Conservation Science and
Habitat Protection at Audubon
Canyon Ranch

THE ARDEID

- local wetlands

International Importance

- non-native crustacean

Signal Crayfish

- protecting habitat

Heronry Life Span

- vernal pools

Nitrogen Pollution

- mapping ecosystems

Charting the Course

2006

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Cover: *Invasive, non-native signal crayfish can measure up to 16 cm long. Photo by* ***Mike Lane / Alamy***
Ardeid *masthead Great Blue Heron ink wash painting by* ***Claudia Chapline***

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PROJECT CLASSIFICATIONS:
C = Coastal Habitat Restoration at Toms Point ◆ **D** = Douglas Fir Management at Bouverie Preserve; ◆ **E** = *Ehrharta erecta* Removal at Bolinas Lagoon Preserve ◆ **G** = Grassland Management at Bouverie Preserve ◆ **H** = Heron/Egret Research ◆ **R** = Invasive Plant Removal and Habitat Restoration ◆ **S** = Shorebird Censuses on Tomales Bay Shorebird Censuses ◆ **W** = Tomales Bay Waterbird Census

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Habitat values in Bolinas Lagoon and Tomales Bay

International Importance

by John P. Kelly

The tidal waters that illuminate the coastal landscapes of Bolinas lagoon and Tomales Bay easily capture one's attention. They trace the contours of the land and highlight the moods of coastal wind and weather. They mark the movements of waterbirds on the surface, mirror flocks that sail overhead, and enhance the power of sunsets. But these waters are not merely captivating and beautiful: they are ecologically special. Bolinas Lagoon and Tomales Bay are two of 22 wetlands in the United States that have been designated as wetlands of international importance by the Convention on Wetlands (Figure 1).

Popularly known as the "Ramsar Convention," the Convention on Wetlands is an intergovernmental treaty for national action and international cooperation for conservation (see box on page 2). Key documents that substantiate Ramsar designation address standard criteria (Table 1) by citing relevant scientific evidence. This article highlights such work by scientific investigators attracted to the rich and abundant life in Bolinas Lagoon and Tomales Bay.

Actually, Bolinas Lagoon and Tomales Bay are part of a larger, relatively undisturbed complex of wetlands along the Marin/Sonoma coast that includes Drakes and Limantour Esteros, Abbotts Lagoon, Estero Americano, Estero San Antonio, and Bodega Harbor. The nearness of these wetlands to each other, along with their common geographic position in the Pacific Flyway, connections to the same coastal ocean waters, and shared proximity to the urbanized San Francisco Estuary, results in a system of estuaries that are likely to be interconnected in numerous ways.

For example, the neighboring wetlands exhibit different hydrographic regimes and nutrient cycles. This creates a broad range of habitat conditions, differences in the timing and composition of species, and alternating opportunities for species

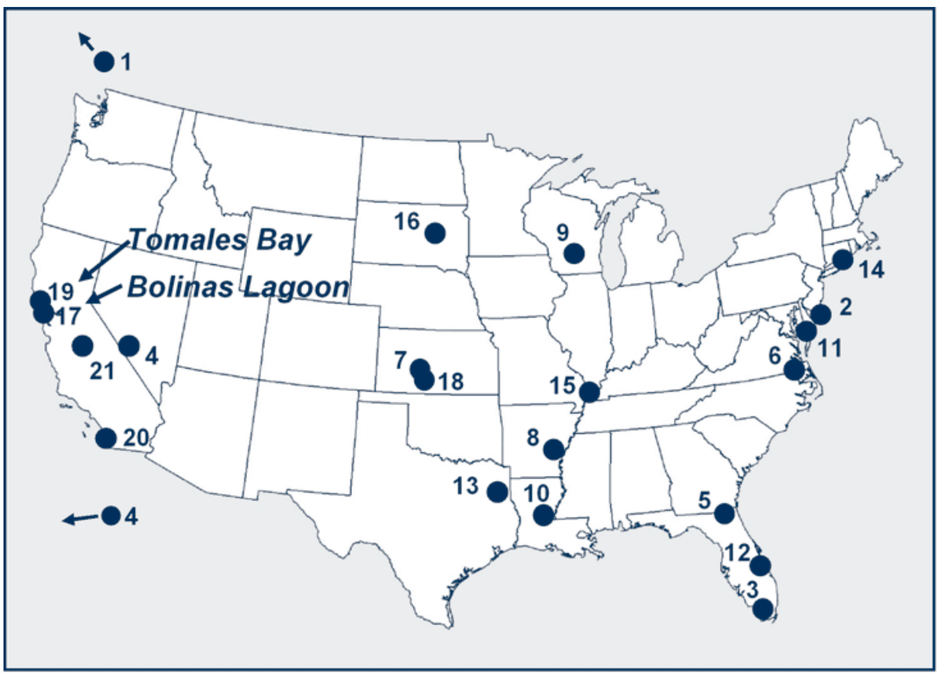


Figure 1. Wetlands of international importance in the United States; numbers refer to the sequence of recognition by the Ramsar Convention: 1= Izembek National Wildlife Refuge (NWR); 2 = Forsythe NWR; 3 = Okefenokee NWR; 4 = Ash Meadows NWR; 5 = Everglades National Park; 6 = Chesapeake Bay Estuarine Complex; 7 = Cheyenne Bottoms; 8 = Cache-Lower White Rivers; 9 = Horicon Marsh; 10 = Catahoula Lake; 11 = Delaware Bay Estuary; 12 = Pelican Island NWR; 13 = Caddo Lake; 14 = Connecticut River Estuary; 15 = Cache River-Cypress Creek Wetlands; 16 = Sand Lake NWR; 17 = Bolinas Lagoon; 18 = Quivira NWR; 19 = Tomales Bay; 20 = Tijuana River National Estuarine Research Reserve; 21 = Grassland Ecological Area; 22 = Kawainui and Hamakua Marsh Complex.

Table 1. Ramsar Criteria used to identify wetlands of international importance[1].

Importance for conserving representative, rare or unique wetland types

Criterion 1: contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.

Importance for conserving species and ecological communities

Criterion 2: supports vulnerable, endangered, or critically endangered species or threatened ecological communities.

Criterion 3: supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.

Criterion 4: supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.

Importance for conserving taxonomic groups

Criterion 5: regularly supports 20,000 or more waterbirds.

Criterion 6: regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.

Criterion 7: supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.

Criterion 8: is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.

Criterion 9: regularly supports 1% of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.

[1]Adopted by the 7th (1999) and 9th (2005) Meetings of the Conference of the Contracting Parties.

recruitment or recolonization between sites. As a group, these wetlands support common populations of mobile species, including the largest concentration of harbor seals *(Phoca vitulina)* in California (Allen et al. 1989). Bolinas Lagoon and Tomales Bay are key components of this network of coastal estuaries, providing important foraging, breeding, nursery, and roosting grounds for a wide variety of coastal and estuarine species (Table 1, Criteria 1 and 3).

Estuaries along the west coast of North America tend to be more dynamic, geomorphologically, than in other regions of the continent, because of their relatively recent geologic history. This dynamism is amplified in Tomales Bay and Bolinas Lagoon by their association with the San Andreas Fault, which underlies both systems (Criterion 1). The fault-generated configuration of Tomales Bay differs from other smaller coastal estuaries and lagoons in that approximately 90% of its 28.5 km^2 area is subtidal, providing vast areas of open water through the tidal cycle. This contrasts with the predominance of tide channels and exposed mudflats during low tide periods in Bolinas Lagoon.

The natural tidal landscapes of Bolinas Lagoon and Tomales Bay contribute strongly to the international significance of these areas (Criteria 1 and 2). Rare and important habitat types in Tomales Bay include vast eelgrass beds that support a rich diversity of birds, marine fishes, and invertebrates (Criterion 2). The north end of the bay is mantled by one of the finest mobile sand dune systems along the Central California coast, with unique dune slack wetland communities that form between the dunes (Criterion 2). Bolinas Lagoon supports a rich and relatively natural balance of tidal sloughs, emergent tidal marsh, and transitional shoreline vegetation. It is important to remember that healthy emergent tidal marsh is rare in California estuaries because of widespread habitat degradation since the mid-1850s (Nichols et al. 1986).

Both estuaries provide habitat for many rare, threatened, and endangered plant and animal species (Table 2; Table 1, Criterion 2). Among these is the beautiful salt marsh annual, Point Reyes bird's beak (*Cordylanthus maritimus* ssp. *palustris*), which forms colonies in numerous locations where freshwater streams flow into tidal marshes (Kelly and Fletcher 1994). Both estuaries support impressive numbers of the Salt Marsh Common Yellowthroat, an elegant and secretive warbler and California Species of Special Concern that thrives in well-established brackish marshes (Hobson et al. 1985, Kelly and Wood 1996, Nur et al. 1997). Both estuaries provide wintering habitat for the federally threatened Western Snowy Plover *(Charadrius alexandrinus nivosus),* which suffers critically from the loss of undisturbed beaches (Page et al. 1986; USFWS 1993). The natural transitions between salt marsh and upland vegetation in both Tomales Bay and Bolinas Lagoon are of particular value, providing high-tide refugia and feeding areas for the state-threatened California Black Rail and other tidal marsh species (Criterion 4; Evens et al. 1991).

Each rare or endangered species has a unique story related to important local habitat values (Criterion 2). For example, the federally endangered myrtle's silverspot butterfly *(Speyeria zerene myrtleae)* is restricted to dune and grassland areas immediately adjacent to the coast and is known only from a few sites in northern Marin County (Launer et al. 1994). It lays eggs only on native violets, possibly only on *Viola adunca*, and is seriously threatened by habitat loss and invasions by European beachgrass *(Ammophila arenaria)* and ice plant *(Carpobrotus edulis).* Current work by Audubon Canyon Ranch to remove these invasive species and restore coastal dunes in northern Tomales Bay could benefit this rare butterfly.

The Ramsar Convention

The Convention on Wetlands is an intergovernmental treaty adopted on 2 February, 1971, on the southern shore of the Caspian Sea, in the Iranian city of Ramsar. Consequently, it has become popularly known as the "Ramsar Convention." Ramsar is the first of the modern global intergovernmental treaties on the conservation of natural resources (http://ramsar.org).

Over the years, the Conference of the Contracting Parties (COP, the decision-making body of delegates from all the Member States) has kept the Ramsar Convention abreast with changing world priorities and trends in environmental thinking. When countries join the Convention, their first obligation is to designate one or more wetlands for inclusion in the List of Wetlands of International Importance (the "Ramsar List") and to promote their conservation. The Convention currently has 152 Contracting Parties. More than 1600 wetlands have been designated as Wetlands of International Importance, covering over 1.4 million km^2, and the list of wetlands continues to grow. The Convention's mission is the conservation and wise use of wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world.

Table 2. Estimated numbers of species with special conservation status in Tomales Bay and Bolinas Lagoon (Ramsar documents; Kelly and Stallcup 2003, WRA et al. 1996, PWA and WRA 2006). The numbers of federally threatened or endangered species are in parentheses.

Taxonomic group	Tomales Bay		Bolinas Lagoon	
Plants	48	(6)	27*	(2)*
Invertebrates	9	(3)	11*	
Fishes	3	(3)	6*	
Reptiles	2		2	
Amphibians	2	(1)	2	(1)
Birds	48	(6)	25	(6)
Mammals	8		8*	(3)*

*special status species that "may occur or are known to occur" in Bolinas Lagoon (PWA and WRA 2006)

Long-term monitoring

Bolinas Lagoon and Tomales Bay are extraordinary feeding areas for birds. Long-term studies of bird use have clearly established the importance of these areas as Ramsar sites (Criteria 3–6). The abundance and diversity of waterbirds that use Tomales Bay (Kelly and Tappen 1998, Kelly 2001a, Kelly and Stallcup 2003) and Bolinas Lagoon (Shuford et al. 1989) reveal the biogeographic importance of these areas as over-wintering areas and, secondarily, as migratory stopover sites (Criterion 4). Episodic invasions of anchovies in Bolinas Lagoon can attract spectacular numbers of roosting and feeding Brown Pelicans (up to 6000) and hordes of Elegant Terns (also as many as 6000; Shuford et al. 1989).

Shuford and others (1989) found that two-thirds of the 70 most numerous bird species using Bolinas Lagoon occurred as winter residents. Bolinas Lagoon is also a major spring staging area for migrating Western Sandpipers (Shuford et al. 1989). During winter, Tomales Bay supports as many as 25,000 waterbirds (877 km^2; Kelly and Tappen 1998), up to 20,700 shorebirds (Kelly 2001a), and 10,000–20,000 thousand gulls (mostly California Gulls; Criterion 5; Kelly et al 1996). Winter waterbird counts by Audubon Canyon Ranch suggest that Tomales Bay may provide the highest quality winter habitat for Bufflehead on the West Coast south of the Columbia River (Kelly and Tappen 1998). In addition, Tomales Bay may support 12% of the statewide Bufflehead numbers, 6% of Surf Scoters, and 31% of Black Brant (well above one percent of the worldwide population indicated by Criterion 6; Kelly and Tappen 1998).

Both sites provide important nesting and feeding areas for Great Blue Herons and Great Egrets (Pratt 1983, Kelly et al. 1993, Kelly et al. 2006) and valuable foraging areas for the state's largest nesting concentration of Osprey (Evens 2000). It is not surprising that several fundamental aspects of shorebird ecology have been determined by field studies in these rich and productive coastal systems (e.g., Page and Whittaker 1975, Kus 1985, Warnock et al. 1995, Kelly 2001b, Kelly and Weathers 2002).

Importance for fishes

Tomales Bay and Bolinas Lagoon are enormously productive nurseries for marine and estuarine fishes (Criterion 7). Numerous species of surfperch (Embiotocidae), distinguished by an impressive array of color patterns and fin shapes, ride tidal currents in and out of these estuaries. Leopard sharks *(Thiakis semifasciata)* forage along channel edges and over tidal flats, where they nip off clam siphons and suck worms from the mud. Vast subtidal meadows of eelgrass *(Zostera marina)* in Tomales Bay are of worldwide significance because of their value as spawning substrate for an average of 30–50 million Pacific herring *(Clupea harengus pallasi)* each year (Criterion 3; Suer 1987, Watanabe and Walters 2004). Work conducted at ACR's Cypress Grove Research Center showed that tens of thousands of California bat rays *(Myliobatis californica)* forage intensively for crustaceans and other invertebrate prey over the inundated mudflats of Tomales Bay (Hopkins 2003).

A 1995 survey of published and unpublished sources documented the occurrence of 163 species of fishes in Tomales Bay and its watershed (Kelly and Fox 1995), and California Fish and Game surveys have found at least 68 species of fishes within Bolinas Lagoon (PWA et al 1996, PWA and WRA 2006). Such variety reflects the wide range of habitat conditions and salinity regimes found in healthy coastal bays and lagoons.

Anadromous salmonids pass through both estuaries en route to spawning areas in tributary creeks. Federally threatened Central California coast steelhead *(Oncorhynchus mykiss)* have been documented in Pine Gulch Creek, which flows into Bolinas Lagoon, and are believed to spawn in other suitable lagoon tributaries (Criteria 2, 7, and 8; PWA and WRA 2006). Anecdotal accounts indicate that federally threatened coho salmon *(O. kisutch)* were once common in Pine Gulch Creek but have since become rare (WRA et al. 1996, PWA and WRA 2006). Approximately 10% of California's coho migrate through Tomales Bay and into Lagunitas and Olema Creeks to spawn and therefore represent a potentially critical part of the protected population known as the Central California "Evolutionarily Significant Unit" (Criterion 9). In addition, brackish tributaries of Tomales Bay have been found to support the extremely rare tidewater goby (*Eucycloglobius newberryi;* Criterion 2), although the species was not detected in recent surveys.

The recognition of Bolinas Lagoon and Tomales Bay as Ramsar sites establishes their national and international value. However, their futures remain challenged by problems related to watershed protection, habitat management, recreational pressure, invasive species, and other coastal management issues. Conservation science at Audubon Canyon Ranch continues to work toward improving habitat protection and stewardship of these and other wetlands in central coastal California.

References cited

Allen, S. G., H. R. Huber, C. A. Ribic, and D. G. Ainley. 1989. Population dynamics of harbor seals in the Gulf of the Farallones, California. California Fish and Game 75: 224-232.

Evens, J. G. 2000. Population size and reproductive success of Osprey at Kent Lake, Marin County, CA – 1999. Avocet Research Associates. Report to Marin Municipal Water District, Corte Madera, CA.

Evens, J. G., G. W. Page, S. A. Laymon, and R. W. Stallcup. 1991. Distribution, relative abundance and status of the California Black Rail in western North America. Condor 93: 952-966.

Hobson, L., P. Perrine, E. B. Roberts, M. L. Foster, P. Wooden. 1986. A breeding season survey of Salt marsh Common Yellowthroats (*Geothlypis trichas sinuosa*) in the San Francisco Bay region. San Francisco Bay Bird Observatory report to the U. S. Fish and Wildlife Service, Sacramento, CA.

Hopkins, T. E., and J. J. Cech. 2003. The influence of environmental variables on the distribution and abundance of three elasmobranchs in Tomales Bay, California. Environmental Biology of Fishes 66: 279-291.

Kelly, J. P. 2001a. Distribution and abundance of winter shorebirds on Tomales Bay, California: implications for conservation. Western Birds 32: 145-166.

Kelly, J. P. 2001b. Hydrographic correlates of winter Dunlin abundance and distribution in a temperate estuary. Waterbirds 24(3): 309-322.

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. Audubon Canyon Ranch. ACR Technical Report 90-3-17 [online: http://www.egret.org].

Kelly, J. P., J. G. Evens, R. W. Stallcup, and D. Wimpfheimer. 1996. The effects of aquaculture on habitat use by wintering shorebirds. California Fish and Game 82(4): 160-174.

Kelly, J. P., and G. Fletcher. 1994. Habitat correlates and distribution of *Cordylanthus maritimus* (Scrophulariaceae) on Tomales Bay, California. Madroño 41:316-327.

Kelly, J.P, and K. J. Fox. 1995. Fish species of Tomales Bay and its watershed. The Tomales Bay Association, Point Reyes Station, CA.

Kelly, J. P., H. M. Pratt, and P. L. Greene. 1993. The distribution, reproductive success, and habitat characteristics of heron and egret breeding colonies in the San Francisco Bay area. Colonial Waterbirds 16:18-27.

Kelly, J. P., and R. W. Stallcup. 2003. Documented occurrences of bird species on Tomales Bay, California, prior to January 2003, and a protocol for future bird species inventories. A report to the Point Reyes National Seashore and the All Taxa Biodiversity Inventory of Tomales Bay. ACR Tech. Rpt. 89-12-6. Audubon Canyon Ranch, Marshall, CA 94940. 103 pp

Kelly, J. P., and S. L. Tappen. 1998. Distribution, abundance, and implications for conservation of winter waterbirds on Tomales Bay, California. Western Birds 29: 103-120.

Kelly, J. P., and C. Wood. 1996. Within-season and diurnal variation in foraging behavior of the Common Yellowthroat. Condor 98: 491-500.

Kelly, J. P., and W. W. Weathers. 2002. Effects of feeding time constraints on body mass regulation and energy expenditure in wintering Dunlin *(Calidris alpina)*. Behavioral Ecology 13: 766-775.

Kus. B. E. 1985. Aspects of flocking behavior and predator avoidance in wintering shorebirds. Ph.D. dissertation, University of California, Davis.

Launer, A.E., D.D. Murphy, J.M. Hoekstra and H.R. Sparrow, 1994. The endangered Myrtle's silverspot butterfly: present status and initial conservation planning. Journal of Research on the Lepidoptera 31 (1-2): 132-146

Nichols, H., J. E. Hoern, S. N. Luoma, and, D. H. Peterson. 1986. The modification of an estuary. Science 231: 567-573.

Nur, N., S. Zack, J.G. Evens and T. Gardali. 1997. Tidal marsh birds of the San Francisco Bay region: status, distribution and conservation of five Category 2 taxa. Final report to the U. S. Geological Survey - Biological Resources Division.

Page, G. W., F. C. Bidstrup, R. J. Ramer, and L. E. Stenzel. 1986. Distribution of wintering Snowy Plovers in California and adjacent states. Western Birds 17: 145-170.

Page, G. W., and D. F. Whitacre. 1975. Raptor predation on wintering shorebirds. Condor 77: 73-83.

Pratt, H. 1983. Marin County California heron colonies. Western Birds 14: 169-184.

PWA and WRA. 2006. Projecting the future evolution of Bolinas Lagoon. Public draft prepared for the Marin County Open Space District by Philip Williams & Associates, Ltd, in association with Wetland Research Associates, Inc. Philip Williams and Associates, San Francisco, CA.

Shuford, D. W., G. W. Page, J. G. Evens, and L. E. Stenzel. 1989. Seasonal abundance of waterbirds at Point Reyes: a coastal California perspective. Western Birds 20: 137-265.

Suer, A. L. 1987. The herring of San Francisco and Tomales Bays. Ocean Research Institute, San Francisco.

USFWS (U. S. Fish and Wildlife Service). 1993. Determination of Threatened Status for the Pacific Coast population of the Western Snowy Plover. Federal Register 58: 12864-12874.

Warnock, N. G., W. Page, and L. E. Stenzel. 1995. Non-migratory movements of Dunlins on their California wintering grounds. Wilson Bulletin 107: 131-139.

Watanabe, R. T., and K. Walters. 2004. Summary of the 2003-2004 pacific herring spawning season and commercial herring fishery for Tomales Bay. California Department of Fish and Game report [online:http://www.dfg.ca.gov/mrd/herring/archive.html].

WRA (Wetlands Research Associates), Philip Williams Associates, and Avocet Research Associates. 1996. Bolinas Lagoon Management Plan Update. Marin County Open Space District, San Rafael, CA.

Controlling *Pacifastucus leniscululus* ***at the Bouverie Preserve***

Signal Crayfish in Stuart Creek

by Jeanne Wirka

A hike to the waterfall through the shady coolness of Stuart Canyon, preferably punctuated by frequent encounters with newts on the Canyon Trail, continues to be the highlight for most visitors to the Bouverie Preserve. And no wonder. Stuart Creek, with its perennial flows, excellent water quality, and wide array of aquatic microhabitats, is one of the most pristine and biologically diverse creeks in Sonoma County. The Bouverie Preserve is also one of the few places in California where the ranges of all three newt species found west of the Rocky Mountains (California, red-bellied, and rough-skinned) overlap. While newts have long ruled the roost at Bouverie, data from a recent study of amphibians at the Preserve have shed light on a potentially major threat to the continued reproductive success of all three newt species, as well as other aquatic taxa: that potential threat is the signal crayfish *(Pacifastucus leniscululus)*.

The signal crayfish is a relatively large, freshwater crustacean native to the Klamath Basin (mostly Oregon and Washington but also north of the Klamath River in California) and southwestern Canada. This western version of the tasty "crawdad" species found elsewhere in the U.S. has been observed in Stuart Creek for at least 15 years (John Petersen, personal communication). While the impact of the crayfish on native fauna in Stuart Creek has not been studied directly, ample evidence exists from other sites in California that invasive crayfish negatively affect amphibians such as the Pacific treefrog *(Hyla regilla)*, foothill yellow-legged frog *(Rana boylii)*, and California newt *(Taricha torosa)* (Cook 2005, Gambrant and Katz 1996, Gambrant et al. 1997, GISD 2006, Watters et al. 2004), all of which are found in Stuart Creek.

Since the early 1900s, signal crayfish have been introduced multiple times into rivers and lakes in more southerly parts of California, in other western states, in Europe, and in Japan. Highly competitive with other crayfish species, the signal crayfish has caused the extirpation or decline of indigenous crayfish species wherever it has been introduced. In California, it is implicated in the extinction of the sooty crayfish *(P. nigrescens)*, once endemic to San Francisco Bay, and is currently threatening the narrowly-endemic Shasta crayfish *(P. fortis)*, a state- and federally-listed endangered species found only in Shasta County. Because they are opportunistic, polytrophic feeders, signal crayfish along with other invasive crayfish species, such as the red swamp crayfish *(Procambarus clarkii)* from the southeastern U.S., can also have a devastating impact on other aquatic taxa, including macroinvertebrates, fish, amphibians, and aquatic plants (GISD 2006, Griffiths et al. 2004, Kerby et al. 2005, Light 2004, Watters et al. 2004). They prey on native aquatic species' eggs and larvae and compete with juveniles and adults of native species for shelter that is needed for protection from predators (Griffiths et al. 2004; Light 2004).

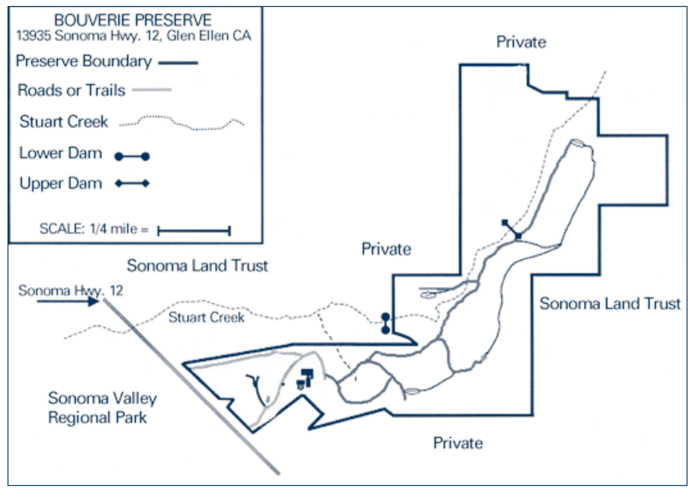


Figure 1. The Lower and Upper dams along Stuart Creek, on the Bouverie Preserve, may be important in controlling invasions by non-native, signal crayfish.

JEANNE WIRKA

Figure 2. The Lower Dam flow outlet on Bouverie Preserve's Stuart Creek. The presence of thick "ladder" vegetation on the right and under the flowing water could facilitate the movement of non-native crayfish.

In his recent study of amphibians at the Bouverie Preserve, herpetologist David Cook made several findings that suggest that signal crayfish may be having a significant negative impact on native amphibians in Stuart Creek (Cook 2005). Cook found that larval red-bellied newts *(Taricha rivularis)* were found in much higher concentrations in the upper reaches of Stuart Creek where crayfish are absent, even though adults were present in all reaches of the stream surveyed. In other local streams, red-bellied newts do not appear to demonstrate a preference

PHOTOS BY JEANNE WIRKA

A signal crayfish is retrieved.

Gerritt Van Sickle, of ACR's Juniper Program, helps with Stuart Creek field work.

for breeding in upstream habitats and larval newt distribution would be expected to be the same as the distribution of adults (David Cook, personal communication). Cook was also unable to locate any larval California newts in summer of 2005, even though egg masses had been present in May 2005. These egg masses were found in the lower reach of the creek where crayfish numbers appeared to be highest. Rough-skinned newts *(Taricha granulosa)* may be similarly impacted. Finally, while adult foothill yellow-legged frogs are found at the preserve, Cook found no evidence of successful breeding, even though certain reaches of Stuart Creek provide excellent breeding habitat. The foothill yellow-legged frog is listed as a Species of Special Concern by the California Department of Fish and Game.

While these findings are not encouraging, the good news is that the distribution of crayfish in Stuart Creek offers a rare opportunity to both study and potentially eradicate or significantly reduce their numbers by taking advantage of high-velocity flows and existing barriers to upstream dispersal. At sites in other parts of California, researchers have found that some portion of crayfish populations in high-velocity streams will wash downstream during high-flow events in winter, only to disperse back upstream as flows subside (Kerby et al. 2005; Watters et al. 2004). It is likely that this same pattern occurs during high-flow events at Stuart Creek (David Cook, personal communication). This seasonal "flushing" has been shown to be an important opportunity to actively control re-invasion of streams by invasive crayfish, especially where barriers exist to limit recolonization upstream (Kerby et al. 2005, Watters et al. 2004).

Cook's surveys of Stuart Creek found that signal crayfish had invaded above the first abandoned concrete dam, located on Sonoma Land Trust Property near the entrance to the Canyon Trail (Lower Dam), but not above the second abandoned concrete dam, located between Creek Access 4 and 5 (Upper Dam; Figure 1). Physical inspection of the two dams confirmed that the lower dam appears to be more accessible to crayfish due to encroachment of entwined roots and other aquatic vegetation, whereas the lack of similar "ladder" vegetation or concrete on the Upper Dam appears to present a substantial barrier to crayfish dispersal (Figure 2).

The presence of barriers has been shown to be an important factor in successful control of invasive crayfish in other California streams. Trapping or netting alone, in the absence of barriers, does nothing to prevent future reinvasion. However, trapping or netting after high-flow events, where a natural or man-made barrier to recolonization exists, can create "crayfish-free" zones that may alleviate predation pressure on native amphibian populations (Gambrant et al. 1997, Watters et al. 2004).

Building on findings from other sites in California, Bouverie staff have launched the first phase of what we hope will be a multi-year effort to control and study the invasion of signal crayfish in Stuart Creek. The timing could not be better, as Cook's (2005) study quantified relative abundances of amphibians in Stuart Creek and provides baseline data to assess the effects of crayfish eradication. The objectives of the first phase of the project are to quantify the distribution of signal crayfish in Stuart Creek and to fortify the existing human-made barriers to upstream dispersal. The fortification will include the removal of any ladder vegetation and installation of metal flashing to create a slippery, vegetation-free surface that the crayfish cannot climb. We will also be monitoring closely to see if the barriers cause any negative consequences for native species. They should not affect upstream migration of steelhead fry, because that occurs during periods of high flow, when water will be flowing well above the barrier. Nor should they affect movement of adult amphibians, which can crawl on land, and no other native species in Stuart Creek is known to "crawl" upstream (David Cook, personal communication). Next spring and summer, we will also monitor the effects of the enhanced barriers on crayfish dispersal upstream.

Our hope is that high-flow events in Stuart Creek may eventually take care of the bulk of the crayfish problem naturally, by washing the crayfish below the barriers. The project also includes some initial pilot trapping to assess the need and feasibility of larger-scale trapping after flow events, to eradicate remaining individuals. The long-term goal is to assess whether the hoped-for declines in crayfish abundance increase the breeding success of native amphibians at Bouverie, thus protecting the long-term biological diversity of the Preserve.

References cited

Cook, D. 2005. Amphibians of Bouverie Preserve. Unpublished study prepared for Audubon Canyon Ranch. 22 pages.

Gambrant, S. C, and L. B. Kats. 1996. Effect of introduced crayfish and mosquito fish on California newts. Conservation Biology 10: 1155-1162.

Gambrant, S. C., L. B. Kats, and C.B. Anzalone. 1997. Aggression by non-native crayfish deters breeding California newts. Conservation Biology 11: 793-796.

GISD (Global Invasive Species Database). 2006. *Pacificus leniusculus.* Website of the IUCN/SSC Invasive Species Specialist Group (ISSG) at http://issg.appfa.auckland.ac.nz/database/species/ecology.asp?si=725&fr=1&sts=sss. Accessed on May 30, 2006.

Griffiths, S. W., P. Collen, and J. D. Armstrong. 2004. Competition for shelter among over-wintering signal crayfish an juvenile Atlantic salmon. Journal of Fish Biology 65: 436-447.

Kerby, J. L., S. P. D. Riley, L. B. Kats, and P. Wilson. 2005. Barriers and flow as limiting factors in the spread of an invasive crayfish *(Procambarus clarkia)* in southern California streams. Biological Conservation 126: 402-409.

Light, T. 2004. Behavioral effects of invaders: alien crayfish and native sculpin in a California stream. Biological Invasions 7: 353-367.

Watters, T., L. Jones, S. O'Hare, M. Kerby, and L. Kats. 2004. Seasonal removal of invasive stream predators to protect sensitive amphibian populations. Poster at the Ecological Society of America 2004 Annual Meeting.

Habitat protection and nesting colonies

What's the life span of a heronry?

by John P. Kelly

Some heronries seem to be permanent features of coastal or wetland landscapes. As centers of intensive nesting activity, such sites become conspicuous reminders that our environment is fundamentally natural, driven by ecological processes that continue year after year. But nature is always changing, and the long-term persistence of colony sites is rare.

In fact, heronries are often deserted after only a few years, as new colonies are routinely established in alternative locations. This process is an important aspect of heron and egret nesting biology, allowing the birds to respond adaptively to nest disturbance, shifts in wetland hydrology, and changes in the quality of nearby feeding areas. The extent to which these birds depend on existing colony sites can be difficult to measure. Some clues can be found in the persistence patterns of heronries monitored for many years.

The nesting colony at Audubon Canyon Ranch's Picher Canyon near Bolinas Lagoon has persisted far longer than most other colony sites in our region. Helen Pratt (1983) determined that the heronry has probably been active since at least the early 20th century and could have been active as far back as the late 1800s, but its actual age is unknown. Although the abundances of nesting herons and egrets in the San Francisco Bay region are stable or increasing (Kelly et. al 2006), the sizes of particular colonies such as the one at ACR's Picher Canyon can be impressively dynamic, as nesting birds move among colony sites between years (Figure 1). New colonies are often initiated with a few nests and grow, either gradually or abruptly, into larger colonies in subsequent years.

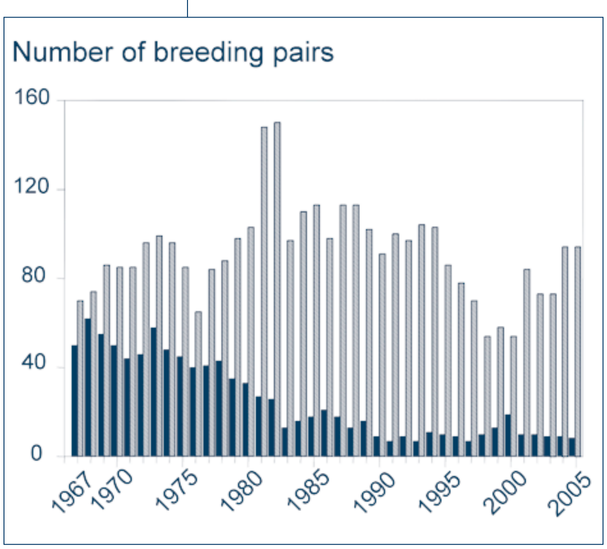


Figure 1. Annual number of nesting Great Blue Herons (solid bars) and Great Egrets (hatched bars) at ACR's Bolinas Lagoon Preserve.

The number of consecutive years that heronries remain active is closely related to the number of nests in the colony and the species that nest there. The relationship between colony size and persistence is evident in the regional dynamics of colony sites. In 1991–2005, an average of 73 active colony sites supported approximately 62 Great Blue Heron colonies, 25 Great Egret colonies, 13 Black-crowned Night-Heron colonies, and 12 Snowy Egret colonies each year. Based on observations from these sites, almost all active heronries in any year are likely to have been active during previous years, but smaller colonies of less than five nests tend to become inactive within five years unless they reach higher levels of nest abundance associated with increasing persistence (Figure 2).

Great Blue Heron colonies generally become inactive within five years if they remain smaller than six nests, but they tend to persist, on average, for 12 or more years if they grow to more than 20 nests (Figure 3). The persistence of Great Egret, Black-crowned Night-Heron, and Snowy Egret colonies increases substantially only after reaching an abundance of 20–30 nests per species. Colony sites with less than ten nests of all species combined tend to remain active, on average, for approximately eight years (Figure 3). These general patterns probably underestimate the average persistence of heronries, because some sites were active prior to discovery or will remain active beyond the 15-year monitoring period. However, the results show clearly that the number of years a colony site is occupied is closely related to maximum colony size.

In general, the regional persistence patterns of heronries suggest that conservation efforts should prioritize the protection of colony sites with 20 or more active nests and that long-term protection is most appropriate for colony sites with more than 100 nests. However, the protection of smaller colonies should not be ignored, because they may be more sensitive to disturbance or prone to abandonment than larger colonies. The importance of protecting mixed-species heronries is enhanced by the presence of additional nesting species, and values

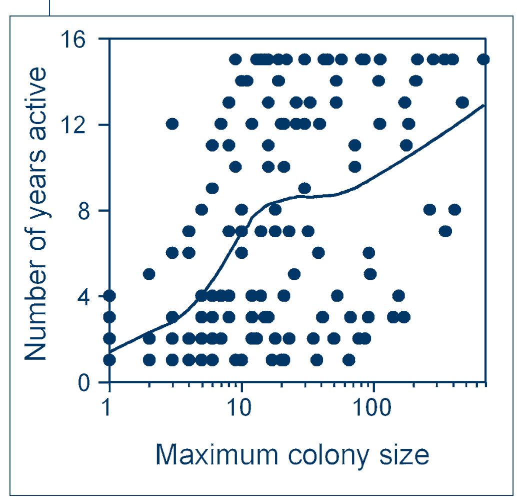


Figure 2. Relationship between the maximum size of heronries (all species) and the number of consecutive years occupied, in the San Francisco Bay area, 1991-2005. (Note that maximum colony size is plotted on a $\log_{10}$ scale; trend lines represent Cleveland's robust locally weighted regression algorithm, LOWESS, f = 0.6; Cleveland 1979).

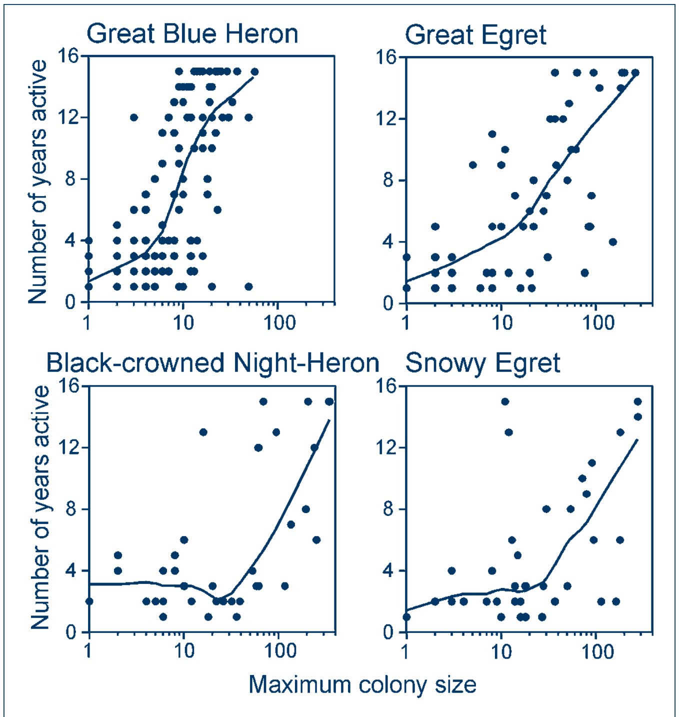


Figure 3. Relationships between the maximum size of heronries and the number of consecutive years occupied, in the San Francisco Bay area, 1991-2005. (Note that maximum colony size is plotted on a $\log_{10}$ scale; trend lines represent Cleveland's robust locally weighted regression algorithm, LOWESS, f = 0.6; Cleveland 1979).

associated with the expected longevity of any heronry grow rapidly as nest abundance increases above six Great Blue Heron nests, 20 Great Egret nests, or 30 Snowy Egret or Black-crowned Night-Heron nests (Figure 3).

Nesting habitat values

Shifts in the distribution of nesting herons and egrets reflect their behavioral responses to rapid changes in habitat value. Such responses reveal not only the resilience of herons and egrets to wetland loss or degradation, but also their ability to benefit from localized habitat restoration efforts. For example, increases in the number of herons and egrets nesting in San Pablo Bay marshes since the late 1990s coincided with increases in the extent of restored tidal marshes (Kelly et al. 2006).

We have also noticed that new colony sites are often initiated within a few kilometers of heronries that were disturbed by nest predators or humans. A mixed colony of Snowy Egrets, Black-crowned Night-Herons, and Cattle Egrets has apparently persisted for many years in the vicinity of Santa Rosa Creek in Sonoma County, by repeatedly moving to new sites—at least four times since 1990—after abandoning sites subjected to various forms of human disturbance. The birds' capacity to tolerate continuing disturbance in order to nest in this area is unknown. In some areas, a scarcity of alternative colony sites in suitable locations might limit the resilience of herons and egrets to the loss of nesting habitat or, alternatively, prevent them from taking full advantage of restored wetlands. Therefore, the conservation of alternative colony sites may be an important part of regional habitat protection for herons and egrets.

The abandonment of heronries is usually associated with disturbance by humans or predators. Sometimes, heronries are recolonized after a few years of inactivity, but this apparently occurs only rarely. Normally, herons and egrets seem to avoid previously abandoned sites. For example, in the early 1990s as many as 29 pairs of Great Blue Herons nested in the dense oak canopy of an isolated island in Stafford Lake near Novato. The site was abandoned in 1993, when a temporary drop in water level resulted in a land bridge that allowed one or more raccoons to raid the nests. Lake managers have since kept water levels high enough to prevent land predators from gaining access to the island, but the site has not been recolonized. Apparently, the value of nesting habitat is influenced by its history.

Ecosystem effects of colony site protection

During the nesting season, herons and egrets tend to forage within a few to several kilometers of their colony sites (e.g., Custer and Osborne 1978, Kelly et al. 2005). Some investigators have suggested that a scarcity of suitable colony sites combined with a tendency to forage near nesting areas could limit or reduce heron or egret use of an entire wetland area or subregion (Gibbs et al. 1987, Fasola and Alieri 1992). Although most wetland landscapes in California seem to provide plenty of suitable nesting habitat, colony site preferences are very difficult to predict, and changes in the number of locally nesting pairs can be considerable.

For example, from 1991 to 2002 Tomales Bay supported, on average, 47 ± 4 (SE) pairs of Great Egrets per year, but in 2003–2005, after two of the three colony sites in the area were abandoned, the number of pairs declined to 18 ± 2 pairs. If the loss of local heronries leads to a substantial decline in foraging activity by these top predators, the abundance or behavior of prey species or competing predators might be affected. Such effects might, in turn, alter other ecosystem processes.

The loss of a local heron or egret colony may also alter ecological processes in other areas. Such effects were suggested in 1994, when the virtual abandonment of the Snowy Egret colony on the Marin Islands, near San Rafael, apparently resulted in a dramatic influx of approximately 100 nesting pairs of Snowies at a colony site in Napa County.

Many people share a sense that everything in nature is somehow connected and that local events can affect (or be affected by) events or processes in other areas. Nesting herons and egrets are good examples of animals that depend strongly on local resources while responding adaptively to opportunities across large regional landscapes. Over time, the regional management of wetland habitats may benefit not only from protecting local heronries, but also by responding to the shifting distributions of nesting herons and egrets.

References Cited

Cleveland, W. S. 1979. Robust locally weighted regression and smoothing scatterplots. Journal of the American Statistical Association 74: 829-836

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

Fasola, M., and R. Alieri. 1992. Conservation of heronry Ardeidae sites in North Italian agricultural landscapes. Biological Conservation 62-219-228

Gibbs, J. P. S. Woodward, M. L. Hunter, and A. E. Hutchinson. 1987. Determinants of Great Blue Heron colony distribution in coastal Maine. Auk 104: 38-47.

Kelly, J. P., K. L. Etienne, D. Stralberg, and M. McCaustland. 2005. Landscape use by herons and egrets in the San Francisco Estuary. State of the Estuary Conference [online: http://www.irwm.org], Oakland, CA.

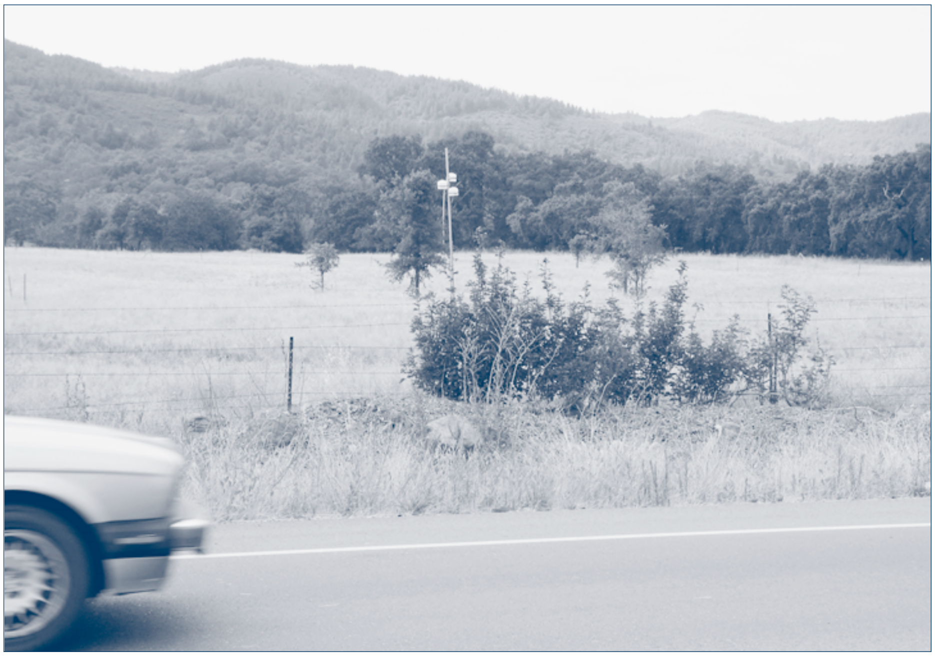
Kelly, J. P., K. Etienne, C. Strong, M. McCaustland, and M. L. Parkes. 2006. Annotated atlas and implications for the conservation of heron and egret nesting colonies in the San Francisco Bay area. Audubon Canyon Ranch. ACR Technical Report 90-3-17 [online: http://www.egret.org].

Pratt, H. M. 1983. Marin County, California heron colonies, 1967-1981. Western Birds 14: 169-184.

Is nitrogen pollution from vehicles harming fragile ecosystems?

Sonoma Valley Vernal Pools

by Daniel Gluesenkamp and Jeanne Wirka



DANIEL GLUESENKAMP

Figure 1. Passive nitrogen sampling station at Bouverie Preserve.

Vernal pools are unique and sensitive ecosystems that form only where topographic basins collect rainwater and soil conditions prevent drainage. Each pool is a discrete watershed that supports a specialized suite of native plants. Vernal pools are famous for their highly adapted wildflower species, including short-stature "belly plants"—many of which can live nowhere else. Unfortunately, vernal pools are in decline statewide, due chiefly to human development of the flat and easily paved wetlands. As a result, many of the plant and animal taxa associated with them are now rare or threatened with extinction. However, even after pools are protected from development they often suffer losses in species diversity, due to competition from invasive non-native species. In this respect, the pools at Audubon Canyon Ranch's Bouverie Preserve are similar to many other protected pools in Sonoma County.

Vernal pools at Bouverie Preserve are dominated by invasive species, such as Italian ryegrass *(Lolium multiflorum)* and velvet grass *(Holcus lanatus)*, and lack many of the characteristic low-stature, vernal-pool plant species, even though these plants are present in nearby uninvaded habitat (Gluesenkamp 2005). For example, at Bouverie the rare dwarf Downingia *(Downingia pusilla)* has been lost from the vernal pools in which it once occurred: these rare plants are simply too short to germinate and grow when buried beneath the deep carpet of invasive grasses. Similar losses have occurred at protected pools throughout Sonoma County.

Loss of unique endangered plant species from protected habitat is a conservationist's nightmare. Protecting habitat from development is supposed to save the species that live there! Unfortunately, loss of biological diversity from nature preserves is far too frequent an occurrence. We are increasingly learning the painful lesson that our protected lands cannot remain biologically diverse without active management—that "benign neglect" is equivalent to abandoning sensitive species to perish in a human-altered world. While we are learning that we must (paradoxically) tend to nature in order to save what is natural, we are also learning that we know relatively little about how these natural systems function.

Research recently initiated at ACR's Bouverie Preserve will test one hypothesis for why some vernal pools lose native plant diversity, and will hopefully provide solutions for rescuing and restoring these rare and beautiful organisms. Specifically, we are investigating whether the invasion of non-native grasses in Bouverie's vernal pools has been facilitated by eutrophication originating from automobile traffic on the nearby highway.

Nitrogen addition: too much of a good thing?

The enrichment of an ecosystem via the addition of chemical nutrients, known as "eutrophication," has been studied in lakes and streams for decades. Research and advocacy by W. Thomas Edmonson in the 1950s saved Lake Washington from a stinky death and was an important step in the development of modern natural resource management (NRC 1999). While the best-known examples of eutrophication generally involve a slimy green muck-covered pond filled with suffocating fish, the same processes can operate on land. For example, eutrophication on land might take the form of a rye grass "bloom" that covers a grassland and outcompetes the smaller plants underneath.

Eutrophication can occur when an ecological system receives addition of nutrients that are otherwise in short supply. In terrestrial systems nitrogen is typically the element most limiting to growth of plants. Farmers have known this for centuries and so increase yields by adding nitrogen fertilizer. Nitrogen limitation of

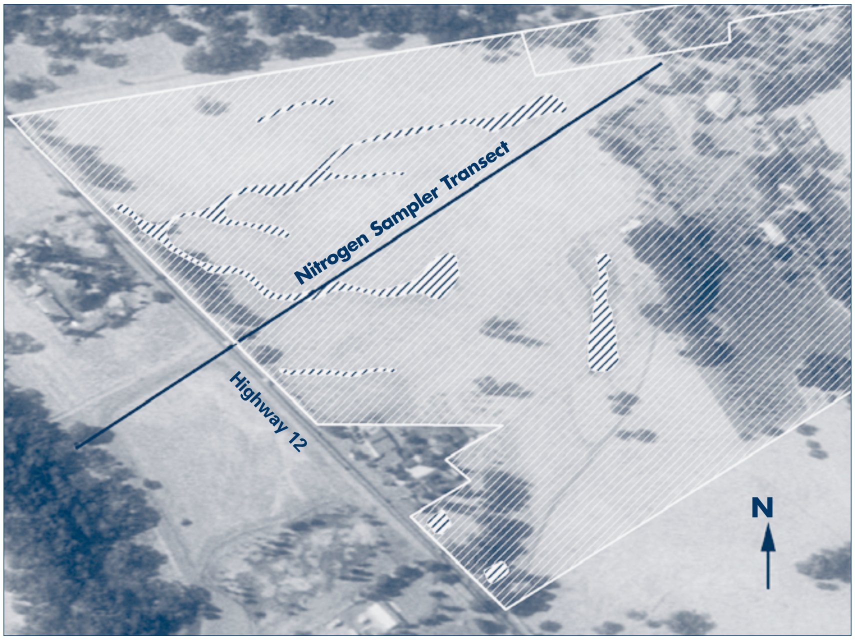


Figure 2. Location of nitrogen deposition sampling stations at ACR's Bouverie Preserve and the adjacent Sonoma Valley Regional Park. Bouverie Preserve is shown with white cross-hatched lines, vernal wetlands are indicated with pale fill, nitrogen sampler transect is indicated with thick black line. Highway 12 is located to the west of Bouverie Preserve, from upper-left to lower-middle of this map.

plant growth may seem counter-intuitive, because 78 percent of our atmosphere is made up of nitrogen in the form of elemental nitrogen gas (N_2). However, very few living things can break down N_2 to acquire the nitrogen atoms needed to build amino acids and other nitrogen-containing compounds. Although Earth's atmosphere is predominantly nitrogen, plants and animals only have access to very small quantities of reactive nitrogen compounds, such as ammonium (NH_4) and nitrate (NO_3). This is one of the great ironies of the natural world, comparable to the Ancient Mariner's lament of "Water, water everywhere, Nor any drop to drink."

In recent decades, human addition of nitrogen worldwide has doubled the rate of nitrogen entering terrestrial systems, with very significant consequences for nitrogen-limited natural systems (Vitousek et al. 1997). Automobiles and trucks emit large quantities of nitrogen compounds, primarily nitrogen oxides (NO_x) that are available for uptake by plants. In the early 1990s automobiles in the United States began using catalytic converters that can over-reduce combustion NO_x to ammonia (NH_3) when they are running fuel rich. Nitrogen compounds produced by automobiles are available to plants either by direct absorption through stomata, via dry deposition on leaf surfaces, or through roots after transfer to the soil. Consequently, automobiles might be fertilizing nearby vernal pool vegetation in the same manner that large urban and agricultural pollution plumes fertilize downwind ecosystems.

A growing body of evidence suggests that dry deposition of nitrogen compounds from fuel combustion is having significant ecological effects on sensitive ecosystems downwind of cities or adjacent to highways through the West (Fenn et al. 2003). Pollution from vehicles also has been shown to change soil chemistry, produce phytotoxic levels of ozone with major ecological and economic consequences in forests, and dramatically impact sensitive lichen communities. Added nitrogen can shift community composition towards "nitrophilic" species, especially fast- growing non-native weeds that take advantage of the extra fertilization and out-compete native species. In southern California dry deposition of nitrogen compounds is one factor driving the conversion of chaparral shrublands to European annual grasslands (Fenn et al. 2003). Stuart Weiss, our collaborator on the Bouverie Preserve study, found evidence that dry deposition from Interstate 280 enabled Italian ryegrass to out-compete native wildflowers in Santa Clara County, leading to the decline of endangered checkerspot butterflies (Weiss 1999).

What's going on in Bouverie's vernal pools?

Bouverie Preserve's seasonal wetlands are adjacent to California Highway 12, a road on which approximately 15,000 vehicles pass by each day (Figure 2). Preliminary estimates indicate that nitrogen deposition in this portion of Sonoma County may be as high as 5–10 kilograms N per hectare per year (G. Tonnesen, CE-CERT, UC Riverside, pers. com.), and these rates may be greater adjacent to Highway 12. Nitrogen deposition rates at this site could be on the order of those leading to eutrophication of other arid and semi-arid ecosystems. Vernal pools occur on shallow soils that are strongly nitrogen limited, and the plant communities in our pools are being smothered beneath a canopy of Italian ryegrass, a species known to respond strongly to dry nitrogen deposition. It seems likely that exclusion of Bouverie's vernal pool plants results at least partly from the effects of nitrogen pollution from the adjacent highway on the growth of invaders such as Italian ryegrass.

In April 2006 we initiated a project that will begin to test this hypothesis. The study is a collaboration between ACR staff and Dr. Stuart Weiss, of the Menlo Park-based Creekside Center for Earth Observations, an expert on assessing the effect of nitrogen deposition on plant communities. This first study will quantify nitrogen dry deposition near Highway 12 and will determine how deposition rates change with distance from Highway 12. Results will tell us whether deposition rates are in the range that has been ecologically significant in other studies.

This deposition study relies on an innovative sampling technology that uses pre-treated cellulose pads to passively sample 5 relevant chemical compounds (NOx, NO2, NH3, O3, HNO3). The pads are placed in small plastic vials that permit flow of the ambient atmosphere. Chemicals on the pads react with nitrogen compounds in the atmosphere and enable us to determine the concentration of each compound over the sampling period. We mounted passive samplers on 3-m poles at eight locations in proximity to Bouverie Preserve's vernal pools (Figure 1). Five stations were established on Bouverie Preserve land east of Highway 12, and three stations were established west of the highway in the Sonoma Valley Regional Park. This will enable us to compare how wind direction influences the

continued on page 12

The importance of mapping in the protection and restoration of native ecosystems

Charting the Course

by Jennifer Jordan

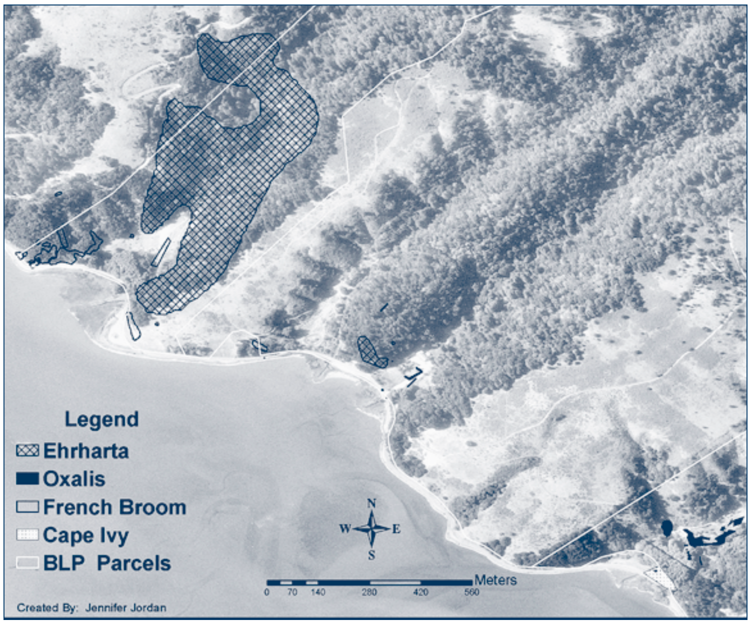


Figure 1. High priority invasive plant species at the Bolinas Lagoon Preserve.

Audubon Canyon Ranch's properties are home to unique habitats, rare plants, and a great diversity of birds and other wildlife. Unfortunately, ACR's lands are also home to a multiplicity of exotic plants, many of which are invasive and can destroy natural habitat that is essential for native flora and fauna to survive. Because of this, the Habitat Protection and Restoration (HPR) program includes an active invasive species management plan that protects biodiversity. Natural resource mapping plays an important role in this plan and the success of our habitat restoration work.

Mapping involves the collection and presentation of spatial information, such as the occurrence of important habitat features and the distributions of invasive plant populations. This can be done by hand drawing infestations to create maps, or by using a Global Positioning System (GPS) to more precisely collect spatial information. At ACR we use both methods, but emphasize the use of GPS along with the WIMS database (see textbox). This allows us to easily transfer and manipulate our data in standardized geographic information systems such as ArcGIS. With these digital tools, we can graphically project data onto aerial photos and topographic maps that can be analyzed and shared within ACR and with our partners and used to develop effective plans for eradicating or managing invasive species, protecting rare plants, or restoring critical habitats.

Effective protection of ACR sanctuaries often requires that staff experiment with novel approaches, and that we communicate and share insights with other land managers and ecological professionals. For this reason, our habitat protection work takes place within an adaptive management framework and emphasizes a collaborative approach to managing our properties.

Adaptive Management

Land managers use adaptive management to continually revise their methods to develop the most effective strategies for managing properties. Adaptive management planning recognizes that uncertainty is inherent in the management of complex ecological systems, frames management actions as experiments, and enables the planner to use the results of management experiments to inform and improve future actions. A vital component of this approach is developing and implementing a system of mapping.

One of the first steps in adaptive management of invasive plants is to identify species that threaten restoration goals. An important goal of the HPR Project Leader is to map the invasive species on Audubon Canyon Ranch properties. Mapping gives us a visual picture of which habitats are threatened by invasive species. This allows us to prioritize restoration efforts according to the degree of threat to native habitats and to determine which infestations require immediate attention. For example, we use maps of the Bolinas Lagoon Preserve to identify the locations of the most invasive species, such as Ehrharta *(Ehrharta erecta),* French broom *(Genista monspessulana),* Oxalis *(Oxalis pescaprae),* and Cape ivy *(Delairea odorata)* (Figure 1). These mapping data are used in combination with impact assessments such as the Cal-IPC Invasive Plant Inventory (http://cal-ipc.org) to prioritize target populations and create an effective management plan for the preservation of our native ecosystems.

Once we have identified and prioritized invasive plant occurrences, we can use the information gained from mapping, along with relevant biological information, to determine which control techniques are appropriate for different habitats and infestations and plan a timeline for treatment and monitoring. It is important to consider not only the presence of invasive species in an area, but also numerous other special considerations, including the extent and density of infestation, phenology of species, proximity to water, abundance of native species, presence of rare or threatened species, scientific or other land management uses, and presence of nesting birds or other wildlife.

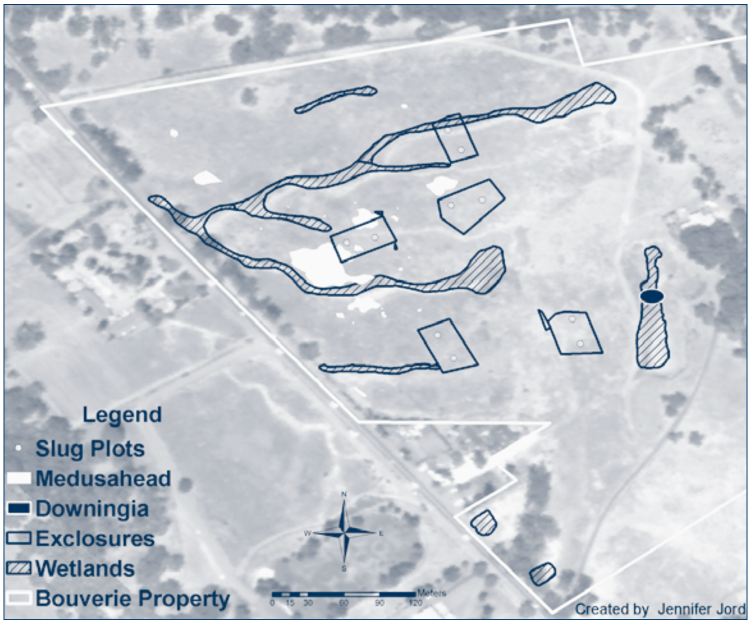


Figure 2. Bouverie Lower Field, showing invasive plants (medusahead, *Taeniatherum caput-medusae*), experimental areas, wetlands, and rare plants *(Downingia pusilla).*

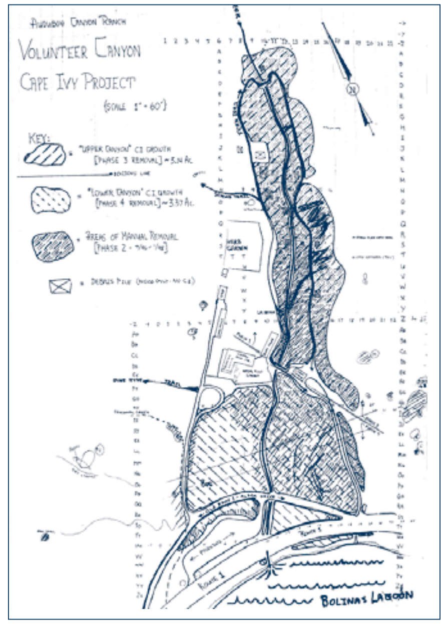


Figure 3. Volunteer Len Blumin's hand-drawn map of the cape ivy project area in Bolinas Lagoon Preserve's Volunteer Canyon.

Bouverie Preserve's Lower Field is one example of the importance of including several of the parameters listed above on a single map when developing an adaptive management plan (Figure 2). The Lower Field grassland is a complex ecosystem with a diversity of interesting native plants and an equally diverse and interesting invasive plant flora. Maintenance of native plant diversity at this site requires prescribed cattle grazing to reduce the biomass of highly competitive European annual grasses. To plan for this, we mapped invasive plant occurrences *(Taeniatherum caput-medusae)*, rare plant occurrences *(Downingia pusilla)*, sensitive wetlands, and experimental grazing exclusion areas. Viewing these resources together on a single map was instrumental in determining the fencing configuration that best divided the pasture and maximized our control of the timing and intensity of grazing.

Perhaps the most critical step in the adaptive management cycle is monitoring and assessing the outcomes of management actions. We track several indicators of effectiveness, such as population density and size, and display them on maps in order to make intuitive assessments. A comparison of multiple assessments made periodically (e.g., annual intervals) allows us to monitor the spread or abatement of infestations and the effectiveness of our treatments. With this information we can modify management plans as necessary.

Partnerships

The success of ACR's habitat restoration work results not only from an adaptive management approach, but also from a large network of professional partners, neighboring private landowners, and volunteer stewards. Mapping plays a vital role in planning and coordinating management actions with all of our partners. Together with professional partners in the Marin Sonoma Weed Management Area, we have mapped the most invasive species in the vicinity of the Bolinas Lagoon Preserve and have obtained grant funding for a project that will remove these invaders from a multi-jurisdictional area of important natural habitat.

Accurate maps of invasive plant populations are also important tools when working with volunteer stewards. Maps are necessary for planning volunteer workdays as well as establishing permanent records for future reference of work performed by some ACR volunteers who have assumed ongoing responsibility for stewardship of specific habitats, sites, or species (Figure 3).

ACR continues to incorporate GIS and other mapping technologies as fundamental tools for conservation science and habitat protection. With the information that mapping provides we are able to work within and beyond the borders of ACR and address the invasions that unless controlled will continue to create management concerns.

Weed Information Management System (WIMS)

Audubon Canyon Ranch's Habitat Protection and Restoration program has adopted a standardized database developed by The Nature Conservancy called the Weed Information Management System (WIMS). The database enhances ACR's ability to inventory and track invasive plant populations. Other agencies in the San Francisco Bay area and beyond are also beginning to adopt the WIMS database to integrate into their programs. This collective effort will enable resource managers from many organizations and agencies to share standardized data so that large scale collaboration efforts to control invasive plants will be possible.

WIMS enables ACR to record occurrences of every exotic plant infestation that we find and then organizes this information into a relational database. The WIMS database allows us to return to the same locations to create additional assessments, review treatments used for different populations, and record the number of person hours spent. By keeping track of this information we are able to determine which control methods are most effective and which methods should be modified.

Nitrogen, *from page 9*

amount of nitrogen deposited on opposite sides of the highway. Our plan is to sample seasonal and annual nitrogen deposition.

If this pilot study indicates that deposition rates are sufficient to have ecological impacts, then we may initiate additional studies to assess the ecological effects of nitrogen deposition on these wetlands. Additional studies may include sampling vegetation biomass at different distances from the highway, with the intent of correlating plant growth with proximity to nitrogen sources. This relationship could be even more strongly substantiated by analyzing the ratios of nitrogen isotopes in plants along the highway distance gradient. Automobile-generated nitrogen compounds have a characteristic isotopic "signature" that can tell us the degree to which plants are incorporating highway nitrogen. Finally, we would like to use "phytometers" (greenhouse-raised plants placed in pots in the field) to better assess ecological effects of nitrogen deposition. Single-species pots could tell us how distance from the highway nitrogen source affects growth of individual species, and pots with multiple species could tell us how deposition alters competitive interactions among species of concern.

Research demonstrating eutrophication due to nitrogen deposition is a meaningful scientific contribution to the conservation biology of vernal pools in itself. Equally important, however, is the application of this work to restoration of Bouverie's vernal pools. If significant, results may be used to calibrate grazing or burning prescriptions specifically to remove the excess nitrogen deposited by vehicles. The results may also be relevant to CalTrans' upcoming widening of Highway 12, which is expected to increase vehicle volume and speed leading to an increase in nitrogen deposition. These increases are easily calculated and the results could provide evidence that a change in traffic would affect adjacent ecosystems. Research conducted by Stuart Weiss in serpentine grasslands predicted that widening Highway 280 would result in quantifiable impacts; this led to mitigation funding by the Santa Clara Valley Transportation Authority for habitat protection along the expansion corridor

As we wait for the first set of samples to be processed it remains unknown whether Sonoma Valley's few remaining vernal pools are being harmed by vehicular nitrogen deposition. However, we are confronted by the fact that Bouverie's vernal pools currently support large populations of invasive plants, instead of the rare vernal pool species that thrived for thousands of generations before humans altered this area. Before we undertake projects to restore and reintroduce endangered vernal pool plants, we must first discover the root cause behind biodiversity loss. Ultimately, this type of research is critical if conservation and restoration efforts are to move beyond the "triage" mode of addressing symptoms without knowing the root causes. Our responsibility is to protect the natural diversity that remains in these systems, to enhance existing populations and to dream about restoring species that have been lost. Through careful study we hope to ensure that nature can persist in a human-dominated world, inches from 15,000 catalytic converters moving 65 miles per hour.

References cited

Fenn, M.E. J.S. Baron, E.B. Allen, H. M. Rueth, K.R. Nydick, L. Geiser, W.D. Bowman, J. O. Sickman, T.Meixner, and D. W. Johnson. 2003. Ecological effects of nitrogen deposition in the western United States. BioScience 53:404-420.

Gluesenkamp, D.A. 2005. Stewardship ethic. 2005 Ardeid. Audubon Canyon Ranch.

NRC (National Research Council). 1999. Perspectives on biodiversity: valuing its role in an everchanging world. National Academy Press, Washington, DC. 129 p.

Vitousek, P.M., J. D. Aber, R. W. Howarth, G. E. Likens, P. A. Matson, D. W. Schindler, W. H. Schlesinger and D. G. Tilman. 1997. Human alteration of the global nitrogen cycle: sources and consequences. Ecological Applications 7:737-750.

Weiss, S.B. 1999. Cars, cows, and checkerspot butterflies: nitrogen deposition and management of nutrient-poor grasslands for a threatened species. Conservation Biology 13:1476-1486.

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.

Tomales Bay harbor seal monitoring. Mary Ellen King, Santa Rosa, CA..

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.

Utility of riparian corridors to native California passerines. Jodi Hilty and Katie Meiklejohn, Wildlife Conservation Society and Columbia University, respectively.

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

In progress:
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.

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 51 species, totaling up to 25,000 birds. Future work will focus on trends and determinants of waterbird variation on Tomales Bay.

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. The data are used to examine regional patterns of reproductive performance, disturbance, habitat use, seasonal timing and spatial relationships among heronries. The project has been incorporated into the Integrated Regional Wetland Monitoring (IRWM) program, a CALFED project to develop regional monitoring for San Francisco Bay. We recently completed an annotated, 250-page atlas of heronries in the San Francisco Bay area [available online: www.egret.org].

Common Ravens in heronries ◗ We have been observing and radio-tracking nesting ravens in Marin County and measuring their predatory behaviors 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. Future work will address diurnal movements of ravens, methods in radio telemetry, and techniques for managing raven predation.

Impacts of Wild Turkeys on forest ecosystems ◗ The goal of this study is to experimentally measure the effects of ground foraging by invasive, non-native Wild Turkeys on vegetation, invertebrates, and herpetofauna 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 leniscululs)* 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. See article in this issue of *The Ardeid.*

Terwiliger Butterfly Grove ◗ ACR property near Muir Beach has supported large concentrations of overwintering monarch butterflies. Monarchs have been absent in recent years, but we are removing non-native shrubs and saplings to restore the native understory while allowing new foliage to grow in areas that are likely to provide suitable butterfly habitat.

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. See article in this issue of *The Ardeid.*

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 level.

***Ehrharta erecta* management and research ◗** *Ehrharta erecta* is a highly invasive perennial grass native to South Africa. We have removed a large patch of *Ehrharta* from ACR's Bolinas Lagoon Preserve. A scientific project to investigate the ecological effects of *Ehrharta* invasion and develop tools for the control of *Ehrharta* was discontinued when experimental plots were destroyed by flood waters.

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 nonnative 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 parsley.

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.

Influence of terrestrial invertebrates on grasslands ◗ This project will determine whether the dominance of European plant species in grasslands at the Bouverie Preserve is caused by herbivory by two types of ground-dwelling invertebrates: African earwigs *(Emborellia cincticollis)* and European slugs *(Derocerius* sp.*).*

Salt marsh 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* spp. *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 herbicide spot treatments to remove invasive outlier patches.

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

Eucalyptus removal ◗The row of non-native eucalyptus trees was removed from the vernal wetland area along Highway 12 at Bouverie Preserve.

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.

THE ARDEID

Conservation Science and Habitat Protection at Audubon Canyon Ranch

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What is this device measuring? And will the information it yields help ACR protect Sonoma Valley's vernal pools?

DANIEL GLUESENKAMP

Monitoring nitrogen pollution see page 8

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