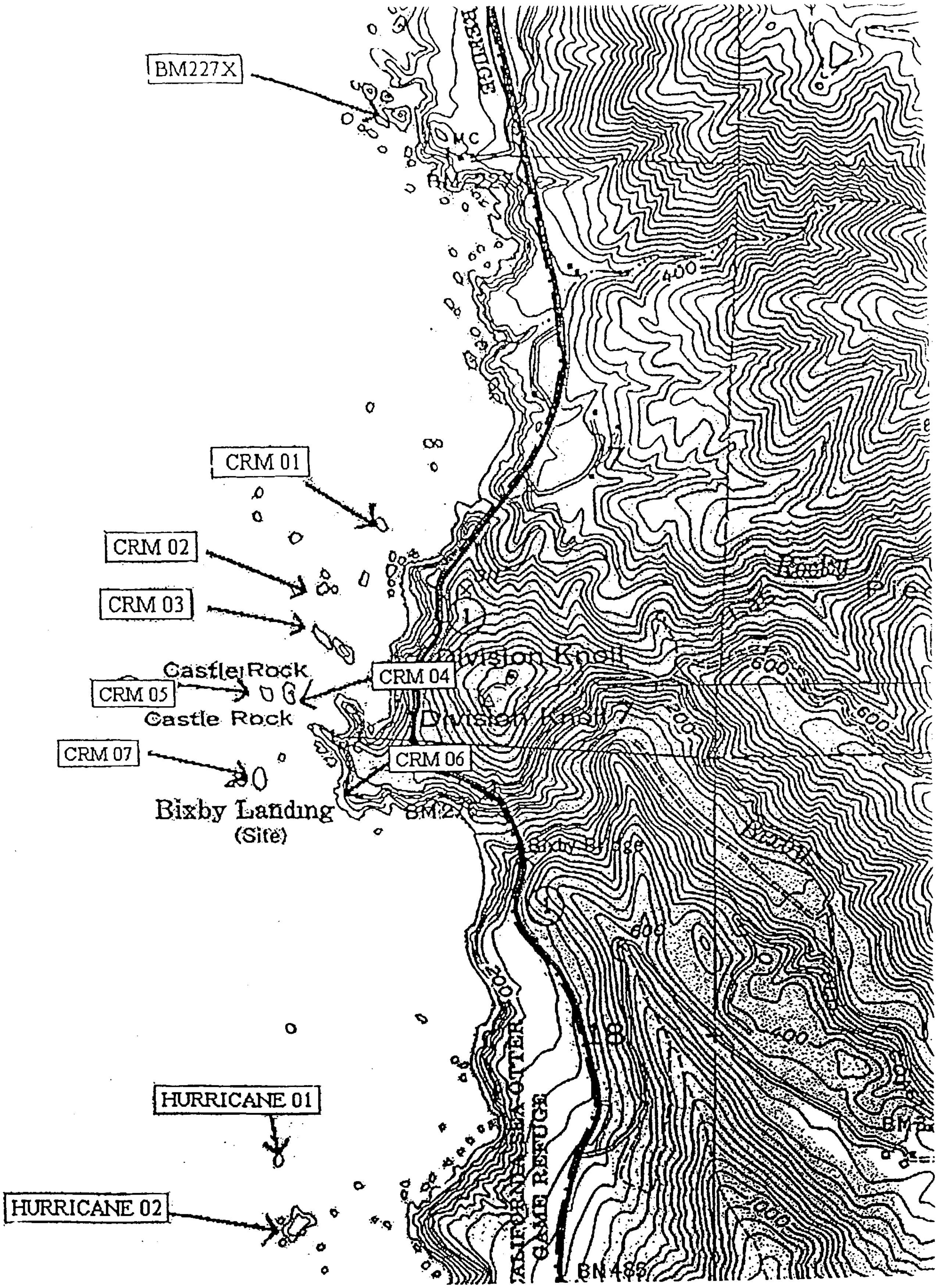

Figure 3. Map of colonies BM227X, Castle Rocks and Mainland, and Hurricane Point Rocks, Monterey County, California (Map created with TOPO!™©1996 Wildflower Productions, www.top.com).

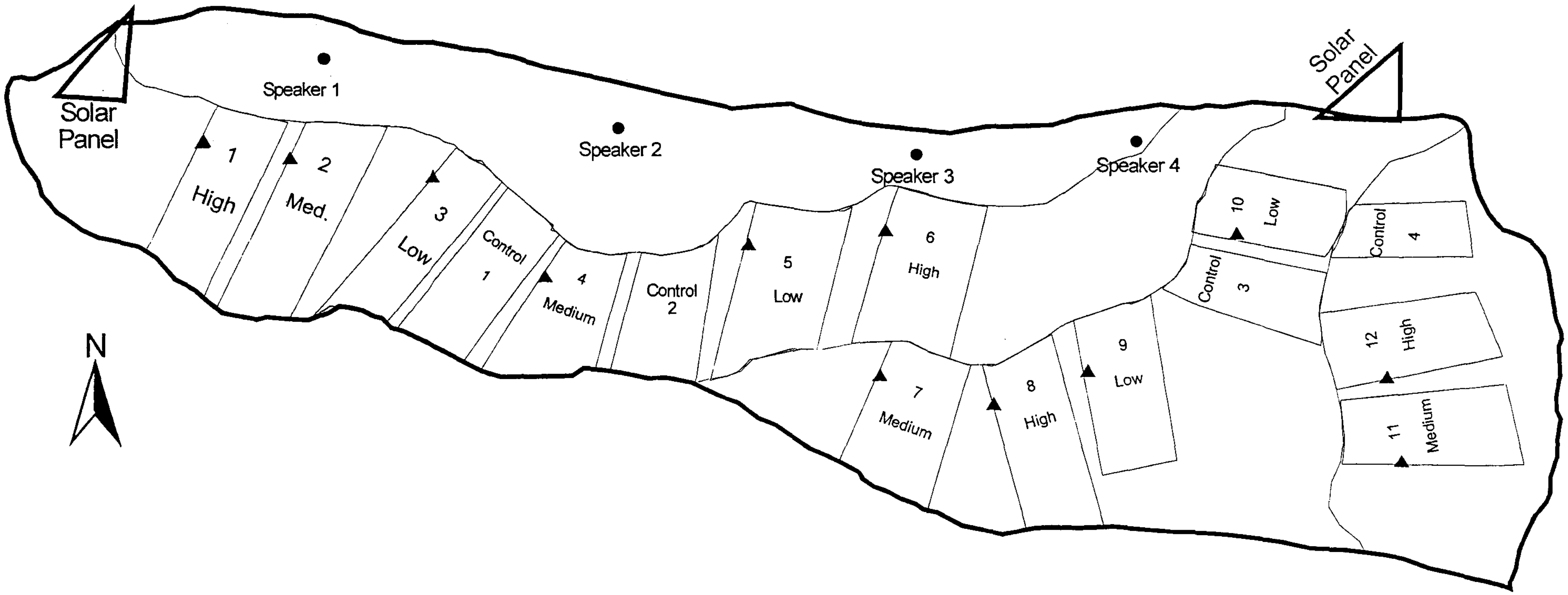

Figure 4. Layout of plots and social attraction equipment on Devil's Slide Rock, as viewed from the mainland point to the south (not to scale). Plots are numbered sequentially from west to east (left to right). Decoy density is indicated with each plot number (High, Medium, and Low). Control plots are numbered to correspond with each block treatment number. Block 1 contains plots 1, 2, 3 and Contirol 1; Block 2 contains plots 4, 5, 6 and Control 2; Block 3 contains plots 7, 8, 9, and Control 3; and Block 4 contains plots 10, 11, 12, and Control 4.

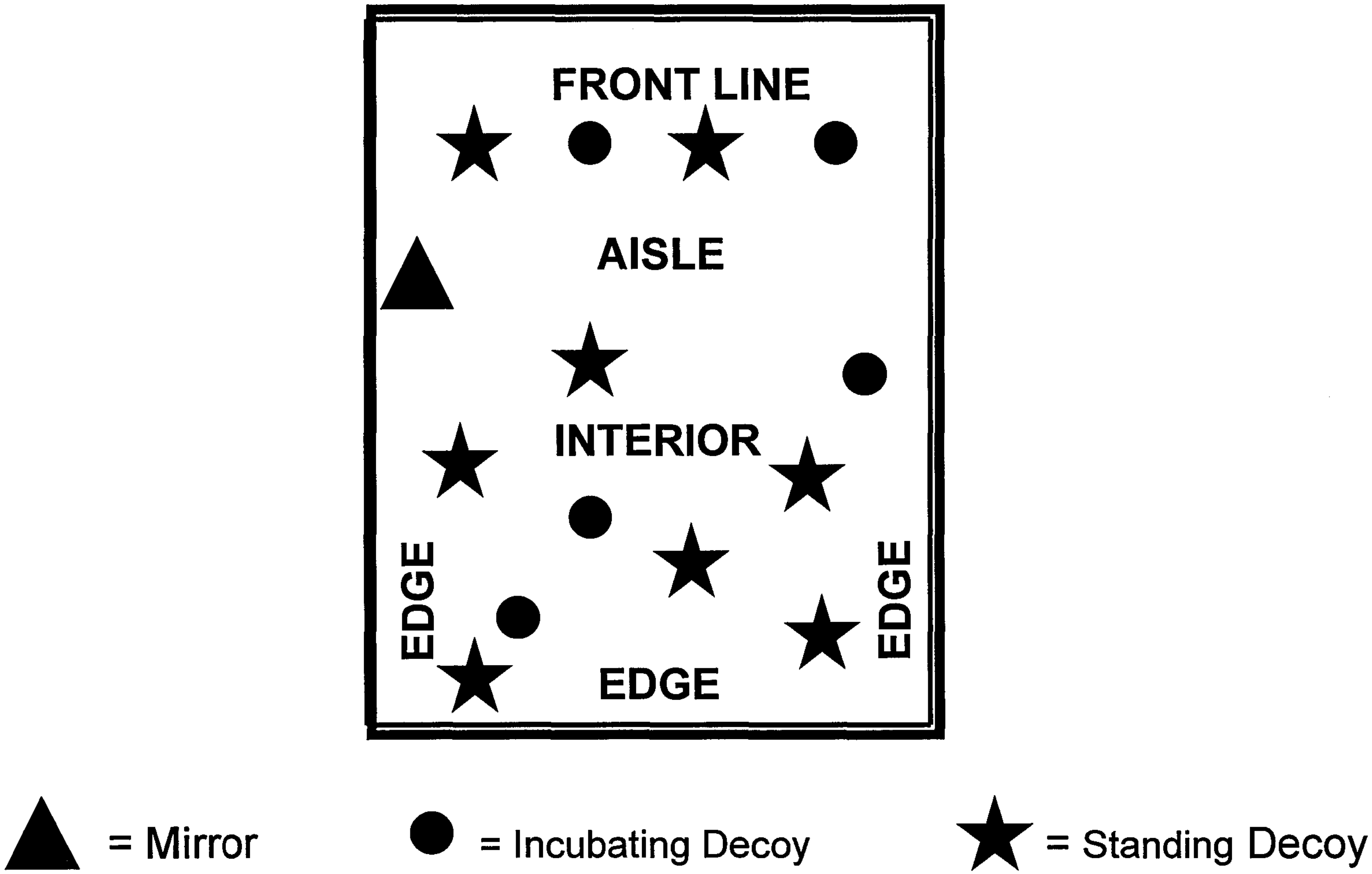

Figure 5. Schematic of Devil's Slide Rock Plot Design

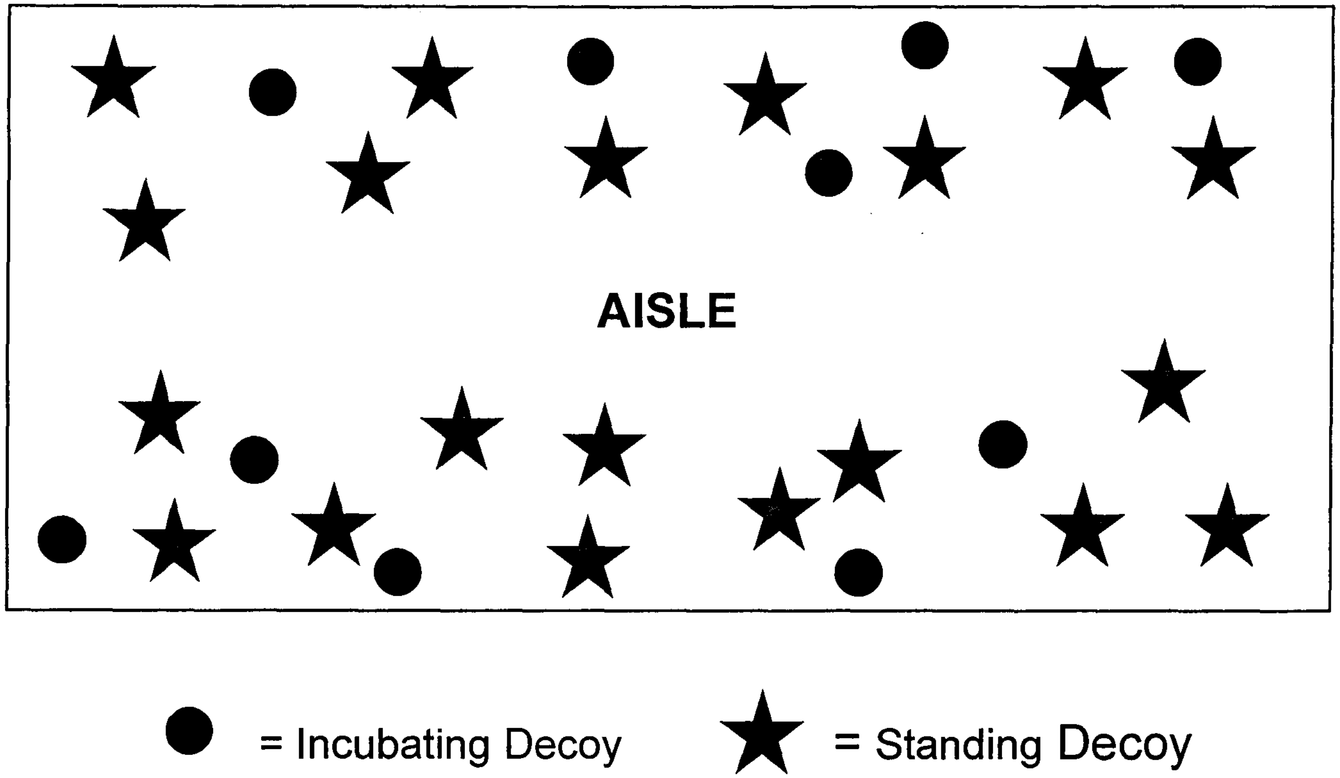

Figure 6. Schematic of San Pedro Rock plot design.

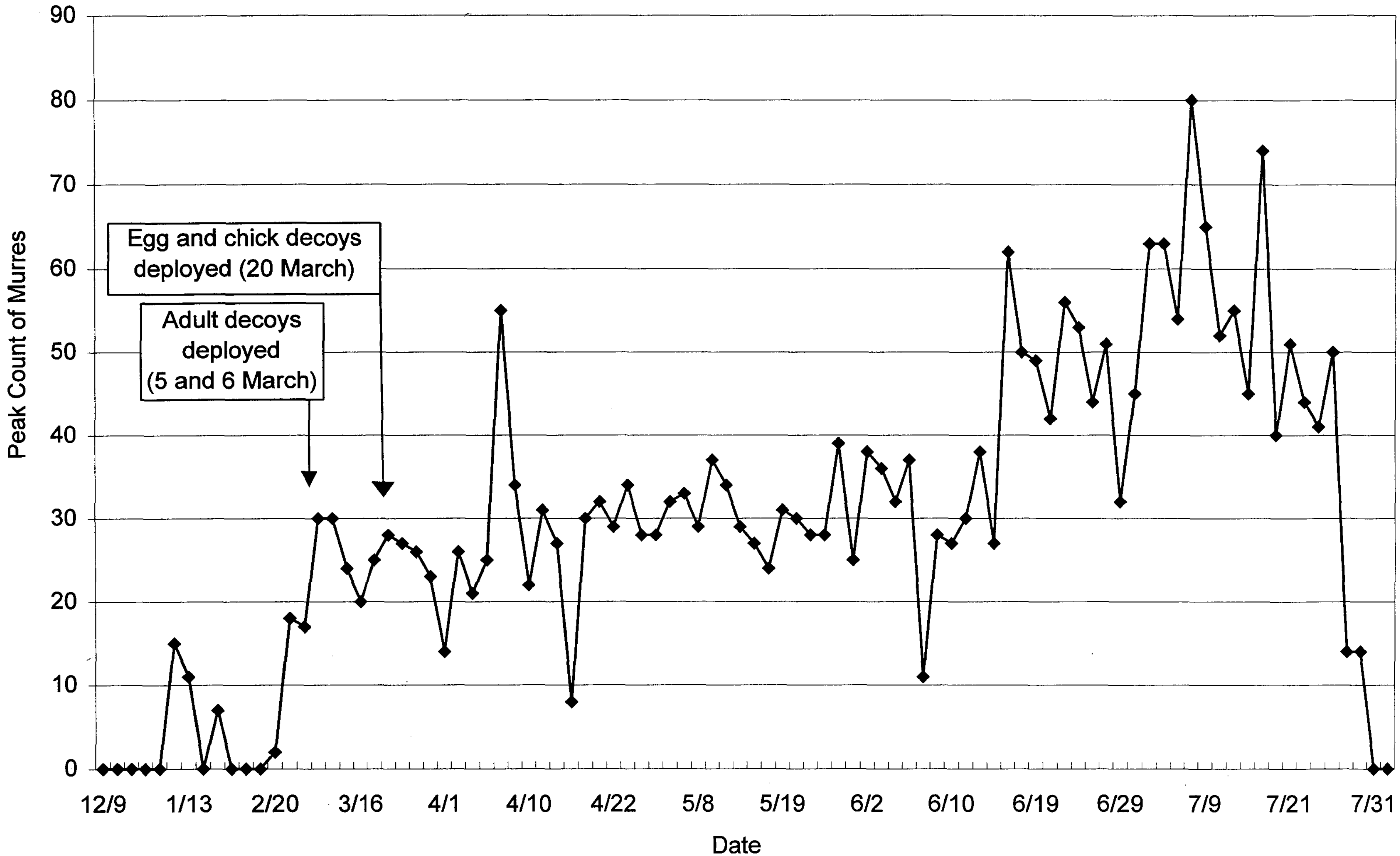

Figure 7. Daily peak counts of Common Murres on Devil's Slide Rock
9 December 1997 to 8 August 1998

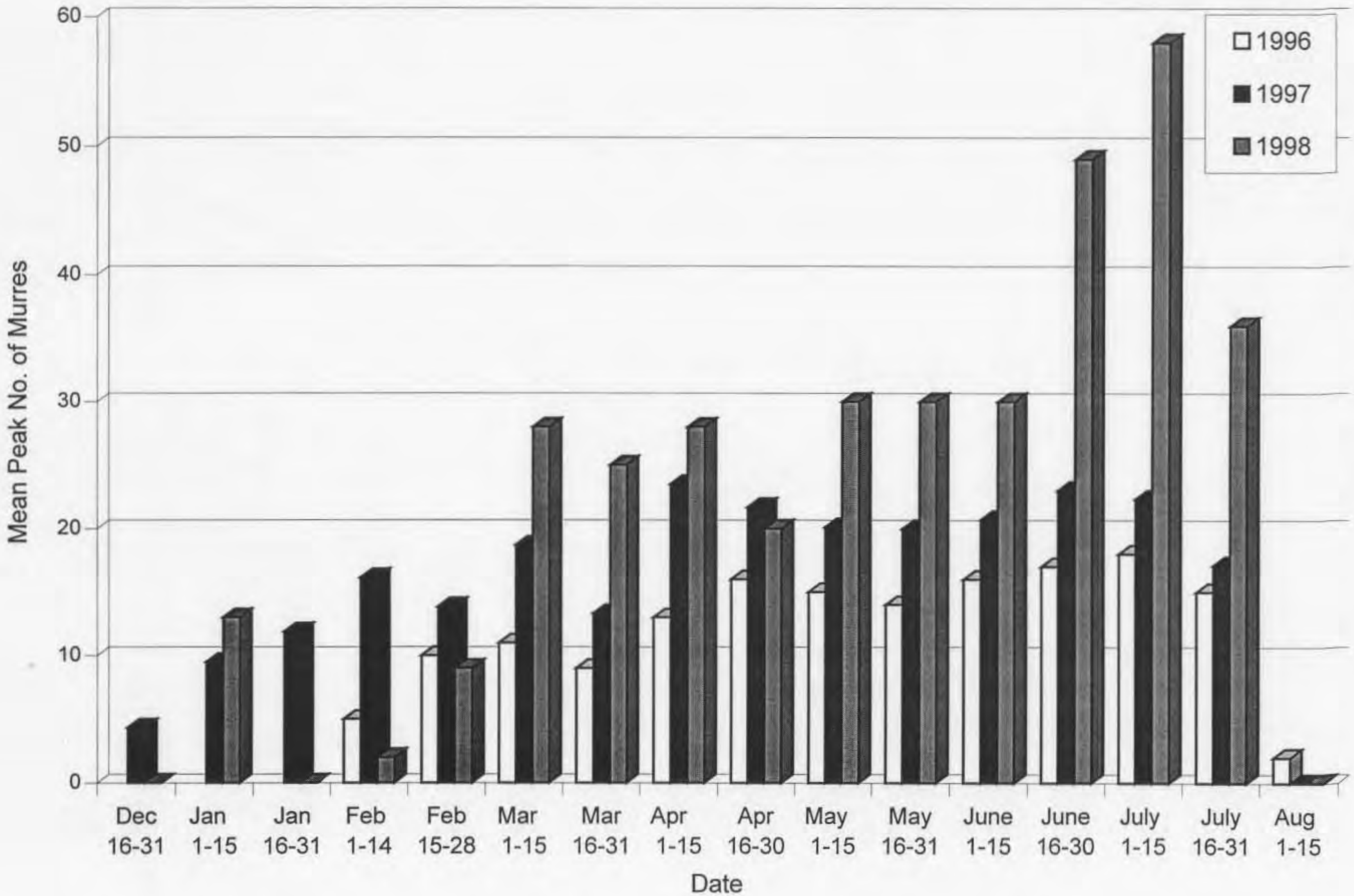

Figure 8. Mean peak number of Common Murres on Devil's Slide Rock at two week intervals during 1996, 1997, and 1998

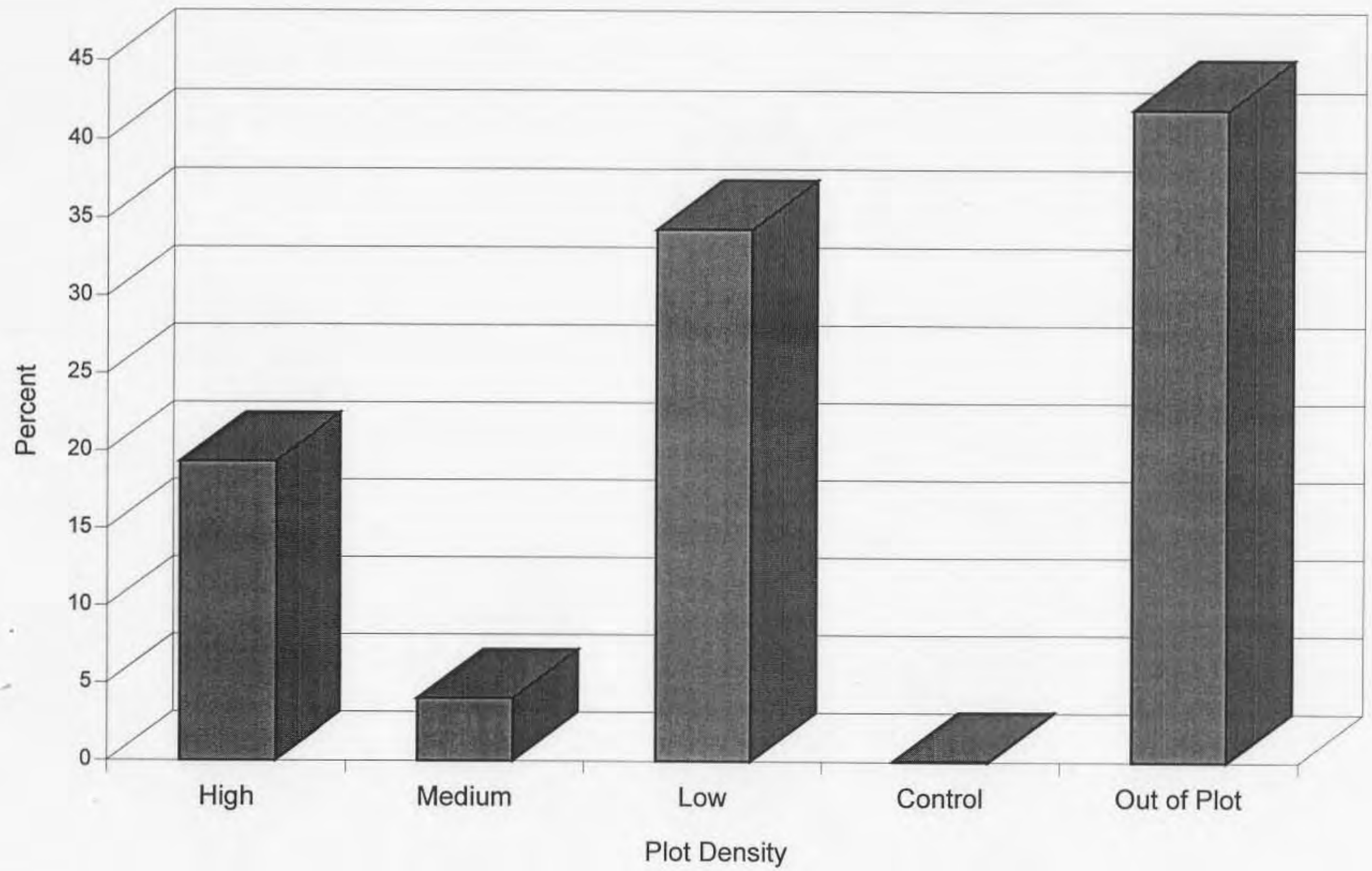

Figure 9. Percent occurrence of Common Murres in the four plot treatments
(N=24,349 from 5 March to 8 August, 1998)

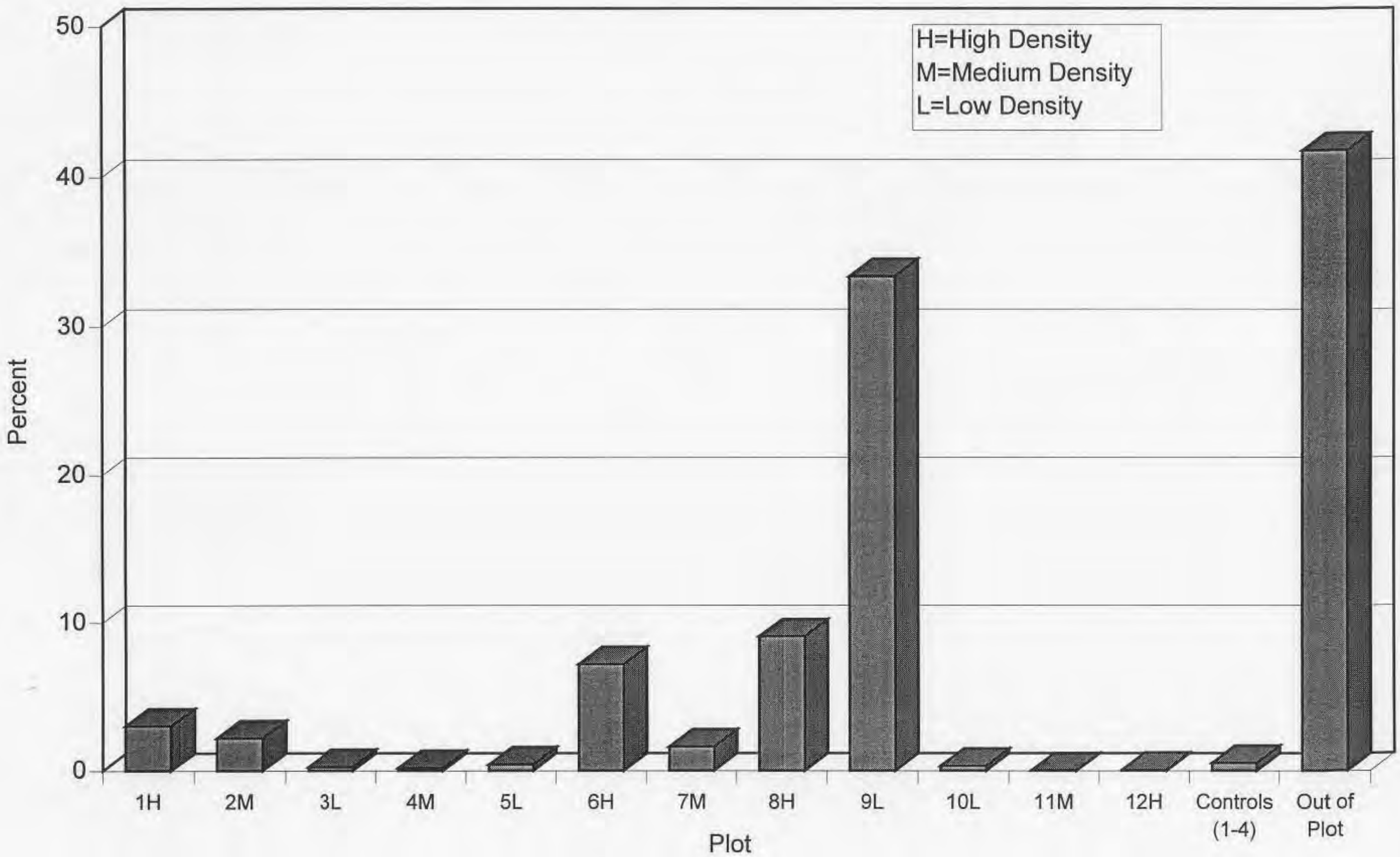

Figure 10. Percent occurrence of Common Murres in decoy plots, control plots, and out of plot areas
(N=24,349 from 5 March to 8 August1998)

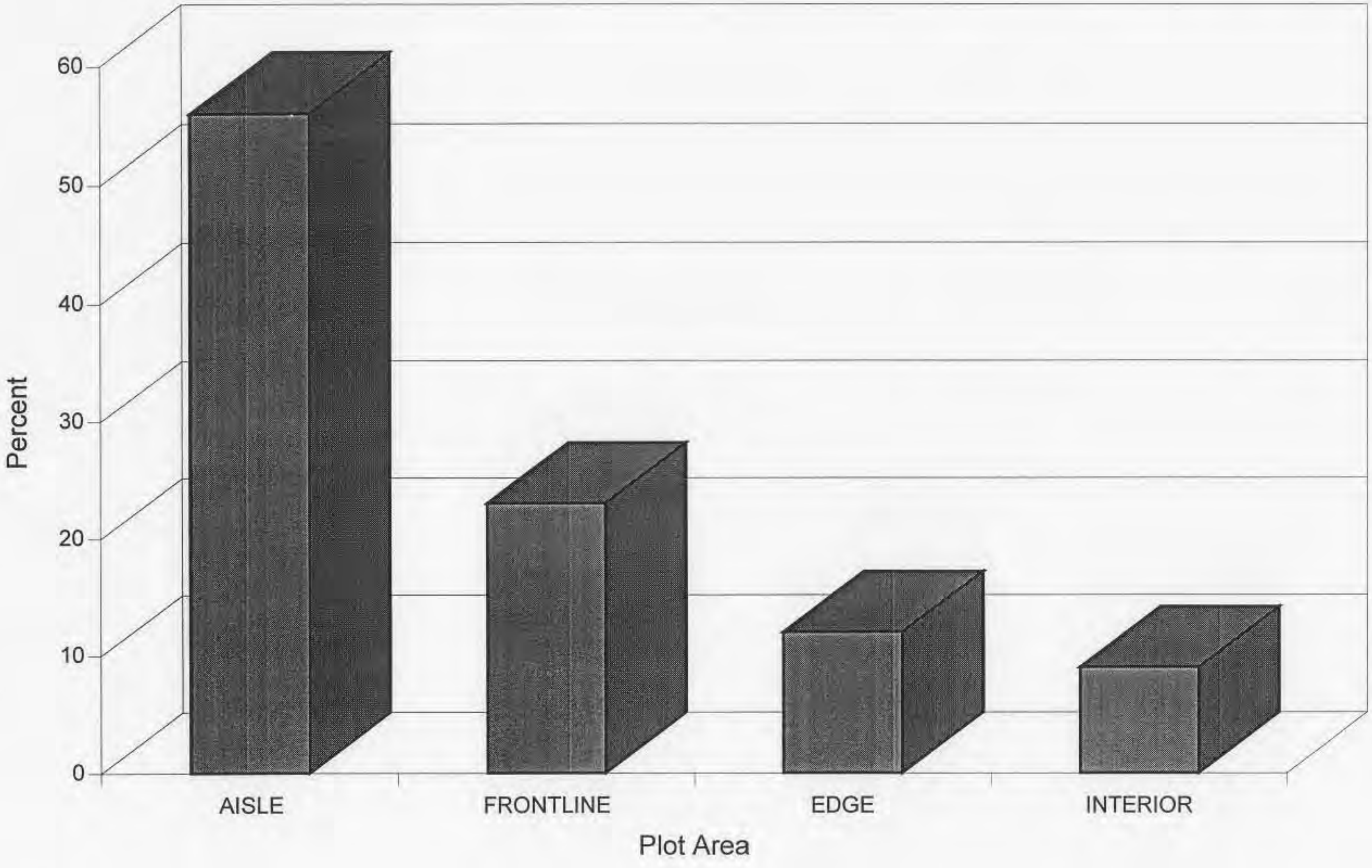

Figure 11. Percent occurrence of Common Murres in areas within plots
(N=14,052 murre observations from March 8 to August 8 1998)

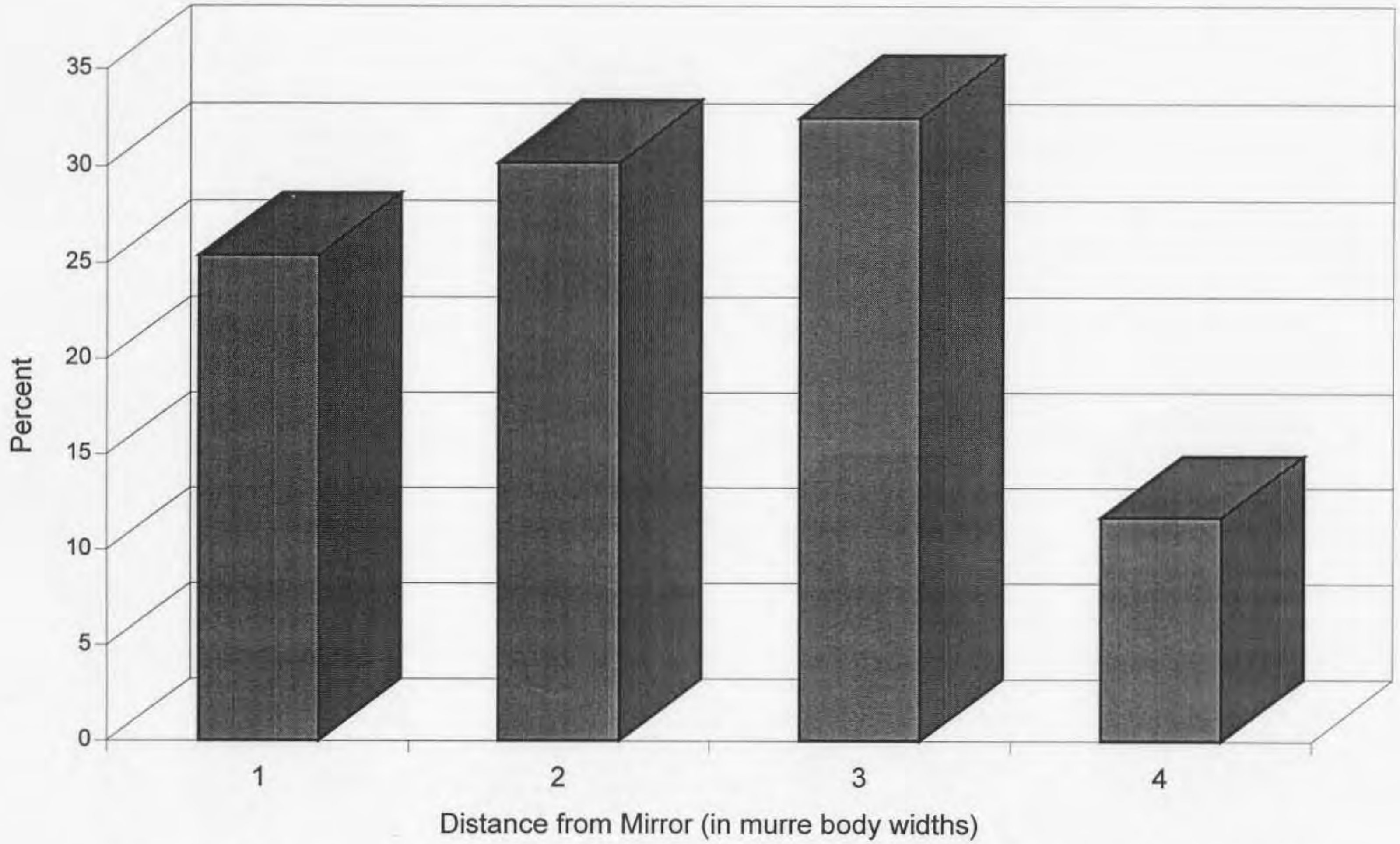

Figure 12. Percent occurrence of Common Murres relative to distance from mirrors, measured in murre body widths
(one murre width=approximately 15cm)
(N=24,349 from 5 March to 8 August, 1998)

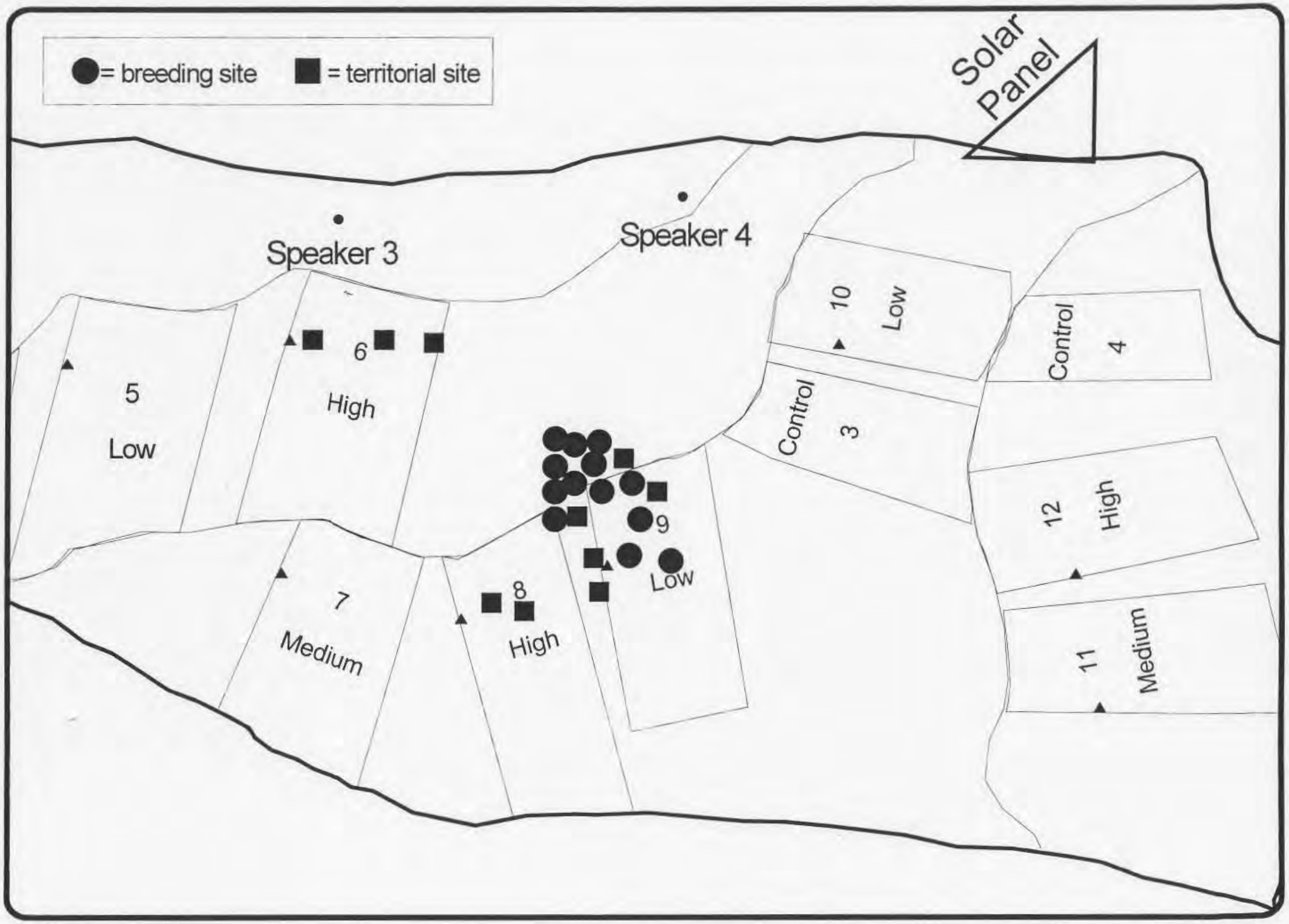

Figure 13. Location of Common Murre territorial and breeding sites on Devil's Slide Rock in 1998.

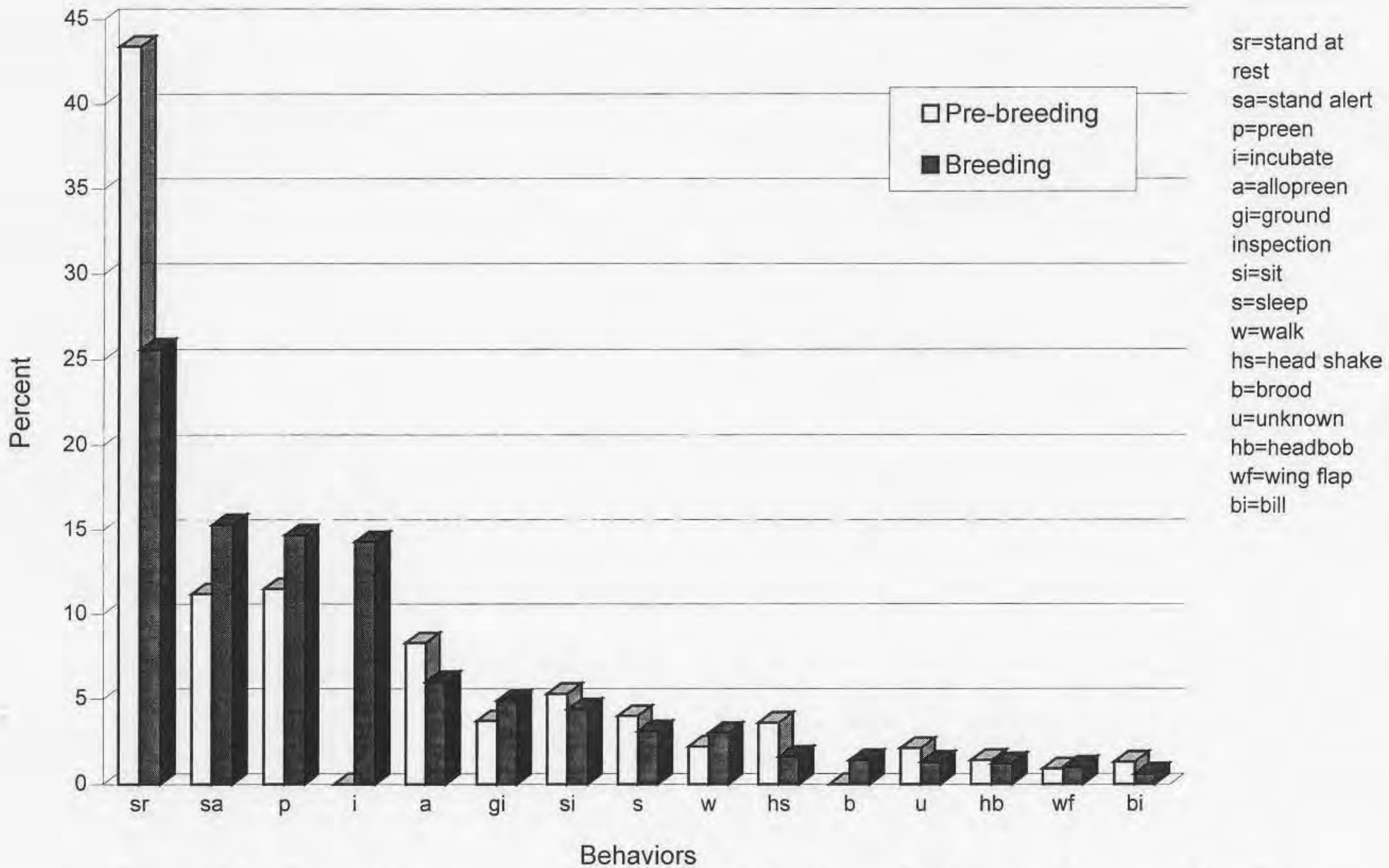

Figure 14. Percent occurrence of prominent behaviors of Common Murres at Devil's Slide Rock during the pre-breeding and breeding seasons (N=24,986 point samples from 13 January to 30 July 1998)

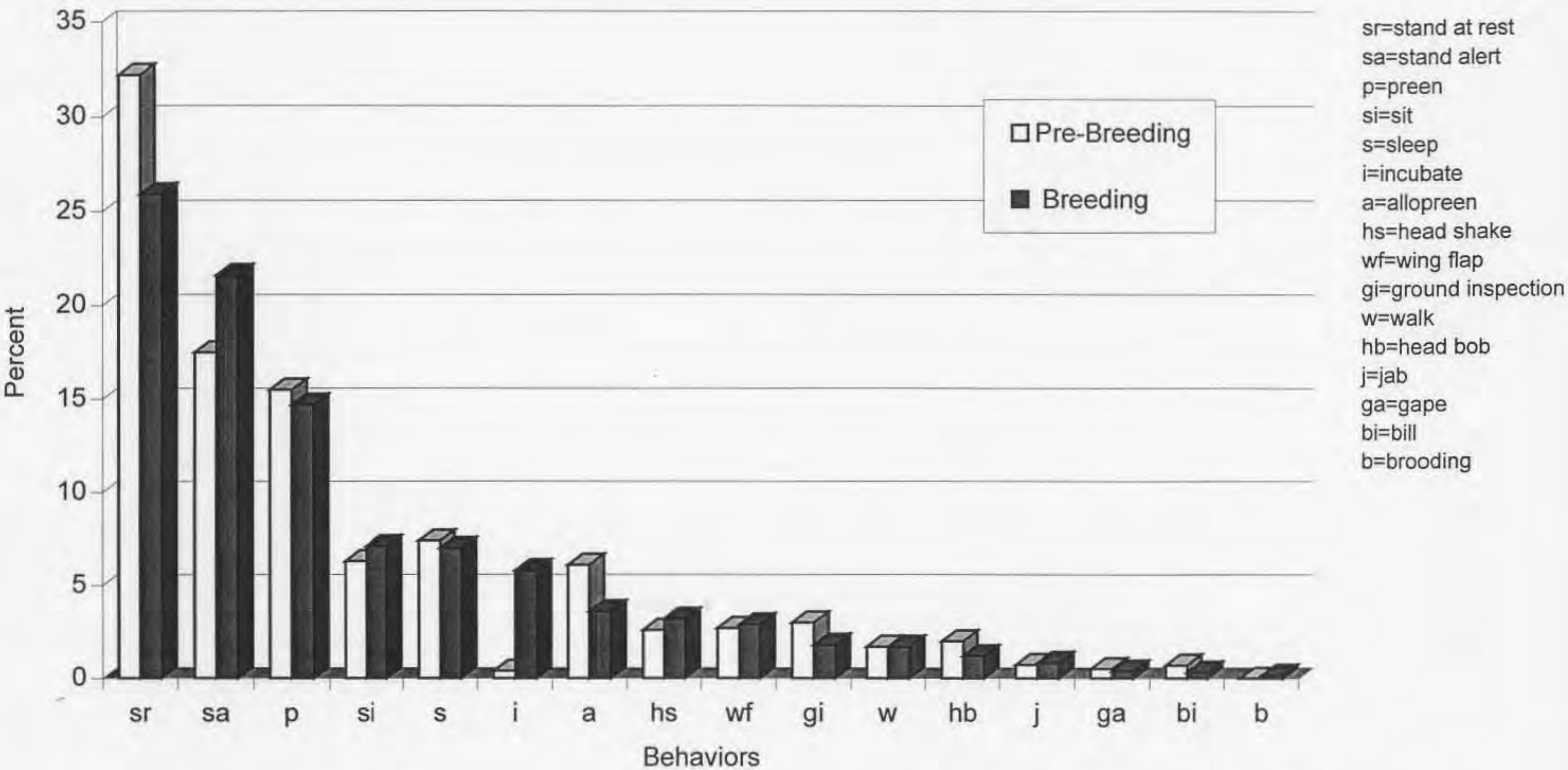

Figure 15. Percent occurrence of prominent behaviors of Common Murres at Point Reyes Headlands during the pre-breeding and breeding seasons
(N=89,584 point samples from 20 February to 24 July 1998)

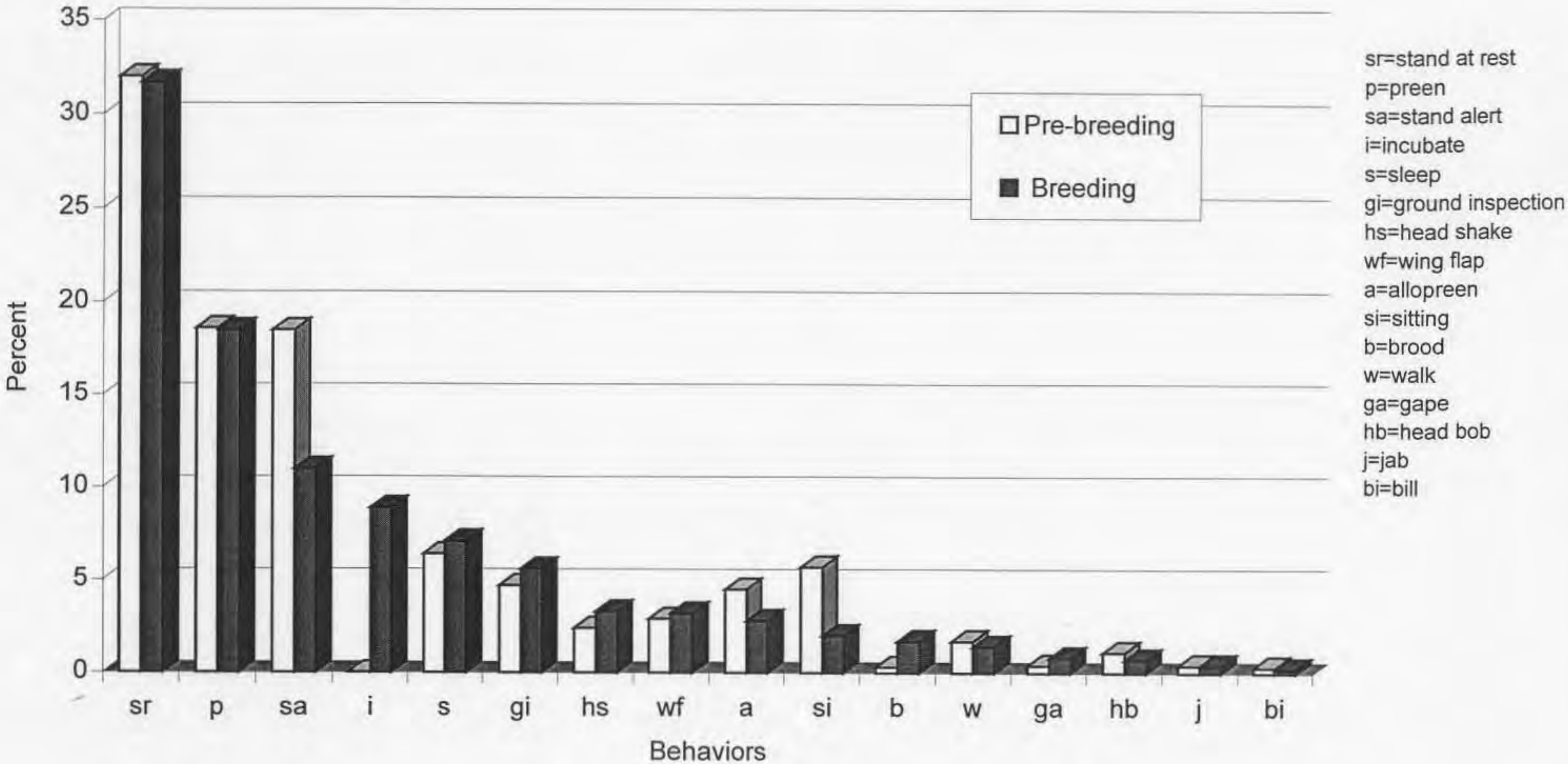

Figure 16. Percent occurrence of prominent behaviors at Castle Rocks and Mainland during the pre-breeding and breeding seasons
(N=92,831 point samples from 14 April to 4 August 1998)

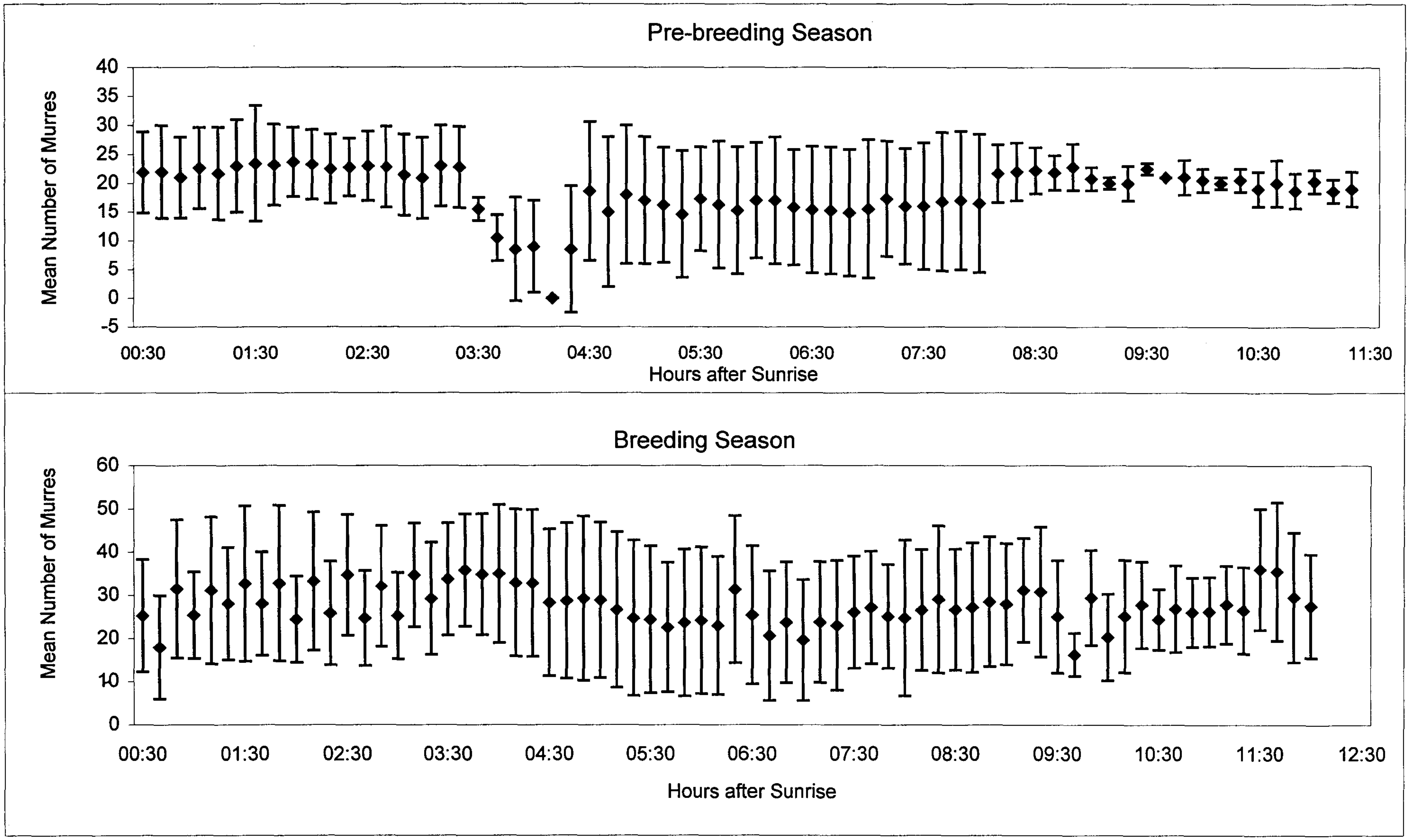

Figure 17. Diurnal attendance patterns of Common Murres on Devil's Slide Rock during the pre-breeding (10 December-13 May) and breeding (4 May-30 July) seasons based on 10 minute counts during daily observations (N=60)

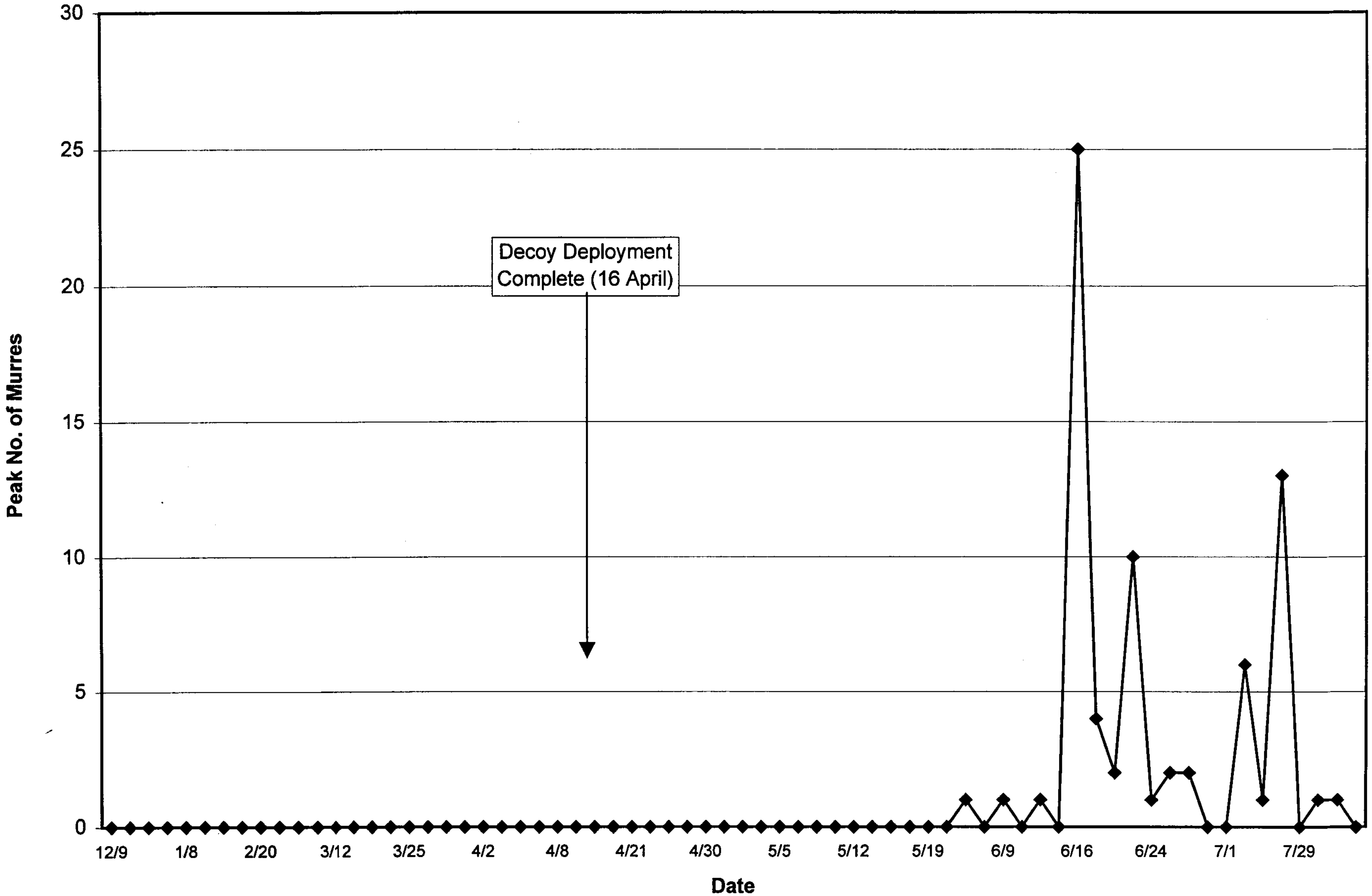

Figure 18. Peak Count of Common Murres at San Pedro Rock,
9 December 1997 - 8 August 1998

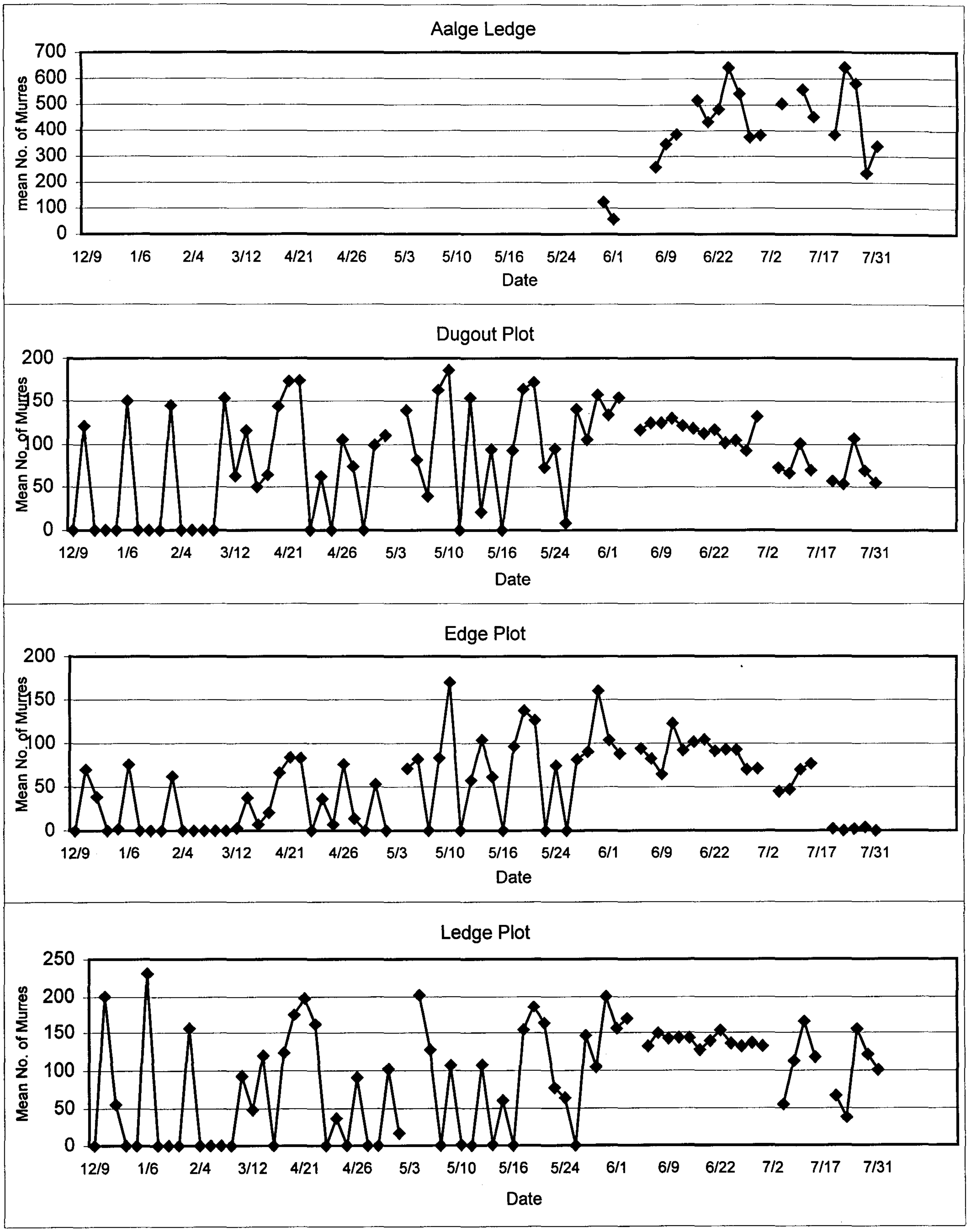

Figure 19. Seasonal attendance patterns of Common Murres at three index plots on Lighthouse Rock and Aalge Ledge, Point Reyes Headlands Subcolony 03

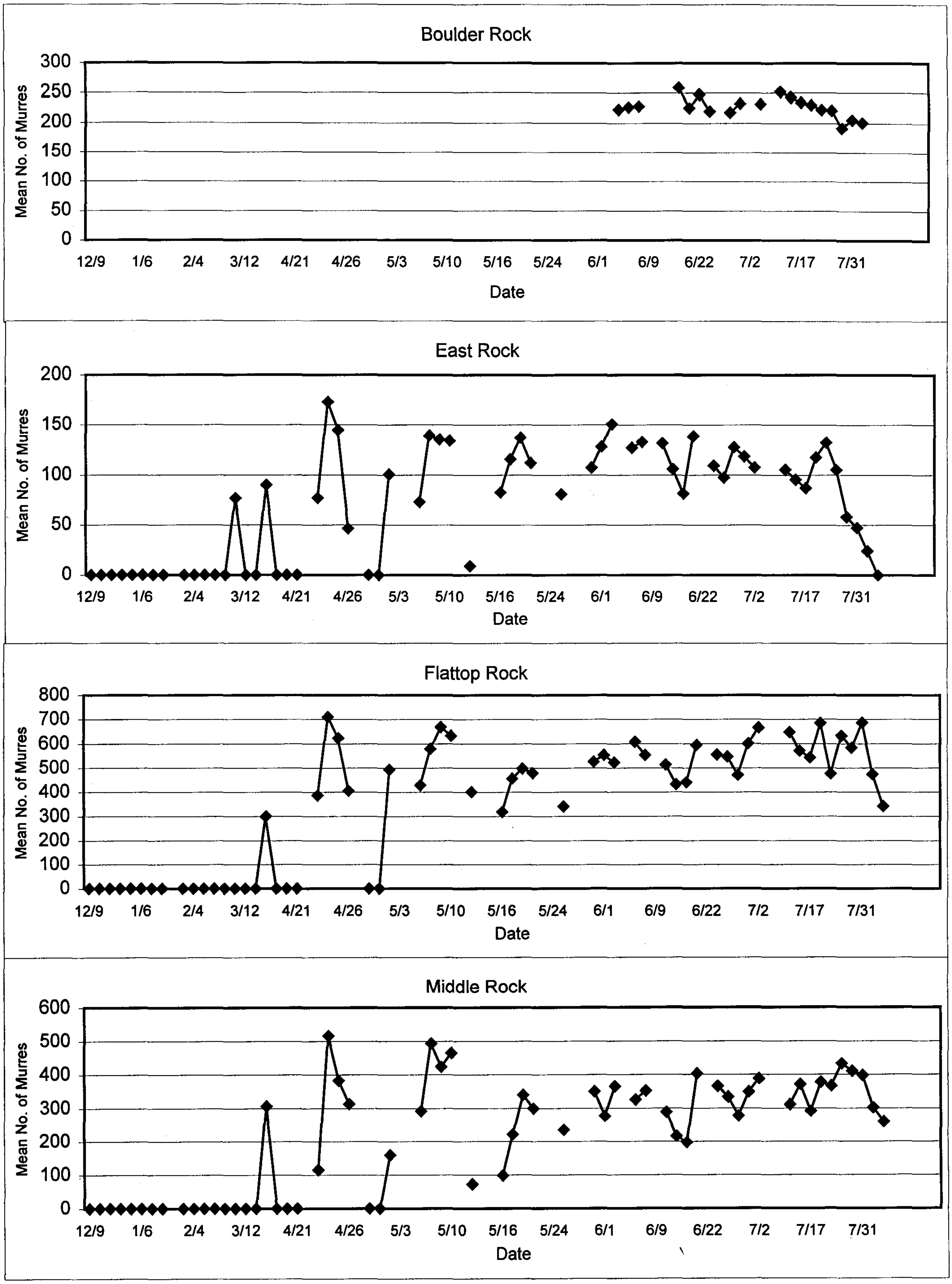

Figure 20. Seasonal attendance patterns of Common Murres at Point Reyes Headlands subcolonies 05 and 10
9 December 1997 to 7 August 1998

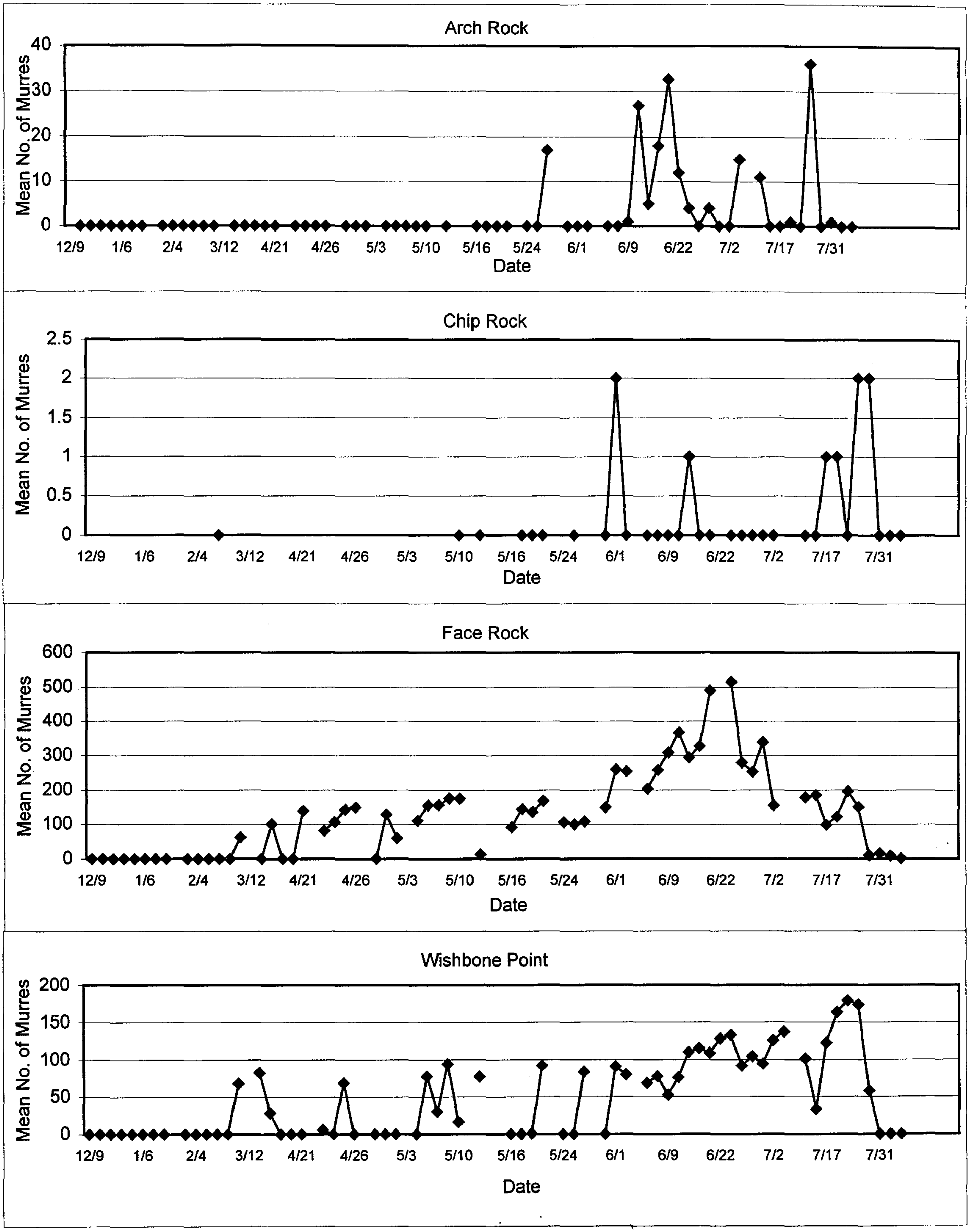

Figure 21. Seasonal attendance patterns of Common Murres at Point Reyes Headlands
Subcolony 11
9 December 1997 to 7 August 1998

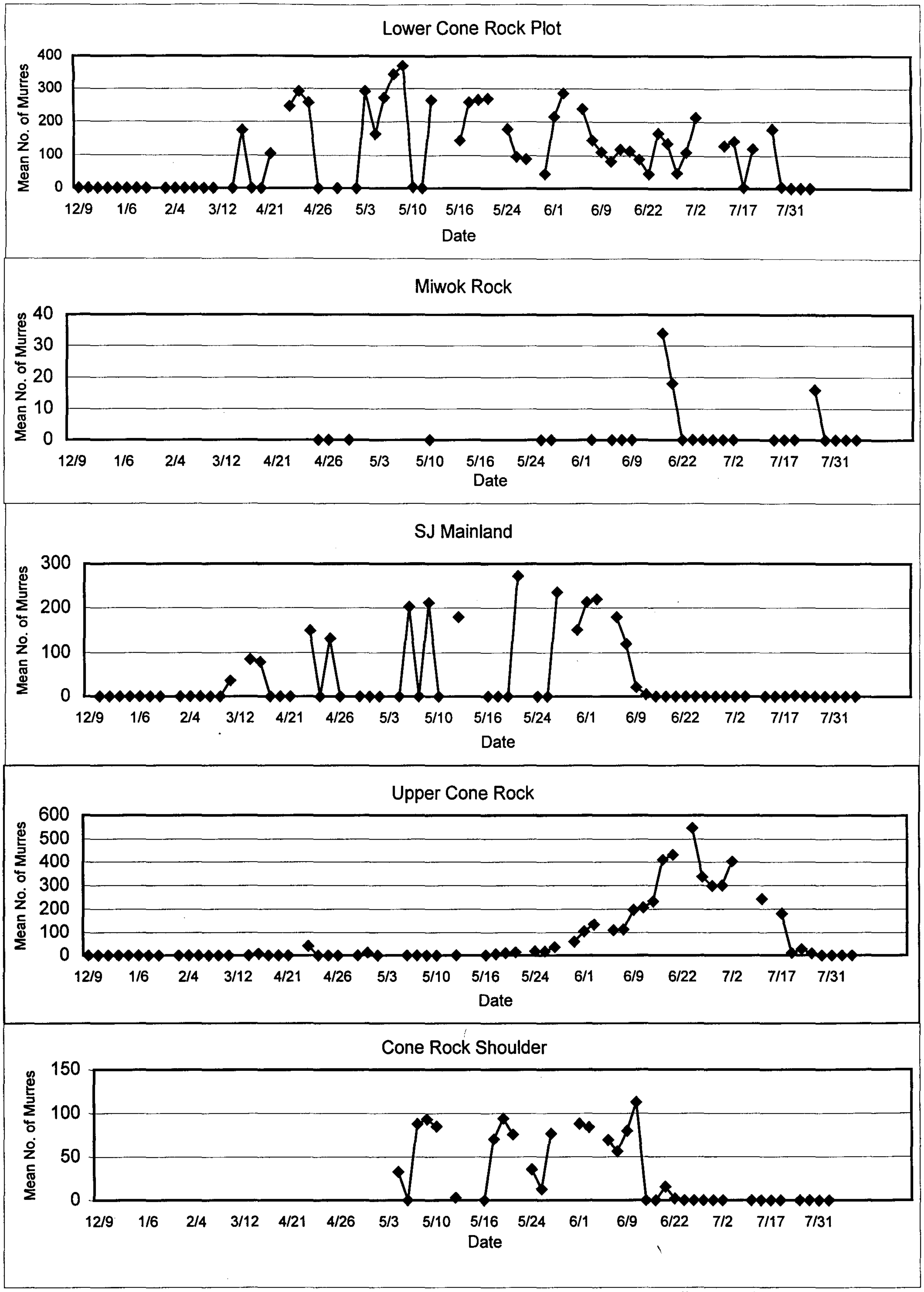

Figure 22. Seasonal attendance patterns of Common Murres at Point Reyes Headlands subcolonies 12 to 14
9 December 1997 to 7 August 1998

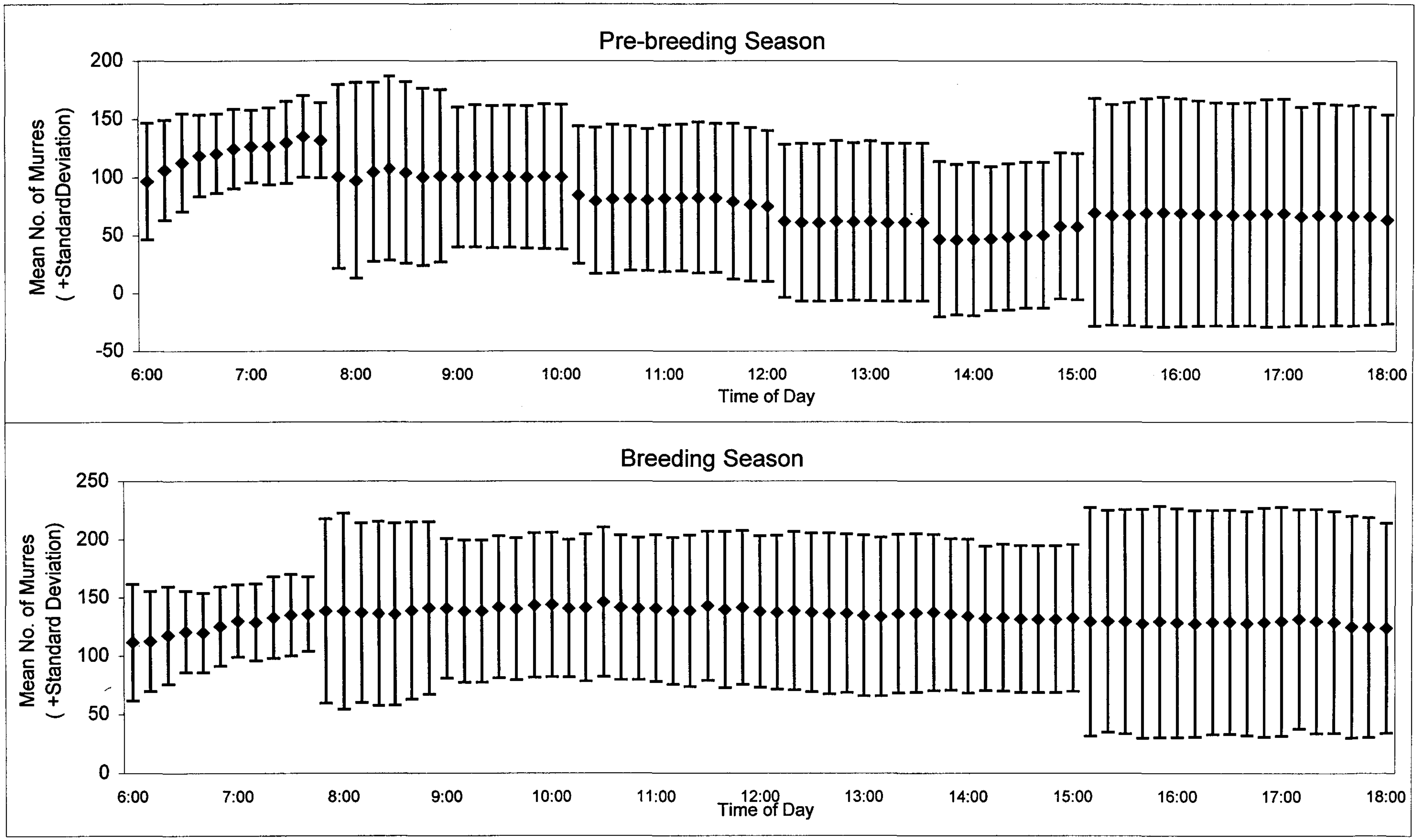

Figure 23. Diurnal Attendance patterns of Common Murres on the Ledge Plot during the pre-breeding (20 February-3 June) and breeding (4 June-24July) seasons based on 10 minute counts during 12-hour watches (N = 8 and 3 respectively)

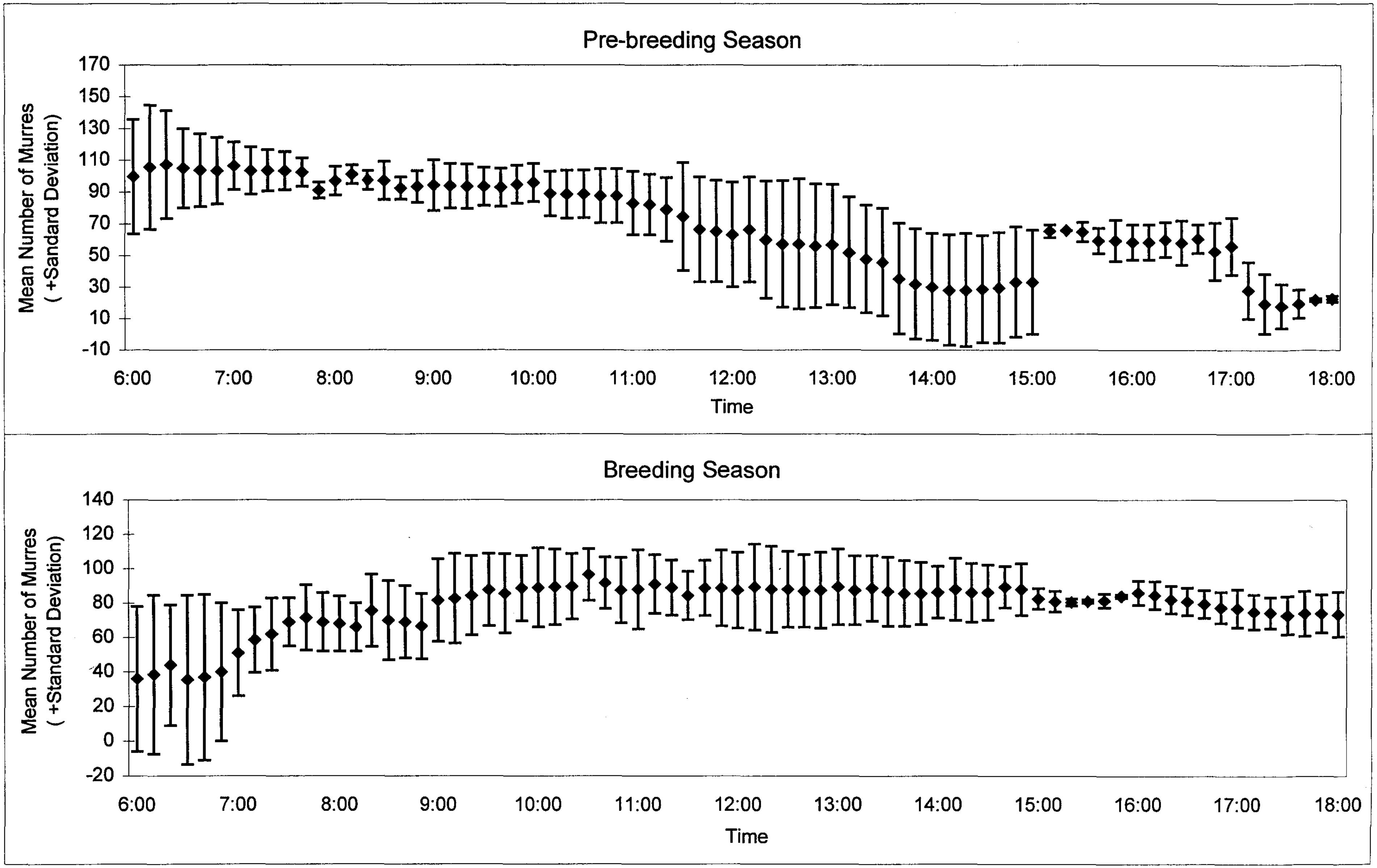

Figure 24. Diurnal attendance patterns of Common Murres on the Edge Plot during the pre-breeding (20 February-3 June) and breeding (4 June-24 July) seasons based on 10 minute counts during 12 hour watches (N = 8 and 3 respectively)

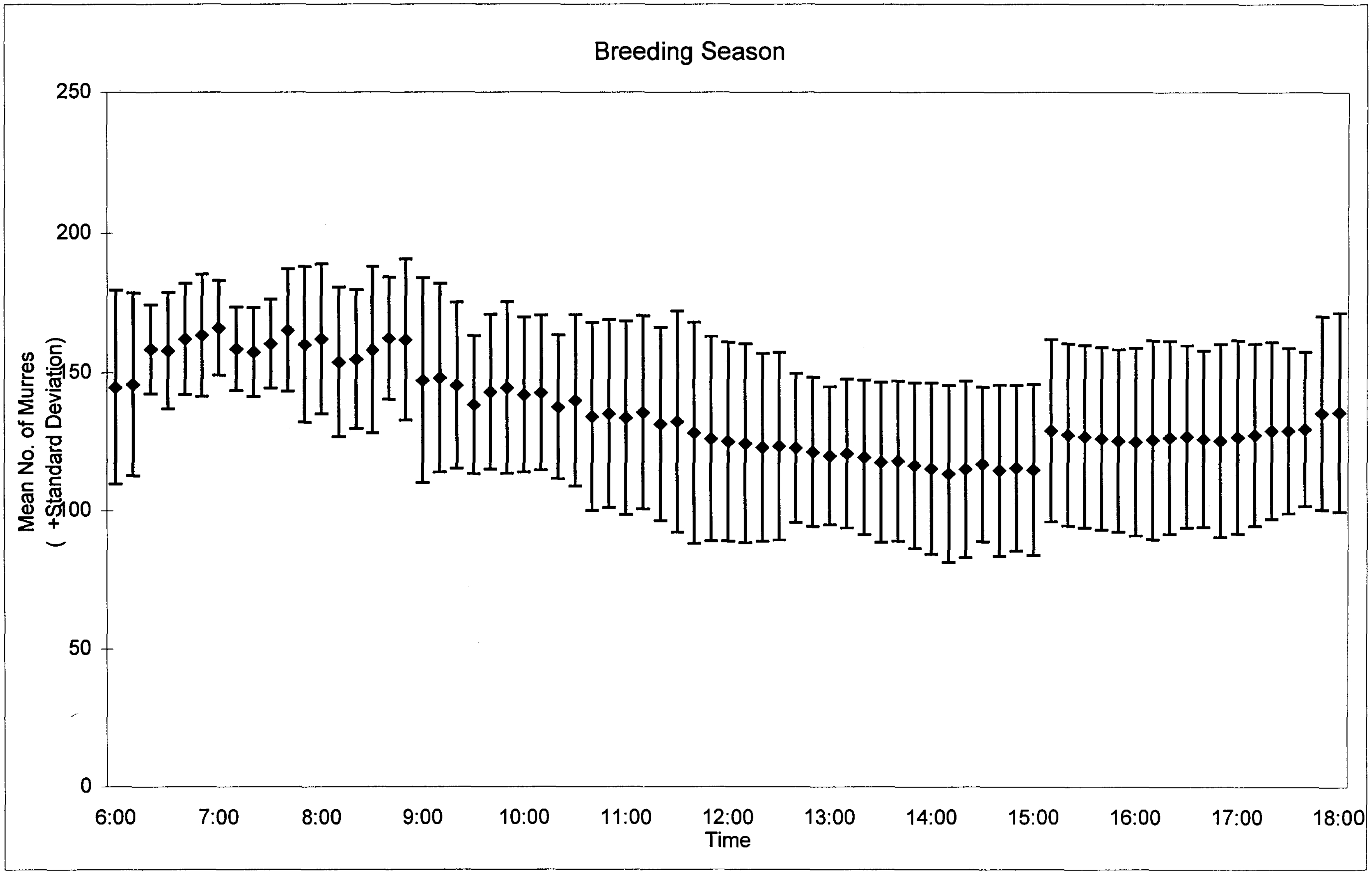

Figure 25. Diurnal attendance patterns of Common Murres at Wishbone Point during the breeding season (18 June to 23 July 1998) based on 10 minute counts during 12-hour watches (N = 3 watches)

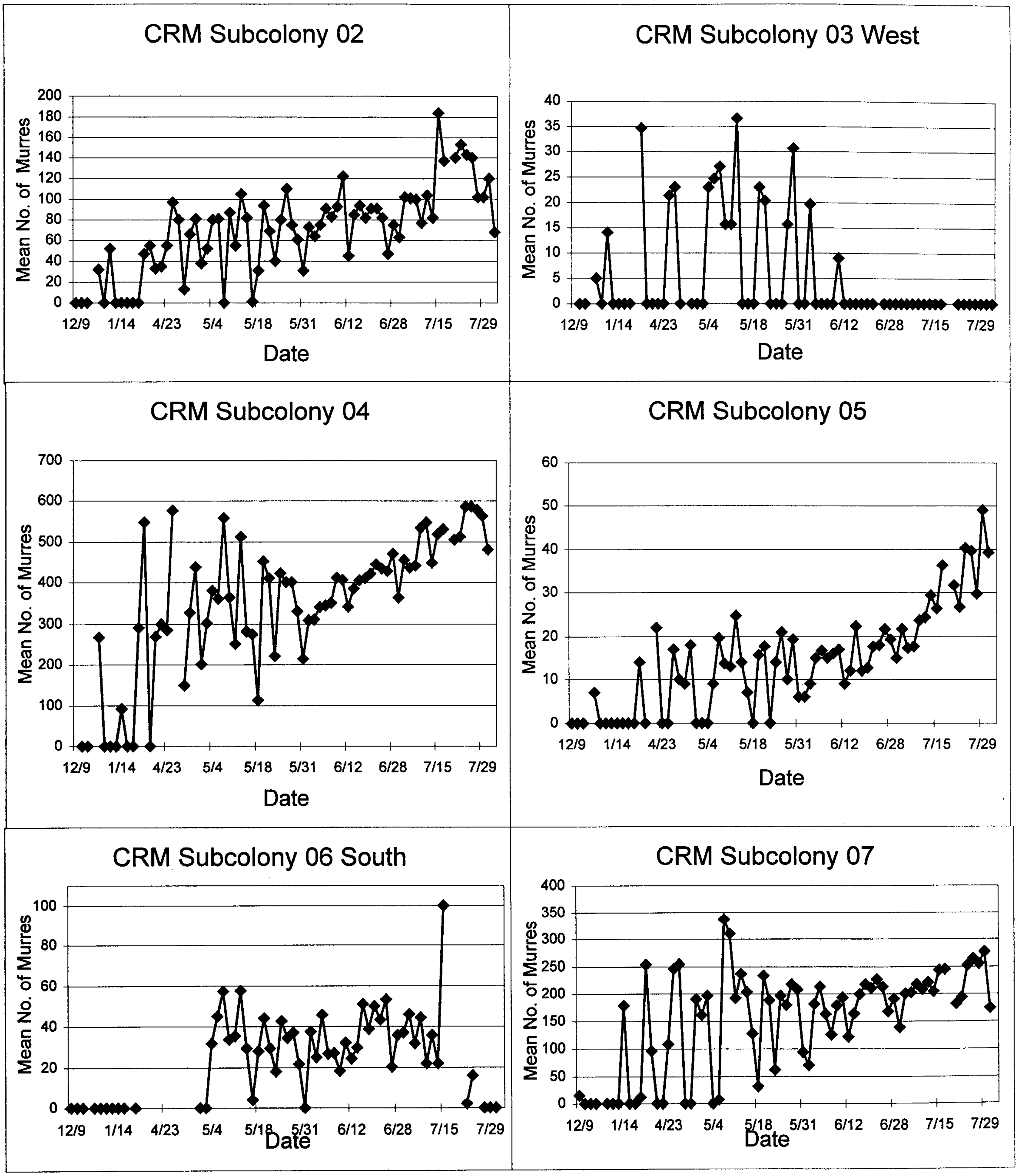

Figure 26. Seasonal attendance of Common Murres at Castle Rock and Mainland subcolonies
9 December 1997 to 29 July 1998

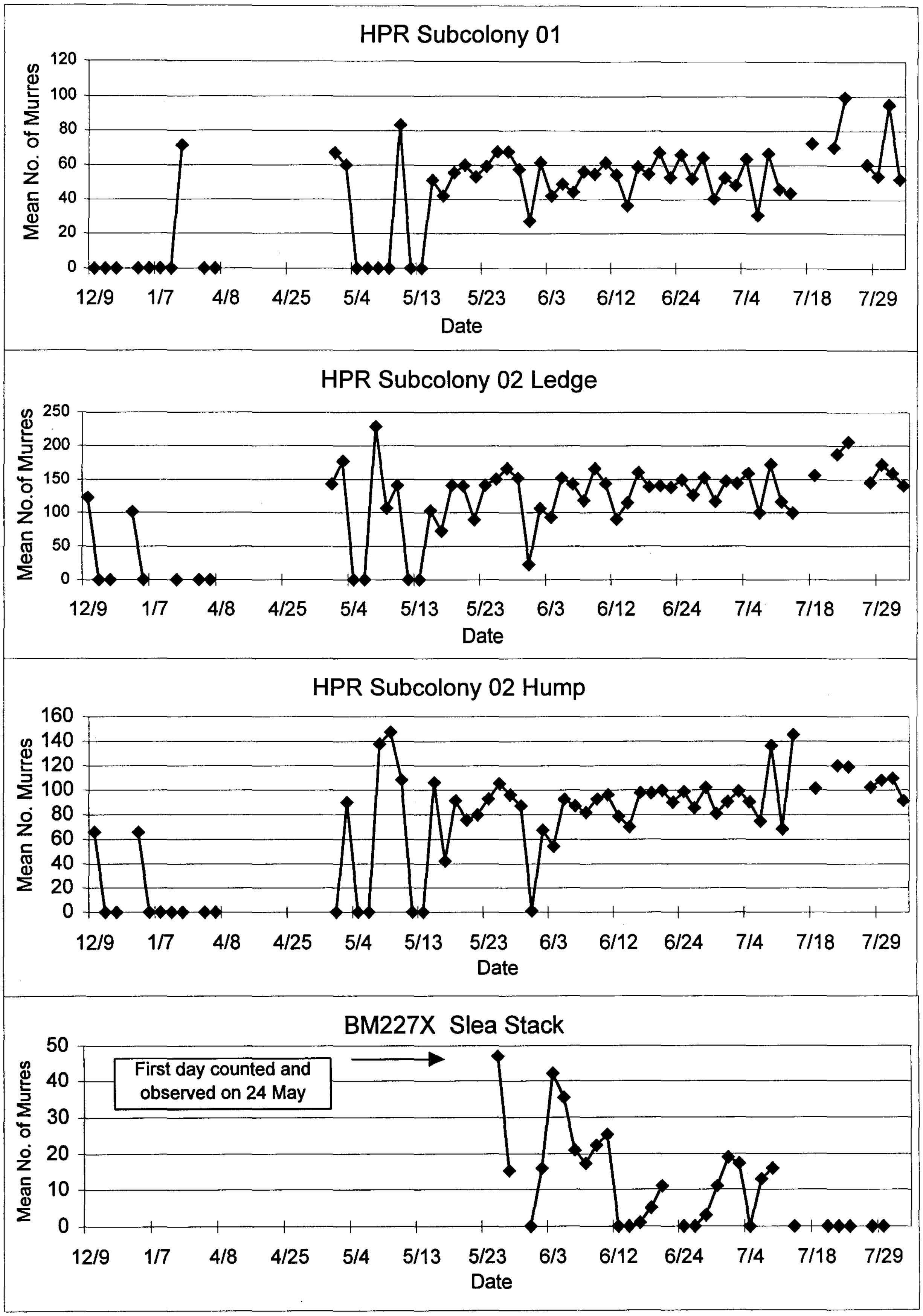

Figure 27. Seasonal attendance of Common Murres at Hurricane Point Rocks and BM227X subcolonies
9 December 1997 to 29 July 1998

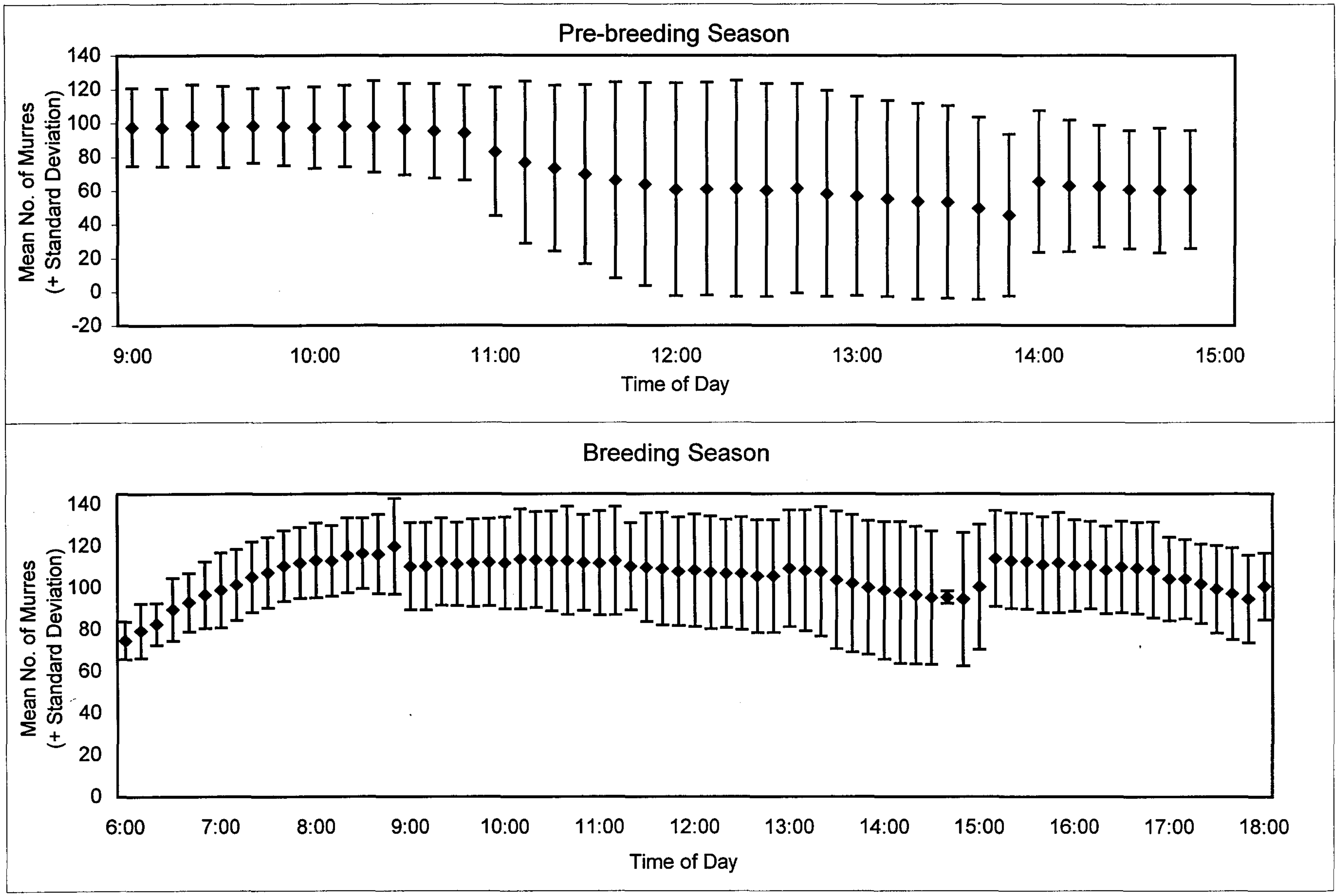

Figure 28. Diurnal attendance of Common Murres at the CRM 04 Plot during the pre-breeding (14 April to 21 May) and breeding (22 May to 4 August) seasons based on 10 minute counts (N=3 and 11 respectively)

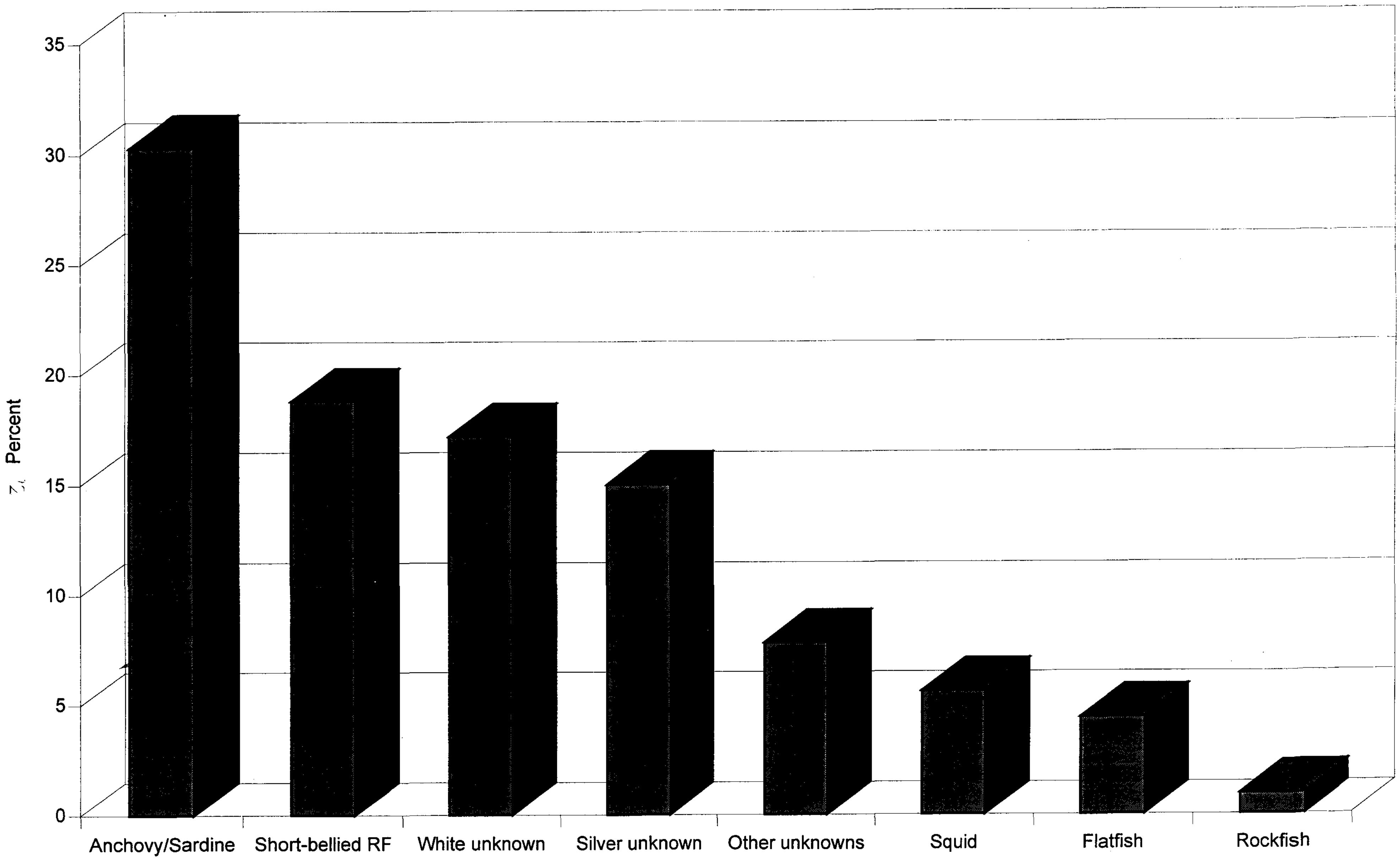

Figure 29. Percentages of diet items fed to Common Murre chicks at the CRM 04 Plot
(N= 320 prey itens recorded from 8 June to 2 July 1998)

Table 1. List of non-breeding and breeding-related behaviors for Common Murre observations at the Devil's Slide Rock, Castle Rocks and Mainland and Point Reyes headlands colonies.

BREEDING-RELATED BEHAVIOR	ABBREVIATION	NON-BREEDING RELATED BEHAVIOR	ABBREVIATION
Allopreen	a	Skypoint	sk
Allopreen Chick	ac	Fly	f
Babysit	bs	Gape	ga
Bill	bi	Ground Inspection	gi
Brood	b	Head Bob	hb
Carry Fish	fi	Head Shake	hs
Carry Pebble	pe	Preen	p
Copulation Attempt	ca	Sit	si
Copulation	c	Sleep	s
Incubate	i	Stand Alert	sa
Interaction with Cormorant	ic	Stand at Rest	sr
Interaction with Gull	ig	Unknown	u
Jab	j	Walk	w
Parade	pa	Wing Flap	wf

Table 2. Common Murre productivity at monitored sites in central coastal California

COLONY/PLOT	No. Sites Monitored	No. Egg-laying Sites	No. Eggs Laid	No. Eggs Hatched	Eggs Hatched/ Pair	Hatching Success[1]	No. Chicks Fledged	Fledging Success[1]	Chicks Fledged/ Pair
DSR	**24**	**14-17**	**17**	**9**	**0.64**	**52.9%**	**6**	**66.7%**	**0.35-0.43**
CRM 04 PLOT	**77**	**37**	**41**	**24**	**0.65**	**58.5%**	**17**	**70.8%**	**0.46**
PRH LEDGE PLOT	**121**	**66**	**72**	**0**	**0.00**	**0.00%**	**0**	**0.00%**	**0.00**
PRH EDGE PLOT	**41**	**13**	**13**	**0**	**0.00**	**0.00%**	**0**	**00.0%**	**0.00**
PRH WISHBONE	**42**	**21**	**22**	**18**	**0.86**	**81.8%**	**0**	**0.00%**	**0.00**

[1] Hatching success is defined as the number of eggs hatched per eggs laid (including first and replacement clutches)

[2] Fledging success is defined as the number of chicks fledged per eggs hatched (including first and replacement clutches)

Table 3. Aircraft disturbances at Castle Rocks and Mainland and Hurrincane Point Rocks from April to August 1998.

DATE	LOCATION	TIME	ALTITUDE	AIRCRAFT DESCRIPTION	EFFECT ON COLONY
April 25	CRM	07:07	900'	white piper w/black stripe	Head bobbing
April 26	CRM	07:08	1000'	CHP Helicopter	Head bobbing
April 26	CRM	07:09	400-500'	CHP Helicopter	50% flushed from CR04 CR07 plus 100% flushed from CR02
April 26	CRM	07:52	700"	Cessna	Head bobbing
April 26	CRM	07:55	100'	Grey Helicopter	10 Comu flush from CR07
April 26	CRM	08:21	700-800'	Cessna N759HY	Head bobbing on CR07 and CR04 5 Comu flush from CR 02
April 26	CRM	10:33	1200'	CHP Helicopter	Head bobbing on CR 02
May 25	CRM	13:12	1000'	High wing Cessna	Head bobbing at CR04
May 26	CRM	12:39	800-1000'	NOAA Amphibian	Flushed 20 COMU from CRO7
June 22	CRM	15:20	600'	9737 JM White Cessna w/ red stripe	Head bobbing at CR 04 and 05
July 15	CRM	12:10	700-800'	Cessna Red and White	Head Bobbing
July 20	CRM	13:52	400'	USCG Helicopter	Head bobbing on CR 02,04,05,07
July 20	CRM	14:02	400'	USCG Helicopter	Head bobbing on CR 02,04,05,07
July 20	CRM	14:20	300-400'	USCG Helicopter	Flushed Comu from CR 02, 04 and 07
July 20	CRM	14:25	600"	USCG Helicopter	Head bobbing on CR 02,04,05,07
July 20	CRM	14:40	600"	USCG Helicopter	Head bobbing on CR 02,04,05,07
July 20	CRM	14:45	600"	USCG Helicopter	Head bobbing on CR 02,04,05,07
July 20	CRM	17:45	500'	Green Military Helicopter	Flushed ~50 Comu from CR 04 and ~20 Comu from CR02
July 30	CRM	15:15	900'	Red/White Bi-Plane	Head bobbing on CR 04