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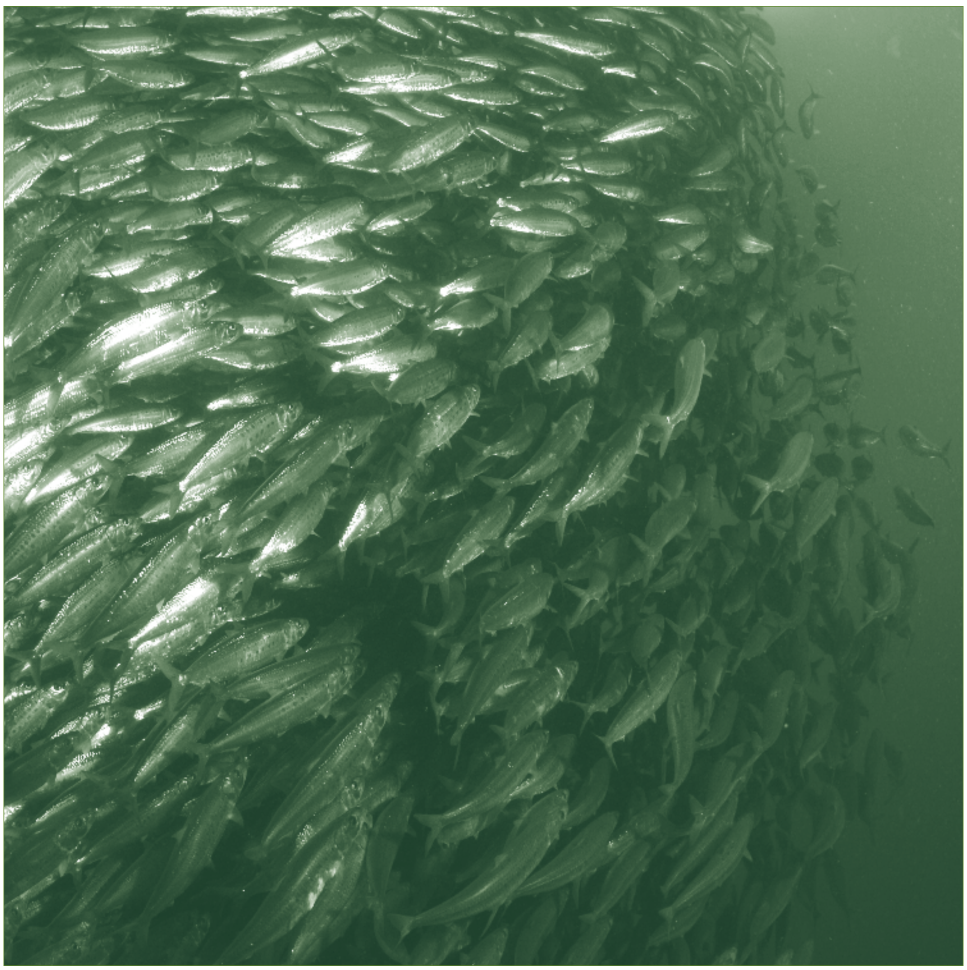

2016

Waterbird reliance on Pacific herring

Modeling heron and egret habitat statewide

Recreation ecology: impact of hikers on wildlife

Mountain lion research at ACR

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

THE ARDEID

2016

In this issue

Cover: Huge schools of Pacific herring enter estuarine waters each winter to spawn, providing important food for waterbirds. Photo © Paul Nicklen/National Geographic.

Ardeid masthead: Great Blue Heron ink wash painting by Claudia Chapline.

Above: The mountain lion is a focus of new ACR research. See page 13. Photo © Phillip Colla.

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GREATER SCAUP. CREATIVE COMMONS.

Waterbird reliance on Pacific herring

Echoes of Ecological Dependence

by John P. Kelly

The estuarine spawning activities of Pacific herring *(Clupea pallasii)* are marked by spectacular clouds of hungry waterbirds. These clouds drift into our estuaries each winter as schools of herring swim in from the outer ocean to lay their eggs in eelgrass. The waterbird flocks are animated by the frenzied foraging activities of cormorants, pelicans, loons, ducks, grebes, and other waterbirds, diving from the surface and plunging from the air to gorge on herring and herring roe (see box: The big role of small fish). These feeding events suggest an important question in estuarine conservation: do waterbirds simply choose to consume herring among the many other alternative prey that collectively provide the winter food-web support they need—or do winter waterbird numbers actually depend on herring runs?

Some phenomena in nature are clearly driven by particular events. If a school of herring swims into an estuary, it will be chased by foraging waterbirds—if A, then B. But the processes that account for the status of natural populations or communities of organisms are usually far more complex. The diverse and beautiful assemblages of life in natural systems are driven by a kaleidoscope of interactions that ricochet and reverberate among species and environmental conditions, across different distances, and over multiple periods of time.

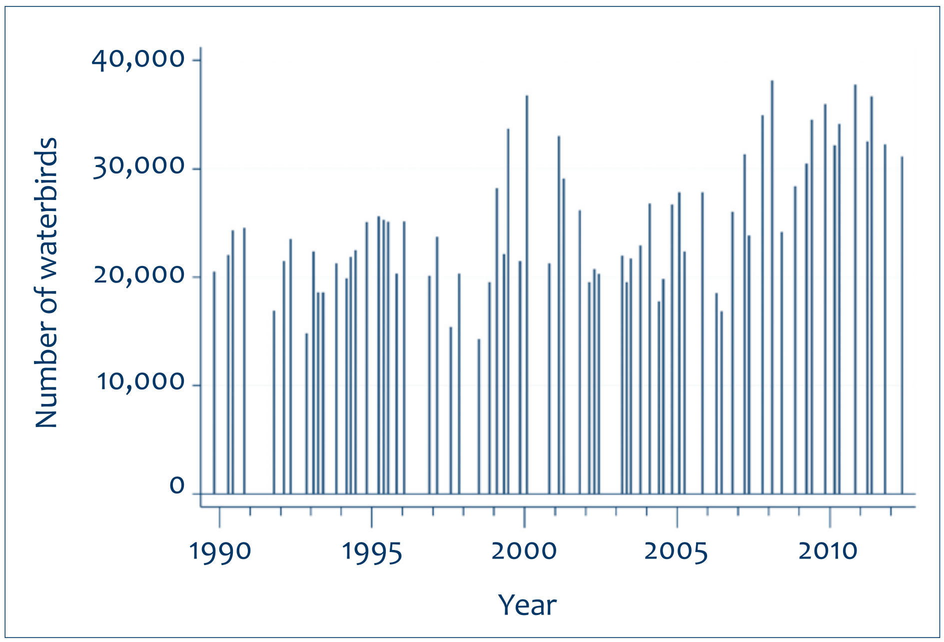


Figure 1. Winter waterbird abundances (all species combined) in Tomales Bay, California, November–February, 1989-2012. Shorebirds and gulls (Charadriiformes) are not included. Months outside of the November–February monitoring season are omitted from the time line.

Consider the spectacular return of up to 35,000 or more waterbirds to Tomales Bay each winter (Kelly and Tappen 1998). Here nearly 60 species of loons, grebes, cormorants, ducks, and other waterbirds, in addition to numerous species of shorebirds and gulls, exhibit complex patterns of growth and decline that are complicated enough to seem mysterious (Figure 1). A current focus of conservation research at ACR is to determine the importance of Pacific herring to the remarkable masses of waterbirds that occupy our estuaries in winter.

Waterbirds might depend on herring to ensure their overwinter survival, to store fuel required for spring migration, and even to develop healthy physiological states needed to improve subsequent reproductive performance when they return to nest at higher latitudes each spring. If winter waterbird populations are tightly linked to the dynamics of available food provided by Pacific herring or their eggs, then the appropriate management of herring populations may be critical to the conservation of estuarine waterbirds (See box, page 5: Keystone policy shift).

The research

To determine just how much, if at all, wintering waterbirds in Tomales Bay depend on Pacific herring, ACR colleague Christine Pavlik

Conservation Keys

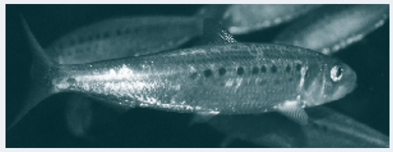
- Management of the Pacific herring fishery in California is subject to a recent policy that prevents the expansion of existing forage fisheries until available science ensures that the targeted species can be fished without negative consequences to their dependent predators.
- ACR is working to measure the extent to which wintering waterbird populations in estuaries depend on Pacific herring *(Clupea pallasii)* for food.
- Increases in the availability of spawning herring or their roe in Tomales Bay lead to sustained increases in the growth or resilience of winter waterbird populations.

and I are conducting a three-part investigation. We are measuring three kinds of responses by each waterbird species to changes in the availability of herring: (1) long-term variation in baywide species abundances, (2) shifts in species' foraging distributions relative to herring spawning events, and (3) potential energy benefits to waterbirds provided by herring or herring roe. In this article, I am pleased to share results from the first of these objectives: new evidence that wintering waterbird abundances in Tomales Bay depend, at least in part, on the periodic incursions of Pacific herring.

We generated statistical time-series models that combined the long-term patterns of waterbird densities with the long-term spawning dynamics of Pacific herring in Tomales Bay. The data for each time series were analyzed across six 14-day time periods within each winter waterbird season (December through February), from 1989 to 2012. Baywide measurements of herring spawning biomass, measured in tons, were provided by the California Department of Fish and Wildlife. The Department discontinued herring monitoring in Tomales Bay after 2007, but we incorporated waterbird responses for an additional five years to track the carryover effects of previous herring activity on the dynamics of wintering waterbird populations.

The key advantage of the time-series analyses is that they control for the effects of previous fluctuations in both waterbird populations and herring spawning activity—processes that are compounded over extended periods of time in complex and potentially confusing ways. This portion of the project culminated in the calculation of "impulse-response functions," which quantify how the densities of waterbirds in Tomales Bay respond over time to any unusual, instantaneous impulse of increased herring abundance (see box: Measuring waterbird dependence on herring). Eventually, waterbird responses to any such impulse fade out, giving way to the normal range of underlying variation and trends related to other influences.

The results of the analyses provide more rigorous evidence of causation than simple



The big role of small fish

Pacific herring *(Clupea pallasii),* which spawn by the tens of millions each winter, from December to March, in the vast, subtidal eelgrass meadows of Tomales Bay, are a potentially critical source of food for the hordes of waterbirds that winter there (Kelly and Tappen et al 1998; Weathers and Kelly 2007). Because herring, or herring roe, also provide food for numerous fishes, crabs, and pinnipeds, the seasonal availability of herring has potentially huge ecosystem importance.

As important "forage fish," Pacific herring represent a vital link in marine food webs because they transfer energy from primary and secondary producers, such as plankton, to top predators such as larger fish, marine mammals, and waterbirds. Like other forage fish in our area, such as northern anchovy *(Engraulis mordax),* Pacific sardine *(Sardinops sagax),* and smelt species *(Osmeridae),* Pacific herring typically swim in large schools and are abundant in healthy ecosystems.

Pacific herring are found throughout coastal waters around the Pacific Rim, from California to Korea. The commercial herring fishery is driven largely by the value of herring roe ("kazunoko" in Japanese cuisine) taken from the seasonal catch of herring attempting to spawn in our estuaries. In San Francisco and Tomales bays, these silvery, olive-green to dark-blue fish average just 16 cm (6 inches) long and can live up to eight years. They feed primarily on tiny (planktonic) crustaceans, including euphausiids, copepods, and amphipods, and also on small mollusks and fish larvae.

Each winter, the schools of herring that migrate from nearshore waters into bays and estuaries to spawn mark spectacular natural events as they drift in and out of estuarine waters under seething swarms foraging waterbirds (Figure 2).

Figure 2 (below). Cormorants and pelicans crowd the water over a herring school in San Francisco Bay's Richardson Bay. Photo by Bob Hinz.

correlations over time. Rather than simply accounting for similarities between changes in waterbird numbers and the availability of herring or herring roe, the results provide significantly improved predictions of future waterbird numbers based on the dynamic responses of waterbirds to past and current changes in herring activity.

Unscrambling benefits to waterbirds

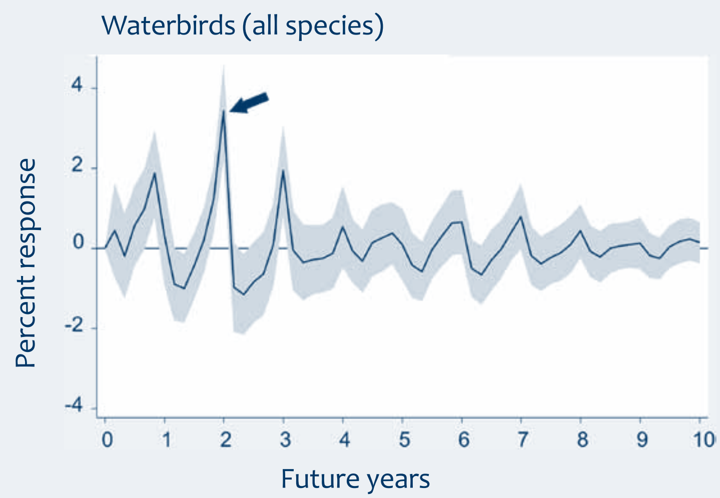
After accounting for normal variation and underlying trends in both waterbirds and herring, we were able to determine how waterbirds respond over time to the annual incursions of herring into Tomales Bay. Overall, the baywide abundance of wintering waterbirds known to consume herring or herring roe (42 species, combined) was found to increase significantly in response to any unexpected increase in herring biomass (see box: Measuring waterbird dependence on herring). The responses were strong, providing evidence that wintering populations of most of the individual waterbird species exhibited significant, positive growth over multiple years in response to impulses of herring spawning activity in the bay (Figure 3).

Some species of waterbirds showed only modest responses. Pacific, Red-throated, and Common loons and Eared Grebes exhibited relatively small (nonsignificant) responses to unusual pulses of herring activity in the current year, with any associated gains in population growth diminishing quickly over subsequent winters. Numbers of Pied-billed Grebes and Horned Grebes (Figure 3) increased significantly above expected levels in response to increased herring abundance in the current year, but their numbers subsided in subsequent years to levels consistent with underlying, expected patterns of variation.

Changes in the abundance of Surf Scoters—an important waterbird species in Tomales Bay and well-known consumer of herring roe (Kelly and Tappen 1998, Bishop and Green 2001, Anderson et al. 2009)—revealed moderate responses that apparently persisted for two years after an increase in herring biomass (Figure 3). However, the magnitude of the response seemed to be relatively marginal. The apparently modest strength of the Surf Scoter response could have been confounded by the difficulty of accounting effectively for their dramatic regional and continental declines, which may be unrelated to herring activity in Tomales Bay (Sea Duck Joint Venture 2015).

Interestingly, Great Blue Herons and Great Egrets showed sustained, positive responses to herring in the bay, for two to four years (respectively) after a pulse of herring activity (Figure 3). These responses seem surprising since these species are unable to reach either the schools of herring or the deposited herring eggs, except in very rare instances when the fish spawn close to shore or in very shallow water. Consistent with these responses, however, groups of 20 to 40 "spectating" herons and egrets are typically seen standing along the nearest portion of the shore during spawning events, apparently standing ready for action in case the spawning herring move into the shallows.

The results of this investigation provide strong evidence that the numbers of wintering waterbird in our estuaries depend at least in part on spawning activity by Pacific herring. As mentioned above, two other complementary aspects of this project will provide further insight into these findings. First, we are documenting the behavioral responses of foraging waterbirds to changes in the distribution of food provided by herring. Specifically, we are



Measuring waterbird dependence on herring

Evidence for waterbird dependence on Pacific herring can be estimated by using time-series analyses to measure the "impulse responses" of waterbirds to any unexpected, one-time increase in herring biomass. In the figure above, based on data from Tomales Bay, 1989 to 2012, changes in winter waterbird abundance (all species combined) are estimated as "the percent waterbird response for each percent increase in herring biomass above expected levels." The arrow in the figure provides an example: a one-time impulse of 10% in herring biomass (at year = 0) would result in a lagged increase in baywide waterbird abundance, two years later, of 34% (10 x 3.4), relative to underlying trends.

The dependence of waterbird abundances on herring is significant if the 95% confidence region (shaded area) is above the horizontal line (>0% response). Persistent responses are indicated by significant positive spikes at annual intervals. The spikes reflect increases in the return of wintering adults and the recruitment of juveniles choosing to winter in the bay. (Negative responses reflect normal declines in the rate of population growth within each winter.)

The responses of waterbirds to unexpected declines in herring activity (negative impulses) are predicted to be the mirror opposite of their responses to the positive impulses in the figure. Therefore, stronger responses suggest more sensitive, or volatile, changes in waterbird numbers with fluctuations in available herring.

Waterbird responses to any single impulse of herring activity decay gradually to zero over time, relative to the normal, underlying variation in waterbird numbers.

Brown Pelican.
Photo by Tom Grey.

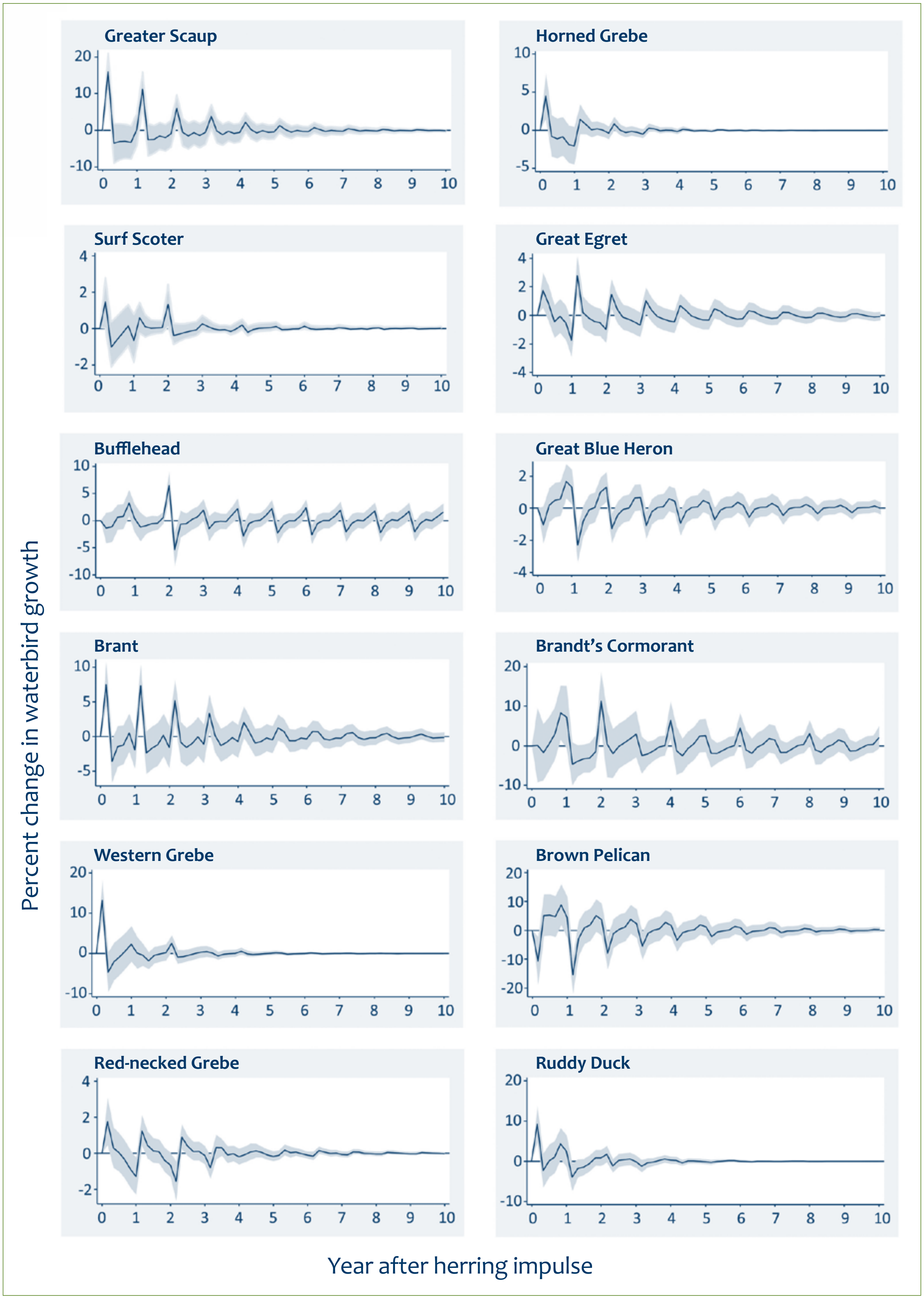


Figure 3. Impulse-response functions revealing the dependence of selected waterbird species on herring activity in Tomales Bay (for full explanation, see box on page 3: Measuring waterbird dependence on herring). The dependence of waterbirds on herring is significant if the 95% confidence region (shaded area) exceeds zero (horizontal line). Persistent effects on waterbird abundances are indicated by repeated, significant responses at annual intervals.

measuring the extent to which waterbirds shift their foraging distributions within the Tomales Bay toward individual herring spawning events.

Second, we are comparing the energy requirements of waterbirds to the amount of food energy available from herring or herring roe. For this component of the study, we are measuring the long-term, baywide energy demands of waterbirds relative to the amount of energy available from herring. The analysis will address this question: if waterbirds feed preferentially on available herring or herring roe, how important is the energy they obtain from herring in balancing their energy requirements during winter?

The preliminary results of our investigations are encouraging, promising important insights into the new state policy for managing forage fisheries. The goal of this work is fundamental for effective conservation—to connect science and policy, to ensure healthy estuaries and protect the teeming masses of estuarine waterbirds that return each winter.

Keystone policy shift

In 2012, the California Fish and Game Commission adopted a new state policy that recognizes the enormously important role of forage fish in supporting healthy oceans (www.fgc.ca.gov/policy/p2fish.aspx). The new policy calls for the cautious, ecologically responsible management of California's forage fisheries. From a conservation perspective, the new policy is impressively progressive, because it addresses the need to leave appropriate numbers of forage fish in the ocean, including Pacific herring, to support ecological values that far exceed the value of the fish harvested in nets.

The new state policy indicates that the Commission intends to make management decisions to protect forage fishes by using "the best available science" and, in addition, to prevent the expansion of existing forage fisheries without first accounting for the "effects on dependent predators."

The California Department of Fish and Wildlife plans to develop a Fishery Management Plan for Pacific herring to incorporate principles outlined in the new policy. But here's the catch: any management revisions incorporated into the plan are likely to require solid scientific grounding. Unfortunately, although waterbirds are widely known to consume herring and herring roe (Bayer 1980, Haegele 1993, Sullivan et al. 2002), their potential dependence on herring remains unknown. Therefore, ACR launched a scientific investigation to document the extent to which estuarine waterbirds depend on the seasonal availability of Pacific herring.

In the early 2000s, historic lows in the spawning biomass of Pacific herring were documented in both Tomales Bay and San Francisco Bay. Since 2007, the commercial herring fishery has been inactive in Tomales Bay and, because of staffing limits, the State Department of Fish and Wildlife has suspended annual monitoring—although the fishery remains open. In San Francisco Bay, the herring fishery is active and spawning activity suggests some recovery in recent years. However, underlying population trends are difficult to discern.

To promote the recovery of herring stocks, the 2015/16 quota for commercial take of herring in San Francisco Bay was set, conservatively, at 5% of the estimated spawning biomass. However, the procedures used to set harvest quotas are risky because they are based on estimates from the previous year—and often overestimate levels of spawning activity (Dewees and Leet 2003). For example, the 2014/15 quota was also conservatively set at less than 5% (2,500 tons) but, because only 16,674 tons of herring actually spawned in that year, the quota effectively authorized a harvest of 15%.

In the meantime, intensive fishing, local problems in spawning areas, and climate change are making herring less available to birds and other estuarine wildlife from Alaska to California. Our studies of relationships between waterbirds and herring are providing insights needed to implement the new state policy and, accordingly, help ensure the protection of our estuaries.

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Figure 4, below: A herring fishing boat plies the waters of central San Francisco Bay. Photo by Mary Sheft.

Using statewide data to model the habitat needs of nesting herons and egrets

Ardeid Landscapes

by Emiko Condeso

PHOTO BY INGRID TAYLAR OF GREAT BLUE HERON CARRYING NEST MATERIAL.

At the tail end of the California winter, when the number of rainy days declines and the sun shines more often than not, herons and egrets begin to appear at traditional nesting sites. They can be seen for a few hours at a time, here and there in the tall trees where, in a month or so, they may choose to build their nests. Elsewhere, throughout most of California, herons and egrets are similarly investigating new sites never before occupied by nesting Ardeids. There are many mysteries involved in nest-site selection. How do individuals assess their environment to determine which feeding area will be productive enough to provision nestlings? Which grove of trees will provide reasonable protection from disturbance? What branch will provide the best location to place a nest and advertise for a mate?

Although herons and egrets undoubtedly incorporate many different kinds of environmental cues into their site-selection process, it is becoming increasingly clear that large-scale features of the surrounding landscape, in addition to the more intuitively obvious local characteristics of the colony site, play an important role in determining where birds choose to nest and how successful they are. Several studies have shown that the distribution of waterbird colonies is influenced by habitat qualities in the surrounding landscape. That is, colonies tend to be located in places associated with particular

Conservation Keys

- ACR is conducting the first statewide investigation of heron and egret habitat needs in California.
- The impacts of climate change on wetlands in California could dramatically affect the distributions and abundances of nesting herons and egrets.
- This study will be used to make recommendations for regional wetland conservation throughout California with regard to the habitat needs of herons and egrets.

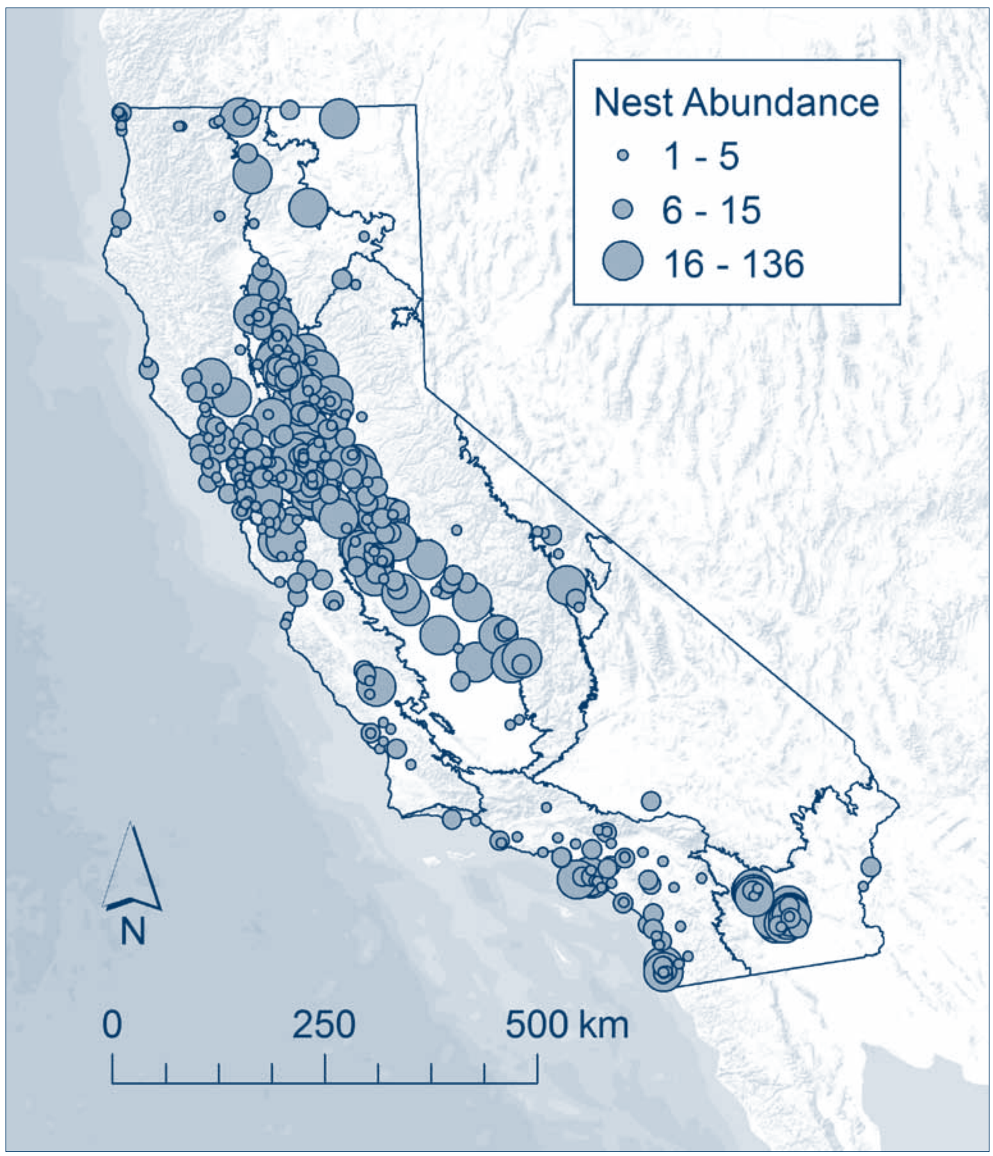

Figure 1. Distribution of Great Blue Heron nesting colony sites in California, 2009–2012 (Shuford, 2014). Symbol size indicates nest abundance, as shown. Solid boundary lines within the state indicate Jepson Ecoregions. Great Blue Herons generally nest in relatively small colonies, near suitable feeding areas in freshwater wetlands and tidal marshes, and along streams and rivers throughout most of the state. (Basemap data sources: ESRI, USGS, NOAA.)

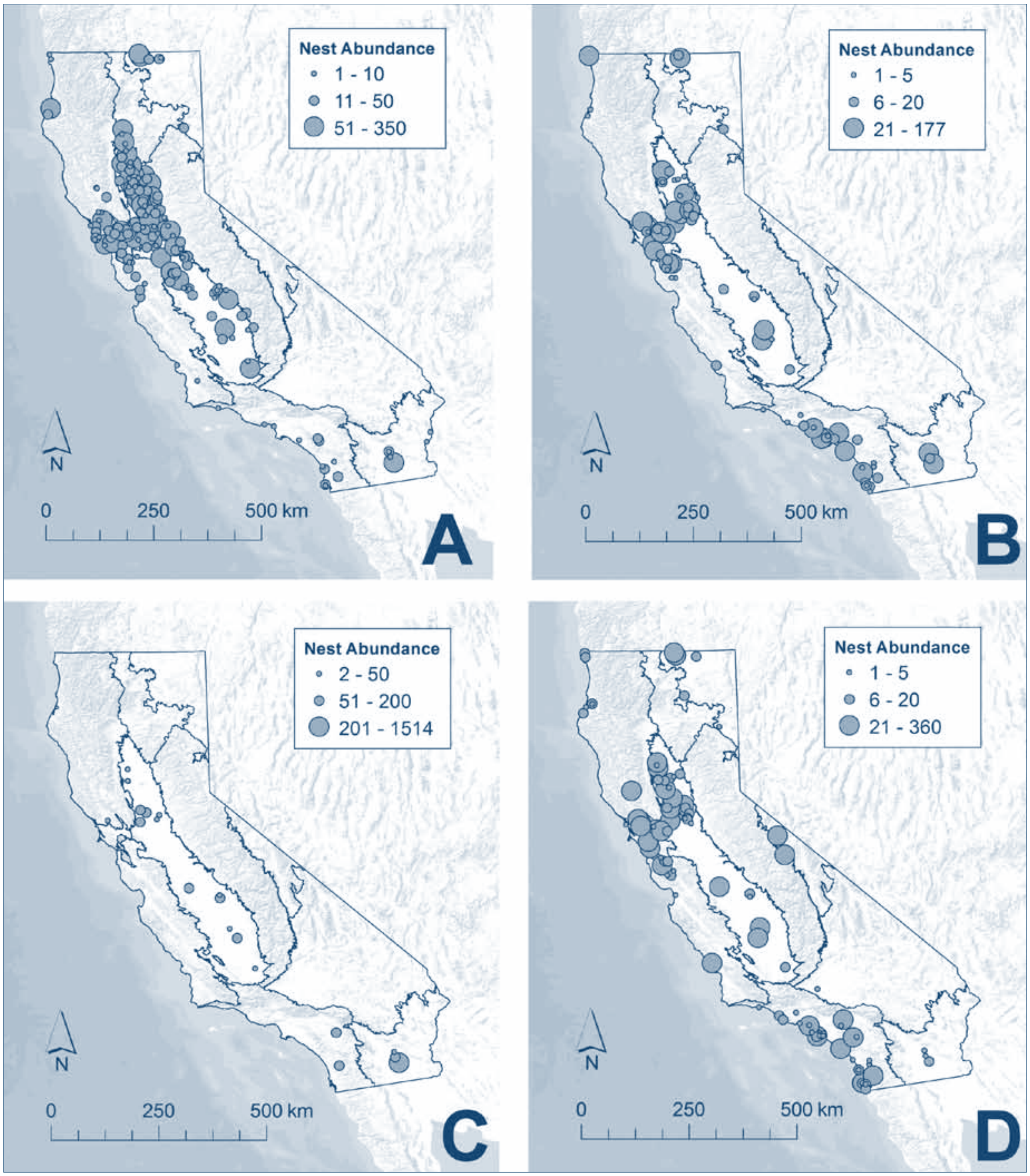

Figure 2. Distribution of (A) Great Egret, (B) Snowy Egret, (C) Cattle Egret, and (D) Black-crowned Night-Heron nesting colony sites in California, 2009–2012 (Shuford, 2014). Symbol size indicates nest abundance, as shown for each map. Solid boundary lines within the state indicate Jepson Ecoregions. (Basemap data sources: ESRI, USGS, NOAA.)

land cover and wetland features measured at scales as great as 10 km away from the actual nests (e.g. Elphick 2008; Kelly et al. 2008).

In 2011, ACR had the opportunity to collaborate with Point Blue Conservation Science on the first comprehensive survey of Ardeid nesting distribution and abundance for the state of California—part of the Western Colonial Waterbird Survey of several breeding species in 11 western states (Condeso and Sterling 2011, Shuford 2014). The wading bird subset of this effort, a statewide "snapshot" capturing the distributions and sizes of heron and egret colonies in California, now provides an ideal foundation for modeling the relationship between nesting abundance and associated landscape features within each county and Ecoregion in the state (Table 1). Great Blue Herons generally nest in smaller, more widely distributed colonies, while other species often form larger colonies and are more restricted in their distributions (Figures 1 and 2; Table 1). This investigation will delve intensively into the landscape conditions that account for current nesting distributions, specifically to determine which features strongly influence nesting abundances in important habitat areas.

Key landscape components, such as the amount of available wetland foraging habitat, the amount of developed land, human population density, and wetland habitat connectivity, will be measured at multiple scales and used to predict nest abundance for each of the five study species (Table 2, Figure 3). The final models will then be used to create a suite of predictive maps, each showing the colony size and nesting abundances expected given the habitat conditions within each county and ecoregion in California.

Conservation targets

Model outputs will be summarized by relevant natural and political boundaries, such as Jepson Ecoregions and counties, for ease of interpretation by local governments and land managers. Comparison of modeled suitability and actual survey data will identify significant matches and mismatches, providing the opportunity to not only improve the model but also to critically examine specific regions in the state that may be important conservation targets. For example, areas of the state that are modeled as highly suitable, but do not currently support many nesting birds, may be brought onto the "radar" of land managers and local governments as potentially valuable resources deserving of protection. Areas of low

Table 1. Estimated average colony size (standard deviation), total number of nesting sites, total nest abundance, and the percent of the statewide nest abundance for five species of Ardeids (2009–2012), summarized by Jepson Ecoregion.

Ecoregion Species	Mean colony size (Std dev)	Number of colony sites	Nest abundance	Percent statewide nest abundance
Cascade Ranges				
Black-crowned Night-Heron	0 —	0	0	0.0
Cattle Egret	0 —	0	0	0.0
Great Blue Heron	9 (4.6)	7	60	1.1
Great Egret	51 (69.2)	2	102	1.3
Snowy Egret	0 —	0	0	0.0
Central Western California				
Black-crowned Night-Heron	21 (23.8)	16	341	13.9
Cattle Egret	0 —	0	0	0.0
Great Blue Heron	7 (5.7)	67	454	8.3
Great Egret	24 (24.3)	27	636	7.9
Snowy Egret	38 (38.0)	16	607	32.2
East of the Sierra Nevada				
Black-crowned Night-Heron	36 (6.4)	2	71	2.8
Cattle Egret	0 —	0	0.0	
Great Blue Heron	6 (5.7)	7	44	0.8
Great Egret	0 —	0	0.0	
Snowy Egret	0 —	0	0.0	
Great Central Valley				
Black-crowned Night-Heron	35 (64.6)	32	1111	45.4
Cattle Egret	58 (54.6)	14	813	30.3
Great Blue Heron	19 (21.0)	158	2959	54.1
Great Egret	56 (71.0)	107	5992	75.2
Snowy Egret	27 (39.3)	25	669	35.4
Modoc Plateau				
Black-crowned Night-Heron	33 (52.1)	5	166	6.8
Cattle Egret	0 —	0	0.0	
Great Blue Heron	23 (13.3)	3	68	1.2
Great Egret	87 (121.8)	6	521	6.5
Snowy Egret	13 (8.3)	3	38	2.0
Mojave Desert				
Black-crowned Night-Heron	3 (<0.1)	1	3	0.1
Cattle Egret	0 —	0	0.0	
Great Blue Heron	8 (<0.1)	1	8	0.1
Great Egret	0 —	0	0.0	
Snowy Egret	0 —	0	0.0	
Northwestern California				
Black-crowned Night-Heron	39 (59.3)	8	308	12.6
Cattle Egret	40 (<0.1)	1	40	1.5
Great Blue Heron	10 (16.1)	41	390	7.1
Great Egret	12 (23.6)	11	213	2.6
Snowy Egret	31 (43.4)	4	125	6.6
Sierra Nevada				
Black-crowned Night-Heron	0 —	0	0	0.0
Cattle Egret	0 —	0	0	0.0
Great Blue Heron	13 (13.9)	22	290	5.3
Great Egret	26 (30.1)	9	230	2.9
Snowy Egret	2 (0.7)	2	3	0.2
Sonoran Desert				
Black-crowned Night-Heron	4 (4.0)	3	13	0.5
Cattle Egret	567 (822.4)	3	1701	63.5
Great Blue Heron	31 (36.6)	23	721	13.2
Great Egret	22 (32.0)	6	129	1.6
Snowy Egret	24 (3.2)	3	71	3.8
Southwestern California				
Black-crowned Night-Heron	12 (13.4)	38	436	17.8
Cattle Egret	65 (1.4)	2	124	4.6
Great Blue Heron	7 (7.6)	67	473	8.7
Great Egret	12 (14.2)	13	150	1.9
Snowy Egret	14 (17.1)	26	375	19.7

modeled suitability may be obvious targets for future wetland restoration efforts.

The predictive maps will also be useful, when combined with other readily available models related to climate change and sea-level rise, for examining future risks to wading birds in California. In previous work, we highlighted one of the potential ways heron and egret populations may be impacted by climate change—their responses to altered patterns of rainfall (Kelly and Condeso 2014). Heavy winter or spring rainfall and increased winter storminess, may cause declines in the annual growth or resilience of heron and egret nest abundances. Additionally, in regions where prey species are particularly sensitive to periods of drought, nest abundances may decline with reduced rainfall.

Predictions of future rainfall in California vary considerably, depending on the climate model and emissions scenario involved. Therefore, to identify areas of conservation concern, it will be useful to compare the current distribution of colonies to predicted patterns of colony site suitability in California, based on various climate futures. In addition, future iterations of the model may take into account predicted ways that wetland foraging habitat, and therefore colony suitability, may change with rising sea level (Figure 4). As the configuration of tidal marshes evolves in California, these models will allow the needs of herons and egrets to be included in climate adaptation planning.

Because herons and egrets select nesting locations in response to the quality of their environment at the regional or landscape scale (Figure 5), it follows that their nesting abundances will also be influenced by land management practices that occur at this scale. For example, changes in the water use practices in the California's Central Valley agricultural fields could have dramatic implications for future heron and egret nesting abundances and distributions (Elphick 2008). These and other changes in the management of California landscapes have the potential to greatly impact the status of wading birds and other wetland-dependent wildlife in the state. A more precise understanding of the relationship between landscape features and nesting distribution and abundance may be a critical component of wetland restoration and climate-change mitigation in California's uncertain future.

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Table 2. Landscape metrics used in modeling statewide nest abundance for five focal wading bird species (Great Blue Heron, Great Egret, Snowy Egret, Black-crowned Night-heron, and Cattle Egret). Estimated rainfall at each colony site (PRISM Climate Group, Oregon State University) and survey year will also be incorporated as predictors into the models.

Metric	Scales of measurement (radius in km)	Predicted influence on nest abundance
Area of wetland foraging habitat Tidal wetland Non-tidal wetland Irrigated/agriculture land Small open water bodies Creeks and streams	1, 10	Increase, at medium and large scales.
Area of suitable nest substrate: Woodland/forest Large woody shrubs	0.1, 1	Increase, at small and medium scales.
Area of developed land	0.1, 1, 10	Decrease, at all scales.
Human population density	0.1, 1	Decrease, at small and medium scales.

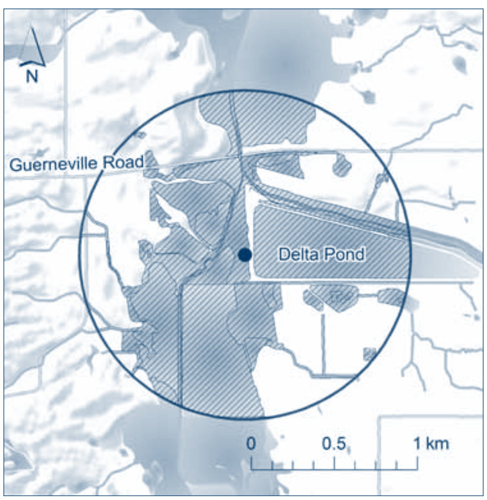

Figure 3. Illustration of foraging habitat calculation. The filled black symbol indicates the center of the colony site at Delta Pond in the Laguna de Santa Rosa, Sebastopol, Sonoma County. Available foraging habitat is estimated by summing the areas of wetland (diagonal fill) within the illustrated 1-km radius around the site center. The lengths of creeks and streams within the circular boundary are also summed as a complementary index of foraging habitat availability.

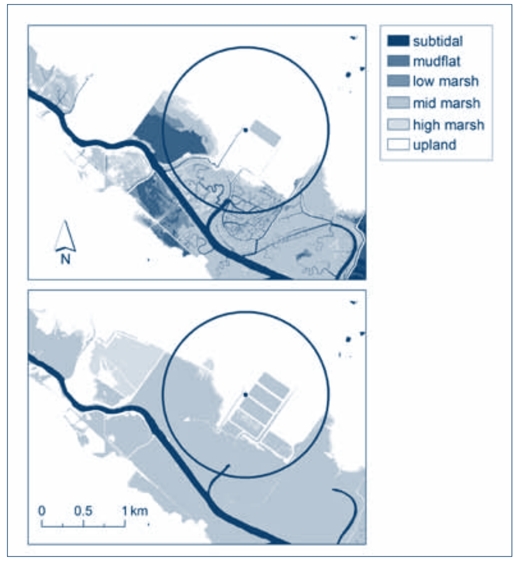

Figure 4. (A) Current (2010) and (B) projected (2110) tidal marsh elevations in the vicinity of an active Great Blue Heron nesting site in Petaluma, Sonoma County (Stralberg et al. 2011). Although this model predicts that, under a scenario of low sedimentation and modest sea-level rise (0.52 m/century), tidal marsh will persist here, the habitat is projected to be of a different character and considerably less complex than what is currently present. Our habitat associations model will help determine the extent to which the current heron and egret nest site distribution in California may change given future changes in coastal wetlands.

Figure 5. Great Egrets nesting at ACR's Martin Griffin Preserve, shown here, responded to localized Bald Eagle disturbance by moving to another nearby colony site, where they can continue to provision their nestlings by foraging in the rich feeding areas of Bolinas Lagoon. Photo by Larry Goodwin.

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Emiko Condeso is ACR's Biologist/GIS Specialist, based at ACR's Cypress Grove Research Center. As the lead investigator on this project, Emiko is working with other ACR staff and with collaborators W. David Shuford (Point Blue Conservation Science), Dan Cooper (Cooper Ecological Monitoring, Inc.), and Kathy Molina (Natural History Museum of Los Angeles County).

PHOTO BY CARLOS PORRATA OF COYOTE.

The impact of hikers on wildlife

Recreation Ecology

by Michelle Reilly and Sherry Adams

How does a nature walk affect nature? Audubon Canyon Ranch has a three-part mission: protect and steward the land, educate and connect people to nature, and conduct research to better understand natural systems. Most of the time, we think of these three imperatives as complementary. However, it is important for us to fully understand whether any of our efforts to achieve these goals conflict and, if so, how they conflict, so that we can optimize the overall benefits to conservation (Figure 1).

A recent Bay Area-wide research project by Michelle Reilly sheds light on the impact of non-motorized recreation on wildlife. Michelle recently completed her PhD dissertation (2016) at Northern Arizona University, on the effects of non-motorized recreation on mid-size and large mammals in the San Francisco Bay area. The study sites spanned eight counties and 87 different protected areas (Figure 2). Some of the study sites provide opportunities for hiking, and others do not. ACR's Martin Griffin Preserve, Bouverie Preserve, and Modini Mayacamas Preserves were among the study sites.

Non-motorized human recreation has the potential to impact habitat used by wildlife by disrupting the normal activities of animals, increasing their energy expenditure, or causing them to avoid otherwise suitable habitat. The goal of the study was to provide land managers with information that can help them to manage recreation in a way that minimizes impacts to wildlife habitat and preserves the value of protected areas for both people and wildlife. Results can also assist in the planning and management of wildlife corridors and buffer zones established to avoid conflicts between wildlife and human recreation.

Data were collected over the course of three years, using motion-activated cameras to document the human use and wildlife use in each of these natural areas. Project staff carefully sifted through tens of thousands of photos. Evidence of hikers and wildlife use picked up by the cameras was tallied to accurately record the rate at which humans and other animals were found at each site. One analysis looked at the correlation between presence of hikers and the presence of 10 different wildlife species.

A further analysis looked at the patterns of animal activity during the course of a 24-hour cycle. Because hikers are primarily active during the day, it is reasonable to assume that wildlife might shift their use of habitat to avoid humans. For this analysis, locations with no people were compared to locations with eight or more people per day. If the wildlife in the areas with people were less active during the day and more active at night than the wildlife in areas with no people, the results would suggest that the animals shifted the timing of their activities to avoid humans.

Some animals of particular interest, such as black bear *(Ursus americanus),* ringtail *(Bassariscus astutus),* and spotted skunk *(Spilogale gracilis)* were present but in such low numbers they could not be used in the analyses. While we are interested in knowing how the presence of hikers affects these animals, additional research is needed to shed light on that question.

Figure 1. Hikers at ACR's Mayacamas Mountains Sanctuary in northern Sonoma County. ACR photo.

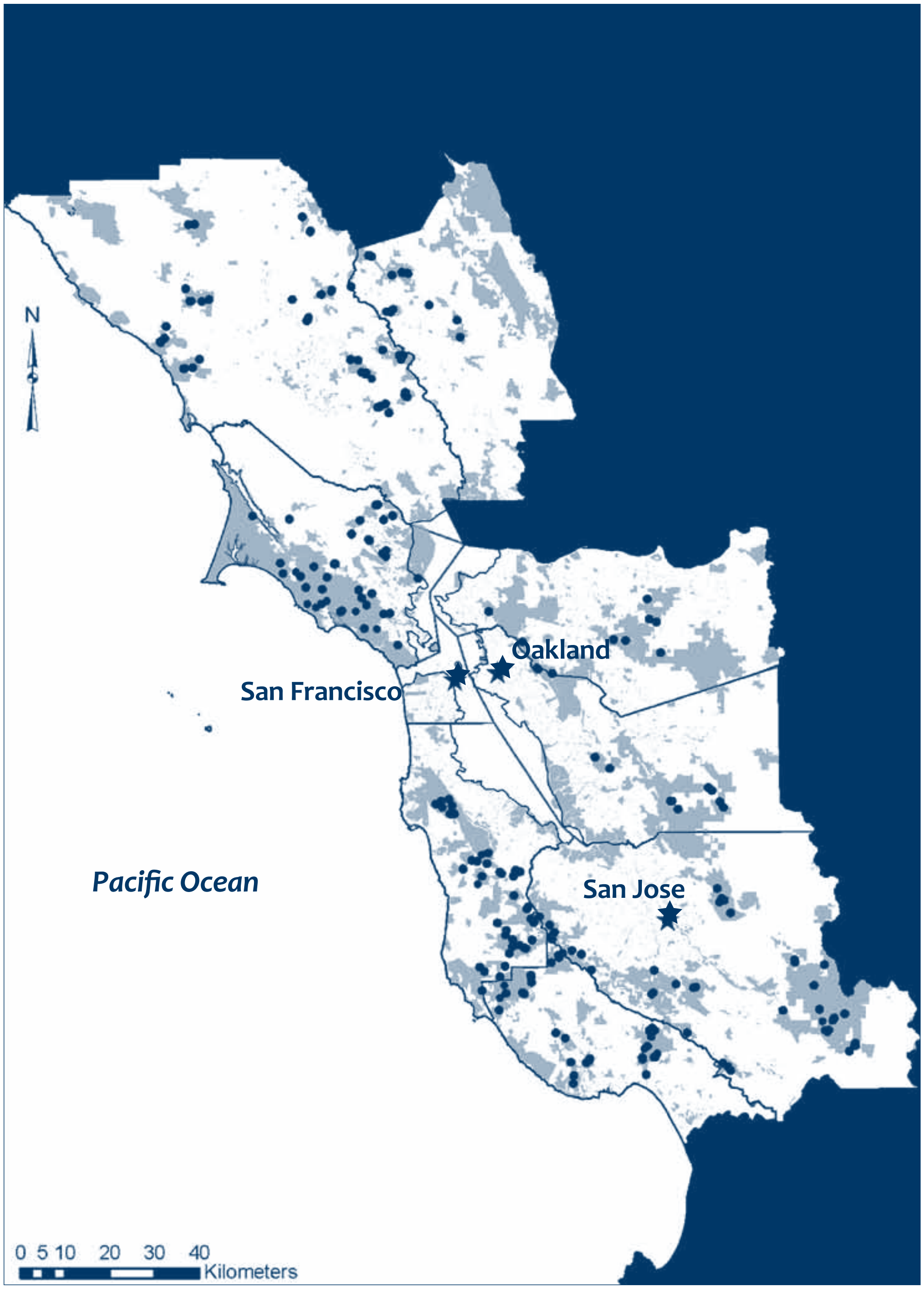

Figure 2. Recreation ecology study area in the San Francisco Bay Area, including sites in Marin, Sonoma, Napa, Alameda, Contra Costa, Santa Clara, Santa Cruz, and San Mateo Counties. The locations of sites sampled from 2011-2013 are denoted by black points. Light blue shading in the background indicates protected areas designated in the California Protected Areas Database (www.calands.org). Lines indicate county boundaries.

Figure 3. Mountain lions are less likely to occur in areas with more hikers. Photo by Joseph Blowers.

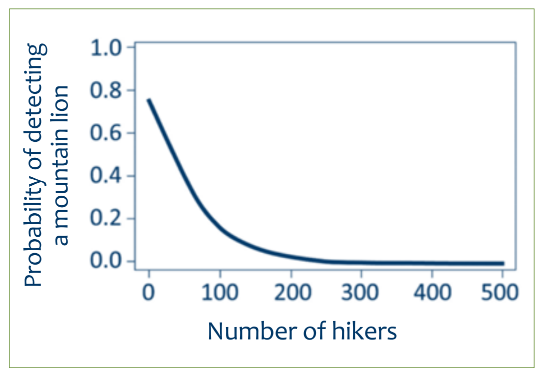

Figure 4. The probability of detecting a mountain lion within a 24-hour period declines as the number of hikers in a natural area increases.

Findings

A strong negative correlation between presence of hikers and probability of detecting mountain lions *(Puma concolor)* suggested that as more hikers use a natural area, mountain lions are less likely to be seen (Figures 3 and 4). The analysis also found small negative correlations between the presence of hikers and mule deer *(Odocoileus hemionus)* and between hikers and feral pigs (*Sus scrofa;* Figure 5). There was no correlation between the number of hikers and the presence of coyotes *(Canis latrans)* or bobcats *(Lynx rufus).* A positive correlation with the number of hikers suggested that the presence of the introduced marsupial Virginia opossum *(Didelphis virginiana)* was associated higher levels of human activity.

Even if the chance of detecting a particular species within a 24-hour period does not show a trend associated with the presence of hikers, the species could be altering its behavior in the presence of humans. That appears to be the case for coyotes. Coyotes were more active at night and less active during the day in areas with high levels of recreation than in areas with no recreation (Figure 6). Several species—grey fox *(Urocyon cinereoargenteus),* raccoon *(Procyon lotor)*, striped skunk *(Mephitis mephitis),* and Virginia opossum—had activity patterns that

Conservation Keys

- Recreational opportunities in natural areas are key mechanisms for creating a citizenry that appreciates the value of wild places.
- In many cases non-motorized recreation is completely compatible with wildlife use of protected areas. However some animals, such as mountain lions and coyotes, adjust their behavior to avoid hikers.
- Natural areas with little or no human use provide sanctuaries for those wildlife species that thrive best in our absence.

Figure 5. Mule deer are detected less frequently in areas with more human activity. Photo by Carlos Porrata.

were mostly nocturnal and did not overlap with the activity patterns of recreationists. Thus, there was no observed shift in their activity patterns in response to recreation. Bobcats, mule deer, and rabbits (*Sylvilagus* spp.) are often active during the day, but they did not shift their activity patterns in response to recreation, suggesting that these species are adapted to the presence of recreation in protected areas.

We can make space for both humans and wildlife

Managing nature preserves wisely requires both conservation science, which helps us to understand the natural world, and also effective judgment needed to apply that knowledge. In addition, recreational opportunities in our natural areas are key mechanisms for creating a citizenry that appreciates the value of wild places (Figure 7). In some areas managed by Audubon Canyon Ranch, we invite human visitation. These are places where adults and children learn about nature, volunteer with our stewardship team, or just enjoy the sights and sounds of a wild place. But we also have some areas where human visitation is very limited. We now understand a little more about how wildlife is affected by hikers enjoying ACR preserves and other natural areas. Many animals coexist successfully with humans. However mountain lions avoid areas with humans, and coyotes are forced to shift their use patterns to avoid humans. In addition, for the least common species such as black bears, we still do not know how human visitation may impact their use of habitat.

Like many people who visit ACR, you probably enjoy having access to numerous natural areas and rejoice at the thought of exploring some place new. This study reminds us of the importance of areas where we are not invited, as sanctuaries for wildlife species that thrive best in our absence.

Michelle Reilly is a visiting professor of Biology at New Mexico Highlands University.

Sherry Adams is the preserve biologist at ACR's Modini Mayacamas Preserves.

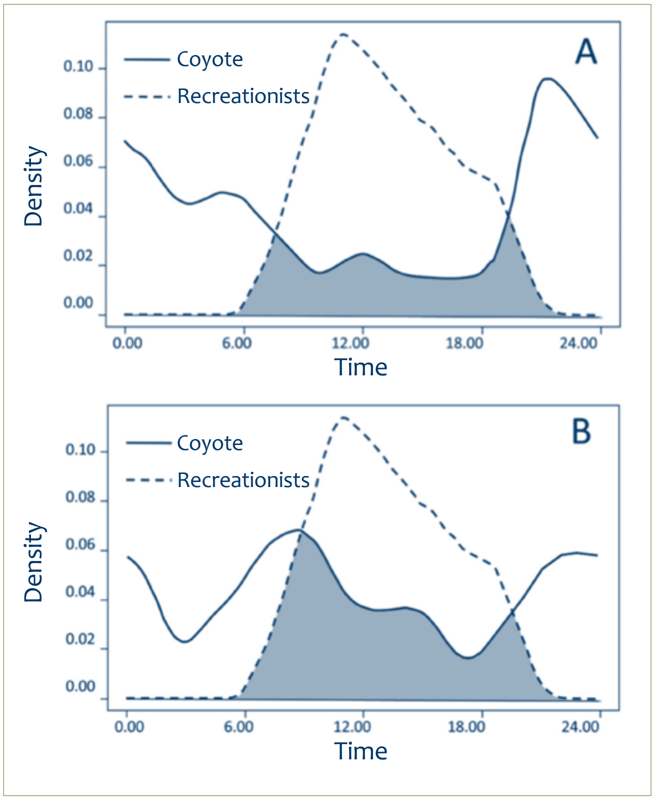

Figure 6. The dotted line shows the use by humans—primarily during the day, peaking in late morning. In panel A, the solid line shows presence of coyotes in areas used intensively by humans. In panel B, the solid line shows presence of coyotes in areas with no use by humans, compared to patterns of recreational activity in other areas. In areas with intensive use by humans, coyotes are less active during the day and more active during the night than in locations with no human use.

Figure 7. Birding outing on ACR's Modini Mayacamas Preserves. Photo by Joe Barkoff.

Mountain lion research at ACR

The Role of Top Predators in Ecosystems

by Quinton Martins

Extinctions on our planet have been a part of nature's process since the first signs of life. Today conservationists are extremely concerned about the recent upsurge in the number of extinctions and the effect these may have on ecological systems. Humans have had an unprecedented effect on ecosystems around the world. Over the last 50,000 years we have witnessed the extermination of a considerable proportion of the megafauna across the globe. It is possible that climate change and resulting changes in vegetation have contributed to extinctions. Nevertheless, as humans became industrialized, colonization and destruction of the Earth's natural resources escalated. Over the past 500 years, human activities have led to at least a quarter of the known extinctions or extinction threats to the world's mammals (Schippers, 2008). The elimination of the world's megafauna includes the past and present loss of most of the large predators. Over recent decades, ecologists have become increasingly concerned about these losses, intensifying scientific efforts to understand the essential roles of large predators in healthy ecosystems (Figure 1).

Figure 1. Mountain lion researchers at ACR used a motion-sensitive camera to obtain this image of a mountain lion at a natural deer kill near ACR's Bouverie Preserve. ACR photo.

Ecological perspective

It has not helped that, ironically, biologists have contributed to the demise of large predators. In some instances, predators were purposely killed to minimize their supposed negative impact on the system. These actions were based on well orchestrated arguments suggesting that the removal of top trophic levels of food webs results in lower trophic levels remaining intact, and that the removal of lower-level primary producers would cause far greater disruption to the ecosystem. Conversely, seminal work by Hairston et al. (1960) promoted the idea that because "the world is green" it is obviously not overgrazed by herbivores. Therefore, if food does not limit the herbivores, they must be held in check by the predators. Accordingly, predators are often keystone species, needed to sustain biological diversity by regulating the number of herbivores in the trophic level below them, thereby reducing the impact of herbivory on plant communities. Predators also interact with other consumers, leading to complex direct and indirect effects on the structure of entire food webs. Over the past 50 years, considerable work has been done to illustrate the ecological importance of large predators and how they have a significant role in the functioning of healthy ecosystems (Terborgh and Estes, 2010).

Major disturbances or imbalances in an ecosystem can result in what Robert Paine (1980) described as a "trophic cascade." Later, John Terborgh and others (2001) observed the chain reactions resulting from the sudden formation of small islands of habitat caused by hydroelectric development in Venezuela. The

Conservation Keys

- Numerous studies have shown that the health of natural systems relies on the presence of apex predators.
- Because mountain lions range over large landscapes, protected habitat areas alone are not enough to ensure their survival.
- ACR is studying the movements of GPS-radio-collared mountain lions and using community outreach to increase both scientific and public understanding of mountain lions.

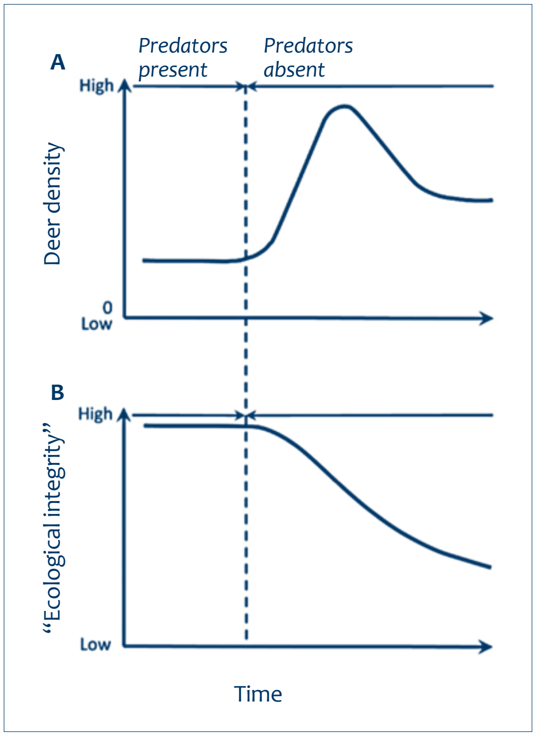

Figure 2. Responses to the release of historic predation pressure, showing (A) increases in the density of deer after removal of large predators and (B) the consequent loss of "ecological integrity" with increased browsing pressure. "Ecological integrity" corresponds to a combination of functional measures related to ecosystem health, including the persistence of species and communities of plants and animals. (Figure from Ripple et al. 2010.)

islands were too small for large predators such as jaguars *(Panthera onca)*, resulting in an explosion of herbivore species, which subsequently destroyed the vegetation. The opposite effects are seen in case studies of keystone predators such as wolves *(Canis lupus)* or bears (*Ursus* spp.) that have been reintroduced into ecosystems after their absence had led to overpopulation of prey species (Ripple and Beschta 2004; Figure 2).

The effects of predator reintroductions demonstrate the importance of predators and that the extirpation or local decline of large carnivores perturbs the biological communities in which they live. The extent of these declining predator populations may alter the entire ecology of extensive landscapes. Thus, the conservation of large carnivores is of global importance, as they serve as umbrella species across habitats, ensuring the broader conservation of wildlife and ecosystems wherever they live. The conservation of intact, healthy ecosystems, in turn, provides numerous benefits to humans, such as clean water, forest regeneration, seed dispersal, improved nutrient cycling, climate regulation, healthy native plant communities, soil fertility, streambank stability, and much more.

Left unchecked, loss of top predators can also result in "meso-predator release," whereby population densities of smaller predators may increase to a point where they have a negative impact on the abundances of other species, including smaller prey. In such cases, top predators operate as "watchdogs," maintaining a balance through interspecific control of other predators. In the United States, wolves regulate coyotes who, in turn, regulate fox populations. Similarly, mountain lions *(Puma concolor)* exert direct or indirect pressures on other predators in their habitat, by feeding on them or influencing their movement by encouraging active avoidance behaviors.

Where ecosystems are lacking integral components, such as large herbivores and/or large carnivores, regaining the functionality of such systems may require the reintroduction of species. In many cases, megafauna indigenous to these ecosystems are extinct—and have been for thousands of years. Efforts to restore large wild vertebrates where the original species no longer exist are termed "rewilding." In the hope of restoring ecosystem integrity, protagonists are attempting refaunation based on events dating back to the Pleistocene. Many others have questioned whether the trophic cascades that followed the megafaunal extinctions of the Pleistocene should be a concern today. This perspective suggests that undoing perturbations observed in ecosystems should focus on reversing more recent changes. However, the reconstruction of a guild of large predators lost in recent history, including animals such as wolves or grizzly bears *(Ursus arctos)*, is not always feasible. Ecological impacts resulting in large-scale fragmentation of the landscape, combined with human settlement and the unlikely coexistence of people with these large predators, confirm the reality of an unrecoverable loss of diversity.

Numerous studies have now shown that the health of natural systems relies on the presence of apex predators, so the loss of apex predators is no longer only of ethical or aesthetic concern. Their iconic nature appropriately reflects their functional importance in maintaining ecosystem integrity and services, and large carnivores such as the mountain lions and wolves are valuable species to effectively promote broader environmental conservation (Figure 3).

Figure 3. Iconic and charismatic predators are used to connect product qualities with people. Here the Puma brand uses mountain lion feet to depict their sports shoes.

The ACR Mountain Lion Project

Mountain lion research at ACR is an exciting technical investigation and community-based outreach program, designed to increase both scientific and public understanding of mountain lions. Mountain lions are one of the most iconic and charismatic species, inspiring awe, curiosity, and sometimes fear in a way that few other animals do. Focusing on the powerful charisma of lions and their ecological role in ecosystems, the project works to increase our knowledge and appreciation of mountain lion behavior, population size, feeding habits, home range, and movements—to help ensure their conservation and the protection of habitat critical for their survival.

Together with a team of scientific advisors and other ACR staff, I am studying the movement of GPS radio-collared mountain lions, primarily in the Mayacamas Mountains and areas east of Highway 101 in Sonoma County (Figure 4). Habitat loss and fragmentation driven by agricultural expansion and human population growth constitute a severe threat to large carnivores, because these animals occur at low densities, have slow population growth rates, range over large areas, and require sufficient prey, all of which make them particularly vulnerable to extinction. Their prey requirements also make them susceptible to conflict with humans and retaliatory killing, further increasing their vulnerability.

Key information on population density and distribution is required for effective conservation management for lions. Because of large carnivores' cryptic nature and large individual ranges, it is inherently difficult to assess their population status, hindering conservation efforts, particularly in fragmented and unprotected areas. We live in landscapes where protected areas alone are not viable for mountain lion survival. Engaging private landowners of unprotected areas and sharing educational material on the ecology and behavior of mountain lions, along with ways to mitigate conflict between lions with humans, are therefore essential for carnivore conservation.

Direct observations of mountain lions are so rare that remote data collection is almost the only way to study their behavior and move-

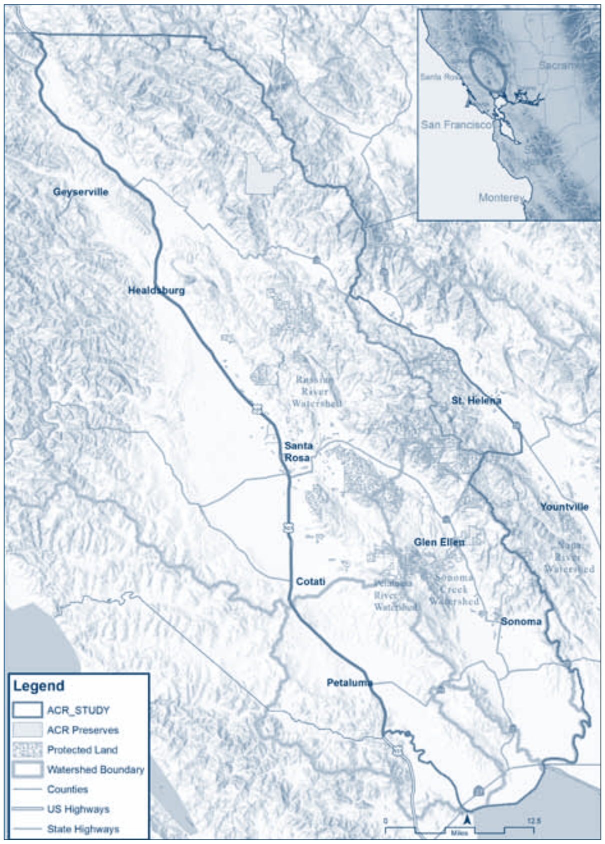

Figure 4. ACR Mountain Lion Project study area.

ments. GPS radio-collars, photographic captures using remote cameras, and DNA material are the primary means of studying them. GPS location data can then be used for simple enumeration of their movements and occurrence or for more complex home-range analyses needed to estimate density. GPS location "clusters" can also be used to establish mountain lion feeding, resting, breeding, and mortality sites. In-depth resource and habitat selection analyses will furnish data necessary to understand the habitat needs and corridor/connectivity requirements of resident and dispersal mountain lions needed to ensure their survival and sustain their regional status. Remote photographic "captures" of mountain lions and other species can provide activity data and relative density estimates, as well as presence/absence data for cryptic species. DNA and associated disease work will provide evidence of potential threats to the population due to lack of gene flow, toxicity from pesticides, and social/sexual behavior associated with relatedness issues such as inbreeding avoidance.

Our research on mountain lions is paired with an extensive education and outreach program that builds on ACR's successful nature education programs. The Mountain Lion Project aims to increase public understanding of mountain lion habits and needs, provide school-age children an opportunity to learn about these animals and conservation generally, dispel myths that contribute to a culture of fear around mountain lions and other top predators, and—through outreach to landowners—reduce the extent of unnecessary depredation of mountain lions.

ACR believes that conservation is successful when people feel personally connected to nature. Follow the ACR mountain lion project on: http://egret.org/acr-mountain-lion-project

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Quinton Martins, PhD, is an ACR Wildlife Ecologist and the lead investigator of ACR's Mountain Lion Project, centered at ACR's Bouverie Preserve near Glen Ellen.

Visiting investigators

Audubon Canyon Ranch hosts graduate students and visiting scientists who rely on the undisturbed, natural conditions of our preserves to conduct investigations in conservation science.

Monitoring Avian Populations (MAPS) banding station at Livermore Marsh. Steve Albert, Lauren Helton, Peter Pyle, Ron Taylor, and others, The Institute for Bird Populations, Point Reyes Station.

National Wetland Condition Assessment. Cara Clark, Moss Landing Marine Laboratories, Moss Landing, CA

Dispersal vectors and risk assessment of noxious weed spread: medusahead invasion in California rangelands. Emily Farrer, University of California, Berkeley.

Context and scale of seagrass effects on estuarine acidification. Tessa Hill, Bodega Marine Lab, University of California, Davis.

The role of microbiota in mediating local adaptation and plant influence on ecosystem function in a marine foundation species. Melissa Kardish, University of California, Davis.

Harbor seal monitoring in northern Tomales Bay. Mary Ellen King, Pinniped Monitoring Program, Point Reyes National Seashore.

Interactions between marsh plants along a longitudinal gradient: the effect of environmental conditions and local adaptation. Akana Noto, University of California, San Diego.

Effects of non-motorized recreation on medium- and large-sized mammals in the San Francisco Bay Ecoregion. Michelle Reilly, Northern Arizona University.

Spatial and temporal variability in eelgrass genetic structure. Laura K. Reynolds, University of California, Davis.

An archaeological study of indigenous landscapes and social networks at colonial Toms Point, California. Tsim D. Schneider, University of California, Santa Cruz, and Lee M. Panich, Santa Clara University.

The wildlife photo index: monitoring connectivity and ecosystem health. Susan E. Townsend, Wildlife Ecology and Consulting/Pepperwood Preserve.

Sonoma County Vegetation & Habitat Mapping Program. Mark Tukman, Tukman Geospatial and Sonoma County Agricultural Preservation and Open Space District.

In Progress

Current projects by Audubon Canyon Ranch focus on the stewardship of preserves, ecological restoration, and issues in conservation science.

Bolinas Lagoon Heron and Egret Project. All heron and egret nesting attempts in Bolinas Lagoon have been monitored annually since 1967. The heronry at the Martin Griffin Preserve was abandoned in 2014, but we are continuing to track nest abundances and reproductive performance in the lagoon, including the active heronry near Bolinas.

Tomales Bay Shorebird Census. Since 1989, qualified birders have helped ACR to monitor the use of Tomales Bay by wintering and migrating shorebirds. The data are used to investigate winter population patterns, local habitat values, benefits of wetland restoration, and other implications for shorebird conservation.

Tomales Bay Waterbird Survey. Since the winter of 1989–90, teams of observers have conducted winter waterbird censuses from survey boats on Tomales Bay. The results provide information on the habitat values and conservation needs of more than 50 species.

North Bay Counties Heron and Egret Project. Annual monitoring of all known heron and egret nesting colonies in five northern Bay Area counties began in 1990. Results are used to measure the effects of climate change, impacts human disturbance, and the status of herons and egrets in the San Francisco Bay area. ACR's regional atlas and a Google-Earth program showing the locations and status of individual heronries (www.egret.org/atlas) are available online.

Heron Telemetry Project. We are using GPS telemetry to track the movements, regional landscape use, and foraging behaviors of Great Blue Herons throughout the Bay Area. The project will determine how key habitat features needed for the survival of these top wetland predators can be used to advance wetland conservation planning and restoration.

Four Canyons Project. In the lower reaches of four canyons at ACR's Martin Griffin Preserve, we are controlling invasive plant species and using locally collected and propagated plant materials to restore the native vegetation.

Hydrogeomorphological Assessment of MGP Canyons. ACR is working with Kamman Hydrology & Engineering to characterize watershed conditions in MGP's four canyons, incorporating climate change and linkages with the Bolinas Lagoon ecosystem.

Cape Ivy Control. ACR stewardship staff have been working with Hanford Associates and MGP stewardship volunteers to identify and implement a phased approach to the control of non-native, invasive cape ivy *(Delairea odorata)* control in the riparian corridor in Volunteer Canyon.

Golden Gate Biosphere Reserve. ACR's Martin Griffin Preserve, a member of the United Nations Golden Gate Biosphere Preserve since the 1990s, will now become part of the "core area" of this regional partnership.

Monitoring and Control of Non-Native Crayfish. Bouverie Preserve staff and volunteers are continuing to control invasive signal crayfish *(Pacifastucus lenisculus)* in Stuart Creek to reduce the impacts on native amphibians, steelhead, and other species.

Biological Species Inventory. Resident biologists maintain inventories of plant, animal, and fungal species known to occur on ACR lands. Staff at Bouverie Preserve and Martin Griffin Preserve have enlisted the help of volunteers to integrate these inventories with the on-line database iNaturalist.

Non-Native *Spartina* and Hybrids. ACR is continuing to collaborate with the San Francisco Estuary Invasive Spartina Project to coordinate and conduct field surveys and removal of invasive, non-native *Spartina* in Tomales Bay.

Perennial Pepperweed in Tomales Bay. We are conducting baywide surveys of shoreline marshes and removing isolated infestations of invasive, non-native pepperweed *(Lepidium latifolium)*, known to quickly cover estuarine wetlands, compete with native species, and alter habitat values.

Saltmarsh Ice Plant Removal. After eradicating non-native ice plant from ACR's Toms Point on Tomales Bay, we are continuing to remove resprouts, along with occasional new patches introduced from other areas by high tides and currents.

Vernal Pool Restoration. We are monitoring native plants in Bouverie Preserve's vernal pools, including a patch of federally endangered Sonoma sunshine *(Blennosperma bakeri)* that ACR restored in 2009, and controlling invasive plants using manual removal and prescribed cattle grazing.

Yellow Starthistle at Modini Mayacamas Preserves. Sherry Adams is investigating the responses of native and non-native grassland plants to the removal of non-native yellow starthistle *(Centaurea solstitialis)*. She has also developed guidelines to reduce the spread of this invasive pest plant.

Invasive Species Management at Modini Mayacamas Preserves. We collaborate with volunteers on early detection, monitoring, and elimination of new invasions by wildland weeds such as distaff thistle *(Carthamus lanatus)* and barbed goatgrass *(Aegilops triuncialis)*. For widespread species, such as milkthistle *(Silybum marianum)* or yellow starthistle *(Centaurea solstitialis)*, we use containment to limit their spread into new areas.

Songbirds of the Central Mayacamas Mountains. To measure the breeding-bird habitat relationships, we are conducting point counts from the bottom to the top of Pine Flat Road, near Healdsburg, including ACR's Modini Mayacamas Preserves. Interested birders who can identify breeding birds by ear are encouraged to contact ACR's Cypress Grove Research Center.

Rosy Sandcrocus. At Bouverie Preserve, ACR staff are testing management techniques, including the use of prescribed fire, to control rosy sandcrocus *(Romulea rosea)*, an invasive forb with a potential to severely degrade California open spaces and rangelands.

Harding Grass Meadow Restoration. ACR's Fujita Research Fellow Dylan Gallagher is working with ACR staff at Bouverie Preserve to test the effectiveness of burning, mowing, solarization, and planting of native grass seeds to restore a grassland dominated by invasive Harding grass *(Phalaris aquatica)*.

Mountain Lion Project. Led by wildlife ecologist Quinton Martins, ACR is tracking the movements of mountain lions fitted with GPS satellite collars to study wildlife corridors and the regional abundance, health, and conservation needs of mountain lions in areas east of Highway 101 in Sonoma County. As part of this effort, ACR is collaborating with Sonoma Land Trust, Sonoma County Regional Parks, CA State Parks, and other members of the Wildlife Observers' Network Bay Area (WONBA) convened by Pepperwood Preserve.

Ecological Restoration of the Inverness Shoreline. After removing non-native vegetation and all of the buildings on a property generously donated to ACR by Helen McLaren, ACR planted native trees and understory plants to restore two acres of native vegetation with a natural gradient of riparian and tidal wetlands in Tomales Bay.

THE ARDEID

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Hugh Robertson, *Director of Finance and Operations*
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The Watch

Volunteers for ACR research or habitat restoration projects since *The Ardeid* 2015. Please call (415) 663-8203 if your name should have been included. **Project Classifications: B**—Bouverie Stewards ▮ **C**—Cypress Grove Research Center Office Volunteers ▮ **H**—Heron and Egret Project ▮ **M**—Modini Ingalls Ecological Preserve Breeding Bird Assessment ▮ **MA**—Pine Flat Road Breeding Bird Survey ▮ **MG**—Martin Griffin Preserve Stewards ▮ **R**—habitat protection and restoration projects ▮ **S**—Tomales Bay Shorebird Census ▮ **W**—Tomales Bay Waterbird Census

Mary Abbott (S), Nancy Abreu (H), Bob Adhers (B, MP), Sarah Allen (S, W), Bob Battagin (S), Katy Baty (W), Tom Baty (H, W), Gordon Beebe (M, S), John Blasingame (H), Patti Blumin (H), Ellen Blustein (S), Janet Bosshard (H), Anna-Marie Bratton (S, W), Bill Bridges (H), Denice Britton (H), Brianne Brussee (H), Joe Burns (W), Phil Burton (H), Denise Cadman (H), Richard Carlson (R), Ann Cassidy (H), Joanna Castaneda (H), Dave Chalk (B), Richard Cimino (W), Margaret Colbert (S), Judith Corning (S,W), Bob Cox (B), Kevin Dankwardt (MP), Sharon Delamore (H), Nancy deLorimer (MP), Donna Dennis (H), Daniel Edelstein (H), Todd Eggert (H), Will Elder (H), Chris Engels (B), Janeann Erickson (H), Jules Evens (S, W), Ginny Fifield (MP), Betsey Finn (MA), Binny Fischer (H, W), Mary Anne Flett (S), Jobina Forder (B), Andrea Freeman (W), Ruth Friedman (H), Dennis Fujita (B, MP), Tom Gaman (S), Daniel George (W), Anthony Gilbert (S), Jim Gray (H, MP), Carolyn Greene (MA), Kathy Hageman (H), Bob Hahn (B), Madelon Halpern (H), Lauren Hammack (H), Deyea Harper (H), Linda Harrington (MG), Roger Harshaw (MA, S, W), Laura Hayden (B), Hugh Helm (B), Earl Herr (B), Howard Higley (W), Lisa Hug (M), Iain Jamieson (MP), Lorraine Johnson (MG), Gail Kabat (W), John Kaufman (H), JoAnne Kazimi (MP), Charles Klein (S), Alexandra Kreis (MG), Joan Lamphier (H, S, W), Brett Lane (H), Stephanie Lennox (H), Robin Leong (H), Ruth Lombard (B), Stephen Long (MA), Carolyn Longstreth (S, W), John Longstreth (S, W), Anne Lowings (MP), Simon Lowings (MP), Leslie Mace (H), Mary Mahoney (MP), Michael Mahoney (MP), Ron Mallory (H), Meg Marriott (H), Kyle Marsh (S, W), Susan Maxwell (MP), Mark McCaustland (H), Bob McLean (H), Leslie McLean (H), Peter Metropulos (W), Maryanne Michaels (B), Patrick Michaels (B), Jim Moir (R), Ian Morrison (M, MA, S, W), David Mortenson (B), Gerry Mugele (H), Kathleen Mugele (H, S), Erin Mullen (MP), Dan Murphy (S), Lynne Myers (R), Brianne Nelson (MP), Len Nelson (H),Wally Neville (H), Kevin O'Dea (MG), Rebecca Olsen (M, W), Trent Orr (W), Lindy Parker (H), Tony Paz (MG), (Matthew Perry (MA, W), Richard Plant (W), Ken Poerner (H), Susan Poirier-Klein (S), Penny Proteau (H), Louis Ptak (W), Peter Pyle (S, W), Diana Rathbone (B), Greg Raynor (H), Tom Reynolds (MP), Melissa Roberts (H), Melissa Roberts (B), Mary Rooney (S), Glenda Ross (B), John Rudell (MP), Ruth Rudesill (MA), Ellen Sabine (H), Donna Schmidt (MP), Ken Schneider (S), John Schwonke (B), Victoria Seher (H), Doris Sharrock (H), Richard Shipps (B), Paul Skaj (W), Grant Snetsinger (R), John Somers (H), Bob Spofford (H), Sue Spofford (H), Jude Stalker (W), Kandice Strako (W), Emilie Strauss (S), Khara Strum (S), Tina Styles (H), Kate Symonds (H), Elliott Thompson (MP), Francis Toldi (W), Gwendolyn Toney (S), Katy Tracy (R), Sara Tracy (R), Mary Anne Turbeville (MP), Claudia Vieira (H), Bud Vieira (H), Village Charter School (MP), Kurt Walsh (B), Anna Weinstein (W), Jim White (W), Adele Wikner (H), Peter Willmott (W), Ken Wilson (M, W), David Wimpfheimer (S, W), Suzie Winquist (W), Mike Witowski (R), Alexandra Wood (R), Patrick Woodworth (C, H, M, MA, MP, S, W).

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THE ARDEID

Conservation Science and Stewardship at Audubon Canyon Ranch

Statewide habitats

At the Salton Sea, a submerged snag supports a Great Blue Heron colony. See page 6.

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