Conservation Science and
Habitat Protection at
Audubon Canyon Ranch

THE ARDEID

Sonoma Sunshine

vernal pools

energy footprints

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waterbirds

foraging horizons

herons and egrets

tiny pathogen

sudden oak death

2007

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Cover: Surf Scoter on cresting wavelet. ***Photo by R. Crossley / VIREO***

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Vernal pool restoration at Bouverie Preserve

Saving Sonoma's Sunshine

by Sherry Adams, Jeanne Wirka, and Daniel Gluesenkamp

Sonoma sunshine *(Blennosperma bakeri)* may yet thrive in the Valley of the Moon. This small yellow daisy-like annual, a federally listed endangered species, is restricted to the vernal pools and swales on the Santa Rosa Plain and in the Sonoma Valley. Indeed, the last remaining viable Sonoma Valley population of this special plant occurs very close to Audubon Canyon Ranch's Bouverie Preserve. Along with the proximity of this population at the Preserve, another rare vernal pool plant is present, dwarf downingia *(Downingia pusilla)*. This offers the Audubon Canyon Ranch science program an opportunity to take a leadership role in the preservation of both of these rare plants, as well as the local vernal pool landscapes that support them. Here we report on the exciting new directions of this work, recently boosted by additional funding, staffing, and strong local partnerships.

A plant species can be rare for many reasons. Some have always been rare, while others have become rare with anthropogenic changes to the landscape. A plant that is a habitat specialist, found in a narrow range of conditions, is particularly vulnerable to becoming rare. Another characteristic that can make a plant vulnerable is dependence on another species for some part of its life cycle. In the case of some flowering plants, a decline in the population of a specialized pollinator, for example, may result in lower seed production. That combination of habitat specificity and specialist pollinators has caused a decline in many vernal pool plants (see box below).

As with vernal pools statewide, the majority of vernal pools in Sonoma County have been eliminated, a casualty of being located on private land that is considered prime real estate for agriculture or development. Three plants found in Sonoma County vernal pools are currently recognized by both state and federal agencies as endangered. Some animal specialists, such as the California tiger salamander, are also impacted by this loss of habitat.

ACR PHOTO

Figure 1. Native plants like the colorful calicoflower *(Downingia concolor)* characterize intact vernal pools.

The Bouverie Preserve contains a network of interconnected vernal pools and swales in the 30-acre grassland on the western boundary of the Preserve. Like most vernal pools in California, the Bouverie pools face a host of challenges that threaten to impair the system. The typical vernal pool hydrological cycle of complete inundation in winter followed by complete desiccation in summer protects the small-stature native plants from being replaced by the invasive plants that dominate the surrounding grassland. Where this hydrologic regime has been compromised by silt deposition, the pools have been invaded and their species composition altered. Furthermore, Bouverie's pools are located immediately adjacent to a busy highway from which nitrogen-laden vehicle exhaust can "fertilize" invasive plants, making them even more competitive with the diminutive native flowers.

California Vernal Pools: Precarious Islands of Nativeness

Vernal pools are spots where rainwater collects because of bedrock or clay soils, creating a seasonal wetland. California's winter rains fill the small pools or interconnected swales, and with the onset of the dry season in spring they become completely desiccated. Vernal pools have a suite of specialist species—stunning plants and animals specially adapted to this challenging environment. Approximately 90% of all vernal pools have been destroyed, as they are often located in areas which are deemed ideal for agriculture or development. Vernal pool destruction is generally mitigated with the creation of substitute pools, with varying success in sustaining populations of the highly specialized plants and animals that are adapted to this unique habitat. The remaining natural pools are a crucial reservoir of the native, and frequently endemic, biota.

Most California vernal pools are located in grasslands with microtopographic relief. These grasslands are among the most invaded habitats anywhere. In a typical California grassland over 90% of the biomass is from grasses of European origin, introduced by people. However, the hydrologic regime in the vernal pools—complete inundation in winter followed by complete desiccation in summer—is one that few species are able to invade. As a result, these depressions are "islands" of native species surrounded by an "ocean" of invasive grasses. Where the hydrologic regime is compromised, pools can quickly become invaded, with an associated decline in native diversity. Adding to the vulnerability of vernal pool flora, many species only thrive when visited by specialist pollinators: solitary ground-nesting native bees that only visit flowers of a particular genus.

Given these threats, in 2005 Audubon Canyon Ranch initiated a vernal pool management program that began with prescribed grazing to remove some of the biomass from European annual grasses. Funding from the Community Foundation of Sonoma County has been crucial, and has allowed us to study the effects of nitrogen deposition from highway vehicles and to fully characterize the floristic and physical characteristics of the pools (Gluesenkamp and Wirka, *Ardeid* 2006). New funding from the U.S. Fish and Wildlife Service enables us to take the next step toward actual restoration of our target species.

Our target species: Sonoma sunshine and dwarf downingia

Sonoma sunshine is a California endemic in the sunflower family (Asteraceae) that blooms from February through April. At least 30% of the documented occurrences of Sonoma sunshine have been eliminated or seriously damaged, and most of the remaining sites are threatened with urbanization, irrigation with wastewater effluent, and conversion of habitat to agricultural lands (CNPS 2007). There are fewer than ten locations in the Santa Rosa Plain where the species remains. Of the five occurrences documented in Sonoma Valley in 2000, only one remains.

ACR PHOTO

Figure 2. Seventh-graders Sawyer Lloyd and Miles Dakin collect seeds for reintroduction in Bouverie vernal pools.

This Sonoma Valley population of Sonoma sunshine is located just a short walk from ACR's Bouverie Preserve. Historical photos suggest that the pools on either side of the highway were once interconnected, indicating that they once shared the same group of species. Preliminary data from work currently underway by the Laguna de Santa Rosa Foundation (Christina Sloop, personal communication) suggests that this patch of Sonoma sunshine may be genetically distinct from occurrences on the Santa Rosa Plain, underscoring the importance of its protection. While the population is currently protected from development, it is within 2 m of an annually disked fire break. There is no fence separating it from a busy rural highway that conveys 15,000 vehicles a day. Recently, the last wild population of *Delphinium bakeri* was eliminated by road crews in Marin County. The elimination of this other endangered roadside plant reinforces our concern that Sonoma sunshine may be just one errant driver away from destruction.

Our other rare plant, dwarf downingia, is a diminutive annual "belly plant" in the bellflower family (Campanulaceae) with tiny white or blue flowers that bloom from March to May. It grows in vernal pools and on margins of vernal lakes and other moderately wet areas in foothill and valley grassland. Dwarf downingia is considered rare in the nine California counties in which it occurs. Sonoma County is the only coastal county where the species persists, yet three of the 14 Sonoma County occurrences listed in State Natural Diversity Data Base have been extirpated (Dittes and Guardino 2003). Because the majority of extant occurrences of this species are located on private land, its conservation trajectory in California will most likely parallel the declines of other vernal pool taxa in the state. Fortunately, the Bouverie Preserve supports a persistent patch of dwarf downingia in a long-abandoned quarry near the vernal pools (Gluesenkamp, *Ardeid* 2005).

Restoration Takes Teamwork

Audubon Canyon Ranch is working with a number of partners to advance the science and practice of vernal pool conservation in Sonoma County. This work benefits from leadership by the Laguna de Santa Rosa Foundation, the Milo Baker chapter of the California Native Plant Society, the Sonoma Valley Regional Park District, representatives of federal and state agencies, and consultants who specialize in vernal pool work. This vernal pool working group is putting together a network of volunteer botanists each of whom adopts a vernal pool to revisit yearly. The goals are to set standards for how vernal pools should be monitored and to provide the baseline data needed to adequately protect the natural resource.

At Bouverie Preserve, the coordinated efforts of staff scientists, volunteers, university researchers, and private consultants make restoration work possible. Dan Gluesenkamp leads the Habitat Protection program at ACR's preserves and, as president of the California Invasive Plant Council, is a statewide leader in invasive species management and education. Jeanne Wirka is the resident biologist at Bouverie and brings extensive experience in native grasses and restoration projects. Sherry Adams has recently joined the Audubon Canyon Ranch science staff and has taken the lead on the vernal pool restoration project. Sherry gained experience in vernal pool monitoring in the Central Valley.

Bouverie's dedicated volunteers make labor-intensive projects like this possible. Young volunteers returned week after week to carefully collect the seeds from the low-to-the-ground vernal pool plants (Figure 2). The dedicated Bouverie Stewards volunteer crew, led by long-time Audubon Canyon Ranch volunteer Ken Ackerman, installed an extensive fencing system in the vernal pool grasslands, which made the grazing program at Bouverie possible. If you are interested in volunteering for this project or other natural areas restoration work, please contact Sherry Adams at sherry@egret.org.

Restoration work at Bouverie

The challenge of restoring habitat for these two species, as well as the myriad other native vernal pool plants at the Bouverie Preserve, is significant. Restoration aims to provide or maintain the necessary habitat characteristics (hydrology, soil type, vegetation), while adding sufficient propagules (seeds or baby plants) to enhance the target species. Because we are not starting from a "clean slate," we must be careful to balance habitat requirements and practical management considerations to yield optimal results.

Several pools at Bouverie do not currently have sufficient water depths to maintain a native species composition and have been invaded by non-native species such as velvetgrass *(Holcus lanatus)* and pennyroyal *(Mentha pulegium)*. Shallow water depths likely resulted from historic management, especially irrigation and tilling which can lead to siltation. There are intact vernal pools as well at Bouverie, which are dominated by native species and host a variety of vernal pool specialist plants, although in low numbers.

Table 1. Native plants in the Bouverie Preserve vernal pools.

Callitriche marginata	winged water-starwort
Crassula aquatica	water pygmyweed
Deschampsia danthonioides	annual hairgrass
Downingia concolor	downingia or calicoflower
Downingia pusilla	dwarf downingia
Eleocharis macrostachya	pale spike-rush
Eryngium aristulatum	coyote thistle
Gratiola ebracteata	bractless hedge-hyssop
Isoetes howellii	Howell's quillwort
Juncus xiphioides	iris-leaved rush
Lilaea scilloides	flowering quillwort
Limnanthes douglasii	meadowfoam
Mimulus guttatus	seep monkey-flower
Montia fontana	water montia
Navarretia intertexta	needle-leaved navarretia
Plagiobothrys stipitatus	popcorn flower
Pleuropogon californicus	California semaphore grass
Psilocarphus brevissimus	dwarf wooly marbles
Ranunculus aquatilis	broad-leaved water buttercup
Triphysaria eriantha	butter-and-eggs

An important part of the restoration work began in 2005, when cattle grazing was reinstituted on the grasslands that contain Bouverie's vernal pools. Research has shown that vernal pool native diversity increases with some grazing (Marty 2005). The cattle preferentially consume the fast-growing European grasses that, left ungrazed, degrade vernal pools by competing with native plants for soil and light resources and leave a thick layer of thatch at the end of the growing season. Importantly, European grasses may have a negative impact on native plants by changing the hydrologic regime, as ground water evaporates into the air through the extensive surface area of these grasses, resulting in less water in ungrazed pools. The Bouverie Stewards volunteer crew dramatically improved grazing at Bouverie by installing professional-quality fences in the grassland.

The next phase in vernal pool restoration at Bouverie involves removing accumulated invasive-grass biomass and possibly even removing silt, which has accumulated in some pools. This work will restore the hydrologic regime that favors the vernal pool species adapted to it. With the help of Bouverie volunteers, invasive species will be removed from pools where they dominate. This phase of the restoration is slated to begin in fall of 2007.

Audubon Canyon Ranch has recently received approval by the State of California to collect Sonoma sunshine seeds using methods that do not negatively impact the species. Through careful hydrologic measurements, locations at Bouverie have been identified that are very similar to the conditions in which the plant currently thrives. Both rare plant species will be grown to the seedling stage in the Bouverie greenhouse and carefully outplanted in the restored vernal pools. In addition, we have been collecting seeds of other vernal pool species that are currently present only in one or two pools, for sowing into restored pools. The reintroduction work will begin in early 2008.

Taking measure of our work

A crucial component of the vernal pool restoration work at Bouverie is the monitoring program. By evaluating the outcome of our restoration efforts, we can adapt methods as necessary and share lessons with other vernal pool practitioners.

In our monitoring efforts at Bouverie, we observe hydrology by measuring water depths at permanently marked locations through the season. In addition, we will survey vernal pool vegetation each year to follow the status of the two species of concern. We have already started to notice an increase in vernal pool plants in areas grazed last year, and we expect that long-lived native seeds will continue to benefit from grazing and the other restoration efforts.

When Audubon Canyon Ranch was granted the necessary permits to collect seeds of the endangered Sonoma sunshine, we agreed to protect the plant in perpetuity where it becomes established and to maintain long-term monitoring of both the established and parent occurrences.

Audubon Canyon Ranch's ability to preserve these plants in perpetuity is one of the most important ways in which we can contribute to the long-term conservation and restoration science of vernal pools in Sonoma County. All too often in conservation efforts, interest or funding dries up after an initial project, resulting in little information about what methods yielded long-term success. With the Bouverie Preserve located in the heart of the Valley of the Moon, our staff, volunteers, and collaborators can continue to use it as a living laboratory to further conservation efforts in the region.

Acknowledgements

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References

CNPS (California Native Plant Society). 2007. Inventory of Rare and Endangered Plants (online edition, v7-07a). California Native Plant Society, Sacramento, CA. [online: http://www.cnps.org/inventory].

Dittes, J. and J. Guardino. 2003. Dwarf Downingia—*Downingia pusilla* (G. Don) Torr. Species account and conservation strategies, first draft (November 2003). Prepared for Sacramento County, Dittes and Guardino Consulting, Sacramento, CA.

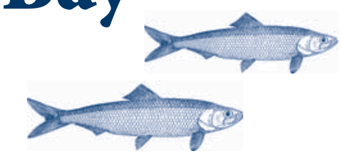
Gluesenkamp, D. 2005. Protecting the rare and uncommon plants of Audubon Canyon Ranch lands: stewardship ethic. Ardeid 2005, Audubon Canyon Ranch.

Gluesenkamp, D. and J. Wirka. 2006. Is nitrogen pollution from vehicles harming fragile ecosystems? Sonoma Valley vernal pools. Ardeid 2006, Audubon Canyon Ranch

Marty, J. T. 2005. Effects of cattle grazing on diversity in ephemeral wetlands. Conservation Biology 19: 1626-1632.

The importance of ephemeral food abundance to wintering waterbirds

Energy Footprints on Tomales Bay



by Wesley W. Weathers and John P. Kelly

PHOTO BY J. JANTUNEN / VIREO

Surf Scoter running to take flight.

How important are waterbirds to Tomales Bay's ecology? Trying to answer this question is like simultaneously putting together numerous jigsaw puzzles. For ecologists, one of nature's most important puzzles is energy. Understanding energy use by waterbirds on Tomales Bay is a puzzle with as many as 25,000 bird "pieces"—one for each loon, grebe, cormorant, duck, or other bird on the open water—plus countless other pieces accounting for the birds' sources of food energy. In addition, several thousand shorebirds and gulls depend each winter on food produced in Tomales Bay. But with jigsaw puzzles, some pieces are more important than others, and all the pieces do not have to be in place before an image appears. All animals require a continual supply of energy, which they obtain from food, to fuel everything from foraging and reproduction to just staying alive. Knowing how much energy a given species needs, and what fraction of the total available energy that need represents, provides a key indication of a species' ecological importance.

During winter, Tomales Bay plays host to over 57 species of waterbirds and provides spawning habitat for Pacific herring *(Clupea harengus pallasi),* which move into the bay between late November and early March to lay their eggs on eelgrass. Spawning herring provide food for a variety of animals including invertebrates, fish, birds, and mammals. Spawning events precipitate huge feeding frenzies at the water's surface that can last for days. Large numbers of ducks, gulls, cormorants, pelicans, and other marine birds, as well as California sea lions and harbor seals, can be seen feasting on herring or herring eggs (roe).

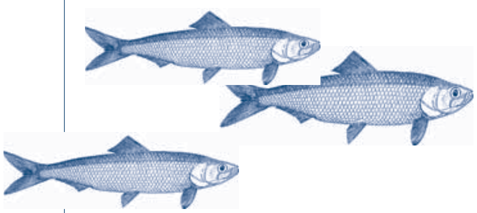
In this article, we assess how important herring eggs might be to Tomales Bay waterbirds by calculating the birds' energy requirement and estimating how much of that requirement could be met by consuming herring roe. We exclude gulls from our calculations because Tomales Bay gulls typically commute to regional landfills to feed on garbage. Although gulls may at times form clouds above active spawns, they can only reach the herring eggs during very low tides and only if the eggs are laid in certain areas that become exposed. Gulls harvest little roe on their own, instead pirating eggs from diving birds and picking up eggs drifting in the water (Bayer 1980). Results of stomach samples reveal the maximum number of eggs found in gulls is variable but mostly much smaller than the number found in scoters and scaup (Haegele 1993).

The feeding frenzies that form over spawning events also attract fishermen who, since 1973, have made herring one of California's most valuable fisheries (Figure 1).

PHOTO BY JOHN P. KELLY

Figure 1. Gill net harvest of Pacific herring in Tomales Bay.

The herring fishery provides two types of roe products that are traditional delicacies in Japan. Egg sacks or skeins, called "kazunoko", constitute the largest part of the fishery and are obtained with anchored gill nets that catch the herring as they move into the bay to spawn, which is when the eggs are at their ripest. The egg skeins are then removed from the females, and the male and female bodies are subsequently processed for animal feed or human consumption. One interesting yet unanswered question is to what extent humans compete with waterbirds for herring roe.



California's Department of Fish and Game (CDFG) monitors the state's herring population and typically sets the maximal annual fishery quota at 15–20% of the previous season's biomass, a level of harvest thought to be sustainable. Yet Tomales Bay spawning biomass has ranged widely from a high of 22,163 short tons in 1977–78 to a low of 345 short tons in 1990–91, making quota-setting inexact at best. Superimposed upon the year-to-year variability, there has been a long-term herring population decline, with spawning biomass falling from 6697 tons per season before 1988 (14-year average) to 3174 tons per season since then (18-year average; Watanabe 2006), a significant decline of one-half (t_{30} = 2.57, $P < 0.02$). Might dwindling Pacific herring stocks be adversely affecting marine birds that feed on herring or their roe?

Each year, up to 78% of the Surf Scoter population that winters in the lower Pacific Flyway is found in the San Francisco Estuary (Accurso 1992, Trost 2002, U.S. Fish and Wildlife 2002). The breeding population of this sea duck, as well as populations of other sea ducks (scaup, goldeneyes, Long-tailed Ducks, and Harlequin Ducks), have been declining since at least 1978 (Hodges et al. 1996, Savard et al. 1998). Winter diets of Surf Scoters and White-winged Scoters are composed primarily of bivalves, but when Pacific herring spawn, scoters shift their diet to herring eggs (Tyler et al. 2007).

If all Tomales Bay waterbirds consumed only herring roe, they would have to consume 8132 kg of roe per day (see box at right). Alternatively, instead of merely consuming roe to meet their routine energy requirement, birds might eat as much roe as possible, exploiting an abundant yet ephemeral food supply to deposit body fat as a hedge against periods of reduced foraging efficiency. If so, maximal consumption rates could be 1.65 times those we calculate (Kirkwood 1983), or 13,417 kg per day.

Given these estimates for how much herring roe Tomales Bay waterbirds might consume per day, the question becomes what fraction of the total roe spawned might waterbirds actually consume? During the 2005–06 season, there were four major spawning events in Tomales Bay which, based on CDFG data (Watanabe 2006), would have produced a total of 275,278 kg of roe. At 750 eggs per gram of roe, this represents over 206 *billion* herring eggs! According to the CDFG surveys, 1224 short tons of herring spawned on January 4th and 777 short tons spawned on January 21st. These two spawning events accounted for 99% of the total roe produced that season. The January 4th spawning event would have produced 167,572 kg of roe. Tomales Bay herring eggs hatch in 10 days. During the 10-day period when eggs are available, the bay's waterbirds would consume 8132 kg of roe per day if they met all their energy needs by eating only herring roe, or up to 13,417 kg per day if maximally depositing fat. Thus, waterbirds could at a maximum consume 49–80% of the roe spawned on January 4th. The comparable consumption values for the January 21st spawning event are 77–100%.

Under these scenarios, during the 2005–06 season roe-feeding Tomales Bay waterbirds might consume 60% of the roe if merely meeting their routine energy needs or 88% of the roe if depositing fat maximally. The actual amount of roe consumed by waterbirds would likely be less, because some roe is lost to tidal and wave action and some is consumed by fish and invertebrates such as crabs. Nevertheless, these calculations permit us to examine the potential effect of the long-term decline in herring numbers on waterbirds.

Estimating Energy Consumption

We used results from seven years of baywide winter waterbird surveys (Kelly and Tappen 1998) to calculate the total biomass of birds that feed on Pacific herring roe (Table 1). We then used the biomass data to calculate each species' total energy requirement, using equations that predict the energy expenditure of free-living wintering waterfowl (Miller and Eadie 2006) or marine birds (Nagy et al. 1999). Such predictions are possible because an organism's energy requirement is proportional to the mass of body tissue it must maintain. The equation of Nagy et al. (1999) is based on the field metabolic rate (FMR) of 36 species of wild marine birds, as determined by the doubly labeled water technique. The equation of Miller and Eadie (2006) is based on the resting metabolic rates of 24 species of wild northern-hemisphere waterfowl and assumes that FMR is three times resting metabolic rate. These predictive equations should provide reasonable energy expenditure estimates for Tomales Bay birds.

We calculated the amount of roe that Tomales Bay waterbirds would consume based on (1) their energy needs, (2) the energy content of roe, and (3) the efficiency with which birds convert ingested roe to metabolizable energy. Using Surf Scoters as an example, the calculations were as follows.

(1) What are the energy needs of Surf Scoters in Tomales Bay? The average winter abundance of Surf Scoters on Tomales Bay is 6810 individuals (Kelly and Tappen 1998). Surf Scoters weigh 950 grams on average (Dunning 1993), yielding a total Surf Scoter biomass on Tomales Bay of 6469.8 kg (Table 1). The FMR predicted for a Surf Scoter of average mass is 1287 kJ day. Multiplying this value by 6810 Surf Scoters gives a total daily energy expenditure of 8767 MJ per day.

(2) What is the energy content of herring roe? According to the USDA National Nutrient Data Laboratory (http://riley.nal.usda.gov/NDL/index.html) the energy content of herring roe is 3.08 MJ per kg wet weight.

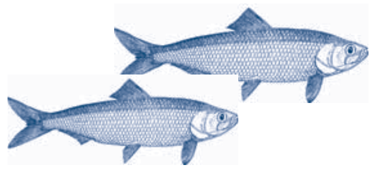
(3) How much roe would the Tomales Bay Surf Scoter population have to consume to satisfy their energy needs of 8767 MJ per day? We can calculate this value by multiplying the energy content of herring roe (3.08 MJ per kg^{-1}) times the assimilation efficiency of roe (0.82), which we derived as follows. Of the metabolizable energy contained in Pacific herring eggs, 60% is derived from protein and 40% is derived from fat and carbohydrate. Only 70% of the energy contained in protein is available to birds, versus 100% of the energy contained in fat and carbohydrate. Based on these values, the overall assimilation efficiency of herring roe is 82%. Thus, birds eating herring roe obtain 2.53 MJ of usable energy per kilogram of eggs ingested. To obtain the 8767 MJ of energy required each day, Tomales Bay Surf Scoters would need to ingest 3465 kg of roe (8767 MJ day^{1} divided by 2.53 MJ kg^{1}).

Repeating these calculations for all of the Tomales Bay waterbirds known to consume herring roe (Table 1) yields a total consumption of 8132 kg of roe per day.

Our calculations suggest that Tomales Bay waterbirds could theoretically consume up to 88% of the roe produced in 2005–06. If they did, the roe would provide 30 days of energy or 33% of the birds' total energy needs during a 90-day herring season.

We can approximate the maximal energy that waterbirds might have obtained prior to the decline in the herring population, based on the mean pre-1988 spawning biomass (6997 short tons) and assuming four equal spawning events per year. Under this scenario, waterbirds could consume 56% of the roe spawned, thereby obtaining an amount of energy sufficient to meet their needs for 66 days, or approximately two-thirds of the entire herring season. This first-order approximation suggests the potentially major importance of herring roe to Tomales Bay waterbirds.

The jigsaw puzzle of energy relationships between waterbirds and herring is far from complete, however. We are continuing to examine related questions, including whether trends in waterbird abundance actually



reflect changes in the spawning intensity of herring, and the extent to which 20–50 million herring entering the bay each winter may provide important food for fish-eating birds.

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References cited

Accurso, L. M. 1992. Distribution and abundance of wintering waterfowl on San Francisco Bay, 1988-1990. Unpublished. M.S. thesis. Humboldt State University. Arcata, CA. 252 pp.

Bayer, R.D. 1980. Birds feeding on herring eggs at the Yaquina Estuary, Oregon. Condor 82:193-198.

Dunning, J. B., Jr. 1993. CRC handbook of avian body masses. CRC Press, Boca Raton.

Haegele, C.W. 1993. Seabird predation of Pacific herring, *Clupea pallasi*, spawn in British Columbia. Canadian Field Naturalist 107:73–82.

Hodges, J. I., J. G. King, B. Conant, and H. A. Hanson 1996. Aerial surveys of waterbirds in Alaska 1957-94: population trends and observer variability. Information and Technology Report 4. USDOI, National Biological Service.

Kelly, J. P., and S. L. Tappen. Distribution, abundance, and implications for conservation of winter waterbirds on Tomales Bay, California. Western Birds 29:103-120.

Kirkwood, J.R. 1983. A limit to metabolizable energy intake in mammals and birds. Comparative Biochemistry and Physiology 75A:1-3.

Miller, M. R., and J. McA. Eadie. 2006. The allometric relationship between resting metabolic rate and body mass in wild waterfowl (Anatidae) and an application to estimation of winter habitat requirements. Condor 108:166-177.

Nagy, K. A., I. A. Girard, and T. K. Brown. 1999. Energetics of free-ranging mammals, reptiles, and birds. Annual Review of Nutrition 19:247B77.

Savard, J. P. L., D. Bordage, and A. Reed. 1998. Surf Scoter *(Melanitta perspicillata)*. in The Birds of North American, No. 363 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Trost, R. E. 2002. Pacific Flyway 2001-2002 fall and winter waterfowl survey report. U.S. Fish and Wildlife Service, Office of Migratory Bird Management, Portland, OR.

Tyler L. L, D. Esler, and W. S. Boyd. 2007. Foraging behaviors of surf scoters and White-winged Scoters during spawning of Pacific herring. Condor 109:216-222.

U.S. Fish and Wildlife Service (USFWS). 2002. Waterfowl population status, 2002. U.S. Department of the Interior, Washington, D.C. 51pp.

Watanabe, R. 2006. Summary of the 2005-06 Tomales Bay herring fishery season. Unpublished report, California Dept. Fish and Game. [online: http://www.dfg.ca.gov/mrd/herring/tomales0506.pdf]

Table 1. Abundance, biomass, and field metabolic rate (FMR) of roe-eating waterbirds in Tomales Bay. Surf Scoters account for approximately 43% of the energy consumed by these species. FMR is calculated from body mass using equations of Nagy et al. (1999) for the American Coot and Miller and Eadie (2006) for waterfowl.

Species	Average abundance	Body mass (g)	Baywide biomass (kg)	FMR (MJ day^{1})	Percent FMR of all species
Surf Scoter *(Melanitta perspicillata)*	6810.3	950	6469.8	8767.0	42.61
Bufflehead *(Bucephala albeola)*	5524.8	404	2232.0	3468.0	16.86
Greater Scaup *(Athya marila)*	2239.7	945	2116.5	2870.5	13.95
Black Brant *(Branta bemicla nigricans)*	1194.3	1300	1552.6	2000.9	9.72
Ruddy Duck *(Oxyura jamaicensis)*	1317.0	545	717.8	1063.1	5.17
Unidentified scaup *(Athya spp.)*[1]	803.4	942	756.8	1027.0	4.99
American Coot *(Fulica americana)*	401.7	642	257.9	405.4	1.97
American Wigeon *(Anas americana)*	209.9	756	158.7	223.0	1.08
Northern Pintail *(Anas acuta)*	139.4	1010	140.8	189.0	0.92
Red-breasted Merganser *(Mergus serrator)*	99.1	1022	101.3	135.6	0.66
Common Goldeneye *(Bucephala clangula)*	96.2	900	86.6	118.4	0.58
Black Scoter *(Melanitta nigra)*	71.1	950	67.5	91.5	0.44
Lesser Scaup *(Athya affinis)*	63.4	820	52.0	72.1	0.35
White-winged Scoter *(Melanitta fusca)*	30.4	1757	53.4	65.5	0.32
Canvasback *(Aythya valisineria)*	26.3	1219	32.1	41.8	0.20
Unidentified scoter *(Melanitta spp.)*[1]	10.6	943	10.0	13.6	0.07
Mallard *(Anas platyrhynchos)*	9.7	1082	10.5	13.9	0.07
Redhead *(Athya americana)*	4.1	1045	4.3	5.7	0.03
Barrow's Goldeneye *(Bucephala islandica)*	1.1	910	1.0	1.4	0.01
Long-tailed Duck *(Clangula hyemalis)*	0.5	873	0.4	0.6	<0.005
Eurasian Wigeon *(Anas penelope)*	0.2	772	0.2	0.3	<0.005
Harlequin Duck *(Histrionicus histrionicus)*	0.1	623	<0.05	<0.05	<0.005
TOTAL	**19,055.7**		**14,822.7**	**20,575.4**	**100.00**

[1]Mass of unidentified species represents a weighted average based on the relative abundances of identified individuals.

How broadly do nesting herons and egrets search the landscape to find food?

Foraging Horizons

by John P. Kelly and Mark T. McCaustland

According to specialists who study flight energetics, the slow, powerful wingbeat that lends rhythm and grace to the movements of herons and egrets is a relatively inefficient form of bird flight. The evolutionary engineering of these birds has, apparently, sacrificed fuel efficiency to meet other ecological needs, such as skillful landings in nest trees or quick take-offs from tight spaces in marshes or along creeks. For extended travel, soaring would be far more efficient. If you know this, the sight of a commuting egret winging steadily along a waterway is a display of the costly expenditure of energy required to access productive feeding areas. This may explain why egrets occasionally seek thermals for extra lift when traveling extended distances. If flight costs challenge the ability of herons and egrets to adequately provision their young, any loss or degradation of habitat that forces them to travel farther to find food might threaten their ability to reproduce.

The quality of wetland foraging sites fluctuates dynamically over short periods of time, a consequence of changing water levels, seasonal growth of wetland vegetation, and the dynamics of various prey populations. To make the most of wetland feeding opportunities, herons and egrets have become masters at searching huge landscapes to find sites of temporarily high prey abundance (Kushlan and Hancock 2005). In spite of this ability, they seem to concentrate their feeding activities near the colony site—a pattern suggesting limits related to the costs of extended travel. In our investigations at Audubon Canyon Ranch, we are asking how this apparent clustering of heron and egret feeding activity near heronries might affect the spatial patterns of other life across wetland landscapes, as well as regional goals for wetland habitat protection and restoration.

We employ two complementary methods to study the foraging dispersion of herons and egrets. First, teams of observers at selected colony sites watch and record the

Flying Great Blue Heron.

PHOTO BY TOM GREY, WWW.GEOCITIES.COM/TGREY41

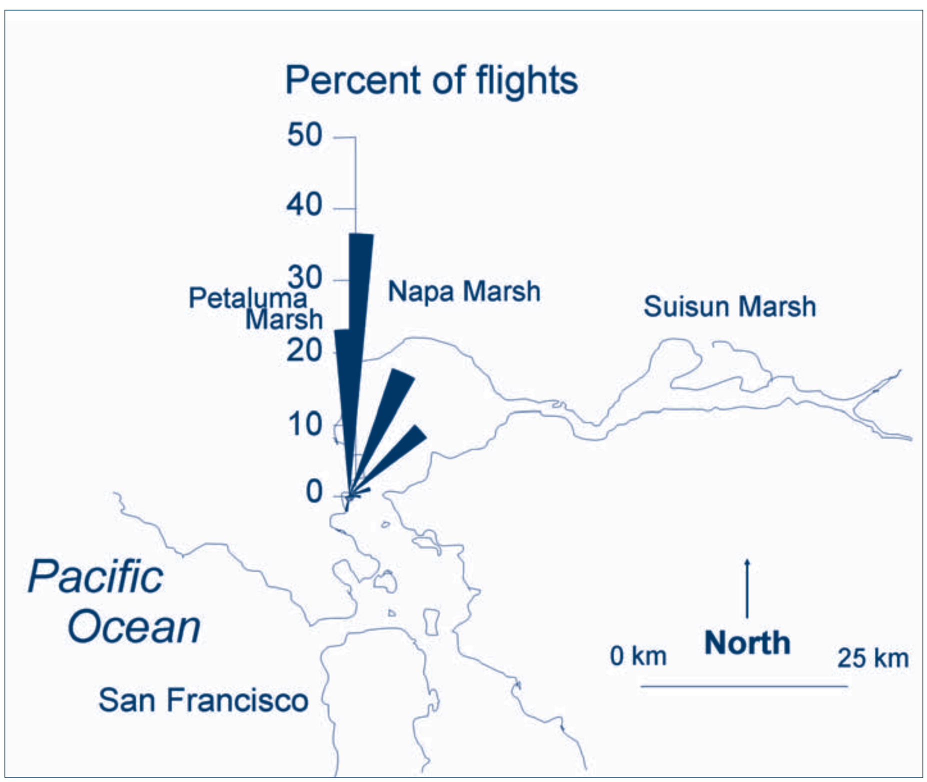


Figure 1. Percent of Great Egret arrival and departure flights (pooled) within 16 compass sectors during low tide (3.1–2.1 ft above MLLW) at West Marin Island in 2006. Most flights were oriented to the north, toward the Petaluma and Napa marshes and the western shoreline of San Pablo Bay.

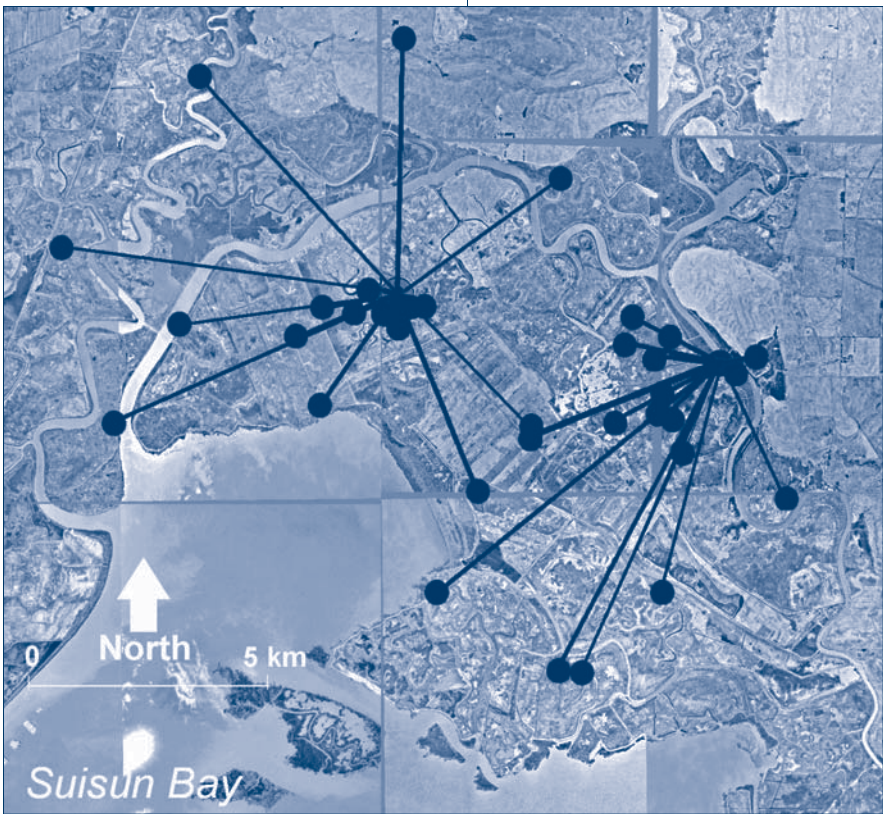


Figure 2. Great Egret foraging flight vectors from two nesting colonies in Suisun Marsh.

flight directions of departing and arriving birds, using panoramic photographs and maps to indicate compass directions from the center of a colony to numerous reference points in the field (Figure 1). But "bird watching" this isn't. It's more like air traffic control, except that the "pilots" (birds) maintain complete radio silence with the observers. Observers follow departing birds as far as possible, and the bearings of arriving birds are recorded as soon as they are picked up, often 2–3 km out. It's not unusual to track three or four or even six birds at once, coming and going in all directions. At a large colony site such as West Marin Island, near San Rafael, we can easily record over 180 flight lines per hour. For the sake of comparison, the tower at San Francisco International Airport coordinates at most 120 takeoffs and landings per hour—with radar.

Flight lines provide an inexpensive way to determine the directions of preferred feeding areas, but they do not reveal distances or particular locations. A second method of evaluating foraging dispersion involves using aircraft to track the flights of individual birds (Figure 2). Following herons and egrets around with airplanes is intense, exhilarating, and expensive, but general patterns begin to emerge fairly quickly. Landscapes that are familiar from the ground take on a fantastical and disorienting aspect when viewed from an altitude of 300–350 m down the wing of a tightly circling Cessna. In Suisun Bay (Figure 2), verdant marshes extend out in all directions, forming a shimmering palette of greens and muted golds laced with meandering, mud-brown sloughs. The twin peaks of Mt. Diablo provide a conspicuous southern reference, and the eastern horizon is marked by the familiar lines of wind turbines along the Montezuma Hills.

It is difficult to coordinate the flight of a single-engine aircraft, throttled back to its minimum flyable threshold of perhaps 135 km per hour, to follow a foraging egret with an air speed of about 35 km per hour (Custer and Osborne 1978, Pennycuick 2001). Such work strongly depends on skilled pilots and copilots who volunteer their expertise and aircraft. Inside the cockpit, it is hot and noisy. Communication is possible only through headsets and hand signals. Sometimes the target bird gets lost in the glare or catches a thermal and rapidly spirals above the plane. But herons and egrets usually fly straight and low, as if following a plumb line to their foraging destination.

We followed one Great Egret as it flew from the Delta Pond colony in the Laguna de Santa Rosa, northward along the Russian River valley. We managed to stay with it for over 20 minutes as it flew with stately, unwavering precision past several apparently suitable marshes and ponds. The bird finally landed in a water treatment pond west of Healdsburg, over 15 km from its nest. Even determined observers find that concentrating, scanning, and circling over a traveling egret can be exhausting and even nauseating. After a long flight, they may feel as if they had done all the flapping themselves!

We use these "following flights" to build statistical models that predict the general pattern of flight distances from heronries. The flight distances we have observed are

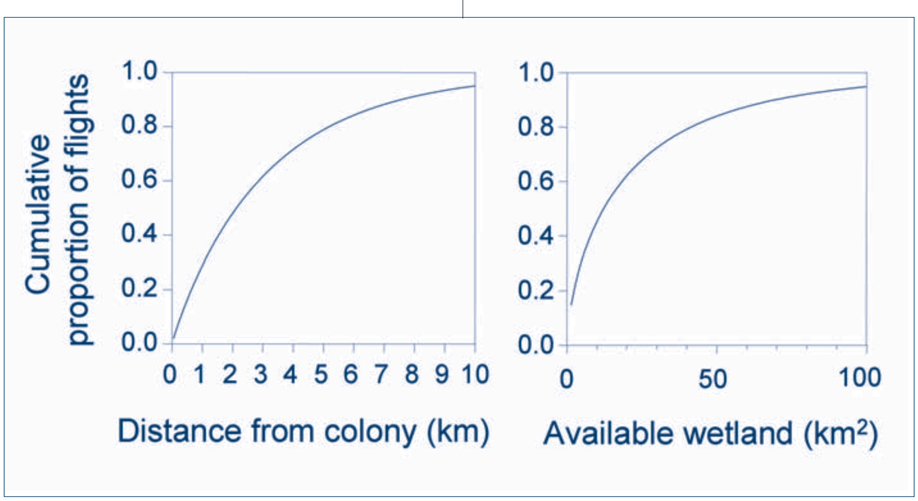


Figure 3. Estimated cumulative foraging dispersion of Great Egrets from heronries in Suisun Marsh, relative to (A) flight distance and (B) areal extent of estuarine and palustrine emergent wetland accessible within the flight radius (models based on 1000 bootstrap samples of 36 flights).

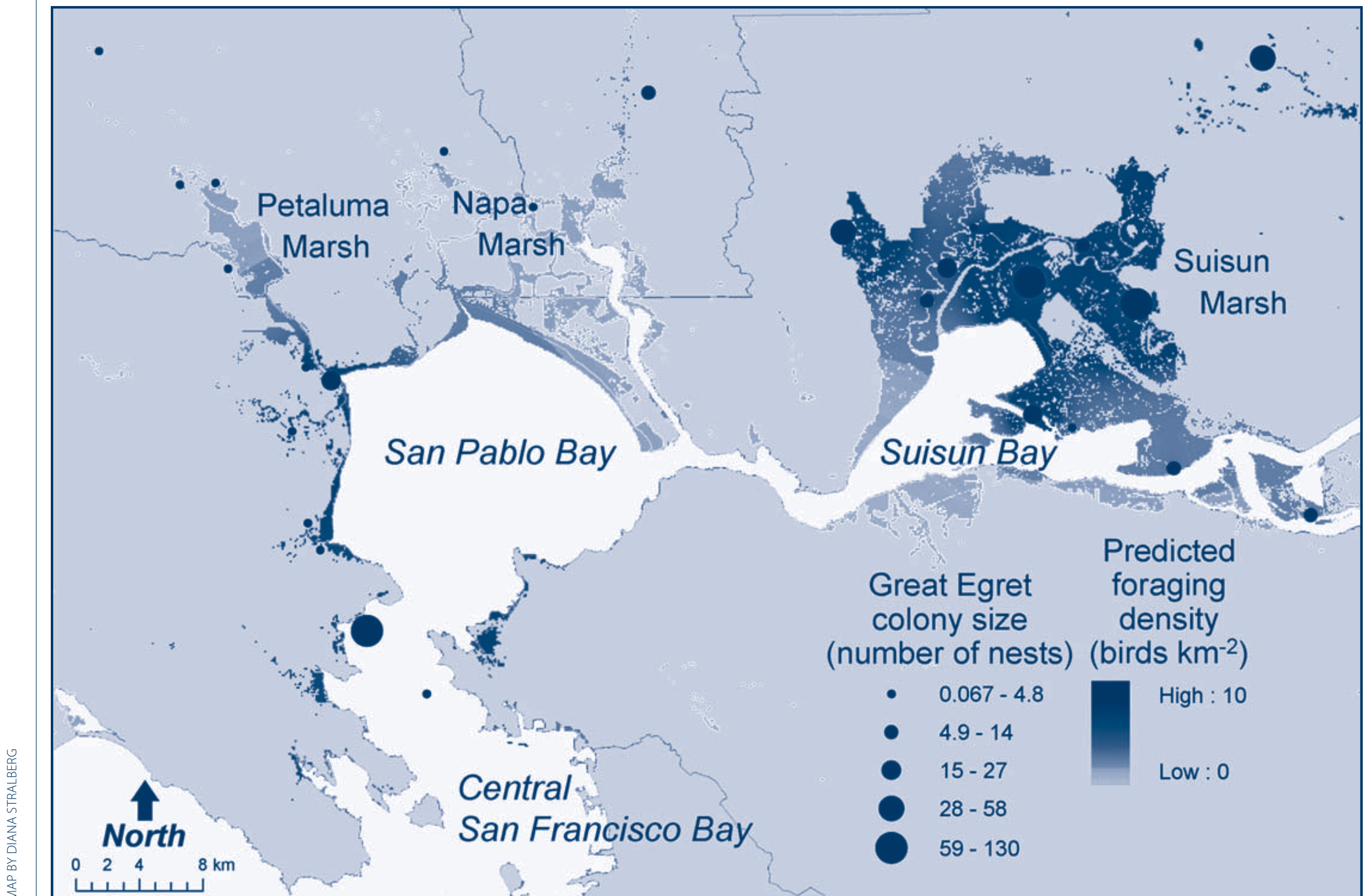


Figure 4. Predicted Great Egret foraging densities in estuarine and palustrine emergent wetlands in northern San Francisco Bay, based on average nesting distribution, 1991–2005, and foraging dispersion from heronries relative to the extent of wetlands accessible within flight distances.

similar to those exhibited by herons and egrets in other regions (Custer and Osborne 1978, Smith 1995, Custer and Galli 2002). We estimated that about 60% of the Great Egrets foraged within 3 km of the heronry or within a radius that encompassed approximately 20 km^2 of estuarine/palustrine emergent wetland (Figure 3). This information is then used to create maps that predict landscape foraging patterns (Figure 4). The patterns are calculated by summing, for each point on the map (100-m resolution), the number of birds expected to disperse from each colony site in the region (Kelly et al. 2006).

The predictive map for Great Egrets suggested that foraging densities were substantially concentrated near heronries, even when relatively fewer wetlands were available nearby (Figure 4). Based on these predictions, regional foraging densities should be highest in Suisun Marsh, the lower Petaluma Marsh, and along the western shoreline of San Pablo Bay southward to the northern shoreline marshes of Central San Francisco Bay. However, information is lacking on the extent to which areas far from heronries might be subject to foraging by non-breeding individuals not limited by the need to return to nest sites. The map also suggests that the restoration of wetlands in northern San Pablo Bay may result in a limited increase in the number of foraging egrets, whereas restoration sites in Suisun Bay may be subject to more intensive egret predation.

Of course, many influences on foraging movements remain unknown, including the complex dynamics of prey availability and the mysterious habitat cues herons and egrets use to optimize foraging success. Nonetheless, predictions of foraging dispersion provide a basis for comparing levels of heron and egret predation between marshes and evaluating the extent to which nesting herons and egrets might be affected by changes in the wetland landscape. Ultimately, such information could be important in understanding how wetland restoration projects are likely to influence—or be influenced by—the foraging activities of these wide-ranging predators.

Literature Cited

Custer, C. M., and J. Galli. 2002. Feeding habitat selection by Great Blue Herons and Great Egrets nesting in east central Minnesota. Waterbirds 25: 115-124.

Custer, T. W, and R. Osborn. 1978. Feeding habitat use by colonially breeding herons, egrets and ibises in North Carolina. Auk 95: 733-743.

Kelly, J. P., K. Etienne, C. Strong, M. McCaustland, and M L. Parkes. 2006. Annotated atlas and implications for the conservation of heron and egret nesting colonies in the San Francisco Bay area. ACR Technical Report 90-3-17 [online: www.egret.org/atlas]. Audubon Canyon Ranch, Marshall, CA 94940.

Kushlan, J. A., and J. A. Hancock. 2005. The herons. Oxford University Press, New York.

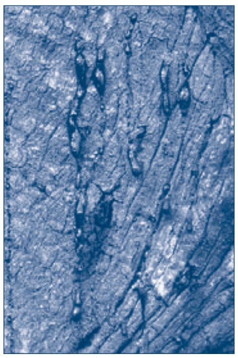
Pennycuick, C. J. Speeds and wingbeat frequencies of migrating birds compared with calculated benchmarks. Journal of Experimental Biology 204: 3283-3294.

Smith, J. P. 1995. Foraging flights and habitat use of nesting wading birds at Lake Okeechobee, Florida. Colonial Waterbirds 18: 139-158.

Landscape perspectives in conservation science

Tiny Pathogen with Tremendous Impact

by Emiko Condeso



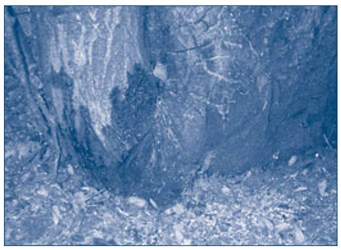


Figure 2. At left: Symptoms of *Phytophthora ramorum* infection on bay laurel *(Umbellularia californica)* leaves (photo courtesy of Sonoma State University).

Figure 1. Above and at left: Symptoms of *Phytophthora ramorum* infection on Coast Live Oak *(Quercus agrifolia)* (photo courtesy of Jennifer Davidson, reprinted with permission of the journal Plant Health Progress, http://www.plantmanagementnetwork.org/php).

From the view atop Sonoma Mountain, not far from the Valley of the Moon, the pattern of the landscape is striking. Patches of oak woodland are like islands in a sea of grasses. Seen from afar, coast live oaks appear as dark, broccoli-like clusters intermixed with lighter, more graceful canopies of Oregon white oak *(Quercus garryana)* and big leaf maple *(Acer macrophyllum).* Occasionally I spot a spray of California bay *(Umbellularia californica)* zigzagging through the woodland as it follows the path of a drainage. From this vantage point it is not difficult to imagine how the mosaic pattern of habitat types—woodland and grassland—might influence the creatures that reside within. My goal as I trekked through the woodlands of Sonoma Mountain was to understand how spatial pattern might influence the spread of an unwelcome but well-established visitor: *Phytophthora ramorum,* the pathogen that causes Sudden Oak Death (Condeso and Meentemeyer 2007).

Although landscape pattern is obvious from this perspective, the reasons for its influence on habitat quality are not. Complex arrangements of vegetation create equally complex patterns of abiotic conditions, such as temperature, humidity, and light. These can, in turn, affect ecological processes that influence the lives of plants and animals. Small patches of oak woodland are often warmer, drier, and brighter than large patches, as their canopies provide less shade and create a distinctly different environment than large patches. In addition to such within-patch effects, the surroundings at a larger scale may also impact woodland species. Differences in the arrangement and types of habitat elements can impact many large-scale processes, from the movement rates of individuals, including disease organisms, to gene flow within populations, to the frequency and intensity of natural disturbances such as fire. As human alteration of the landscape increases, understanding how ecological processes are related to spatial pattern has become increasingly important. This "landscape geometry" influences the persistence of the native inhabitants of our woodlands—and non-native invaders as well.

The pathogen that causes Sudden Oak Death is just such an invader. This forest disease has reached epidemic levels in coastal California and is also impacting managed landscapes in Europe. First described in 2000, the pathogen has caused extensive mortality of tanoak *(Lithocarpus densiflorus),* coast live oak *(Quercus agrifolia),* California black oak *(Quercus kelloggii),* and Shreve's Oak *(Quercus parvula v. shrevei).* Rather than a single disease, Sudden Oak Death can actually be thought of as a suite of diseases

PHOTO BY EMIKO CONDESO

The patchy oak woodland / grassland landscape of Sonoma County hill country.

caused by a single pathogen. The symptoms we see differ among species but can be grouped roughly into two categories: canker disease and foliar disease.

Oaks of the genus *Quercus* (excluding the white oaks), as well as tanoak, are susceptible to the canker form. This form is usually lethal, and infected individuals develop bleeding lesions in the lower part of the trunk (Figure 1). The appearance of bleeding lesions is often followed (sometimes years later) by a rather sudden and complete browning of the crown or canopy. Other susceptible species develop a foliar form of the disease. Infected plants develop leaf lesions, which usually occur where water can collect on the surface (Figure 2). This leaf blight is not fatal and is mostly what I encountered as I walked through the woodlands of Sonoma Mountain. Many California native species are foliar hosts, and these hosts play the major role in disease transmission. Dispersal spores are not produced by most canker hosts (tanoak being the only exception), but are produced in volume by foliar lesions. California bay, in particular, produces copious amounts of spores and is believed to be the main reservoir host for this pathogen in coastal California.

During the winter and spring of 2005, I spent many hours with many field assistants counting these symptomatic bay leaves. I found that the number of symptomatic versus healthy leaves provided a good index of the severity of Sudden Oak Death disease. In order to determine the relationship between the spatial pattern of forested habitat and the severity of Sudden Oak Death, we assessed the disease at a number of different, randomly selected locations (Figure 3). We also kept track of which plant species were present at each site, the abiotic conditions (temperature, relative humidity, and light penetration), and the broad-scale pattern of the surrounding habitat (densely wooded or sparse and patchy). All of these data were brought back to the lab and entered into a GIS (Geographic Information System) for analysis. GIS has become an important tool in ecology and has played a critical role in many aspects of the research and management of Sudden Oak Death (Kelly et al. 2004).

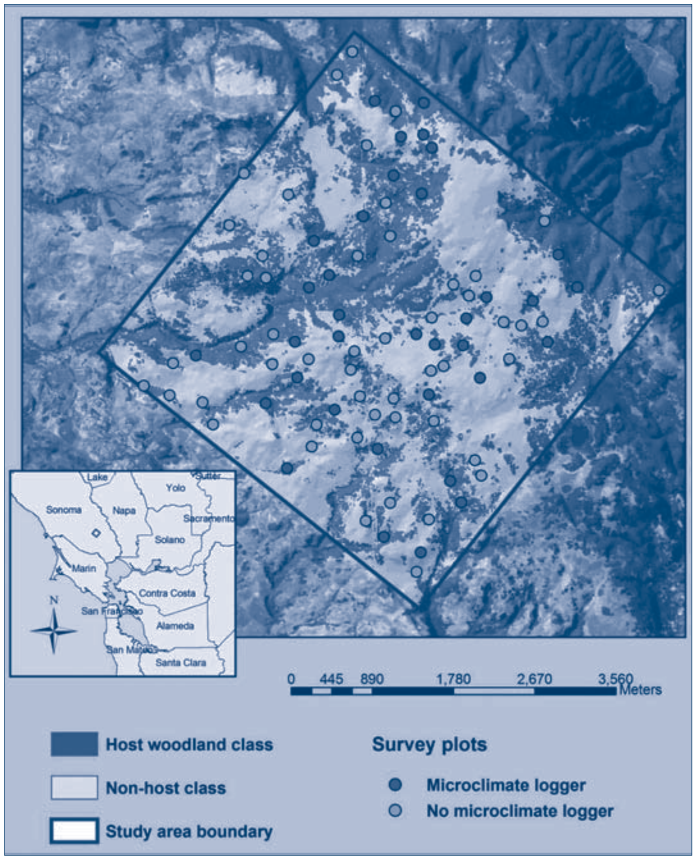


Figure 3. Study area map of Sonoma Mountain based on aerial photography. The land cover classes (host and non-host) and locations of survey plots are shown.

We found that the amount of forested area in a large region surrounding a sample plot predicted the severity of Sudden Oak Death in our plots better than any other variable (Figure 4). Plots surrounded by large swaths of contiguous forest had higher levels of disease, while small, isolated patches of woodland had lower levels. It was quite surprising to find that landscape pattern was a stronger predictor than the number of susceptible hosts within the sample plot. An analogous situation would be if the number of people in your neighborhood was a better predictor of the number of family members who will get the flu than the size your household.

From the perspective of *P. ramorum,* our patches of oak woodland did operate somewhat like islands—albeit islands with a lot of traffic from one to another. Our data strongly suggested that the dispersal ability of *P. ramorum* far exceeded the maximum distance between islands of woodland. Disease severity was high in plots located in large, contiguous woodland islands and low in small ones. This trend was most likely due to the absolute number of trees in the area capable of supporting *P. ramorum* reproduction, and to a lesser degree, to the abiotic conditions within each sample plot or the distance between forested patches. Our results were consistent with ecological principles that explain the dynamics of isolated subpopulations (island biogeography and metapopulation biology), as well as with studies of host population effects on disease incidence and severity. Large, contiguous swaths of host woodland may provide more surface area to intercept incoming spores compared to areas with less woodland cover, increasing colonization rates and disease severity. A greater number of susceptible hosts may lead to higher spore production and a lower probability of disease extinction. Over time, contiguous woodlands may be more effective pathogen reservoirs, maintaining more resilient levels of disease than their smaller neighbors.

The emergence and rapid spread of *P. ramorum* has increased awareness of the impact of invasive pathogens on natural communities. Regulatory officials, land managers, and landowners are in need of information that will help them understand the potential ecological impacts of this disease and guide management decisions. If the probability of oak infection in a given location is proportional to the number of *P. ramorum* spores being produced in that region, as suggested by our results, it is possible that fragmentation will keep the number of infected oaks low. However, even fragmented areas were not disease free on Sonoma Mountain, so thinning or removal of forest would not necessarily guarantee protection—and any such habitat loss could devastate other oak woodland species.

Intentionally manipulating the habitat mosaic would be risky business, but we may be able to mimic the effect of fragmentation by means other than outright thinning or clearing. In Sonoma County, a history of logging and fire suppression may have increased the overall cover and density of bays and created conditions that favor disease (Moritz and Odion 2005, Rizzo et al 2005). Therefore, forests could be managed for decreased connectivity of reservoir hosts (such as bay laurel) by increasing the diversity and abundance of non-host species within a forest stand. In addition, restoring historic disturbance regimes such as fire, or finding creative ways to reintroduce their effects, may result in woodlands that are more resistant to Sudden Oak Death.

If I had been able to take in a broader view from my place atop Sonoma Mountain, I would have seen a mosaic not only of woodland and grassland, but of golf courses, residential areas, and urban developments, all dissected by many roads. Human-driven landscape change marches on, with undeniable and, in some cases, poorly understood effects on the ecosystem. Studies that incorporate the larger context of landscape influences on ecological process, in conjunction with an understanding of the historical ecology of our region, will help us to better manage what is left behind.

Literature Cited

Condeso, T. E., and R. K. Meentemeyer. 2007. Effects of landscape heterogeneity on the emerging forest disease sudden oak death. Journal of Ecology 95: 364-375.

Kelly, M., K. Tuxin, and F. Kearns. 2004. Geospatial informatics for management of a new forest disease: Sudden Oak Death. Photogrammetric Engineering and Remote Sensing 70: 1001-1004.

Moritz, M. A., and D. C. Odion. 2005. Examining the strength and possible causes of the relationship between fire history and Sudden Oak Death. Oecologia 144: 106-114.

Rizzo, D. M., M. Garbelotto, and E. M. Hansen. 2005. *Phytophthora ramorum:* integrative research and management of an emerging pathogen in California and Oregon forests. Annual Review of Phytopathology 43: 309–335.

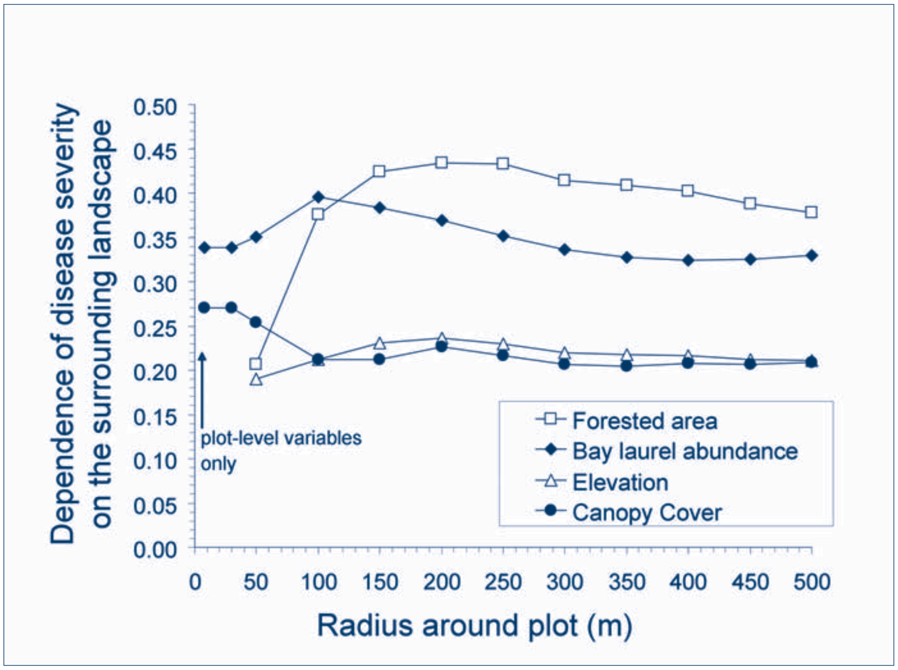


Figure 4. Landscape influences on leaf counts, indicating levels of infection by *Phytophthora ramorum.* Sudden Oak Death infection was most strongly dependent on the amount of forested land within 150–250 m of the sample plot (standardized regression coefficients; all predictors were significant, $P < 0.05$).

For more information on Sudden Oak Death, see the California Oak Mortality Task Force's web site at www.suddenoakdeath.org.

Visiting 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.

Practical restoration tools to increase native grass establishment in invaded habitats. Jeff Corbin, UC Berkeley.

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

Long-term monitoring of the Giacomini wetland. Lorraine Parsons, Point Reyes National Seashore.

Analysis of sedimentation in natural and restored marshes. Lorraine Parsons, Point Reyes National Seashore.

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

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.

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

Bouverie Preserve amphibian study. David Cook, Santa Rosa, CA.

Surface water ambient monitoring program: south coastal Marin and San Francisco surface water quality study. Karen Taberski, San Francisco Regional Water Quality Control Board.

Effects of landscape context and recreational use on carnivores in northern California. Sara Reed, UC Berkeley.

Effects of macroalgal bloom on seagrass bed productivity in Tomales Bay. Brittany Huffington, San Francisco State University.

Impact of an introduced plant pathogen on Lyme Disease Ecology. Cheryl Briggs and Andrew Swei, UC Berkeley.

California Rapid Assessment Method—wetland assessment calibration. Letitia Grenier and Sarah Pearce, San Francisco Estuary Institute.

Impacts of Wild Turkey (Maleagris galpavo) *on native avifauna in northern California.* Angela Gillingham, Duke University/California State Parks.

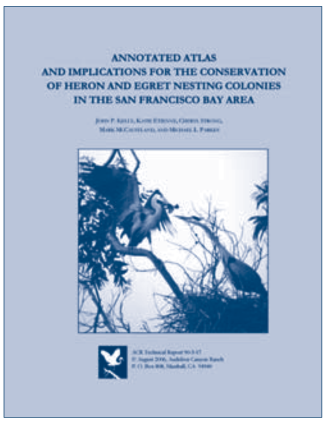
Lyme disease and western gray squirrels. Dan Skalkeld and Bob Lane, UC Berkeley.

Effects of planktivorous fish predation on larvae release patterns of estuarine crabs. Leif Rasmuson, University of Puget Sound.

The Watch:
project updates

Picher Canyon Heron and Egret Project ◗ The fates of all nesting attempts at ACR's Picher Canyon heronry have been monitored annually since 1967 to track long-term variation in nesting behavior and reproduction.

North Bay Counties Heron and Egret Project ◗ Annual monitoring of reproductive activities at all known heron and egret nesting colonies in



five northern Bay Area counties began in 1990. We recently completed the *Annotated Atlas and Implications for the Conservation of Heron and Egret Nesting Colonies in the San Francisco Bay Area* [available online: www.egret.org]. The 250-page report evaluates the regional status, trends, reproductive performance, and habitat values of herons and egrets, as well as conservation concerns, and includes individual accounts of all known heronries in the region (over 150 sites). The work is based on field studies of regional heronries by Audubon Canyon Ranch and the San Francisco Bay Bird Observatory over 15–37 years.

Tomales Bay Shorebird Project ◗ Since 1989, we have conducted annual shorebird censuses on Tomales Bay. Each census involves six baywide winter counts and one baywide count each in August and April migration periods. A team of 15–20 volunteer field observers is 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 more than 50 species, totaling up to 25,000 birds. Future work will focus on trends and determinants of waterbird variation on Tomales Bay.

Common Ravens in Heronries ◗ By radio-tracking nesting ravens and conducting field studies of raven activity in heron and egret nesting colonies, we have produced scientific papers on the status of ravens and crows in the San Francisco Bay area, on home range use, and on raven predatory behaviors.

Impacts of Wild Turkeys on Forest Ecosystems ◗ Invasive, non-native Wild Turkeys are common at Bouverie Preserve and throughout most of Sonoma County. The goal of this study is to experimentally measure the effects of ground foraging by Wild Turkeys on vegetation and invertebrates in the forest ecosystem of Bouverie Preserve. The results will provide information that can be used by agencies to improve management and control of turkey populations.

Monitoring and Control of Non-native Crayfish ◗ Jeanne Wirka and others are studying the distribution of non-native signal crayfish *(Pacifastucus leniscus)* in Stuart Creek at Bouverie Preserve and investigating the use of barriers and traps to control the potential impacts of crayfish on native amphibians and other species.

Highway-Generated Nitrogen Deposition in Vernal Wetlands ◗ Dan Gluesenkamp, Stuart Weiss, and Jeanne Wirka are quantifying the potential effects of highway-generated nitrogen deposition on Sonoma Valley vernal pools. Enhanced availability of nitrogen near highways might facilitate invasion by non-native plant species and the loss of biodiversity in sensitive vernal wetlands.

Cypress Point Restoration ◗ We are conducting a feasibility study for restoring the shoreline dunes at ACR's Cypress Grove Research Center on Tomales Bay. The project includes options for reducing the vulnerability of the Research Center to rising sea levels.

Plant Species Inventory ◗ Resident biologists maintain inventories of plant species known to occur on ACR's Tomales Bay properties and at Bouverie and Bolinas Lagoon preserves.

Cape Ivy Control, Volunteer Canyon ◗ Manual removal has proven to be very successful in reducing non-native cape ivy from the riparian vegetation in ACR's Volunteer Canyon. Continued vigilance in weeded areas has been important, to combat resprouts of black nightshade, *Vinca,* and Japanese hedge parsely.

Annual Surveys and Removal of Non-native *Spartina* and Hybrids ◗ In collaboration with the San Francisco Estuary Invasive Spartina Project, Emiko Condeso and Gwen Heistand coordinate and conduct comprehensive field surveys for invasive, non-native *Spartina* in the shoreline marshes of Tomales Bay and Bolinas Lagoon.

Saltmarsh Ice Plant Removal ◗ Native vegetation is recruiting into areas where we have been removing non-native ice plant from marshes and upland edges at Toms Point on Tomales Bay.

Eradication of *Elytrigia pontica* ssp. *pontica* ◗ *Elytrigia* is an invasive, non-native perennial grass that forms dense populations in seasonal wetland sites. At Bouverie Preserve, we are eliminating a patch of *Elytrigia* using manual removal and light starvation/solarization (black plastic tarps), and using herbicide spot treatments to remove invasive outlier patches.

Nest Boxes ◗ Rich Stallcup maintains several Wood Duck nest boxes along Bear Valley Creek in ACR's Olema Marsh. Tony Gilbert maintains Western Bluebird nest boxes in the Cypress Grove grasslands.

Restoration of Coastal Dunes by Removal of *Ammophila arenaria* ◗ *Ammophila arenaria* is a highly invasive, non-native plant that alters the topography and function of coastal dunes. This project at ACR's Toms Point, on Tomales Bay, is helping to protect native species that depend on mobile dune ecosystems.

Grazing of Bouverie Grasslands ◗ A prescribed grazing program has been implemented to maintain or increase the abundance of native grassland plant species and to protect the vernal wetlands at Bouverie Preserve.

Control and Possible Eradication of Perennial Pepperweed in the Walker Creek Delta ◗ We are using a variety of methods to remove and monitor the first known infestations of *Lepidium latifolium* in Tomales Bay and, hopefully, prevent further invasion. This non-native weed is known to expand quickly and establish huge stands that cover floodplains and estuarine wetlands, compete with native species, and alter habitat values.

Vernal Pool Restoration and Reintroduction of Imperiled Plants ◗ Dan Gluesenkamp, Jeanne Wirka, and Sherry Adams are restoring habitat conditions in the vernal pools at Bouverie Preserve. The project includes the removal of problematic invasive plants and reëstablishment of the federally listed Sonoma sunshine *(Blennosperma bakeri)* and California species of conservation concern dwarf downingia *(Downingia pusilla)*. The work includes considerable manual effort by volunteers, propagation and planting of native plants, use of prescribed fire, cattle grazing, and monitoring of changes in vegetation and hydrology.

THE ARDEID

Conservation Science
and Habitat Protection
at Audubon Canyon Ranch

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

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BOLINAS LAGOON PRESERVE • CYPRESS GROVE RESEARCH CENTER • BOUVERIE PRESERVE

Coast live oak tree, a member of woodlands undergoing change.

CLAIRE PEASLEE

Landscapes perspectives in conservation science see page 10

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