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Abstract.—Colonial seabirds such as alcids often do not rapidly recolonize former breeding habitat following extirpation of nesting colonies. Social attraction (e.g., use of decoys, recorded vocalizations and mirrors) artificially stimulates nesting by providing social cues that encourage colonization. Common Murres (*Uria aalge*) stopped breeding at Devil's Slide Rock, San Mateo County, California following the 1986 *Apex Houston* oil spill. Natural recolonization did not occur between 1987 and 1995. Common Murres began regular visits to Devil's Slide Rock within 24 hours of social attraction equipment installation in January 1996 and six pairs nested by June 1996. Over 90% of murre observations were in decoy plots in contrast to control plots and outside of plots where few murre observations occurred. Significantly more murre presences versus absences were recorded in low density decoy plots and these birds most often frequented open areas (aisles) within decoy clusters. Significantly larger groups of murres visited high density decoy plots and aisle sub-plots. Murre densities were significantly greater within 30 cm of mirrors. Five of six nests were within 60 cm of mirrors. Nests coincided with areas where prior nesting and last pre-1996 attendance had been concentrated. Rapid breeding response combined with recent nonbreeding attendance suggests that the first colonists may have been surviving breeders from the original colony or young produced at the rock prior to the oil spill. The initial recolonization event and continued restoration efforts have prompted further colony growth to 190 pairs nesting by 2004. This study suggests that social stimuli can limit natural colonization of otherwise suitable habitat. *Received 11 May 2006, accepted 23 October 2006.*

Key words.—Common Murre, social attraction, restoration, seabird, Devil's Slide Rock, California, alcid, *Uria aalge*.

Avian restoration programs in North America have been conducted using various passive and active techniques (Yoakum *et al.* 1980; Franzreb 1997). In terrestrial and freshwater ecosystems, habitat protection is widely used to protect feeding, breeding, and wintering areas and to allow for natural recovery of avian numbers or distribution, if conditions permit such recovery. However, in many cases, additional efforts are needed to stimulate natural recovery of wildlife, especially in specific areas or habitats where they have been extirpated. For example, restoration of extirpated land birds to upland communities relies largely on changing plant community structure (Thomas *et al.* 1976). To increase land bird diversity, managers usually replicate quality habitat observed in natural ecosystems or perform specific techniques (e.g., burns, revegetation and impoundments) to relieve limitations in food, shelter or water (Askins 2000). Following the principal of "plant it and they will come," land managers typically protect, create and enhance specific habitats with the hope that birds will eventually discover improved sites and establish new populations (U.S. Forest Service 1969).

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In marine ecosystems, protection of breeding habitats for seabirds is widely recognized as beneficial, but protection of at-sea foraging areas is very limited. Seabird restoration has focused primarily on improving habitat at breeding colonies to increase numbers of breeding individuals and reproductive success. However, protection and enhancement of seabird breeding habitat by itself can be inadequate to restore extirpated seabird colonies, even when human factors contributing to extirpation have been removed. Unlike many landbirds, many seabirds (more specifically alcids, family Alcidae) have colonial nesting habits, strong mate and breeding-site fidelity, and strong colony-site philopatry (Thibault 1993; Halley et al. 1995; Harris et al. 1996; Gaston and Jones 1998). Because of these characteristics, individuals often fail to colonize new habitat or return to former nesting sites following loss of the colony. Thus, alcids originating from other colonies are unlikely to rapidly reestablish breeding at an extirpated colony location because they tend to either return to breed at their natal colony or on occasion join another existing colony. For these reasons, restoration of colonial nesting seabirds must also consider social constraints as a fundamental component of habitat quality (i.e., the social environment should be considered as important as food, shelter, and water).

Conspecifics often attract potential recruits to established seabird nesting colonies (Stamps 1991; Reed and Dobson 1993; Boulinear and Danchin 1997). Established breeders, pre-breeders, and birds immigrating from other colonies presumably have strong adaptations for and derive enormous benefits from colonial breeding such that little pioneering of new breeding habitat occurs without established pairs of birds being present. In this manner, at least some colonial nesting birds assess the reproductive success of existing colonies when selecting future breeding sites (Danchin et al. 1998). However, in murres (genus *Uria*) and other colonial alcids, strong philopatry and minimal change in nesting habitats over time has led to very stable colony locations; new colonies are rarely formed and abandoned colonies rarely recolonized (Gaston and Jones 1998; Manuwal and Carter 2001; Carter 2004). In certain areas, murre recolonization of apparently extirpated colonies has been recorded over long time periods but has not been well studied (Carter et al. 2001; Capitolo et al. 2005). Thus there is little information on colony formation or recolonization in murres and many other alcids.

Specific techniques to address social constraints are needed to reestablish seabird nesting colonies, especially those extirpated through human actions where nesting habitat and other environmental attributes are still adequate for supporting a colony. The "social attraction" technique was first used to establish a colony of Common Terns (*Sterna hirundo*) and Arctic Terns (*S. paradisaea*) in the Gulf of Maine (Kress 1983). The premise of this technique is to attract and hold prospecting birds among decoys, mirrors and recordings so that first arriving birds will remain long enough to help attract additional arrivals. As growing numbers of birds congregate at the site, potential breeders should have an increased chance of pairing and breeding. Social attraction has also been used for Atlantic Puffins (*Fratercula arctica*), Common Murres (*Uria aalge*) and at least 38 other colonial waterbirds (e.g., Kress and Nettleship 1988; Kress 1997, 1998; Crouch et al. 2002; SKW, unpubl. data); however, there have been no experimental demonstrations of the efficacy of the technique for colony restoration (but see Burger 1988).

Since 1996, we have used social attraction to mimic the social environment of a well-established colony and facilitated recolonization of a recently extirpated site of the Common Murre at Devil's Slide Rock in central California, following colony loss after the 1986 *Apex Houston* oil spill (Carter et al. 2003). In this paper, we report this first successful use of social attraction techniques to reestablish a Common Murre colony and factors associated with successful recolonization. We also examine the relative value of seasonal responses, decoy densities, use of different arrangements of decoys within decoy plots, and mirrors to social attraction techniques for the restoration of Common Murres. Key objec-

tives of our work were to 1) restore breeding murres to Devil's Slide Rock, 2) assess methods to restore murres, and 3) examine colony growth after recolonization.

History of the Devil's Slide Rock Colony

Common Murre colonies in central California occur at the South and North Farallon Islands, 20-40 km from mainland shorelines, and on nearshore rocks and adjacent mainland points between Marin and Monterey counties (Sowls et al. 1980; Carter et al. 2001). Along the central California coast, murres declined >50% between 1980-1982 and 1986, including 46-100% declines at individual colonies (Takekawa et al. 1990). Additional declines (about 7%) occurred from 1986 through 1989 (Carter et al. 2001). At Devil's Slide Rock, 2,300, 2,900, and 2,600 breeding murres were estimated in 1979, 1980, and 1982, respectively (Sowls et al. 1980; Briggs et al. 1983). By 1986, Devil's Slide Rock was devoid of breeding murres (Takekawa et al. 1990). Population decline and colony loss between 1983 and 1986 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 1982-83 (Takekawa et al. 1990; Carter et al. 2001). Devil's Slide Rock was last documented as an active colony on 10 June 1984, when "24-26 pairs incubating eggs or brooding chicks" were noted, although hundreds of birds could have been standing nearby that were not counted (Carter et al. 2003). No known observations occurred in 1983 and 1985.

Seabird mortality resulting from the Apex Houston oil spill was well documented (Page et al. 1990; Carter et al. 2001, 2003). This spill killed about 9,900 seabirds in January and February 1986, including about 6,300 Common Murres. Following the January spill, murres apparently did not breed successfully on Devil's Slide Rock in 1986 since no birds were seen on 4 June during the peak of the incubation period, although 93 birds were counted on 5 June (Takekawa et al. 1990; Carter et al. 2001). Mortality during the Apex Houston oil spill was considered to be the final event that caused colony extirpation, although up to a few hundred birds survived after breeding ceased (Carter et al. 2003). On 27 May 1987, 128 murres were noted on Devil's Slide Rock but breeding was unlikely because most murres were standing and not in incubating postures. During annual monitoring using aerial photographs in 1988-90 and 1993-95, murres were not observed on Devil's Slide Rock, except for one bird in 1990 and four birds in 1994 (Carter et al. 2001). Small numbers of murres also were noted attending the rock with non-aerial counts in 1992-95. On 2 June 1992, four birds were noted on the rock from a boat (G. Divoky, pers. comm.). On 3 and 9 July 1994, nine and four birds, respectively, were observed on the rock from the adjacent mainland but none were breeding; no murres were observed on 1 July 1995 (MWP, pers. obs.). Thus, between 1986 and 1994 it appears as though murres sometimes visited the rock but did not breed.

METHODS

Study Site

Devil's Slide Rock is a relatively flat-topped sea stack with 22 m vertical walls consisting of approximately 200 m² of vegetation-free surface substrate. It is located about 300 m from the mainland shore at 37°34.65'N, 122°31.23'W in San Mateo County, California, about 25 km south of the City of San Francisco. The rock is owned by the U.S. Bureau of Land Management (BLM) and in 1996 was managed by the California Department of Fish and Game as part of the California Islands Wildlife Sanctuary. The rock is now part of the California Coastal National Monument, designated in 2000 and managed by BLM. The waters surrounding the rock are part of the Monterey Bay National Marine Sanctuary.

Devil's Slide Rock lies near the southern end of an oceanographic region known as the Gulf of the Farallones. This area is well recognized as one of the more productive regions of the California Current Upwelling System (Ainley and Boekelheide 1990). The Devil's Slide Rock murre colony is part of the central California murre population. This population held about 75,700 breeding pairs of murres in 1995 (calculated from Carter et al. 2001), most of which occurred at six colonies in the Gulf of the Farallones within 45-65 km of Devil's Slide Rock.

Social Attraction Design

Life-sized murre decoys and an audio system that broadcast murre calls were used to simulate the appearance and sound of an active murre colony. Mirrors were used to give the appearance of larger numbers of birds,

and reflections of live birds added apparent bird movements in the colony. Adult murre decoys (288 wooden in standing posture and 96 hollow polyethylene in incubating posture) were installed at Devil's Slide Rock on 12-13 January 1996. Decoys were painted with an exterior latex paint to resemble the alternate plumage of adult murres. On 14 April, about two weeks prior to the typical onset of egg-laying at central California murre colonies (Boekelheide *et al.* 1990), 48 wooden egg and 36 wooden chick decoys were added among the adult models to further simulate the appearance of breeding activity. Chick decoys were prepared with a polyester cloth material to resemble 15-day-old chicks in downy plumage; faces were painted with exterior latex paints. Egg decoys were painted to resemble the natural variation of egg colors in murres. Decoy adults, chicks, and eggs were secured to the rock with 6 mm diameter metal rods set into holes drilled seven to 15 cm into the rock.

To examine the response to variations in social attraction techniques, we used a randomized-block design with four blocks on Devil's Slide Rock that possessed similar microhabitat characteristics (Fig. 1). Each block was divided into four plots approximately 100 cm by 170 cm. Each plot was on gently-sloped (<10°) terrain with a vertical rock wall (>five cm high) at one edge of the plot. Thus, each block contained a similar range of suitable microhabitats for murre breeding and was located within the limits of the historic colony based on examinations of archived aerial photographs.

Within each block, plots were randomly assigned to one of four decoy density treatments: high-density plot (40 standing decoys and 13 incubating decoys); medium-density plot (20 standing decoys and seven incubating decoys); low-density plot (twelve standing decoys and four incubating decoys); and control plot (no decoys). Thus, the four blocks contained high, medium, and low-density plots plus a control plot. Two of the four plots within each block received egg and chick decoys and two were adult only plots. High-density plots received ten chick and twelve egg decoys, medium-density plots received five chick and eight egg decoys, and low-density plots received three chick and four egg decoys.

To determine areas used within the decoy plots, each plot was further subdivided into four sub-plots: front line, aisle, edge, and interior (Fig. 2). The front line area had decoys arranged in two rows adjacent to the vertical rock wall; this area was approximately 30 cm deep by one m wide. In medium and high-density plots, the front line contained seven (three incubating and four standing) and 13 (seven incubating and six standing) decoys, respectively. Low-density plots contained one row of four decoys (two incubating and two standing). The aisle area separated the front line and the main group of decoys. This area was approximately 30 cm deep by one m wide and was without decoys. The interior area was inside the main group of decoys within the plot. A live murre was considered to be in this area if decoys surrounded its body on all sides. The edge area surrounded the main group of decoys, excluding the aisle and front line areas. A live murre was considered within this area if it was within approximately 15 cm (about one murre body width) of any edge decoy.

A three-sided mirror box was placed in each of the twelve decoy plots. Mirrors were 20 cm wide by 40 cm high with a peaked roof to prevent nesting Western Gulls (*Larus occidentalis*) or other roosting gulls from standing on boxes. Including the roof and plywood base, mirror boxes were approximately 60 cm in total height. Mirrors were placed approximately 0.33 m from the front line on one side of each plot that contained decoys.

To provide the sound of an active murre colony, two identical but independent sound systems broadcast recorded murre vocalizations continuously from speakers arranged at regular intervals along the main ridge of the island. Each sound system consisted of a portable six-volt compact disc player, a 50-watt amplifier and two weatherproof speakers. Speakers were placed approximately 4 m apart and secured to the rock with expandable bolts. Three twelve-volt DC deep-cycle gel-cell batteries connected in series provided power; these were continuously recharged by two 60-watt photovoltaic panels. The sound equipment was housed in a fiberglassed wood box that was fitted under each pair of photovoltaic panels. Murre vocalizations played from compact disc had
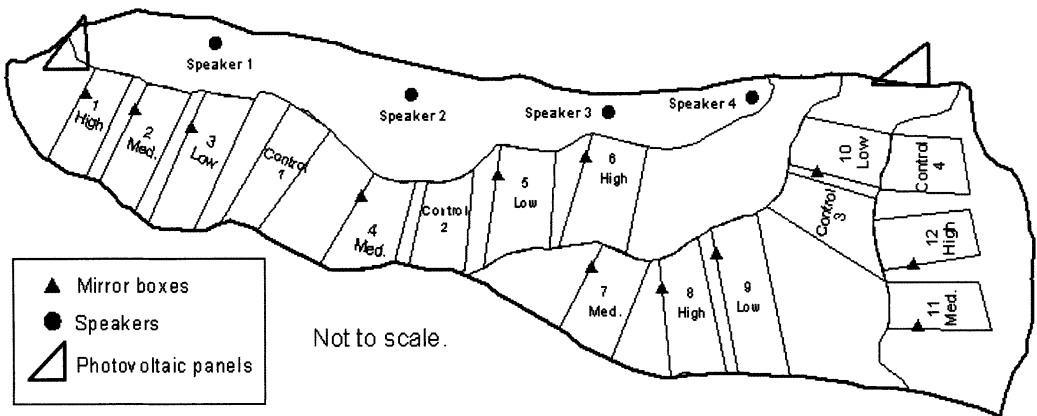

Figure 1. Location of decoy plots and other social attraction equipment on top portion of Devil's Slide Rock, 1996. Decoy densities are indicated by High, Medium, or Low. Controls corresponded with each block of plots (Block 1 contained plots 1, 2, 3 and Control 1; Block 2 contained plots 4, 5, 6 and Control 2; Block 3 contained plots 7, 8, 9 and Control 3; and Block 4 contained plots 10, 11, 12 and Control 4). Speakers were located on the highest ridgeline of the rock.
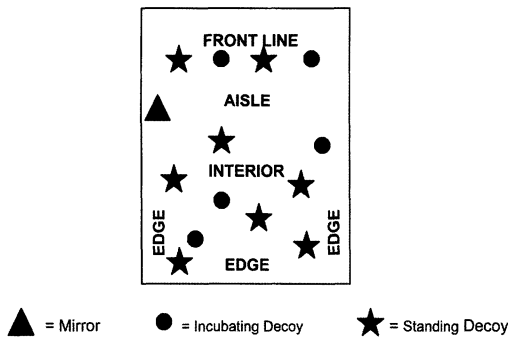
Figure 2. Illustration of the placement of decoys (sub-plot areas) and mirrors within plots.

been recorded at the Farallon National Wildlife Refuge in May 1995 using a digital audio tape recorder and stereo microphone. The recording was made from thousands of murres and included female copulation calls.

Observation Protocol

Most observations were conducted from a standardized mainland vantage point located 400 m distant and at an elevation of 55 m above Devil's Slide Rock. Preliminary observations began on 27 December 1995 and consisted of counts of all birds on the rock. Beginning on 2 February, observations were conducted daily, weather permitting. Daily observations consisted of two 3-hour observation periods. The first period began 0.5 hours after sunrise. The beginning of the second period varied systematically to ensure that all daylight hours greater than 3.5 hours after sunrise were surveyed once per week. During each observation period, Devil's Slide Rock was scanned at five-minute intervals by one to two observers using a Questar telescope with 16 mm (105 power magnification) or 24 mm (65 power magnification) eyepiece (Altmann 1974). Each time a murre was seen in a scan, location by plot, location within the plot by sub-plot, behavior, and proximity to mirror or speaker (in murre body widths) were recorded.

Attendance patterns were determined from daily maximum counts obtained during observations conducted from 27 December 1995 to 13 August 1996 (after all murres had departed Devil's Slide Rock for the season). Variation in attendance patterns through the day were determined by calculating the mean number of murres present during each hour from 0.5 to 13 hours after sunrise.

For each day, the number of sites used by murres was determined and categorized as nest sites or territorial sites. We defined a territorial site as a site consistently occupied by a murre or pair of murres on at least 15% of observation days. All active pairs were observed daily until all chicks fledged or a pair had clearly failed and no longer attended a nest site.

Data Analysis

To control for pseudoreplication within a day, only one scan of the plots at a standardized time of day was used for analyses of attendance patterns. We assessed all times of day and found that maximum counts occurred primarily between one and two hours after sunrise.

Thus, the scan two hours after sunrise was chosen to examine the effect of decoys and murres.

Logistic regression (Hosmer and Lemeshow 1989) was used to test the ability of the following variables to attract murres to the rock: seasonal effect; block (area of the rock); density of decoys within plots; and sub-plots (i.e., areas within plots that represented the arrangement of decoys). Seasons were defined as: pre-breeding, prior to the first egg laid (2 February to 25 May); breeding (26 May to 27 July); and post-breeding, after the last chick fledged until the last murre was observed (28 July to 8 August). Within the representative scan on each day, we assigned presence and absence of live murres to each plot and to each sub-plot. Each day was treated as an independent event. During early recolonization, we reasoned that not only did we need to attract birds to the site, but we needed to keep them returning to the site each day, regardless of whether or not they nested (in which case a nest site could be abandoned if the colony became unattractive). Thus, each daily presence or absence in each plot or treatment was treated as an independent measure of site attractiveness. Use of presence or absence rather than number of birds controlled for the attractive effect of live birds. Logistic regressions were conducted on the entire data set and separately for odd and even dates. Significant variables were identified, and subdivided chi-square tests (Zar 1998) were conducted to detect differences within variables.

Abundance of live birds was examined using contingency tables for counts of birds associated with each significant variable on each day. Because birds were not marked, we could not control for repeated measures of specific individuals between days. However, using repeated visits through time acted as a good measure of success and the effect of social attraction techniques to acquire and aid in holding birds. Thus we again treated a day as an independent measure of attractiveness.

Because mirrors were present in all plots except controls, we could not use plots or sub-plots to examine the potential effect of mirrors. Consequently, we evaluated the effect of mirrors on the number of murre observations on each day inside and outside a radius extending about two murre body widths (30 cm) from mirrors but still within plots. We tested the difference between the numbers of murres observed within the 30-cm mirror zone versus outside the mirror zone but still within the plot. To account for differences in size between these two areas, counts of live murres were converted to number of murres per m^2 of rock surface. A matched case logistic regression was used to test for a difference in density of murres within and outside the areas 30 cm from the mirror (Hosmer and Lemeshow 1989), again using each day as a different independent assessment of the attractiveness of mirrors.

RESULTS

No murres were observed during preliminary observations prior to social attraction installation in 1996. However, the day after decoys were installed, one murre was observed on Devil's Slide Rock. On the next day, four murres were seen. After installation of decoys, murres were observed on Devil's
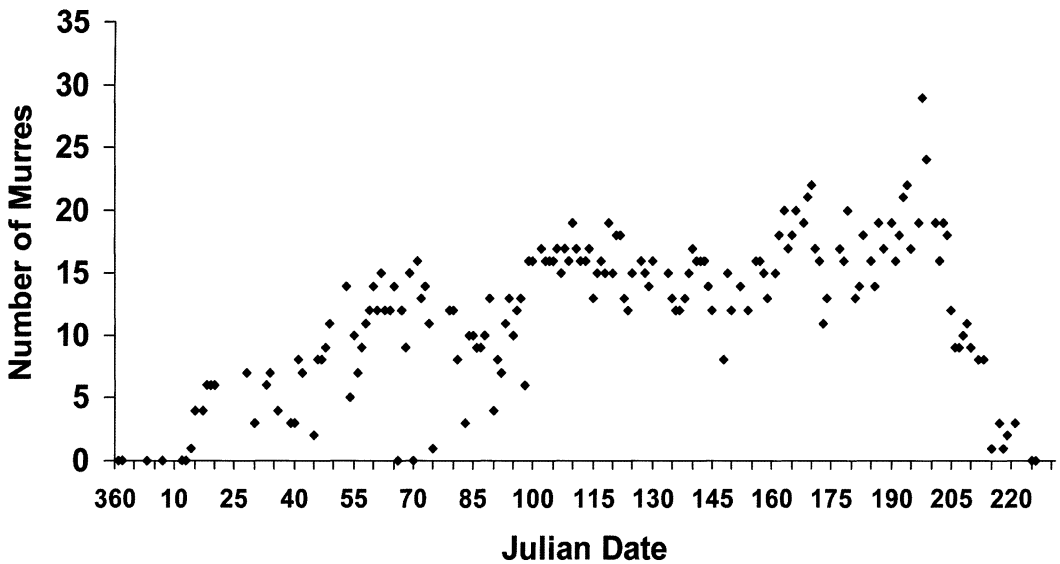
Figure 3. Daily maximum counts of Common Murres on Devil's Slide Rock, 27 December 1995 to 13 August 1996, by Julian Date (where Julian Date 1 = January 1). Social attraction equipment was deployed on 12-13 January 1996.

Slide Rock during all but two days between 14 January and the last day of murre attendance for the season on 8 August (Fig. 3).

In general, daily maximum counts were lowest and most variable in January to March, then increased in April to early June. Maximum counts increased further in early June following the egg-laying period but then declined rapidly during fledging and post-fledging periods in late July to early August. The maximum count during standardized scans was 25 murres on 16 July; another count on the same day had 29 birds. High counts during pre-breeding and post-breeding seasons were 19 and nine birds, respectively. Of 68,332 murre observations (sum of all murre counts), 90.5% occurred in decoy plots compared to only 0.4% in control plots and 9.2% outside of plots.

During the sampling period, a total of 7,286 full scans of the rock were completed on 157 observation days. For analyses, we examined a sample of 114 daily scans for each of the four sub-plots in the twelve decoy plots (i.e., 48 sub-plots), or 5,472 total scans that included 634 murre presences, 4,838 murre absences, and 1,143 murre observations. A final logistic regression model was significant for season (pre-breeding, breeding, and post-breeding), block, decoy density, and sub-plot

($\chi^2 = 1253$, overall percent correct 90.6; Table 1). We also subdivided data by odd and even dates and conducted two additional models. The significance level did not change for any variable (odd dates: $\chi^2 = 667.8$, overall percent correct 90.6; even dates: $\chi^2 = 593$; overall percent correct 90.6; Table 1).

Presence versus absence of murres differed between blocks (P < 0.001), decoy densities (P < 0.001) and sub-plots (P < 0.05; Fig. 4). Presence during the post-breeding season was significantly different than pre-breeding and breeding seasons (P < 0.001). Greatest numbers of presences were in the pre-breeding season (N = 371), block 3 (N = 396), low-density plots (N = 347), and aisle sub-plots (N = 219).

Murre group sizes within sub-plots ranged from one to eight birds. Because of low sample sizes, group sizes greater than three birds were combined. Group size differed significantly with block (P < 0.001), density of decoys (P < 0.001), and sub-plot (P < 0.001) but not for season (Fig. 5). Counts of murres were greatest in block 2, high-density plots, and aisle sub-plots.

Throughout the season, there were 117 standardized daily scans available for analyzing murre density relative to mirrors. Murre densities inside and outside 30 cm from mirrors

Table 1. Factors influencing the presence of Common Murres within decoy plots on Devil's Slide Rock, California, 1996 (N= 114 scans of twelve plots with four nested treatments or sub-plots within each plot).

Model	Variable	Regression Coefficient	df	Wald Statistic	P-value
Complete Data Set	Season	0.0686	2	22.45	<0.001
	Block	0.3316	3	437.04	<0.001
	Density	0.2307	2	212.58	<0.001
	Sub-plot	0.1362	3	78.75	<0.001
Odd-day Subset	Season	0.0630	2	11.82	<0.001
	Block	0.3290	3	218.79	<0.001
	Density	0.2330	2	110.77	<0.001
	Sub-plot	0.1130	3	31.10	<0.001
Even-day Subset	Season	0.0565	2	10.23	<0.001
	Block	0.3295	3	218.13	<0.001
	Density	0.2184	2	97.18	<0.001
	Sub-plot	0.1506	3	50.34	<0.001

were significantly different ($\chi^2 = 47$, P < 0.001), with more murres close to mirrors. Density averaged 3.07 murres m^{-2} inside 30 cm and 0.25 murres m^{-2} outside of 30 cm from mirrors.

Murres established six breeding and five territorial sites on Devil's Slide Rock in 1996. Two breeding and three territorial sites were established in high-density plots, while three breeding and two territorial sites were in low density plots. Only one breeding site occurred outside of the plots. Seven of the eleven sites (four breeding and three territorial) were established within aisles and nine sites (four breeding and five territorial) occurred within 60 cm of mirrors. Egg-laying dates ranged from 26 May to 4 June, similar to monitored colonies at Point Reyes and Castle Rocks & Mainland in 1996 (USFWS, unpubl. data). Three eggs hatched and all chicks survived to depart the colony.

The number of breeding pairs and territorial sites at Devil's Slide Rock has continued to increase from 1996 to 2004 with social attraction equipment deployed each year. In 2004, 190 breeding pairs and 51 territorial sites were documented (Table 2) despite the decrease in the number of installed adult decoys from 384 to 112 over the same period.

DISCUSSION

In 1996, social attraction techniques were used successfully to restore breeding murres to Devil's Slide Rock after a ten-year absence from this colony. Breeding habitat and conditions at this rock had not changed substantially between 1986 and 1996, except for a major reduction in gill-net fishing and some reduction of oil spills (Carter *et al.* 2001; Carter 2003). Social attraction techniques appear to be the principal factor that caused recolonization of Devil's Slide Rock in 1996. Since 1996, social attraction equipment has been used annually and the colony has increased in size (i.e., number of breeding pairs) each year through 2004.

Murres were attracted to nesting habitat that had decoys. Since habitat characteristics were similar across the study site, more murres would be expected in areas void of decoys if habitat was the only variable affecting site establishment. However, murres returning to Devil's Slide Rock chose to interact, establish territories and breed among decoys. This result alone provided strong evidence for efficacy of this restoration technique.

The density of decoys and area within decoys also appeared to affect murre presence within decoys. Low-density plots had more murre presences than high and especially medium density plots. However, high-density plots had a greater number of large groups of murres. This suggests that murres were attracted to either low or high-density plots depending on differing circumstances. For example, we observed individual murres walking among plots, while groups of murres grew at predictable locations. Further research
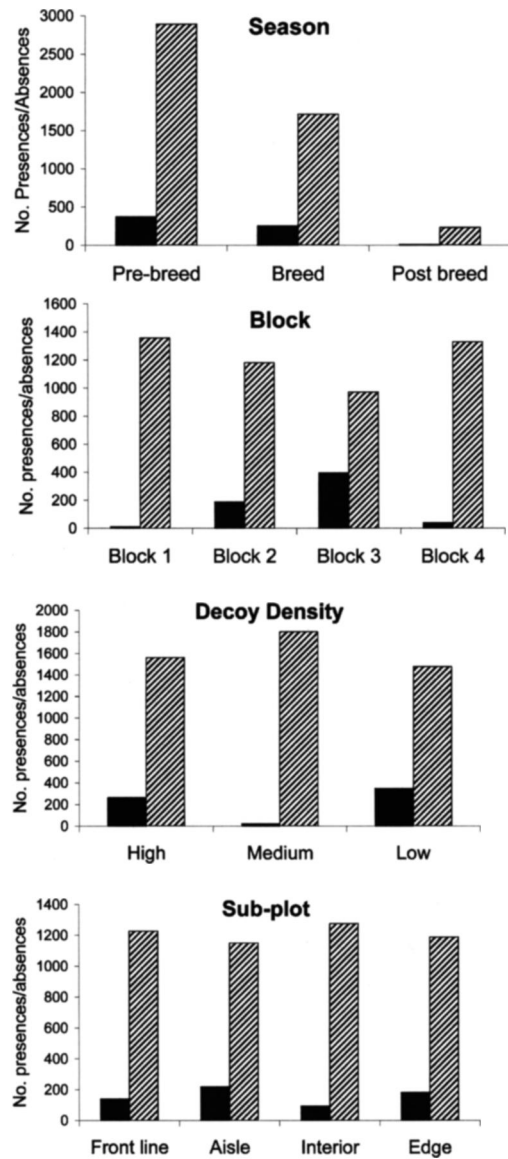
Figure 4. Numbers of Common Murre presences (solid bars) and absences (hatched bars) by season, decoy block, decoy density, and decoy sub-plot.

Figure 5. Group sizes of Common Murres by season, decoy block, decoy density, and decoy sub-plot.

might help to determine the significance of these differences.

Characteristics of decoy placement in plots were also important in influencing murre presence. Aisles had greatest numbers of murre observations and four of six breeding sites occurred in these areas. Aisle areas tended to be relatively flat and behind decoys placed against a small rock wall that provided suitable locations for a murre to
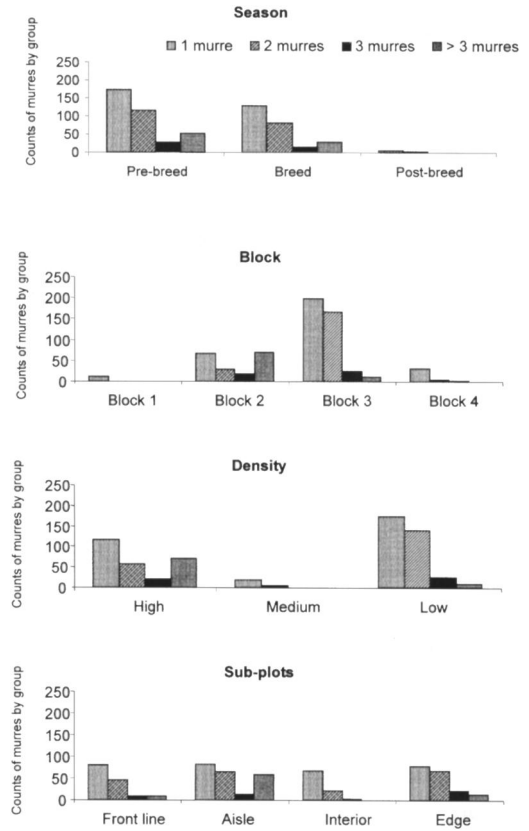
join an existing group of breeding murres, as often occurs in natural colonies. Aisle space (30 cm wide by 100 cm long) likely provided easily accessible routes for murres to move amongst decoys, as well as adequate space to interact socially with other murres (e.g., courtship behavior) and still be surrounded by apparent conspecifics. Perhaps this environment provided murres the feeling of a dense, natural colony with high social interaction and less vulnerability to predators (e.g., Western Gulls or Common Ravens, *Corvus corax*; Birkhead 1977, 1978). The choice of aisle areas for most breeding sites also indicated that aisles provided preferred breeding habitat on Devil's Slide Rock in 1996. Edge habitats also provided suitable breeding habitat used extensively within plots. Due to limited space available on Devil's Slide Rock, most edge area created by decoy plots also occurred adjacent to other decoy

Table 2. Numbers of Common Murre nesting pairs and territorial sites at Devil's Slide Rock, 1996-2004.

Year	Nesting Pairs	Territorial Sites
1996	6	5
1997	9	9
1998	13	10
1999	70	16
2000	100	23
2001	113	46
2002	123	43
2003	110	88
2004	190	51

plots, creating aisle-like characteristics (e.g., open space surrounded by decoys) but less associated with a rock wall.

Murre presence or absence did not vary significantly between the pre-breeding and breeding seasons. This suggested that breeding birds did not influence results with regards to variables block, density and subplot. If this study had occurred on an existing active colony, breeding pairs with established breeding sites would most likely influence locations that prospecting birds selected for their breeding sites. Since no breeding pairs were established on Devil's Slide Rock when social attraction was initiated in 1996, initial responses by prospecting birds were not directly influenced by breeding birds. Once breeding began, the small numbers of breeding pairs likely were not a major influence on behavior of prospecting birds visiting Devil's Slide Rock. We suspect that there was a consistent influx of prospecting birds making initial visits to Devil's Slide Rock throughout the 1996 pre-breeding and breeding seasons. We observed an increase in the number of murres attending the rock through the study period and documented murres arriving on the rock and visiting each decoy group (i.e., probably indicative of a new prospecting bird), as well as other "returning" murres that arrived and walked immediately to established sites.

Mirrors apparently attracted murres, especially five of six pairs that established breeding sites near mirrors. A significantly greater density of murres was observed within 30 cm of mirrors than outside of this area. Mirror reflections appeared to enhance the effect of decoy numbers, making the "colony" appear larger. In addition, mirrors acted as artificial vertical walls that murres could nest or lean against and be surrounded by apparent conspecifics. Additional work is needed to better understand specific characteristics that attracted murres to mirrors. Regardless, mirrors were important to our primary goal of restoring breeding murres to this recently extirpated colony.

Although fairly rapid attraction to social attraction equipment was expected, we had anticipated several years before murres would start breeding again on Devil's Slide Rock (Carter et al. 2003). However, very rapid attraction of murres and breeding in the first year of the project suggested that some birds with prior experience at Devil's Slide Rock had returned to the colony. Given survival of at least 128 birds from this colony by 1987, typical high annual survivorship (e.g., 94% at South Farallon Islands; Sydeman 1993) and long life span (≥20 years; Ainley et al. 2002), some surviving birds could be expected in 1996, ten years after colony extirpation in 1986. Timing of breeding in 1996 at Devil's Slide Rock also was similar to other established colonies in central California, suggesting the possibility of prior breeding experience by at least some birds because first time breeders often lay later in the season (Birkhead and Harris 1985; Boekelheide et al. 1990). If true, prior experience may have been acquired at Devil's Slide Rock prior to colony extirpation or some birds may have nested recently at other nearby colonies. Although colony switching by adult murres has not been demonstrated, intercolony movements of Atlantic Puffins are facilitated under conditions of habitat loss or saturation (Harris and Wanless 1991).

To investigate possible relationships to historic nesting, we examined locations of six nest sites occupied in 1996 in archived photos taken between 1979 and 1987 (Sowls et al. 1980; Briggs et al. 1983; Takekawa et al. 1990; Carter et al. 2001). These breeding sites occurred in the center of both the densest mass of breeding birds observed in photographs taken in 1979-82 (when the colony numbered 2,300-2,900 breeding birds) and

where smaller numbers of murres (4-128 birds) attended the colony without breeding in 1986, 1987 and 1994. Breeding site locations in 1996 could partly reflect past breeding sites, natal sites prior to 1986, or best available habitat for first colonists regardless of colony origin.

Six major implications for successful seabird restoration using social attraction can be drawn from the Common Murre restoration project at Devil's Slide Rock:

1) Begin social attraction soon after extirpation occurs to better ensure availability of potential breeders with experience at the former colony.

2) Install social attraction equipment prior to the breeding season to attract prospecting birds with sufficient time for site and pair establishment before breeding. In this project, social attraction equipment was installed in January because murres arrive back to many central California colonies in November or December, several months prior to the breeding season.

3) Provide both low- and high-density decoy groups for individuals to choose from various suitable alternatives.

4) Provide space among decoys, even in high-density groups, to allow prospecting birds to move within decoys and interact socially.

5) Provide mirrors in open spaces among decoys to enhance apparent numbers and movements of birds.

6) Concentrate decoys in historic nesting areas, particularly in high-density areas or areas with most recent activity, to facilitate return of previous breeders or chicks to historic areas with presumably high-quality habitat.

In this project, several plots of decoys were used in order to: a) facilitate a study design to measure efficacy of social attraction techniques; and b) place social attraction equipment within the main historic colony areas to provide opportunities for birds to be attracted to and breed in all these areas. Our continued social attraction efforts resulted in colony growth to 190 murre pairs by 2004 (Table 2) spread over most of the decoy ar-

eas. Following the first few years of restoration, efforts turned to adaptive management of the social attraction equipment to increase murre numbers and densities within the main nesting areas. Whether observed colony growth on Devil's Slide Rock was enhanced or slowed by spacing out decoy plots and live murres in these plots could not be determined. However, for similar expenditures of time and money, initial recolonization efforts could have been focused on one concentrated area of decoys, with suitable placement of decoys and mirrors, to facilitate a more concentrated group of prospecting and nesting birds. This in turn could have resulted in more rapid colony growth or simply in fewer, larger or denser nesting groups. Denser nesting is preferred because murres nesting in such groups tend to have higher breeding success than those nesting in low density or edge areas (Birkhead 1977). Furthermore, since live birds serve as better attractants than the equipment, the combination of more concentrated decoys and live birds may further enhance such growth.

After a ten-year absence of breeding, social attraction techniques (in this application, the combination of decoys, recorded murre vocalizations, and mirrors) resulted in recolonization of Devil's Slide Rock by Common Murres. Continued social attraction efforts through 2004 have encouraged and ensured the return of successful breeding at this location which has further sped colony growth over time. However, various other factors have contributed to subsequent colony growth, especially an overall increase in the central California population (which likely led to greater numbers of potential young prospectors from other colonies for attraction to Devils' Slide Rock). Also, the establishment of a colony of Brandt's Cormorants (*Phalacrocorax penicillatus*) on the rock in the mid-1990s likely enhanced attraction of murres; nesting cormorants are often associated with murre colony formations in California (McChesney *et al.* 1998, 1999; Carter *et al.* 2001; Capitolo *et al.* 2005; USFWS, unpubl. data). While social attraction equipment and monitoring efforts can

be costly in certain circumstances, this project has demonstrated its efficacy for seabird restoration purposes. Although efforts to prevent catastrophic anthropogenic events (e.g., oil spills) are needed, such events will continue to occur (hopefully less frequently) and social attraction can be viewed as a potential restoration tool under appropriate circumstances. Natural recolonization at Devil's Slide Rock probably would not have occurred for decades or centuries, if at all, without effective use of social attraction techniques (Carter *et al.* 2003).

We demonstrated that social factors were influential in the recolonization of the Devil's Slide Rock murre colony. Managers of colonial-nesting seabirds should consider the possibility of manipulating the social environment when necessary for restoration purposes, as colonial species can be reluctant to pioneer new colonies where social cues are absent.

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