Disturbance ecology of herons and egrets

Slow Local Recovery

by John P. Kelly

Sometimes, a passing boat is noticed only after it is no longer in view. Tiny waves sweep the shoreline, rise to a brief crescendo, then give way to the persistent ambient conditions of the day. On most days, the wakes of passing boats, along with changes in wind and tidal currents, the daily routines of birds, the secret activities of myriad tiny creatures beneath the surface, and countless other phenomena are lost in the natural complexity that forms and reforms the more conspicuous, emergent displays of wetland life. More rarely, a sudden change in just one thing can destabilize an entire ecosystem.

The important ecological roles of herons and egrets (Ardeidae) as top predators in wetland landscapes may be highly sensitive to sudden changes that occur only rarely within any particular wetland system. Such sensitivity is seldom considered in evaluating species' conservation status, a process that typically targets entire species, subspecies, or genetically distinct populations as units of conservation. Based on such units, which generally extend across huge geographic scales, herons and egrets in North America are assumed to be of low conservation concern (IUCN, International Union for Conservation of Nature: http://www.iucnredlist.org; Reddish Egret *[Egretta rufescens]* is a noteworthy exception, considered vulnerable to extinction along the Gulf Coast of the United States and in Mexico, the Caribbean, and Central America). Even within regional landscapes such as the San Francisco Bay area, the ecological standing of herons and egrets is considered to be dynamic but stable over long periods of time (Kelly et al. 2006, 2007; Kelly and Nur 2015). However, major declines in nesting abundance within individual wetland systems can occur even when populations or regionwide abundances are stable. Therefore, the effective protection of these beautiful birds—and their important roles in sustaining the ecological health of individual wetlands—warrants a much closer look.

Figure 1. Great Egrets are among the Ardeidae whose conservation status ACR has evaluated. Pictured on the shore beyond this tidal flat is Cypress Grove Research Center.

We know that herons and egrets establish nesting colonies not only to secure safe places to raise their young, but also to facilitate efficient access to foraging locations throughout the surrounding landscape (see page 3 box: Subregional Roles of Herons and Egrets). Conservation planning groups involving government agencies, nonprofit organizations, and local citizens tend to coalesce around concerns for the protection of particular watersheds or subregional wetland systems. For example, stakeholder groups have formed to address, specifically, the conservation of Tomales Bay, the Laguna de Santa Rosa, Suisun Marsh, and other wetland subsystems of San Francisco Bay area. At such scales, planning groups make management recommendations that directly affect the ecosystem needs of herons and egrets.

The conservation status of herons and egrets may be the most critical, ecologically, at scales corresponding to the individual wetland systems that provide the resources needed for both nesting and foraging. Within each system, the numbers of nesting birds fluctuate with a rhythm that differs dramatically from the regional or global dynamics of populations, which typi-

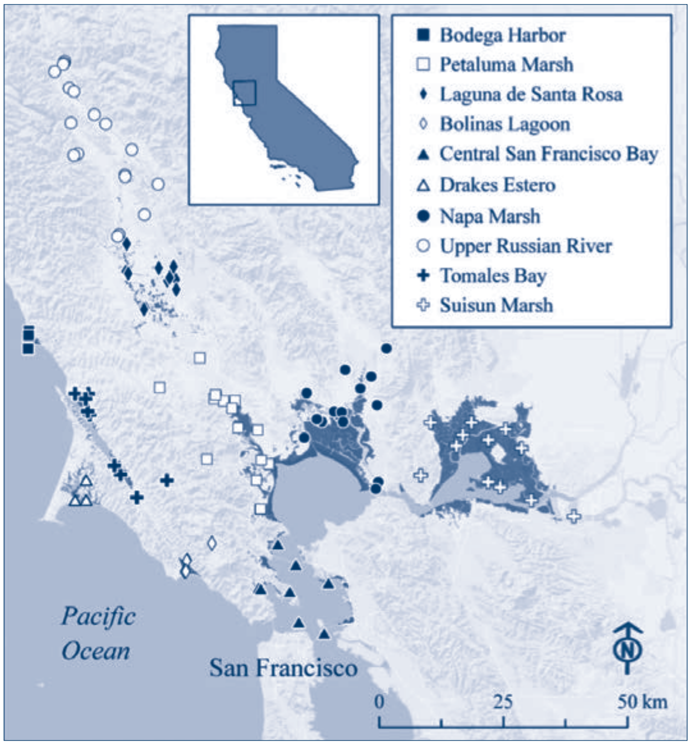

Figure 2. Colony sites used by nesting Great Blue Herons, Great Egrets, Snowy Egrets, and Black-crowned Night-Herons within 10 km of each subregional core wetland system in the northern San Francisco Bay area, California, USA.

Table 1. Wetland subregions in the northern San Francisco Bay area, California, the areal extent of the core wetland habitat considered suitable for foraging by ardeids in each subregion, and the areal extent of the associated landscape within 10 km of the core wetlands (Figure 2).

Wetland Subregion	Core Wetland Area (km^2)	Subregional Area (km^2)
Laguna de Santa Rosa	20.7	1,499
Petaluma Marsh	53.1	1,177
Napa Marsh	129.6	1,342
Suisun Marsh	249.2	1,947
Central San Francisco Bay	12.8	1,298
Tomales Bay	11.	1,222
Bolinas Lagoon	4.7	497
Bodega Harbor	2.4	481
Drakes Estero	10.9	699
Upper Russian River	2.2	1,426

Table 2. Mean nest abundances and standard errors (SE) of colonial ardeid species within subregional wetland systems of the northern San Francisco Bay area, California, 1991–2010 (n = 20).

	Great Blue Heron		Great Egret		Snowy Egret		Black-crowned Night-Heron	
Subregion	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Bodega Harbor	3.6	0.40	11.8	10.43	2.1	13.65	1.3	0.40
Bolinas Lagoon	13.0	0.96	77.2	2.20	4.1	0.76	0.0	–
Central San Francisco Bay	22.9	1.56	120.7	1.90	158.1	5.10	219.3	27.81
Drakes Estero	3.3	0.65	8.4	1.90	0.0	–	0.0	–
Laguna de Santa Rosa	41.4	1.86	55.4	5.26	34.9	16.87	85.1	11.09
Napa Marsh	121.1	10.14	24.2	5.59	106.8	1.71	122.1	9.86
Petaluma Marsh	20.4	1.81	22.1	0.48	10.4	0.92	39.2	4.25
Suisun Marsh	93.4	5.98	424.3	23.45	2.1	0.92	0.6	0.55
Tomales Bay	31.0	2.35	36.4	0.75	0.0	–	0.7	0.22
Upper Russian River	22.8	2.65	2.6	0.48	0.0	–	0.9	0.80
Entire region (all subregions)	372.9	12.72	783.1	27.03	318.5	22.41	469.2	31.83

cally drive priorities for conservation. Similarly, the subregional status of these birds cannot be discerned from changes observed at the colony-site scale, because the trends and fates of individual nesting colonies are averaged out as nesting birds relocate within and between individual wetland systems. Consequently, the rhythm of life most relevant to both the foraging and nesting needs of herons and egrets has remained mysterious—until now.

Conservation status within individual wetlands

I recently collaborated with Sarah Millus (former ACR Biologist) and Emiko Condeso (ACR Ecologist and GIS Specialist) to investigate the effects of sudden major declines in the abundances of four ardeid species within major subregional wetland systems of the San Francisco Bay area (Kelly et al. 2018). We examined the extent to which sudden major subregional declines in nesting abundance, below selected thresholds of annual change, affect the future numbers of Great Blue Herons *(Ardea herodias)*, Great Egrets *(A. alba)*, Snowy Egrets *(Egretta thula)*, and Black-crowned Night-Herons *(Nycticorax nycticorax)*. Specifically, we used time-series models within each of ten wetland systems of the northern San Francisco Bay area to estimate the number of years subregional numbers of herons and egrets need to recover from sudden major declines in subregional nest abundance.

We used the California Aquatic Resource Inventory (San Francisco Estuary Institute 2016) to approximate the boundary and areal extent of the central, "core wetland system" in each wetland subregion (Table 1). Nesting colonies within 10 km of each core wetland system were assumed to be within foraging range of the associated wetlands and grouped to facilitate the analysis of subregional nesting abundances (Table 1; Figure 2).

The locations of all known colony sites in each subregion were determined as part of ACR's ongoing, annual effort to monitor approximately 60 active colony sites each year in the northern San Francisco Bay area (Table 2; Figure 2). Most colony sites are visited at least four times each breeding season, primarily by 60 to 100 qualified field observers who generously volunteer their time to contribute to ACR heron and egret research.

To evaluate the effects of sudden major declines in nesting activity, we analyzed up to ten 20-year time series of annual nesting abundances for each species—one time series for each species in each wetland subregion (Figure 2). Our analytical approach controlled for all trends and other background dynamics in each wetland system, allowing us to estimate the isolated impacts of sudden major declines and associated rates of recovery. We defined thresholds of sudden major decline in a manner similar to defining a 100-year flood (a floodwater level with a 1% chance of annual occurrence): we defined 0.80, 0.90, and 0.95 impact thresholds as "major decline" in annual nest abundance that were more extreme than 80%, 90%, or 95% of the observed changes for each species within each subregion. Therefore, the absolute thresholds of sudden major decline were allowed to differ among species and subregions with different nesting dynamics or levels of tolerance to human activity, potential nest predators, or other sources of disturbance.

Our results further allowed for average interannual movements of nesting birds between subregions and for average rates of recruitment of first-time breeders from other areas. Therefore, we make no claims that subregional nesting dynamics operate independently as closed systems—they definitely do not! As expected, this new look into the dynamics of nesting herons and egrets at scales delineated simply by their access to individual wetland systems and the flow of water across the landscape raises many unanswered questions about mechanisms that might account for the observed impact and recovery rates (see box: "Subregional Roles of Herons and Egrets").

Seriously slow recovery

The predicted time required, on average, for subregional nest numbers to recover to less than 5% of the original impact was 18.8 years for Great Blue Heron, 13.0 years for Great Egret, 7.2 years for Snowy Egret, and 14.5 years for Black-crowned Night-Heron (Table 3; Figures 3 and 4 on page 4). The confidence intervals in our results further suggested the possibility of substantially shorter or longer periods of recovery (Figures 3 and 4). Estimated recovery rates appeared to be faster in subregions with more extensive core wetlands, although this

Table 3. The impacts of sudden major declines in subregional nest abundance on four heron and egret species at three impact thresholds. Years to 95% recovery, with 95% confidence intervals (CI), is the predicted time for the impact to drop below 5% of the initial decline in nest abundance. (Initial impacts are back-transformed from modelled $\log_e$ values; *P [modelled coefficient] < 0.001.)

Species	Number of observed sudden major declines	Initial impact (average % decline)	Year-to-year persistence of the impact % +/- SE	Years to 95% recovery (95% CI)
0.80 impact threshold				
Great Blue Heron	28	-46*	85 ± 3.6*	18.8 (9.0 – 28.7)
Great Egret	8	-69*	79 ± 3.2*	13.0 (8.6 – 17.4)
Snowy Egret	6	-72*	66 ± 7.1*	7.2 (3.6 – 10.9)
Black-crowned Night-Heron	10	-68*	81 ± 5.4*	14.5 (5.3 – 23.7)
0.90 impact threshold				
Great Blue Heron	13	-49*	83 ± 3.9*	15.8 (8.1 – 23.4)
Great Egret	3	-86*	79 ± 3.3*	13.1 (8.4 – 17.8)
Snowy Egret	1	-73*	63 ± 7.7*	6.6 (3.2 – 10.1)
Black-crowned Night-Heron	6	-73*	76 ± 5.7*	11.0 (5.1 – 17.0)
0.95 impact threshold				
Great Blue Heron	9	-61*	78 ± 3.6*	12.1 (7.7 – 16.6)
Great Egret	1	-96*	79 ± 3.2*	13.0 (8.6 – 17.5)
Snowy Egret	1	-73*	64 ± 7.7*	6.6 (3.2 – 10.1)
Black-crowned Night-Heron	3	-81*	74 ± 6.3*	10.1 (4.4 – 15.7)

Subregional Roles of Herons and Egrets

San Francisco Bay and the adjacent Central Valley of California have been recognized as a region of hemispheric importance to ardeids in North America, with critical value to heron species conservation in the Pacific flyway. Because nesting ardeids generally forage within a few to several kilometers of their nest sites, individual wetland systems within a regional wetland complex provide potentially important units for conservation—ecologically reasonable units corresponding to both the scales of hydrologic connectivity that distinguish individual wetland systems and the foraging and nesting requirements of individual herons and egrets. Within particular wetland systems such as coastal estuaries and lagoons, inland lakes, large tidal marshes, riverine floodplains, coastal embayments, and shallow wetland basins, unexpected sudden major declines in heron or egret nesting abundance may have dramatic ecosystem impacts if their collective ecological role as top predators is diminished. Ecological theory suggests that such declines could lead to cascading, top-down effects on the structure of food webs and, ultimately, to the loss of biological diversity. If so, our recent research suggests that system-wide recovery could take a very long time (Kelly et al. 2018).

Nesting herons and egrets respond to environmental changes beyond the immediate vicinity of their colony sites. Patterns of colony-site selection and reproductive success reflect adaptive responses to surrounding landscape conditions within their foraging range (Ardeid 2008: "The Protection of Nesting Landscapes"), to disturbance by potential nest predators (Ardeid 2004: "Vague Consequences of Omnipresence"), to interference associated with nearby human activities (Ardeid 2002: "A Safe Place to Nest"), and to climate change, especially heavy rainfall (Ardeid 2010: "Herons in the Mist").

Herons or egrets may readily abandon their nest attempts in response to changes in habitat conditions at a colony site or across the surrounding wetland landscape (Ardeid 2014: "Where Have All the Egrets Gone?" and "Ripples in the Pool"). After nest failure, or between nesting years, they may establish new nest locations within the same wetland subregion, relocate to a different subregion within the larger regional landscape, or disperse to another region (Ardeid 2012: "Outcasts on the Wing").

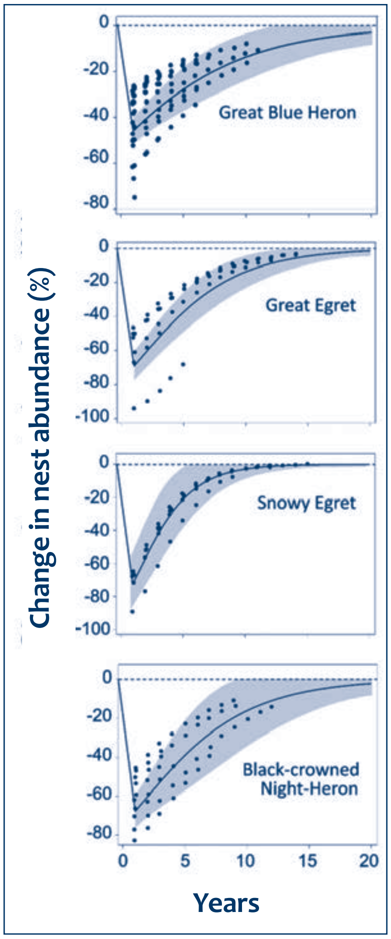

Figure 3. Predicted values (filled circles) of sudden major decline (below the lower 0.80 quantile of standard normal annual variation; Year 1) and subsequent recovery of heron and egret nest abundances over 20 years, within subregional wetland systems of the northern San Francisco Bay area, California. Values represent (back-transformed) percent annual change, relative to underlying background dynamics and trends, which were controlled for and reduced to zero (dashed line). Solid lines represent modeled impact and recovery patterns; shaded areas represent 95% confidence intervals.

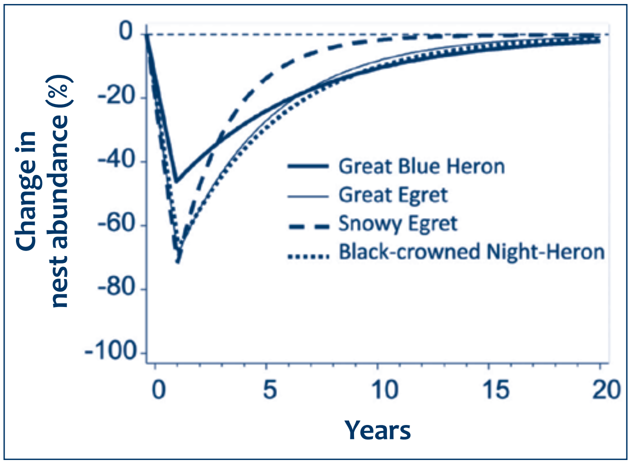

Figure 4. Comparison of recovery rates in subregional nest abundance among four ardeid species after sudden major declines (exceeding the lower 0.80 quantile of standard normal annual variation) within ten wetland subregions of the San Francisco Bay area, California (Table 3). The horizontal dashed line represents full recovery with a stable growth rate of zero, relative to other underlying trends.

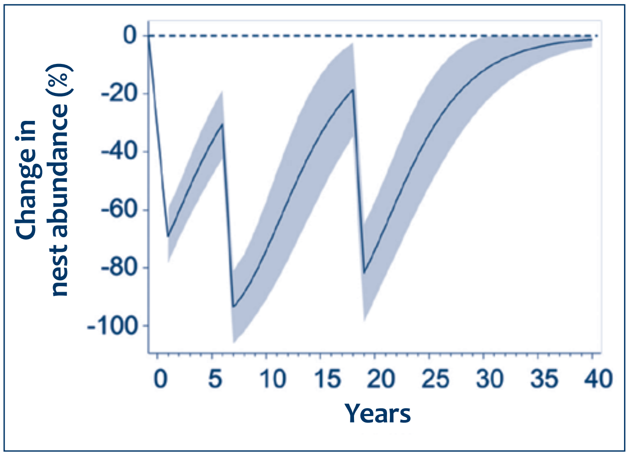

Figure 5. Predicted recovery of Great Egret nest abundance after repeated, major declines of −69%, −96%, and −86% in years 1, 7, and 19, respectively, with 79% annual persistence of the initial ($\log_e$) impact (Table 3), within ten subregions of the San Francisco Bay area, California. The horizontal dashed line represents full recovery with a stable growth rate of zero, relative to other underlying trends

effect was only marginally confirmed by our data and would benefit from additional study.

During our 20-year period of study, Great Blue Herons experienced a substantially higher frequency of sudden major declines than other species, but with significantly lower initial impacts (Table 3). Snowy Egrets exhibited the fastest annual recovery rates and Great Blue Herons exhibited the slowest annual recovery rates after a sudden major decline in nest abundance (34 ± 0.07% and 15 ± 0.04% [SE] per year, respectively). Great Egrets and Black-crowned Night-Herons exhibited intermediate rates of annual recovery (21 ± 0.03% and 19 ± 0.05% per year, respectively). Repeated sudden major declines in nest abundance at intervals shorter than the considerably long recovery times estimated by our results are likely to result in ongoing depression or decline of growth rates over very long periods of time (Figure 5).

We cannot conclusively explain why, based on our results, Snowy Egret nest abundances apparently recover more quickly than other species. However, their faster recovery rates may be associated with their lower sensitivity than other ardeids to boat disturbance and their tendency to select colony sites near developed areas of the northern San Francisco Bay area where they apparently tolerate higher levels of human activity. In addition, the relatively fast recovery rates exhibited by Snowy Egrets may be related to their consistent use of mixed colony sites where the presence of other species provides a continuing nesting stimulus.

Great Blue Herons were subject to more frequent major subregional declines in nest abundance than other species, but with relatively lower initial impact. This is likely the outcome of establishing smaller, more widely distributed nesting colonies than our other study species, possibly in response to higher rates of colony-site disturbance. The relatively slower subregional recovery rates we observed in Great Blue Herons are also consistent with potentially slower recruitment in less conspicuous, more isolated colony sites. If Great Blue Herons establish multiple, smaller colonies in a given subregion, major disturbance at any particular colony site will result in a smaller impact on subregional nest abundance. Among our study species, the relatively lower initial impacts of sudden major subregional declines on Great Blue Heron nest numbers are reflected in relatively stable subregional and regional abundances over more than 25 years (Kelly et al. 2007; Kelly and Nur 2015).

Great Egrets experienced more severe sudden declines in subregional nest abundance than other species. Great Egrets tend to nest in fewer, larger colonies than Great Blue Herons do. Thus, for Great Egrets and other species that typically nest in large colonies, major disturbance at the colony-site level is likely to have a greater impact on subregional nesting abundance.

Everything is connected

The long periods of recovery demonstrated by our study suggest that a sudden major decline in nest abundance in any particular wetland system may suppress the ecological roles of ardeids as top wetland predators for a long time. It is important to emphasize that the gradual recovery rates we observed may be enhanced or further reduced by other processes operating at subregional, regional, or larger spatial scales. For example, the number of nesting birds in a particular wetland subregion might increase if nesting dispersal stimulated by colony-site disturbance in a nearby subregion leads to an increase in local recruitment. Processes operating over larger spatial scales, including changes in population growth, nesting or natal dispersal, birth or death rates, or extrinsic processes such as weather or habitat change, might similarly reduce or enhance predicted subregional recovery rates after a sudden major decline in nest abundance. More obviously, predicted recovery from a sudden major decline in subregional abundance may be limited by concurrent degradation or loss of foraging habitat or by continuing nesting disturbance by humans or potential nest predators.

The similarity of recovery rates across levels of initial impact suggests that the observed rates may reflect species' inherent patterns of behavior or reproduction. For example, limited recovery rates may be "hard-wired" by characteristically low levels of colony-site fidelity, spatial limits of dispersal and intraregional movement, productivity rates and recruitment of new breeders, and the need to limit foraging movements to within a few-to-several kilometers of nests. If so, average recovery rates at subregional scales might be similar among regions or vary over much larger geographic scales. A particularly striking insight from this investigation is that most of the major subregional declines in nest abundance were associated with observed or inferred disturbance at a single colony site (Great Blue Heron: 68 ± 9% of sudden major declines, n = 28; Great Egret: 88 ± 13%, n = 8; Snowy Egret: 67 ± 21%, n = 6; Black-crowned Night-Heron: 100%, n = 10). Disturbances include interference by various nest predators, nearby human activity, and direct impacts to nesting substrates.

Sudden major declines in heron and egret nest abundances are generally noticed only after many birds have departed and are out of view. Our results reveal the persistent long-term effects of major nesting disturbance on individual wetland systems. Given such risks, this work provides a strong rationale for protecting the nesting herons and egrets that enrich individual wetland systems.

John P. Kelly, PhD, served as ACR's Director of Conservation Science until his retirement in 2018.

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ACR's "Pirate's Code"

In 1989, we published ACR's first issue of The Ardeid. Since then, this annual account of conservation science and stewardship at ACR has become a valuable bridge linking our technical contributions to the practical interests of citizen conservationists, decision makers, and dedicated observers of nature. Sometimes, direct action by ACR fills a similar gap to help protect the natural areas we love or to make sure our scientific contributions are clearly understood, here and in other parts of the planet. This is exactly what I love about ACR: full-spectrum conservation science, from original research to public policy and hands-on stewardship, and from nature education and public outreach to citizen action. Now, with my departure from ACR, my heart is exploding with gratitude and appreciation for everyone involved with ACR. Your amazing hearts and minds have enriched and inspired my life beyond measure. Thank you so much—what a team!

As I reflect on my time at ACR, I immediately think of ACR founder Marty Griffin's many inspiring insights into conservation action, which form a sort of "pirate's code." A key tenet of Marty's "code" that has guided my life at ACR is this: successful conservation is never complete and requires persistent action—as a way of life—fueled by deep personal connections to nature. And what a life! Although I'm sad about moving on, I'm also super excited to see so many new things happing at ACR!

I am especially thrilled to welcome Dr. Nils Warnock to ACR! I cannot think of anyone with a more perfect set of skills or more suitable personal style to lead ACR's "full-spectrum" work in conservation science. Nils arrives as a renowned avian ecologist and conservation scientist with extensive publications based on decades of scientific work, especially on shorebirds and waterbirds. He comes to ACR after eight years of leading Audubon Alaska and its numerous conservation campaigns involving the Arctic National Wildlife Refuge, Tongass National Forest, off-shore drilling, climate change, and several bird conservation initiatives. Nils also brings a ton of ecological knowledge about our region, with a long history of living and working in West Marin, previously serving as co-director of the Wetlands Division at PRBO (Point Blue Conservation Science). Nils and his wife Sarah—who is also a scientist and educator—have moved into ACR's Cypress Grove Research Center and are a fantastic addition to ACR!

Warmest wishes to all! — JK