RESTORATION OF COMMON MURRE COLONIES IN CENTRAL COASTAL CALIFORNIA: ANNUAL REPORT 1996

REPORT TO THE *APEX HOUSTON* TRUSTEE COUNCIL

FINAL

by

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RESTORATION OF COMMON MURRE COLONIES ON THE CENTRAL CALIFORNIA COAST: FIRST YEAR RESULTS

EXECUTIVE SUMMARY

Between January 28 and February 4, 1986 the transportation 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. The oil spill adversely affected federal and State of California resources from Sonoma to Monterey Counties. Approximately 9,000 seabirds were killed, including 6,000 Common Murres (*Uria aalge*), in addition to probable impacts to other aquatic life in and around the coastal waters of central California. State and federal natural resource trustees commenced litigation in this matter against potentially responsible parties in 1988-1989. The complaints alleged claims for natural resource damages, costs, and penalties pursuant to the Clean Water Act, National Marine Sanctuaries Act, California Harbors & Navigation Code, and other State Laws.

In August 1994, the case was settled in a Consent Decree (dated August 1994) entered by the Federal District Court for the Northern District of California 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 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 have been approved to date: 1) the Common Murre Restoration Project; and 2) the Marbled Murrelet (*Brachyramphus marmoratus*) Nesting Habitat Acquisition Project.

The Trustee Council selected the U.S. Fish and Wildlife Service (San Francisco Bay National Wildlife Refuge Complex) to lead the Common Murre Restoration Project. Following preparation of a publicly reviewed restoration plan the Refuge established two programs, the Scientific and Education programs, within the Common Murre Restoration Project. Results from the first year efforts (Federal Fiscal Year 1996) are provided in this report. The Trustee Council designated the California Department of Fish and Game (Office of Oil Spill Prevention and Response) to lead the Marbled Murrelet Project. The latter project will be the subject of a separate report.

Scientific program efforts to restore the Common Murre colony at Devil's Slide Rock in central California were initiated on 12 January 1996. 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. Less than 24 hours after decoy deployment, one murre was observed visiting the former colony and four murres were present within 48 hours. Thereafter, murre attendance was constant and numbers increased throughout the season with a peak count of 29 murres on 12 July.

Six pairs of murres nested and three chicks successfully fledged. This is the first known breeding at Devil's Slide Rock in the last decade and is the first documented breeding in response to social attraction techniques for murres in North America.

In addition to the social attraction work and monitoring at Devil's Slide Rock, Common Murres were monitored extensively at the Point Reyes National Seashore headlands and along the Big Sur Coast at Castle and Hurricane Point rocks. Limited monitoring efforts also occurred at San Pedro Rock. The information collected will be used to help evaluate and refine restoration efforts at Devil's Slide Rock 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, diet) that may affect the success of recolonization efforts also were monitored.

The environmental education program began in September 1996. Sixteen teachers and 533 elementary and middle school children from 6 schools located in coastal San Mateo County participated. The program focused on teaching students about: 1) seabirds of the central coast of California; 2) anthropogenic 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 when they repainted the 384 adult murre decoys (used during 1996) prior to their re-deployment in 1997.

The Scientific and Education Programs were extremely successful in the first year of this restoration project. Efforts of the Scientific Program resulted in the re-establishment of breeding by Common Murres at the Devil's Slide Rock colony in a very rapid time frame. With continued efforts over the next several years, we now expect that breeding will continue at this colony and the colony will grow to a much larger population size. In addition, extensive information collected from other nearshore and offshore colonies will aid in refining restoration techniques. The Education Program taught a large number of students about seabirds and seabird conservation while involving them in a hands-on project in their own backyard.

PROJECT ADMINISTRATION

Trustee Council

U.S. Fish and Wildlife Service

Dan Welsh, Primary Representative, Sacramento Field Office
Jean Takekawa / 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
Miles Croom, Alternate Representative, Silver Springs Restoration Center

California Department of Fish and Game, Office of Oil 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 Foundation

Rick Golightly, Cooperative Agreement Administrator

Introduction

Common Murre (*Uria aalge*) colonies in central California occur offshore at the South and North Farallon Islands 20-40 kilometers from mainland shorelines in the Gulf of the Farallones as well as on nearshore rocks and adjacent inaccessible mainland points between Marin and Monterey counties (Sowls et al. 1980; Carter et al. 1992). The history of Common Murre colonies at the South Farallon Islands has been well documented (Ainley and Lewis 1974; Manuwal et al., in prep.), but until recently little information has been available for the North Farallon Islands and eight nearshore colonies (see Manuwal et al., in prep.).

The entire California breeding population of murres was surveyed during the 1980's (Sowls et al. 1980, Briggs et al. 1987, Carter et al. 1992). In 1980, 1982, and 1989 the central California murre population comprised 42%, 44%, and 26% of the State's total population (Sowls et al. 1980, Briggs et al. 1983, Carter et al. 1992, Manuwal et al., in prep). The lower percentage reported in 1989 reflects a severe decline in the central California murre population between 1980 and 1989 (Takekawa et al. 1990; Carter et al. 1992; Manuwal et al., in prep.). Takekawa et al. (1990) documented a 52.6% decline within 4-6 years from 1980-82 to 1986. In addition, a 45.8% - 100% decline at certain individual colonies occurred during this time (Takekawa et al. 1990). The population decline was attributed to high mortality caused by an intensive nearshore gill-net fishery, compounded by mortality from oil spills (the most notable being the 1984 *Puerto Rican* and 1986 *Apex Houston* spills) and a severe El Niño-Southern Oscillation (ENSO) event in 1982-1983. Additional but lower levels of decline (about 7%) occurred from 1986-1989 (Carter et al. 1992; Manuwal et al., in prep.).

Due to the efforts of biologists from the Point Reyes Bird Observatory, seabird mortality resulting from the *Apex Houston* oil spill was well documented (Page and Carter 1986, Page et al. 1990). This spill, which impacted coastal areas from Sonoma to Monterey counties in January and February 1986, killed nearly 9,000 seabirds, of which approximately 6,300 were Common Murres. The Common Murre colony at Devil's Slide Rock (DSR) was abandoned and other central coastal breeding sites were impacted (Takekawa et al. 1990, Swartzman and Carter 1991, Carter et al. 1992, Siskin et al. 1993).

State and federal natural resources trustees commenced litigation against potentially responsible parties in 1988-1989. In August 1994, the parties settled this matter in a Consent Decree entered by the Federal District Court for the Northern District of California for a total of $6,400,000. As part of the natural resources damage settlement, $4,916,430 was allocated for the restoration of Common Murres in central California. An additional $500,000 was allocated for the acquisition of nesting habitat for the Marbled Murrelet (*Brachyramphus marmoratus*), a state endangered and federally threatened species that was also impacted by the spill.

A Natural Resources Trustee Council (the Apex Houston Trustee Council), that includes representatives of the U.S. Fish and Wildlife Service, the National Oceanic and Atmospheric Administration, and the California Department of Fish and Game, oversees the restoration project. A Final Restoration Plan was published in the Federal Register in April 1995 (USFWS 1995a), after public review of earlier versions of the plan.

Field work for the Common Murre restoration project is being conducted by the U.S. Fish and Wildlife Service (San Francisco Bay National Wildlife Refuge Complex) in collaboration with the U.S. Fish and Wildlife Service (Ecological Services), Humboldt State University Foundation, National Audubon Society, U.S. Geological Survey-Biological Resource Division and Point Reyes Bird Observatory. Additional collaboration has been provided by: National Park Service (Point Reyes National Seashore), Gulf of the Farallones National Marine Sanctuary, the California Department of Fish and Game and the California Department of Parks and Recreation. In addition, an environmental education program is being implemented by the San Francisco Bay National Wildlife Refuge Complex. This report summarizes the first year's efforts of the Common Murre Restoration Project's scientific and environmental education programs.

HISTORY OF COMMON MURRES IN CENTRAL CALIFORNIA

By 1995, data from aerial surveys indicated little or no recovery of the three southern colonies (i.e., Devil's Slide Rock, Castle Rocks and Mainland and Hurricane Point Rock) affected by the *Apex Houston* oil spill and prior reductions due to gill-net fishing mortality (Carter et al. 1996, Manuwal et al., in prep). Interestingly, limited partial recovery has occurred at certain other larger colonies in central California, especially the South Farallon Islands (Sydeman et al., in prep) and Point Reyes headlands (McChesney et al., 1997). The DSR colony, extirpated as a result of the spill (Takekawa et al. 1990), was first documented after the construction of Highway 1 in 1937. Stephens reported observations of approximately 75-200 murres on 3 days in June 1938 (Manuwal et al., in prep). Records dating from between 1939 and 1959 report 100-200 murres on DSR (Manuwal et al., in prep). In 1970, 700 murres were observed from a mainland count (Osborne and Reynolds 1971, Osborne 1972). In 1980, Sowls et al. (1980) reported approximately 2,300 breeding murres at this colony. In 1980 and 1982 Briggs et al. (1987) reported approximately 2,900 and 2,600 breeding murres on DSR, respectively. Unfortunately, aerial surveys were not conducted between 1983 and 1986. However, on 10 June 1984, L.Spear reported 24-26 pairs of murres in incubating or brooding postures, and later stated that hundreds of birds may have been present (Manuwal et al., in prep). In 1986, murres probably did not breed successfully, as they were absent from the rock on one of two survey days during aerial surveys conducted in early June. Aerial survey photographs from 1987 showed 127 murres on DSR but it is unlikely that they bred successfully since most of the birds were standing and no birds were present in 1988 surveys. With the exceptions of 1 bird seen in 1990 and 5 birds seen in 1994, Common Murres were not observed on DSR during

aerial surveys conducted from 1988 to 1995. However, G. Divoky observed 4 murres standing on the rock on 2 June 1992 from a mainland and boat survey (Divoky 1993). During mainland surveys conducted on 3 and 9 July 1994, 9 and 4 murres were observed on DSR (Parker, pers. obs.). However, none of the murres had eggs or chicks and were wandering amongst Brandt's Cormorant nests. Common Murres were not observed on DSR during any ground surveys conducted in 1995 (Parker, pers. obs.).

Murre colonies at Hurricane Point Rocks (HPR) and Castle Rocks and Mainland (CRM), located along the Big Sur coast, also were impacted by gill-net fisheries, oil spills and ENSO events (Takekawa et al. 1990, Manuwal et al. in prep). Breeding of Common Murres was first recorded at HPR in 1940 (Manuwal et al., in prep). Between 1940 and 1955, murres were observed several times at HPR but not at nearby CRM where other species were recorded {Manuwal et al. in prep.; Cogswell and Pray 1955). However, on 6 May 1970, 200 murres were reported at CRM (Osborne and Reynolds 1971, Osborne 1972). Between 1970 and 1980, the colonies at HPR and CRM increased to 2,300 and 3,500 breeding birds, respectively. However, by 1982, the breeding population had decreased to 1,710 at HPR and 1,860 at CRM (Briggs et al. 1983, Takekawa et al. 1990). In 1986, these two colonies totaled only 3,160 breeding birds and by 1989 the number had dropped to 1,660 breeding birds (Takekawa et al. 1990, Carter et al. 1992). These colonies have remained depleted. In 1995 only 1,816 Common Murres were recorded (i.e., approximately 3,033 breeding birds)(Carter et al. 1996; Manuwal et al., in prep.). Limited partial recovery apparently has occurred at CRM but no recovery and possibly further decline has occurred at HPR.

SCIENTIFIC PROGRAM

METHODS

Social Attraction

Devil's Slide Rock

Social attraction was used as the restoration management technique to encourage Common Murres to recolonize DSR. This technique uses decoys, recorded vocalizations, and mirrors to mimic an active colony. If birds with prior experience (i.e., breeding, attending, hatching location) still exist, these birds have the highest likelihood of attraction during early stages of recolonization. In the absence of birds with prior experience at an extirpated colony site, pre-breeding aged or "subadult" birds prospecting for a nest site are most likely to be attracted using these techniques. Subadults may prospect at several colony sites before selecting a potential nest site and obtaining a mate. If these birds can be attracted for long enough periods where they interact with other similarly attracted murres, these subadults should select nest sites, obtain mates, and lay eggs at the site were social attraction techniques were used. Kress and Carter (1991) considered that "a critical mass" of attracted birds may be required before nesting will occur.

There is increasing evidence demonstrating 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).

Three hundred eighty-four life-sized adult murre decoys were used to at DSR create an artificial Common Murre colony that provided space for nesting within the decoys. The decoys consisted of two hundred eighty-eight wooden standing posture and 96 polyethylene (plastic) incubating posture decoys. Wooden adult decoys were painted with an exterior latex paint that closely resembles the plumage color of adult murres. Polyethylene decoys were painted black with a similar exterior latex paint. 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 1). 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. High density decoy plots: contain 40 standing decoys, 13 incubating decoys and one mirror box.
b. Medium density decoy plots: contain 20 standing decoys, 7 incubating decoys and one mirror box.
c. Low density decoy plot: contain 12 standing decoys, 4 incubating decoys and one mirror box.
d. Control plots: without decoys or mirrors.

Therefore, 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.

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 2). 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.

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.

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 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 8" wide x 16" high. Including the roof and the plywood base, they stand approximately 25" 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 which fit securely under the solar panel stand. Murre vocalizations played at DSR were recorded by Parker and McLaren at the Farallon National Wildlife Refuge in May 1995.

All adult decoys (standing and incubating postures) were deployed on 12 and 13 January 1996. Previous visits in August, October and December 1995 had occurred to develop a safe rock climbing system and for plot lay-out planning purposes.

To complete the illusion of an active colony, 48 wooden egg and 36 wooden chick decoys were placed among the adult decoys on 14 April. 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. 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 could act as a direct breeding stimulus.

After Common Murres departed DSR for the fall, decoys were removed in September 1996 for cleaning and repairs. To prepare the decoys for repainting, dried guano was scraped off and the decoys were soaked for at least one day in a solution of Biz laundry detergent and water. The decoys were then scraped again, washed with a pressurized power washer and repainted.

Behavior Observations

Devil's Slide Rock

Observations at DSR were conducted daily during two three-hour shifts, the first beginning 0.5 hours after sunrise and the second on a rotating schedule throughout the day (i.e., so that all parts of the day were surveyed at least once per week). The colony was scanned at the start of each five minute period using a Questar telescope with 24mm eyepiece (65X magnification). For each murre observation, we recorded the bird's location in the colony by plot, location within the plot, behavior, and proximity to

mirror or speaker. Furthermore, to assist with evaluating the effectiveness of social attraction devices as reproductive stimuli, we divided behaviors into breeding-related behaviors and non-breeding related behaviors (Table 1). Observations were conducted from a roadway pullout located along Highway 1 overlooking DSR. Observers were approximately 300m from DSR at an elevation of approximately 100 m.

Castle Rocks and Mainland and Point Reyes Headlands
At the CRM and Point Reyes headlands (PRH) colonies, behavior scans were conducted within a sample of a subcolony surveyed during rotating three-hour shifts. A visual scan was made every 5 minutes using the Questar telescope along an imaginary transect line spanning the breadth of the subcolony, thereby sampling both edge and interior birds. Every fifth murre in the contiguous line was noted for behavior at the instant of sighting until a total of 30 birds were scanned. When less than 30 birds where attending a subcolony, the behavior of each bird present was recorded. Observation shifts were conducted throughout the day to allow for comparisons between all monitored colonies. As with DSR, behaviors were divided into breeding-related behaviors and non-breeding-related behaviors during analyses.

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 that particular day) obtained during behavior scans conducted from 27 December 1995 to 13 August 1996. Diurnal attendance patterns were determined by calculating the mean number of murres present during each hour from 0.5 hours to 13 hours after sunrise. Attendance patterns were not monitored after 13 August 1996 when the murres left the island for the fall.

Castle Rock and Mainland, Hurricane Point Rocks, and Point Reyes Headlands
Seasonal attendance patterns were determined for 4 subcolonies at PRH (between 29 November 1995 and 7 August 1996) and 7 subcolonies at CRM and HPR (between 24 January and 27 July 1996). Subcolony counts were repeated three times and a mean was calculated. Counts were conducted between 06:00 and 12:00 hours, unless delayed by fog.

Diurnal attendance during the breeding season was monitored at two productivity plots at the PRH Lighthouse subcolony and at one productivity plot on CRM subcolony 04. At PRH, four all-day counts of the plots were conducted between 25 June and 24 July, 1996. At CRM, six all-day counts were conducted between 26 June and 16 July, 1996. During all-day counts, plots were counted three times on the hour from 06:00-18:00 hours. An hourly mean was calculated. The hourly means for each all-day count were

then averaged in order to determine the average diurnal attendance patterns during the height of the breeding season (see Takekawa et al. 1990).

Productivity - Common Murres

Devil's Slide Rock

In this first year of restoration efforts at DSR, we did not anticipate the need to monitor reproductive success of Common Murres at this colony. However, on 26 May, we documented the first murre egg on DSR in 10 years. Thereafter, we conducted daily checks, prior to or following behavior observations, in order to detect additional nests and monitor productivity. In order to better view nest contents, we periodically conducted observations from pull-outs located 0.2-0.5 miles north of our "main" observation pull-out along Highway 1. Observer distance from DSR was between 300m-400m depending on pull-out utilized. Nests were checked until all chicks had fledged.

Point Reyes Headlands and Castle Rock and Mainland

We planned to monitor productivity of Common Murres at the PRH and CRM colonies in 1996 by establishing three "Type 1" plots (see Birkhead and Nettleship 1980). We established two plots at the PRH Lighthouse subcolony where approximately 12,000 birds breed. A third plot was established on CRM subcolony 4, a subcolony consisting of approximately 600 birds. The plots were placed in areas where the birds could be easily viewed, and were delineated by natural features of the rock substrate.

Point Reyes Lighthouse Plots - Because the 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). Our primary study plot (the Ledge Plot), consisted of approximately 115 breeding pairs and was located on a small ledge near the center of the subcolony. The second plot was located on the northeast edge of the subcolony (the Edge Plot) and consisted of approximately 20 pairs. Although the Edge plot was smaller than is ideal for a Type I study plot, we were limited to utilizing areas in which we could view the eggs and chicks of birds. Observations of both plots were conducted from within or just outside of a small room in the Lighthouse Building, located almost directly above the colony at a distance of approximately 100 meters.

Castle Rock 4 Plot - At CRM subcolony 4, a single plot containing 66 sites was established near the lower edge of the subcolony. Because this subcolony consists of just 600 birds, we established only one plot. Observations were conducted from a pull-out located along Highway 1, approximately 200 meters from the rocks.

The plots at both sites were monitored every other day beginning when the first eggs were observed. We numbered and mapped sites as eggs were laid. Thereafter, sites were checked for presence or absence of eggs or chicks. Although observations were

conducted at varying times of day, we attempted to focus our efforts in the morning hours. At this time birds were most active and we could more easily determine nest status. We monitored all egg-laying sites until the nests had failed or chicks had fledged.

Common Murre Chick Diet

We conducted observations of diet items brought to chicks in the PRH Ledge and CRM subcolony 4 plots. All fish observed were identified to the lowest possible taxonomic level, and size of the prey items was 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 day during the chick rearing period at the colony. However, weather conditions (e.g. fog) often prevented observations. In addition, we conducted 5 all-day observations (i.e., from 06:00 hours to 18:00 hours) in order to increase our chick diet sample size.

Productivity - Brandt's Cormorants

Brandt's Cormorant Colonies at DSR and Mainland, CRM and PRH were monitored to determine productivity and nesting phenology. Nests were observed from points along the mainland and observations were made using a Questar Telescope. Once nests were identified, they were given a number and mapped. To the extent possible, the 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 five days to determine the status of the chicks. Chicks were considered to have fledged if they survived to at least 25 days of age. After this time, many chicks begin to wander from their nests and become more difficult to follow (Carter and Hobson 1988).

RESULTS

Social Attraction

Devil's Slide Rock

We began conducting observations of DSR in late December 1995, prior to deployment of the decoys. No murres were observed during any of 5 initial observation periods. However, 24 hours after the decoys were deployed, one live Common Murre was present on DSR. Within 48 hours, 4 murres were present. Thereafter, we conducted 157 days of observation until 13 August 1996. Murres were observed on DSR during all but one day until 11 August, when the birds departed for the fall (Figure 3).

In order to evaluate the attraction response of Common Murres to the decoys, we compared the number of murre observations recorded in plots with decoys to the

number recorded in the control plots. During our scans, we also recorded observations of murres that were not located within a plot at the time of the scan. In total, 90.5% of murre observations occurred within plots with decoys, 0.3% of observations occurred within control plots, and 9.2% of observations occurred outside of plots (Figure 4).

Murre observations in individual plots varied greatly, ranging from a low of 7 (C1) to a high of 25,997 (plot 9) (Figure 5). Plots 6 (a high decoy density plot) and 9 (a low decoy density plot) comprised 74.9% of all murre observations recorded during 1996. The use of these two plots was established early in the season as they constituted 68.8% of all observations that were recorded in February and March.

Murre observations were not directly correlated with plot decoy density. Overall, 47% of murre observations occurred in low density plots, 2.1% were in medium density plots, and 50% were in high density plots. The extensive use of Plots 6 and 9 greatly affected the relationship between murre use and decoy density. The effect of decoy density on Common Murre use was further complicated by the occurrence of breeding birds (that were constantly present) in both high and low density plots. However, in Block Treatment 1, which was visually isolated from the other 3 block treatments, we saw a direct positive relationship between decoy density and murre observations. The topography of DSR in this location prevented murres from viewing the remainder of the plots. Therefore, they may not have been influenced by the larger number of decoys and live Common Murres that occurred in other areas of the rock.

Within the plots, murres appeared to prefer the area of the aisle as 47.2% of murre observations occurred in this area (Figure 6). The remaining areas, edge, front line, and interior, comprised 25.3%, 18.4% and 8.9% of murre observations recorded within plots, respectively.

The attractive effect of the mirrors was evaluated by comparing the number of murre observations inside and outside of the mirror zone. We defined the mirror zone as the area extending 4 murre body widths (60 cm) from the mirror. In total, 45.3% of murre observations occurred within the mirror zone versus 54.7% that occurred outside of the mirror zone. This is a surprisingly high number given that the mirror zones comprised only 2.5% of the potential nesting and visitation areas of DSR.

We also compared murre activity relative to the distance of the birds from the mirrors (Figure 7). The highest number of observations was recorded within one murre width of the mirror. The number of observations decreased as the distance from the mirror increased.

To evaluate the effects of egg and chick decoys, we compared plots prior to and post deployment of egg and chick decoys. We found that the number of murre observations increased by 17.4% in those plots that received egg and chick decoys while observations of murres in adult only plots decreased by 17.4%.

The best measure of success for evaluating the effectiveness of social attraction is the establishment of "territorial" sites and breeding by the target species. We define a territorial site as one used regularly by a pair or single bird. Eggs may eventually be laid at these sites or no egg may be laid or recorded there. Eleven territorial sites (including 6 nests) were established on DSR in 1996 (Figure 8). Five territorial sites (including 2 nests) were established in high decoy density plots 6 and 8 while 5 territorial sites (including 3 nests) were established in low decoy density plot 9. One nest occurred outside of the plots in the area between plots 6, 8, and 9. Within the plots, 7 of 10 territorial sites (including 4 nests) were established within the aisles and 9 of 10 territorial sites (including 4 nests) occurred within the mirror zone.

Behavior

Devil's Slide Rock

Behavior observations at DSR were initiated on 2 February and continued throughout the pre-breeding (from initial behavior observations to one day prior to first egg), breeding (first egg until last chick fledged), and post-breeding (after last chick fledged until all murres departed for the fall) seasons. In total, 4,902 hours of observations (58,824 scans) were logged during 157 days.

The most prevalent behavior observed at DSR was standing at rest, comprising 27.0% of all observed behaviors (Figure 9). Other behaviors frequently observed included standing alert (18.8%), preening (10.5%), sleeping (9.5%) and sitting (7.5%). In total, these behaviors comprised 46.3% of the observed behaviors. Breeding-related behaviors made up 14.8% of the behaviors seen over the course of the season. The most frequently observed breeding-related behaviors were allopreening (5.4%), incubation (5.2%), and brooding (2.0%). Head-bobbing, a behavior often indicating disturbance in a natural colony, comprised only 1.5% of all behavior observations.

We also examined Common Murre behaviors at DSR during the pre-breeding (2 February to 17 May), breeding (18 May to 28 July), and post-breeding seasons (29 July to 8 August). Standing at rest was the most prominent behavior in all three periods, followed by standing alert and preening (Figure 10). When comparing all three time periods at DSR certain differences become apparent. During the pre-breeding period the birds spent a higher percentage of their time in resting behaviors such as standing at rest, sleeping, and sitting. These resting behaviors comprised 51.1% of the total observed behaviors during the pre-breeding season, while only 36.3% and 30.5% of the breeding and post-breeding seasons respectively. During the breeding season, the majority of the behaviors other than standing at rest and standing alert were breeding-related and included incubating (11.2%), brooding (4.4%) and allopreening (4.8%). In total, breeding-related behaviors comprised 22.5% of total behaviors during the breeding season. During the post-breeding season the most frequently observed behaviors were standing at rest (25.4%), standing alert (25.0%) and preening (16.7%).

Point Reyes Headlands

A total of 137 hours of observations (1,646 behavioral scans) were conducted at PRH. From these scans, a total of 52,145 behavioral point samples were obtained. Behavioral observations were conducted between 1 February and 26 July 1996. Scans were conducted at varying times of day to capture changes in behavior throughout the course of a day. We divided the season into the pre-breeding (initial observation to one day prior to first egg laid in the Ledge plot) and breeding (first egg laid in Ledge plot to last observation) seasons. The pre-breeding season was from 1 February to 16 May

and the breeding season was from 17 May to 7 August. Because fog prevented us from conducting observations after 7 August, when a few chicks and adults remained in the colony, we did not collect data during the post-breeding season. Twenty-four observation shifts were conducted during the pre-breeding season and 20 observation shifts during the breeding season. Our behavior monitoring was primarily focused on the Lighthouse Rock, Face Rock, Wishbone Point, and Cone Rock subcolonies. To summarize, we pooled all behavioral observations from these subcolonies.

Standing at rest was the most frequently observed behavior, comprising 27.0% of all observations, followed by standing alert (15.0%), sitting (11.0%), incubating (10.2%), preening (10.0%) and sleeping (8.9%)(Figure 11). These behaviors comprised 82.1% of the observed behaviors. Behaviors indicative of disturbance or stress (e.g. head-bobbing), comprised only 1.8% of observed behaviors. Breeding-related behaviors comprised a total 20.8% of all observed behaviors during the entire season.

We also analyzed our behavior information in relation to changes between the pre-breeding and breeding seasons (Figure 12). The most prominent behaviors observed during the pre-breeding season were standing at rest, standing alert, sitting, and preening. During the breeding season, incubating became the most prominent behavior at 27.0%. Some interesting differences became apparent when comparing behaviors during the pre-breeding and breeding periods (see Figure 12). Standing at rest, standing alert, preening, sleeping, and sitting all decreased during the breeding season, however, birds were allocating more of their time to breeding-related behaviors such as incubating and brooding. During the pre-breeding season, breeding-related behaviors consisted of only 5.0% of the total observed behaviors, while during the breeding season breeding-related behaviors comprised 39.0% of the total observed behaviors.

Castle Rocks and Mainland

A total of 122 hours of observations (1,456 behavioral scans) were conducted at CRM between 28 February and 24 July 1996. From these scans, a total of 42,559 behavioral point samples were obtained. As at PRH, we divided the season into the pre-breeding (initial observation to one day prior to first egg laid in subcolony 04 plot) and breeding (first egg laid in subcolony 04 plot to last observation) seasons. Again, we had intended to conduct observations until the birds departed from the colony for the fall, however, heavy fog prevented us from continuing observations late in the season when a few chicks and adults were still present on the colony. Our observations were focused primarily on subcolonies 04 and 03 East. However, subcolonies 02, 05, and 07 were also observed. To summarize data, we pooled behavioral observations from all subcolonies.

The primary behavior exhibited by the murres was standing at rest (33.8%), followed by standing alert, preening, sleeping, and sitting (Figure 13). These 5 behaviors combined

constituted 76.3% of all behaviors observed during the season. The remaining behaviors each constituted less than 5.0 % of the total.

We found little variation between pre-breeding (28 February to 19 May) and breeding (20 May to last observations) season behavior at this colony (Figure 14). Two exceptions were: standing at rest, which decreased by 11.0% during the breeding season; and standing alert, which decreased by approximately 4.0%. As expected, incubation constituted a sizable portion (~17.0%) of the birds' behavior during the breeding season. Brooding of chicks also was documented, but to a lesser degree than incubation, presumably because adult murres spend less time actively brooding as the chicks grow larger.

Attendance Patterns

Devil's Slide Rock

During the pre-breeding season an average high count of 11.7 murres were present at DSR. High counts were variable, ranging from 0 (10 March) to 19 (19, 28 April)(Figure 15). During the breeding season, the mean number of murres observed on DSR per day was 16.1, an increase of 37.6% over the pre-breeding season. Attendance was less variable, with numbers ranging from 8 (27 May) to the seasonal peak of 29, which occurred on 16 July. In the post-breeding season, the mean number of birds was 3.7, a decrease of 77.0% from the breeding season mean. Daily high counts ranged from 8 (30, 31 July) to 1 (5 August), prior to murres departing for the season.

Castle Rock and Mainland and Point Reyes Headlands

During the pre-breeding season, murres were noted attending the PRH Lighthouse subcolony as early as November 1995. However, murres were not seen on other PRH subcolonies (e.g., Face Rock, Wishbone Point, and Cone Rock) before 11 March 1996 (Figure 16). Although not attending nesting sites at these subcolonies, murres were often observed rafting on the water around these areas in January and February. Toward the middle of the pre-breeding season, attendance at Lighthouse Rock, Face Rock, and at Cone Rock became more regular. However, attendance at Wishbone Point (approximately 100 murres) remained sporadic until 5 June, after which they did not return. Attendance at Lighthouse Rock, Face Rock and Cone Rock was consistent throughout the breeding season (17 May-7 August), with a small peak in mid-July. Attendance declined rapidly thereafter until 7 August when we ceased observations.

Seasonal attendance of Common Murres at CRM and HPR was determined from colony counts taken between 24 January and 27 July 1996 (Figure 17). At all subcolonies, attendance was sporadic during the pre-breeding season. Numbers of murres were more stable during the breeding season (17 May-22 July). As at PRH, murre numbers fluctuated in mid to late July, probably due to non-breeders attending

the colony. At CRM subcolony 03 east, a rock with less than 50 birds, attendance was sporadic throughout the pre-breeding season, and murres did not attend after 16 May 1996.

We observed differences in pre-breeding attendance between small subcolonies (<200 birds) and larger subcolonies (>200 birds) at both PRH and CRM. At the PRH - Lighthouse subcolony (approximately 12,000 birds), murres were present 91.7% (i.e., 22 out of 24 days). Similarly, at CRM subcolony 4 (approximately 500 birds), birds were present on 93.9% of observation days (i.e., 31 out of 33 days). Conversely, at the PRH- Wishbone Point subcolony (100-200 birds), murres were completely absent from the colony on 45.5% of observation days (i.e., 10 of 22 days). At CRM subcolony 3 East (20-40 birds), murres were absent on 56.3% of observation days (i.e., 18 out of 32 days). DSR, however, differed from these small colonies in that birds were absent on only 1.1% of observation days (i.e., 1 of 89 days) during the pre-breeding season.

We examined diurnal variation in numbers of Common Murres at DSR, PRH and CRM. At DSR, murre numbers were highest in the morning, and gradually declined throughout the day (Figure 18). The steepest declines occurred during the pre-breeding season from sunrise to 5 hours after sunrise. During the breeding season, morning declines in attendance were not as pronounced. In the post-breeding season, the number of birds present on DSR was relatively stable in the morning hours, with a small peak occurring approximately 6 hours after sunrise. In the later part of the day, murre numbers dropped to almost zero.

Diurnal attendance at PRH was examined during the breeding season at two plots on Lighthouse Rock (Figure 19). Attendance in the Ledge plot peaked at 07:00, and was most stable from 11:00-16:00 hours. The edge plot showed an early morning increase in attendance, a slight decline at midday, and a stable period from 13:00 hours on.

Interestingly, at the CRM subcolony 04 plot, attendance of Common Murres during the breeding season was lowest at sunrise, and slowly increased until 09:00 hours (Figure 20). Thereafter, numbers remained stable until 16:00 hours, when they began to decrease.

Productivity - Common Murres

Devil's Slide Rock

The first Common Murre egg laid on DSR in approximately a decade was observed on 26 May 1996. In total, 6 pairs of murres bred (i.e., laid eggs) on DSR in 1996 and nest sites occurred near the center of the historic colony. Three of the six eggs hatched successfully; no replacement eggs were laid after failed nesting attempts (Table 2). Two eggs disappeared and the causes of loss were unknown. One egg rolled from the nest site and was stopped by a Brandt's Cormorant nest. However the attending murre

could not retrieve the stray egg. Hatching dates ranged from 19 June to 4 July 1996. The three chicks that hatched all fledged successfully, resulting in 0.5 chicks fledged per pair. Chicks remained on the rock an average of 24.6 days, 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 monitored plots at PRH on 17 May 1996. In the Ledge plot, a total of 115 eggs were laid at 110 nest sites. Five eggs were replacements for failed first eggs (see Table 2). Of 115 eggs, 94 eggs (81.7%) hatched successfully (i.e., 85.5% of 110 nest sites hatched successfully). We considered chicks to have fledged if they survived to 15 days of age. In the Ledge Plot, 83 chicks (88.3%) fledged successfully, resulting in a total of 0.75 chicks fledged per breeding pair. Due to difficulties associated with viewing certain sites within the plot, we were uncertain of the ages of 5 of the chicks, and thus could not ascertain whether or not they had survived to fledging age. Additionally, 3 young chicks were still present in the plot on 7 August, the last day of observations. These 8 sites were not included in the analysis of productivity.

Productivity in the Edge Plot was considerably lower than for the Ledge Plot. Because we did not begin monitoring this plot until mid-June (i.e., well-after egg-laying had commenced), we could not measure any egg loss that occurred earlier. We documented a total of 16 eggs, 9 of which hatched successfully. Of these, only 2 chicks (22.2%) survived to fledging, resulting in 0.13 chicks fledged per breeding pair.

In addition to the two plots at the Lighthouse Rock, we had also intended to monitor productivity at the Wishbone subcolony, located further east along the Point Reyes Headlands. This subcolony consists of approximately 100-200 birds and breeding has been documented in previous years. Although murres were present regularly early in the year, attendance grew increasingly erratic as the season progressed. After 5 June, the birds discontinued attendance of this area. Thus, we were unable to utilize the subcolony for productivity estimates.

Castle Rock and Mainland

The first eggs appeared in the CRM subcolony 04 plot on 20 May 1996. In total, 60 eggs were laid at 57 nest sites in the plot, 3 of which were second attempts. Of 60 eggs, 41 eggs (68.3%) hatched successfully (i.e, 71.9% of 57 nest sites hatched successfully). Only 25 of 41 chicks (61.0%) survived to fledging, resulting in 0.44 chicks fledged per breeding pair (see Table 2). As at PRH, we were uncertain of the age of 6 chicks when they disappeared, and were unable to determine if they successfully fledged. Therefore, they were not included in the analysis.

Similar to the PRH Edge plot, productivity for the CRM subcolony 04 plot was low for Common Murres in central California. This may have been due to the presence of Peregrine Falcons that were regularly seen on the adjacent mainland. Although we did

not witness any predation of murres by the falcons, we frequently observed head-bobbing in response to the falcons' vocalizations and movements along the mainland. On 20 August, we visited subcolony 06, located on the mainland directly opposite the CRM subcolony 04. We found a total of 13 murre carcasses at this subcolony, with signs typical of Peregrine Falcon kills (i.e., birds that were beheaded and with breast muscles eaten), confirming that Peregrine Falcons were preying upon murres.

Chick Diet

Devil's Slide Rock

Data on chick diet at DSR was unobtainable due to the distance of the colony from our mainland observation point (i.e., observers could not identify species of fish being fed to the murre chicks).

Point Reyes Headlands

We conducted observations of diet items fed to chicks in the Lighthouse Rock Ledge plot for a total of 30 hours between 5 and 23 July 1996 (Figure 21). Of 226 diet items identified, 31.4% of our observations consisted of Northern Anchovy (*Engraulis mordax*). However, we were not able to distinguish between Northern Anchovy and Pacific Sardine (*Sardinops sagax*) in 49.8% of our observations. These two species combined (anchovy/sardine) comprised at least 71.2% of our observations (see Figure 21). We were unable to identify 18.6% of the diet items fed to chicks, 9.7% of which consisted of silver-colored fish that may have been Northern Anchovy or Pacific Sardine. These data suggest that Common Murres at PRH relied in large part on these two species in 1996. Juvenile rockfish (Family Scorpaenidae) and salmon (*Oncorhynchus* sp.) also were utilized to a much lesser degree.

Castle Rocks and Mainland

A total of 45 hours of observations were conducted at the CRM subcolony 04 plot between 25 June and 15 July 1996. Due to a variety of factors (see Discussion), we were unable to identify 70.9% of the 261 diet items fed to chicks. We did, however, document the presence of juvenile Short-bellied Rockfish (*Sebastes jordani*) and flatfish (Order Pleuronectiformes) in the diet of chicks at Castle Rocks (Figure 22). These species were not observed at PRH. Juvenile rockfish comprised 7.4% of chick diet in the CRM subcolony 04 plot.

Productivity - Brandt's Cormorants

Devil's Slide Rock and Mainland and Castle Rocks and Mainland

The nesting phenology of Brandt's Cormorants at CRM subcolony 04 was slightly ahead of the cormorants at DSR and Mainland. Cormorant eggs were first observed at

CRM subcolony 04 in early May, with the first chicks appearing at the end of May. By the end of June, most chicks had hatched. On DSR and Mainland, chicks were first observed in the middle of June, with the majority of the chicks hatching by the beginning of July. DSR Mainland colony produced 2.58 chicks per pair while DSR and CRM subcolony 04 produced 1.17 and 1.24 chicks per pair, respectively.

Brandt's Cormorants did not attempt to breed at any of the colonies we monitored at the Point Reyes National Seashore headlands.

DISCUSSION

We anticipated that it would take several years before murres would start to lay eggs on DSR. We believe that the quick response of the murres and the fact that breeding occurred in the first year of the project suggests that birds with prior experience at DSR returned to the colony. This is further supported by the fact that the timing of breeding at DSR was similar to other established nearshore colonies at PRH and CRM as well as at the South Farallon Islands (Ainley and Boekelheide 1990). First time breeders often lay later in the season, suggesting that the murres at DSR were experienced breeders. It is not clear if breeding experience was acquired previously at DSR or whether birds had bred in the interim at other active colonies but had fledged from DSR. In either case, birds would have had "previous experience" at DSR. When comparing the nest sites occupied in 1996 with photos taken in 1980, we found that the sites occupied in 1996 occurred in the center of the historic colony. We identified this "center" as the largest mass of breeding birds on the rock in photographs taken during 1979, 1980 and 1982. The location of nest sites in 1996 further suggested that some or all of the Common Murres observed may have hatched or previously bred at DSR. This factor may have important implications for the rapid response of murres to social attraction techniques in situations where a colony has been recently extirpated. Consequently, it may be very important to begin restoration as soon as possible in order to attract remaining murres (or other target species) that have a history of attachment with a colony. However, we will continue to investigate other possible contributing factors such as microhabitat features of DSR, location of nesting cormorants, and placement of social attractants.

In order to refine social attraction as a restoration technique at DSR and elsewhere, we developed a project design that would allow the evaluation of effects of decoy density, plot use, mirror importance, and response to egg and chick decoys, without jeopardizing our management objectives. Our analysis of the importance of decoy density was confused by the presence of territorial sites and nests within two of the block treatments. The only block treatment that did not have a site established in it occurred on the west end of the rock. Because this block was also "visually isolated" (i.e., murres standing in this block could not see other blocks) from the other blocks, visiting murres may not have been enticed into the plots by murres attending nearby

territorial sites. The occurrence patterns documented in this block (i.e., higher use in higher density plots) suggests that prospecting murres, possibly without breeding or previous DSR experience, may find higher density plots more attractive. Further data on the effects of decoy density will need to be obtained in order to better understand the importance of decoy density to the overall effectiveness of social attraction.

Within the plots, murres preferred the aisles. We believe the high use of this area, relative to its small size (<1% of the surface area of DSR), was a function of providing open, high quality habitat for prospecting birds to establish sites within the center of the decoy group. Similar to the aisles, the mirror zone represented just a small fraction of the DSR surface area, yet most territorial sites and nests were established in it. The mirrors may have made the area appear more populated with murres, each decoy being mirrored by nearby mirrors. In addition, the mirrors may have provided an element of movement that attracted live murres to this area. Egg and chick decoys also proved to be important additions to the social attraction layout. When comparing plots prior to and post deployment we observed an increase in murre observations in plots that received eggs and chicks while adult only plots decreased. We believe that egg and chick decoys may encourage murres to investigate an area and may encourage them to establish territorial sites in these areas. After a 10-year absence of breeding, the combination of decoys, recorded Common Murre vocalizations, and mirrors resulted in restoration of a breeding Common Murre colony on DSR.

The activity budgets of murres observed at DSR, CRM, and PRH were very similar. At all three colonies standing at rest, standing alert, sleeping, and preening were the most frequent behaviors observed. Furthermore, the percentages of the less frequently observed behaviors were similar at all three colonies. This demonstrates that the murres observed at DSR were behaving in a manner consistent with other established nearshore colonies. In addition, this provides further evidence that social attraction equipment does aid in mimicking a natural colony. Otherwise, we would expect different types or frequencies of behaviors by birds attending a possible future breeding colony site without social attractants.

Diurnal attendance patterns at DSR and the PRH were similar with murre numbers highest in the morning, and gradually declining throughout the day. A stable period generally occurred in late morning to early afternoon. This is the usual pattern for Common Murres in central California, where numbers are usually highest in the morning hours and stable in the late morning/early afternoon (Ainley and Boekelheide 1990, Takekawa et al. 1990). Conversely, attendance at CRM subcolony 04 was lowest at sunrise, with numbers increasing in the early morning and then remaining stable throughout the afternoon. In the early evening, attendance began to decrease. Unusual attendance of murres at CRM suggests that perhaps nocturnal or pre-dawn activity may be keeping the birds from this colony (i.e., owl predation). Further observations are needed to determine the cause of this behavior.

Seasonal attendance patterns were similar at DSR, PRH, CRM, and HPR, showing sporadic attendance during the pre-breeding (winter) season and stabilization once breeding commenced. Although the seasonal attendance patterns and nesting chronology of murres at DSR was similar to other nearshore colonies in central California, murres at DSR attended more regularly and for a longer period during the day in the pre-breeding season than at these other colonies. We believe that this occurred in response to the social attraction equipment and played an important role in attracting and maintaining relatively high numbers of murres in a short period of time.

Productivity of Common Murres varied considerably between the nearshore colonies. CRM had relatively low reproductive success that may have been the result of disturbance from Peregrine Falcon activity in the area. In addition, the unusual diurnal attendance patterns observed at CRM suggest that there may have been some other nocturnal or pre-dawn disturbance that further affected productivity.

Reproductive success at the two plots on Lighthouse Rock varied greatly. Productivity at the Ledge plot was relatively normal, while at the Edge plot it was exceedingly low. This was most likely related to the location of the Edge plot on the periphery of the subcolony. While predation by Western Gulls (*Larus occidentalis*) at the Ledge Plot was not documented, they were frequently observed roosting near the Edge Plot. In late-July, we observed a Western Gull enter the Edge plot and attempt to prey upon a murre chick. This incident caused a great deal of disturbance and resulted ultimately in the loss of several chicks in the plot and in areas adjacent to the plot. We also observed predation by Common Ravens and Western Gulls taking place on the peripheries of several other subcolonies at PRH. In addition, disturbance by a Brown Pelican landing and moving through the Cone Rock murre colony was observed. This disturbance resulted in many eggs and chicks being depredated by Common Ravens and Western Gulls.

Our ability to identify chick diet items, particularly at CRM, was lower than we had anticipated. While this was partly due to the distance between our observation point and the subcolony, the relative inexperience of our observers at identifying locally-occurring fish from a distance also played a role. Because this was the first year of fieldwork, a substantial amount of effort was required to establish study plots and map breeding sites within the plots. Thus, we were not able to devote as much time to training field personnel in fish identification. We believe though, that with additional training, the level of accuracy of our observers can be significantly improved. Thus, we plan to conduct a more thorough training session before the onset of the 1997 breeding season.

At DSR, 3 chicks hatched and fledged successfully. Unlike PRH, there was no documented predation of eggs or chicks despite the presence of 3 Western Gull nests that occurred on DSR. This may have been due to the murres breeding among the decoys at the center of the colony. Also, the presence of breeding Brandt's Cormorants

may have aided in keeping Western Gulls at the periphery of the colony. There is some anecdotal evidence that murres often establish new colonies within active Brandt's Cormorant colonies, presumably because of the additional protection the cormorants provide (Carter et al. 1996; McChesney et al., 1997). Although the presence of a Brandt's Cormorant colony may encourage visitation by murres, their presence on DSR did not stimulate murres to breed during the decade prior to the use of social attraction equipment. Numbers of nesting cormorants at DSR did grow during this period (Carter et al. 1992, 1996), possibly affecting murre attendance, but only small numbers of murres were documented in any year between 1987 and 1996. We believe that the Brandt's Cormorant colony may have assisted with the recolonization of murres on DSR, but that the catalyst that attracted murres to regularly attend and begin breeding was the social attraction equipment.

ENVIRONMENTAL EDUCATION PROGRAM

Overview

The seabird restoration education program began in Fall 1996. Sixteen teachers and 533 elementary and middle school children in Montara, Pacifica, Half Moon Bay, and El Granada participated. The education program focused on: 1) seabirds of the central coast of California; 2) the negative effects of egg collecting in the early 1900s, gill-net fishing, oil spills, and disturbance; 3) efforts to restore seabirds, including the restoration project at Devil's Slide Rock; and 4) ways for students to help protect and restore seabirds. The education program was coordinated by Amy Hutzel and Fran McTamaney, Environmental Education Specialists at San Francisco Bay National Wildlife Refuge Complex.

Participants

Six schools from two school districts, sixteen teachers, and 533 students participated in the education program. Grade level ranged from second to seventh grade.

Cabrillo Unified School District

El Granada Elementary

Jennifer Austin, 3rd grade, 20 students

Farallone View Elementary

Diana Purucker, 4th/5th grade, 34 students
Linda Carol, 2nd/3rd grade, 40 students

Hatch Elementary

Lyn Kelly, 5th grade, 34 students
Lori Olsen, 5th grade 34 students
Melissa Moriarty, 5th grade, 30 students

Laguna Salada Union Elementary School District

Linda Mar Elementary

Gretchen Delman, 5th grade, 30 students
Sandi Jaramillo, 5th grade, 32 students
Tom Mann, 3rd/4th grade, 31 students
Nora Chickhale, 3rd/4th grade, 31 students

Ortega Middle School

Jane Scott-Jones, 7th grade, 90 students

Vallemar Elementary

Natalie Taylor, 5th grade, 31 students
Doreen Barnes, 5th grade, 32 students
Carol McMahon, 4th grade, 32 students
Pat Ladner, 3rd grade, 30 students

Methods

Learn About Seabirds Workshop

On 7 September 1996 staff and volunteers from the San Francisco Bay National Wildlife Refuge Complex conducted a workshop for the teachers involved in the education program. The workshop provided teachers with background information and activity ideas about seabird biology, reasons for seabird declines, and restoration techniques (specifically the Common Murre restoration project). Teachers were supplied with educational materials to use in their classrooms including:

1.) *Learn About Seabirds* Curriculum Guide, Slide Show, and Poster (U.S. Fish and Wildlife Service 1995b); 2.) *Zoobooks:Seabirds*, (Brust 1995); 3.) *Plastics Eliminators: Protecting California's Shorelines*, California Aquatic Science Education Consortium, University of California, Santa Barbara (English and Spanish)(Shinkle and Copeland); 4.) Selected pages from *Beached Marine Birds and Mammals of the North American West Coast* (Ainley et al. 1993); 5.) Selected pages from 1980 and 1992 *Seabird Breeding Catalogs of California* (Sowls et al. 1980, Carter et al. 1992); 6.) Video footage from Common Murre Restoration Project biologists, KRON, KPIX, and CNN; 7.) Audio tape of murre calls prepared by Parker and McLaren at the South Farallon Islands; 8.) Newspaper articles about the Common Murre Restoration Project at Devil's Slide Rock; and 9.) Pre and Post Unit Assessments, Potential Field Trip Sites, and Murre Data Charts.

Classroom Presentations

Refuge staff and volunteers, gave classroom presentations to each class during September. The one-hour presentations began with an introduction to seabirds and their ocean environment. Students were shown a mounted specimen of a murre, a photo collage of other seabirds, and a poster with an ocean food web. An activity about seabird food chains followed, with the students playing the roles of phytoplankton, zooplankton, fish, squid, and Common Murres. The presentation ended with a discussion about the restoration project at Devil's Slide Rock. Students passed around adult murre, chick and egg decoys, and 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. Stands were created to hold decoys while the students painted. Decoys, painting supplies, and decoy stands were taken to the schools during October. One school was visited per day, with one to two classes painting at a time. Refuge staff 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. Furthermore, teachers have created a web page, set up seabird learning centers in the classroom, recruited parents to assist with decoy painting, spoken to local reporters about the education program, and coordinated a Murre Celebration. Classes have participated in beach clean-ups and field trips. Students have written letters and reports about seabirds, participated in activities, and created artwork, including cliff scenes with paper mache eggs and adult murres.

Data
The participating classes will be sent biweekly updates of the number of murres on DSR. The students will keep track of the number of murres on the rock by using a data chart that will be located on their classroom wall.

Murre Celebration
On 25 January 1997, a Murre Celebration was held at Farallon View Elementary School. Approximately 45 people attended including teachers, students and their families. The Common Murre Restoration Project video was shown. In addition, Murray, the murre puppet, interviewed restoration biologists about the murre restoration project and the biologists answered questions for students, teachers, and parents. Teachers and students brought artwork and photos to share with others.

Conclusion
The first year of the education program was extremely successful. The program included numerous activities and involved a large number of students in a hands-on action project. This project offered an opportunity for students to participate in an exciting natural resource project occurring in their own backyards. Students demonstrated a strong interest in and knowledge of the murre restoration project. The pre and post unit assessments should be able to show changes in knowledge, attitude, and behavior. These assessments will be completed by the end of the school year in June 1997. 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. Point Reyes Bird Observatory

During Federal Fiscal Year 1996, two projects were identified to be conducted by the Point Reyes Bird Observatory (PRBO) at the Farallon National Wildlife Refuge in order to help refine social attraction techniques at DSR and other sites and to assist with determination of Common Murre breeding population estimates. A description of the work to be conducted and report due dates are provided below.

Project A. Colony and Nest Site Selection and History of Farallon Island Common Murre Colonies.

This work involves conducting retrospective analysis of existing PRBO data on site occupancy from 1984 through 1996 for the Shubrick Point and Upper Upper Murre colonies. Specifically, PRBO will report on colony growth, habitat selection and patterns of recruitment in relation to physical and social features of populations within the Shubrick and Upper Upper colonies. A report will be provided to the San Francisco Bay National Wildlife Refuge Complex and the Apex Houston Trustee Council. A Draft Report is due on 15 November 1997.

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

Diurnal and seasonal patterns of egg laying and attendance will be utilized to assess the most appropriate time to conduct aerial surveys of Common Murre colonies in central California. The correction factors will be used to convert numbers of individuals counted from aerial surveys into breeding pairs. These data will be collected from two Type I study plots on the Southeast Farallon Island. It is anticipated that this project will last a minimum of three years, ending in August 1998. Draft annual reports are due to the San Francisco Bay National Wildlife Refuge Complex on 28 February each year.

B. Aerial Surveys

Population Estimates - Aerial Surveys

In 1996, aerial surveys of central California Common Murre colonies were conducted on 23-24 May, 28-30 May and 10-11 June. Northern California Common Murre colonies were surveyed on 3-4 June. Brandt's and Double-crested Cormorant colonies were surveyed on 28-31 May in central California and 3-4 June in northern California. Surveys were conducted using standard methods (Takekawa et al. 1990; Carter et al. 1992, 1996). Surveys were flown at 50-90 knots (depending on wind speed) from a twin engine, wing-over Partenavia aircraft or a single engine, wing-over Cessna 182 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 were also taken using a 50 mm lens and color slide film (ASA 64 or 100). When possible, the airplane passed directly overhead to minimize oblique photographs, except at the South Farallon Islands, where the airplanes were flown further off the islands due to steep topography and to minimize the potential for disturbance.

Coastal Brandt's Cormorant and Common Murre colonies in central California received complete coverage during 1996 aerial surveys. However, due to a mechanical failure in our primary camera, coverage of the South Farallon Islands was incomplete. Slides of the central California colonies are currently being counted and population estimates are not yet available. A complete report on breeding population estimates will be provided to the Apex Houston Trustee Council as soon as the data are summarized.

C. Marbled Murrelet Habitat Acquisition

This project is being completed under leadership of the California Department of Fish and Game and will be the subject of reports authored by Fish and Game personnel, as appropriate.

MEDIA COVERAGE AND SCIENTIFIC PRESENTATIONS / PUBLICATIONS

The Trustee Council and project personnel recognize that this restoration project provides a unique opportunity to enhance public knowledge concerning seabirds, seabird conservation and restoration, and the marine environment. During the first year of the project the efforts to educate the public through presentations, news coverage, and other appropriate venues are listed below. Emphasis was placed on increasing awareness of seabird resources in the area, the problems caused by oil pollution and oil spills, gill nets, and other anthropogenic factors as well as the restoration efforts conducted by the cooperating agencies, environmental organizations, and biologists.

1. PRINTED MEDIA COVERAGE

Graham, F., "How to lure more murres ". Audubon 98(3). May-June 1996. pp. 82-86.

Hoo, S. " Luring the vanishing murre-decoys, sounds used to encourage nesting on Devil's Slide Rock" San Jose Mercury News -Peninsula Living 9 February 1996.

Holbrook, S. "Bird Project off to a flying start", Half Moon Bay Review Vol. 99-No. 37 17 January 1996.

Holbrook, S. "Birds find themselves a piece of the Rock" Half Moon Bay Review Vol. 98, No.-12. 24 July 1996.

Khorge, K. "A second chance for Seabirds at Devil's Slide Rock" Pacifica Tribune. 2 October 1996.

Mitchell, E. "Decoys tempt murres back to breed. San Francisco Examiner. 13 February 1996.

Mitchell, E. "Uncommon Comeback for Common Birds" San Francisco Examiner 21 July 1996.

"Murre Restoration Begins at Devil's Slide Rock" Egg Rock Update -Newsletter of the Seabird Restoration Program. National Audubon Society 1996.

Parker, M.W. "Back on the Rock-Common Murres return to Devil's Slide Rock". Beach Watch NOAA'S Bark Vol. III No. I. Spring 1996.

"A Rocky Life" A Visitors Guide to the Point Reyes National Seashore. Pg. 7 May 1997.

News Release "U.S Fish and Wildlife Service Leads Seabird Recovery Project" San Francisco Bay National Wildlife Refuge Complex January 1996.

News Release "Success continues for Seabird Restoration Project" San Francisco Bay National Wildlife Refuge Complex 5 July 1996.

2. TELEVISION COVERAGE

The following News Programs featured segments on the Restoration Project :

CNN 8 May 1996
KRON TV Channel 4
KPIX Channel 5- 18 March 1996
E-TV, Channel 53- 11 February 1997

SCIENTIFIC PRESENTATIONS AND PROJECT PRODUCTIONS

Boyce, J. A. and E.B. McLaren. "An Overview of Common Murre Biology and the Results of the Common Murre Restoration Project's First year of Monitoring at the Point Reyes Headlands"- presented for the Point Reyes National Seashore Lunch Time Seminar. February 1997.

Monterey Bay Aquarium - Common Murre Exhibit. This exhibit features live Common Murres in a swim tank with several panels adjacent to the viewing window that describe Common Murre biology and conservation issues. In addition, the exhibit includes a description of the Common Murre restoration project. The photographs, murre decoy, and murre sounds were provided to the Aquarium by the Apex Houston Trustee Council and the San Francisco Bay National Wildlife Refuge Complex.

Parker , M.W. Restoration of Common Murre Colonies in Central California: First Years Efforts Result in Eggs and Chicks Paper presented at the 24 Annual Meeting of the Pacific Seabird Group, Portland, Oregon. 8-11 January 1997.

Parker, M.W. "Apex Houston Common Murre Restoration Project"-a presentation at the U.S.F.W.S National NRDA Training Conference , Lake Harmony, PA. 28 April-2 May 1997.

Parker, M.W. "Apex Houston Common Murre Restoration Project"-a presentation at the U.S.F.W.S Region 1, NRDA Restoration Workshop, Silver Falls, OR. 22-24 July 1996

Schubel, S. The Common Murre Restoration Project 1996- a video produced for the Common Murre Restoration Program. September 1996.

PLANS FOR 1997

Devil's Slide Rock

Decoys will be deployed during the winter of 1996-1997. Decoy Blocks 2, 3 and 4 will remain the same. Decoys in Block 1 will be rearranged so that each plot within Block 1 receives a different density of decoys from the 1996 season. This small change in project design will aid in assessing the importance of decoy density in the reestablishment of common murre colonies.

San Pedro Rock

San Pedro Rock will be assessed and evaluated for feasibility of decoy deployment. Reconnaissance work will be conducted during the late summer and early fall of 1997.

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 1996 season. A recommendation about whether or not to deploy social attraction equipment at Castle Rocks and Mainland and Hurricane Point Rocks in 1998 will be made at the end of the 1997 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 1996.

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 1997. In addition, replicate surveys of Common Murre colonies will be conducted in May and June 1997, using methods similar to those used in 1996.

Environmental Education

The environmental education program will continue to be conducted in San Mateo County schools. Sixteen teachers and approximately 500 students will be involved with the program.

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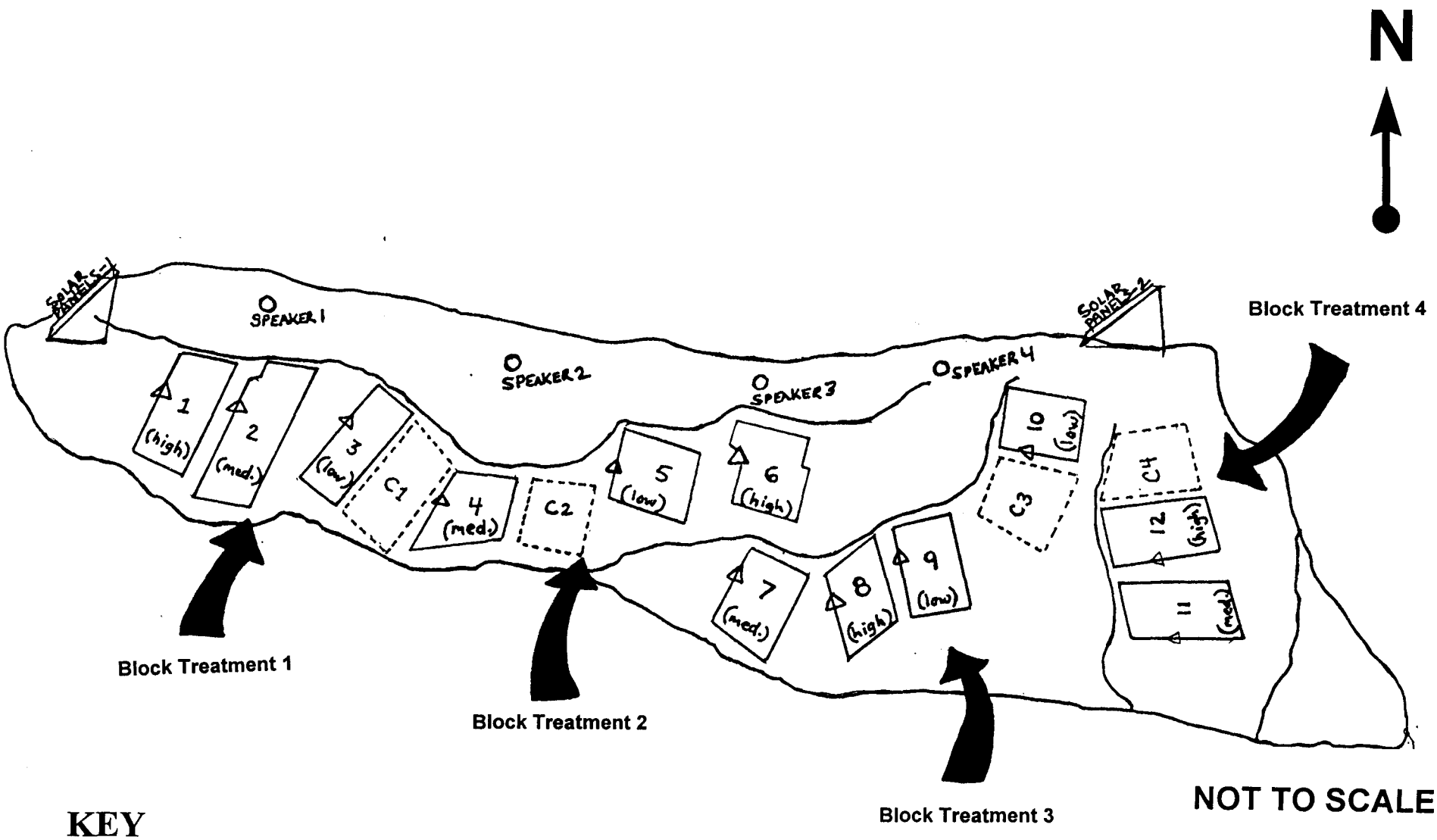


KEY

MIRROR BOX

SPEAKER

SOLAR PANEL

PLOT CONTROL

SMALL VERTICAL ROCK LEDGE

Figure 1. Layout of plots and social attraction equipment on Devil's Slide Rock, as viewed from the south point opposite the rock. Plots are numbered sequentially from west to east (left to right). Decoy density is indicated with each plot number (High, medium, low) and control plots are numbered to correspond with block treatment number. Block treatments are indicated by an arrow and consist of three plots and a control.

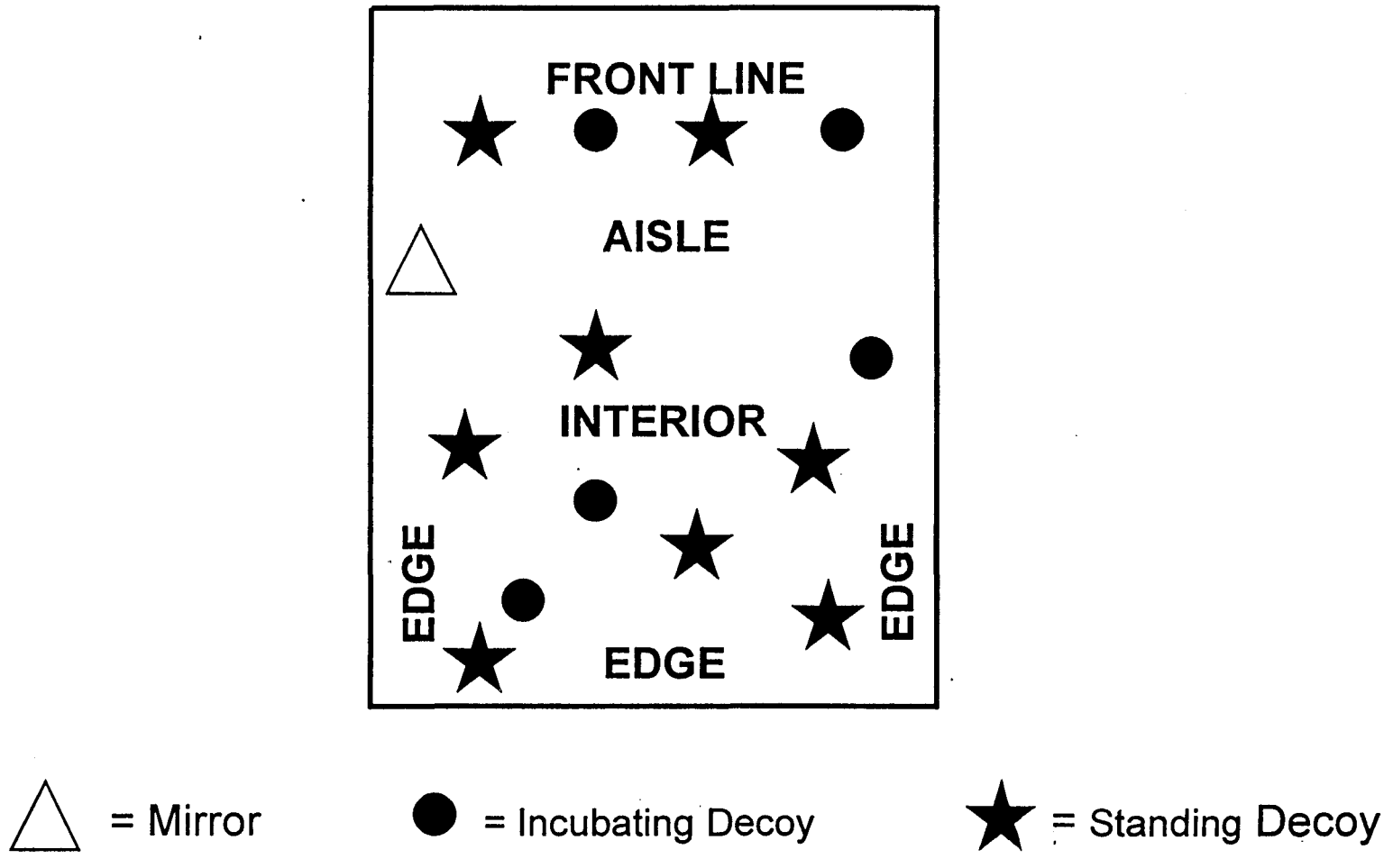


Figure 2. Schematic of plot interior

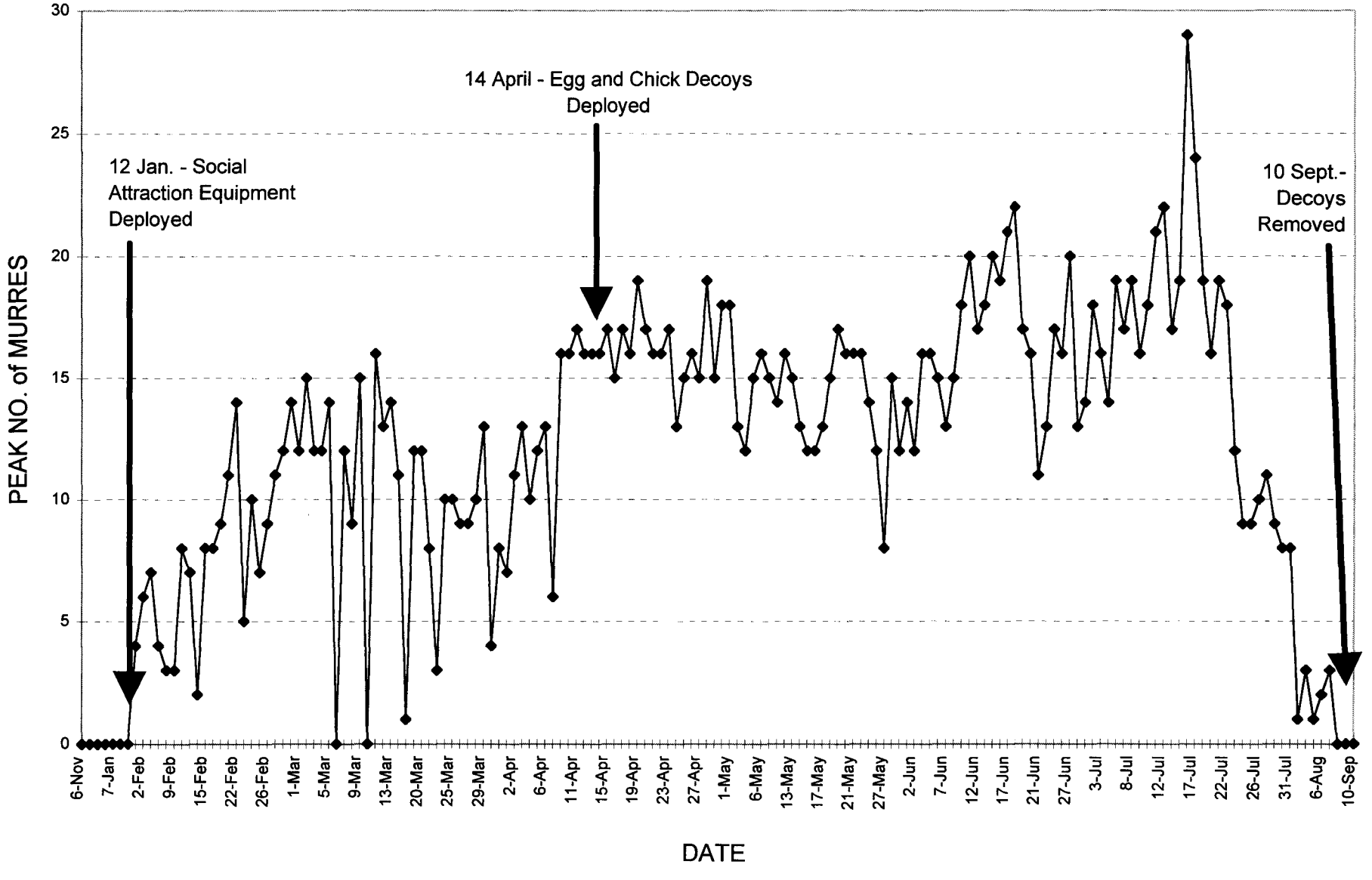


Figure 3. Daily peak numbers of Common Murres on Devil's Slide Rock, November 1995 - August 1996.

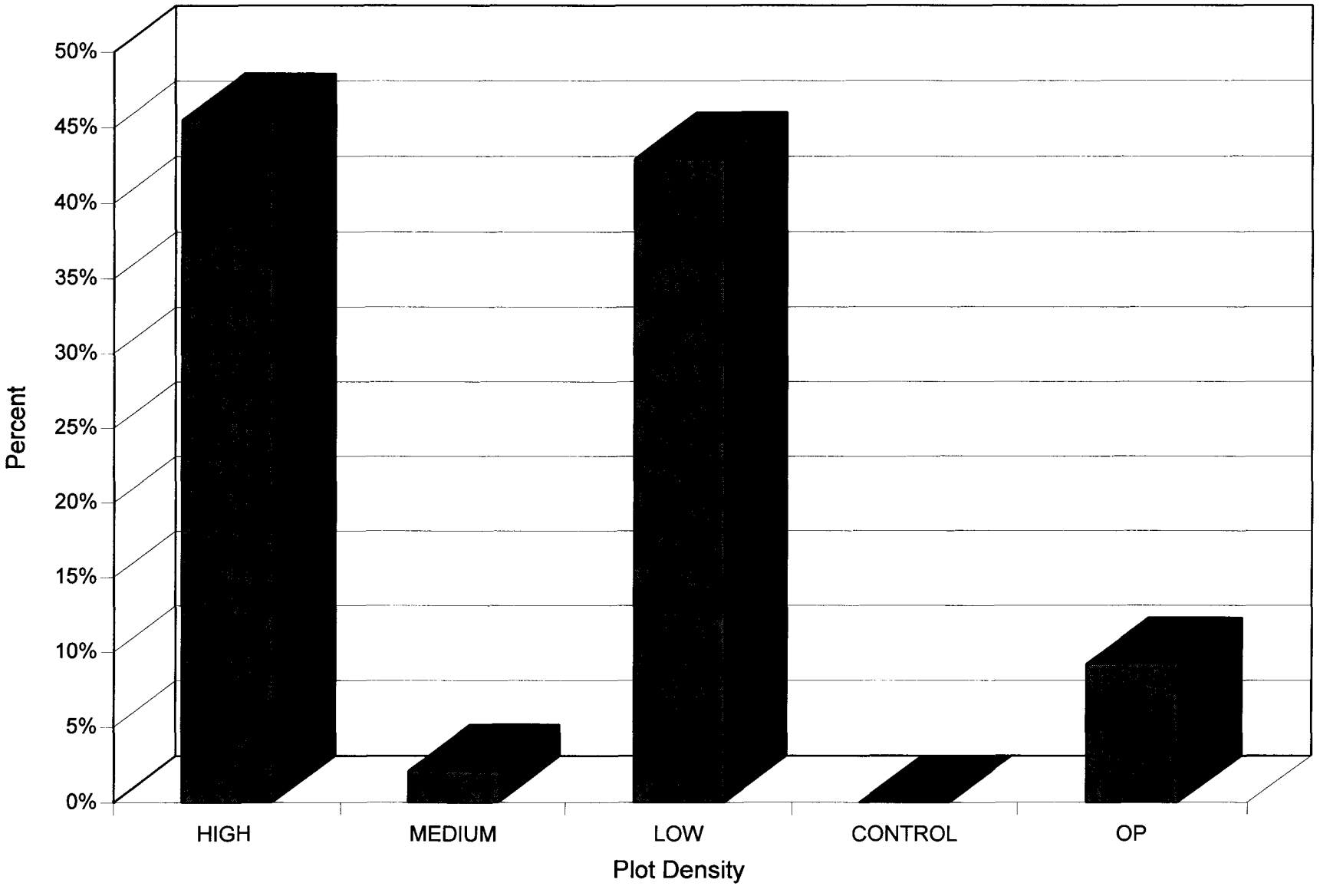


Figure 4. Percent occurrence of Common Murres in the four plot density treatments (OP = out of plot).
(N= 68,332 murre observations from 2 February - 8 August 1996.)

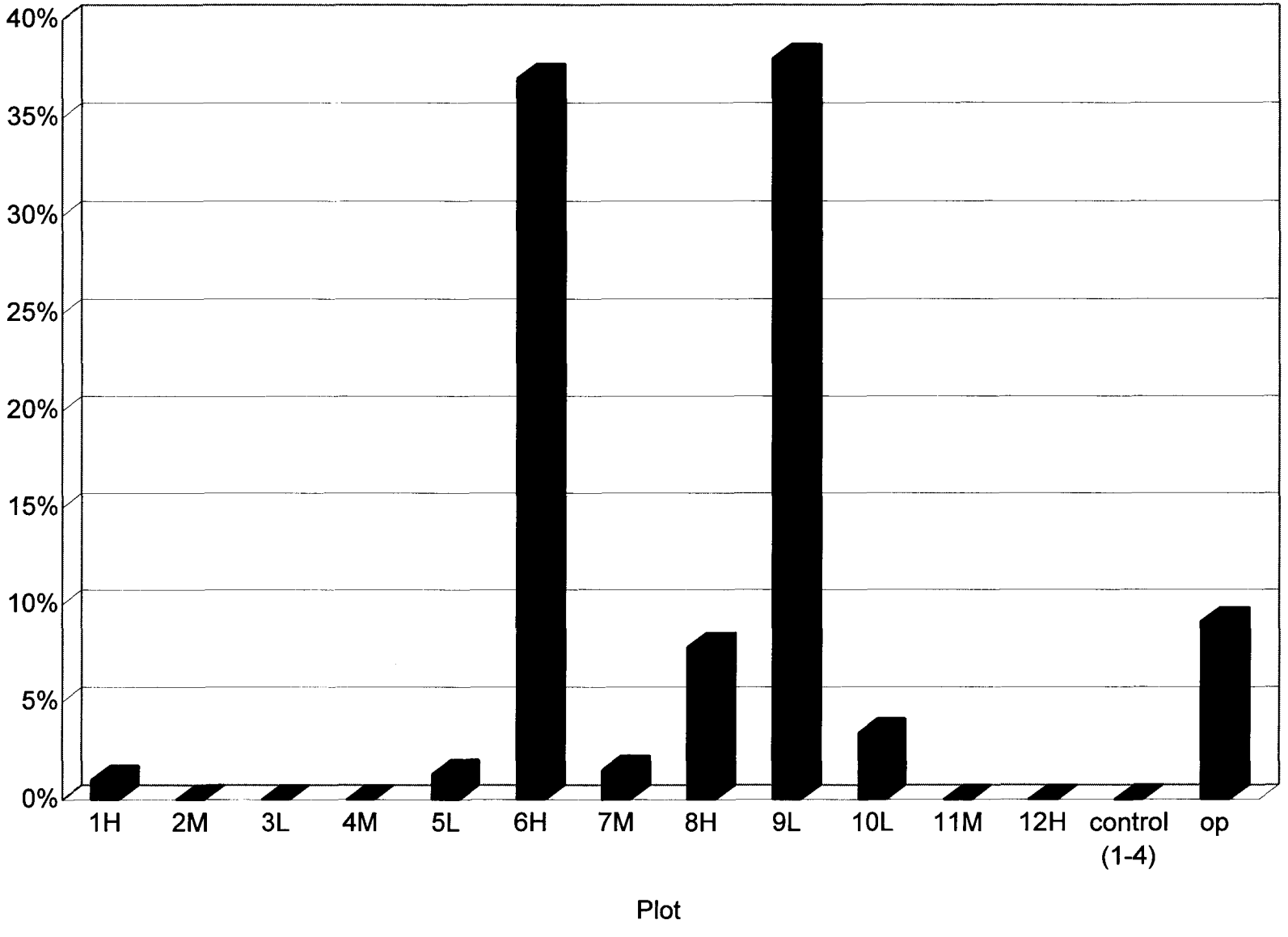


Figure 5. Percent occurrence of Common Murres in decoy plots, control plots, and out of plot areas.
(N= 68,332 murre observations from 2 February - 8 August 1996.)

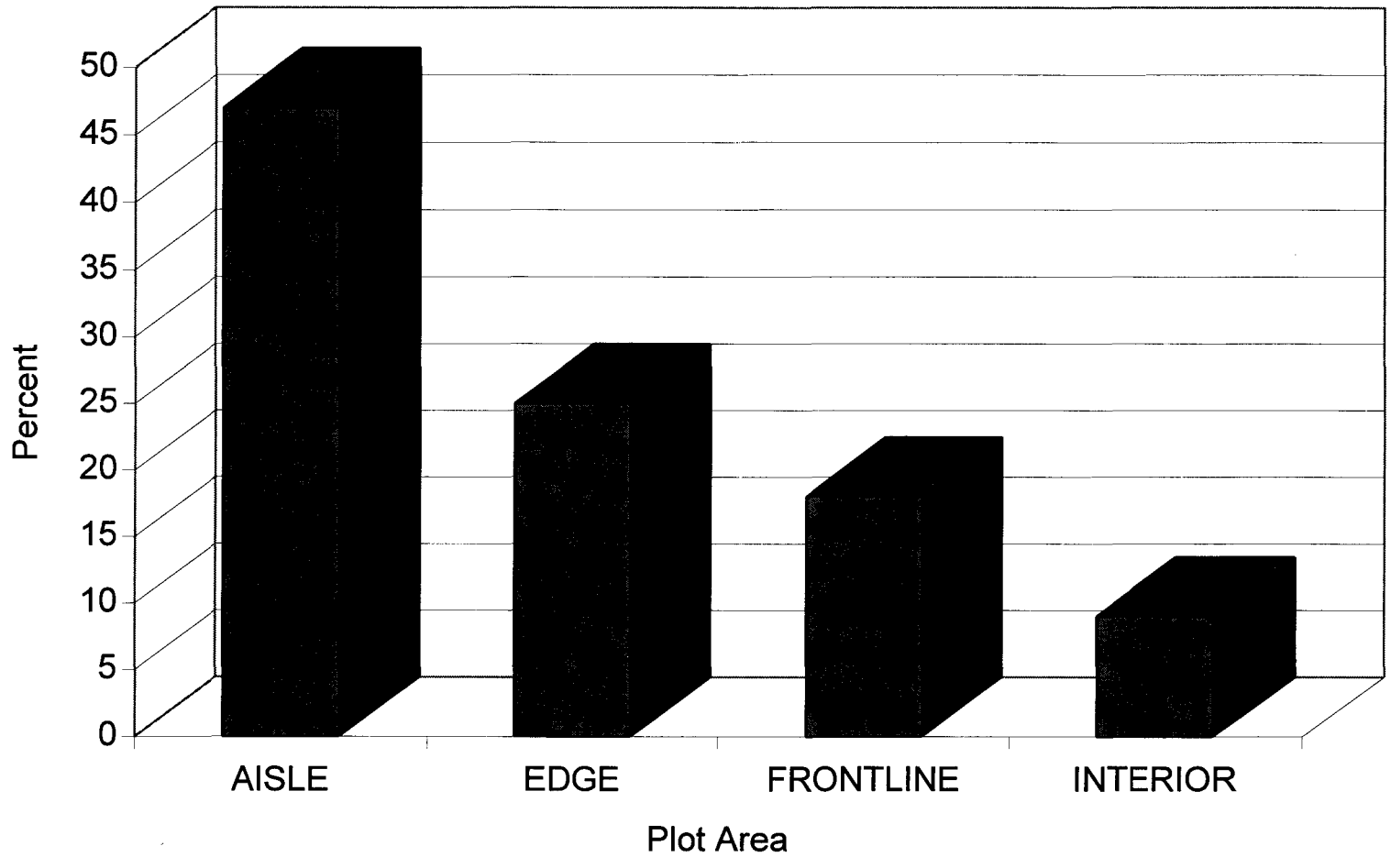


Figure 6. Percent occurrence of Common Murres in areas within plots.
(N= 60,914 murre observations from 2 February - 8 August 1996.)

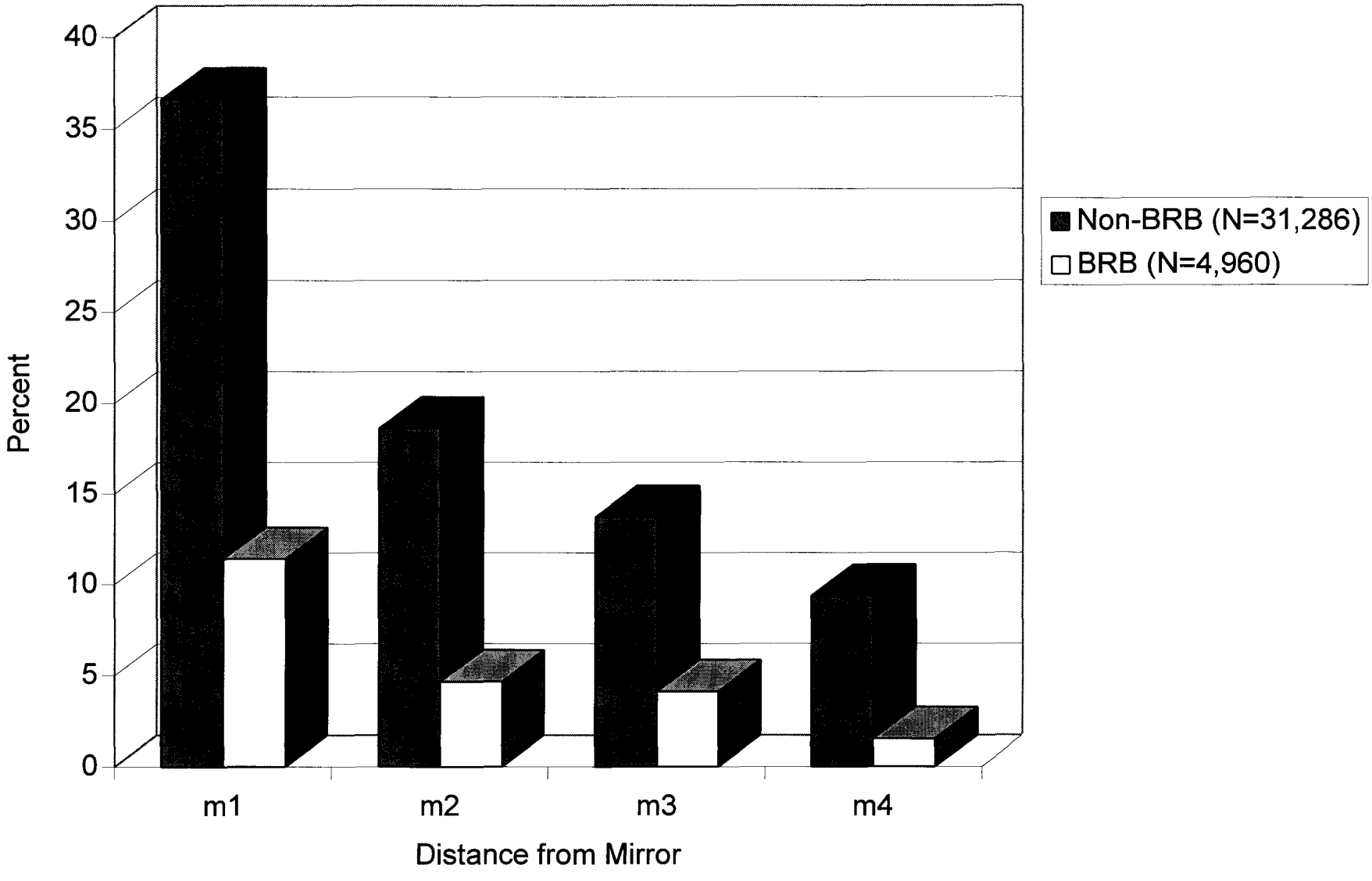
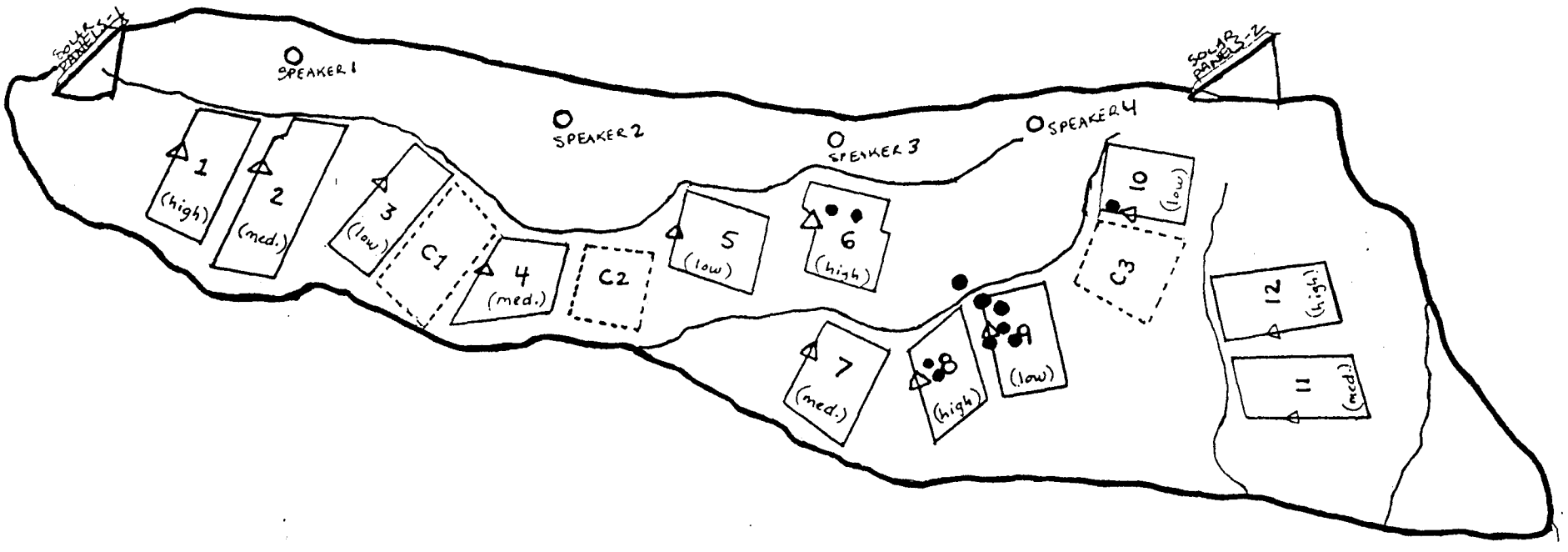


Figure 7. Percentage of breeding and non-breeding related behaviors relative to distance from mirrors.
(m1 = one murre width; m2 = two murre widths; m3 = three murre widths; m4 = four murre widths)



KEY

See Figure1

● SITES

Figure 8. Location of Common Murre territorial and breeding sites on Devil's Slide Rock in 1996. Format after Figure 1.

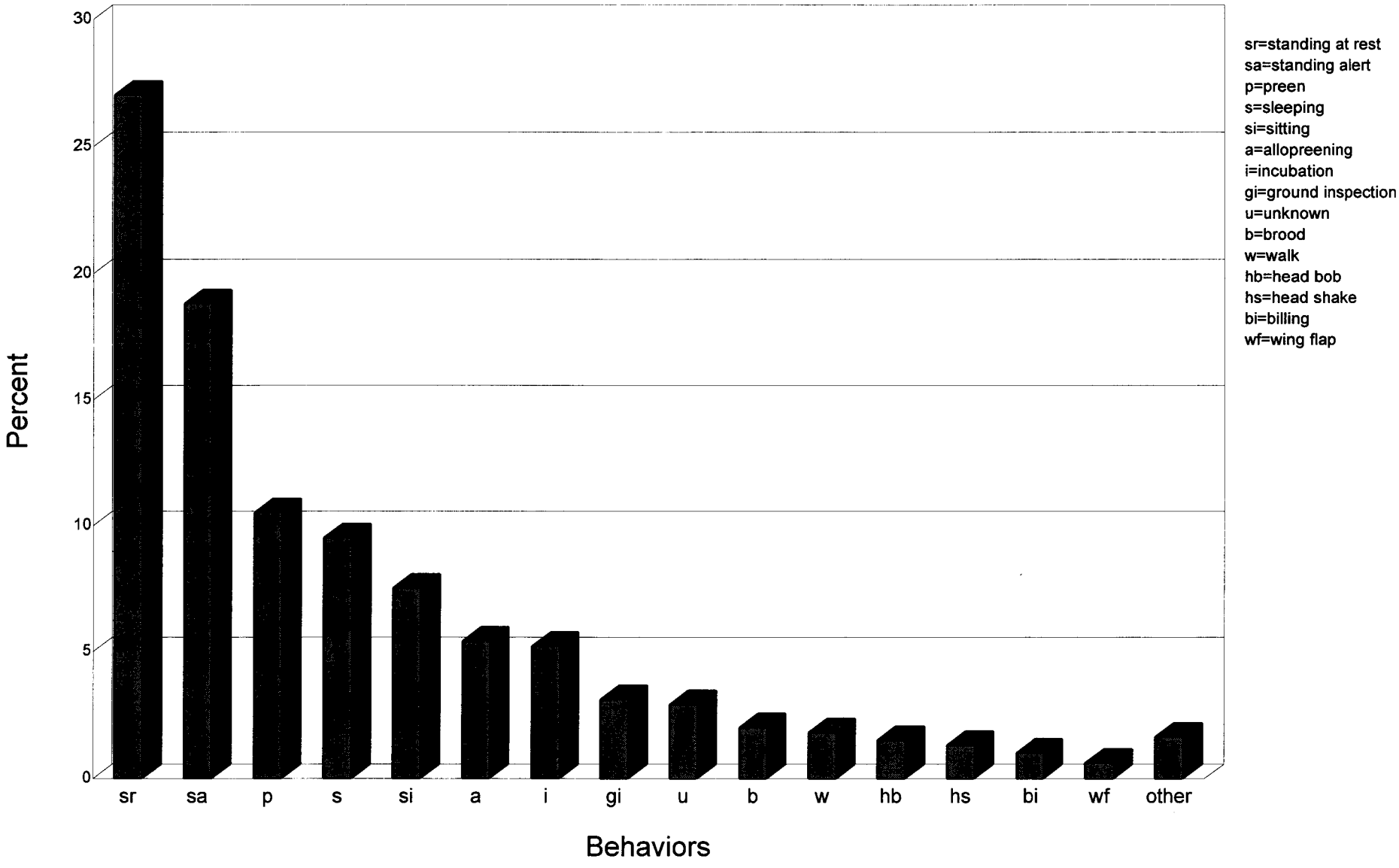


Figure 9. Percent occurrence of Common Murre behaviors at Devil's Slide Rock. (N= 68,332 murre observations from 2 February to 8 August 1996.)

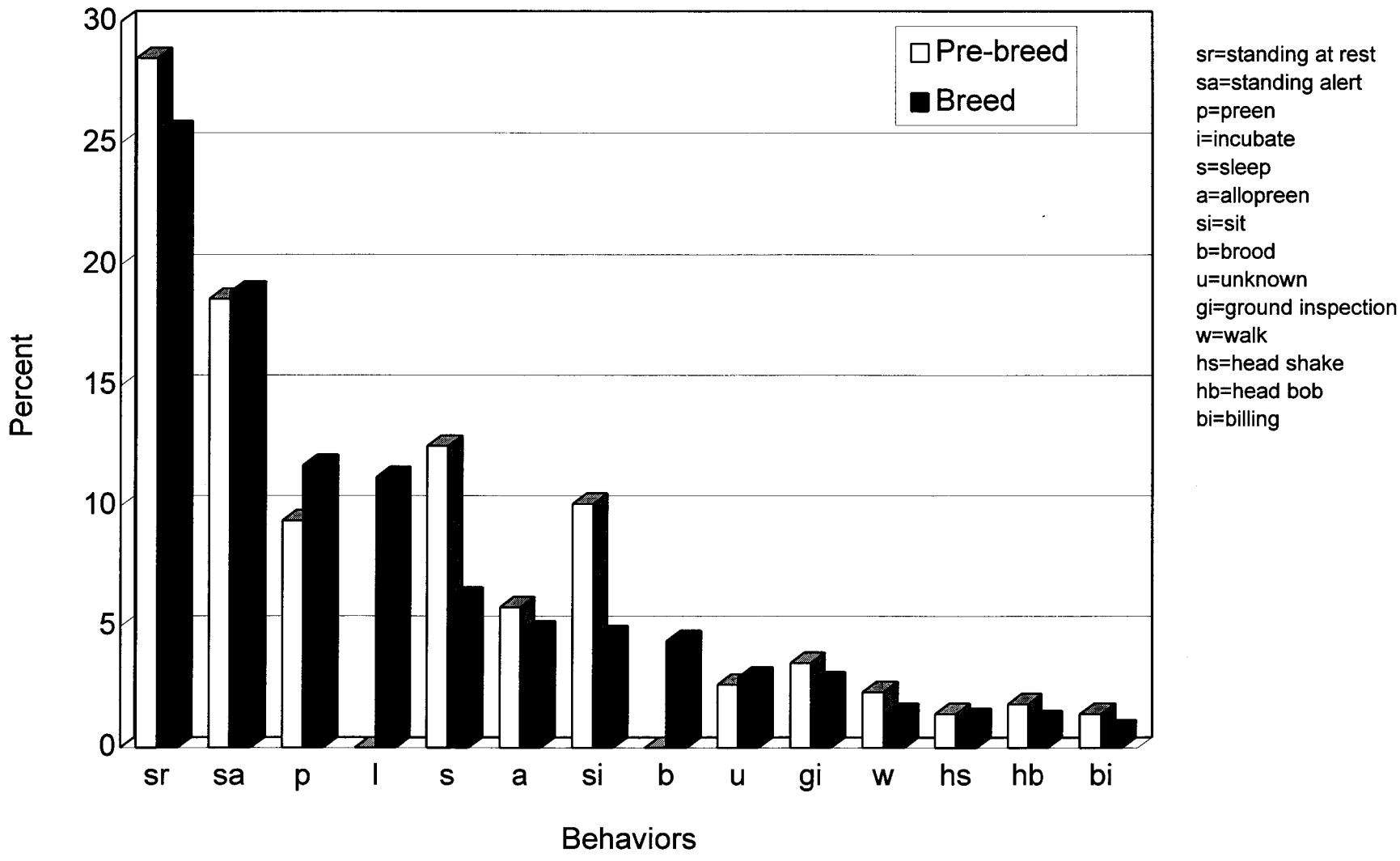


Figure 10. Percent occurrence of prominent behaviors of Common Murres at Devil's Slide Rock during the pre-breeding and breeding seasons from 2 February to 28 July 1996.

(N= 64,318 murre behaviors from 2 February to 28 July 1996.)

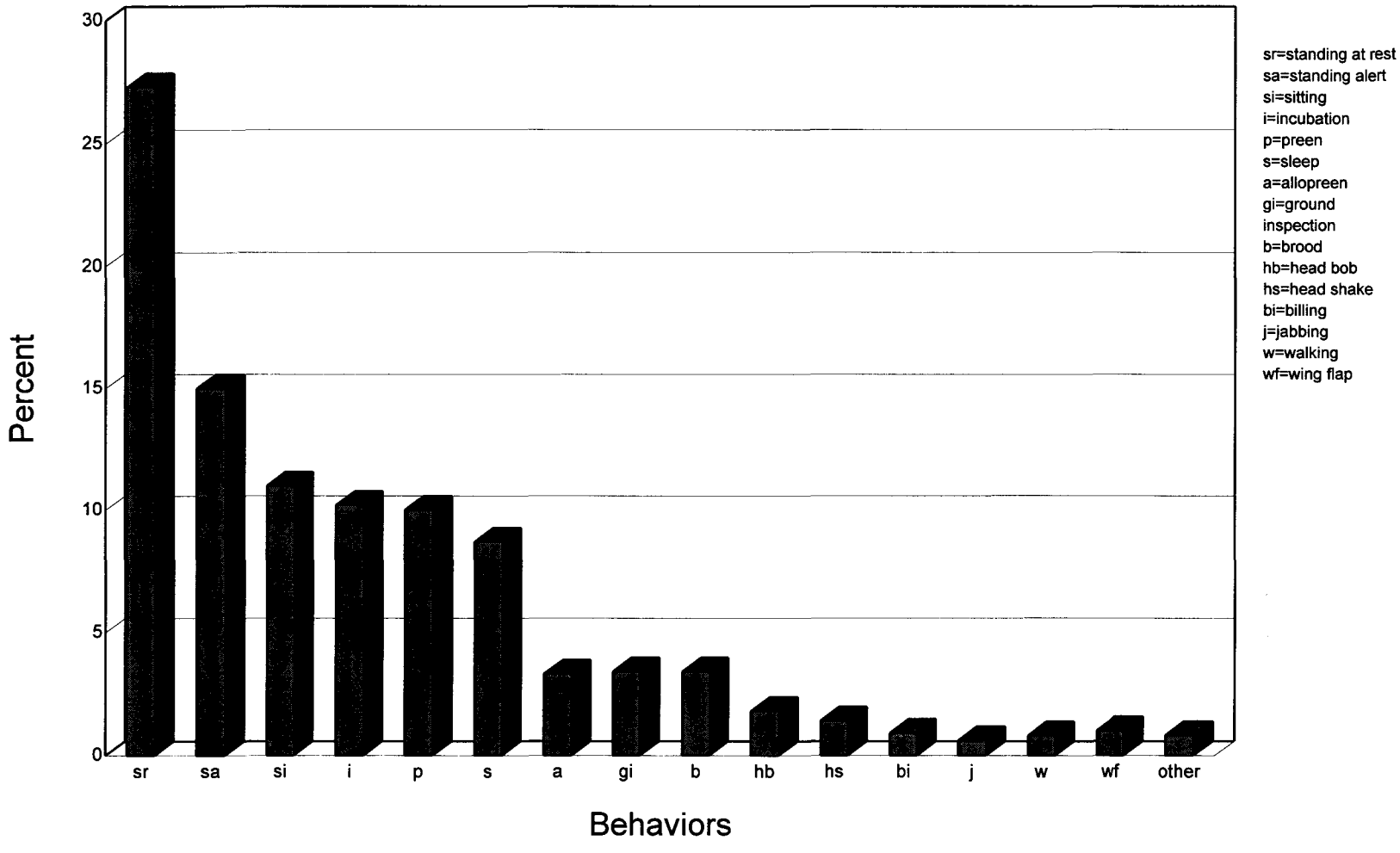


Figure 11. Percent occurrence of Common Murre behaviors at Point Reyes headlands subcolonies. (N = 52,145 murre observations from 2 February to 26 July 1996.)

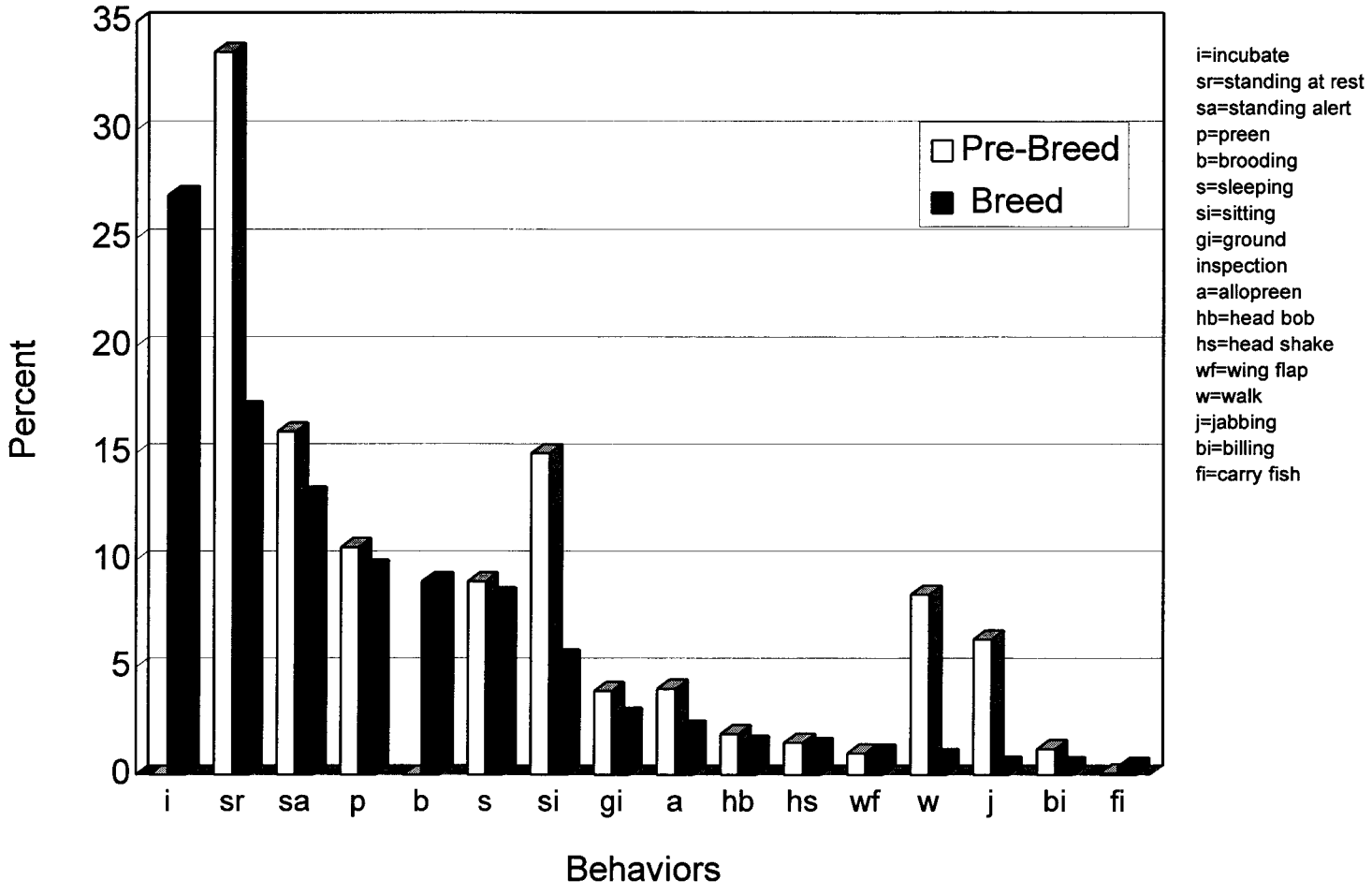


Figure 12. Percent occurence of prominent behaviors of Common Murres during the pre-breeding and breeding seasons at Point Reyes headlands.
(N=52,145 murre observations from 2 February - 28 July 1996.)

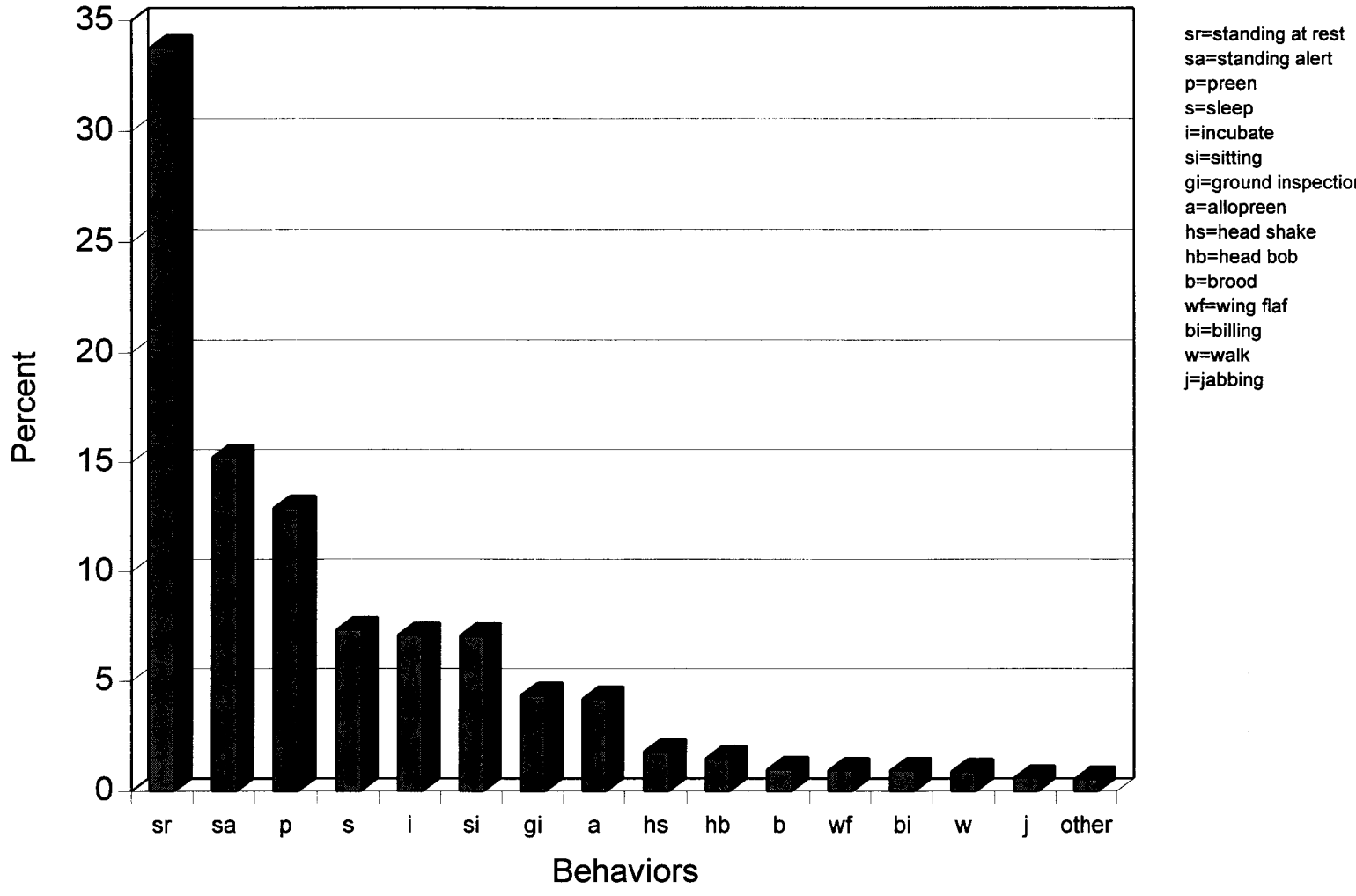


Figure 13. Percent occurrence of Common Murres behaviors at the Castle Rock and Mainland subcolonies. (N=42,559 murre observations from 2 February to 28 July 1996.)

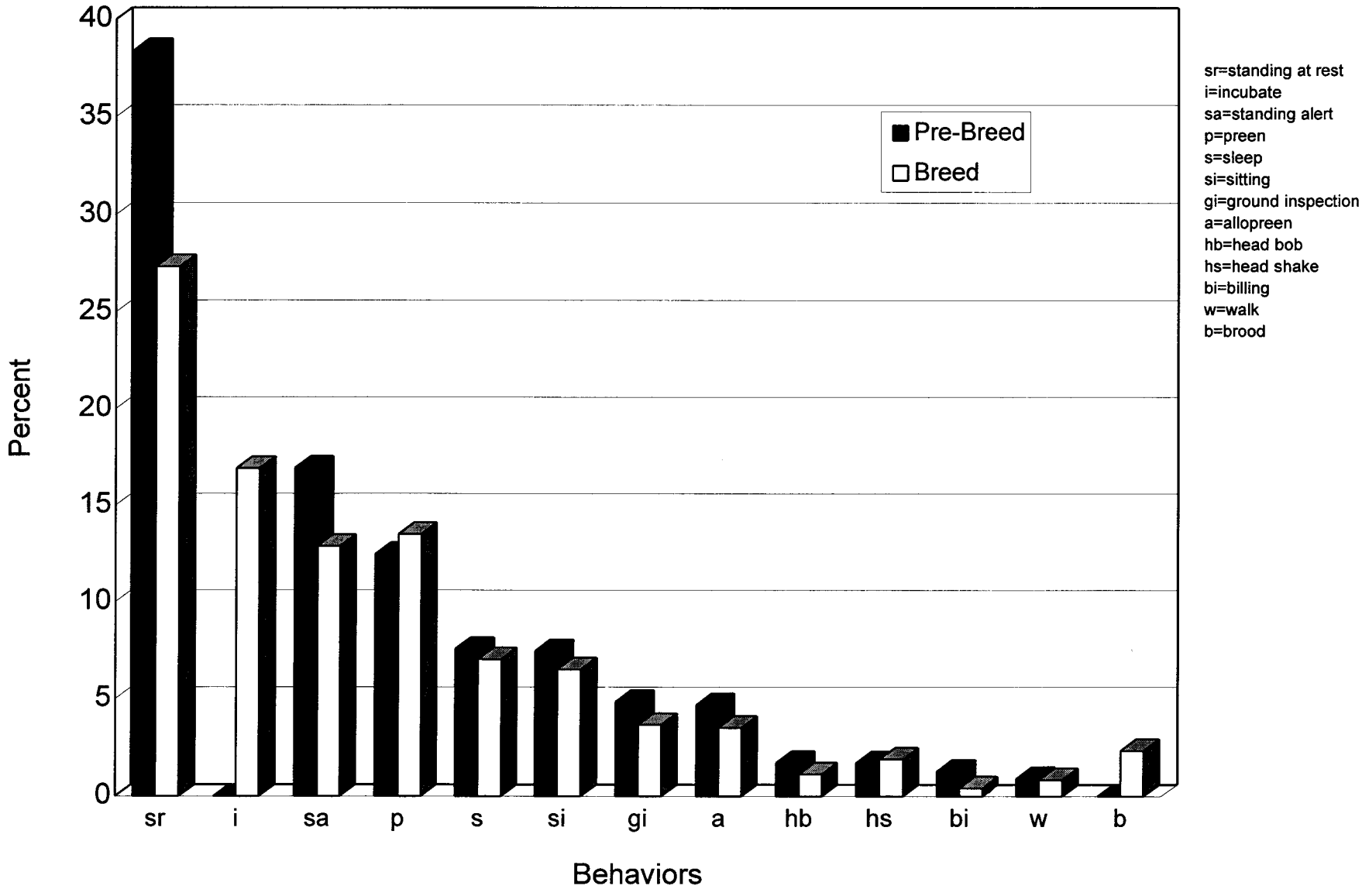


Figure 14. Prominent behaviors of Common Murres during the pre-breeding and breeding seasons at the Castle Rocks subcolonies. (N= 42,559 murre observations from 2 February to 28 July 1996.)

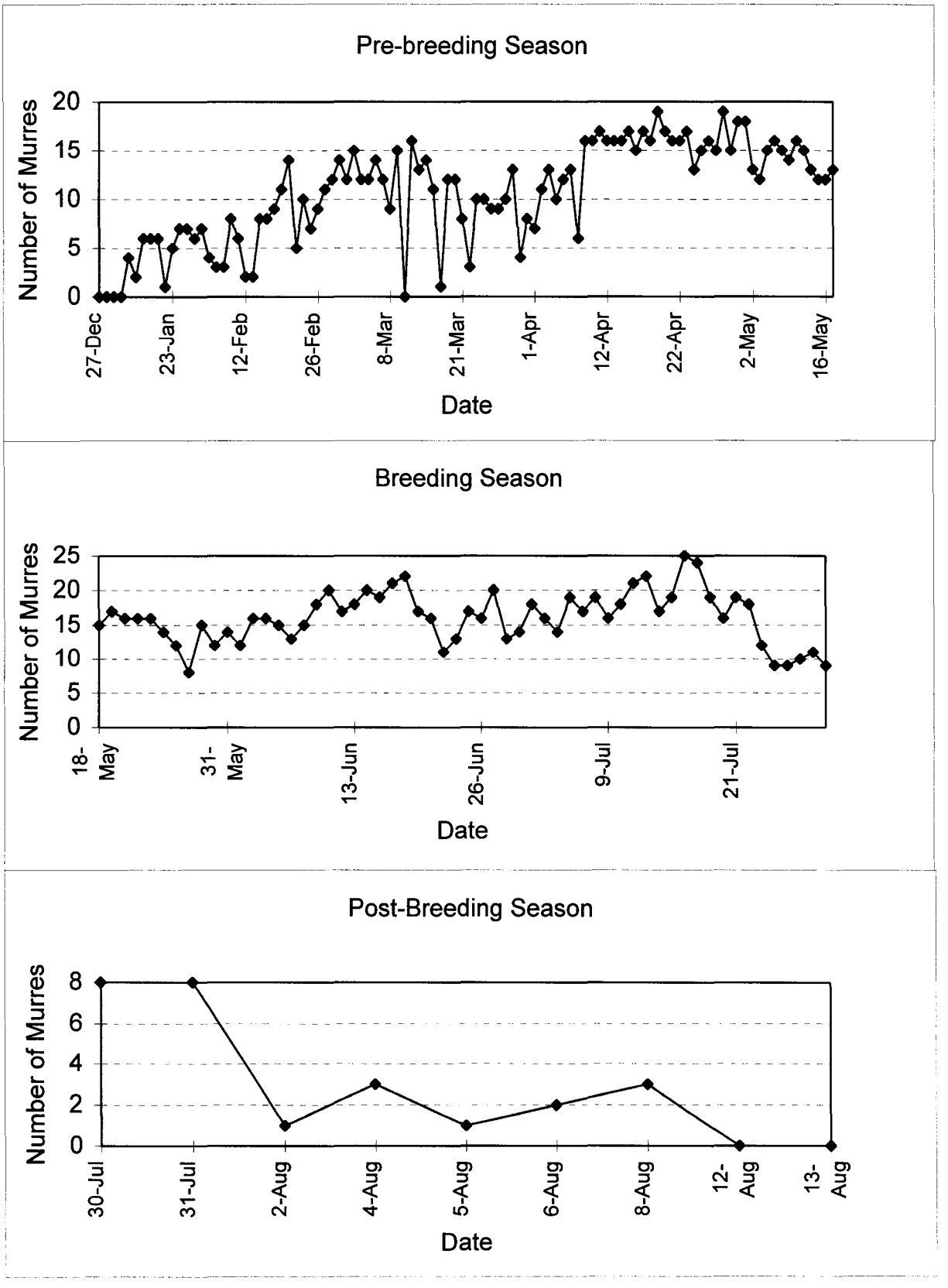


Figure 15. Seasonal Attendance of Common Murres at Devil's Slide Rock in 1995 and 1996 during the pre-breeding (26 December-17 May), breeding (18 May-28 July), and post-breeding (29 July-8 August) seasons.

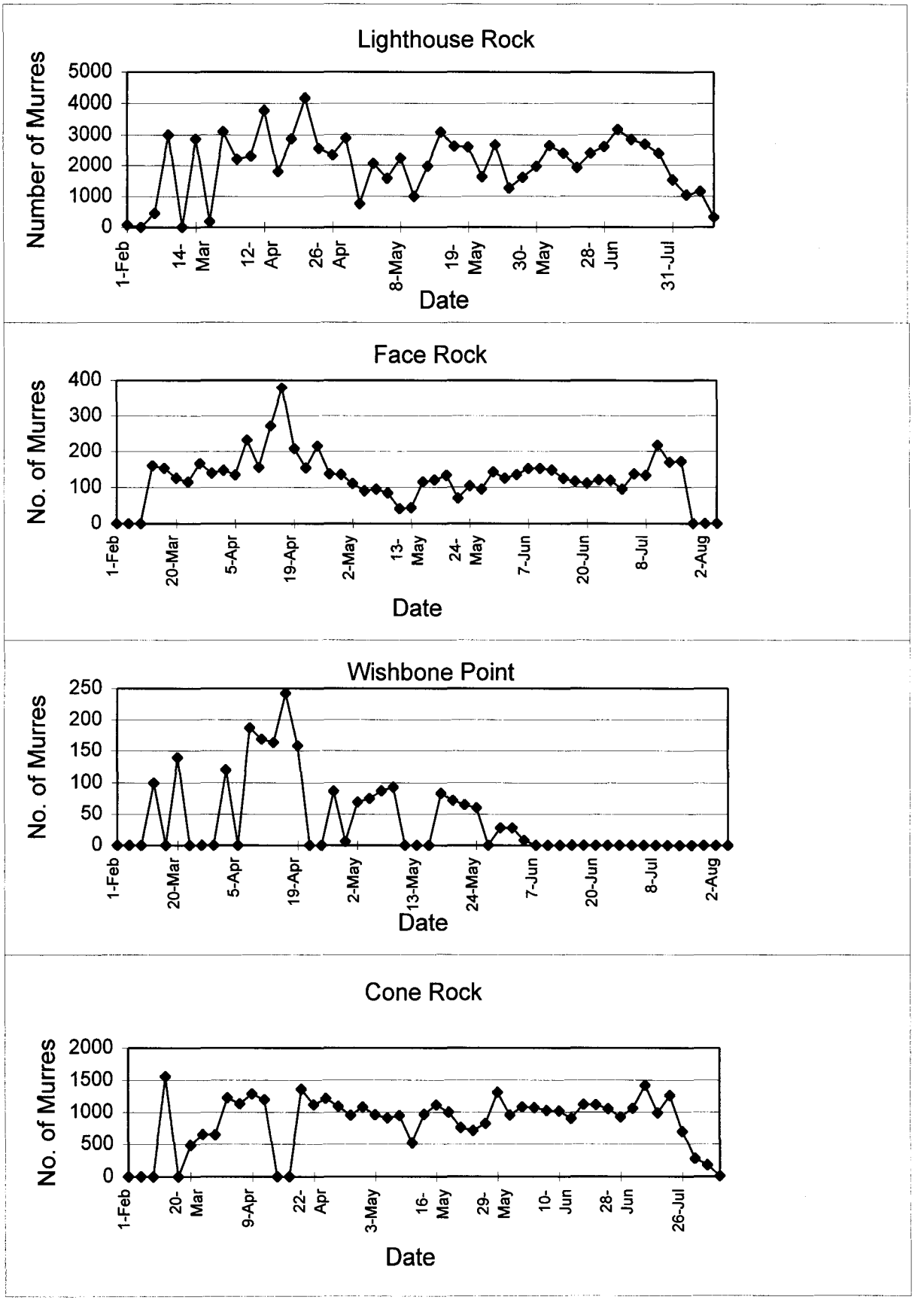


Figure 16. Seasonal attendance patterns of Common Murres at four Point Reyes headlands subcolonies from 2 Februrary to 8 August 1996.

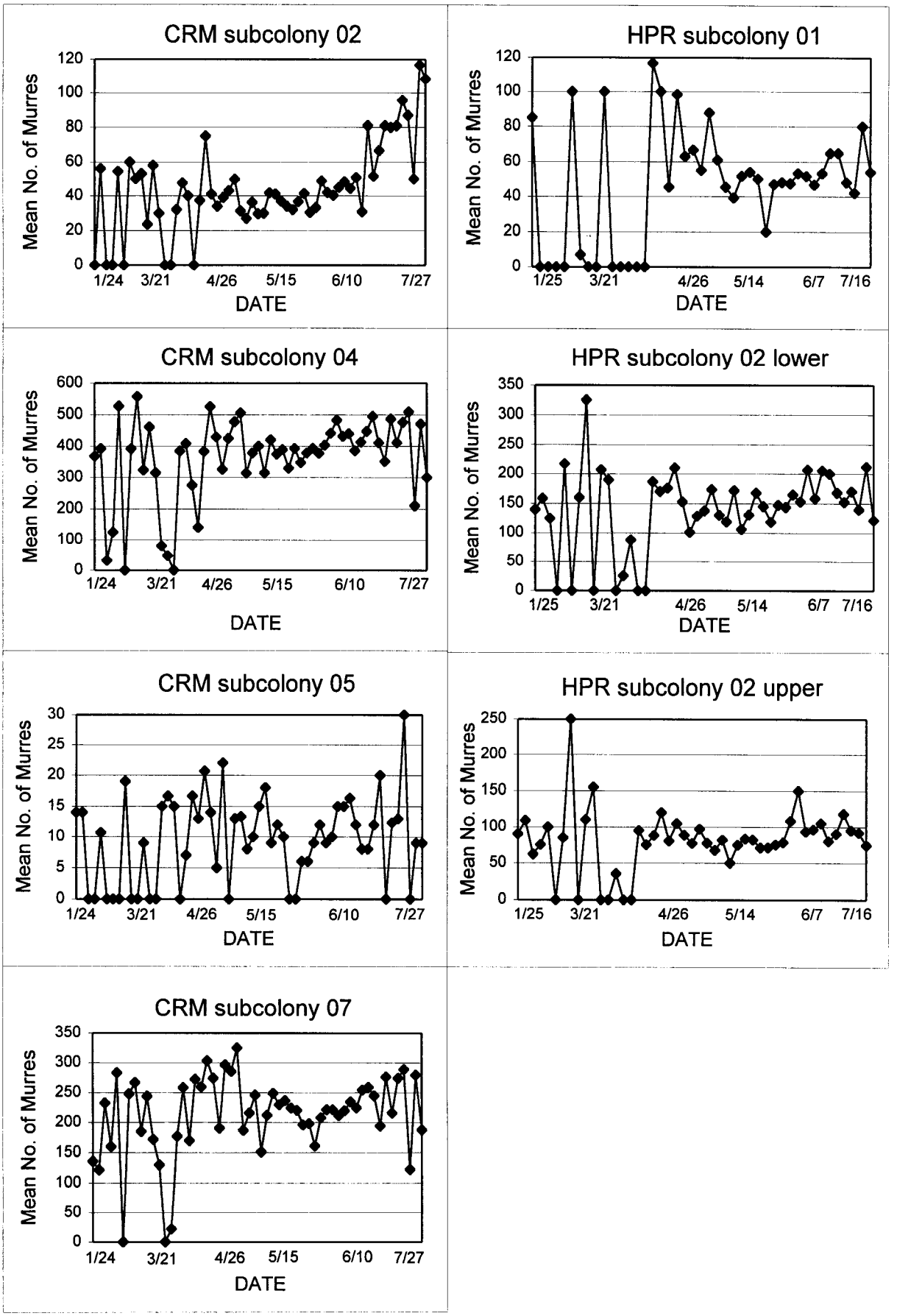


Figure 17. Seasonal attendance of Common Murres at Castle Rock and Mainland (CRM) and Hurricane Point Rocks (HPR) subcolonies from 24 January to 27 July 1996.

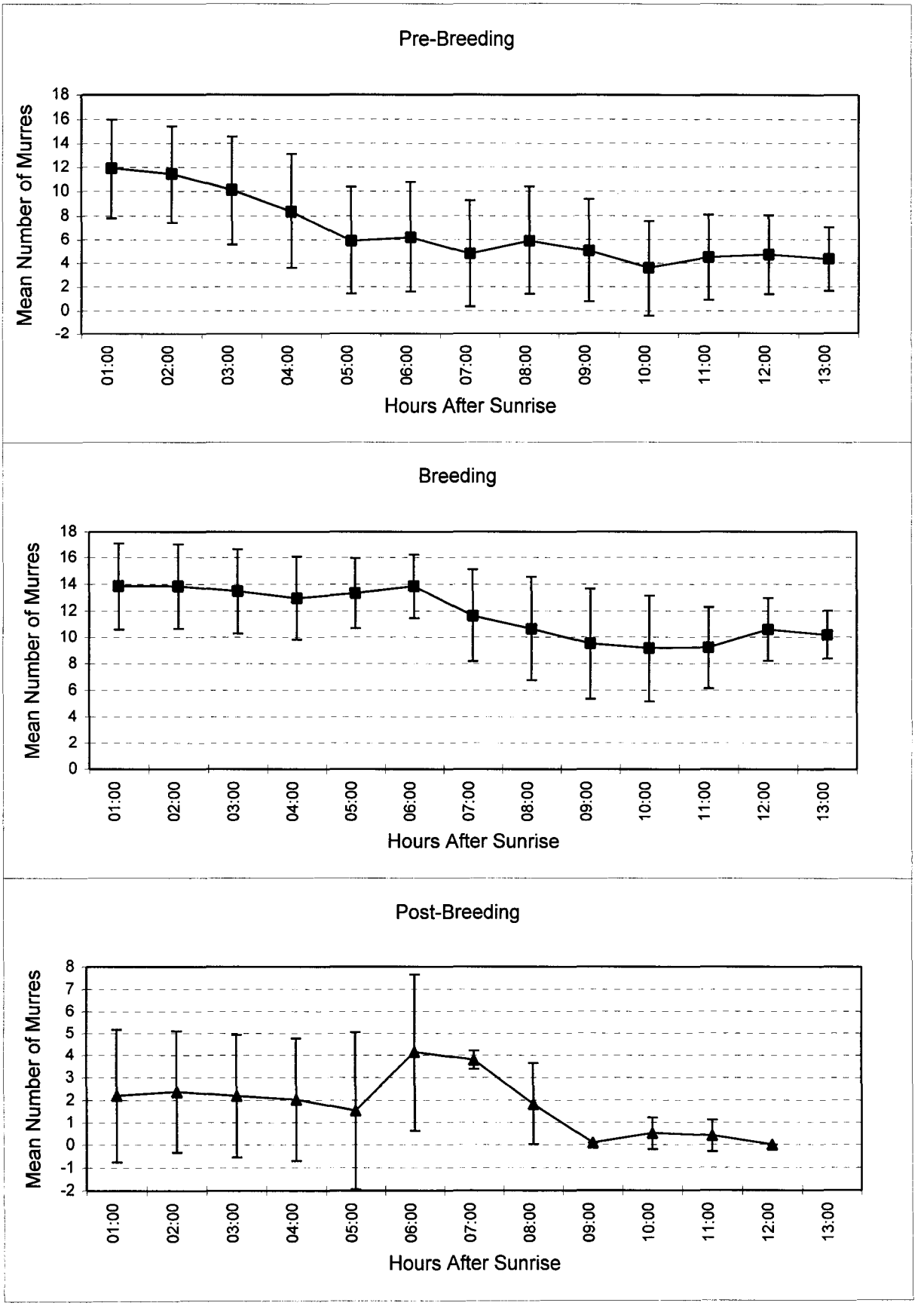


Figure 18. Diurnal attendance patterns of Common Murres at Devil's Slide Rock during the pre-breeding, breeding and post-breeding periods in 1996.

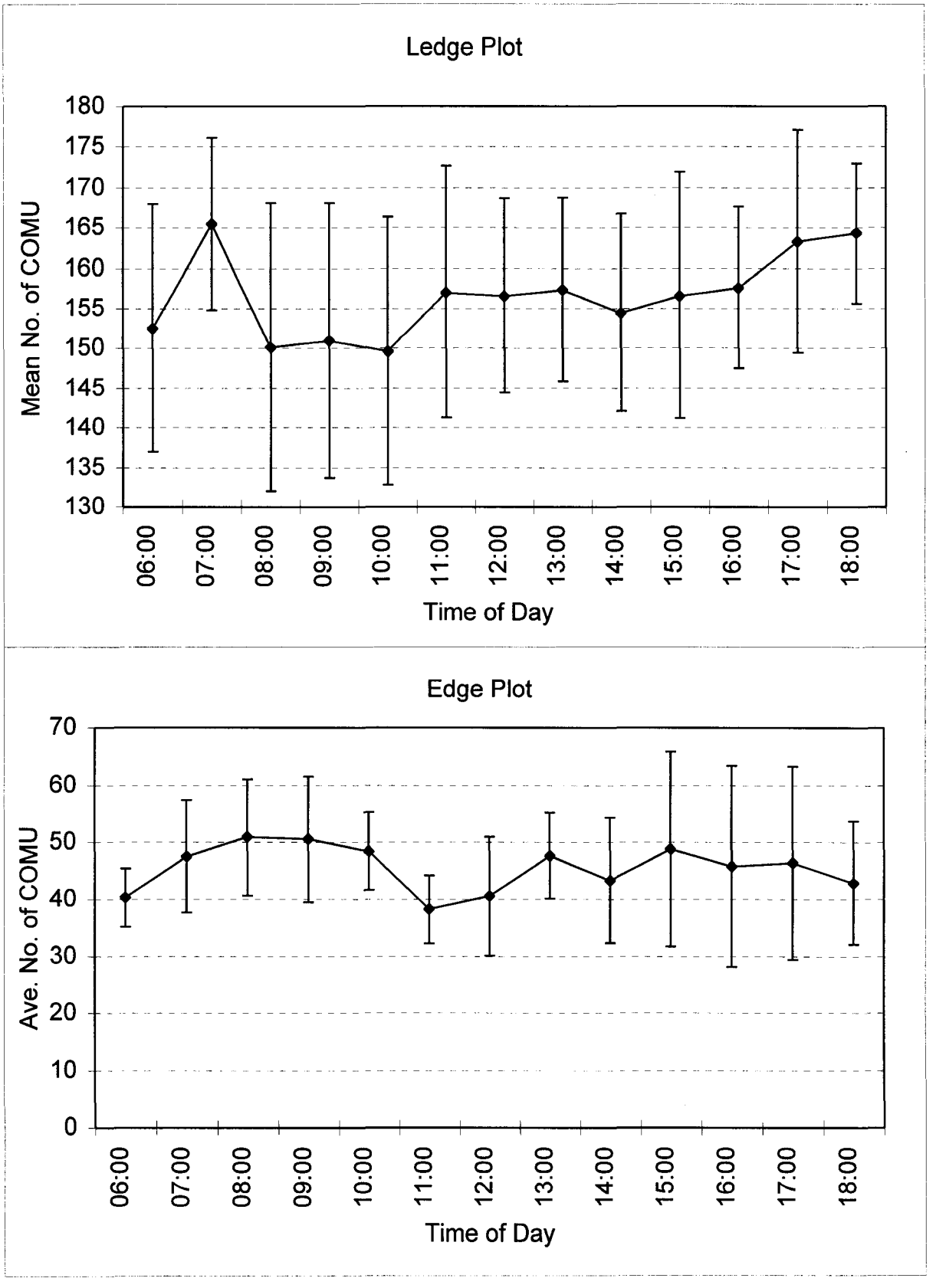


Figure 19. Diurnal attendance patterns of Common Murres at the Point Reyes headlands during the 1996 breeding season (17 May to 7 August).

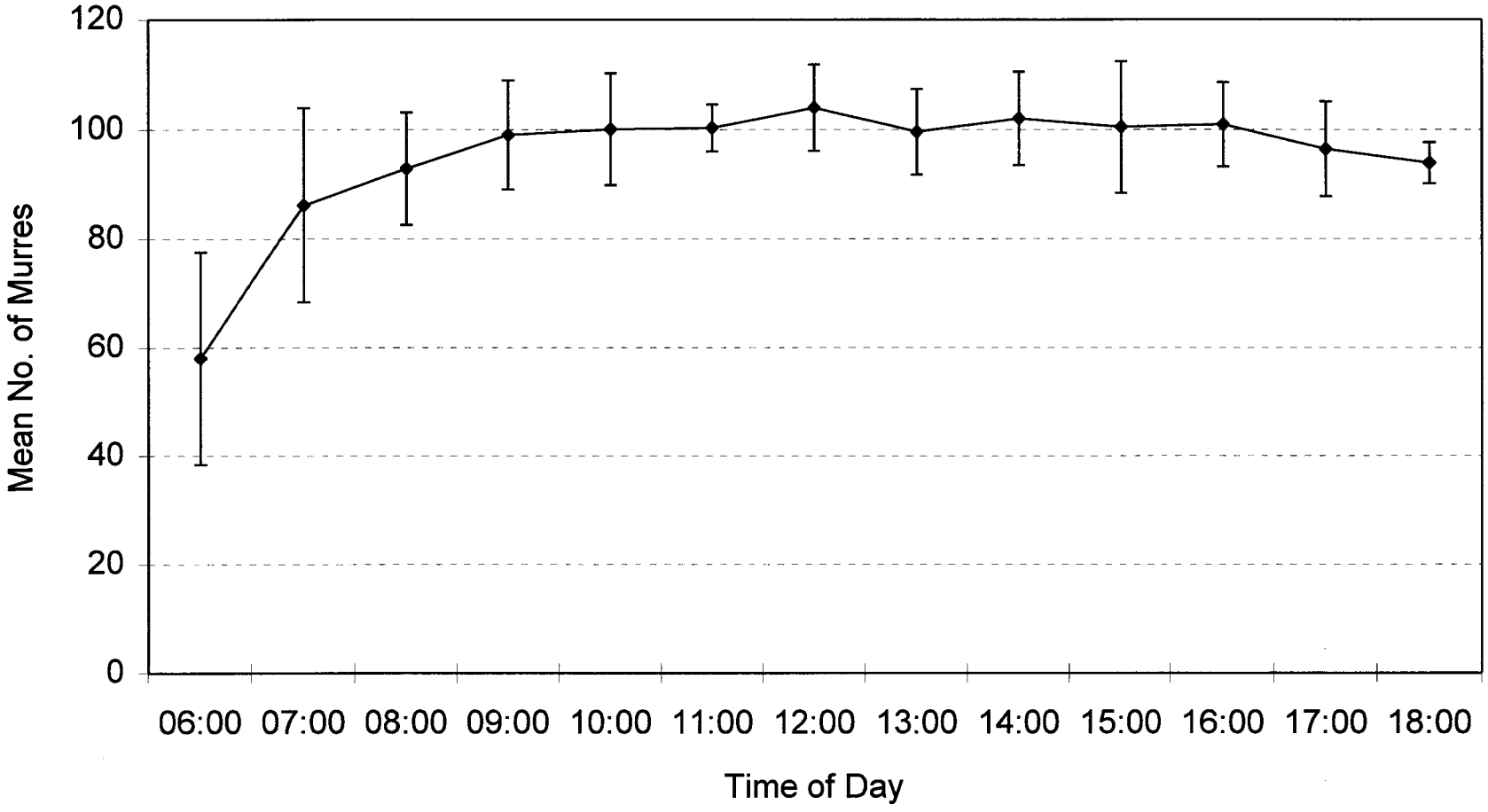


Figure 20. Diurnal attendance of Common Murres at the CRM subcolony 04 plot during the breeding season (20 May to 24 July 1996.)

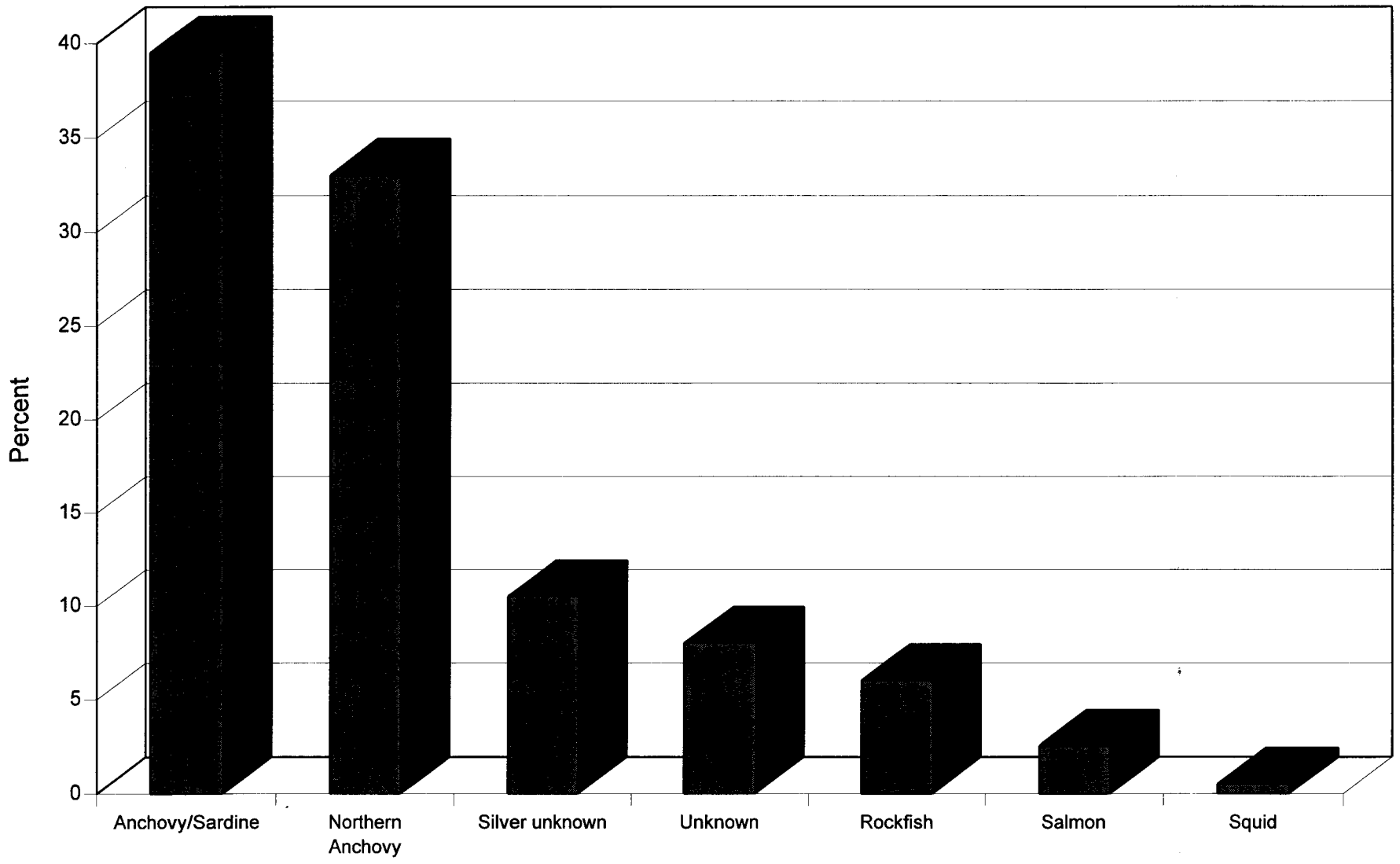


Figure 21. Percentages of diet items fed to Common Murre chicks at PRH Lighthouse Ledge plot. (N=226 prey items recorded from 5 July to 23 July 1996.)

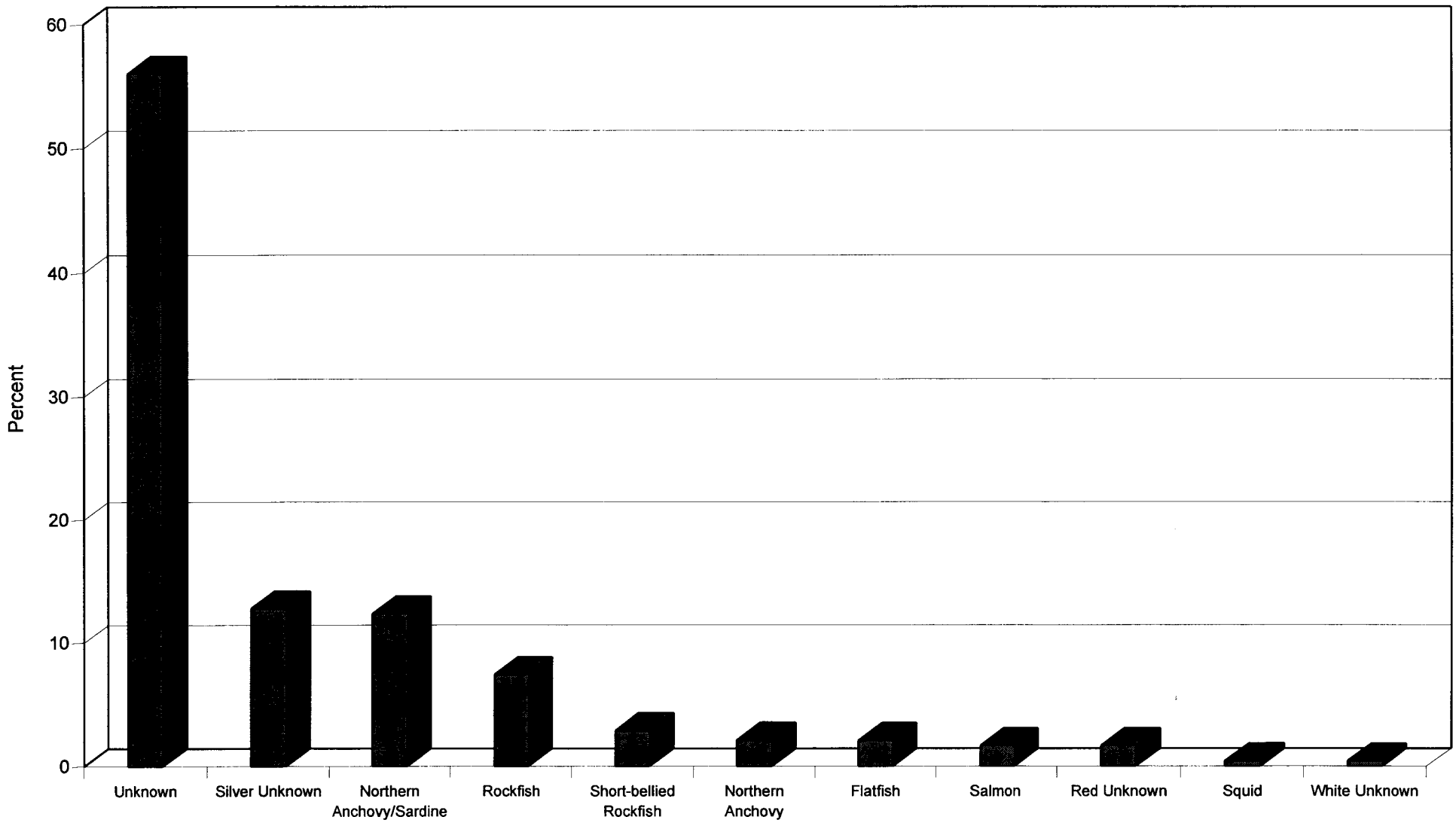


Figure 22. Percentages of diet items fed to Common Murre chicks at the CRM subcolony 04 plot. (N= 261 prey items recorded from 29 June to 17 July 1996.)

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 the Devil's Slide Rock colony, PRH Ledge and Edge plots, and CRM subcolony 04 plot.

COMMON MURRE PRODUCTIVITY								
Colony/Plot	No. Nest Sites	No. Eggs Laid	No. Eggs Hatched	Eggs Hatched/Pair	Hatching Success[1]	No. Chicks Fledged	Fledging Success[2]	Chicks Fledged/ Pair
DSR	6	6	3	0.50	50.0%	3	100%	0.50
Ledge Plot	110	115	94	0.85	81.7%	83	88.3%	0.75
Edge Plot	16	16	9	0.56	56.3%	2	22.2%	0.13
CRM 04 Plot	57	60	41	0.72	68.3%	25	61.0%	0.44

[1] Hatching success is defined as the number of eggs hatched in relation to the total number of eggs laid (including first and replacement clutches).

[2] Fledging success is defined as the number of chicks fledged in relation to the total number of eggs hatched (including first and replacement clutches).