Reproductive Success of Black-crowned Night-Herons (*Nycticorax nycticorax*) at Alcatraz Island, San Francisco Bay, California, 1990-2002

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Abstract.? Nesting chronology, habitat use, subcolony use, and hatchability were documented for Black-crowned Night-Herons (*Nycticorax nycticorax*) nesting at Alcatraz Island during 1990-2002. Reproductive success was estimated using the Mayfield method and compared among years. Totals of monitored nests per year ranged from 68 in 2001 to 341 in 1996, with a trend toward declining numbers since 1996. A trend of increasing numbers of nests of Western Gulls, the primary competitor with the Black-crowned Night-Herons, was identified during the same period. Calculated nest success has generally declined since 1994, with success less than the 13-year average of 63.9% each of the last six years. Although fledging success declined to its nadir in 1997, the 13-year average was 87.6%, and the rate has generally increased during the past 5 years. The net result, however, has been that the overall reproductive success of Black-crowned Night-Herons at Alcatraz Island has been below the 13-year average of 56.3% since 1996. During the study, the average number of chicks fledged per nest ranged from 0.46 to 1.27 chicks per monitored nest, far below the required two chicks per nest required for a sustained population. Embryos in 5 of the 187 failed Black-crowned Night-Heron eggs that were examined contained deformed embryos. In 1990 and 1991 eggs were analyzed for a wide range of contaminants, but none appeared to be sufficiently elevated to have caused the observed deformities. Based on these relatively low levels of contaminants, a high hatchability rate (94.5%), and relatively low levels of embryotoxicity, contaminants did not appear to significantly affect Black-crowned Night-Heron reproduction at Alcatraz Island. However, predation by Common Ravens (*Corvus corax*) and Western Gulls (*Larus occidentalis*), interspecific competition with the Western Gulls, habitat deterioration, and possible human disturbance are likely factors contributing to the decline in Black-crowned Night-Heron reproduction on Alcatraz Island in recent years.

Studies conducted in the early 1980s suggested that environmental contaminants were adversely affecting reproduction by Black-crowned Night-Herons (*Nycticorax nycticorax*) nesting in South San Francisco Bay (Ohlendorf *et al*. 1988; Hoffman *et al*. 1986). A project designed to evaluate the effects of contaminants on the reproductive success of Black-crowned Night-Herons and Snowy Egrets (*Egretta thula*) nesting in San Francisco Bay was initiated in 1989 and included Alcatraz Island beginning in 1990 (Hothem *et al*. 1995). Black-crowned Night-Herons had nested on Alcatraz Island since at least the early 1980s, with estimates of total nests ranging from 24 in 1981 (Boarman 1989) to about 60 in 1989 (M. Alvarez and T. Thomas, Golden Gate National Recreation Area, unpubl. data). Although gross numbers of nests had been estimated sporadically, neither the reproductive success of the colony nor the potential adverse impacts of environmental contaminants on reproduction had been estimated. In addition, to facilitate the conservation of nesting birds on Alcatraz, the National Park Service (NPS) needed data on nesting, hatching, and fledging success of Black-crowned Night-Herons to facilitate their planning for increased visitor access to the island. In 2002, we monitored Black-crowned Night-Heron reproduction at Alcatraz for the thirteenth consecutive year.

METHODS

Study Area

The study site was Alcatraz Island (37° 49’ N, 122° 25’ W), a National Historic Landmark within the Golden Gate National Recreation Area. This 9.1-ha island, in the central portion of San Francisco Bay, about

1.8 km north of the city of San Francisco (Fig. 1), has been managed by the NPS since 1973 (Howell and Pollak 1991). Since its transformation from a federal penitentiary to a tourist attraction, Alcatraz has become known as one of the main nesting sites for Black-crowned Night-Herons in San Francisco Bay.

Nest Monitoring

Each year, as many Black-crowned Night-Heron and Snowy Egret nests as possible were monitored at as many as thirteen separate locations (subcolonies) on Alcatraz Island (Fig.1). Beginning in late March, subcolonies were observed to learn the nesting stage of the Black-crowned Night-Herons. To reduce disturbance to the nesting birds, initial visits to each subcolony were delayed until the Black-crowned Night-Herons were in the laying or early incubation stages (Custer *et al*. 1983). The earliest initial visit ranged from April 9 to April 30 (Table 1).

Most nest-monitoring visits were conducted in the morning, starting before the first contingent of park visitors arrived by boat (about 9:00 AM) and ending by early afternoon (before 3:00 PM). To reduce disruption to incubating adults and chicks, time spent within individual subcolonies was kept to a minimum, only exceeding 15 minutes at some of the larger subcolonies (Rubble, Rubble West, and Tunnel). Time spent in certain subcolonies was extended in 1993 during periods that transmitters were attached to selected Black-crowned Night-Heron chicks for a radio telemetry study of their movements.

Most nests were monitored by observers who entered the subcolonies and recorded the presence and status of eggs and chicks. Nests that were beyond the reach of the observers were examined using a mirror mounted on an aluminum pole. A ladder was used to check nests at the Shower subcolony, and binoculars were used to monitor a few nests in inaccessible locations. Each active nest was assigned a unique number and marked with plastic flagging to simplify its relocation. Nests were checked regularly to learn their fates and to detect any signs of reproductive impairment, such as cracked or crushed eggshells.

Most years, all nests that could be found were monitored in all subcolonies at least through mid-May. In 1991 and 1992, however, based on concern for potential adverse effects from human disturbance, the Greenhouse subcolony was not monitored. The numbers of nests in this subcolony in 1991 and 1992 were estimated, based on the presence of nesting birds each year and the average numbers of nests recorded in 1990 and 1993-94 (Table 2).

The continuation of monitoring after mid-May was largely based on the nesting status of the Western Gulls (*Larus occidentalis*). Once Western Gull chicks reached about 2-3 weeks of age, observer visits to the subcolonies increased the likelihood that Black-crowned Night-Heron chicks would be exposed to attacks by adult Western Gulls. Sometimes the Black-crowned Night-Heron chicks were injured or killed as a result of these attacks. Therefore, visits to certain subcolonies were terminated earlier in the season than others, depending on the level of disturbance caused by these visits. Monitoring of sites closest to Western Gull colonies, including the Greenhouse, Bench, Tunnel, Foghorn, Rubble, and Rubble West subcolonies, was most often suspended early (See Table 2).

Data recorded at each nest included: subcolony name, nest height, nesting substrate, numbers of eggs and chicks, chick ages, and status of the nest (*i.e*., active, destroyed, abandoned). Eggs past-due for hatching were collected and returned to the laboratory where their fertility, stage of embryo development (Caldwell and Snart 1974), and embryo condition (i.e., viability and normality) were assessed. Each egg was processed and frozen to allow for possible contaminants analyses. In addition to failed eggs, ten eggs were collected at random in 1990 and 1991, and selected eggs were analyzed for contaminants both years (Hothem *et al*. 1995).

Comprehensive surveys of other nesting waterbirds on Alcatraz Island have been conducted since 1990. Western Gulls were surveyed each year except 1994 by D. Bell (1990-1991), A. Fish (1992), D.

Hatch and A. Fish (1993 and 1995), M. Brown (1996-1998), J. Thayer and D. Hatch (1999), and B. Saenz (2000-2002). Brandt's Cormorants (*Phalacrocorax penicillatus*) have been monitored by PRBO Conservation Science (J. Thayer, N. Fairman, and B. Saenz) since 1995.

Estimate of Reproductive Success

Based on previous studies in San Francisco Bay (Hothem *et al*. 1995) and on the Atlantic coast (Custer *et al*. 1983), the combined length of the egg-laying and incubation periods for Black-crowned Night-Herons (from first egg laid to first egg hatched) was assumed to be 25 days. The incubation stage of nests found with incomplete clutches was estimated by backdating, based on Black-crowned Night-Herons laying one egg every other day (Tremblay and Ellison 1980). Hatching dates were predicted based on these criteria or on the estimated ages of chicks present in the nests (Klett *et al*. 1986; McVaugh 1972).

Chicks were monitored as long as possible after hatching to estimate fledging success. However, because monitoring unmarked chicks was difficult once they began leaving the nest, 15 days was set as the arbitrary cutoff date for successful fledging. Therefore, we considered that the nestling period began with the hatching of the first egg and extended for 15 days.

Nests were considered successful if at least one egg hatched (Mayfield 1961, 1975). If eggs within a clutch failed for more than one reason, the event that finally ended the nesting effort was considered the cause of nest failure. Causes of nest and egg failure included predation, abandonment, and unknown causes (including lost nests or those not revisited).

We classified eggs that disappeared before the hatching date as unknown unless we found indications of predation or another fate. Nests with eggs that were cold and that did not hatch by the predicted hatching date were considered abandoned. Evidence of predation included partially eaten eggs in or below the nest and dead chicks with wounds attributed to predators.

Rates of nest and fledging success (and associated 95% confidence intervals) were calculated using the computer program MICROMORT (Heisey and Fuller 1985; Ohlendorf *et al*. 1989). Exposure days were calculated following Johnson (1979) and Klett *et al*. (1986). Program CONTRAST (Hines and Sauer 1989) was used to conduct two-tailed Z-tests for comparisons of nesting, fledging, and overall success. Experimentwise error was controlled by setting the significance level at 0.00064, based on the Bonferonni method of selecting a/m as the significance level, where a is 0.05 and m is the number of multiple comparison tests made (Sauer and Williams 1989). Hensler and Nichols (1981) and Bart and Robson (1982) discussed these tests in relation to statistical comparisons of estimated nesting success by the Mayfield (1961) method.

Mean clutch sizes were calculated for nests that we considered to have completed clutches, but those terminated before a full clutch was achieved and those nests found with fewer than three older (> 7 days of age) chicks were not included. We considered that, in nests with older chicks, one or more chicks may have succumbed to predation, siblicide or other factors before the nest was found. The mean clutch size was compared with previous years using Analysis of Variance (ANOVA), and Fisher's Exact Test was used to compare clutch size among years. Hatchability (egg success) was calculated by dividing the total eggs that hatched by the full clutch size for each successful nest, minus those collected, abandoned, destroyed by predators, lost, or unknown.

RESULTS AND DISCUSSION

Nesting Chronology

During 1990-2002, the date of the first nest initiation (first egg laid) was estimated to range from March 11 to April 10 (Table1). The average median initiation date was April 27, but the annual median ranged from April 7 (in 1998) to May 14 (in both 2001 and 2002).

During the study, 53% of all the nests were initiated during the 5-week period from April 1 to May 5 (weeks four through eight in Fig. 2). Of all the nests that were monitored, only 11.8% were initiated after May 26 (week 11). A bimodal nesting pattern has been observed elsewhere in studies of Black-crowned Night-Herons (Parsons and Burger 1981) and other herons (Rodgers 1980). Although the composite graph did not show a bimodal pattern, such a pattern is suggested in the initiation graphs of four individual years: 1990, 1997, 1998, and 2000 (Fig. 2).

Total Nests

A total of 2,255 nests were found on Alcatraz Island during 1990-2002 (including an estimated 68 nests initiated at the Greenhouse subcolony in 1991 and 1992), an average of 173.5 nests per year. The total numbers of monitored nests were conservative during 1992-2002 because monitoring was curtailed early in at least some of the subcolonies after 1991.

The total numbers of nests per year have varied greatly during the 13-year study (Fig. 3). During a comprehensive survey in 1990, 170 nests were found, but numbers in 1991 declined by about 27%. This decline may have been partly the result of human disturbance by observers entering nesting subcolonies for the first time in 1990. After three years of stable numbers (1991-1993), nest numbers climbed to a peak of 341 in 1996 (Table 2, Fig. 3). During 1996 to 2002, the total numbers of nests declined significantly ($r = 0.994$; $P < 0.0001$) from the high in 1996 to a low of 68 nests in 2001 before increasing in 2002 to more than twice the number found in 2001 (Fig. 3).

A major disruption that occurred on Alcatraz Island during a critical phase of the Black-crowned Night-Heron nesting season in 1996 was the June 2 premiere of the motion picture, "The Rock." An estimated 338 nests had been initiated by June 2, and about 96% of those that were still viable should have hatched by that date. Less than 1% of the chicks, however, would have been old enough to have left the island by June 2. During May 28 through June 5, there was a significant increase in human disturbance at Alcatraz, including barge off-loading, use of heavy equipment, increased lighting after dark, increased noise levels during both day and night hours, and elevated levels of activity during much of this nine-day period (Hatch 1996; Brown 1996).

According to Brown (1996) about 23% of the Western Gull nests were lost because of disturbance related to the movie premiere, and the total number of nests in 1997 declined by about 11%. Although a thorough assessment of the near-term impacts of the movie premiere and its associated activities on Black-crowned Night-Herons was not possible (Hatch 1996), there may have been long-term impacts. Nest numbers in the more-remote (from the premiere) subcolonies in the South Coast Area of the island were similar in 1997 to those seen in 1996, while those in the North Coast declined by 25%. However, the Greenhouse, Recreation Yard, and Wall subcolonies, which were located closest to movie-premiere activities (Fig. 1), had 60.9% fewer Black-crowned Night-Heron nests in 1997 than in 1996 (Table 2). The disturbance during activities associated with the movie premiere may have been sufficient to cause some subcolony abandonment or relocation to other subcolonies the following year.

It is clear that the Alcatraz Island colony, in recent years, has comprised an important part of the total nesting Black-crowned Night-Heron population in San Francisco Bay. In 1990, Alvarez and Thomas (unpubl. data) estimated that Black-crowned Night-Heron nests on Alcatraz comprised about 16% of the total in San Francisco Bay. Using conservative numbers (*i.e.*, peak numbers of simultaneously active nests) from the North San Francisco Bay nesting sites (Kelly *et al*. 1993; J. Kelly, pers. commun.), we estimate that

the Alcatraz population comprised about one-third (32.6%) of the North Bay total during 1991-2002. During 1991-1995, about one-third (25-32%) of the nesting population of Black-crowned Night-Herons in the North San Francisco Bay were located on Alcatraz Island. This proportion increased during 1996-1998 when the Alcatraz colony comprised about half (48-51%) of the North Bay nesting Black-crowned Night-Herons. These years were also the three years with the highest numbers of nests on the island (Fig. 3). The high numbers of nests at Alcatraz during 1996 (Table 5) coincided with the total collapse of the colony at Brooks Island, located about 10 km northeast of Alcatraz. While 251 nests were observed at Brooks Island in 1995 (J. Kelly, pers. commun.), only 13 nests (in 2000) have been observed at Brooks Island since then.

While the nesting population on Alcatraz declined during 1996-2002, the percentage of the North Bay population of Black-crowned Night-Herons nesting on Alcatraz also declined, dropping from 51.2% in 1996 to 12.3% in 2001 and then increasing in 2002 to 25.9%. Although the size of individual nesting colonies (including Alcatraz) has varied greatly in the recent past, it appears that the overall nesting population of North San Francisco Bay is relatively stable, averaging 533 nests during 1991-2002. During that time period, the nests on Alcatraz comprised an average of 32.4% of those in the North San Francisco Bay.

Other Species

During 1995-2002, the three most abundant nesting species on Alcatraz Island were Black-crowned Night-Herons, Western Gulls, and Brandt's Cormorants. The total numbers of nests of both the Western Gulls and the Brandt's Cormorants peaked in 2002 (Fig. 4). During 1990-1995, the number of Western Gull nests was relatively stable, averaging about 431 nests per year (D. Hatch, pers. commun.). However, during 1996 to 2002, while the numbers of Black-crowned Night-Heron nests were declining, the number of Western Gull nests increased significantly ($r = 0.93$; $P = 0.003$), reaching a total of 825 nests in 2002. The number of Brandt's Cormorant nests increased by 112% during 1996-2002, from 231 to 463 nests. However, the annual change was more variable than the Western Gulls, and the increase was only marginally significant ($r = 0.71$; $P = 0.072$).

Black-crowned Night-Herons and Brandt's Cormorants were not observed to interact. However, the Western Gulls and Black-crowned Night-Herons nested in close proximity to one another and had frequent interactions. We found no significant correlation ($r = -0.49$, $P = 0.223$) between numbers of nests of Brandt's Cormorants and Black-crowned Night-Herons during 1995-2002. Numbers of nests of Western Gulls and Brandt's Cormorants both increased during this same period and were positively correlated ($r = 0.77$, $P = 0.026$). However, numbers of nests of Black-crowned Night-Herons and Western Gulls were negatively correlated ($r = -0.81$, $P = 0.016$), with Western Gulls tending to increase while Black-crowned Night-Herons decreased, indicating a possible role for Western Gulls in the decline of the Black-crowned Night-Herons. In addition to increasing in numbers, Western Gulls were also observed to expand their range over time, increasingly encroaching on areas formerly inhabited by only Black-crowned Night-Herons. Such encroachment and subsequent interspecific conflict were likely major factors in the decline in numbers of nests of Black-crowned Night-Herons on Alcatraz Island.

During this study, the first observed nesting by Snowy Egrets was in 1997, when three nests were observed from outside the Tunnel subcolony. In 1998, 11 nests were monitored, followed by 8 in 1999, 17 in 2000, and 2 in 2001. No nesting by Snowy Egrets was detected in 2002. All but one of the 41 Snowy Egret nests were found in the Tunnel subcolony; one nest was found in the Foghorn subcolony in 1999. The relatively few Snowy Egrets nesting at Alcatraz comprised a small proportion of the total North San Francisco Bay population. Compared with peak totals compiled by J.P. Kelly (pers. commun.) for North San Francisco Bay, the 41 Snowy Egret nests on Alcatraz comprised less than 1.5% of the North Bay total during 1991-

2002. Even at their peak number in 2000, Snowy Egrets nesting on Alcatraz only comprised about 5% of the North Bay population.

Subcolony Use

The relative distribution of Black-crowned Night-Heron nests at Alcatraz Island has changed significantly during the past 13 years. The distribution in 1990 was generally dispersed throughout suitable habitats at 11 subcolonies on the island, but, especially beginning in 1997, nesting became concentrated at seven sites, primarily on the south end of the island (Table 2). Of the 141 nests found in 2002, 115 (81.6%) were in the South Coast area (Tunnel, Bench, Rubble, Rubble West, Dock, and Auxiliary Dock subcolonies) (Table 2; Fig. 5). The total number of South Coast nests increased by 71.6% over the course of the study. In addition, the percentage of the island's total nests found in the South Coast more than doubled from 1990 to 2002, and this increase has been significant as shown by a linear regression of percentage of the total island's nests on year ($r = 0.915$, $P < 0.0001$) (Fig. 6). Unlike the South Coast, the other two areas declined in total numbers and percentage of nests on the island during 1990-2002. The total number of nests in the Central Island subcolonies (Greenhouse, Recreation Yard, Wall, shower and Warden's House) declined 80.8%, from 73 to 14 nests, and the decline in percentage of total nests (Table 2) was significant ($r = 0.934$, $P<0.0001$). The total number of nests in the North Coast subcolonies (Foghorn and Power Plant) declined 60.0%, from 30 to 12 nests, but the decline in percentage of total nests (Table 2) was not significant ($r = 0.375$, $P = 0.207$).

South Coast Subcolonies: During 1990-1995, three adjacent subcolonies on the South coast, the Bench, the Auxiliary Dock, and the Dock, averaged 5.0, 12.0, and 16.7 Black-crowned Night-Heron nests per year, respectively (Table 2). All three subcolonies recorded peak numbers of Black-crowned Night-Heron nests in 1996, with a total of 101 nests found that year. However, all three subcolonies then experienced significant declines in nest numbers from 1997 through 2002, with a total of only 6 nests found in these subcolonies in each of the last two years (2001 and 2002). The close proximity of these three subcolonies to the "parade grounds" colony of Western Gulls (Fig. 1) may have contributed to the decline in Black-crowned Night-Heron nesting in these subcolonies. Another negative factor in the Dock subcolony has been the increasing senescence of mirrorbush (*Coprosma baueri*), which has seriously reduced the amount of available nesting substrate. Although the Bench and Dock are located in areas closed to human visitation during the Black-crowned Night-Heron nesting season, the Auxiliary Dock is closest to the debarkation point for visitors to Alcatraz and is likely most impacted by human activities.

During 1990-2002, the Rubble and Tunnel subcolonies were the most heavily used for Black-crowned Night-Heron nesting. Together, 949 nests were found in these two areas. Overall, we observed a trend of increasing nest numbers in the Rubble and Tunnel through 1997, with slight decreases in 1998 at both sites (Table 2). However, in 2001, there were only 10 nests in the Tunnel subcolony, a decline of 86% from 1997. The 14 nests found in the Rubble subcolony in 2001 was slightly more than the 11 found there in 1990. Compared with 1997, however, there was an 85% decline. In 2002, nesting in both of these two subcolonies nearly tripled from the previous year (Table 2). Visitor disturbance is not likely a factor for these two subcolonies, because the areas are both closed to visitors during the breeding season. Western Gull competition, however, appears to be a factor affecting nest numbers at these two sites.

The Rubble West subcolony was comprised of demolished apartment buildings and was located between the Tunnel and Rubble subcolonies (Fig. 1). Black-crowned Night-Herons were not observed to nest in this area until 1999, but the 42 nests found at this site in 2002 made it the largest subcolony on Alcatraz that year. In addition to increased nesting by Black-crowned Night-Herons, Western Gulls have also

increased their use of this subcolony for nesting. Interspersion of Western Gull and Black-crowned Night-Heron nests in this subcolony frequently resulted in interspecific competition, the outcome of which most often favored the gulls.

Central Island Subcolonies: Overall, the total number of nests monitored in the Central Island Area declined by 80.8% over the 13-year study, with three colonies (Recreation Yard, Wall, and Shower) actually declining to zero nests in 2002 (Table 2). Although the Greenhouse subcolony was probably the most stable in terms of total nests through 1996, averaging about 35 nests per year, the total decreased by 64% the year after the movie premiere (1997), and a total of only three nests was found during 1999-2001 (Table 2). In 2002, however, the Greenhouse supported 11 nests. This subcolony, located adjacent to a walkway open to year-round human access, had dense vegetation, especially figs, rose, and blackberries, that provided Black-crowned Night-Herons with both visual and physical isolation from human disturbance. In 1998, an electric tram, used to transport visitors from the dock to the cellhouse, began operation. This tram passed by the Greenhouse once every 30 minutes, coinciding with the arrival of the boats, turned around, and passed by the subcolony again a few minutes later. These trams presented a disturbance different from pedestrian traffic that may have contributed to the reduced level of nesting observed at the Greenhouse subcolony in 1998 and later years. However, numbers of nests in the Greenhouse increased in 2002 without any change in tram operation.

Although the Wall subcolony supported 24 nests, 14% of the island's total (Table 2), in 1990, no Black-crowned Night-Heron nest was found there in 2002. Disturbance associated with increased visitor access, increased nearby park activities, and Common Raven predation may be factors related to the decline at this subcolony.

North Coast Subcolonies: In 1990, the Foghorn subcolony comprised 17.1% of the island's total, but there were no nests found there in either 2001 or 2002. The loss of nests in the foghorn subcolony was partially offset by the Power Plant subcolony which increased from one nest in 1990 to 12 in 2002 (Table 2). The senescence and almost total defoliation of the mirrorbush that comprised the habitat in this area is probably the primary factor in this subcolony's decline, but an increase in nearby human activity and the proximity of nesting Western Gulls may also be factors.

Habitat Use

In the first nine years of the study, an average of 62% of the Black-crowned Night-Heron nests were located in mirrorbush (nine subcolonies) (Fig. 7). However, during 1999-2002, only about 18.5% of the nests were in this habitat type, and less than 10% of the nests were found in mirrorbush in 2001 and 2002. The increasing senescence of this shrub in many of the subcolonies has made it less desirable for nesting than it was earlier in the study. In addition, other habitats, notably English ivy (*Hedera helix*) and "rubble," have supplanted mirrorbush as important nesting habitats in recent years. An average of 12.6% of the nests found during 1990-1998 were in English ivy, while the average for 1999-2002 increased to 25.2%.

Likewise, "rubble," which consisted primarily of concrete, reinforcing rods, metal, scrap wood, and miscellaneous debris, with very little vegetation, increased from less than 0.1% of the utilized nesting habitat during 1990-1998 to an average of 29.8% during 1999-2002. Black-crowned Night-Heron nesting in rubble, reached a peak of 44% in 2002 (Fig. 7), with 41 of 42 nests in the Rubble West subcolony and 21 of 33 nests in the Tunnel subcolony using this substrate. The portion of the Tunnel subcolony that has been most heavily colonized by Black-crowned Night-Herons in recent years is the area of a demolished building, similar in character to the adjacent Rubble West.

Factors leading to the recent colonization by Black-crowned Night-Herons of the various rubble habitats have not been identified. However, the simultaneous increase in Western Gull use of these habitats may jeopardize Black-crowned Night-Heron the nesting success. Management to vegetate the barren parts of the Rubble West and Tunnel subcolonies should improve the habitat for Black-crowned Night-Heron nesting, while reducing the suitability for Western Gulls. This would potentially reduce the susceptibility of the Black-crowned Night-Heron chicks to predation by the gulls in this area.

Other major nesting habitat types (and the percentage of nests using them during the study) were English ivy (16.5%) at five subcolonies, rose (*Rosa spp*.) (5.4%) at five subcolonies, and fig (*Ficus carica*) (5.7%) at only the Greenhouse subcolony. Fig was not recorded as a nesting substrate in 1991 or 1992 because the Greenhouse subcolony was not assessed that year. Other recorded substrates included: California blackberry (*Rubus vitifolius*) at one subcolony, Australian tea tree (*Leptospermum laevigatum*) at one subcolony, mimosa (*Albizia lophantha*) at four subcolonies, Victorian boxwood tree (*Pittosporum crassifolium*) at two subcolonies, and Monterey cypress (*Cupressus macrocarpa*) at three subcolonies.

Clutch Size

The mean clutch size for Black-crowned Night-Herons during this study ranged from 2.78 eggs per clutch in 1995 to 3.04 eggs per clutch in 1992, with an overall mean of 2.87 (Table 3). Differences among years were significant (One Way ANOVA; F = 2.37, P = 0.0049), and, using Fisher's exact test, differences among years were determined (Table3). The means in 1990 and 1992 were higher than those in 1995 and 1998, but no overall trend was detected. Each year the modal clutch size was three eggs, and, overall, 67.3% of the nests had three eggs, 21.6% had two, and 9.9% had four. Only seven five-egg clutches (0.4%) and 16 (0.9%) one-egg clutches were found during the study.

The mean clutch size for Black-crowned Night-Herons at Alcatraz was lower than 20 other colonies assessed in recent years (Wolford and Boag 1971; Tremblay and Ellison 1980; Custer *et al*. 1983; Erwin *et al*. 1996; Blus *et al*. 1997). The range of clutch sizes was from 3.0 in Alberta, Canada in 1975 to 4.2 in 1976 in Quebec, Canada.

Reproductive Success

The annual mean nest success (nests that hatched at least one egg) for Black-crowned Night-Herons during this 13-year study, as measured by the Mayfield method, averaged 64.1 % and ranged from 45.2% in 2001 to 81.3% in 1994 (Table 4). The mean fledging success (the percentage of nests that hatched that fledged at least one chick to 15 days of age) ranged from 72.1% in 1997 to 98.6% in 1993, an average of 87.7%. The mean overall success (percentage of all nests that fledged at least one chick) ranged from 35.5% in 1998 to 76.7% in 1994, an average of 56.4%. There were significant differences among years for all three measurements of success (P<0.01) (Table 4).

The average nest success during the first seven years of the study was 73.9%, but, during the last six years, the average dropped to 52.4%. When the nest success for 1990-1996 was compared with that for 1997-2002, the earlier period had significantly higher nest success (P<0.05). When fledging success during these two periods were compared, the differences were not significant. However, overall success was found to be higher during 1990-1996 than 1997-2002.

Black-crowned Night-Heron nest success and Western Gull nest numbers were not significantly correlated (r = -0.500, P = 0.21) during this period, but, interestingly, there was a positive correlation (r = 0.727, P = 0.041) between numbers of Western Gull nests and Black-crowned Night-Heron fledging success.

The average nest success at Alcatraz Island (64.1%) was lower than that found at other colonies recently studied in South Carolina, Washington, and Oregon (Post 1990; Blus *et al*. 1997). Compared with recent studies in San Francisco Bay, the average nest success rate was higher than that at West Marin Island in 1990 (47.5%), Bair Island in 1989 (53.1%), and Brooks Island in 1990 and 1991 (55.7% and 38.5%) (Hothem *et al*. 1995). Colonies with higher success rates than Alcatraz included West Marin Island in 1989 (73.3%) and Bair Island in 1990 (67.0%).

Compared to fledging success rates reported from 28 sites, the mean Black-crowned Night-Heron fledging success rate at Alcatraz Island was the fourth highest. Only two colonies in Washington and one in Oregon (Blus *et al*. 1997) had higher fledging success. Other colonies had fledging success rates that ranged from 0.0% at Summer Lake, Oregon in 1980, which was devastated by predators (Henny *et al*. 1984) to 86.5% at Drum Island, South Carolina (Post 1990). Alcatraz fledging success was also greater than at the three other islands studied in San Francisco Bay in 1989-1991 (57.3% to 76.6%) (Hothem *et al*. 1995).

The overall mean success at Alcatraz was greater than 71% of the other colonies studied in recent years, including the Potholes Reservoir in Washington that only had 11.8% overall success in 1991 (Blus *et al*. 1997). Overall success at the other three San Francisco Bay sites was lower than at Alcatraz and ranged from 26.2 % at Brooks Island in 1991 to 42.7% at Brooks in 1990 (Hothem *et al*. 1995).

Nest Fate

During 1990-2002, 1,372 of the 2,187 monitored nests (62.7%) were confirmed to have hatched at least one egg (Table 5). The observed percentage hatch ranged from 36.8% in 2001 to 75.2% in 1993. Predation was the primary limiting factor at Alcatraz, with predators destroying 12.3% of the nests before hatching. Another 1.8% of the nests were destroyed, but the cause was unconfirmed. Predators destroyed an average of 6.9% of the nests per year during 1990-1996, compared with an average of 23.4% during 1997-2002. Predation during the first two years of the study was relatively high (12.9% and 18.9% in 1990 and 1991, respectively), but that was likely related to the continuing of nest monitoring in all the subcolonies through late July or early August, despite observed adverse interactions between the Black-crowned Night-Herons and the Western Gulls. In subsequent years, nest visits in subcolonies susceptible to Western Gull predation were curtailed early to prevent human-induced predation. From 1992 through 1997, the predation rate averaged 3.2%, but, in 1998, it jumped to 21.8%, almost ten times that observed in 1997 (Table 5). Predation exceeded 25% each of the remaining four years of the study, despite precautions taken by observers to minimize human-induced predation. During 1998-2002, the same time that Western Gull nests increased by 70% on Alcatraz (Fig. 4), a yearly average of 29.0% of the monitored nests was destroyed by predators, or more than four times the average percentage destroyed during 1990-1996.

During 1990-2002, 59.6% of the hatched nests were observed to have fledged at least one chick to 15 days (Table 5). This fledging rate ranged from 49.4% in 1996 to 80.3% in 1990. Predators destroyed 4.4% of the nests before fledging, and another 5.0% of the nests were destroyed by unknown causes. The average percentage of hatched nests destroyed by predators during 1990-1996 was 3.3%, compared with 6.0% during 1997-2002. As observed with nest predation, the high rate of predation on hatched nests during 1990 and 1991 (7.9% and 12.9%, respectively) was likely related to observer disturbance. Estimates of the fates of hatched nests were more conservative than estimates of nest fate because a smaller percentage of nests could be followed to fledging that to hatching. This was in response to the early cessation of monitoring in many of the subcolonies after 1991.

The largest colonies of Western Gulls were nearest the South Coast subcolonies, and Western Gulls were most likely responsible for most of the predation in that area. Western Gulls were observed harassing Black-crowned Night-Heron adults and chicks and, on one occasion, a Western Gull was observed dragging

a dead Black-crowned Night-Heron chick through the Western Gull colony on the parade grounds (R. Hothem, pers. observation). In other parts of the island, especially in the Central Island Area, Common Ravens (*Corvus corax*) were frequently observed carrying Black-crowned Night-Heron eggs from nesting areas to ledges on the cellhouse where the eggs were eaten (C. Hellwig, pers. commun.). The presence of one pair of nesting Common Ravens and their young in a Monterey cypress near the Wall subcolony was likely a major factor contributing to the recent collapse of that subcolony. Common Ravens are known to have decimated the nesting population at Summer Lake, Oregon in 1980 (Henny *et al*. 1984). Other potential predators reportedly present on Alcatraz Island during the 13-year study include Norway rats (*Rattus norvegicus*), a Northern Harrier (*Circus cyaneus*), and an unidentified owl. The effects of these other predators could not be assessed.

Predation is commonly a major limiting factor for Black-crowned Night-Herons (Wolford and Boag 1971; Tremblay and Ellison 1980; Henny *et al*. 1984; Blus *et al*. 1997). However, predation rates at Alcatraz, especially during the years since 1997, were among the highest reported in the recent literature. Only nests in Alberta in 1964 and 1965 (Wolford and Boag 1971) and Summer Lake (Henny *et al*. 1984) had higher predation rates. Predation rates at all three of the San Francisco Bay sites monitored in 1989-1991 were lower than Alcatraz during 1998-2002 (Hothem *et al*. 1995).

The overall abandonment rate before hatching was low (3.4% of the monitored nests), but estimated post-hatch abandonment was even lower (0.4%). The average annual nest abandonment rate during 1990-1996 was 3.2%, and it increased to 4.2% during 1997-2002, but no clear annual trends were apparent. Abandonment could have been underestimated by an unknown amount if nests destroyed by predators after abandonment were classified as predation. Although delaying entry into the subcolonies (at least 2-4 weeks after the first nest initiation) and curtailing monitoring visits once inter-specific conflicts were imminent reduced the precision of our estimates of reproductive success (i.e. more unknown fates), it also likely reduced abandonment and human-induced predation. Tremblay and Ellison (1979) found that visiting colonies before egg-laying had occurred or in the very early stages of egg-laying resulted in increased nest failures, mostly due to abandonment, but also due to human-induced predation.

Nests with unknown fates, including those lost or not rechecked for other reasons, comprised 19.8% of the monitored nests (Table 5). The percentages of unknowns for the first two years of the study (7.6% and 2.2% in 1990 and 1991, respectively), however, were lower than subsequent years because nests were followed longer into the season, until a higher percentage of their fates were determined.

The post-hatching fate of a high percentage of nests was unknown (average = 30.6%), primarily because nest visits were terminated before post-hatching success of later nesting Black-crowned Night-Herons could be evaluated. As with pre-hatching fates, the percentages of unknowns for the first two years of the study (10.2% and 14.5% in 1990 and 1991, respectively) were lower than subsequent years. The percentage of post-hatching unknowns was higher those years that monitoring was terminated early (especially 1992 and 1996) and those years with fewer monitoring visits (Tables 1 and 5). During five of the years, subcolonies were visited from three to eight times (average = 5.6), and the average percentage of total unknowns was 28.0%. However, the eight years that the subcolonies were visited 13-16 times (average = 13.9) the average percentage unknown nest fate was 13.7%.

The nesting chronology of the Black-crowned Night-Herons relative to that of the Western Gulls was especially important in determining duration of nest monitoring. Although Black-crowned Night-Heron nesting initiation during this study varied by about 4 weeks (Table 1), Western Gull initiations at Alcatraz varied by only a few days (D. Hatch, pers. commun.). Those years that Black-crowned Night-Heron chicks were produced later in the season generally resulted in earlier and often more intense harassment of and predation by Western Gull adults on the Black-crowned Night-Heron chicks. During those years, nest monitoring was

terminated in certain subcolonies before the fates of many of the hatched Black-crowned Night-Heron nests could be determined.

Failed Eggs and Chick Mortalities

During this study, 187 of 3,388 eggs (5.5%) failed before hatching (Table 6). Hatchability ranged from 89.1% in 2002 to 97.6% in 1992 and averaged 94.5%. This rate was higher than that observed in the St. Lawrence Estuary in 1975 and 1976, where reproduction was considered normal with 10% egg failure (Tremblay and Ellison 1980). Overall hatchability was slightly better at Alcatraz than the 93.3% hatchability found by Custer *et al*. (1983) at Atlantic Coast heronries, and it was similar to that found at three other San Francisco Bay nesting sites assessed in 1989-1991 (Hothem *et al*. 1995). Hatchability was higher all years than Black-crowned Night-Herons from Idaho (87.7%) where DDE-induced losses significantly reduced reproductive success in 1979 (Findholt and Trost 1985).

Some failed eggs showed signs of reproductive impairment, including crushed, cracked, dented or brittle shells. During 1989-1991, such eggs were also found at other sites in San Francisco Bay, but teratogenesis was only observed in embryos from Alcatraz. Two deformed embryos were collected in 1990, one was collected in 1995, and two were found in 1997. Multiple defects were found in one or more of the embryos, and they included missing or reduced mandibles, swollen joints, missing eyes, shortened neck, and encephalocele of the forebrain.

Mortality was also observed in chicks. Of the 3,201 eggs that were observed to have hatched, 1,608 chicks (50.2%) were observed to have survived to at least 15 days (Table 6). During the study, 192 dead chicks were found, with 68% of them found during 1996-1998 (Table 6). Overall, 6.0% of the chicks that hatched were later found dead, but in 1996, the percentage was 13.7%. Only one chick was found with a gross deformity during the study. The chick, found alive in 1990, had a deformed upper mandible. An average of 0.74 chicks fledged per monitored nest, 1.17 chicks fledged per hatched nest, and 1.97 chicks fledged per fledged nest. Fledgling production per monitored nest ranged from 0.46 per nest in 2001 to 1.27 in 2001 (Table 6). The estimated total chick production per year ranged from 31 in 2001, the year with the fewest nests monitored, to 232 in 1996, the year with the most nests monitored.

The estimated production of chicks every year of the study was below the recruitment standard of two chicks per nesting pair required to maintain a stable population of Black-crowned Night-Herons (Henny 1972). The production at Alcatraz ranged from about 23 to 64% of the recommended level. Ten of the colonies studied recently (Tremblay and Ellison 1980; Custer *et al*. 1983; Henny *et al*. 1984) exceeded the two chick per monitored nest criterion, but none of the colonies studied in San Francisco Bay met the criterion (Hothem *et al*. 1995). Assuming that survival from 15 days to independence (about 50 days) is less than 100%, it is certain that the actual fledging success at Alcatraz during the 13-year study was much less than that needed to maintain a stable population.

While hatchability at Alcatraz Island was similar to uncontaminated sites, the incidence of observed reproductive impairment could be related to foraging in contaminated "hot spots" in San Francisco Bay. Black-crowned Night-Herons nesting in colonies in Oregon, Idaho, and Nevada are migratory, wintering in Mexico or the southwestern United States where they likely acquire substantial loads of pollutants (Henny and Blus 1986). Black-crowned Night-Herons in the San Francisco Bay area, however, tend to disperse within the Bay and are thus more likely to acquire their contaminant loads locally (Gill and Mewaldt 1979).

The five abnormal embryos collected during this study appeared to have exhibited the effects of contaminant-induced impairment. However, chemical analyses of random and failed eggs, including the two deformed embryos in 1990, did not confirm the causes of the deformities (Hothem *et al*. 1995). Concentrations of DDE, mercury, and selenium residues in the two deformed embryos from Alcatraz Island

were all well below concentrations associated with reproductive effects (Hothem *et al.* 1995). However, PCBs were within the range of concentrations that caused teratogenic effects in Common Terns (*Sterna hirundo*) (Hoffman *et al.* 1993). No developmental abnormalities were found in 78 pipping Black-crowned Night-Heron embryos examined from sites in Oregon and Washington in 1991 (Blus *et al.* 1997). Mean PCB concentrations from these colonies ranged from below the detection limit (0.05 µg/g, wet weight) to 0.55 µg/g. The mean at Alcatraz Island in 1991 was 6.08 µg/g (Hothem *et al.* 1995). Further investigation into the potential links between contaminants, especially PCBs, and reproductive impairment at Alcatraz is warranted.

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Table 1. Black-crowned Night-Heron reproductive chronology, Alcatraz Island, 1990-2002.

	Initiation Date I.D.		Predicted Hatching Date (H.D.) (I.D. + 25 days)		Predicted Fledging Date (F.D.) (H.D. + 15 days)		Predicted Colony Departure Date (F.D. + 34 days)		Observation Dates
Year	**Median**	**Range**	**Median**	**Range**	**Median**	**Range**	**Median**	**Range**	**(Visits)**
1990	4/28	3/24-7/11	5/23	4/18-8/5	6/7	5/3-8/20	7/11	6/6-9/23	4/28-8/9 (16)
1991	5/8	3/26-7/4	6/2	4/20-7/29	6/17	5/5-8/13	7/21	6/8-9/16	4/25-7/26 (14)
1992	4/13	3/20-5/28	5/8	4/14-6/22	5/23	4/29-7/7	6/26	6/2-8/10	4/30-5/28 (3)
1993	4/23	3/16-7/24	5/18	4/10-8/18	6/2	4/25-9/2	7/6	5/29-10/6	4/20-8/20[1] (15)
1994	5/6	3/25-7/18	5/31	4/19-8/12	6/15	5/4-8/27	7/19	6/7-9/30	4/22-8/1 (8)
1995	4/25	3/11-6/28	5/20	4/5-7/23	6/4	4/20-8/7	7/8	5/24-9/10	4/26-6/28 (7)
1996	4/12	3/15-6/4	5/7	4/9-6/29	5/22	4/24-7/14	6/25	5/28-8/17	4/29-6/10 (4)
1997	4/8	3/13-5/28	5/3	4/7-6/22	5/18	4/22-7/7	6/21	5/26-8/10	4/22-6/12 (6)
1998	4/7	3/15-6/21	5/2	4/9-7/16	5/17	4/24-7/31	6/20	5/28-9/3	4/9-7/10 (14)
1999	5/3	3/27-6/12	5/28	4/21-7/7	6/12	5/6-7/22	7/16	6/9-8/25	4/13-7/17 (13)
2000	5/13	4/4-7/16	6/7	4/29-8/10	6/22	5/14-8/25	7/26	6/17-9/28	4/18-8/8 (16)
2001	5/14	4/10-6/18	6/8	5/5-7/13	6/23	5/20-7/28	7/27	6/23-8/31	4/24-7/24 (13)
2002	5/14	3/16-6/23	6/8	4/10-7/18	6/23	4/25-8/2	7/27	5/29-9/5	4/22-7/1 (10)
Overall	4/27	3/11-7/24	5/22	4/5-8/18	6/6	4/20-9/2	7/10	5/24-10/6	4/9-8/20 (139)

[1]One active nest at the Wall subcolony was observed until 10/5.

Table 2. Black-crowned Night-Heron nests per subcolony (and percentages), Alcatraz Island, 1990-2002.

	Year														
SUBCOLONY	1990	1991	1992[1]	1993[2]	1994[3]	1995[4]	1996[5]	1997[6]	1998[7]	1999[8]	2000[9]	2001[10]	2002[11]	Totals	Means
SOUTH COAST	**67**	**57**	**68**	**60**	**90**	**129**	**243**	**240**	**199**	**136**	**90**	**51**	**115**	**1545**	**118.8**
%	**39.4%**	**46.0%**	**53.5%**	**48.0%**	**58.1%**	**64.5%**	**71.3%**	**83.0%**	**80.2%**	**82.9%**	**87.4%**	**75.0%**	**81.6%**		**67.0%**
Tunnel	19	15	21	24	32	32	57	70	64	39	14	10	33	430	**33.1**
Bench	3	3	7	2	2	13	46	27	16	5	7	2	0	133	**10.2**
Rubble	11	14	17	19	17	48	85	94	88	48	30	14	34	519	**39.9**
Rubble West	0	0	0	0	0	0	0	0	0	27	29	21	42	119	**9.2**
Dock	24	15	16	7	23	15	23	21	8	3	2	1	1	159	**12.2**
Aux. Dock	10	10	7	8	16	21	32	28	23	14	8	3	5	185	**14.2**
CENTRAL	**73**	**48**	**43**	**49**	**48**	**57**	**70**	**28**	**20**	**8**	**6**	**5**	**14**	**469**	**36.1**
%	**42.9%**	**38.7%**	**33.9%**	**39.2%**	**31.0%**	**28.5%**	**20.5%**	**9.7%**	**8.1%**	**4.9%**	**5.8%**	**7.4%**	**9.9%**		**21.6%**
Greenhouse	38	34[12]	34[12]	30	34	38	36	13	7	2	1	0	11	278	**21.4**
Rec. Yard	7	4	3	4	7	6	13	4	4	2	1	0	0	55	**4.2**
Wall	24	8	5	9	4	13	20	10	8	4	2	1	0	108	**8.3**
Shower	4	2	1	6	3	0	1	1	1	0	0	0	0	19	**1.5**
Warden	0	0	0	0	0	0	0	0	0	0	2	4	3	9	**0.7**
NORTH COAST	**30**	**19**	**16**	**16**	**17**	**14**	**28**	**21**	**29**	**20**	**7**	**12**	**12**	**241**	**18.5**
%	**17.6%**	**15.3%**	**12.6%**	**12.8%**	**11.0%**	**7.0%**	**8.2%**	**7.3%**	**11.7%**	**12.2%**	**6.8%**	**17.6%**	**8.5%**		**11.4%**
Foghorn	29	18	13	14	14	8	22	12	14	12	2	0	0	158	**12.2**
Power Plant	1	1	3	2	3	6	6	9	15	8	5	12	12	83	**6.4**
Totals	**170**	**124**	**127**	**125**	**155**	**200**	**341**	**289**	**248**	**164**	**103**	**68**	**141**	2255	**173.5**

[1] Only three visits in 1992 at all colonies (last one on 5/28). (Visits in 1990 and 1991 were not ended early at any of the visited subcolonies.).

[2] In 1993, the last visits were: Tunnel and Greenhouse: 5/25; Rubble: 6/7; and Foghorn: 6/11; other subcolonies last visited on 8/20.

[3] In 1994, the last visits were: Tunnel, Rubble, and Greenhouse: 5/22; Foghorn: 6/6; other subcolonies last visited on 8/1.

[4] In 1995, the last visits were: Greenhouse, Foghorn, Tunnel, and Rubble: 5/31; Bench: 6/14; other subcolonies last visited on 6/28.

[5] In 1996, the last visits were: Greenhouse, Tunnel, and 50% of Rubble: 5/13; Aux. Dock, Dock, Bench, Wall, and remaining Rubble: 5/28; Foghorn, Recreation Yard, Power Plant, and Shower: 6/10.

[6] In 1997, the last visits were: Rubble, Tunnel, and Bench: 5/13; Aux. Dock: 5/28; Dock, Wall, Greenhouse, Foghorn, Recreation Yard, Power Plant, and Shower: 6/12.

[7] In 1998, the last visits were: Tunnel: 5/30; Rubble, Bench: 6/5; Dock, Shower: 6/11; Wall: 6/18; Greenhouse, Recreation Yard, and Power Plant: 6/25. Aux. Dock and Foghorn: 7/10.

[8] In 1999, the last visits were: Tunnel, Bench, Rubble, and Rubble West: 6/15; Dock, Aux. Dock, Power Plant, Shower, and Recreation Yard: 6/21; Greenhouse and Foghorn: 6/29; Wall: 7/17.

[9] In 2000, the last visits were: Tunnel: 6/6; Rubble West: 6/13; Rubble: 6/20; Bench, Dock, Foghorn, Recreation Yard, and Warden's House: 6/27; Wall, Shower, and Power Plant: 7/25; Greenhouse and Aux. Dock: 8/1.

[10] In 2001, the last visits were: Tunnel, Rubble, Rubble West, Bench, Wall, Shower, Greenhouse, Rec. Yard, and Foghorn: 5/29; Dock: 6/5, Warden's House and Power Plant: 7/11; Aux. Dock: 7/24.

[11] In 2002, the last visits were: Tunnel, Rubble, Rubble West, Bench, Wall, Shower, Rec. Yard, Dock, and Aux. Dock: 6/24; Foghorn and Power Plant: 6/17; Warden's House and Greenhouse: 7/1.

[12] Nesting was observed, but nests were not monitored in 1991 or 1992. We estimated that 34 nests were initiated in the greenhouse subcolony based on the average of those observed in 1990, 1993, and 1994.

Table 3. Black-crowned Night-Heron clutch size at Alcatraz Island, 1990-2002.

Year	Nests per clutch size[1]					Total Eggs	Total Nests	Mean Clutch Size[2]	SD	95% Confidence Interval
	1	2	3	4	5					
1990	1	20	109	23	0	460	153	3.01 A	0.556	2.98 - 3.03
1991	0	19	49	8	0	217	76	2.86 ABC	0.582	2.83 - 2.88
1992	1	3	60	6	1	216	71	3.04 A	0.491	3.02 - 3.06
1993	1	25	66	16	1	318	109	2.92 ABC	0.668	2.89 - 2.95
1994	1	37	80	15	1	380	134	2.84 BC	0.651	2.81 - 2.87
1995	2	41	106	7	2	440	158	2.78 C	0.601	2.76 - 2.81
1996	5	60	189	27	0	800	281	2.85 BC	0.599	2.82 - 2.87
1997	1	46	159	19	0	646	225	2.87 BC	0.540	2.85 - 2.90
1998	2	61	148	17	0	636	228	2.79 C	0.578	2.76 - 2.82
1999	1	37	95	17	1	433	151	2.87 BC	0.629	2.84 - 2.90
2000	0	21	59	6	0	243	86	2.83 BC	0.536	2.80 - 2.85
2001	0	6	29	6	0	123	41	3.00 AB	0.548	2.97 - 3.03
2002	1	16	73	12	1	305	103	2.96 AB	0.593	2.93 - 2.99
Totals	16	392	1,222	179	7	5,217	1,816	2.87	0.591	2.85 - 2.90

[1] Only nests thought to have a complete clutch were included. Nests terminated before a full clutch was achieved and those hatched when found with older (>7 days old) chicks were deleted from this analysis.

[2] Differences among years were detected (One-Way ANOVA; F=2.37; $P = 0.0049$). Among years, clutch size estimates sharing a capital letter are not significantly different by Fisher's Exact Test ($P < 0.05$).

Table 4. Estimates of percent nesting and fledging success (and 95% CI) of Black-crowned Night-Herons at Alcatraz Island, 1990-2002[1].

Year	Nests Found	Mayfield Nests	Exposure Days	Nesting Success	Fledging Success	Overall Success
1990	170	140	1840.5	70.1 AB[2]	89.6 AB	62.8 ABC
				(60.5-79.6)	(84.1-95.2)	(53.4-72.2)
1991	90	81	1230.0	63.7 ABC	82.4 ABC	52.5 ABCD
				(51.7-75.7)	(72.5-92.3)	(40.8-64.2)
1992	93	54	351.0	80.7 ABC	87.8 ABC	70.8 ABCD
				(61.1-100)	(76.6-99.0)	(51.4-90.3)
1993	125	96	1178.5	77.4 AB	98.6 A	76.3 A
				(66.2-88.6)	(95.8-100)	(65.1-87.6)
1994	155	117	969.0	81.3 A	94.4 AB	76.7 AB
				(69.6-93.0)	(88.2-100)	(64.6-88.8)
1995	200	142	1257.0	77.1 AB	91.9 A	70.8 ABC
				(66.2-88.0)	(85.6-98.1)	(59.7-82.0)
1996	341	179	1441.0	66.9 ABC	79.0 BC	52.8 ABCD
				(55.9-77.9)	(70.9-87.2)	(42.6-63.1)
1997	289	173	1502.0	63.5 ABC	72.1 C	45.8 CD
				(52.7-74.4)	(64.0-80.1)	(36.4-55.2)
1998	248	203	2352.0	45.5 C	78.1 BC	35.5 D
				(37.2-53.7)	(70.5-85.6)	(28.2-42.8)
1999	164	155	2052.5	54.7 BC	91.1 AB	49.8 CD
				(45.4-63.9)	(84.8-97.4)	(40.7-58.9)
2000	103	87	1073.5	51.6 ABC	87.2 ABC	45.1 CD
				(39.0-64.3)	(76.8-97.7)	(32.8-57.4)
2001	68	61	576.5	45.2 BC	94.8 AB	42.9 BCD
				(28.7-61.8)	(84.8-100)	(26.5-59.3)
2002	141	125	1507	53.7 ABC	92.6 AB	49.8 ABCD
				(43.0-64.5)	(85.7-99.6)	(39.1-60.4)
Mean	168.2	123.9	1332.6	64.1	87.7	56.4

[1] Based on days of nest exposure (see Hensler and Nichols 1981).
[2] Among years, survival estimates sharing a capital letter are not significantly different (z-tests; $P < 0.05$).

Table 5. Nest fates (and %) of Black-crowned Night-Herons at Alcatraz Island, 1990-2002.

Nest Fate	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total
Nests Monitored	**170**	**90**	**93**	**125**	**155**	**200**	**341**	**289**	**248**	**164**	**103**	**68**	**141**	**2187**
Predation	**22**	**17**	**2**	**9**	**2**	**4**	**13**	**8**	**54**	**44**	**33**	**19**	**41**	**268**
(% of monitored)	12.9%	18.9%	2.2%	7.2%	1.3%	2.0%	3.8%	2.8%	21.8%	26.8%	32.0%	27.9%	29.1%	12.3%
Destroyed (Other)	**3**	**3**	**0**	**2**	**2**	**7**	**5**	**12**	**6**	**0**	**0**	**0**	**0**	**40**
(% of monitored)	1.8%	3.3%	0.0%	1.6%	1.3%	3.5%	1.5%	4.2%	2.4%	0.0%	0.0%	0.0%	0.0%	1.8%
Abandoned	**5**	**6**	**3**	**3**	**5**	**5**	**5**	**10**	**18**	**6**	**3**	**5**	**1**	**75**
(% of monitored)	2.9%	6.7%	3.2%	2.4%	3.2%	2.5%	1.5%	3.5%	7.3%	3.7%	2.9%	7.4%	0.7%	3.4%
Unknown	**13**	**2**	**21**	**17**	**58**	**68**	**79**	**66**	**24**	**20**	**17**	**19**	**28**	**432**
(% of monitored)	7.6%	2.2%	22.6%	13.6%	37.4%	34.0%	23.2%	22.8%	9.7%	12.2%	16.5%	27.9%	19.9%	19.8%
Hatched	**127**	**62**	**67**	**94**	**88**	**116**	**239**	**193**	**146**	**94**	**50**	**25**	**71**	**1372**
(% of monitored)	74.7%	68.9%	72.0%	75.2%	56.8%	58.0%	70.1%	66.8%	58.9%	57.3%	48.5%	36.8%	50.4%	62.7%
Fledged	**102**	**42**	**34**	**72**	**56**	**76**	**118**	**96**	**76**	**62**	**25**	**16**	**43**	**818**
(% of monitored)	60.0%	46.7%	36.6%	57.6%	36.1%	38.0%	34.6%	33.2%	30.6%	37.8%	24.3%	23.5%	30.5%	37.4%
(% of hatched)	80.3%	67.7%	50.7%	76.6%	63.6%	65.5%	49.4%	49.7%	52.1%	66.0%	50.0%	64.0%	60.6%	59.6%
Predation	**10**	**8**	**1**	**0**	**0**	**1**	**0**	**8**	**19**	**5**	**4**	**0**	**4**	**60**
(% of hatched)	7.9%	12.9%	1.5%	0.0%	0.0%	0.9%	0.0%	4.1%	13.0%	5.3%	8.0%	0.0%	5.6%	4.4%
Destroyed (Other)	**2**	**1**	**4**	**1**	**2**	**4**	**20**	**25**	**6**	**2**	**1**	**1**	**0**	**69**
(% of hatched)	1.6%	1.6%	6.0%	1.1%	2.3%	3.4%	8.4%	13.0%	4.1%	2.1%	2.0%	4.0%	0.0%	5.0%
Abandoned	**0**	**2**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**5**
(% of hatched)	0.0%	3.2%	0.0%	0.0%	1.1%	0.9%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	0.4%
Post-hatch Unknowns	**13**	**9**	**28**	**21**	**29**	**34**	**101**	**64**	**45**	**25**	**19**	**8**	**24**	**420**
(% of hatched)	10.2%	14.5%	41.8%	22.3%	33.0%	29.3%	42.3%	33.2%	30.8%	26.6%	38.0%	32.0%	33.8%	30.6%

Table 6. Hatchability and chick survival of Black-crowned Night-Herons at Alcatraz Island, 1990-2002.

	Year														
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Mean
Nests Monitored	170	90	93	125	155	200	341	289	248	164	103	68	141	2,187	168.2
Nests Hatched	127	62	67	94	88	116	239	193	146	94	50	25	71	1,372	105.5
Eggs Observed to Hatching	339	155	169	265	199	279	540	446	372	254	144	61	165	3,388	260.6
Failed Eggs	19	7	4	17	10	23	20	28	16	11	9	5	18	187	14.4
Hatchability	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%	94.5%	94.1%
Fledged Nests	102	42	34	72	56	76	118	96	76	62	25	16	43	818	62.9
Chicks Observed to Fledging	210	81	56	159	101	122	232	183	148	145	48	31	92	1,608	123.7
Fledged Chicks/ Monitored 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	0.74	0.74
Dead chicks found	5	7	10	7	3	7	71	31	29	17	2	2	1	192	14.8
Fledgeability	97.6%	91.4%	82.1%	95.6%	97.0%	94.3%	69.4%	83.1%	80.4%	88.3%	95.8%	93.5%	98.9%	88.1%	89.8%

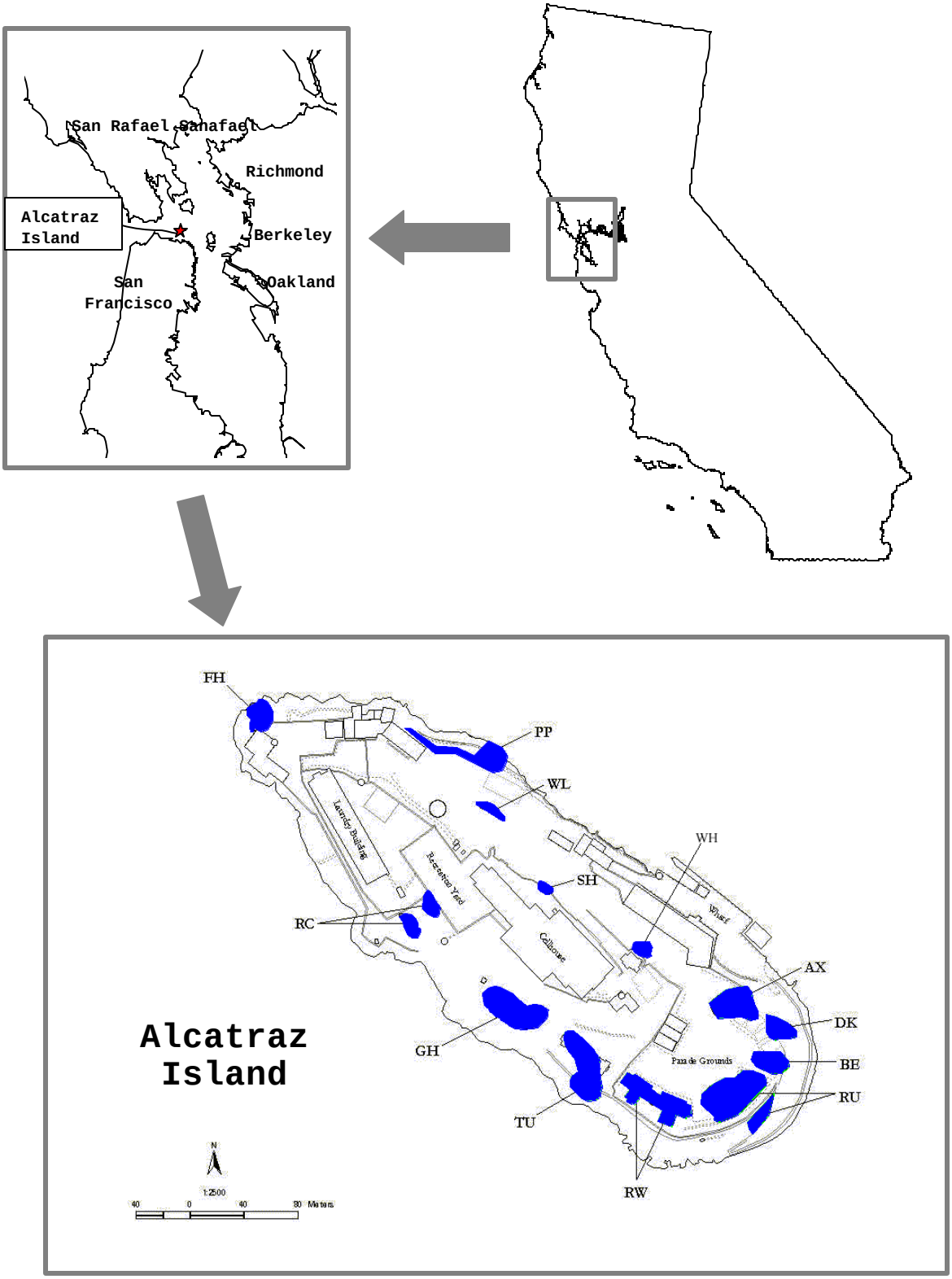

Figure 1. Black-crowned Night-Heron nesting subcolonies on Alcatraz Island, San Francisco Bay, California, during 1990-2002: Foghorn (FH), Power Plant (PP), Greenhouse (GH), Recreation Yard (RC), Wall (WL), Shower (SH), Auxiliary Dock (AX), Dock (DK), Bench (BE), Rubble (RU), Rubble-West (RW), Tunnel Bush (TU), and Warden's House (WH).

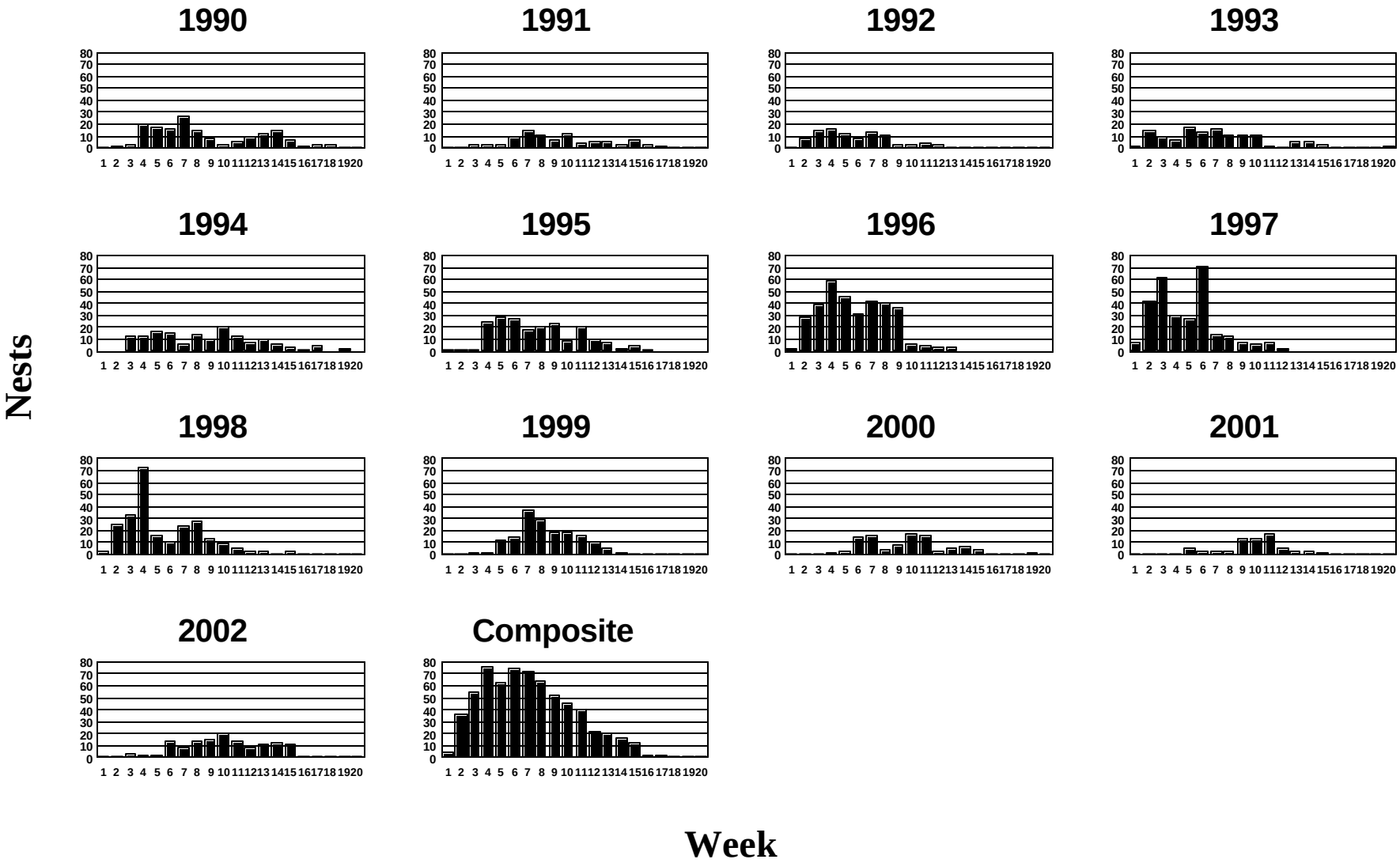

Figure 2. Weekly Initiation dates (March 11-July 28) by year and combined weekly initiation dates of Black-crowned Night-Heron nests at Alcatraz Island, 1990-2002.

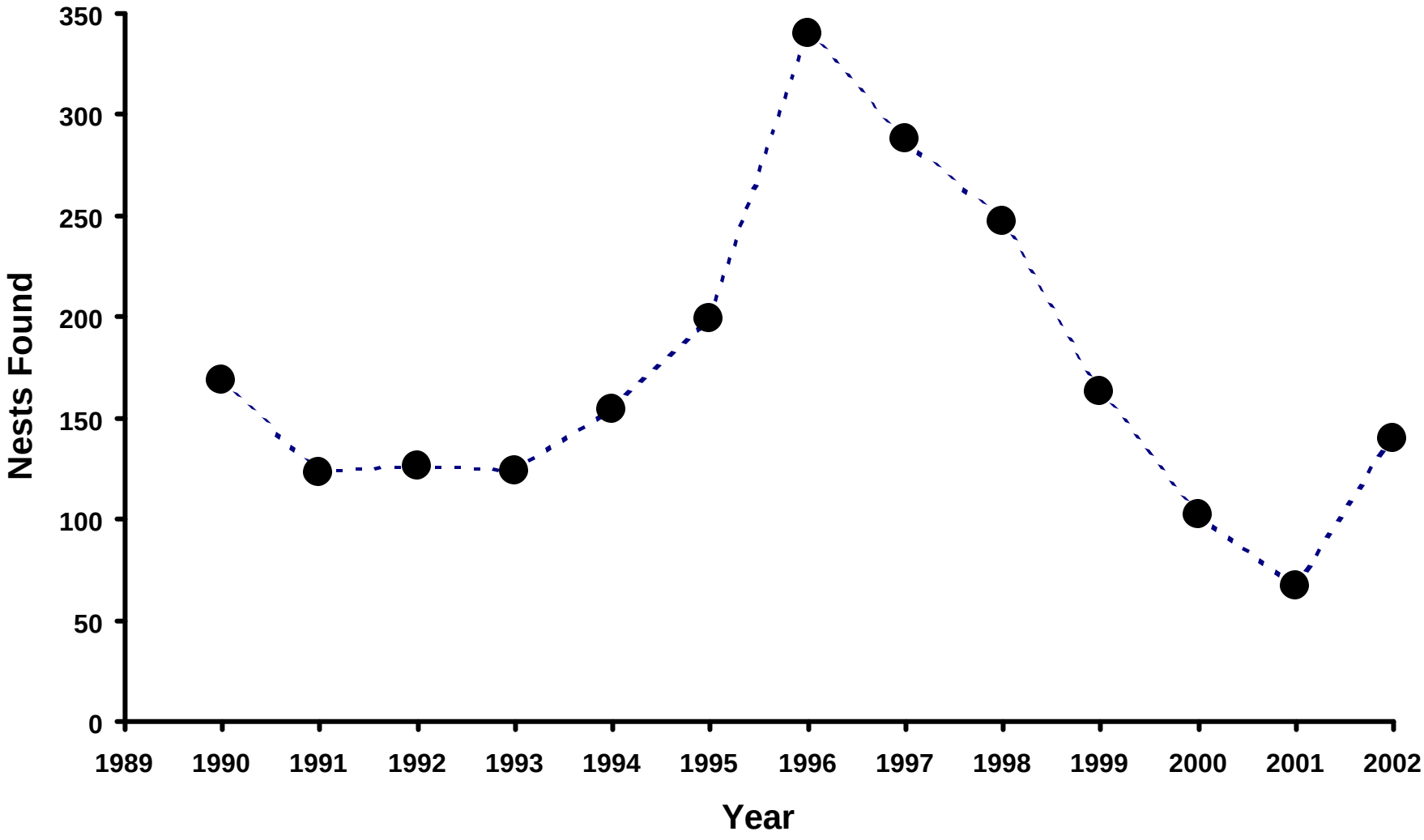

Figure 3. Total Black-crowned Night-Heron nests monitored at Alcatraz Island during 1990-2002.

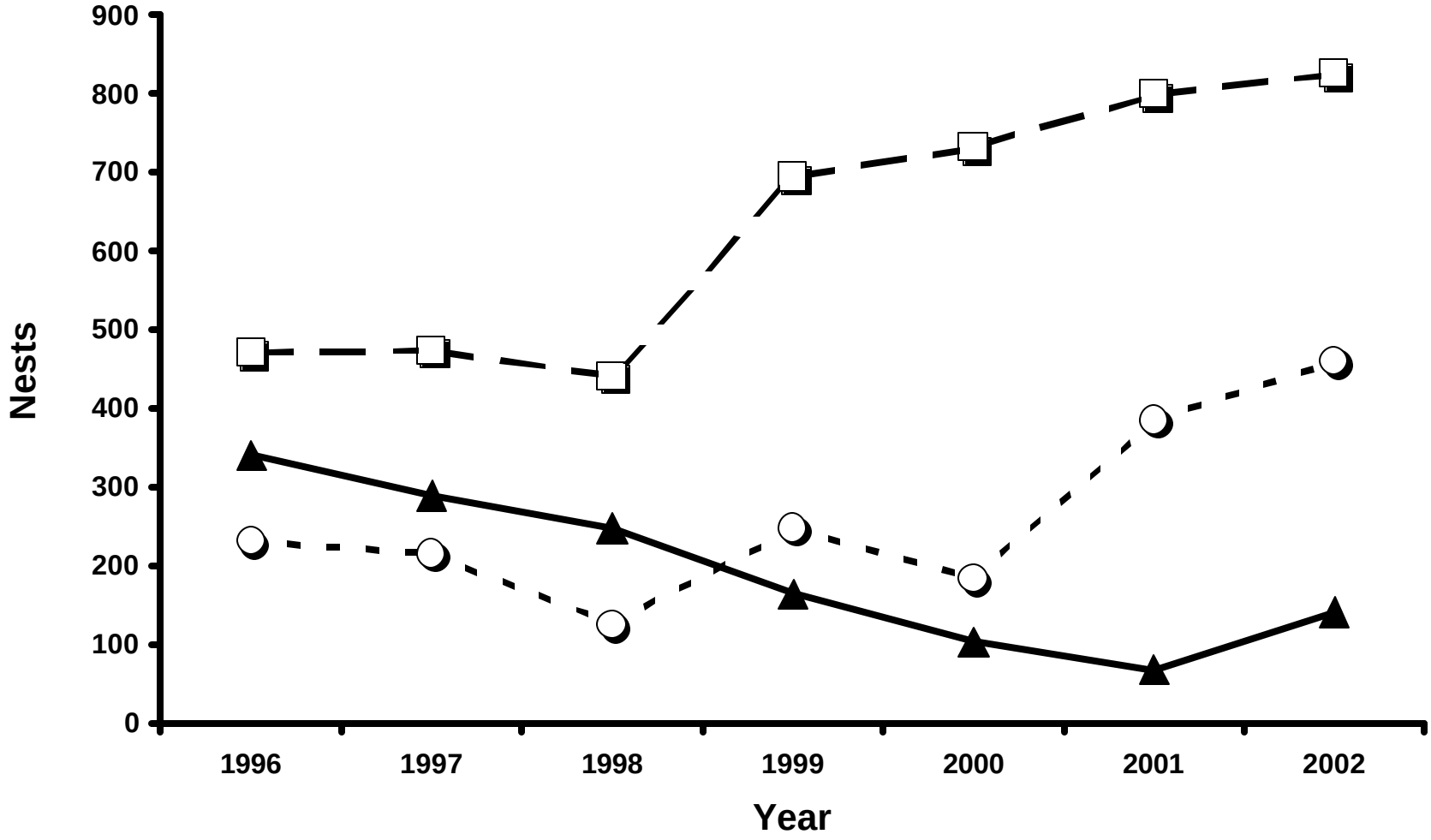

Figure 4. Trends of Western Gull (?), Brandt's Cormorant (?), and Black-crowned Night-Heron (?) nests on Alcatraz Island, 1996-2002 (Western Gull and Brandt's Cormorant data courtesy J. Thayer and B. Saenz, PRBO Conservation Science, pers. commun.).

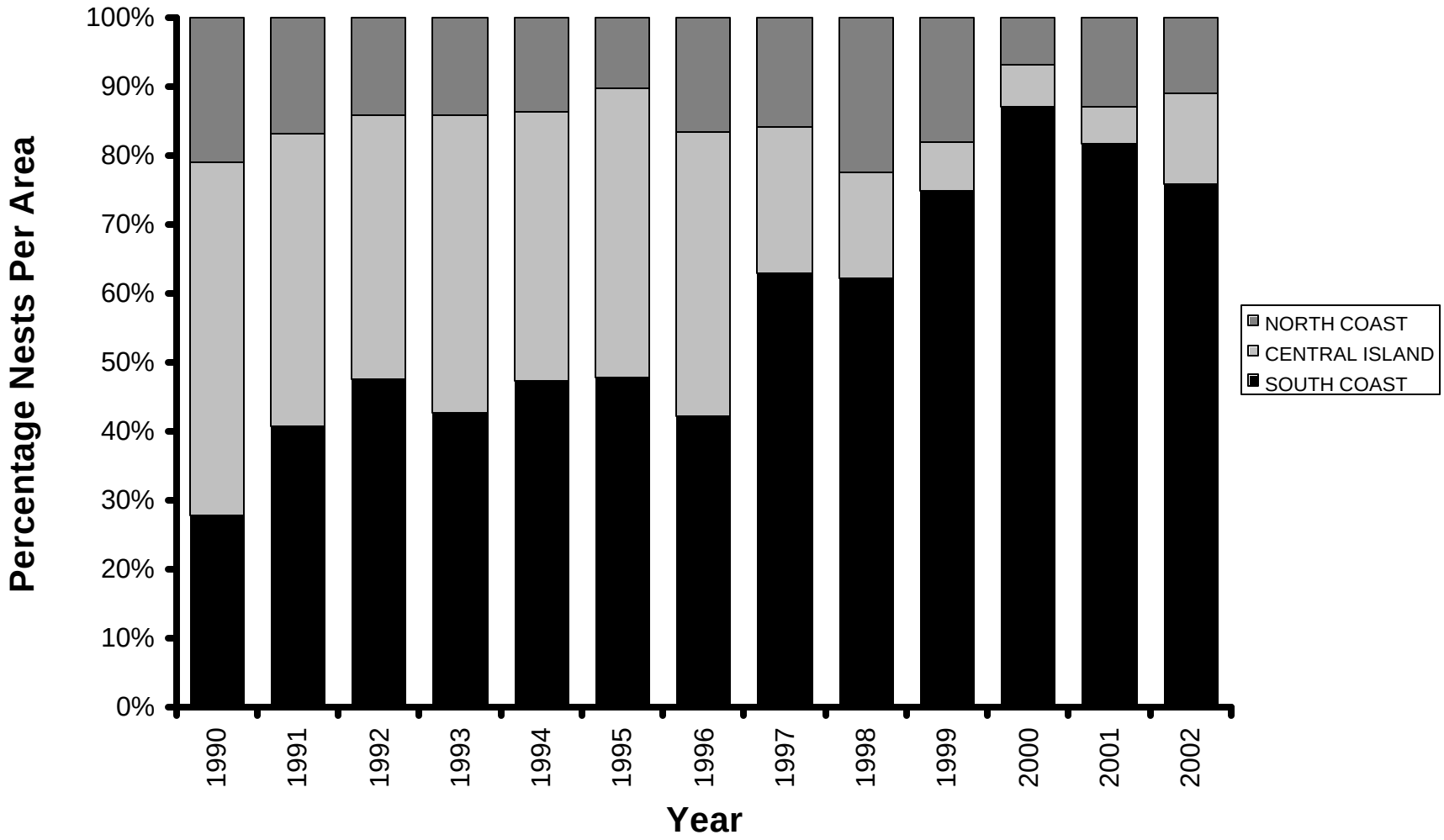

Figure 5. Spatial trends in Black-crowned Night-Heron nesting for Alcatraz Island during 1990-2002: North Coast Area = Foghorn and Power Plant; Central Area = Wall, Shower, Greenhouse, Recreation Yard, and Warden's House; South Coast Area = Auxiliary Dock, Dock, Bench, Rubble, Rubble West, and Tunnel Bush (See Fig. 1 and Table 2).

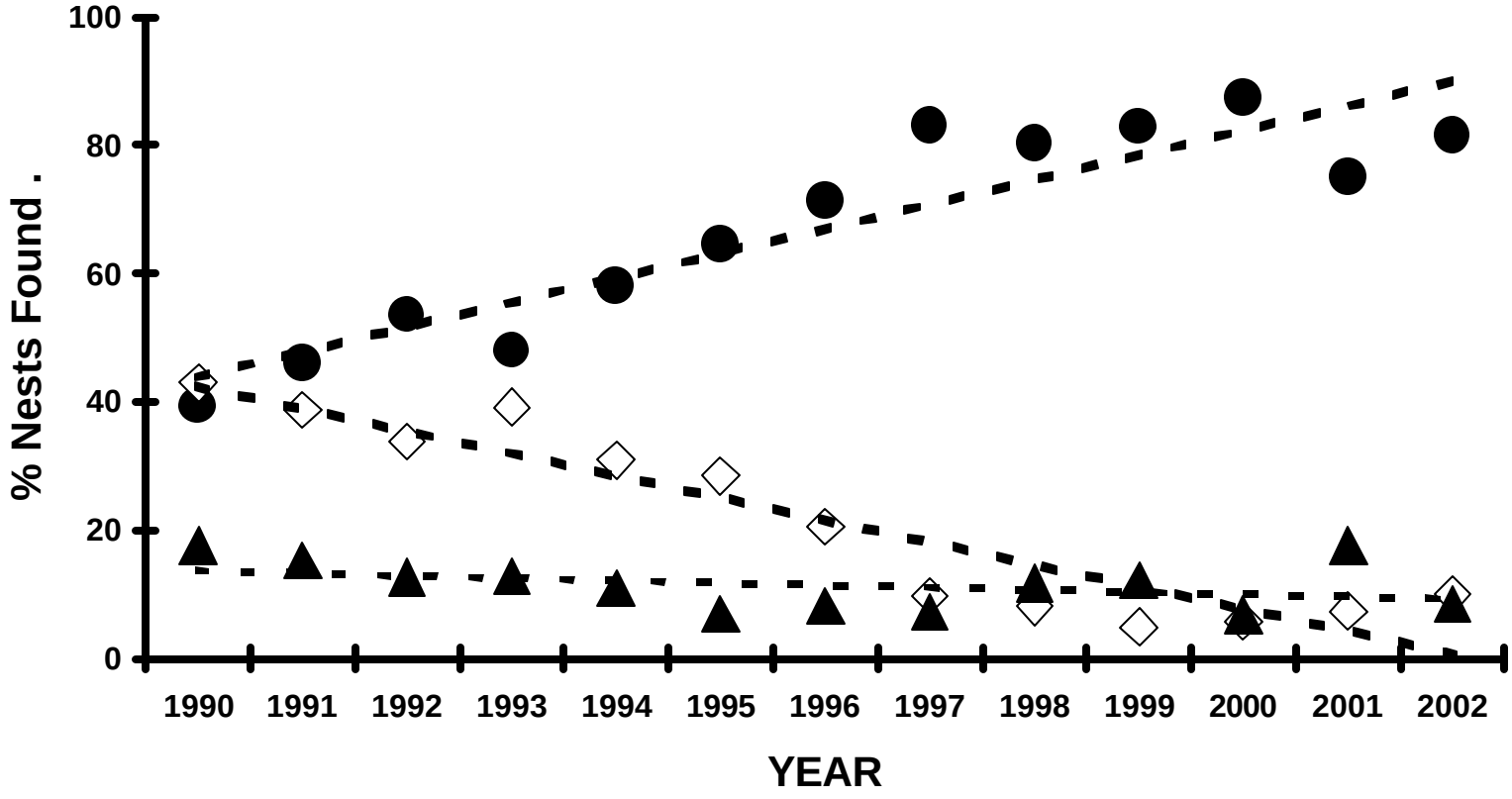

Figure 6. Linear regressions of percentage Black-crowned Night-Heron nests in the North Coast (?) (r = 0.14), Central Island (?) (r = 0.78), and South Coast (?) (r = 0.84) areas of Alcatraz Island during 1990-2002.

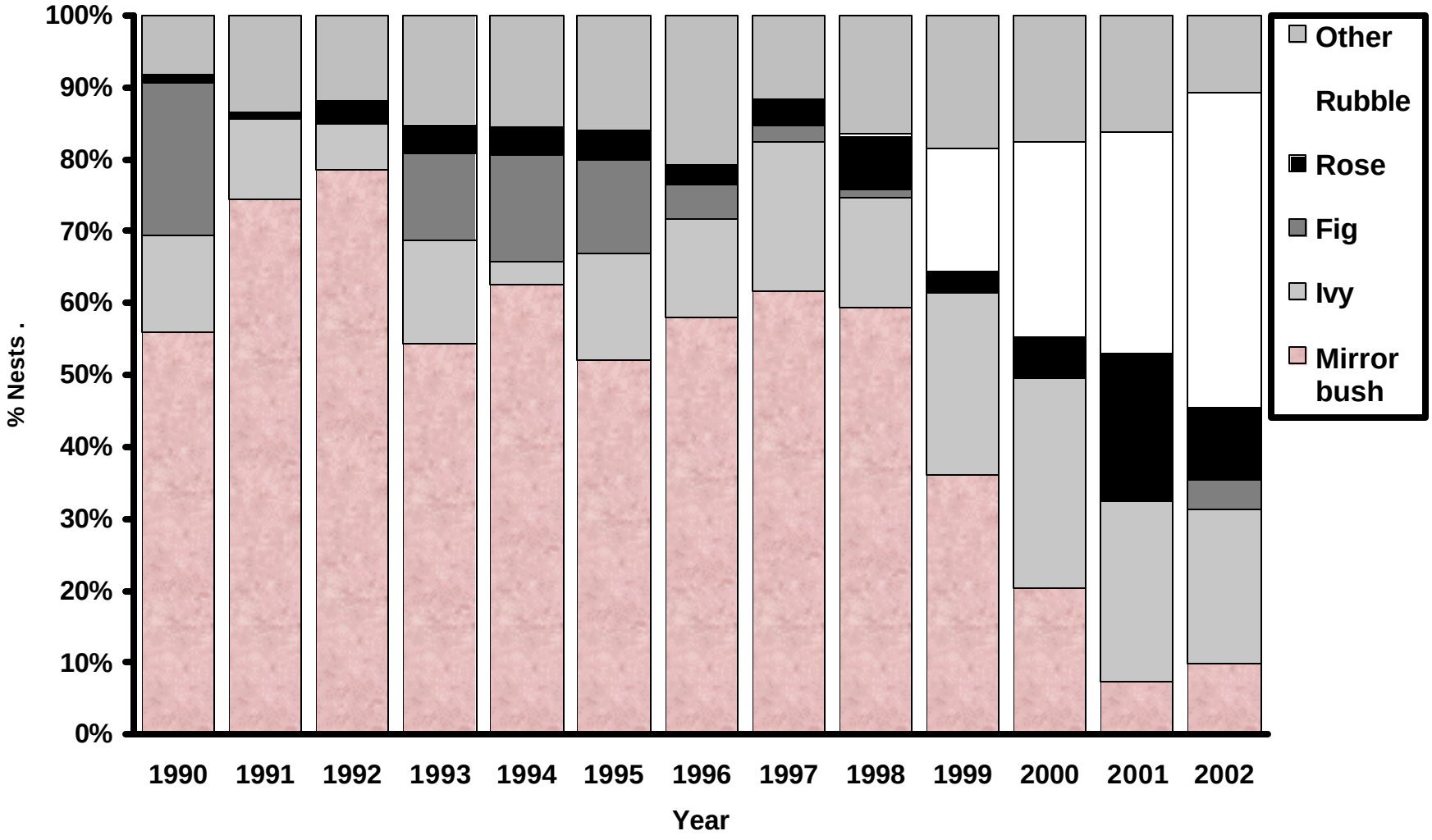

Figure 7. Nesting habitat used by Black-crowned Night-Herons at Alcatraz Island, 1990-2002.