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Reproductive Success of Black-crowned Night-Herons and Snowy Egrets at Alcatraz Island, San Francisco Bay, California: 2007

Administrative Report

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Reproductive Success of Black-crowned Night-Herons and Snowy Egrets at Alcatraz Island, San Francisco Bay, California: 2007

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Abstract. — As part of a program initiated in 1990, we documented nesting chronology, habitat use, subcolony use, hatchability, and reproductive success for black-crowned night-herons (*Nycticorax nycticorax*) and snowy egrets (*Egretta thula*) nesting at Alcatraz Island, San Francisco Bay, California. In 2007, we found 202 night-heron nests, a 44% increase from the 140 nests found in 2006, and nearly twice the number found in 2005. We also found 79 snowy egret nests, more than twice the previous high of 36 recorded in 2005. As in the previous three years, all snowy egret nests were located in the Greenhouse subcolony. Black-crowned night-heron incubation-period success at Alcatraz Island in 2007 was 29%, nestling-period success was 83%, and overall reproductive success was 24%, all decreases from 2006. All success rates were lower than the 18-year averages, and incubation-period success and overall success were the lowest recorded during the study. A primary cause of this poor reproductive success was the elevated rate of nest predation (40%), the highest observed during the 18-year study and more than twice the overall mean (18.5%). Incubation-period success (89%), nestling-period success (98%), and overall success (87%) for snowy egrets were higher than the night-herons and were similar to those observed for snowy egrets the previous two years. Predation on snowy egret nests was low (6%). The most common habitats for night-heron nests in 2007 were English ivy (*Hedera helix*) (27%), mirrorbush (*Coprosma baueri*) (16%), *Albizia* sp. (15%), and rubble (concrete, reinforcing rods, and other remnants of demolished buildings) (10%). Snowy egrets nested primarily in *Albizia* (48%) and fig (*Ficus carica*) (34%). The trend of increasing numbers of the Western Gull (*Larus occidentalis*), a predator on night-heron and snowy egret eggs and chicks and a competitor for nest sites, continued in 2007, with the estimated total number of gull nests reaching an all-time high of 1,060. We assumed that much of the predation, especially on night-heron eggs and chicks, was by gulls, based on the close proximity of the two species' nests and the highly aggressive nature of the gulls to both adult and young night-herons. Predation on night-heron eggs by common ravens (*Corvus corax*), which was frequently observed, likely also reduced nesting success. In 2007, the Alcatraz colony had the most night-heron and snowy egret nests of all the North San Francisco Bay colonies. Within the Central Bay area, the percentage of night-herons nesting at Alcatraz increased from 41% in 2006 to 64% in 2007, while the percentage of snowy egrets increased from 23% in 2006 to 65% in 2007.

We monitored reproduction by black-crowned night-herons and snowy egrets on Alcatraz Island for the 18th consecutive year in 2007. The primary objectives of this study were: 1) to conduct baseline monitoring to describe and estimate the distribution and abundance of black-crowned night-herons and snowy egrets nesting on Alcatraz Island, 2) to evaluate reproductive parameters, including nesting chronology, clutch size, incubation-period success, nestling-period success, and overall reproductive success, 3) to evaluate the effects of disturbance on the numbers and distribution of nests and their reproductive success, and 4) to compare annual and long-term variation and trends in the nesting populations.

METHODS

Study Area

The study site was Alcatraz Island (37° 49' N, 122° 25' W), a 9.1-ha island in San Francisco Bay, which has been managed as a National Historic Landmark by the National Park Service since 1973 (Howell and Pollak 1991) (Fig. 1).

Nest Monitoring

Techniques used for nest monitoring in previous years (Hothem and Hatch 2004) were used in 2007. We searched each previously occupied nesting subcolony (Fig. 1) and other potential sites for active night-heron and snowy egret nests. In 2007, we visited the subcolonies 16 times between 23 April and 10 August to locate night-heron and snowy egret nests and to monitor active nests until their fate was determined (Table 1). The Shower and the Wall subcolonies (Fig. 1), used for nesting by night-herons in earlier years, were not checked in 2007 (Table 2). Removal of vegetation and subsequent maintenance at these two sites have made the remaining

habitat unsuitable for nesting by wading birds. As in all previous years, except 1990 and 1993, nest searching and monitoring were terminated early in certain subcolonies to prevent observer-induced adverse interactions between gulls and the wading birds (Table 1). The Greenhouse subcolony, site of the most concentrated nesting activity in 2007 (with 79 egret and 31 night-heron nests), was last checked on 12 June. The Bench and Recreation Yard were last checked on 18 June, and most of the nests in three subcolonies (Rubble, Rubble West, and Tunnel) were last checked on 25 June. The last visits to the Auxiliary Dock, Foghorn, and Power Plant subcolonies were on 5 July, while the last visit to the Dock subcolony was 10 July. The Warden's House subcolony was isolated from gull harassment and was monitored until 10 August. Although early termination of nest monitoring has prevented us from compiling a total census of the numbers of nests on the island, the use of standardized collection procedures has produced data on nest numbers and reproductive success that are comparable among years.

Estimates of Reproductive Success

Reproductive success was calculated in 2007 similar to previous years (Hothem and Hatch 2004), with the nestling period beginning with the hatching of the first egg and extending for 15 days for night-herons and 10 days for snowy egrets. Since we delayed our first visits to the subcolonies until many of the birds had begun incubation, and since we did not visit subcolonies daily, it is likely that some nests were initiated and lost between visits. We used the Mayfield method (Mayfield 1961, 1975), a less biased estimator of reproductive success, to calculate incubation-period and nestling-period success. We also calculated apparent rates of predation and other causes of nest failure.

Mean clutch size was calculated for nests considered to have completed clutches (i.e., no increase in eggs between successive visits to an active nest). Nests that failed before a full clutch was achieved and those nests first found more than 7 days after hatching were not included in clutch size calculations. Apparent hatchability (egg success) was calculated by dividing the total number of eggs that were observed to have hatched by the total number of eggs monitored to the hatch date (including hatched and failed eggs). We also calculated apparent egg and chick survival.

RESULTS and DISCUSSION

Black-crowned Night-Herons

Nest Monitoring

In 2007, night-herons initiated nests (first egg laid) from 22 March to 29 June, a 99-day period, 6 days longer than the 18-year average (Table 1; Fig. 2-3). Based on an analysis of weekly initiation dates, nesting by night-herons at Alcatraz Island was not highly synchronous, with nests initiated over a minimum of 10 weeks in 1992 to a maximum of 19 weeks in 1993 (Fig. 4). The median initiation date in 2007 (14 May) was about 2 weeks later than the average for the study and 4-5 weeks later than the three years with the largest numbers of nests (1996-1998) (Table 1). In 2007, 39.3% of the night-heron nests were initiated during the 7 weeks between 11 March and 28 April, compared with only 13.0% of the total found during that period in 2006 (Hothem and Bergen 2007) (Fig. 2). Overall, 50.0% of the nests we found were initiated in this same 7-week period. There appeared to be a bimodal distribution in nest initiations in 2007, with one peak the week of 15 April (week 6) and the other from 13 May through 2 June (weeks 10-12) (Fig. 2).

The number of nests found on the island each year has ranged from a low of 68 in 2001 to a high of 341 in 1996 (Fig. 5). It appeared that the number of night-heron nests had stabilized during 2002-2006, with an average of 131 nests (SD = 16.6) per year (Fig. 5 and Table 2). In 2007, however, the total number of nests increased by 62 nests compared with 2006 and 100 nests compared with 2005.

Area Trends

We grouped nesting subcolonies on Alcatraz into three areas, the South Coast, the Central Island, and the North Coast (Fig. 1 and Table 2). The South Coast subcolonies included the Tunnel, the Bench, the Rubble, the Rubble West, the Dock, and the Auxiliary Dock. These areas are located in an area of the island closed to visitor use during the breeding season, about February through August. The Central Island subcolonies included the Greenhouse, Recreation Yard, and the Warden's House. These colonies are located in areas open for visitor use year-round. The Shower and Wall subcolonies are located in the Central Island area but have not had any night-heron nesting in recent years (Table 2). The North Coast subcolonies included the Foghorn and the Power Plant subcolonies, both located on north-facing slopes of the island. While the Power Plant subcolony is located adjacent to an area open to visitors, the steep slope and the dense vegetation (primarily rose) isolate the nests from human disturbance. The Foghorn subcolony is in an area closed to visitor use during the breeding season.

Although we found 51 more nests in the South Coast subcolonies in 2007 than we found there in 2006, the percentage of the total found on the island only rose from 72% to 75% (Fig. 6 and Table 2). A slight decrease was noted at the Rubble West subcolony (four fewer nests), but increases were noted at the Tunnel subcolony (three nests) and the Rubble subcolony (10 nests).

The Rubble subcolony, which had a high of 94 nests in 1997, increased from a low of two nests in 2005 to 38 nests in 2007. We found 24 nests in the Bench subcolony, an increase from the eight found there in 2006. All 24 nests were found in the dense *Agave* sp. area down slope from the Agave Trail steps (Fig. 1), an area with poor accessibility because of the hazard posed by the spines of the *Agave* plants. Based on the number of night-herons that commonly flushed from the area, it is certain that we did not find all of the nests present in the Bench subcolony. The Auxiliary Dock subcolony increased by five nests compared with 2006 (Hothem and Bergen 2007), but the subcolony with the greatest increase was the Dock, which increased from only two nests in 2006 to 23 in 2007, a total comparable to the numbers found there in 1990, 1994, and 1996-1997. During 1999-2006, only 12 nests were found in the Dock, an average of 1.5 per year. Reasons for these increases in nesting in the Bench and Dock subcolonies were not clear.

The number of night-heron nests in the Central Island subcolonies comprised 20% of the total on the island, similar to the percentage in 2006 (Hothem and Bergen 2007) (Fig. 6 and Table 2). We found more than twice as many night-heron nests (31) in the Greenhouse subcolony in 2007 as we found there in 2006 (15). When the 31 night-heron nests are combined with the 79 snowy egret nests found in the Greenhouse subcolony, the total comprises 39% of all the wading birds nesting on Alcatraz Island in 2007. The Recreation Yard subcolony had only two nests in 2007, a decline of seven from 2006, while the eight nests found in the Warden's House subcolony was the highest found during the study.

Compared with previous years, the North Coast area had the second-fewest night-heron nests (9) in 2007 (Fig. 6 and Table 2). Four nests were found in the Power Plant subcolony, the fewest since 1994, while the total in the Foghorn subcolony increased to five in 2007, the most since 2003.

Nesting Habitat

As we found in 2006, English ivy (*Hedera helix*) was the most common nesting substrate for night-herons (27.2%) in 2007 (Fig. 7). Although an average of 59% of the night-heron nests were found in mirrorbush (*Coprosma baueri*) in the 1990s (Fig. 7), only 15.8% of the nests were found there in 2007. The third most common nesting substrate was *Albizia* sp. (14.9%) which is included in the "other" category in Fig. 7. The fourth most common habitat used for nesting in 2007 was rubble (10.4%), which consisted primarily of the remains of demolished buildings. The percentage of nests using rubble in 2007 represented a large decline from the previous 8 years, during which an average of 28% of the nests were found in this habitat. In recent years (since 2001) rose (*Rosa* sp.) had been the substrate for as many as 20.6% of the night-heron nests, but only 3.0% of the nests were found in rose in 2007. The habitats listed as "other" on Fig. 7 included 12 plant species, ranging from one nest in a large Jade plant (*Crassula ovata*) and one in a *Eucalyptus* sp. tree, to 30 nests in *Albizia* sp.

Unfortunately, we have calculated neither the availability of nesting habitat nor the presumed temporal change in available habitat on Alcatraz. Qualitatively, it appears that the area of mirrorbush has declined over the course of the study, while the area of ivy has increased. The area with figs, only present in the Greenhouse subcolony, has remained about the same as have the areas with roses. It is likely that the habitat that has changed the least is the rubble.

Reproductive Success

We estimated that the mean clutch size for black-crowned night-herons in 2007 was 2.70 eggs per nesting attempt, the lowest recorded for the 18 years of the study (Table 3) and lower than the mean for the previous 17 years (2.90 eggs per nest). The estimated nest incubation-period

success (nests that hatched at least one egg) for night-herons during 2007, as measured by the Mayfield (1961, 1975) method, was 29% (95% confidence interval = 22-38%), the lowest recorded in this study (Table 3). The 2007 incubation-period success was about one-half the average for the previous 17 years (60.1%) and was significantly lower than nine of the previous years ($P > 0.05$) (Table 3; Fig. 8). The temporal distribution of hatching was bimodal as was that of the initiation dates (Fig. 9), with the median hatching date being 23 May. The estimated nestling-period success (the percentage of successful nests in which at least one chick survived to 15 days of age) for night-herons in 2007 (83%) was lower than the average nestling-period success for the previous years of the study (87.5%), but there were no significant differences in nestling-period success among years ($P >0.05$) (Table 3; Fig. 8).. The overall success rate (incubation-period and nestling-period success combined) of nesting night-herons on Alcatraz in the previous 17 years ranged from 34% in 2005 to 77% in 1994 and averaged 52.8%. In 2007, the overall success rate was 24%, the lowest recorded in the 18-year study (Table 3). The overall success rate was lower than the apparent average (62%) for night-herons from the northern San Francisco region during 1993-2005 (Kelly et al. 2006).

Failed eggs have been documented throughout the course of this study, and we found that 16 of the 208 eggs (7.7%) in successful nests failed to hatch in 2007 (Table 4). Egg hatchability averaged 94.1% during the study, ranging from 89.1% in 2002 to 98.6% in 2006. Of the 192 eggs that hatched in 2007, 103 chicks (53.6%) survived to at least 15 days; 11 chicks were found dead. An average of 0.51 fledglings were produced per nesting attempt in 2007, below the overall average of 0.70 chicks per nest for this study. The number of chicks per hatched nest in 2007 (1.26), however, was similar to the overall average of 1.22 chicks per nest (Table 4). Bay-wide, the average number of young fledged per nest attempt for 1993-2005 (1.15) was more than

twice as high as Alcatraz, and the number of chicks fledged per successful nest (1.82 in SF Bay) was 44% higher than Alcatraz (Kelly et al. 2006).

Other studies have found predation to be a major limiting factor (Wolford and Boag 1971; Tremblay and Ellison 1980; Henny et al. 1984; Blus et al. 1997). In 2007, however, predation was especially severe. Based on apparent nest success, we estimated that eggs in 40% of the nests were destroyed by predators before hatching, a rate 2.3 times higher than the overall average of 18.5% and 1.5 times higher than the 1998-2006 average of 26.9% (Table 5). Renesting, often a response to pre-hatching losses to predators, was presumed to have occurred at 30 night-heron nests, 22 (73%) of which had been destroyed by predators. It is uncertain whether the same bird actually renested or if the nest structure was simply reused by another. Presumed renesting was observed at six subcolonies: five each at the Bench, Dock, and Rubble, four each at the Greenhouse and Rubble West, and seven at the Tunnel. We found that 33% of the renests were also destroyed by predators, while only 30% hatched.

The overall distribution of nest predation was bimodal, peaking in weeks 7 (April 22-28) and 13 (June 3-9) (Fig. 9). These two peaks of predation appeared to occur about one week after the two peaks of nest initiation and about two weeks before the hatching peaks. Predation was unevenly distributed across the island, with the four easternmost subcolonies (Auxiliary dock, Dock, Bench, and Rubble) losing 60% of their nests to predators, compared with an average predation loss of 22% for the rest of the nesting subcolonies. Unlike other sites where mammalian predators dominate (Frederick and Collopy 1989), there are no mammalian predators on Alcatraz, and predation is presumed to be primarily avian. Although predation previously was linked to numbers of gulls nesting on the island, compared with 2006, the number of Western gull nests only increased by four nests and nests of California gulls (*Larus californicus*)

increased by only two nests (Fig. 10) (Acosta et al. 2006). As in previous years, one pair of common ravens (*Corvus corax*) was observed nesting on Alcatraz. Raven predation was documented on several occasions, with ravens observed leaving nesting colonies with night-heron eggs (S. Acosta, pers. commun.) The presumed predation rate for hatched nests was 10%, an increase from the previous years' average of 5.0%.

The pre-hatching nest abandonment rate in 2007 (4%) was similar to the average for the previous 17 years (3.5%). The numbers of nests with unknown hatching (15%) and unknown fledging (18%) fates were lower than the averages for the previous years of the study. Unknown fates included those that were either lost or which were not rechecked for any reason.

Snowy Egrets

Nest Monitoring

We observed snowy egrets nesting at Alcatraz for the first time in 1997, when three nests were found in the Tunnel subcolony (Fig. 5). Since 1997, we have documented 231 snowy egret nests, with annual totals increasing from none in 1990-1996 and 2002 to 79 in 2007 (Fig. 5). Snowy egrets first nested in the Greenhouse subcolony in 2003 when three of the island's eight nests were found there, and since 2004, all snowy egret nests on Alcatraz have been located in the Greenhouse. In 2007, snowy egret nests were initiated over a 77-day period, compared with a 34-day period in 2006 (Hothem and Bergen 2007) (Fig. 2). Based on our nest-monitoring data, the first snowy egret nest was initiated on 2 April 2007 and the last on 18 June. Nest initiations in 2006 ranged from 15 April to 19 May. The median initiation date in 2007 was 24 April, compared with 1 May in 2006. The snowy egret median initiation date was 20 days earlier than the island-wide date for night-herons, and the nesting period was 22 days shorter. Compared with

the night-herons nesting in the Greenhouse subcolony, however, egrets began nesting 9 days later, and the last egret nest was initiated 14 days later than the last night-heron nest.

Nesting Habitat

Of the 79 egret nests found in 2007, 48% were found in *Albizia*; only eight night-heron nests were found in *Albizia* in the Greenhouse subcolony. Before 2004, only night-heron nests were found in fig trees (*Ficus carica*) in the Greenhouse, but only 10 night-heron nests were found there in 2007, compared with 34% (27) of the egret nests. Acacia (9%), Himalayan blackberry (*Rubus discolor*) (4%), privet (*Ligustrum vulgare*) (4%), and mirrorbush (1%) comprised the other egret nest substrates in 2007. Of these other substrates, only privet contained substantial night-heron nests (29% of the total night-heron nests in the Greenhouse).

Reproductive Success

In addition to the 79 snowy egrets, there were also 31 night-heron nests in the Greenhouse subcolony in 2007. This made monitoring with minimal disturbance especially difficult, because so many birds were nesting in close proximity to one another. As a result, to prevent observer-caused nest failure and chick mortality, nest searching and monitoring were terminated early (June 12) in the Greenhouse subcolony, before the fates of all the nests could be determined.

The clutch size for snowy egrets in 2007 ranged from one to four eggs per nest, with a mean of 3.34 (Table 6), similar to the average clutch size (3.30) observed during 2004-2006 and similar to those found in studies cited by Parsons and Master (2000). The mean clutch size for snowy egrets was greater than the annual means for night-herons all years at Alcatraz (Table 3).

Applying the Mayfield (1961, 1975) method to the snowy egrets, incubation-period success was 89%, nestling-period success was 98%, and overall nest success was 87.2% (Table 6). These values were similar to those calculated for the previous two breeding seasons and the overall average for the four years that snowy egrets nested in significant numbers at Alcatraz. All estimates for breeding success were greater than the values found for the night-herons (Table 3). However, compared with the success of the night-herons nesting in the Greenhouse (incubation-period: 50.0%; nestling-period: 84.0%; overall: 42.0%), the differences were not as great as when compared with the island as a whole. Kelly et al. (2006) reported nest survivorship during 1993-2005 to be 66% for snowy egrets throughout the San Francisco Bay area, lower than that observed at Alcatraz in 2005-2007, but similar to that observed at Alcatraz in 2004 (Table 6).

Of the 79 snowy egret nests found on Alcatraz in 2007, eggs were observed to have hatched in 64 (81%), predators destroyed five (6%), one nest (1%) was destroyed by unknown causes, and the fates of nine nests (11%) were undetermined (Table 7). Of the 64 nests that hatched, young in 49 (77%) were observed to survive to 10 days, one (2%) was destroyed by a predator, and the fates of 14 (22%) of the nests were undetermined because of early termination of monitoring (Table 7). Comparable data for the 31 night-heron nests found in the Greenhouse subcolony indicate that the percentage of nests that hatched (15 nests; 48%) was lower than that for the egrets, while the percentage destroyed by predators was higher (8 nests; 26%). A similar percentage of night-heron nests (7 nests; 23%) was undetermined. Of the 15 night-heron nests that hatched, 11 (73%) were observed to survive to 15 days, two (13%) were destroyed by predators, and two (13%) were undetermined.

Higher reproductive success at the Greenhouse subcolony for snowy egrets is likely related to the lower observed predation rates in that subcolony. Based on the low rate of

predation during the past 4 years (0-6%; Table 7), it appears that the Greenhouse subcolony is relatively safe for snowy egrets. Predation on night-heron nests (26%) in the same subcolony, while lower than the overall rate (43%) for the other subcolonies, was more than four times that of the egrets. The factors leading to the higher predation rate for night-herons than for snowy egrets at the Greenhouse are unknown.

Hatchability (89.6%) of snowy egret eggs was lower than the mean for the previous 3 years (93.4%); 20 of the 193 eggs observed to the hatching date failed (Table 8). Egret hatchability was lower than that recorded for night-herons on Alcatraz in 2007 (92.3%) and for the 18-year study (94.1%) (Table 4). Night-heron hatchability in the Greenhouse subcolony was 97.0%, with only one egg observed to fail. Of the 173 egret eggs that hatched, we observed 126 chicks (73%) surviving to at least 10 days (2.0 chicks fledged per successful nest; 1.6 chicks fledged per found nest), and 11 chicks were found dead. Snowy egret nestling-period success was similar to that reported by Kelly et al. (2006) for the entire San Francisco Bay area (2.5 chicks per successful nest and 1.8 chicks per monitored nest), although our nestling-period success was based on survival to 10 days of age, while Kelly et al. used 14 days.

San Francisco Bay Trends

According to Kelly et al. (2006), wading bird breeding populations in the San Francisco Bay area, including night-herons and snowy egrets, were stable or increasing during recent years. Although the total number of night-heron nests (absolute numbers) increased at Alcatraz by 44% in 2007, preliminary data from Audubon Canyon Ranch (M. McCaustland, pers. commun.) indicate that the total number of nests (peak numbers for all but Alcatraz; estimates from boat survey for West Marin; See Kelly et al. 2006) at Central Bay colonies (West Marin Island,

Brooks Island, Red Rock, Yerba Buena, and Alcatraz) declined slightly (8%) from 2006. Thus, within the Central Bay area, the percentage of night-herons nesting at Alcatraz increased from 41% in 2006 to 64% in 2007. Unlike 2006, when both West Marin Island (200 nests) and Napa State Hospital (170 nests) had more night-heron nests, Alcatraz had the most nests within the North Bay in 2007. With the abandonment of Brooks Island in 2001 and Red Rock in 2004, the significance of the Alcatraz colony in the Central Bay has increased.

Although the total number of snowy egret nests (absolute numbers) increased at Alcatraz by 126% in 2007, preliminary data from Audubon Canyon Ranch (M. McCaustland, pers. commun.) indicate that the total number of nests (peak numbers for all but Alcatraz; See Kelly et al. 2006) at Central Bay colonies (West Marin Island, Brooks Island, Red Rock, and Alcatraz) declined by 18% from 2006. Thus, the percentage of snowy egrets within the Central Bay area that nested at Alcatraz increased from 23% in 2006 to 65% in 2007. Unlike 2006, when both West Marin Island (114 nests) and Napa State Hospital (168 nests) had more snowy egret nests than Alcatraz (35 nests), Alcatraz had more nests than any of the other North Bay colonies in 2007. As was found for night-herons, the abandonment of Brooks Island in 2001 and Red Rock in 2004 has increased the significance of the Alcatraz colony of snowy egrets.

CONCLUSIONS

We documented reproduction by black-crowned night-herons and snowy egrets nesting at Alcatraz Island for the eighteenth consecutive year. Night-heron nest numbers have tended to increase since the low of 68 nests in 2001, reaching 202 in 2007, the fourth highest number ever recorded at Alcatraz. Snowy egrets appear to be increasing their use of Alcatraz, with the 79 nests found in 2007 being more than twice the previous record high of 36. Although nest

numbers were higher for night-herons, all categories of reproductive success were lower than the averages for the previous 17 years, and hatching and overall success were the lowest recorded during the study. The record low reproductive success for night-herons was directly related to the record predation rate (40%), which was more than twice the mean for the 18-year study.

All categories of reproductive success were higher for snowy egrets than the night-herons and were similar to those observed for snowy egrets the previous two years. Predation on snowy egret nests was low, about 15% that of the night-herons. Although we assumed much of the predation on night-heron nests was by gulls, common ravens were observed taking eggs from night-heron nests, and likely destroyed many nests. In the future, the use of remote cameras could help to confirm the role of various species as predators on night-heron nests.

The Greenhouse subcolony, although relatively small in area, was home to 39% of all the wading birds nesting on Alcatraz Island in 2007. This subcolony is located adjacent to a walkway open to year-around visitor use. We have observed that human-caused flushing of adult or young night-herons or egrets in this and other subcolonies often attracts avian predators, primarily gulls, which then frequently attack the birds. Egret or night-heron mortalities may occur when this happens. In general, the barrier presented by the dense vegetation at the Greenhouse subcolony (fig, rose, *Albizia*) is sufficient to prevent human-caused flushing of the nesting birds. However, in 2007, barricades had to be established along the subcolony's margins to exclude visitors from an area where the natural barrier had been reduced by pruning. In addition to the barricades, signs alerting visitors to the presence of nesting waterbirds likely helped reduce visitor disturbance. The survival of this vital nesting area for snowy egrets and night-herons is dependent on the preservation of the physical and visual barriers between humans and birds.

Seasonal exclusion of visitors from the South Coast nesting area has contributed to the preservation of these subcolonies, which, in 2007, had 75% of the nesting night-herons on the island. This area closure has contributed to the expansion of nesting night-herons into the *Agave* area (Fig. 1) and has protected the breeding birds currently using those areas.

Within the Central Bay area, the percentage of night-herons nesting at Alcatraz increased from 41% in 2006 to 64% in 2007, while the percentage of snowy egrets increased from 23% in 2006 to 65% in 2007. Following the collapse of nesting by night-herons and snowy egrets at nearby islands, Alcatraz has become the largest single nesting colony for both species in not only the Central Bay, but also within the entire North San Francisco Bay.

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Table 1. Black-crowned night-heron reproductive chronology, Alcatraz Island, 1990-2007.

Year	Median Initiation Date	Range of Initiation Dates	Colony Visits	Observation dates[1]
1990[2]	28-Apr	24 March – 11 July	16	28 April – 9 August
1991	8-May	26 March – 4 July	14	25 April – 26 Jul
1992	13-Apr	20 March – 28 May	3	30 April – 28 May
1993[1]	23-Apr	16 March – 24 July	15	20 April – 20 August
1994	6-May	25 March – 18 July	8	22 April – 1 August
1995	25-Apr	11 March – 28 June	7	26 April – 28 June
1996	12-Apr	15 March – 4 June	4	29 April – 10 June
1997	8-Apr	13 March – 28 May	6	22 April – 12 June
1998	7-Apr	15 March – 21 June	14	9 April – 10 July
1999	3-May	27 March – 12 June	13	13 April – 17 July
2000	13-May	4 April – 16 July	16	18 April – 8 August
2001	14-May	10 April – 18 June	13	24 April – 24 July
2002	14-May	16 March – 23 June	10	22 April – 1 July
2003	18-May	27 March – 20 June	11	21 April – 14 July
2004	3-May	12 March – 22 June	12	30 April – 19 July
2005	2-May	23 March – 7 June	13	22 April – 15 July
2006	16-May	3 April – 14 June	12	3 May – 20 July
2007	14-May	22 March – 29 June	16	23 April – 10 August
Mean	1-May	22 March – 23 June	11.3	23 April – 15 July

[1] When present, snowy egret nests were also monitored during these periods.
[2] Observations were discontinued at most sites before nesting was completed every year except 1990 and 1993, primarily to prevent adverse interspecific competition with Western Gulls.

Table 2. Number and percentage of black-crowned night-heron nests found per subcolony, Alcatraz Island, 1990-2007.

SUBCOLONY	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Totals	Mean
S. COAST	67	57	68	60	90	129	243	240	199	136	90	51	115	61	66	48	101	152	1973	109.6
% of total	39%	46%	54%	48%	58%	65%	71%	83%	80%	83%	87%	75%	82%	44%	50%	47%	72%	75%		64.4%
Tunnel	19	15	21	24	32	32	57	70	64	39	14	10	33	15	19	16	28	31	539	29.9
Bench	3	3	7	2	2	13	46	27	16	5	7	2	0	0	0	3	8	24	168	9.3
Rubble	11	14	17	19	17	48	85	94	88	48	30	14	34	22	21	2	28	38	630	35.0
Rubble W.	0	0	0	0	0	0	0	0	0	27	29	21	42	24	23	25	32	28	251	13.9
Dock	24	15	16	7	23	15	23	21	8	3	2	1	1	0	3	0	2	23	187	10.4
Aux. Dock	10	10	7	8	16	21	32	28	23	14	8	3	5	0	0	2	3	8	198	11.0
CENTRAL	73	48	43	49	48	57	70	28	20	8	6	5	14	64	51	40	29	41	694	38.6
% of total	43%	39%	34%	39%	31%	29%	21%	10%	8%	5%	6%	7%	10%	46%	38%	39%	21%	20%		24.7%
Greenhouse	38	34	34	30	34	38	36	13	7	2	1	0	11	51	41	34	15	31	450	25.0
Rec. Yard	7	4	3	4	7	6	13	4	4	2	1	0	0	8	3	0	9	2	77	4.3
Wall	24	8	5	9	4	13	20	10	8	4	2	1	0	0	0	0	0	0	108	6.0
Shower	4	2	1	6	3	0	1	1	1	0	0	0	0	0	0	0	0	0	19	1.1
Warden	0	0	0	0	0	0	0	0	0	0	2	4	3	5	7	6	5	8	40	2.2
N. COAST	30	19	16	16	17	14	28	21	29	20	7	12	12	15	16	14	10	9	305	16.9
% of total	18%	15%	13%	13%	11%	7%	8%	7%	12%	12%	7%	18%	9%	11%	12%	14%	7%	4%		10.9%
Foghorn	29	18	13	14	14	8	22	12	14	12	2	0	0	5	2	1	0	5	171	9.5
Power Plant	1	1	3	2	3	6	6	9	15	8	5	12	12	10	14	13	10	4	134	7.4
Total	170	124	127	125	155	200	341	289	248	164	103	68	141	140	133	102	140	202	2972	165.1

[1] Numbers of nests estimated in 1991 and 1992 based on numbers found in 1990 and in 1993-1996.
[2] Total nests in Greenhouse include nests on north side of walk near cell house: 5 in 2004, 7 in 2005, 3 in 2006, and 1 in 2007.

Table 3. Estimates of clutch size and percentage nesting success (and 95% CI) of the black-crowned night-heron at Alcatraz Island, 1990-2007[1].

Year	Clutch size	Nests found	Mayfield nests[2]	Exposure days	Nest success		
					Incubation-period[3]	Nestling-period[4]	Overall[5]
1990	3.01	170	140	1840	70 ABCD[6] (60-80)	90 (84-95)	63
1991	2.86	90	81	1230	64 ABCD (52-76)	82 (72-92)	52
1992	3.04	93	54	351	81 ABC (61-100)	88 (77-99)	71
1993	2.92	125	96	1178	77 AB (66-89)	99 (96-100)	76
1994	2.84	155	117	969	81 A (70-93)	94 (88-100)	77
1995	2.78	200	142	1257	77 AB (66-88)	92 (86-98)	71
1996	2.85	341	179	1441	67 ABCD (56-78)	79 (71-87)	53
1997	2.87	289	173	1502	64 ABCD (53-74)	72 (64-80)	46
1998	2.79	248	203	2352	46 DE (37-54)	78 (70-86)	36
1999	2.87	164	155	2052	55 ABCD (45-64)	91 (85-97)	50
2000	2.83	103	87	1073	52 ABCDE (39-64)	87 (77-98)	45
2001	3.00	68	61	576	45 BCDE (29-62)	95 (85-100)	43
2002	2.96	141	125	1507	54 ABCDE (43-64)	93 (86-100)	50
2003	2.84	140	131	1482	50 BCDE (39-60)	90 (82-98)	45
2004	2.9	133	113	1240	42 DE (32-55)	90 82-97	38
2005	2.92	102	85	846.5	42 CDE (29-55)	81 (69-94)	34
2006	2.96	140	126	1287.5	54 ABCDE (44-67)	86 (76-97)	47
2007	2.70	202	176	1705	29 E (22-38)	83 (75-93)	24
Mean	2.89	161.3	124.7	1327.2	58.3	87.2	51.2

[1] Based on days of nest exposure (see Hensler and Nichols 1981).

[2] Nests included in the analysis (Mayfield 1961, 1975), deleting nests that had hatched or failed before found.

[3] Percent of monitored nests in which one or more eggs hatched.

[4] Percentage of nests that hatched in which one or more chicks reached at least 15 days of age.

[5] (Incubation-period success) x (Nestling-period success); % of nests in which ≥ 1 chicks survived to 15 days of age.

[6] Incubation-period success rates among years were different (One way ANOVA; $P < 0.001$); Means not sharing a common letter were different ($P < 0.05$) by Holm-Sidak multiple comparison method. Nestling-period success rates were not different among years ($P > 0.05$).

Table 4. Apparent egg and chick survival of the black-crowned night-heron at Alcatraz Island, 1990-2007.

	Year																			
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Totals	Mean
Found nests	170	90	93	125	155	200	341	289	248	164	103	68	141	140	133	102	140	202	2,904	161.3
Successful nests[1]	127	62	67	94	88	116	239	193	146	94	50	25	71	67	71	54	62	82	1,708	94.9
Eggs observed to hatching (A)	339	155	169	265	199	279	540	446	372	254	144	61	165	167	187	126	139	208	4,215	234.2
Failed eggs (B)	19	7	4	17	10	23	20	28	16	11	9	5	18	17	14	5	2	16	241	13.4
% Hatchability ((A-B)/A)	94.4	95.5	97.6	93.6	95.0	91.8	96.3	93.7	95.7	95.7	93.8	91.8	89.1	89.8	92.5	96.0	98.6	92.3		94.1%
Hatched eggs/ found nest	1.88	1.64	1.77	1.98	1.22	1.28	1.52	1.45	1.44	1.48	1.31	0.82	1.04	1.07	1.30	1.19	0.98	0.95		1.35
Hatched eggs/ successful nest	2.52	2.39	2.46	2.64	2.15	2.21	2.18	2.17	2.44	2.59	2.70	2.24	2.07	2.24	2.44	2.24	2.21	2.34		2.34
Nests with fledged chicks	102	42	34	72	56	76	118	96	76	62	25	16	43	38	42	32	34	57	1,021	56.7
Fledged chicks[2]	210	81	56	159	101	122	232	183	148	145	48	31	92	82	88	61	88	103	2,030	112.8
Fledged chicks/ found nest	1.24	0.90	0.60	1.27	0.65	0.61	0.68	0.63	0.60	0.88	0.47	0.46	0.65	0.59	0.66	0.60	0.63	0.51		0.70
Fledged chicks/ successful nest	1.65	1.31	0.84	1.69	1.15	1.05	0.97	0.95	1.01	1.54	0.96	1.24	1.30	1.22	1.24	1.13	1.42	1.26		1.22
% hatched eggs that fledged	65.6	54.7	33.9	64.1	53.4	47.7	44.6	43.8	41.6	59.7	35.6	55.4	62.6	54.7	50.9	50.4	64.2	53.6		52.0%

[1] Successful nests were those with at least one egg that was confirmed to have hatched.

[2] Fledged chicks: the number of chicks observed to have survived to 15 days of age or more.

Table 5. Fates of black-crowned night-heron nests at Alcatraz Island, 1990-2007.

Nesting outcome	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total	Mean
Found nests	170	90	93	125	155	200	341	289	248	164	103	68	141	140	133	102	140	202	2904	161.3
% predation[1]	13	19	2	7	1	2	4	3	22	27	32	28	29	26	26	31	21	40		18.5
% destroyed (other)[1]	2	3	0	2	1	4	1	4	2	0	0	0	0	0	3	0	2	1		1.4
% abandoned[1]	3	7	3	2	3	2	1	3	7	4	3	7	1	3	6	2	1	4		3.4
% unknown[1]	8	2	23	14	37	34	23	23	10	12	17	28	20	26	12	14	31	15		19.4
% Hatched[1]	75	69	72	75	57	58	70	67	59	57	49	37	50	48	53	53	44	41		57.4
Number of hatched nests[2]	127	62	67	94	88	116	239	193	146	94	50	25	71	67	71	54	62	83	1709	94.9
% predation[3]	8	13	1	0	0	1	0	4	13	5	8	0	6	8	6	13	0	10		5.3
% destroyed (other)[3]	2	2	6	1	2	3	8	13	4	2	2	4	0	0	0	0	11	0		3.3
% abandoned[3]	0	3	0	0	1	1	0	0	0	0	2	0	0	0	4	0	0	4		0.8
% unknown[3]	10	15	42	22	33	29	42	33	31	27	38	32	34	36	31	28	34	18		29.7
% fledged[3]	80	68	51	77	64	66	49	50	52	66	50	64	61	57	59	59	55	69		60.8
Number of fledged nests[4]	102	42	34	72	56	76	118	96	76	62	25	16	43	38	42	32	34	57	1021	56.7

[1] Fate of found nests (%).

[2] Nests observed with at least one egg that hatched.

[3] Fate of hatched nests (%).

[4] Nests observed with at least one chick that survived to age 15 days.

Table 6. Estimates of clutch size and percentage nesting success (and 95% Confidence Interval) of the snowy egret at Alcatraz Island, 2004-2007[1].

Year	Clutch Size	Nests Found	Mayfield Nests[2]	Exposure days	Mayfield success (%)		
					Incubation-period[3]	Neatling-period[4]	Overall[5]
2004	3.00	32	20	152.5	61 (34-1.1)	84 (68-1.0)	51.2
2005	3.45	36	26	279.5	91 (76-1.1)	100 (100-100)	91.0
2006	3.41	35	35	594.5	92 (82-1.0)	100 (100-100)	92.0
2007	3.34	79	75	1058	89 (80-99)	98 (95-100)	87.2
Mean	3.30	45.5	39.0	521.1	83.25	95.5	80.35

[1] Based on days of nest exposure (see Hensler and Nichols 1981).

[2] Nests included in the analysis (Mayfield 1961, 1975). Nests that had either hatched or failed before they were found were rejected from the analysis; such nests would have no exposure days.

[3] Percent of monitored nests in which one or more eggs hatched.

[4] Percentage of nests that hatched in which one or more chicks reached at least 10 days of age.

[5] Percent of monitored nests in which one or more chicks reached at least 10 days of age, calculated by multiplying incubation-period success by nestling-period success.

Table 7. Fates of snowy egret nests found at Alcatraz Island, 2004-2007.

Nesting outcome	2004	2005	2006	2007	Total	Mean
Found Nests	32	36	35	79	182	45.5
% predation	6	0	3	6		3.8
% destroyed (other)	3	0	0	1		1.0
% abandoned	0	3	3	0		1.5
% unknown	22	17	11	11		15.3
% hatched	69	81	83	81		78.5
Number of hatched nests	22	29	29	64	144	36.0
% predation	0	0	0	2		0.5
% destroyed (other)	5	0	0	0		1.3
% abandoned	9	0	0	0		2.3
% unknown	50	14	24	22		27.5
% fledged	36	86	76	77		68.8
Number of fledged nests	8	25	22	49	104	26.0

[1] Fate of found nests (%).
[2] Nests observed with at least one egg that hatched.
[3] Fate of hatched nests (%)
[4] Nests observed with at least one chick that survived to age 15 days.

Table 8. Egg and chick survival of the snowy egret at Alcatraz Island, 2004-2007.

	Year					
	2004	2005	2006	2007	Totals	Mean
Found nests	32	36	35	79	182	45.5
Successful nests[1]	22	29	29	64	144	36.0
Eggs observed to hatching (A)	62	93	85	193	433	108.3
Failed eggs (B)	4	9	3	20	36	9.0
% Hatchability ((A-B)/A)	93.5%	90.3%	96.5%	89.6%		92.49%
Hatched eggs/found nest	1.81	2.33	2.34	2.19		2.17
Hatched eggs/successful nest	2.64	2.90	2.83	2.70		2.77
Nests with fledged chicks	8	25	22	49	104	26.0
Fledged chicks[2]	18	54	63	126	261	65.3
Fledged chicks/ found nest	0.56	1.50	1.80	1.59		1.36
Fledged chicks/ successful nest	0.82	1.86	2.17	1.97		1.71
% hatched eggs that fledged	31.0%	64.3%	76.8%	72.8%		61.2%

[1] Successful nests were those with at least one egg that was confirmed to have hatched.
[2] Fledged chicks: the number of chicks observed to have survived to 10 days of age or more.

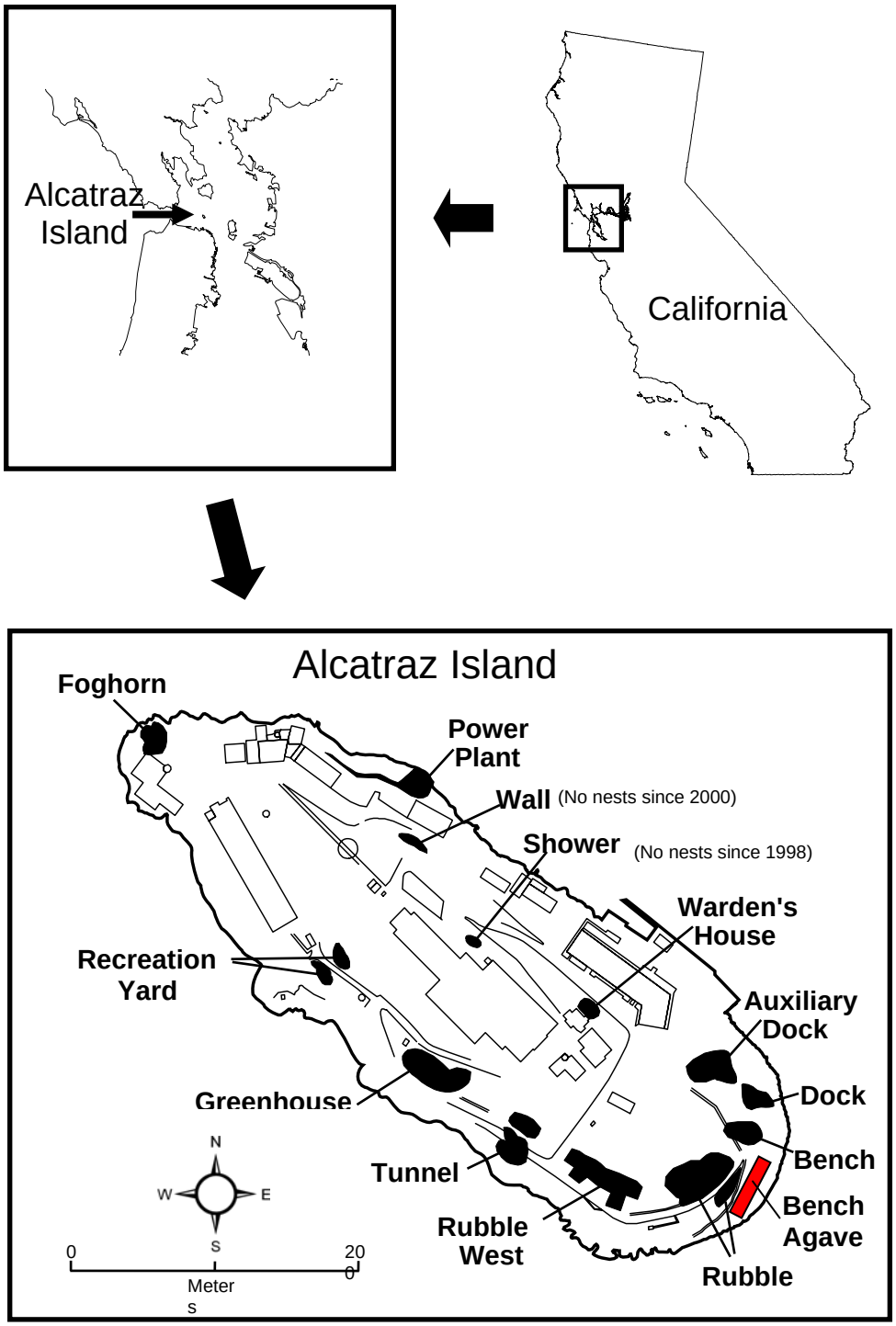
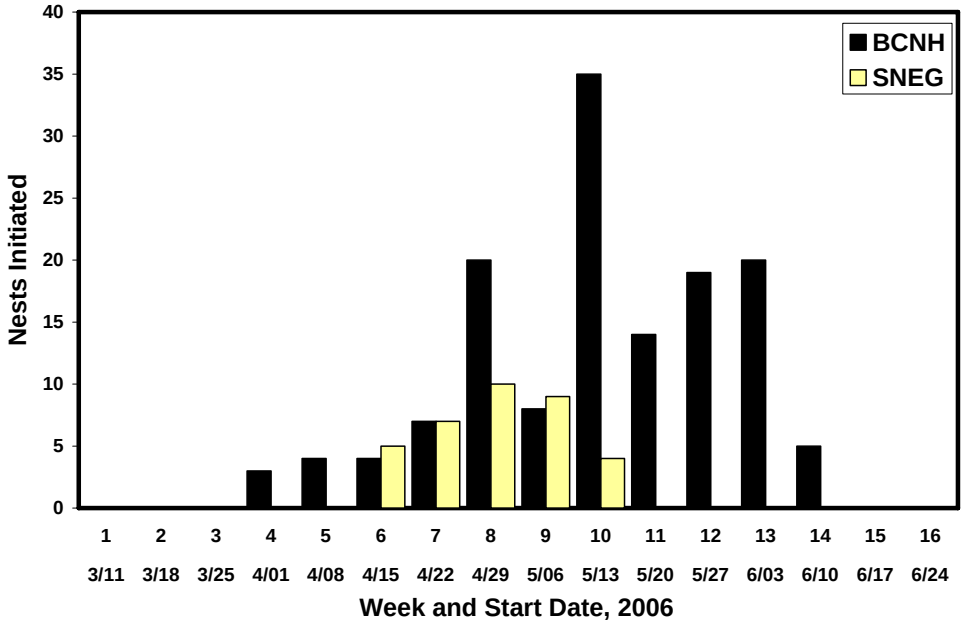


Figure 1. Black-crowned night-heron nesting subcolonies on Alcatraz Island, San Francisco Bay, California, during 1990-2007; 24 nests were found in the Agave area of the Bench (see red area) in 2007. Snowy egrets previously nested in the Foghorn and Tunnel subcolonies; they only nested in the Greenhouse in 2007.



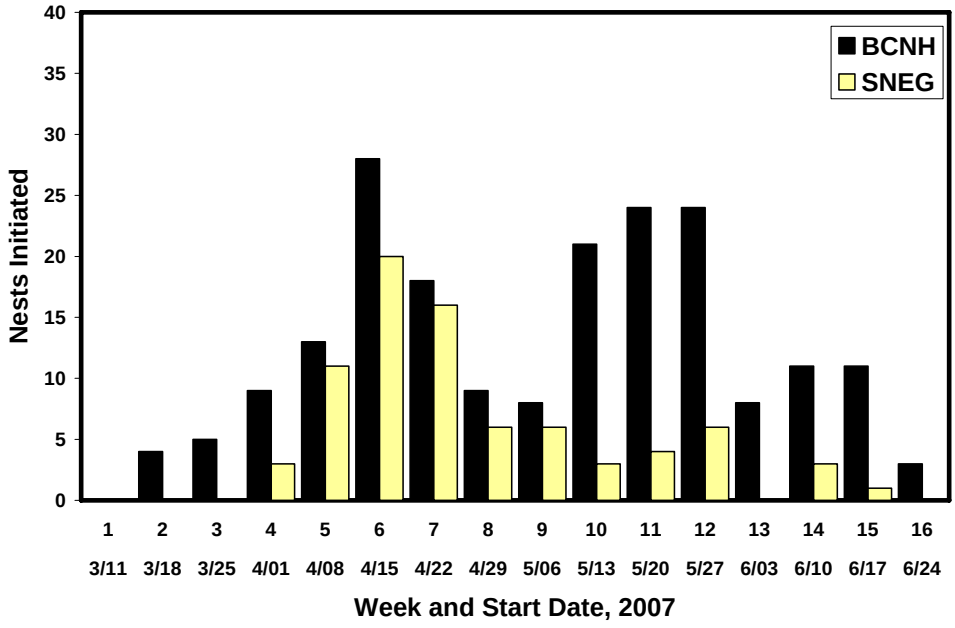


Figure 2. Comparison of nest initiations of black-crowned night-heron and snowy egret nests found at Alcatraz Island in 2006 and 2007.

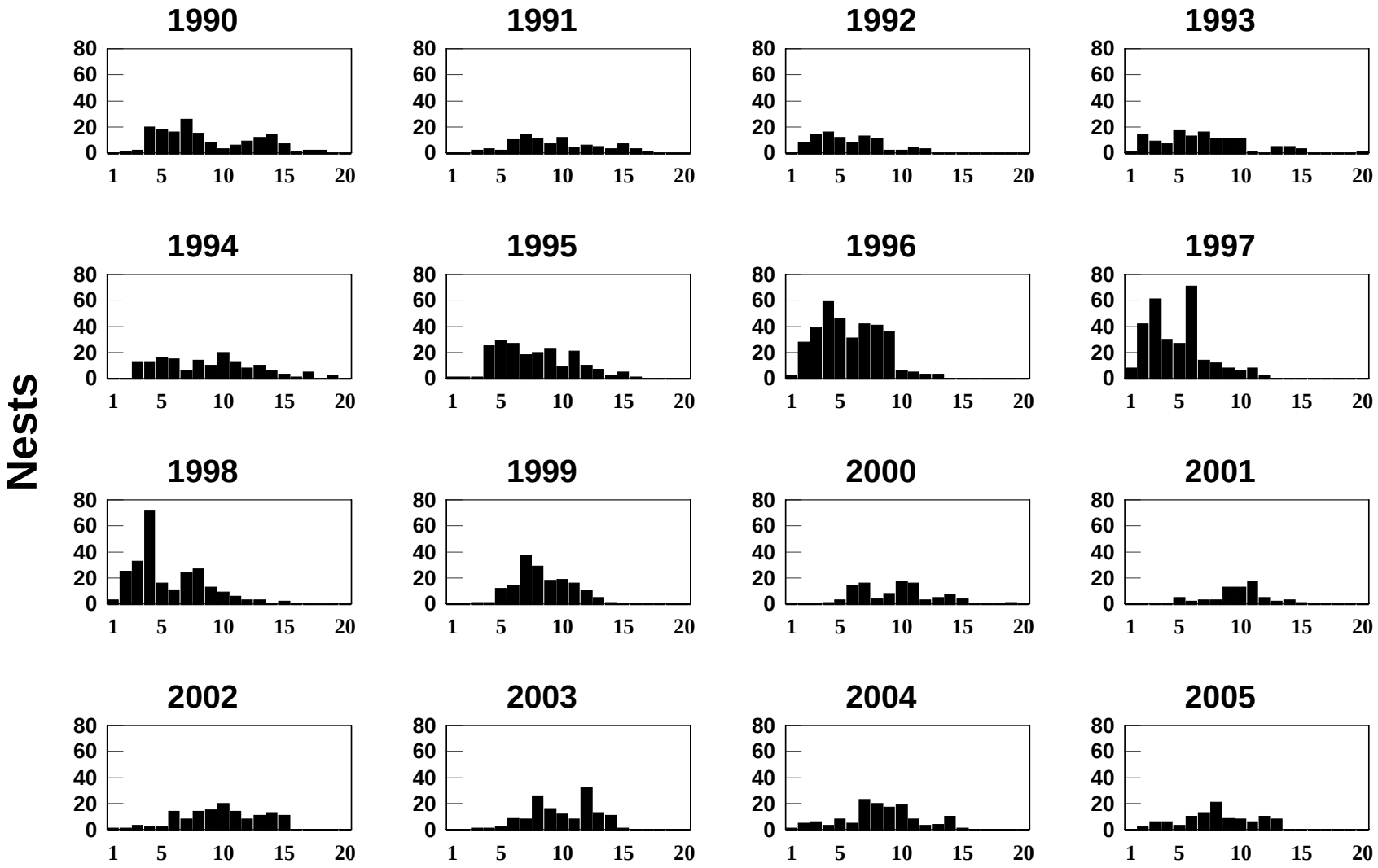


Figure 3. Weekly nest initiation dates by year for black-crowned night-heron nests found at Alcatraz Island, during weeks beginning March 11 – July 22, 1990-2005.

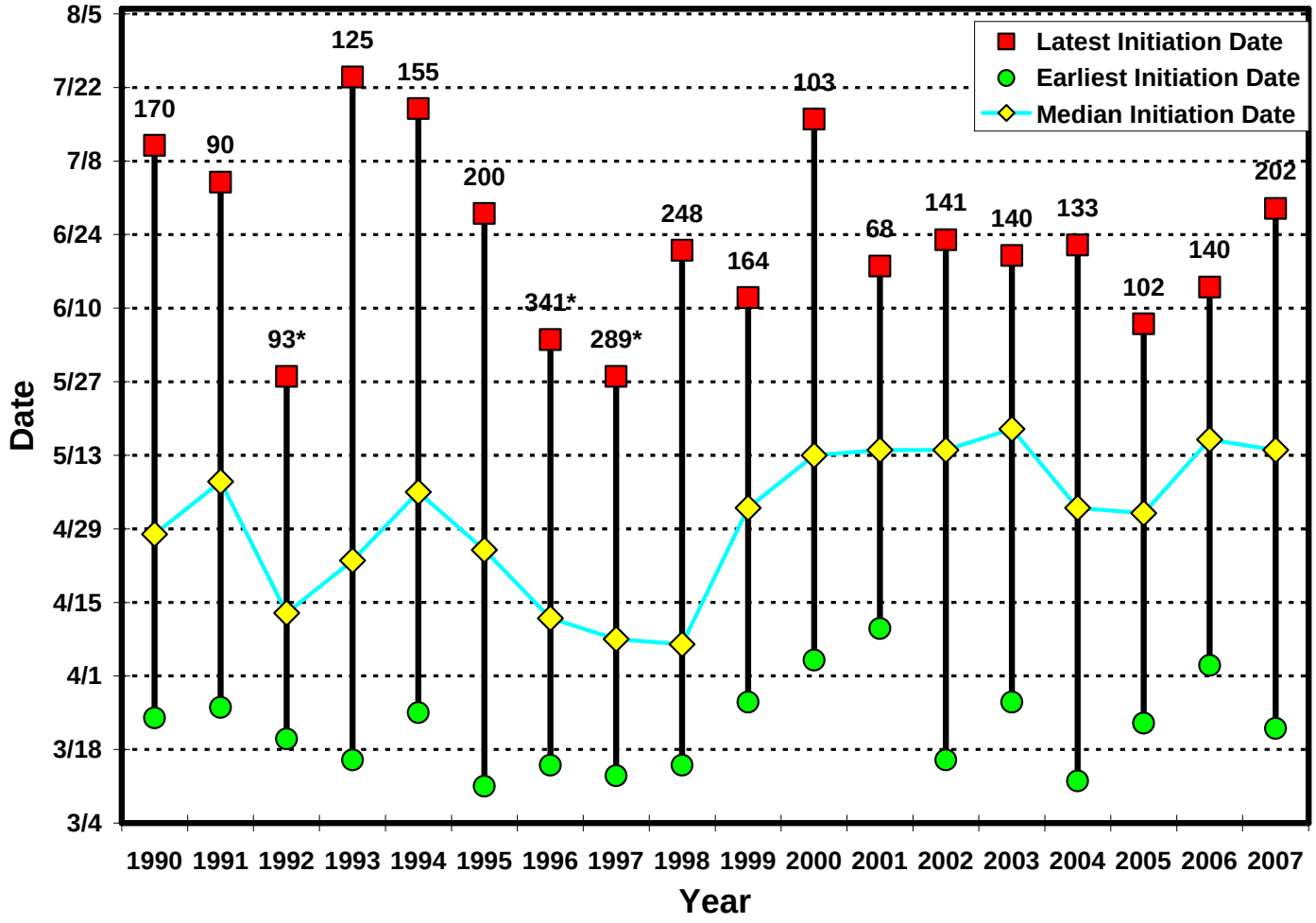


Figure 4. Range of initiation dates, median initiation dates, and numbers of black-crowned night-heron nests found at Alcatraz Island, 1990-2007. (* Observations in 1992, 1996, and 1997 were terminated 4-6 weeks early because of excessive interspecific conflict between night-herons and Western gulls)

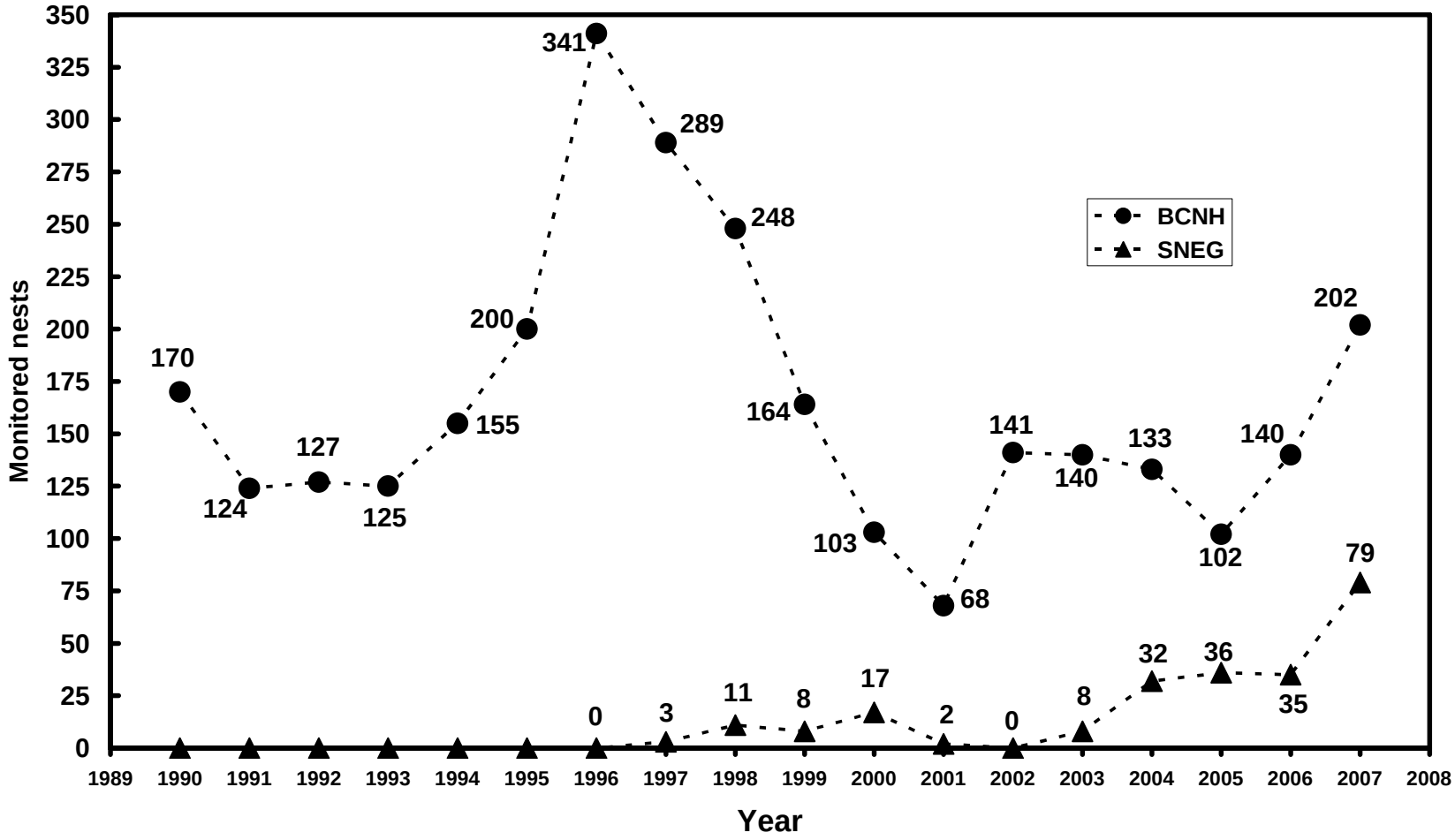


Figure 5. Total black-crowned night-heron and snowy egret nests found at Alcatraz Island during 1990-2007. Totals include estimated 34 nests of black-crowned night-herons in 1991 and 1992.

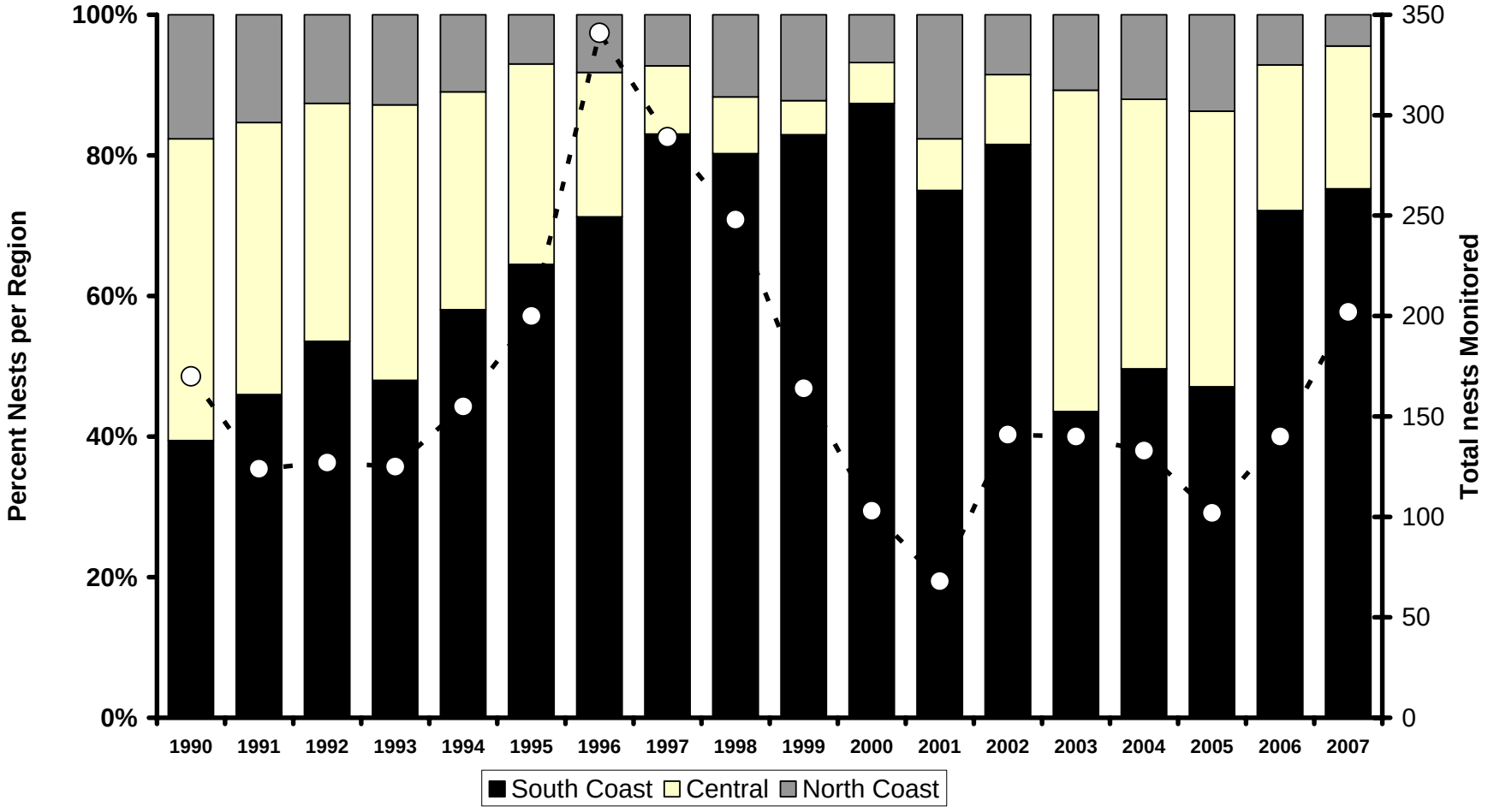


Figure 6. Total black-crowned night-heron nests (circles; right y-axis) and spatial trends (bars; left y-axis) at Alcatraz Island, 1990-2007: North Coast Area = Foghorn and Power Plant; Central Area = Wall, Shower, Greenhouse, Recreation Yard, and Warden's House; South Coast Area = Auxiliary Dock, Dock, Bench, Rubble, Rubble West, and Tunnel Bush (See Fig. 1).

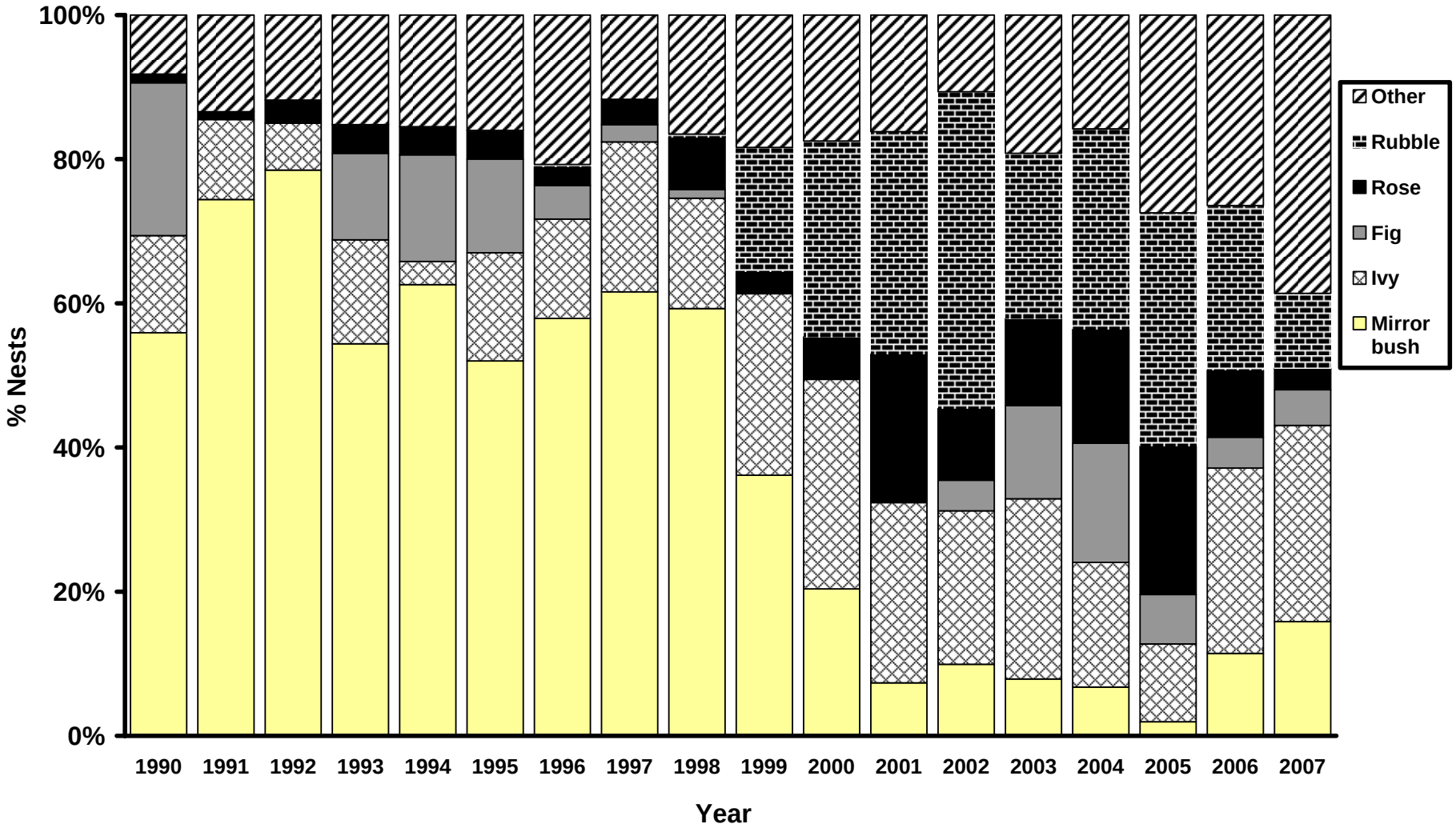


Figure 7. Nesting habitat used by black-crowned night-herons at Alcatraz Island, 1990-2007.

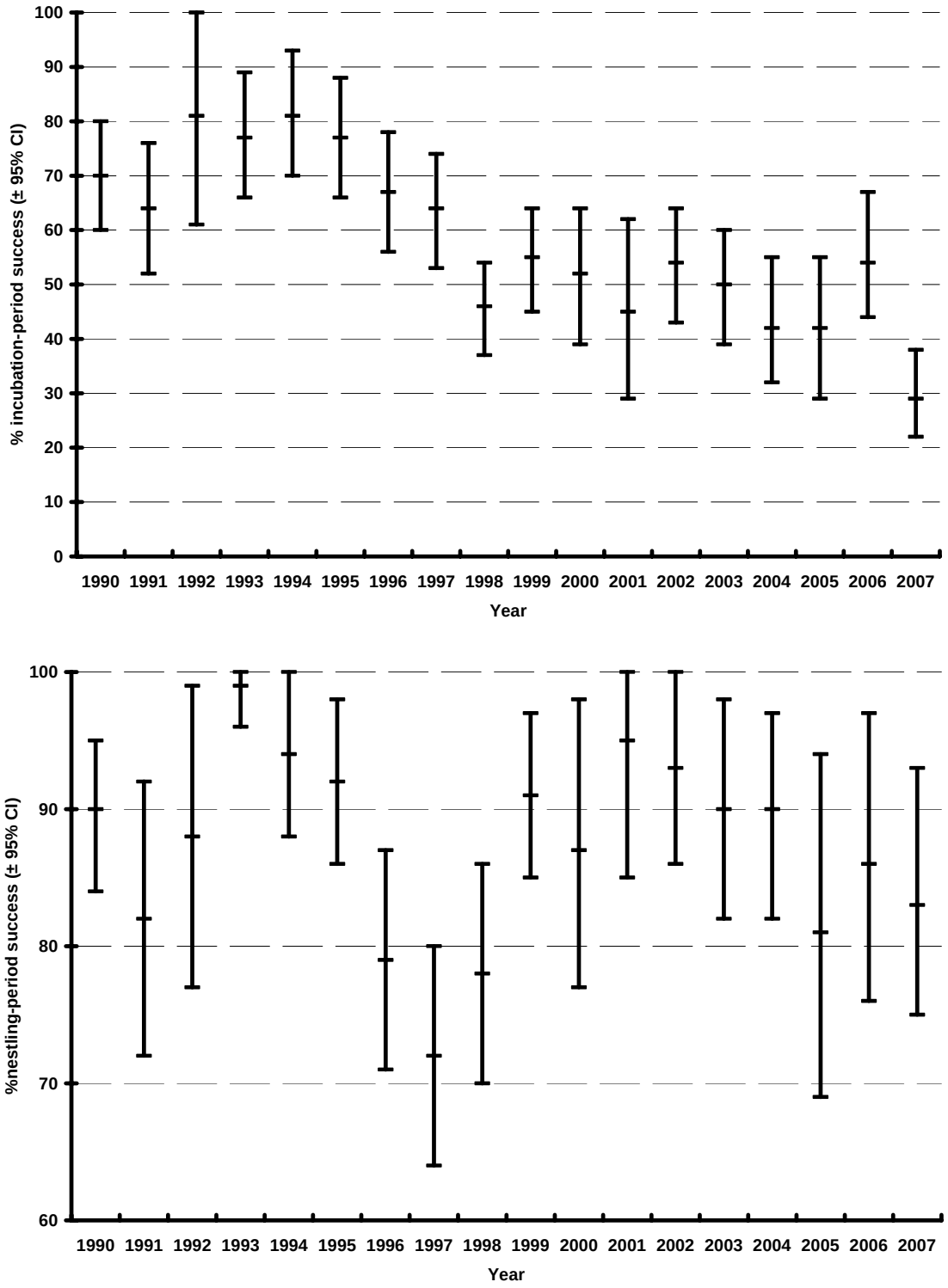


Figure 8. Estimates of incubation-period and nestling-period success (and 95% confidence interval) of the black-crowned night-heron at Alcatraz Island, 1990-2007.

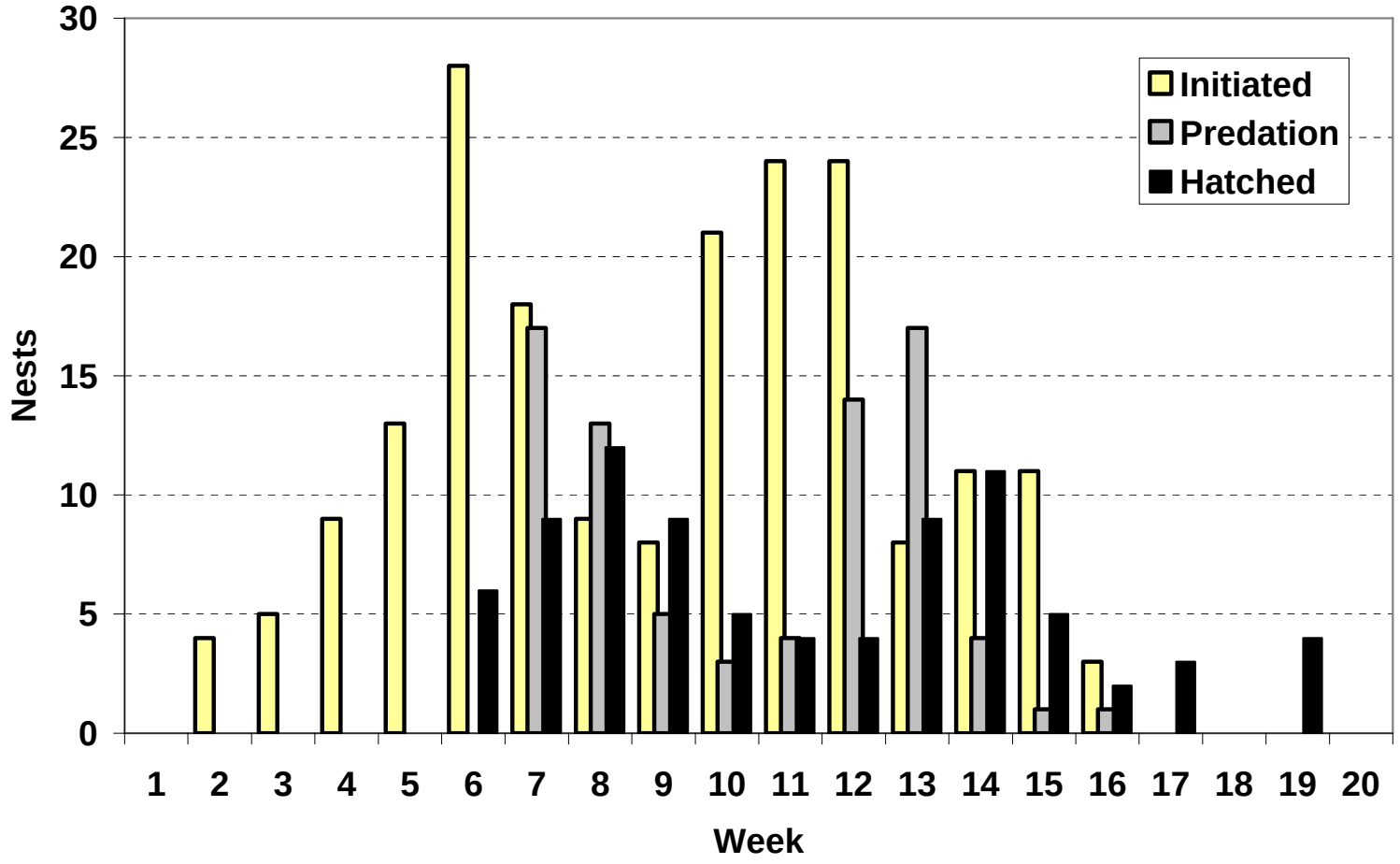


Figure 9. Black-crowned night-heron nests: Initiations, hatching, and predation, Alcatraz Island, 2007

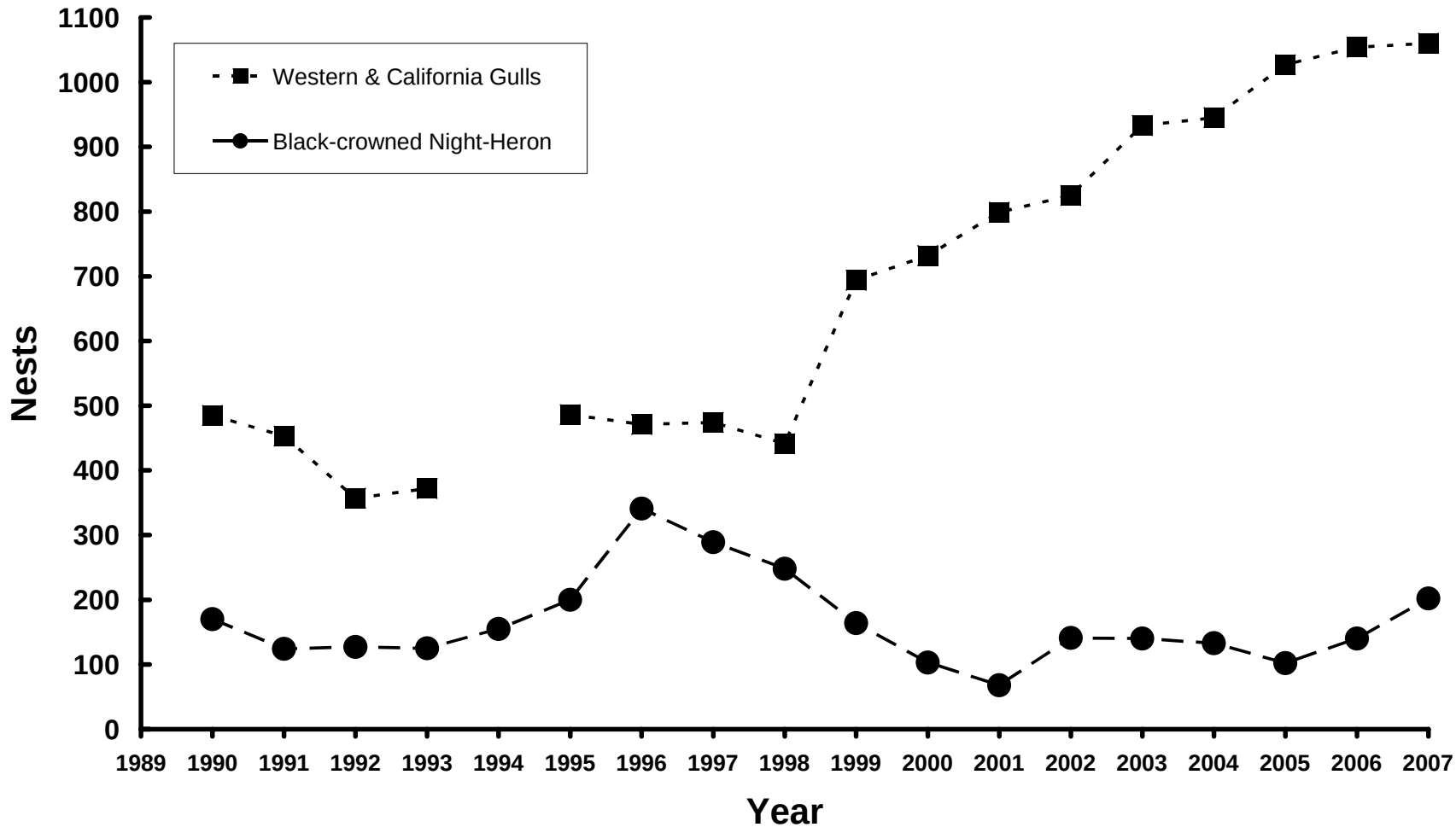


Figure 10. Trends of gull (Western and California gulls) (Acosta et al. 2006 and S. Acosta, pers. comm.) and black-crowned night-heron nests on Alcatraz Island, 1990-2007. Gull totals include 5 (2004), 14 (2005), 21 (2006), and 23 (2007) California gull nests.