Modeling the regional effects of disturbance at heron and egret colonies

Outcasts on the Wing

by Sarah Millus

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Every year, egrets return to Picher Canyon at Audubon Canyon Ranch's Martin Griffin Preserve (MGP), on Bolinas Lagoon, to build nests and raise their young. It is something that we have come to expect. Around March, their sleek white figures begin to dot the towering redwoods, and exclamations of "The egrets are back!" are shared throughout the canyon.

The herons and egrets that return to this canyon are carrying on a tradition that has lasted for decades. The first record of Great Egrets *(Ardea alba)* on Bolinas Lagoon dates to 1929 (Pratt 1983, Western Birds 14:169-181), when they began reappearing in this area after they were apparently extirpated by plume hunters in the 1880s. Egrets that forage in the lagoon are generally known to nest in Picher Canyon, so it seems likely that egrets foraging on the lagoon in the 1920s were breeding in Picher Canyon. However, herons and egrets do not always return to the same nesting sites or wetland feeding areas year after year.

Heron and egret breeding colonies are dynamic, as the number of nesting pairs fluctuates across years. We have observed both dramatic and gradual changes in heron and egret numbers at MGP. More than 50 Great Blue Herons *(Ardea herodias)* nested in the canyon when monitoring first began in 1967, but their numbers decreased gradually over several decades, and the species was absent in the canyon during the last couple of years. The underlying reasons for such changes are generally a mystery.

We know from other studies that shifts in the breeding distributions of herons and egrets are influenced by several factors (Kushlan and Hafner 2000, Heron Conservation, Academic Press; Kelly et al. 2008, Wetlands 28:257-275). Food resources affect the number of young that parents can raise, and if food resources are poor near a particular colony, herons may not return to breed at that site in subsequent years. Disturbance is another factor that can affect the dynamics and distribution of heronries. Disturbances to heronries range from harassment by juvenile Bald Eagles *(Haliaeetus leucocephalus)* to the removal of nesting trees to changes in nearby human activity.

Herons and egrets are able to withstand some disturbance, but levels that exceed their thresholds of tolerance may lead them to abandon a colony. When disturbed, they will readily move to nearby breeding colonies, or they may leave the wetland area altogether, which could lead to a decline in the number of nesting herons and egrets in the surrounding landscape. Understanding the effects of disturbance at one colony is therefore important for understanding the

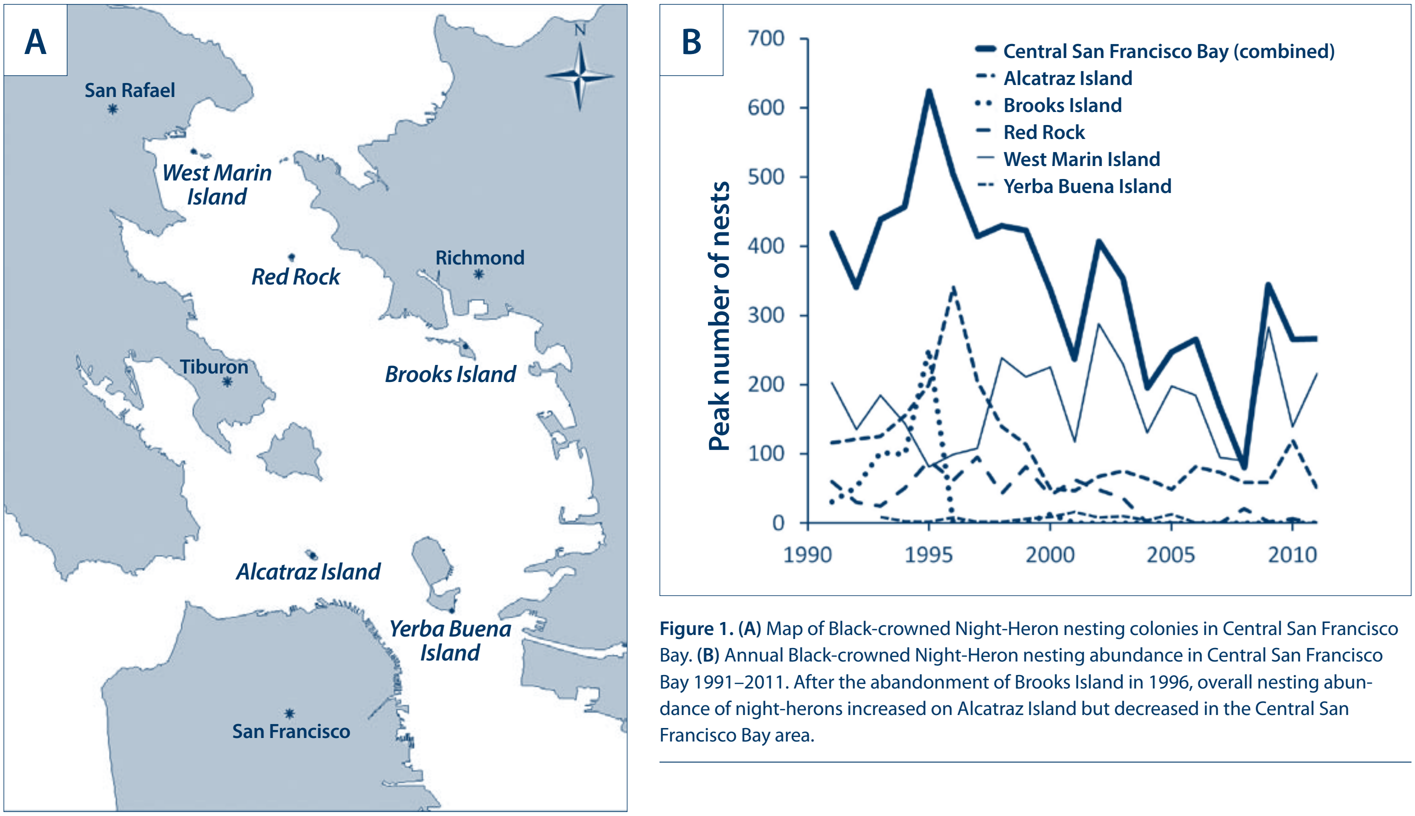

Figure 1. (A) Map of Black-crowned Night-Heron nesting colonies in Central San Francisco Bay. **(B)** Annual Black-crowned Night-Heron nesting abundance in Central San Francisco Bay 1991–2011. After the abandonment of Brooks Island in 1996, overall nesting abundance of night-herons increased on Alcatraz Island but decreased in the Central San Francisco Bay area.

dynamic nature of heron and egret abundance and distribution.

I am currently working with ACR's John Kelly and Emiko Condeso to investigate the effects of colony-size fluctuations on region-wide abundance of herons and egrets. The analysis is based on over 20 years of monitoring data and the work of numerous volunteer field observers who contribute to ACR's Heron and Egret Project, an ongoing effort to track the nesting activities of herons and egrets in the northern San Francisco Bay area. We currently monitor over 150 colony sites, and the resulting data are used to measure changes in the size and location of colonies as well as reproductive success of individual nests.

The responses of herons and egrets to nesting disturbance are illustrated by several examples in our study area. One striking example concerns Black-crowned Night-Herons *(Nycticorax nycticorax)* in Central San Francisco Bay. Brooks Island, located just off Richmond's Marina Bay (Figures 1A and 2), has historically been an important breeding colony site for night-herons. Prior to the breeding season in 1996, a non-native red fox *(Vulpes vulpes)* made its way onto Brooks Island, and that year the colony was abandoned. That same year, overall nest abundance in the Central Bay decreased, although the number of breeding Black-crowned Night-Herons increased on Alcatraz Island (Figure 1B). Presumably, some of the individuals from Brooks Island moved to Alcatraz, but it was not enough to account for the number that failed to return to Brooks Island and too many birds were missing to suspect that they had all died. During the next four years, the number of nests on Alcatraz continued to decrease (for unknown reasons). These decreases had an impact on the total abundance of breeding Black-crowned Night-Herons in Central San Francisco Bay. It is also interesting to note that Black-crowned Night-Herons have not yet returned to Brooks Island (although 13 pairs did nest there in 2000), suggesting that the presence of the fox in early 1996 has had a lasting impact on the total night-heron abundance in Central San Francisco Bay.

Unmasking disturbance effects

The observed effect of disturbance at a particular colony site on the region-wide abundance of nesting herons and egrets leads to several potentially important questions. How does disturbance at one colony affect the nesting abundance of a wetland subregion such as Tomales Bay, the Napa Marsh, or the Laguna de Santa Rosa? How long does it take for a wetland subregion to recover from a disturbance at a particular site? How do multiple impacts at one or more colonies within a subregion affect the recovery? We are addressing these questions using a time series analysis of annual heron and egret nesting abundances in ten wetland subregions of the northern San Francisco Bay area. Time series analysis allows us to evaluate changes in heron and egret nest numbers in each subregion, using data collected as part of the Heron and Egret Project.

Just as everything in nature is connected in space, elements are also connected in time. Nesting abundance naturally varies over time, and this variation is not random. The number of breeding pairs in a particular wetland area in one year is closely related to the number of breeding pairs in previous years. Therefore, the number of nesting birds that return to nest each year cannot be treated as a purely random collection of independent abundances but, rather, represents a string of interrelated data points. The first step of time series analysis involves using mathematical models to describe this natural variation. These initial models form the basis of our analysis and remove the "noise" that results from natural, expected changes in nesting abundance. This variation needs to be accounted for in our models; otherwise it can obscure the effect of a disturbance event. Once normal variation is accounted for, we can then examine the effect of a disturbance.

Figure 2. If disturbed, nesting Black-crowned Night-Herons may not choose to nest at other colony sites in the surrounding wetland landscape but, instead, may move to a distant subregion (Figure 1).

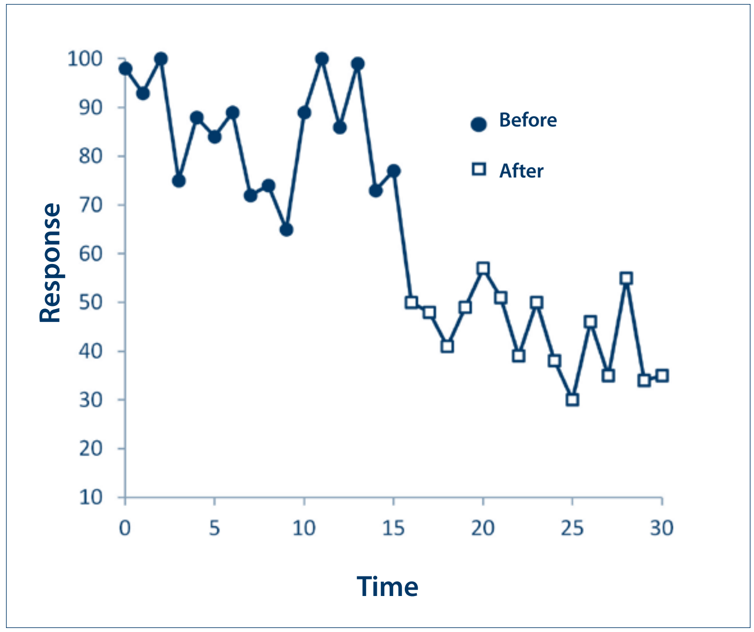

Figure 3. Time series plot of simulated data with a disturbance at observation time 15. Time series analysis controls for the natural variation in a dataset. Adding an intervention component to the model allows us to examine differences in the height and slope of the time series before and after a disturbance.

Significant changes in the number of herons or egrets within a wetland area, such as those caused by a colony-site disturbance, are considered to be an "interruption" of the natural variation in the data. The next step in our analysis is to add a component to the model that describes the effect of the colony-site disturbance. This changes the analysis from a simple time series to an "interrupted time series" analysis. If a colony-site disturbance impacts the number of birds nesting in the surrounding wetland area, the post-disturbance data will have a different level or slope than the pre-disturbance data (Figure 3).

Two parameters estimated from the interrupted time series model allow us to evaluate the level of a disturbance event and its duration. One parameter is ω (omega), which estimates the difference between the data series before and after the disturbance event. It is a measure of how many nests were lost in a given wetland area due to a particular disturbance. The other parameter, δ (delta), can be interpreted as the rate of recovery after a disturbance. The δ value is large if nest abundances after the disturbance made a slow recovery back towards its level prior to the disturbance. Therefore, the δ parameter can be used to make inferences about the resilience of a given wetland area, i.e., its ability to absorb colony-site disturbance and maintain overall nesting abundance within the surrounding area.

Once these parameters are estimated from the time series model, the real fun can begin. We can use these parameters to make predictions about how colony-site disturbances might affect overall nest abundance in any particular wetland area. We will be able to simulate disturbances of different magnitudes, as well as model the effects of repeated disturbances. Also, because the sizes of wetland areas vary across our study area, we will be able to determine the extent to which recovery rates are related to the size of the wetland area. For example, the wetland subregion of Drakes Estero is much smaller than the wetland subregion that encompasses Suisun Bay. Disturbance events of similar magnitude may have dramatically different effects on heron and egret abundance in these two areas. Birds that abandon a colony in Drakes Estero have limited opportunities to establish a new colony site or immigrate to another existing colony in the Estero, because nesting and foraging habitat is more limited in this area. Suisun Bay provides ample habitat for both nesting and foraging, and birds that leave a colony in this wetland region may more easily establish a colony within the same area.

When a heronry is threatened by increased human activity or proposed development, the apparent availability of other possible nesting sites in the area is often claimed as a compensating consideration. Unfortunately, we currently have no scientifically substantiated way to determine the effects of colony disturbance on the surrounding area. These time series models will provide planners and decision-makers with a valuable tool for predicting the extent to which impacts to particular heronries are likely to affect the number of herons and egrets that nest and feed in the surrounding wetland landscape.

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