Research and
Resource Management
at Audubon Canyon Ranch

THE ARDEID

2004

Common Raven behaviors in heronries

Vague Consequences of Omnipresence

by John P. Kelly

It's as if the ravens are not even there. Although Common Ravens fly frequently through some heronries in search of opportunities to prey on eggs and chicks, nesting Great Egrets exhibit little or no defiance. In fact, they seem to show a complete lack of interest or concern. In addition, Great Egrets leave their nests unguarded as nestlings approach three weeks of age, several weeks before young egrets can fly—even though many of these broods are taken by patrolling ravens.

New cohorts of herons and egrets continue to disperse from heronries each summer and to contribute beautifully to the life in our marshes and estuaries. But raven numbers are booming throughout most of the San Francisco Bay area (see *The Ardeid* 2001). Whether heron and egret populations will continue to reproduce adequately under the growing presence of ravens or, alternatively, suffer major declines in productivity has become a common concern among observers of heronries. The particular threat posed by ravens is difficult to understand fully, because most instances of nest predation are phantom events revealed only by sudden nest vacancies.

The wisdom of egret behaviors in the presence of ravens is also mysterious. Their apparent carelessness is consistent among individuals and structured by a long evolution of adaptive responses to complex ecological forces, including nest predation. Scientific attempts to understand how birds respond to the risk of nest predation have failed to discover reliable ways to predict nest success. Therefore, to learn more about the threat of growing raven populations on heron and egret nesting colonies (see *The Ardeid* 2002), I conducted an investigation of predator—rather than prey—behaviors (Kelly et al. in review). Collaborators included ACR's Katie Etienne, Jennifer Roth of PRBO, several ACR field biologists, and numerous volunteer observers. Specifically, we asked: under what conditions and to what extent do ravens exploit heronries for food?

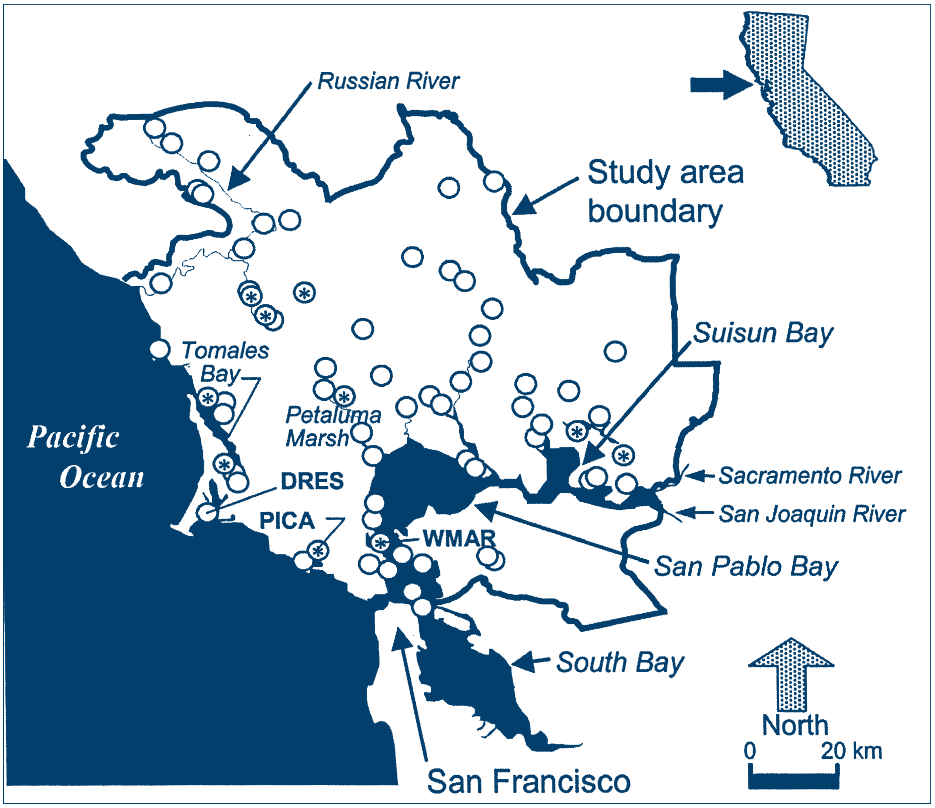

Figure 1. Study area and heronries (circles) in the northern San Francisco Bay area, including colony sites for extended watches (*) and intensive observations of raven activity (PICA: Picher Canyon; WMAR: West Marin Island; DRES: Drakes Estero).

Measuring every move

From 1999 through 2003, Audubon Canyon Ranch field observers measured nest mortality and raven occurrence at all of the known heronries in the northern San Francisco Bay area (Figure 1). At ten of these sites, we conducted two all-day watches for raven activity. We then selected three heronries with resident ravens for more intensive study: (1) ACR's Picher Canyon, near the shoreline of Bolinas Lagoon, where Great Blue Herons, Great Egrets, and Snowy Egrets settle among the branches of coast redwoods in the bottom of a narrow canyon; (2) Drakes Estero in the Point Reyes National Seashore, where nesting Great Egrets and Great Blue Herons crowd into a small patch of bishop pines surrounded by grazed prairie grasses and vegetated dunes; and (3) West Marin Island, a 2.7-acre "rock" in the Marin Islands National Wildlife Refuge just off the eastern Marin County shoreline, where a blend of California buckeyes and woody shrubs often supports the San Francisco Bay area's largest concentration of nesting Great Egrets, Snowy Egrets, Black-crowned Night-Herons, and Great Blue Herons (see *The Ardeid* 2003).

At each of the three heronries selected for close study, we recorded detailed information on raven occupancy, landings, patrol flights, and interactions with other species. At five-minute intervals during hundreds of two-hour observation periods, we recorded the presence of

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Cover photo: Common Raven by Peter LaTourrette ◗ Ardeid *masthead Great Blue Heron ink wash painting by* Claudia Chapline

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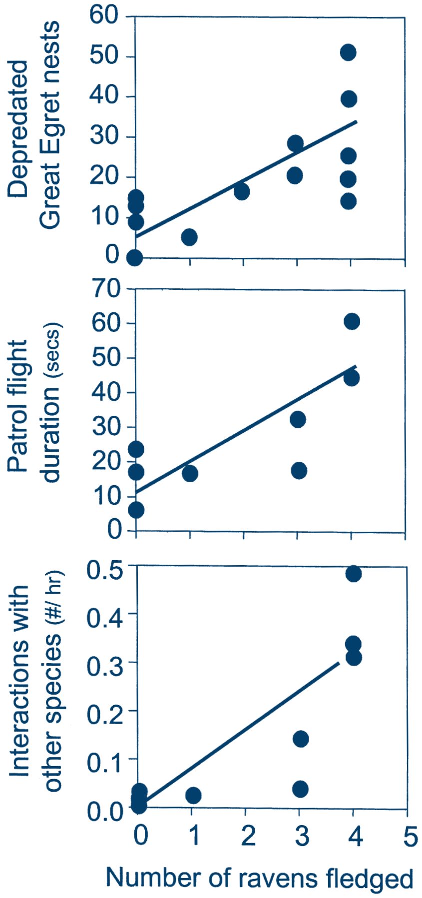

Figure 2. Raven predation on Great Egret nests, length of raven patrol flights, and number of raven interactions with other species increased significantly ($P < 0.05$) with increased raven productivity.

ravens in and near colony sites, identified perching substrates, and noted their positions above or below the tree canopy or on open ground. We measured how long ravens remained at each landing site and estimated their distances to heron or egret nests. Whenever a raven landed in or near a nest, we recorded the nest contents, nesting stage, age of chicks, and number of adult herons or egrets flushed from the area. For each patrol flight, we recorded the time of day, flight duration, height above nests, and alert responses of adult or nestling herons or egrets. When ravens interacted with other bird species, we determined which individuals were dominant and subordinate, the duration of chases, and other details. And of course, we recorded any evidence of nest predation. From these data, we looked for evidence that the nest predatory behaviors of ravens might be influenced by their foraging experience, energy needs, time of day or season, or the availability of prey.

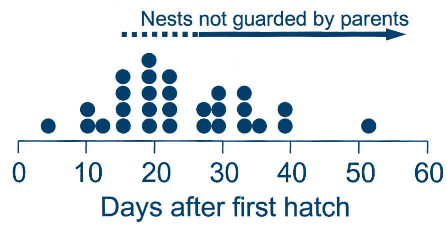

Figure 3. Great Egret nest failures known to have resulted from raven predation peaked as nestlings approached three weeks of age, at ACR's Picher Canyon, 2000-2001.

Evaluating occurrence

Our surveys revealed substantial nest predation by ravens at some heronries in the region but high variability among colony sites—even though ravens are common throughout the San Francisco Bay area. We estimated a regional average of only about one raven occurrence in each heronry every five hours and detected ravens in only about one-fourth of the heronries each year. At Picher Canyon, resident ravens were present less than 5% of the time, but ravens occupied colonies at West Marin Island and Drakes Estero about 30% of the time. The resident ravens occupied all three sites of intensive study more often after mid-June, often in pairs or accompanied by fledgling ravens. Keep in mind, however, that ravens occurred only rarely at most other heronries.

Resident ravens preyed on about 27 Great Egret nests per year at West Marin Island, 20 nests per year at Picher Canyon, and only two to three nests per year at Drakes Estero. Great Blue Heron nest mortality was less than two nests per year at each site and, for most of these, we did not determine the cause of failure. Of 11 instances of complete colony site abandonment in the region, only one—at a site with nesting Great Blue Herons and Great Egrets—was associated with repeated heavy disturbance by ravens, and a single Great Blue Heron nest was established there the following year.

The low regional rates of raven occurrence and nest predation in heron and egret colonies were associated with recent influxes of ravens. If ravens move into an area without prior experience in heronries, they may exhibit "neophobia" for the first few to several nesting seasons. Neophobia is a characteristic cautiousness toward novel food items that subsides as ravens learn through experience not to fear what may later become important food. Because nesting ravens occupy the same home ranges across years (see article on page 3), nest predation in waterbird colonies by new resident pairs of ravens might increase as neophobia subsides.

We did not find significant annual increases in nest predation, but we did find significant annual increases in raven predatory *behaviors:* longer patrol flights, more landings, more frequent movement among landing sites, and more flushing and harassment of nesting Great Egrets. In addition, recovered (fresh) prey remains at the Marin Islands suggested increasing predation of *adult* Snowy Egrets: ravens killed at least four adult Snowies in 2000, seven in 2001, 15 in 2002, and eight in 2003. On one occasion, ACR biologist Mark McCaustland watched in awe as a raven chased an adult Snowy Egret to the ground and killed it. Such trends in behavior are consistent with the attenuation of neophobia in adult ravens and suggest that nest predation might increase annually for some years after ravens begin to occupy heronries.

The notion that ravens might become more daring predators across years is consistent with previously known behaviors. For example, ravens may have difficulty overcoming neophobia by their typical means of approaching slowly (Heinrich 1988, *Condor* 90: 950-952), because egrets build their nests in isolated locations in the nest-tree canopy. Ravens also require unusually long periods of time, under experimental conditions, to accept carcasses of large birds (Heinrich et al. 1995, *Auk* 112: 499-503). Perhaps most importantly, however, the risk of major injury if egrets become defensive may be enough to prolong their neophobic behavior.

Assessing predation risk

The lack of annual increases in nest predation at the three study sites, in spite of annual increases in associated behaviors, suggests that resident ravens may interfere with the activities of other nest predators, such as raccoons, owls, or raptors. Ravens were dominant in 93% of interactions with visiting bird species such as Osprey, Golden Eagle, Red-tailed Hawk, Peregrine Falcon, and American Crow. In one instance, a Red-tailed Hawk that was flushing egrets from their nests at the Marin Islands was harassed repeatedly by the resident ravens until it left the area. Although ravens often chase visitors away, they also respond opportunistically to nest distur-

see Omnipresence, *page 5*

Home-range dynamics in western Marin County

The Spatial Dimensions of Raven Life

by Jennifer E. Roth

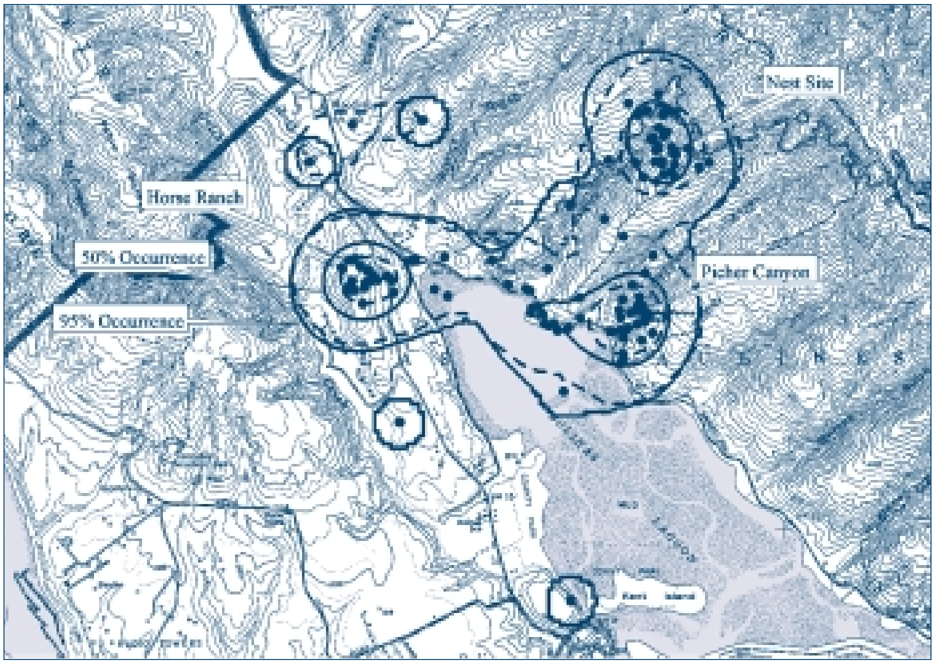

Figure 1. Locations, centers of activity (50% occurrence), and home ranges (95% occurrence) of the female (dashed lines) and male (solid lines) ravens nesting near ACR's Picher Canyon heronry. Unlabeled outlying areas are isolated portions of home ranges.

Early one morning, a pair of ravens flies over the heron and egret colony at ACR's Picher Canyon in search of unattended eggs or young chicks. At Point Reyes National Seashore, ravens soar routinely over dune beaches in search of Snowy Plover nests. Meanwhile, at Tony's Seafood Restaurant on Tomales Bay, a pair of ravens lingers each day in the vicinity of a nearby dumpster. What impact is raven predation having on heronries and rare bird species? What factors are influencing their movements and use of the landscape? These questions prompted us to begin radio-tracking breeding ravens in western Marin County in order to learn more about their impact on sensitive bird species and the factors affecting their distribution (Roth et al. 2004).

Radio-tracking

We captured and attached backpack-mounted radio-transmitters to 16 adult ravens from 15 resident pairs, including both members of the pair residing near Picher Canyon. Capturing ravens was one of the most difficult parts of the study, and we went to great lengths to outsmart these intelligent birds. We started by identifying birds that we were interested in studying and then watched them for several days to learn more about their habits and decide on a suitable trapping location. Once we decided to attempt a capture, we rose several hours before dawn to place the bait and hide our traps and ourselves before first light; the birds would avoid the area for days at the first hint that something was amiss. We hid in bushes and ditches, covering ourselves with branches and dried grass. We often spent several hours in our makeshift blinds before the ravens came near the bait. Ravens are surprisingly cautious around unknown food sources, often approaching the area and backing away several times before eating anything. Meanwhile, we waited breathlessly as they approached the traps or moved into a position where we could shoot a net over them. Our disappointment over near misses was tangible.

On one occasion, a bird that discovered our traps and escaped without being captured flew into the air, circling and calling angrily. Ravens came from all directions. We soon had a large group of ravens circling the area and calling. The warning had gone out! Conversely, imagine our excitement each time we handled one of these large, intelligent birds. Each bird responded differently to being captured; some birds struggled and others quietly observed us. Each release was followed by a few tense moments as we watched to see whether there would be any problems with the harnesses we used to attach the radio-transmitters to the birds. Fortunately, all radio-tagging activities were successfully completed without mishap, but the challenges of following their movements were just beginning.

We radio-tracked each bird for one to three years. Each time we detected a bird, we mapped its location on a topographic map and recorded information on behavior and habitat use. For example, we recorded birds flying over grazed grasslands, foraging along beaches, attending nests in cypress trees, and roosting in pine groves. We also mapped nest sites and concentrated food sources in the area. We used the data we collected to estimate the home-range size of each bird and to evaluate some of the factors likely to affect home-range size and space use within home ranges.

Home-range size

A home range is the area used by an animal during normal activities such as food gathering, mating, and caring for young. We measured each home range by calculating the area that

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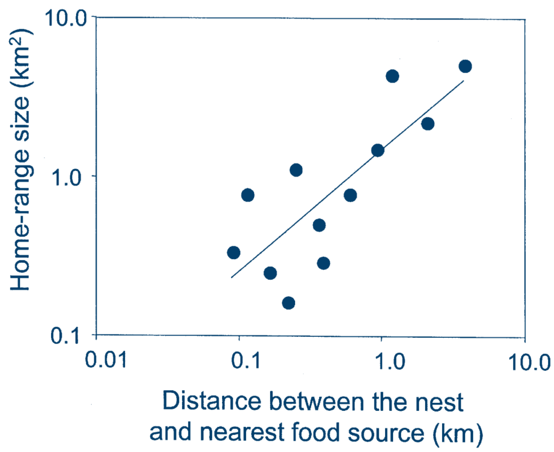

Figure 2. Raven home-range size increases with the distance between the nest and the nearest concentrated food source ($P < 0.05$). Labels indicate the home ranges of ravens occupying familiar locations in western Marin County. The male raven at Picher Canyon was not included in the analysis. Note the log scale on both axes.

encompassed a 95% probability of an individual raven's occurrence, assuming that this area would include all normal activities and exclude rare excursions to more distant areas (Figure 1).

Home-range size was highly variable for the ravens in our study (Figure 2). Sizes ranged from 0.2–4.9 km^2 for females and 0.3–4.9 km^2 for males. The home ranges of the Picher Canyon pair were large compared to other pairs: 4.2 km^2 for the female and 4.9 km^2 for the male.

Many factors may contribute to variation in home-range size among individuals. For example, food supply, competition for food, territoriality, vegetation type, and body size might influence the distances birds must travel. We tested the possibility that differences in sex and distance to important sources of food could explain the large differences in home-range size among ravens in western Marin County.

Sex differences

Sex may influence home-range size in birds when there are differences in body size or behavior between females and males. When males and females differ greatly in size, associated differences in agility and power might allow them to compete less for particular prey or perhaps increase their collective menu of available prey. However, male ravens are only slightly larger than females. Nonetheless, we expected to find a difference between female and male home-range sizes during the breeding season due to differences in behavior between the sexes: females are largely responsible for incubation and males leave the vicinity of the nest to forage while females are attending the nest. Contrary to our expectations, home-range size did not differ significantly between female and male ravens in our study. Also, we did not find a significant difference in the distribution of locations for the female and male of the Picher Canyon pair (Figure 1). It may be that sex roles do not differ enough during the breeding season to affect overall home-range size in ravens. Alternatively, the similar home-range sizes between male and female ravens may reflect their tendency to interact frequently with their mates through courtship, pair-bond reinforcement, increased vigilance by the male during egg laying and incubation, or other social behaviors associated with nesting (Boarman and Heinrich 1999).

Distance to food sources

In general, prey abundance and distance to food and water influence home-range size and movements in birds. Besides preying on egret eggs and chicks, ravens in our study fed on small mammals and reptiles; grain, calf carcasses, and afterbirths found at many local dairies; human refuse at beaches, parking lots, and dumpsters; and eggs and young of other birds in the area. On several occasions, we even saw ravens harass Turkey Vultures until they regurgitated their food. The ravens were able to catch the regurgitations in mid-air! However, despite the wide variety in raven diets and some unusual foraging behaviors, home-range sizes are most likely to be influenced by the locations of stable, concentrated sources of food.

We determined the distance between each raven nest and the nearest ranch, human food source, or waterbird colony in order to evaluate the influence of concentrated food sources on home-range size. We found a general trend indicating that ravens nesting farther away from concentrated food sources had larger home ranges (Figure 2). For instance, the Picher Canyon ravens nested about 1 km away from the heron and egret colony, which was the nearest concentrated food source to their nest, and they occupied relatively large home ranges compared to other ravens in western Marin County (Figure 2).

Space use within home ranges

Birds are likely to use some areas more intensively than others due to the patchy distribution of food and habitat areas suitable for feeding, caching food, and nesting. We evaluated space use within home ranges to determine whether ravens' locations exhibited random, uniform, or clumped distributions. We also estimated the size of core areas or centers of activity, defined as areas with a 50% probability of an individual raven's occurrence (Figure 1). We found that locations of females were significantly clumped within 83% and 100% of home ranges in 2000 and 2001, respectively. Males were more variable in their use of space, with locations clumped in only 38% and 44% of home ranges in 2000 and 2001, respectively.

We used these data to determine the relationship between centers of activity, nest sites, and concentrated food sources. All 16 of the radio-tagged birds centered their activities around their nest sites. In some cases, there was a concentrated food source within that center of activity. Other birds had two centers of activity, with one centered around the nest site and one centered around a concentrated food source. The Picher Canyon ravens were unique among the individuals we studied in having three distinct centers of activity that centered around (1) their nest site, (2) the Picher Canyon heron and egret colony, and (3) a nearby horse ranch where they could rely on a daily supply of grain at feeding time (Figure 1). These activity centers were separated by habitat areas that the ravens only rarely occupied.

Annual variation

Like most things in nature, food supply, habitat quality, and other factors that affect home-range use, may vary from year to year, causing corresponding changes in home-range size. We compared home-range sizes between years and found no significant differences-large home ranges remained large and small ones remained small. However, there were significant small-scale shifts in home-range placement for most females (67%) and males (63%). These shifts were associated with changes in nest location and the distribution of desirable food resources between years. Given the

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apparent association between ravens and concentrated food sources in the area, variation in the size and placement of home ranges likely reflected variation in grazing or harvesting rotations on ranches, the distribution of and access to human foods and garbage, and the seasonal timing and reproductive success of nearby waterbird colonies.

It may be no surprise that the way in which ravens are distributed across the landscape is related to both natural and anthropogenic features of the environment. Raven populations are increasing in many parts of the San Francisco Bay Area (Kelly et al. 2002; see *The Ardeid* 2002) and throughout the western United States (Sauer et al. 1997). Their successful adaptation to human-dominated landscapes has likely been a major contributing factor to these population increases, and such adaptations are evident in the home-range dynamics of individuals ravens. Because ravens structure their lives, in part, around ours, human land use has become an important consideration for resource managers concerned with the effects of increasing raven populations on sensitive species (Boarman 2003). Such concerns suggest that fundamental changes in how we manage agricultural, recreational, and urban environments may be necessary to control the effects of growing raven populations. ◗

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bances by other predators or humans. We did not test directly whether ravens influence other nest predators, but our results suggested that ravens might reduce or displace the nest predatory activities of other species: raven predation on nestling Great Egrets at Picher Canyon did not differ significantly from 1968–1979 predation levels (Pratt and Winkler 1985, *Auk* 102: 49-63), when ravens were not present (P=0.56).

One consistent pattern we found was that ravens with large families engaged in more nest predatory activity (Figure 2, page 2). This suggests that the extent of raven predation depends on the food demand of resident ravens. If so, nest predation might be managed effectively by limiting raven reproductive success. However, this interesting possibility has not been tested.

At the Marin Islands, we surveyed prey remains in the vicinity of the raven nest and in a cache and shell dump area used routinely by the resident ravens. The results of these surveys, and the timing and rates of nest predation on Great Egrets, indicated that the resident ravens obtained most or all of their energy needs from the heronry. Such dependence on the heronry for food is consistent with the apparent link between predatory activity and food demand in resident ravens, but contrasts strongly with low rates of nest predation at most other colony sites in the region. At other sites, alternative food sources may be more available. For example, resident ravens at Picher Canyon spend much of their time feeding at a horse ranch approximately 2 km from their nest site and the heronry (see article on page 3).

PHIL NOTT

Color-banded Common Raven at Abbotts Lagoon, Point Reyes National Seashore.

In general, ravens were more likely to occupy heronries after 10 AM and before 3 PM. This suggests possible early morning foraging for other available food, such as road kills, or improved opportunities for nest predation with midday declines in colony attendance by adult herons and egrets. In contrast, West Marin Island ravens were present continuously through the day, spending little or no time patrolling other areas for food. They were also more likely to occupy colony positions below the nest-tree canopy in early morning, perhaps foraging for fallen chicks. However, the overall risk of nest predation in heronries was best revealed by the prevalence of raven *activities* (such as number of landings)—not by how often ravens were present.

Predation of Great Egret nests was most likely early in the post-guardian period, when parents are absent and nestlings can be taken easily by ravens (Figure 3, page 2). Interestingly, the timing of nest predation by ravens at Picher Canyon did not differ from that measured for 1968–1979 (Pratt and Winkler 1985), when ravens were not present ($P > 0.91$). So the timing of nest predation reflects a general pattern of vulnerability rather than the timing of raven predation per se.

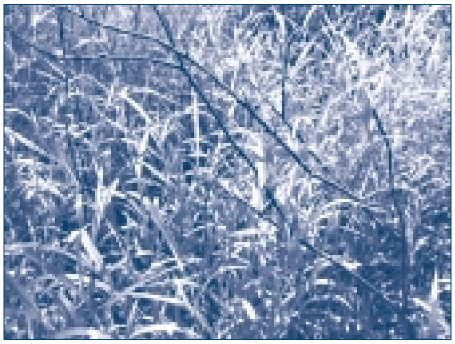
Most observers have noticed that ravens are now present throughout our region and that their overall numbers are increasing. But our closer look at raven behavior suggests that we should be cautious about assuming increases in nest predation in heronries. On the other hand, where ravens have been present for only a few to several years, nest predation might increase with continuing declines in neophobia. To further complicate things, whether ravens add to, displace, or buffer nest predation by other species remains a mystery. As a result, the extent to which ravens occupy heronries may not closely reflect predation risk.

For those who watch the lives of ravens with particular interest, it should be no surprise that their behavior challenges as well as inspires our understanding of nature. In assessing the risk of raven predation, herons and egrets as well as human observers should look beyond the mere presence of these prominent predators. ◗

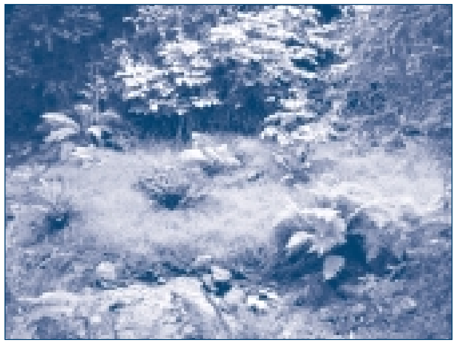
ACR's Bolinas Lagoon Preserve as a test area for regional conservation

Eliminating *Ehrharta*

by Daniel Gluesenkamp



Ehrharta erecta.



Ehrharta covering native habitat.

Pike County Gulch.

In 1930, near the University of California Berkeley campus, an alien invader escaped from a government-sponsored genetics experiment. Although the escapee was a genetically natural (not genetically modified) species, created by evolution, its escape into a new land has had serious consequences to the natural inhabitants of our region. In the decades since, the green monster has spread quietly, wiping out resident flora and fauna as it invades, and is now on the verge of taking over much of western Marin County. The invader is a South African grass named *Ehrharta erecta*, and this article tells the story of Audubon Canyon Ranch's efforts to understand and defend against its spread.

Ehrharta erecta is a highly invasive perennial grass native to South Africa. The species was part of an experiment at the U.C. Berkeley botanical garden investigating whether increasing chromosome numbers increases invasive ability; as it turns out, *Ehrharta erecta* was tremendously invasive without any alteration whatsoever. By 1950 the species was abundant at the U.C. Berkeley campus, and in 1996 the tremendous abundance of *Ehrharta erecta* in San Francisco natural areas compelled recognition of the species as a major conservation concern (Sigg 1996). *Ehrharta erecta* is currently invading western Marin, with large populations in Olema Valley, along the Panoramic Highway on Mt. Tamalpais, around the towns of Inverness and Bolinas, and in Audubon Canyon Ranch's Bolinas Lagoon Preserve.

Ehrharta erecta is a prolific seed producer, and the small seeds likely are carried to new sites via soil on shoes, on deer hooves, and as contamination in potted plants. *Ehrharta* can thrive in an extremely wide range of habitats, from coastal dunes to closed-canopy forest, and forms robust monospecific stands under full sun or in as little as 2.5% of daylight (Haubensak and Smyth 2000). Once established, populations increase rapidly and *Ehrharta*

Ehrharta Underground: There's more to an invasion than meets the eye

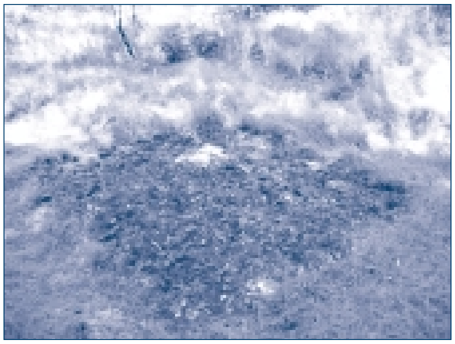
by Gwen Heistand

Cryptosphere—even the name given to the soil and leaf litter environment is laced with the promise of discovery. What creatures inhabit this hidden world? Strange primitive insects without wings (some without eyes), springtails (named for their anal appendages called furcula that propel them through soil pore spaces), nematodes, thousands of species of mites, feather-winged beetles, and larval insects of all sorts, to name a few. The diversity and complexity of the cryptosphere has been compared to coral reefs and tropical rainforests. And yet, we know very little about it.

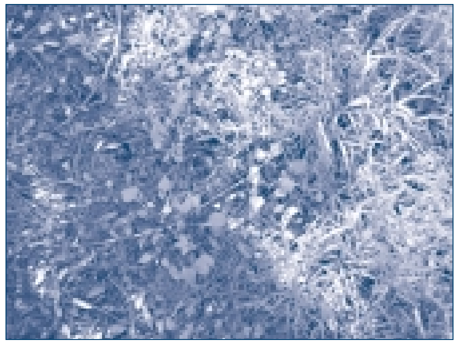
As mentioned in the accompanying article, *Ehrharta erecta* creates a dense thatch of vegetation both above and below ground, thereby altering the environment's physical attributes. The dense sward of green grass sweeping up ACR's Pike County Gulch is an obvious result of *Ehrharta* invasion. Impacts of the invader on soil chemistry and biotic communities are unknown. While it is not feasible at present to perform a detailed study, one piece of the *Ehrharta* experiment involves collecting data on leaf litter invertebrates in an attempt to understand the impact of the invasive grass on soil fauna.

Hidden ecologies

One square meter of fertile soil can contain more individual organisms than all the humans that have ever lived. Various studies have reported up to 10^{12} bacteria (1 trillion), 10^{12} protozoa, 10^{7} nematodes, springtails and mites, 10^{7} insects,



Ehrharta removal plot.



Uninvaded versus invaded habitat.

becomes the dominant herbaceous plant, excluding native and non-native vegetation (McIntyre and Ladiges 1985). There are currently no established techniques for controlling the plant or for restoring invaded habitat (Pickart 2000).

We have recently discovered several patches of *Ehrharta erecta* in each of the three canyons that comprise ACR's Bolinas Lagoon Preserve. While most of the patches are still small, the *Ehrharta* infestation in Pike County Gulch provides a glimpse at one possible future for ACR's flagship preserve: nearly 2000 m^2 of the canyon floor is covered with a dense monospecific sward, and the bright green invader is climbing the sides of the canyon into the brown leaf litter of the natural herbaceous understory. Given the plant's amazing rate of spread and ability to thrive in a range of habitats, immediate action is required to prevent *Ehrharta* from expanding, merging, and smothering the natural diversity of this singular preserve.

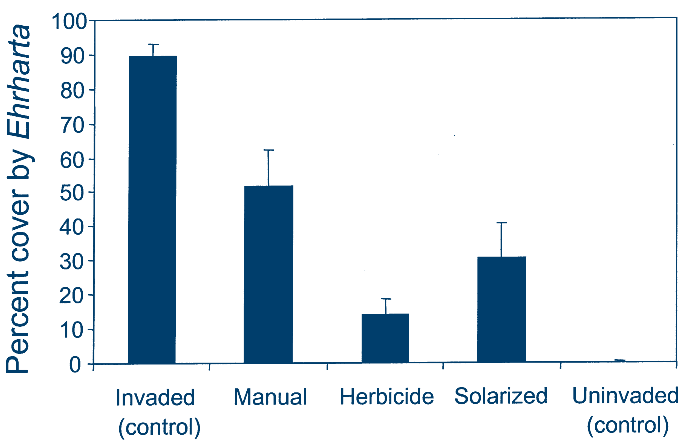


Figure 1. After one year, all three treatments significantly reduced the percent cover of *Ehrharta erecta,* relative to the invaded control plots, while manual removal also stimulated germination from the seed bank (see text). Solid bars indicate the percent of plots covered by *Ehrharta;* error bars indicate one standard error ($P < 0.001$).

Three lines of defense

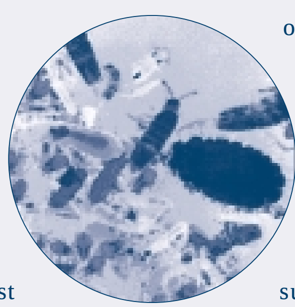
In 2003 ACR's Habitat Protection and Restoration (HPR) Program initiated an ambitious project to address the threat posed by this aggressive invader. The project includes (1) scientific research targeted to identify techniques for controlling *Ehrharta erecta*; (2) eradication of *Ehrharta* on ACR lands; and (3) collaborating with other groups and land managers to develop regional solutions to the *Ehrharta* invasion.

In June 2003 we began an experimental assessment of *Ehrharta* removal techniques. The experiment compares three promising techniques: manual removal by pulling, dilute herbicide treatment, and solarization (covering with black plastic). Each treatment is applied to 10 *Ehrharta*-dominated plots. Data collected from this experiment will allow us to determine which *Ehrharta* removal treatment is most effective and to evaluate how each treatment influences recovery of the natural communities that we are trying to restore.

In addition to the 30 experimental plots designed to evaluate removal techniques, the *Ehrharta* experiment includes two different sets of unmanipulated controls with 10 plots each, *Ehrharta*-dominated plots and uninvaded plots. In each of the 50 plots, we are quantifying the abundance of *Ehrharta*, vegetation composition, the abundance of native plants and of other

continued on page 8

1,000 earthworms, and 20,000 km of fungal mycelia. (Neher 1999, Pennisi 2004). Bacteria, fungi, and nematodes are three of the taxonomic groups that have the lowest percentage of described species, making classification of soil communities difficult at best. In addition, within each taxonomic group, some species feed on bacteria, some

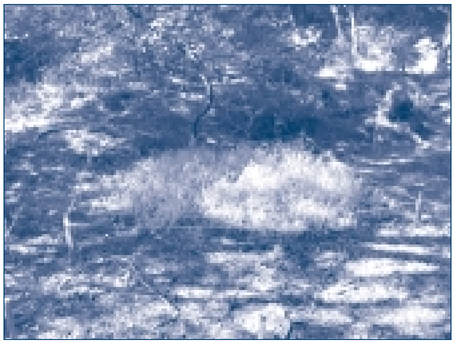


on fungus, some on roots, and some on other invertebrates. Where studied, different ecosystem types have been found to support different assemblages of soil biota. Grasslands have shown a marked abundance of omnivorous soil invertebrates. Agricultural soils can have greater numbers of bacterial feeders and root-feeding nematodes. Forests display a relative abundance of fungal feeders (Neher 1999).

Belowground food webs and ecological relationships are intricate and intimately linked to the aboveground environment (Wardel et al. 2004, Wardel 2002). Science is just beginning to delve into these connections. Few studies have attempted to assess soil biota in relation to either habitat restoration or invasive species. Invasion of non-native plants may affect above and belowground feedbacks, potentially changing soil chemistry and altering soil biota to facilitate invasion (van der Putten 2002).

Hidden consequences?

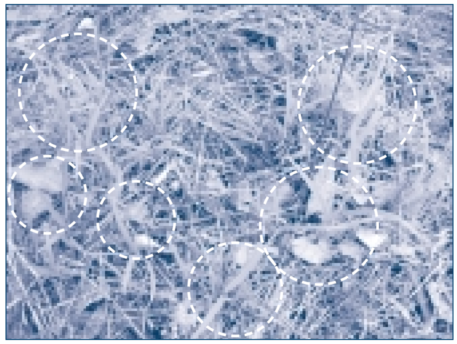
During February through April of 2004, Dan and I worked with several volunteers to collect 350 1-cm^2 litter samples from the center of each of the 50 experimental plots used in the *Erharta* study. Each sample



Ehrharta plot.

non-native invaders, important habitat characteristics, and leaf-litter invertebrate communities.

Preliminary results indicate that a weak herbicide solution is most effective at reducing *Ehrharta* abundance, while



Buried seed bag sprouting (*Ehrharta* in circles).

manual removal actually stimulates *Ehrharta* seed germination and increases abundance of the invader (Figure 1). While Year One results show solarization to be moderately effective at reducing *Ehrharta* cover, some adult *Ehrharta* plants are able to survive beneath the plastic tarp; the utility of this technique will depend on how well these survivors recover in the next year.

Ehrharta control may further depend on limiting the ability of *Ehrharta* populations to recover from buried seeds, so we are experimentally assessing seed longevity by burying small bags of seeds at two depths, exhuming seedbags at regular intervals, and germinating the exhumed seeds to determine seed survival. Twelve

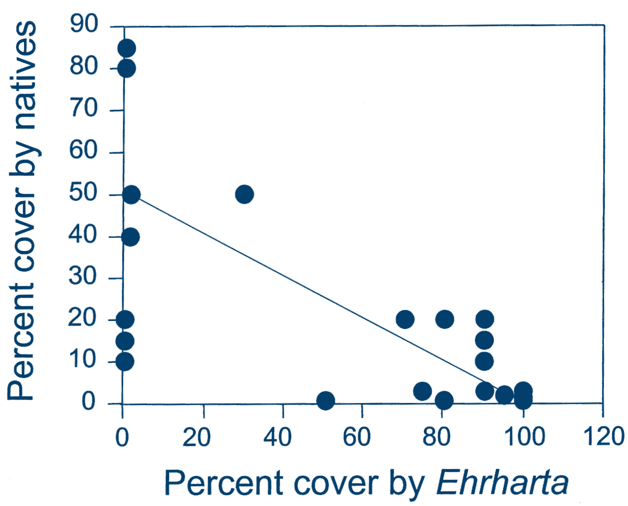


Figure 2. Native plant cover declines with increasing cover by *Ehrharta erecta*. Data are from unmanipulated plots ($r^2 = 0.59$, $P < 0.001$).

bags were buried at each of 10 locations, and the first set of bags will be exhumed and tested for viability in November 2004. Early observations of buried seed bags provide reason for hope. Each of the marker stakes is surrounded by a constellation of small clusters of *Ehrharta* seedlings, one cluster for each seed bag! This shows that the germination rate of these buried seeds is very high and that relatively few seeds remain dormant, and suggests that control efforts may not have to contend with a large and persistent soil seedbank.

Although the increasing ground cover by *Ehrharta* clearly reduced the cover of native plants (Figure 2), recovery of native plants one year after treatment did not differ significantly among treatments. However, differences in native cover among treatments may become significant as the small native plants mature.

Probably the most interesting variable that we will be monitoring is the response of leaf-litter invertebrate critters (see accompanying article). Very few scientific studies have quantified the impacts of plant invasion on animal communities, and only a handful have assessed how animal communities are affected by invasive plant control efforts. Terrestrial invertebrates are extremely important, both as elements of decomposition and nutrient cycles and as the basis of many terrestrial food webs, and ACR's *Ehrharta* research will be one of only a few studies that assess how the terrestrial invertebrate community is affected by non-native plant invasion. It will be extremely interesting to observe how invertebrates recover following *Ehrharta* removal!

While the scale of Bolinas Lagoon Preserve's *Ehrharta* invasion is daunting,

was run through a Berlese Funnel, which uses light to drive soil fauna downward into a container, producing approximately $^1/_8$ to $^1/_4$ teaspoon of invertebrates. Characterization, on a broad scale, of invertebrate assemblages in each of these samples has begun. Just to give a flavor of the numbers found in less than a teaspoon, one sample currently being analyzed contains 187 acari (mites), 214 collembolans, 3 dipterans (flies), 12 coleopterans (beetles), 13 diplurans (primitive wingless insects), and 11 unidentified larvae—with approximately two-thirds of the sample still to be sorted!

Once all samples have all been processed, we will analyze the results to determine whether there is any difference in soil fauna between the three treatments (herbicide, solarization, and manual removal) as well as between the invaded control sites and uninvaded plots. We might expect to see more omnivores in the grass dominated plots versus more fungal feeders in the native forest understory. Plots covered in black plastic might be expected to have a different suite of creatures during and immediately after treatment. One aspect of what we are hoping to ascertain is how resilient the ecologically important leaf litter community is in response to restoration efforts. Because so little is known about soil ecology on ACR lands, whatever we discover will be exciting. These data, combined with data on the abundance *Ehrharta* and other non-native and native plant species, as well as data characterizing plant species composition for each plot, should advance our understanding of how *Ehrharta erecta* control, eradication, and dispersal might affect native biota.

On a more personal note, it is difficult to describe the thrill of seeing a microscopic fly with beaded antennae and perfectly formed halteres or a

Volunteers set up the experiment.

our commitment to protecting the preserve's natural diversity mandates that we act to restrain this harmful invader. In the last year we have conducted surveys to locate and map all ACR *Ehrharta* patches and have begun work to treat the high priority sites. ACR has followed a "stitch in time" policy with regard to control work, focusing on small easily- eradicated patches of *Ehrharta* that have the potential to become intractable infestations. Results of this first year have been promising, and we expect that several years of concerted effort by staff and volunteers will be required to control this advanced invasion.

Invasive species such as *Ehrharta erecta* do not recognize property boundaries, and so we are working with our neighbors and with other restorationists to improve *Ehrharta* management across the region. In the last 18 months, ACR staff have helped make the Marin-Sonoma Weed Management Area (WMA) aware of the threat posed by *Ehrharta* invasion, and as a result the WMA contributed significant support to implementing ACR's *Ehrharta* experiment and assigned 2 interns to map all *Ehrharta* occurrences in Marin County. As ACR's HPR Specialist, I communicate frequently with biologists from California State Parks, the National Park Service, and other agencies to share information and insights regarding *Ehrharta* management. When ACR's *Ehrharta* experiment is completed we will use the data to develop a prescription for restoring *Ehrharta*-invaded habitat, and we expect that presentation of results will further increase regional *Ehrharta* control efforts.

Conservation commitment

The genus *Ehrharta* is largely restricted to the Cape region of South Africa, which, like California, is one of 5 regions on the planet with a Mediterranean climate. *Ehrharta erecta* has the greatest geographic range of any plants in the genus, and it is interesting to think that *Ehrharta erecta* may, by its nature, be a colonizer of new sites. In a manner reminiscent of many of California's most marvelous natives, the taxon named *Ehrharta erecta* emerged in an accelerated burst of speciation stimulated by the appearance of summer-arid climate in southern Africa. *Ehrharta erecta* is not a "bad" plant but, rather, is an amazing and tremendously vital organism that is the singular result of a unique evolutionary history. Unfortunately, its aggressive spread in coastal California threatens to eliminate some surviving representatives of California's own unique evolutionary history.

Harmful invaders like *Ehrharta* pose very significant challenges, but they also provide important opportunities. Research on invasive species is helping us understand how natural systems work and is creating a fruitful nexus of collaboration between "pure" scientists and "applied" restorationists. The urgent need for research and restoration volunteers has fueled a joyful reconnection of citizens with nature that is similar to the amateur scientist revolution of 19th century England. Most importantly, the ubiquity and impact of biological invasions is helping humans realize that they must be active and conscientious stewards of this planet: where Rachel Carson's *Silent Spring* demonstrated that human actions can have global impacts, the replacement of a diverse natural community by a single species of grass is teaching us that *inaction* is not without consequences.

Over decades and centuries, *Ehrharta erecta* may or may not accumulate new pathogens and herbivores and become a well-regulated and harmless part of our coastal plant communities. In the meantime, conservation organizations such as ACR remain committed to defending California's ancient natural diversity from the negative impacts of *Ehrharta erecta* and other runaway invaders. ◗

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beetle larva with a wildly intricate exoskeleton that looks like it is made from tortoise shell or the field of view under a dissecting scope *completely* filled with mites of different sizes and shapes. Knowing that these creatures live their lives navigating the pore spaces in the soil or the underside of decomposing leaves adds to my amazement at the intricacy of life on this planet. And, along with the sheer aesthetic pleasure of viewing these spectacular, minute beings and a feeling of increased respect for all that lives underfoot, I can't help but wonder what we may be doing to alter this world as we move invasive species around the globe and practice less than sustainable methods of agriculture. ◗

ACR is extremely fortunate to have a crew of committed, and possibly slightly crazy, volunteers who share this sense of respect and adventure and who enjoy spending Saturdays and Sundays bent over microscopes keying out and counting wee beasties found in the cryptosphere. Many thanks go to Tom Bradner, Anna-Marie Bratton, Judy Dugan, Ann Mintie, and Tony Paz.

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Influences on the hydro-geomorphology of Livermore Marsh

The Power of Rainfall

by Katie Etienne

The North Pacific Coast Railroad constructed a levee along the Tomales Bay shoreline in the 1870s that modified the hydrology of east-shore marshes. Although wooden trestles were built across major tide channels, water circulation was altered and sediment began to accumulate behind the levees. Livermore Marsh at the Cypress Grove Research Center is one of these wetlands that exhibit some interesting physical and biotic characteristics. Before Audubon Canyon Ranch (ACR) purchased the property in 1971, previous owners installed floodgates in the levee so they could use the 26-acre wetland for grazing and freshwater storage. In 1982, the levee was eroded by El Niño flood waters. ACR decided to repair the levee and construct a spillway at an elevation that would prevent tidewater from entering Livermore Marsh. ACR excavated four ponds in the lower marsh to maintain coveted freshwater habitat during dry seasons. However, when the levee breached by flood waters again in 1998, ACR decided to allow the wetland to be restored naturally to a tidal marsh system.

In 1999, grants from the Frank A. Campini Foundation and the Marin Community Foundation allowed ACR to restore trail access across the levee breach and to conduct a five-year study to document physical and biotic changes associated with the reintroduction of tidal circulation. In recent issues of *The Ardeid,* we presented reports summarizing our research objectives (1999), watershed effects (2001) and changes in bird use (2003). This article examines principal factors influencing the shape (topography) of the lower marsh (Figure 1).

The physical characteristics of tidal marshes have been studied extensively around the world, and some of the most important research on the morphology of diked salt marshes has been conducted in the San Francisco Bay area (Coats et al.1989; Coats and Williams 1990, and Williams and Orr 2002). These engineers have identified correlations between key marsh features, such as channel dimensions and tidal exchange, that are often used to design marsh restoration projects. We measured the same topographic features to document changes during the transformation of Livermore Marsh from a freshwater to a tidal system.

This study included monthly measurements of the tidal inlet, annual surveys of developing tide channels, and two detailed topographic surveys of the lower marsh in 1999 and 2003 (see photo on back cover). Hydrologist Lauren Hammack used these data to estimate four characteristics of tidal marsh systems: tidal inlet area, active tide channel length, active tide channel volume, and tidal prism volume (Table 1, page 12). The tidal prism estimate represents the volume of tide water that flows through the levee below the elevation of the mean higher-high water (3 ft NGVD29, or 5.4 ft NOS based on NOAA predictions).

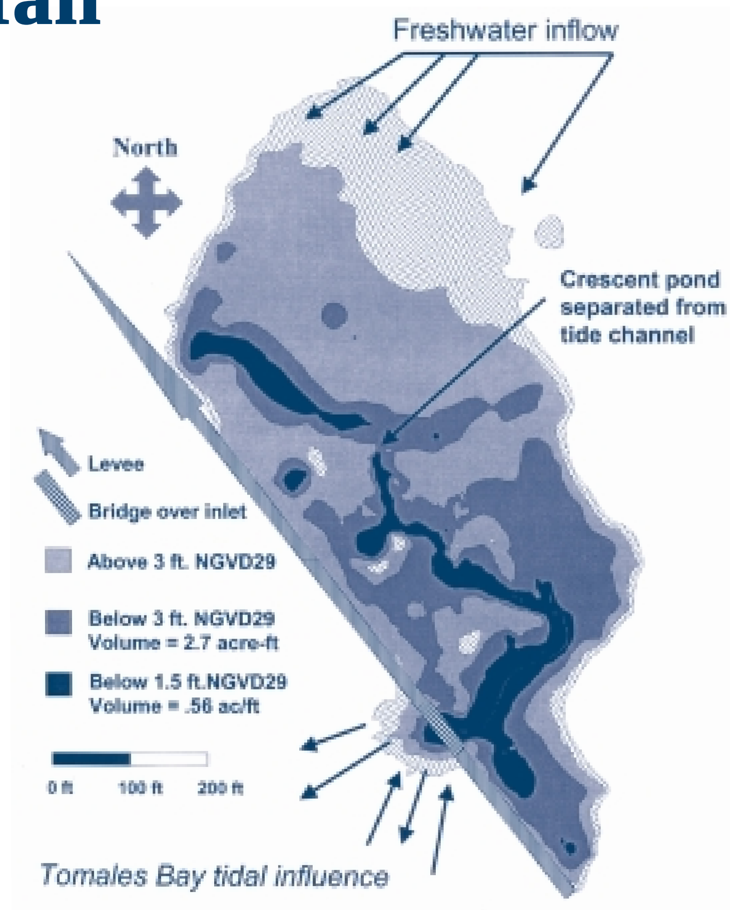

Figure 1. Elevations associated with tidal inundation at Livermore Marsh, in 2003.

Tidal versus fluvial effects

Tidal processes and terrestrial river flow are important factors that should be evaluated before applying scientific models to particular sites. This is a complex and demanding challenge, but at Livermore Marsh, we had the advantage of being able to routinely and accurately monitor changes in the inlet area. We used a laser level mounted at either end of the bridge to provide a stable reference for depth measurements at 47 locations across the 96-ft bridge.

One of the interesting questions we are exploring is whether different types of tidal patterns have predictable effects on the cross-sectional area of the tidal inlet. “Neap” tides exhibit the minimum range between high and low tides, while “spring” tides exhibit the largest range between highs and lows. “Median” tides range between mean-higher-high water (MHHW) and mean-lower-low-water (MLLW) and occur for several days between the neap and spring tide cycles.

I measured the inlet each month during the last day of a median tide cycle and scheduled neap and spring measurements at least three times a year. We were surprised to find that tidal action did not significantly influence either the cross-sectional area of the inlet or the rate of change in the inlet area.

From our analysis, it appears that cumulative rainfall was the primary factor

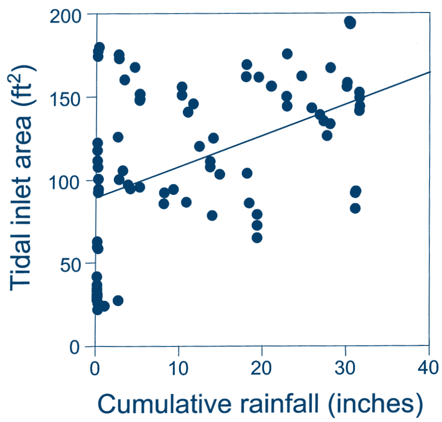

Figure 2. The tidal inlet area of Livermore Marsh increased significantly with cumulative rainfall ($P < 0.001$).

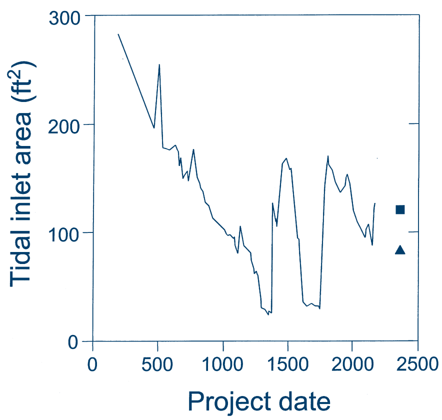

Figure 3. The tidal inlet area of Livermore Marsh is approaching predicted values based on studies of mature levee marshes in San Francisco Bay (square) and Tomales Bay (triangle).

KATIE ETIENNE

Figure 4. Six years after the levee breach, the tidal prism increased rapidly after the tide channel finally eroded the sill of the perched pond. The increased tidal circulation and winter flooding contributed to a 28% increase in inlet area between 18 Dec 2003 and 7 Jan 2004.

influencing changes in the inlet area (Figure 2). In addition, the effects of rainfall were not significantly influenced by tide conditions. Figure 3 illustrates the high variability in the size of the tidal inlet during the first five years, although the inlet area appears to be stabilizing around the values predicted from mature marsh systems (see *The Ardeid* 2002).

The role of sediment

We calculated the volume of primary and secondary tide channels, as well as incipient channels that may eventually become tertiary channels or blind sloughs. During the first year after the levee breach, the primary channel increased in length by 128 ft. The primary tide channel did not lengthen between 1999 and 2000, but there was a small increase in channel volume as the channel became deeper and wider. This pattern of channel lengthening followed by widening is consistent with other developing marshes where changes in width are also more rapid than changes in depth (Coats et al. 1995).

Although there was an increase in channel length and volume in 2001 that contributed to the increase in tidal prism, the tidal inlet continued to fill in (Table 1). This inverse relationship between changes in the tidal prism and the inlet is different from the direct relationship in mature marsh systems, where increased inlet area corresponds to increased tidal prism volume (Coats et al. 1995).

Subsequent channel surveys indicated that although most channels were becoming wider and longer, the total channel volume and tidal prism decreased in 2002. However in 2003, we measured a large increase in channel volume and length as well as an increase in tidal inlet area (Table 1). These episodic changes in channel development are probably associated with rainfall events and the cohesive nature of the sediment, which tends to erode in blocks.

In 1999, Gian-Marco Pizzo identified the significance of the dense substrate, which is not easily eroded by runoff or tidal action. His calculation of tidal velocity in the primary channel (0.2 m/sec) was far less than the 1 m/sec normally required to cause erosion. Pizzo concluded that channel development in Livermore Marsh was primarily influenced by the propagation of vertical head cuts that produce the stair-step shape in developing channels. During the next five years, we continued to document the lateral movement of numerous head cuts and slumping banks. Over time, head cuts and channel banks became taller and the music of falling water became louder as turbulent flow scoured material away from the base of new waterfalls.

Sporadic changes in tidal prism

Prior to analysis, we partitioned the topographic survey data to distinguish between active tide channels and isolated or “perched ponds” that did not drain during diurnal tidal cycles (Figure1). The small circular pond closest to the levee is one of four ponds constructed in 1983, when ACR was managing the system as a freshwater marsh. The larger, crescent-shaped pond is a remnant of a pre-existing channel that was mapped by the U.S. Coast Survey in the1862 (see *The Ardeid*, 1999). Because water level in these and other small ponds in the marsh did not rise and fall with the tides, we excluded their volumes from tidal prism estimates in 1998 through 2001.

The head cut of the primary tide channel progressed very slowly through the middle of the marsh, compared to channel banks that developed in the perimeter of the marsh. The rate of erosion in the middle marsh was reduced by a remnant stand of tules, because their dense stems decreased water velocity and their rhizomes bound the sediment together. Another factor was probably the percolation of water from the perched pond, which maintained soil saturation in the middle of the marsh. Saturation with water prevented cracking of the substrate that allows blocks of sediment to tip and fall downstream.

Meanwhile, channel banks around the perimeter of the marsh continued to collapse into the channel, and sediment was slowly transported through the system. Finally, after several weeks of heavy rain and the spring tide cycle of 6-8 Jan 2004, the sill between the crescent pond and the head cut eroded, and water previously stored in the large pond was released (Figure 4). As rain continued to fall, high tides began to circulate through the crescent pond, which increased the tidal prism by at least 0.36 acre-ft. This estimated increase does not include the additional tidal volume resulting from the erosion of unconsolidated material in the pond by winter runoff and high tides.

This process of slow erosion and tide channel development indicates the importance of substrate composition. Another major factor is the elevation of the marsh plain. Survey data show that most tide water never flows above the deepest portions of the developing chan-

Table 1. Changes in the geomorphic characteristics of Livermore Marsh (1998-2004) show a continuing increase in channel length and tidal prism volume, but fluctuations in channel volume and inlet area (2002-2003).

Year	Inlet area[1] (ft^2)	Tide channel length (ft)	Active tide channel[2] (acre-ft)	Tidal prism (acre-ft)
1998	283	230	0.32	1.4
1999	176	420	0.40	2.3
2000	94	420	0.44	2.6
2001	62	560	0.52	2.8
2002	32	712	0.46	2.4
2003	95	770	0.56	2.7
2004	127	1170	0.92	3.1

[1] below 3 ft NGVD29
[2] below 1.5 ft NGVD29

nels, and only extreme high tides have any effect on the surface of the marsh plain. This helps explain why salinity in most areas with restricted tidal exchange tends to remain fresh or slightly brackish. From 1998-2003, salinity measurements in the crescent-shaped pond remained near 1 ppt, and most of the tide channel was brackish (4.0–9.6 ppt). The isolated pond near the levee exceeded the salinity of Tomales Bay during summer months. These salinity differences reflect the importance of marsh plain elevation, which continues to restrict tidal influence.

The dominant factors influencing the early development of Livermore Marsh were fluvial action, sediment characteristics, and marsh plain elevation. We anticipate the effect of tidal action on physical and biological processes in the marsh will depend upon future rates of sediment transport and sea level rise. ◗

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Visting investigators

Effects of invasive species on nitrogen retention and other issues in the ecology and restoration of coastal prairie. Jeff Corbin and Carla D'Antonio, UC Berkeley.

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Multi-scaled vegetation data to predict wildlife species distributions using a wildlife habitat relationship model. Jennifer Shulzitski, USGS Golden Gate Field Station.

Impact of butterfly gardens on pipevine swallowtail populations. Jacqueline Levy, San Francisco State University.

The effect of landscape changes on native bee fauna and pollination of native plants in Napa and Sonoma counties. Gretchen LeBuhn, San Francisco State University.

Ecological indicators in West Coast estuaries. Steven Morgan, UC Davis Bodega Marine Lab; Susan Anderson, UC Santa Barbara; and numerous collaborators.

Consequences of species invasion under global climate change. Elizabeth Brusati, UC Davis.

Community based assessment of biological health of riparian wetlands in the Sonoma Creek watershed. Caitlin Cornwall, Sonoma Ecology Center.

Water quality monitoring at several points in Tomales Bay, including ACR's Walker Creek delta. Lorraine Parsons, Point Reyes National Seashore.

Bird communities in North Coast oak-vineyard landscapes. Emily Heaton, UC Berkeley.

Factors causing summer mortality in Pacific oysters. Fred Griffin, Bodega Marine Lab.

Effects of sudden oak death-induced habitat change on vertebrate communities. Kyle Apigian and Don Dahlson, UC Berkeley.

The differential invisibility of annual and perennial grasslands in California by a non-indigenous invader, Foeniculum vulgare. Joel Abraham and Jeff Corbin, UC Berkeley.

Differences in arthropod community composition in native and exotic dominated grasslands. Natalie Robinson, UC Berkeley.

A comparison of carbon cycling and material exchange in grasslands dominated by native and exotic grasses in Northern California. Laurie Koteen, UC Berkeley.

Black Brant counts at Drakes Estero, Tomales Bay and Bodega Bay. Rod Hug, Santa Rosa, CA.

Monitoring Avian Productivity and Survivorship (MAPS) station at Livermore Marsh. Denise Jones, Institute for Bird Populations.

Tidewater goby inventory for Tomales Bay. Darren Fong, GGNRA.

Conservation concerns for Cordylanthus maritimus *ssp.* palustris. Todd Wilms, Emeryville, CA.

Strophariaceae of California. Peter Werner and Dennis Desjardin, San Francisco State University.

In progress: project updates

North Bay counties heron and egret project ◗ Annual monitoring of reproductive activities at all known heron and egret colonies in five northern Bay Area counties began in 1990. The data are used to examine regional patterns of reproductive performance, disturbance, habitat use, seasonal timing and spatial relationships among heronries. The project has been recently incorporated into the Integrated Regional Wetland Monitoring (IRWM) program, a pilot project to develop regional monitoring for San Francisco Bay. We are currently preparing an annotated atlas of regional heronries.

Picher Canyon heron/egret project ◗ The fates of all nesting attempts at ACR's Picher Canyon heronry are monitored annually, based on procedures initiated by Helen Pratt in 1967, to track long-term variation in nesting behavior and reproduction.

Livermore Marsh ◗ As ACR's Livermore Marsh, on Tomales Bay, transforms from a freshwater system into a tidal salt marsh, we are studying the relationship between increasing tidal prism and marsh channel development. Monitoring of winter and breeding bird use began in 1985. The data will be linked to measurements of vegetation to reveal changes associated with the developing tidal marsh. We also monitor the depth and duration of ground water which strongly influences biological conditions in the upper marsh.

Newt population study ◗ Annual newt surveys have been conducted along the Stuart Creek trail at Bouverie Preserve since 1987. The results track annual and intraseasonal abundance, and size/age and spatial distributions along the creek.

Tomales Bay Shorebirds ◗ Since 1989, we have conducted annual baywide shorebird censuses on Tomales Bay. Censuses involve six baywide winter counts and one baywide count each in August and April migration periods. A team of 15-20 volunteer field observers are needed to conduct each count. The data are used to investigate winter population patterns of shorebirds, local habitat values, and conservation implications.

Tomales Bay waterbird survey ◗ Since 1989-90, teams of 12-15 observers have conducted winter waterbird censuses from survey boats on Tomales Bay. The results provide information on habitat values and conservation needs of 51 species, totaling up to 25,000 birds. Future work will focus on trends and determinants of waterbird variation on Tomales Bay.

Predation by ravens in heron/egret colonies ◗ We have been observing ravens in Marin County and measuring raven predatory behaviors at heron and egret nesting colonies. The field work involves radio telemetry and behavioral observations. We have produced scientific papers on the status of ravens and crows in the San Francisco Bay area, patterns of home range use, and raven predatory behaviors in heronries.

Experimental assessment of Wild Turkey impacts ◗ Invasive Wild Turkeys are common at Bouverie Preserve and throughout most of Sonoma County. Dan Gluesenkamp is measuring the effects of ground foraging by Wild Turkeys on vegetation, invertebrates, and herpetofauna in the forest ecosystem of Bouverie Preserve. The results will and provide information that can be used to improve management and control of turkey populations by agencies.

***Ehrharta erecta* management and research ◗** *Erharta erecta* is a highly invasive perennial grass native to South Africa. It is currently invading west Marin County and is abundant in ACR's Pike County Gulch. The goals of this project are to understand the effects of *Ehrharta* invasion, develop tools for control of *Erharta,* and restore habitat invaded by *Erharta* at Bolinas Lagoon Preserve.

Olema Marsh bird census ◗ Although considerable bird census work was conducted at ACR's Olema Marsh in the 1980s and early 1990s, recent information on bird use is needed to include Olema Marsh in the Point Reyes National Seashore Giacomini Wetland Restoration Project. Methods involve point counts and distance sampling, conducted by Rich Stallcup.

Plant species inventory ◗ Resident biologists maintain inventories of plant species known to occur along the Tomales Bay shoreline, and on ACR's at Bouverie and Bolinas Lagoon preserves.

Cape ivy control, Volunteer Canyon ◗ Work conducted by Len Blumin has proven that manual removal of nonnative cape ivy can successfully restore riparian vegetation. Continued vigilance in weeded areas of ACR's Volunteer Canyon has been important, to combat resprouts of black nightshade, Vinca, and Japanese hedge parsely.

Annual surveys and removal of non-native cordgrass ◗ Protection of ACR's shoreline properties from invasion by nonnative Spartina species is critical to the protection of ACR lands and provides a critical contribution to the overall monitoring and management of Tomales Bay and Bolinas Lagoon. In addition to conducting surveys on ACR lands, Katie Etienne is collaborating on surveys of other shoreline properties in these estuaries.

Vernal wetland botanical surveys at Bouverie Preserve ◗ As part of our overall effort to determine the ecological values of vernal wetlands at Bouverie Preserve, botanist Ramona Robison conducted floristic surveys designed to target rare plants. The surveys provide plant species lists, vegetation cover values for each species, and exact (GPS) delineation of wetland habitats and locations of rare plants.

Salmarsh ice plant removal ◗ Non-native ice plant is being removed from marshes and upland edges at Toms Point on Tomales Bay, using manual removal, shading with black plastic, and glyphosate. The goals are to eliminate invasive ice plant from Toms Point and to collaborate with other land managers to remove ice plant from other sites in Tomales Bay.

Eradication of *Elytrigia pontica* spp. *pontica* ◗ Elytrigia is an invasive, non-native perennial grass that forms dense populations with nearly 100% cover in seasonal wetland sites. We are using manual removal by groups of volunteers, light starvation and solarization using black plastic tarps, and glyphosate spot treatments.

Eucalyptus removal ◗ Eucalyptus trees are being removed, with incremental annual cutting, from ACR's Bolinas Lagoon Preserve, and along the Highway 12 border of Bouverie Preserve. Dan Gluesenkamp is conducting an experiment to determine the optimal method for controlling Eucalyptus resprouts.

Wood Duck boxes ◗ Rich Stallcup has installed and maintains several Wood Duck nest boxes along Bear Valley Creek in ACR's Olema Marsh.

Bluebird boxes ◗ Tony Gilbert has installed four bluebird boxes in the Cypress Grove grasslands with the objective of providing nest sites for two pairs of Western Bluebirds.

THE ARDEID

Ardeid (Ar-DEE-id), n., refers to
any member of the family
Ardeidae, which includes herons,
egrets, and bitterns.

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Pacific Land Surveys measured the topography of ACR's Livermore Marsh during a five-year study of ecological changes associated with the reintroduction of tidal circulation.

KATIE ETIENNE

Livermore Marsh see page 9

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