


U.C. Davis Arboretum
Wildlife Management and Enhancement Plan


Final Report
Museum of Wildlife and Fish Biology
13 January 2006

FINAL REPORT

UC Davis Arboretum
Wildlife Management and Enhancement Plan
(AWMEP)

Prepared for the

UC Davis Arboretum,

Facilities: Operations and Maintenance Division,

and

UC Davis Office of Resource Management and Planning

by the

UC Davis Museum of Wildlife and Fish Biology

Biomonitoring Program

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Cover photos taken in UC Davis Arboretum by M. Truan (clockwise from top right): California ground squirrel (*Spermophilus beechyi*), western fence lizard (*Sceloporus occidentalis*), ruby-crowned kinglet (*Regulus calendula*), and immature white-crowned sparrow (*Zonotrichia leucophrys*).

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Executive Summary

In 2004, the UC Davis Museum of Wildlife and Fish Biology (MWFB) began an assessment of current wildlife species composition, distribution, and abundance in the UC Davis Arboretum in order to make recommendations for wildlife damage management and habitat enhancement in support of the UC Davis Arboretum Ten-Year Plan 2002-2012. This document, the UC Davis Arboretum Wildlife Management and Enhancement Plan (AWMEP), presents past findings on the status and trends of Arboretum wildlife together with new findings based on our wildlife assessment conducted between October 2004 and October 2005.

Section 2 of this document presents a summary of the species known to occur in the Arboretum, as well additional species that might occur if habitat were suitable for them, given their current range and habitat requirements. We recorded 169 vertebrate and invertebrate species, including one State Threatened species (Swainson's hawk), 2 State Species of Special Concern (western pond turtle, Townsend's big-eared bat), and 21 bird species of special concern. We discuss the current status and trends of various invertebrate and vertebrate taxa, their life histories, and habitat requirements, focusing on ways to improve habitat for native species. We also present results from two focused surveys for groups of particular concern due to their potential to damage sensitive Arboretum resources, California ground squirrels, and a large heron and egret colony currently occupying the Shields Oak Grove.

Section 3 presents specific wildlife damage management options and recommendations for nuisance species, including rodents, rabbits, cats, ducks, and geese, with a special section on the Shields Oak Grove heronry. We find that baits and fumigants are the only efficacious way to control rodents, and that burgeoning winter Canada goose populations are an emerging problem. We present results from ground squirrel control surveys finding relatively little change before and after treatment, and suggest that more effective control might be achieved with some changes to the timing and extent of applications. We also present evidence that the sizeable heron colony in the Shields Oak Grove is likely to have substantial negative effects on the health of its host trees and suggest ways in which this damage might be ameliorated.

Section 4 presents ideas on how Arboretum habitats might be enhanced for wildlife, including improvements to the Arboretum waterway and enhancements to terrestrial habitats, such as installation of water gardens and nesting structures. Throughout, we reference management and enhancement options to Ten-Year Plan goals.

A series of appendices contain annotated species lists for confirmed and expected wildlife, information on survey methods, environmental education and outreach opportunities, wildlife professionals available for consultation, plant resources for butterflies, and information on status and trends of native ant communities in the Arboretum.

1. Introduction

Due to ongoing habitat loss in the Sacramento Valley, urban "wild" spaces, such as the University of California Davis Arboretum, will become increasingly important as refuges for local wildlife in the years to come (Novotny 2003; Spinks *et al.* 2003). Until recently, the focus of Arboretum management has rested largely on the health and well being of its valuable plant collection. In 2002, however, the Arboretum underwent a period of extensive self-examination and goal-development in the preparation of the UC Davis Arboretum Ten-Year Plan 2002-2012. During this process, Arboretum staff determined that wildlife populations were highly valued by visitors, and were, in some cases, also detrimental to collections. In 2004, the UC Davis Museum of Wildlife and Fish Biology (MWFB) was recruited to assess current species composition, distribution, and abundance of wildlife in the Arboretum and to make recommendations for wildlife management and habitat enhancement. This document, the UC Davis Arboretum Wildlife Management and Enhancement Plan (AWMEP), presents a compilation of past findings on the status and trends of Arboretum wildlife together with new findings based on a wildlife assessment conducted between October 2004 and October 2005 by the MWFB. We hope it will serve as an important reference towards effective management and conservation of Arboretum terrestrial and aquatic wildlife resources in the years to come.

1.1 Wildlife enhancement as part of the UC Davis Arboretum Ten-Year Plan

This document was designed to complement and support the mission and goals of the Davis Arboretum as presented in the UC Davis Arboretum Ten Year Plan 2002-2012. In preparation of the Plan, the Arboretum surveyed over 4,000 of their visitors, including administrators, faculty, staff, students, and Friends of the Arboretum, who identified Areas in Need of Improvement. Of the twelve Areas identified, eight are relevant to wildlife issues:

1) Design and general beauty
2) Educational signs and exhibits
3) A healthy ecosystem
4) A K-12 resource
5) A source of information
6) Regional emphasis
7) Educational programs
8) Volunteer opportunities for UC Davis students

The Ten-Year Plan set six Goals to address the Areas in Need of Improvement, of which five are directly related to the mission of wildlife enhancement:

1) Provide an exemplary place of beauty, learning, and environmental stewardship as a UC Davis campus emblem

2) Inspire and educate visitors about the natural world and appropriate horticulture for California's Central Valley and beyond

3) Strengthen the Arboretum's museum function and scientific and academic value

4) Disseminate the expertise of UC Davis to the regional community and promote environmental responsibility as a major outreach arm of UC Davis

5) Build a high-performance volunteer and staff corps dedicated to leadership, teamwork, and service

Throughout this document, we will highlight findings and recommendations pertinent to these Needs and Goals with an asterisk, accompanied by a text box. For example, the box at the right pertains to a point relevant to Areas in Need of Improvement 1, 2 and 3 and Goals 2 and 5, as defined above.

10-Year Plan
Needs 1- 3
Goals 2, 5

In this document, Section 2 identifies species known to inhabit the Arboretum and provides information on their ecology and life history, Section 3 presents recommendations for wildlife damage control actions to protect Arboretum collections and native wildlife, and Section 4 discusses possibilities for wildlife habitat enhancement. These chapters are followed by a series of appendices that include annotated species lists (Appendix A and B), methods used for data collection (Appendix C), ideas and protocols for environmental education and outreach (Appendix D), contact information for various wildlife experts available for consultation on future management and enhancement programs (Appendix E), a list of plant resources for enhancement of butterfly habitat (Appendix F), and information on the status and trends of native ant populations in the Arboretum (Appendix G).

2. Current Wildlife Resources

Table 1 presents a summary of the number of species known to occur in the Arboretum, as well as the number of additional species that might occur, given their current range and habitat requirements. Many more invertebrate species undoubtedly occur than are listed; comprehensive surveys for invertebrates have not been undertaken. Additional surveys for reptiles and amphibians are also needed. Fish, mammals and birds have been relatively well-surveyed.

TABLE 1. NUMBER OF SPECIES KNOWN TO OCCUR OR EXPECTED TO OCCUR IN THE ARBORETUM, INCLUDING SPECIAL STATUS SPECIES

Taxonomic Group	Species Confirmed	Additional Species Expected	Special Status Species[a]
Invertebrates	11 [b]	unknown	none
Fish	5	2 natives, additional non-natives possible	none
Reptiles and Amphibians	13	9	western pond turtle (SSSC)
Mammals	16	14	Townsend's big-eared bat (SSSC) pallid bat (SSSC) possible
Birds	124	66 additional species expected based on data from nearby Putah Creek	Swainson's hawk State threatened 21 special status species (see Appendix B)

[a]Special status species include federal and state endangered and threatened, state species of special concern (SSSC), California Partner's in Flight focal species, Audubon WatchList, and California endemics. See Appendices A and B for further explanation of special status rankings.
[b] Invertebrates have not been well-surveyed.

2.1 Invertebrates

Terrestrial and aquatic invertebrates are an important element of the Arboretum ecosystem, but have not been well-surveyed. Since they are directly dependent on and responsive to physical conditions and vegetative composition, invertebrates serve as information-rich indicators of the health, structure, and function of an ecosystem. Located near the base of the food chain, they provide food resources for a variety of other organisms.

Nonnative crayfish (*Procambarus clarki*) are abundant in and around the waterway. Their carcasses were the most commonly observed prey item beneath the Shields Grove heronry during the months of March through April. Crayfish are prolific burrowers, causing damage to stream beads and levees throughout the region. Their burrowing may also lead to increased turbidity and damage to submerged aquatic plants (Godfrey 2004).

While our surveys focused mainly on vertebrates, the MWFB Putah Creek Butterfly Survey Team surveyed the Arboretum during the late summer and fall of 2005. Eleven butterfly species were confirmed in the Arboretum, and another forty-four are expected to occur (Appendix A). These results are preliminary, since data were collected during a small portion of the flight season.

Eighteen species of ants, fourteen native and four non-native, are known to occur in the Arboretum (Appendix G). Native ant populations have declined steadily over the last twenty-five years, while populations of the non-native Argentine ant (*Linepithema humile*) have grown. Irrigation favors Argentine ants over native ants. Currently, there are only a few remaining strongholds for native ants within the Arboretum. These areas are the West End Swale, the fields surrounding Garrod Rd, and a large valley oak tree (*Quercus lobata)* behind the Putah Creek Lodge. Additional information on Arboretum invertebrates could be derived from volunteer and citizen-scientist monitoring efforts (Appendix D).*

10-Year Plan
Needs 3 - 5, 7, 8
Goals 2 - 5

2.2 Fish

The Arboretum waterway is an extreme environment for fish, shallow, with wide temperature fluctuations. Because it serves as a repository for storm water and other runoff, the waterway is a soup of organic and inorganic compounds, with low dissolved oxygen levels and high nutrient levels. Blooms of cyanobacteria occur occasionally, leading to anoxic conditions that kill off large numbers of fish and other aquatic vertebrates. In addition, the waterway is nearly devoid of aquatic vegetation that might otherwise serve as rearing habitat and refugia for larval and juvenile fishes.

Visitors release many non-native fish species into the waterway each year. However, only a few of these are able to establish stable breeding populations (Appendix A). Among these are some of the most invasive fish in California, including the common carp (*Cyprinus carpio*) and the western mosquitofish (*Gambusia affinus*). The feeding habits of common carp, rooting in the substrate for benthic invertebrates, significantly increases turbidity and uproots aquatic vegetation that would otherwise serve as habitat for juvenile fishes and waterfowl (Moyle 2002). Western mosquitofish have been widely introduced throughout California and have been implicated in the demise of other small fish species through competition and depredation. They also feed on the eggs and larvae of larger fish and amphibians. Additionally, it is likely that the popularity of mosquitofish as a vector control agent has hindered the consideration of equally suitable native species for this purpose (Moyle 2002).

Very few of California's native fish can survive and compete in such an environment. In fact, only one native fish species, the Sacramento blackfish (*Orthodon microlepidotus*) has been able to maintain a stable reproductive population in the waterway. This species has hemoglobin with a particularly high affinity for oxygen and so is able to survive anoxic conditions. Two other native fish, the hitch (*Lavinia exilicauda*) and the Sacramento perch (*Archoplites interruptus*), could live in the waterway if anoxic conditions were ameliorated, if suitable rearing habitat were created, and if at least some of the non-native species were removed (PB Moyle personal communication).

2.3 Amphibians and Reptiles

The bullfrog (*Rana catesbeiana)* is the only amphibian currently known to inhabit the Arboretum. This extremely adaptable non-native species has been implicated in the decline of native frogs throughout the world (Cox 1999; Stebbins 2003). They are also voracious consumers of other species, including birds. Fortunately, the bullfrog population in the Arboretum appears to be small and not particularly successful (HB Shaffer personal communication). This may be due to the lack of emergent aquatic vegetative cover, such as cattails, that protect bullfrogs from predators (Stebbins 2003).

Two species of native amphibians, the California slender salamander (*Batrachoseps attenuatus)* and the Pacific tree frog (*Pseudacris regilla),* might be supported in the Arboretum since their historical range encompasses the Central Valley (DB Wake personal communication). However, currently there is no evidence that these species inhabit the Arboretum, probably due to unsuitable habitat conditions. See Chapter 3 for discussion of how habitat might be enhanced for these species.

Western pond turtle (*Emmys marmorata*) in the Arboretum Waterway. Photo: M. Truan

Despite a paucity of amphibians, the Arboretum features a particularly large assortment of turtles, largely composed of non-native species. Spinks *et al.* (2003) found nine non-native turtle species inhabiting the waterway, most of them refugees from the pet and food trade.

The only native turtle species to inhabit the Arboretum is the western pond turtle (*Emmys marmorata)* (Spinks *et al.* 2003). It has been classified as a California Species of Special Concern, because its population is declining throughout its range, largely due to habitat loss. Spinks *et al.* (2003) found that western pond turtles, while still relatively abundant, were reproducing poorly compared with the invasive red-eared slider (*Trachemys scripta elegans)*. Several factors may be responsible for this: a lack of basking sites, unsuitable nesting and rearing habitat, a lack of refuges for hatchlings and juveniles; increased depredation; direct encounters with humans and dogs, competition with non-natives (particularly red-eared sliders); exposure to disease through introduced turtles; and egg mortality due to irrigation (hard-shelled eggs swell and burst in wet soils) (Spinks *et al*. 2003).

Two additional reptile species have been found in the Arboretum, the western fence lizard (*Sceloporus occidentalis)* and the Pacific gopher snake (*Pituophis catenifer catenifer).* The western fence lizard is relatively abundant, while the Pacific gopher snake is rarely seen. Both the western fence lizard and the Pacific gopher snake are beneficial to the ecosystem since they feed on pest species, such as insects and rodents (Stebbins 2003). The southern alligator lizard (*Elgaria multicarinatus*) is also expected to occur in the Arboretum, though none have been found. This beneficial species is common in brush piles and near streams where there is abundant plant cover (Stebbins 2003).

Red-eared slider (*Trachemys scripta elegans*) in the Arboretum waterway. Photo: M. Truan.

A young western fence lizard (*Sceloporus occidentalis*) basks on a rock in the Arboretum. Photo: M. Truan.

2.4 Mammals

Our surveys for mammals included visual observations and mapping, remote-sensing camera stations, and track tubes (Appendix C). Confirmed species are listed below. Other species that may occur, based on their range and habitat preferences, include: ornate shrew (*Sorex ornatus*), broad-footed mole (*Scapanus latimanus*), eastern gray squirrel (*Sciurus carolinensis*), muskrat (*Ondatra zibethicus*), California vole (*Microtus californicus*), western harvest mouse (*Reithrodontomys megalotis*), and deer mouse (*Peromyscus maniculatus*) (Appendix A).

Systematic live-trapping surveys would likely confirm the presence of many of these species. Live-trapping is logistically difficult to conduct in the Arboretum, however (see Appendix C for discussion).

2.4.1 Opossums

We captured photographs of Virginia opossums (*Didelphis virginiana*) using remote cameras (see Appendix C). The opossum is the only native North American marsupial. Virginia opossums were introduced to California about a century ago and have become well established throughout California, Oregon and Washington. Opossums are opportunistic foragers, eating mostly animal material, but plant material is also taken, particularly fruits and seeds (McManus 1974). They take shelter in the burrows of other animals, tree cavities, brush piles, woodpiles, under decks, steps, and in sheds. Opossums are very good climbers and they are able to hang from tree branches using their hairless prehensile tail. The opossum can be considered a pest in urban environments through confrontations with and disease transmission to pets (Salmon *et al.* 2005).

2.4.2 Bats

Several species of bats are known to frequent the campus, including: hoary bat (*Lasiurus cinereus*); pallid bat (*Antrozous pallidus*), a State Species of Special Concern; red bat (*Lasiurus borealis*); Yuma myotis (*Myotis yumanensis*); big brown bat (*Episticus fuscus*); Townsend's big-eared bat (*Plecotus townsendii*), another State Species of Special Concern; and Mexican free-tailed bat (*Tadarida brasiliensis*) (Appendix A). A Yuma myotis bat colony currently exists under the California Avenue Bridge (south pier) near the Arboretum Headquarters. In past years, Townsend's big-eared bats have also been found living under the bridge in association with the Yuma myotis colony (RE Cole personal communication). We did not survey for bats, but Rachael Long, Farm Advisor with the UC Cooperative Extension (Appendix E), has surveyed widely throughout the area and is available to help the Arboretum with future bat surveys, if desired.

2.4.3 Mesocarnivores

Domestic cats (*Felis catus*) and dogs (*Canis familiaris*) are the most abundant medium-sized mammalian predator ("mesocarnivore") in the Arboretum. We observed cats regularly both day and night, and captured some in Trailmaster photographs (Appendix C). The Arboretum's close proximity to residential areas, abundance of small prey, and low numbers of predators (coyote and great-horned owl) makes it a good habitat for cats, though actual numbers are unknown.

Overpopulation of feral cats is a huge concern. A single female can produce over 3200 offspring in a 12-year period. Disease is common in feral cat colonies and can be spread to domestic cats. Feral cats often live dangerous and short lives. Domestic cats, even those that are well fed, will still hunt small mammals, birds, and reptiles for sport. While free-ranging domestic cats predominantly depredate small mammals, birds constitute a large secondary source of prey (Lepczyk *et al.* 2004). Cats also damage young plants through territorial spray-marking and through excavation of soil in defecation.

Dogs also threaten wildlife in the Arboretum since many dog owners let their dogs run off-leash. Dogs have been observed chasing wildlife such as ducks, geese, rabbits and squirrels. Spinks *et al.* (2003) identified dogs as a major danger to western pond turtles and observed predation events and turtles with dog-inflicted injuries.

At one time, red fox (*Vulpes vulpes*) were seen regularly in the West End Swale, but none have been seen in the Arboretum in at least five years (RE Cole personal communication). Dens have been found on campus west of Highway 113 and at Russell Ranch (JP Marie personal communication).

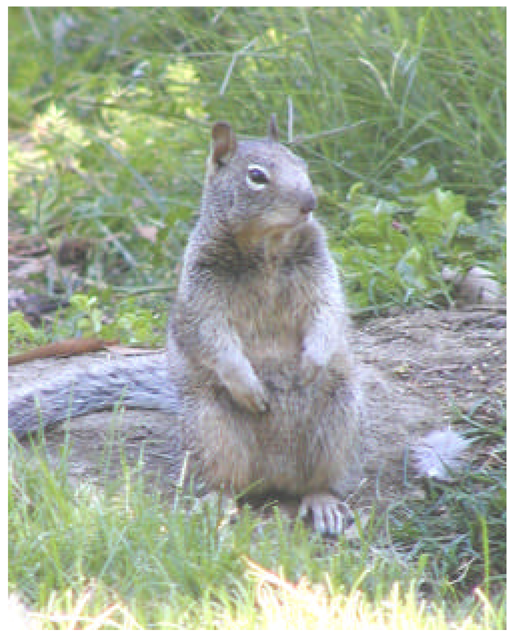
The largest mesocarnivore in the Arboretum is the native coyote (*Canis latrans*). Arboretum staff has, over the years, regularly observed adult and juvenile coyotes in the area. We observed an adult coyote trotting along the dirt road between the West End Swale and the Equestrian Center in broad daylight on 9 December 2005. Coyotes travel great distances and maintain large home ranges (Beckoff 1977). A coyote den exists at the Wildlife, Fish and Conservation Biology Experimental Ecosystem site. Coyotes may also inhabit the Speith Reserve and other less-developed lands east of Highway 113, using the old north fork Putah Creek channel as a travel corridor into the Arboretum. We did not capture any coyotes in our remote camera surveys. Alpha coyotes tend to be particularly cautious and are almost never detected at scent stations within their home range (Séquin *et al.* 2003). Coyotes are major predators of rodents. Coyotes are attracted to human trash and food and also prey on feral and domestic cats and small dogs.

2.4.4 Ground Squirrels

The most abundant mammal in the Arboretum is the native California ground squirrel (*Spermophilus beecheyi).* Ground squirrels are an important part of the Central Valley ecosystem because they are an important prey item for native carnivores and their burrows provide habitat for many different organisms. One of these is the endangered California tiger salamander (*Ambystoma californiense*), a species entirely dependent upon ground squirrels for burrow construction (HB Shaffer personal communication). Many other amphibians, reptiles, small mammals, and birds use ground squirrel burrows for shelter and reproduction.

Ground squirrels are also major pests. When subsidized by human activities and allowed to grow unchecked, ground squirrel populations can reach levels detrimental to humans, other species, and the environment. Ground squirrels present a threat to public safety and can cause a tremendous amount of direct and indirect ecological, landscape, crop, and property damage. They carry fleas that transmit bubonic plague (Marsh 1987). Burrows can be dangerous to pedestrians and livestock. Gnawing activities damage young trees, electrical wiring and plastic water pipes (Salmon and Gorenzel 2002a).

Ground squirrels have a unique life cycle compared to other rodent species (Marsh 1994). To be effective, management efforts must be timed to correspond with this annual life cycle (Marsh 1994). In the following description, dates are approximate and should be used as a guide in correspondence with observed behavior. They hibernate in their burrows during the winter months (November through January) and for a short period in late summer with emergence dependent upon temperature. Soon after emerging from hibernation in late January or February, breeding activity peaks. All of the adults in a given area are synchronized in this breeding effort, with the majority conceiving within a six-week period (Marsh 1994). Gestation lasts 28 days, with females producing one litter of six to eight young per year. The altricial young mature quickly below ground and emerge to begin feeding at approximately six weeks of age (May to mid-July). During this time, adult ground squirrels feed on green vegetation and grasses. Once the grasses begin to dry out in late August, adults and juveniles shift their diet to seeds and fruits (Marsh 1994).



California ground squirrel (*Spermophilus beechyi*) in the Arboretum. Photo: M. Truan

Over the years, campus managers have worked to reduce ground squirrel populations through various control programs. However, public opposition in 2002 caused the control program to be suspended. By spring 2005, squirrel populations were burgeoning and control was again deemed necessary. In 2004 and 2005, we mapped the distribution and abundance of ground squirrels both before and after treatment (Phostoxin fumigation) to identify areas of squirrel concentration, estimate relative population density, and evaluate the efficacy of control treatments. We mapped locations of squirrel observations over three separate surveys during late September and early October, 2004, and again in 2005, from which we created squirrel population density maps using GIS (Figs. 1 and 2). We also analyzed differences in relative population density of squirrels between years and within specific Arboretum plant collection boundaries (Figs. 3, 4 and Table 2). (See Appendix C for more information on survey and mapping methods.)

Overall squirrel density decreased, though not significantly, between 2004 and 2005, suggesting that the Phostoxin treatment reduced squirrel numbers, but not to the extent desired. According to our estimates, squirrel density dropped by approximately 27% between 2004 and 2005 (Table 2).

Relative squirrel density differed between plant collections, as did inter-annual changes in relative density. The Yolo County Riparian, East Asian, South African, and Chilean collections had the highest squirrel densities (Fig. 4). Squirrel density decreased in 58% of the collections with statistically significant (a = 0.10) declines observed for five collections: Yolo County Riparian, East Asian, Mediterranean, Acacia/Sierra Woodland and the Mary Wattis Brown Garden. Conversely, relative squirrel density *increased* in 30% of the collections, especially the Putah Creek Lodge and Cottonwood. In these collections, squirrel burrows are often well-hidden and/or difficult to access. This may have resulted in incomplete treatment of these areas. Empty burrows may also have been recolonized by squirrels from other areas. See Chapter 2 for further discussion of ground squirrel management issues and recommendations for improving the efficacy of treatment efforts.

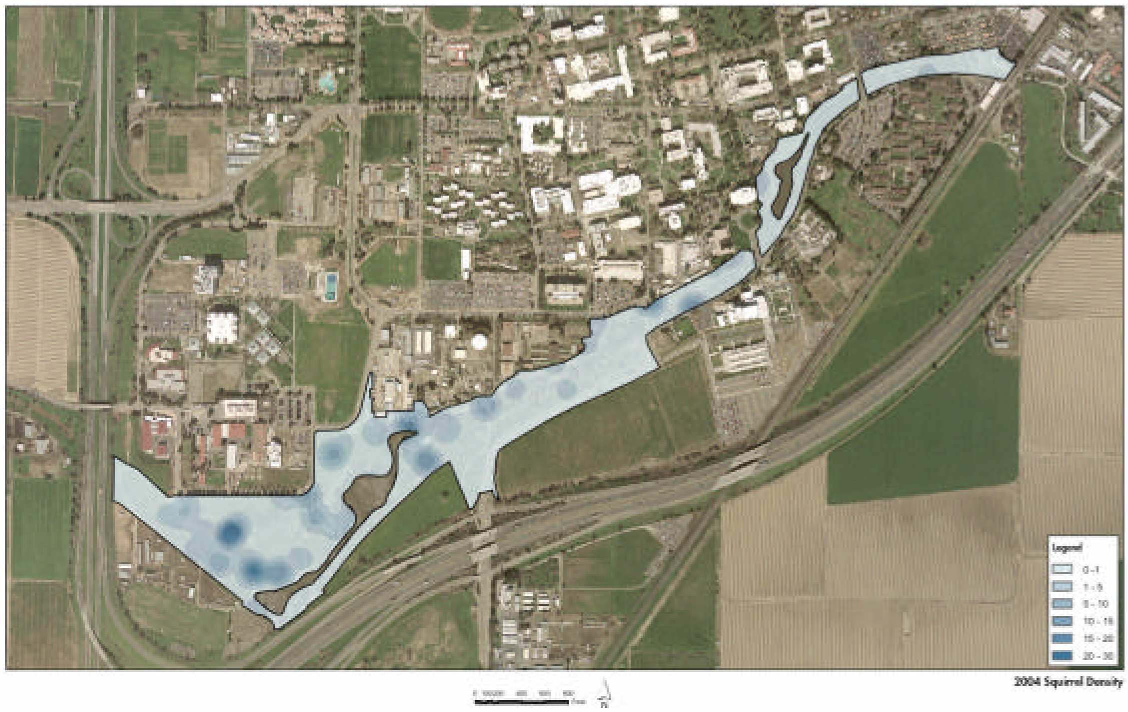


Figure 1. 2004 California ground squirrel (*Spermophilis beecheyi*) observed density, (September-October), UC Davis Arboretum. Map shows all squirrels seen in 2004, all three trials combined.

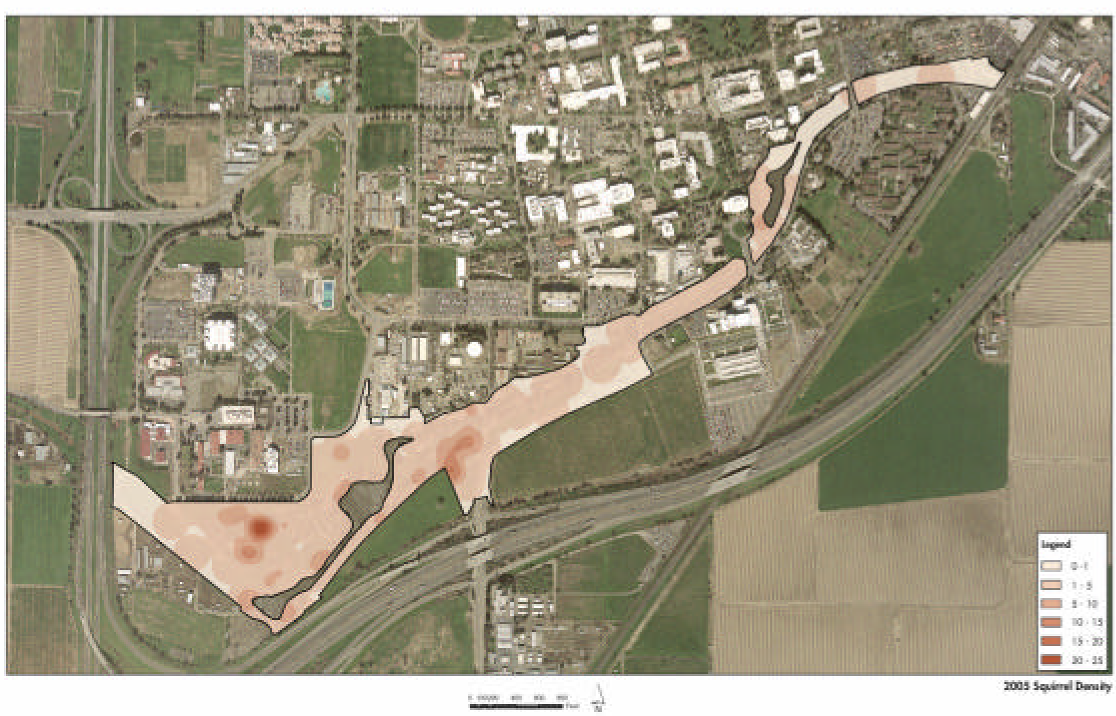


Figure 2. 2005 California ground squirrel (*Spermophilis beecheyi*) observed density, (September-October), UC Davis Arboretum. Map shows all squirrels seen in 2005, all three trials combined.

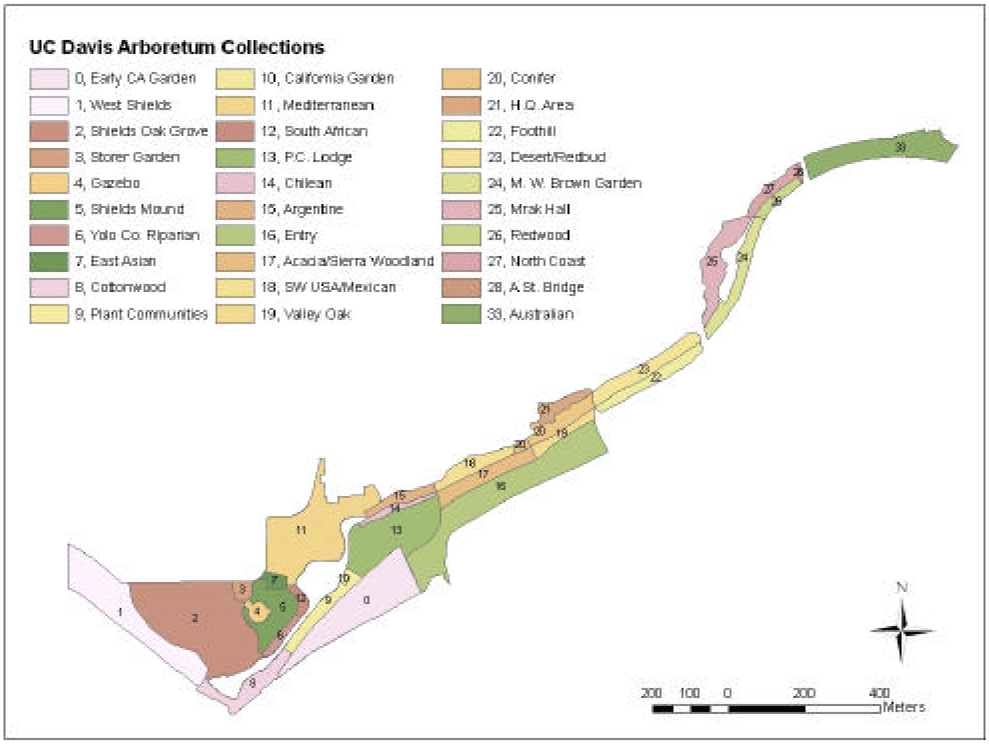


Figure 3. Arboretum Collections Map.

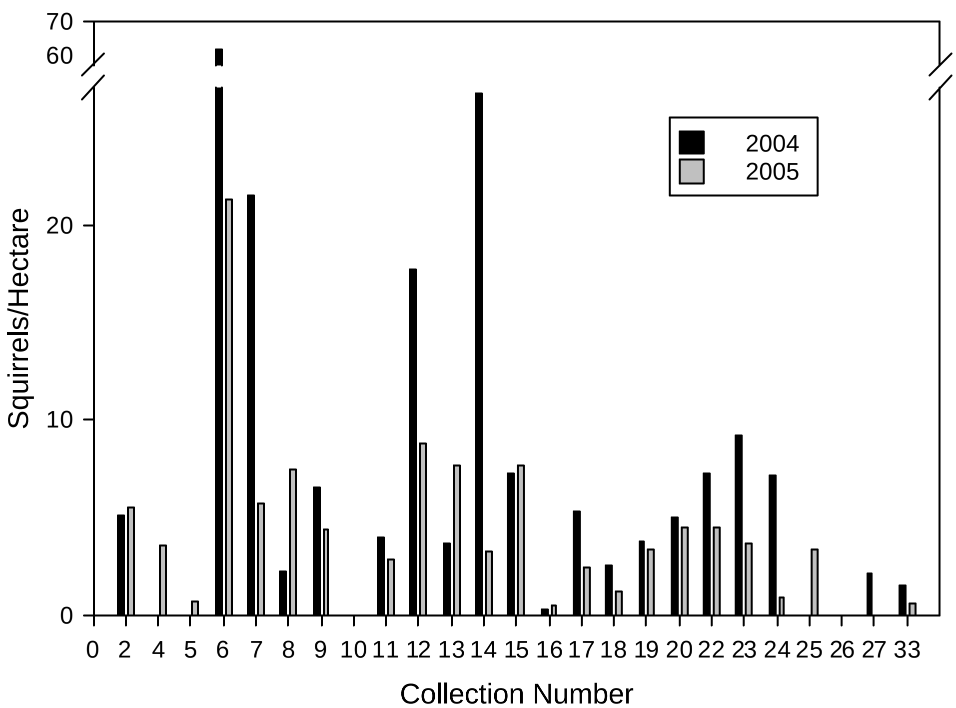


Figure 4. Annual ground squirrel relative density within specific plant collections.

TABLE 2. RESULTS OF ANOVA FOR RELATIONSHIPS BETWEEN MEAN RELATIVE DENSITY OF GROUND SQUIRRELS IN ARBORETUM COLLECTIONS PRE- AND POST-TREATMENT

Collection[a]	Year	Mean Density[b]	SE[c]	p
Entire Arboretum	2004	4.641	1.161	0.13
	2005	3.399	1.151	
Shields Oak Grove	2004	4.836	1.206	0.64
	2005	5.518	1.206	
Yolo Co. Riparian	**2004**	**61.930**	**1.138**	**0.09**
	2005	**21.200**	**1.095**	
East Asian	**2004**	**21.456**	**1.492**	**0.10**
	2005	**5.409**	**1.260**	
Cottonwood	2004	1.866	1.784	0.20
	2005	6.449	1.605	
Plant Communities	2004	6.353	1.207	0.22
	2005	4.367	1.165	
Mediterranean	**2004**	**3.987**	**1.101**	**0.08**
	2005	**2.904**	**1.101**	
South African	2004	17.133	1.534	0.32
	2005	7.660	1.534	
P.C. Lodge	2004	1.950	1.948	0.24
	2005	7.257	1.948	
Chilean	2004	20.843	2.081	0.39
	2005	3.337	2.821	
Argentine	2004	6.315	1.359	0.73
	2005	7.584	1.456	
Entry	2004	0.316	1.328	0.30
	2005	0.547	1.328	
Acacia/Sierra Woodland	**2004**	**5.307**	**1.200**	**0.04**
	2005	**2.389**	**1.200**	
Valley Oak	2004	3.597	1.284	0.79
	2005	3.203	1.358	
Conifer	2004	4.297	1.435	0.33
	2005	2.164	1.667	
Foothill	2004	6.613	1.451	0.45
	2005	3.971	1.576	
Desert/Redbud	2004	7.367	1.530	0.28
	2005	3.452	1.530	
M.W. Brown Garden	**2004**	**7.029**	**1.154**	**0.01**
	2005	**0.956**	**1.154**	
Australian	2004	1.379	1.501	0.30
	2005	0.616	1.501	

[a] Arboretum plant collection (see Fig. 3).
[b] Mean density (n=3).
[c] Standard error back transformed from naturalized data.
Statistically significant results in boldface (a = 0.10).

2.4.5 Tree Squirrels

Native western gray squirrels (*Sciurus griseus*) were not historically found in the Central Valley, but have become more common over the last decade (RE Cole, A Engilis Jr., and DA Kelt, personal communication). The species is fairly common along the length of Putah Creek, and frequents the creek near the confluence with the North Fork, which connects to the Arboretum. The western gray squirrel is rarely seen in the Arboretum, however, as it is not commonly found in developed habitats.

The nonnative fox squirrel (*Sciurus niger*), maintains a large resident population in the Arboretum and surrounding campus lands, having increased dramatically in the five years since they were first discovered on campus (RE Cole and DA Kelt, personal communication). Another nonnative species, the eastern gray squirrel (*Sciurus carolinensis*) has also been introduced into urban settings in the West, but has not been observed on campus or in the Arboretum. It is possible that areas like the Arboretum could serve as reservoirs or corridors for the movement of nonnative tree squirrels into western gray squirrel habitats like Putah Creek, and *vice versa*. Much still needs to be learned about the status, ecology, and interactions between native and nonnative tree squirrels in California.

Fox Squirrel (*Sciurus niger*) in the Arboretum. Photo: M. Truan

2.4.6 Rats

Two nonnative rat species inhabit the Arboretum, the Norway (or brown) rat (*Rattus norvegicus*) and the black (or roof) rat (*Rattus rattus*). While they exploit similar food resources, the two species differ significantly in their behavior and nesting habitats (Salmon *et al.* 2003). The black rat is smaller and lighter-bodied than the Norway rat, with a longer tail (Salmon *et al.* 2003). Black rats are more agile climbers, but Norway rats are better swimmers. (Dead Norway rats have been seen floating in the waterway on occasion, however.) Black rats nest in trees, dense vegetation, roofs and attics, while Norway rats nest in burrows and beneath debris piles on the ground. Black rats are often found in field settings, especially riparian habitats, while Norway rats are generally associated with human developments. The two species do not coexist peacefully; Norway rats tend to kill the smaller black rats when confrontations occur. Both species are very aware of their surroundings and are constantly exploring. They tend to avoid new objects in their environment, making them difficult to trap (Salmon *et al.* 2003).

Rats can damage wooden structures, gardens, and landscaping, chew electrical wires, food storage containers, walls, ceilings and insulation, and undermine the foundation of buildings with their burrows. They are also known to transmit diseases to humans, pets and livestock including: murine typhus, leptospirosis, trichinosis, salmonellosis, ratbite fever, and plague (Salmon *et al.* 2003). Rats are also common nest predators of a wide variety of wild birds (Whisson *et al.* 2004).

Rats are a common prey for many birds and mammals, including the herons and egrets nesting in the Shields Grove heronry. While they are mainly nocturnal, rats were observed in the Arboretum during the day, suggesting that their populations have reached high densities and that they have become relatively accustomed to humans. They were frequently photographed by our remote cameras (Appendix C).

2.4.7 Rabbits

Two species of native rabbits are found in the Arboretum, the larger black-tailed jackrabbit (*Lepus californicus*) and the smaller desert cottontail (*Sylvilagus audubonii*). Both species feed on grasses, though the black-tailed jackrabbit will also eat cacti, sagebrush, and the bark from woody plants when grasses are in short supply. Both species are inactive during the hottest times of the day (Ballenger 1999, Cizek 1999, Salmon and Gorenzel 2002b). Despite their similarities, the two species differ markedly in their breeding biology and habitat requirements.

Black-tailed jackrabbits have large home ranges and can cover up to five miles a day traveling between food and shelter. They feed throughout the evening and into early morning. Jackrabbits can produce up to six litters per year, consisting of two to three young (or "leverets"), between January and August. The young are precocial and nurse for just a few days before becoming relatively self-sufficient (Salmon and Gorenzel, 2002b).

A black-tailed jackrabbit (*Lepus californicus*) at a Trailmaster remote-sensor camera station in the West End Swale.

Desert Cottontails are found in areas with dense, brushy cover, or in piles of rocks and debris (Salmon and Gorenzel 2002b). They may feed in cultivated fields at night, but do not venture more than a few feet from cover. Their home range typically averages 10-15 acres in area (4-6 hectares), but tends to be more patchily distributed towards areas of good cover. Cottontails can produce litters of three to four young up to six times per year between December and June. The young are altricial and remain in the nest for several weeks.

Rabbits are well-known pests of agriculture and landscaping, particularly when landscaped areas lie adjacent to wild areas (Salmon and Gorenzel 2002b). Within the Arboretum, the two species have been observed using different habitats, as expected. Cottontails are most commonly observed in the Mediterranean section, darting in and out of the cover provided by the dense rosemary bushes. (The rosemary bushes also provide excellent cover for other small mammals, including ground squirrels.) Jackrabbits are most commonly observed in the empty fields on either side of Garrod Road, in Shields Oak Grove and the West End Swale. Remote camera stations captured photographs of jackrabbits in the swale (Appendix C).

2.5 Birds

Surveyors have recorded 124 species of birds during standardized surveys (Appendix C) conducted 1990-91, 1993-94, 1995-96, and 2004-05 (236 visits). This represents 39% of all species recorded for Yolo County. By comparison, 58% of all species recorded for Yolo County (190 species) have been recorded along Putah Creek, a nearby riparian area. Several more species have been observed in the Arboretum as incidental sightings (Appendix B). The Arboretum appears to be particularly attractive to thrushes, nuthatches, pigeons and doves, hawks, swallows, and finches.

Of the species detected, four species were new Arboretum records for 2004-05: common peafowl (*Pavo cristatus*), western bluebird (*Sialia mexicana*), cattle egret (*Bubulcus ibis*), and herring gull (*Larus argentatus*). Peafowl were represented by one resident female observed over several different occasions. Cattle egrets arrived in the area in 2002, and are currently breeding in the Shields Grove area. The appearance of bluebirds is probably due to local population increases resulting from the installation of nest boxes along a nearby waterway (Putah Creek Nestbox Highway) (Truan 2005). In fact, many of the species that have benefited from nest box placement along Putah Creek—ash-throated flycatcher (*Myiarchus cinerascens*), house wren (*Troglodytes aedon*), oak titmouse (*Baeolophus inornatus*), tree swallow (*Tachycineta bicolor*)—increased in abundance in the Arboretum over the survey period. Other


Green heron (*Butorides virescens*) fishing in the Arboretum. Photo: M. Truan.

species also increased.

Canada goose (*Branta canadensis*) abundance increased over 660% between the 1990's surveys and the 2004-05 surveys (Table 3). Canada geese can be aggressive towards humans and other species of waterfowl and their droppings create aesthetic and sanitation issues. Furthermore, as birds congregate to eat artificial foods they can more readily pass diseases if some birds are infected. These diseases can be transmitted to humans. Geese feed on the ready supply of grass and leave behind piles of "goose cigars." Loaded with bacteria, the goose feces can make water unattractive for swimming, and make lawns, parks and beaches distasteful for picnics, walking, and other outdoor recreation. Recent studies have found four potentially pathogenic E. coli and two virulence factors on goose feces and that the overall prevalence of pathogenic E. coli was 25% (Kullas *et al*. 2002, Clark *et al*. unpublished). One virulence factor is known to produce severe diarrhea, while the other is associated as a causative agent for infantile meningitis. These two studies suggest that Canada goose feces do pose a health risk to humans and cattle and that geese may transport pathogens between rural and urban sites.

Numbers of wintering wood ducks (*Aix sponsa*) also increased, perhaps due to nest box augmentation along Putah Creek. Wood ducks are often observed beneath a tree overhanging Spafford Lake.

As a whole, raptors also increased, with the exception of the state-threatened Swainson's hawk (*Buteo swainsoni*), which decreased over 40%. Swainson's hawks prefer habitats with tall trees for nesting and roosting adjacent to agricultural fields for foraging. Historically, Swainson's hawks were often observed foraging in the alfalfa fields south of the Arboretum, an area currently under development.

Some species declined in abundance. Brown-headed cowbirds (*Molothrus ater*) lay their eggs in the nests of other songbirds, usually causing host chick mortality. While no cowbirds were detected during the 2004-2005 surveys, no significant increases in the abundance of cowbird host species were observed either, nor were any host species confirmed to be nesting in the Arboretum (though systematic nesting surveys have not been conducted).

TABLE 3. SPECIES SHOWING SIGNIFICANT CHANGES IN SIGHTING PROBABILITY BETWEEN SURVEY PERIODS

	Sighting Probability		
Species	**Surveys conducted 1990-91, 1993-94, 1995-96 by England et al.**	**Surveys conducted 2004-05 by Castañeda**	**% Change**
Common Peafowl	0.00%	19.07%	New record
Western Bluebird	0.00%	17.45%	New record
Cattle Egret	0.00%	8.43%	New record
Herring Gull	0.00%	6.25%	New record
Tree Swallow	1.59%	29.72%	1768.25%
Red-winged Blackbird	1.43%	22.78%	1494.44%
House Wren	2.47%	22.87%	824.50%
Canada Goose	3.31%	25.14%	660.14%
Double-crested Cormorant	2.40%	15.93%	563.36%
Ash-throated Flycatcher	0.56%	2.78%	400.00%
White-tailed Kite	0.60%	2.78%	366.67%
Oak Titmouse	0.60%	2.59%	335.56%
Downy Woodpecker	2.45%	10.14%	314.41%
White-throated Swift	6.66%	26.94%	304.78%
Red-shouldered Hawk	8.33%	30.37%	264.70%
Western Wood-Pewee	0.49%	1.67%	240.00%
Wood Duck	6.85%	17.82%	160.39%
American Pipit	6.37%	15.97%	150.70%
Orange-crowned Warbler	20.03%	47.55%	137.40%
Spotted Towhee	4.83%	11.39%	135.59%
Red-breasted Nuthatch	8.98%	21.11%	135.09%
Nashville Warbler	0.42%	0.93%	122.22%
Lesser Goldfinch	17.16%	37.50%	118.50%
Bushtit	32.77%	68.70%	109.62%
Snowy Egret	12.72%	24.95%	96.10%
Cooper's Hawk	6.00%	10.00%	66.69%
Black Phoebe	51.51%	80.00%	55.30%
Cedar Waxwing	21.30%	32.50%	52.56%
Nuttall's Woodpecker	59.56%	90.00%	51.11%
Red-tailed Hawk	15.69%	23.61%	50.51%
American Goldfinch	42.87%	63.10%	47.21%
Great Egret	16.24%	23.61%	45.38%
Killdeer	8.67%	12.59%	45.24%
Anna's Hummingbird	54.86%	78.75%	43.55%
Black-crowned Night-Heron	19.41%	27.18%	40.00%
House Finch	50.14%	65.60%	30.83%
Lincoln's Sparrow	7.49%	9.72%	29.83%
Belted Kingfisher	32.19%	0.00%	Declined to zero
Purple Finch	15.90%	0.00%	Declined to zero
Pine Siskin	10.45%	0.00%	Declined to zero
Common Merganser	10.40%	0.00%	Declined to zero
Brown-headed Cowbird	5.89%	0.00%	Declined to zero
Varied Thrush	5.65%	0.00%	Declined to zero

TABLE 3. SPECIES SHOWING SIGNIFICANT CHANGES IN SIGHTING PROBABILITY BETWEEN SURVEY PERIODS

Species	Sighting Probability: Surveys conducted 1990-91, 1993-94, 1995-96 by England et al.	Sighting Probability: Surveys conducted 2004-05 by Castañeda	% Change
Northern Mockingbird	34.86%	24.54%	-29.62%
Mourning Dove	39.79%	27.82%	-30.08%
Rock Pigeon	76.75%	53.52%	-30.27%
Pied-billed Grebe	27.25%	18.29%	-32.90%
American Coot	16.84%	10.00%	-40.61%
Green Heron	60.59%	35.51%	-41.39%
Swainson's Hawk	22.04%	12.13%	-44.97%
California Gull	26.11%	10.65%	-59.22%
House Sparrow	53.88%	17.59%	-67.35%
Brewer's Blackbird	49.21%	10.00%	-79.68%
Northern Rough-winged Swallow	16.12%	1.39%	-91.39%

Inclusion criteria for significant percent change: 1) percent change > 20%, and 2) former or current sighting probability > 5% unless percent change > 100%.

2.5.1 Temporal Patterns of Abundance

Avian species richness was highest during the winter months (Fig. 5). This pattern is characteristic of the Central Valley as a whole, since its temperate Mediterranean climate supports high numbers of wintering species (Engilis 1995).

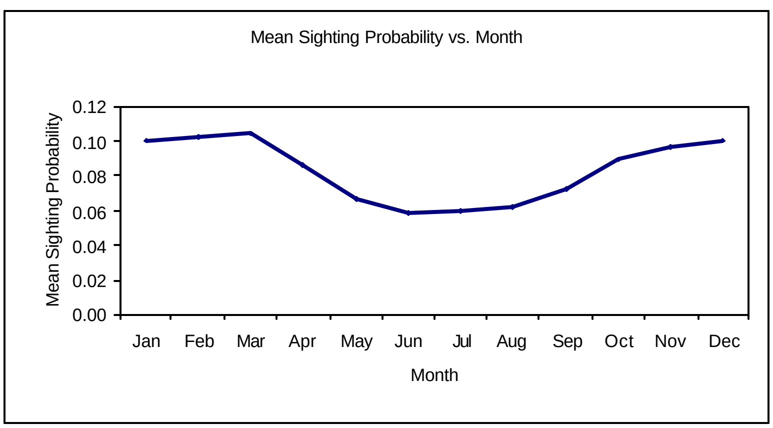


Figure 5. Cumulative sighting probabilities for all avian species by month. Data compiled from 1990-91, 1993-94, 1995-96, and 2004-05 surveys. Probability of sighting calculated as the total number of times a species was recorded, divided by the number of surveys. Probabilities were then averaged across species for each month.

2.5.2 Guild-based Analyses

A guild is a group of species with similar ecological resource requirements and foraging strategies and therefore, similar roles in the community. Classifying species into ecological guilds can provide additional insight into composition of the avian community and into the structure and function of the ecosystem.

2.5.2.1 Migratory Guild

The majority of species recorded in the Arboretum were residents (Fig 6). Habitat quality is believed to be more important to resident species, since habitats must meet all the life-history requirements of residents throughout the year. Transect 3 supported more resident species than either of the other two transects, suggesting that transect 3 had higher habitat quality. For all transects, species richness of winter visitors was higher than that of summer visitors (26% and 10%, respectively).

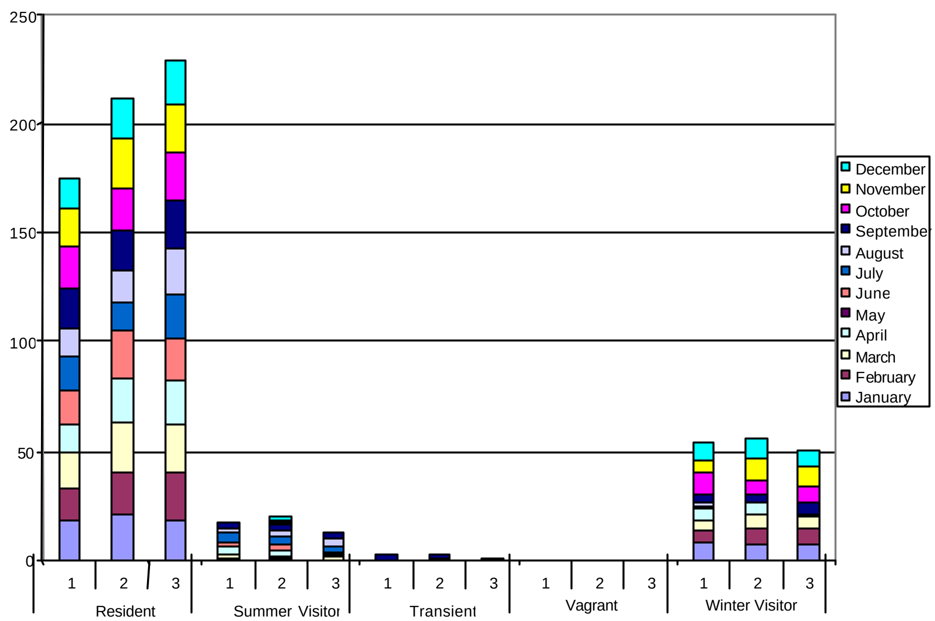


Figure 6. Species richness for different migratory guilds by transect and month. Numbers beneath histogram bars are survey transects. Transect 1 extends from eastern edge of Arboretum to Mrak Bridge. Transect 2 extends from Mrak Bridge to Putah Creek Lodge. Transect 3 extends from Putah Creek Lodge to West End Swale.

By comparison, species richness of winter visitors on nearby Putah Creek was lower (19%) than in the Arboretum and more self-similar in species richness of summer visitors (13%) (Fig 7). This suggests that the Arboretum may be an especially important area for overwintering birds, perhaps due to a more benign microclimate and the presence of non-deciduous vegetative plantings that provide food and cover during the winter. On the other hand, summer habitat may not be as suitable for summer visitors and breeders as it is on Putah Creek.

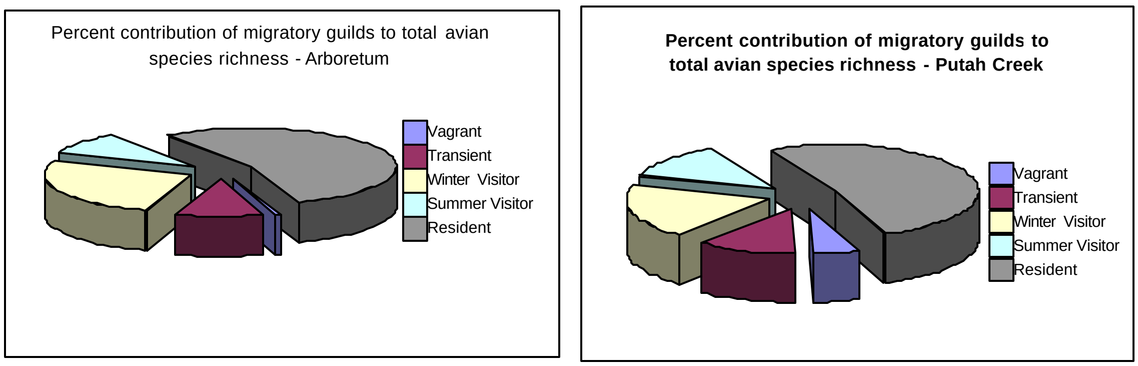


Figure 7. Percent contribution of migratory guilds to total avian species richness for the Arboretum and for Putah Creek, a nearby riparian habitat.

2.5.2.2 Nesting Guild

Birds are generally more sensitive to habitat conditions and disturbance during the breeding season. Since the migratory guild analysis indicated that summer species richness was lower in the Arboretum than for other local riparian areas, we analyzed its nesting guild composition to determine whether certain nesting guilds were lacking in representation. Conclusions as to breeding habitat suitability are preliminary, and should be verified through nest searches and other assessments of breeding activity.

Fifty-four percent of the species detected in the Arboretum belonged to the tree nesting guild, 27% were ground nesters, and 6% were shrub nesters (Fig. 8). By contrast, Putah Creek hosted twice as many shrub nesters (12%), but fewer ground nesters (19%) than did the Arboretum (Fig. 8). Based on the species list for Putah Creek and other regional areas, we expected to see many more shrub and ground nesting species in the Arboretum, including house wren (*Troglodytes aedon*), Swainson's thrush (*Catharus ustulatus*), spotted towhee (*Pipilo maculatus*), California towhee (*Pipilo crissalis*), song sparrow (*Melospiza melodia*).

These numbers may reflect the availability, suitability, and/or safety of shrub habitat in the Arboretum. Indeed, only two shrub nesters have been identified as breeding in the Arboretum [western scrub jay (*Aphelocoma californica*) and northern mockingbird (*Mimus polyglottos*)]. By comparison, 18 species of tree nesters are known to breed in the Arboretum (Appendix B). The greater abundance of ground nesting species found in the Arboretum is probably an artifact of a greater abundance of winter visitors, many of whom are ground nesters during the breeding season but do not nest in the Central Valley. Indeed, only one ground nesting species is a confirmed breeder in the Arboretum (Mallard). (Orange-crowned warbler is a probable breeder.) Overall, it appears that the Arboretum does not offer much in the way of breeding habitat for ground or shrub nesting birds. This may be due to a lack of cover, increased predation, and/or anthropogenic disturbance during the breeding season.

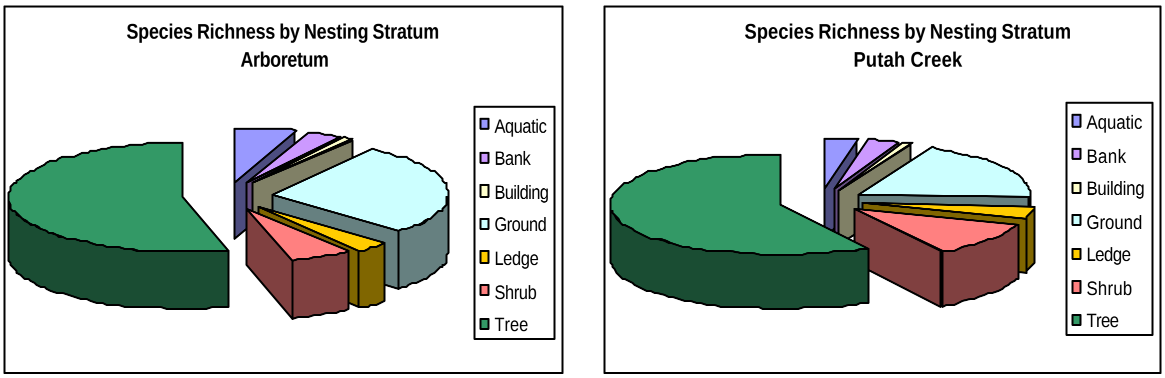


Figure 8. Comparison of percent contribution of nesting strata to total avian species richness for UC Davis Arboretum (124 species) and lower Putah Creek (134 species). Arboretum data compiled from 1990-91, 1993-94, 1995-96, 2004-2005; Putah Creek data compiled from 2003-2004. Transects and months pooled.

2.5.2.3 Dietary Guild

An analysis of species composition by dietary guilds can provide information on foraging resources and habitat quality. For example, omnivorous species are often indicative of disturbed habitats since they can survive opportunistically on a broad array of variable resources. On the other hand, insectivores and carnivores usually require a more complex food web to meet their needs. Arboretum dietary guild composition was very similar to that for lower Putah Creek, suggesting that the two habitats are similar in their dietary resources (Fig. 9). For the Arboretum, 20% of species were omnivores, 34% were insectivores, 19% were carnivores, 27% were granivore/herbivores, and less than 1% were nectarivores.. For lower Putah Creek, 17% were omnivores, 37% were insectivores, 19% were carnivores, 25% were granivore/herbivores, and 2% were nectarivores.

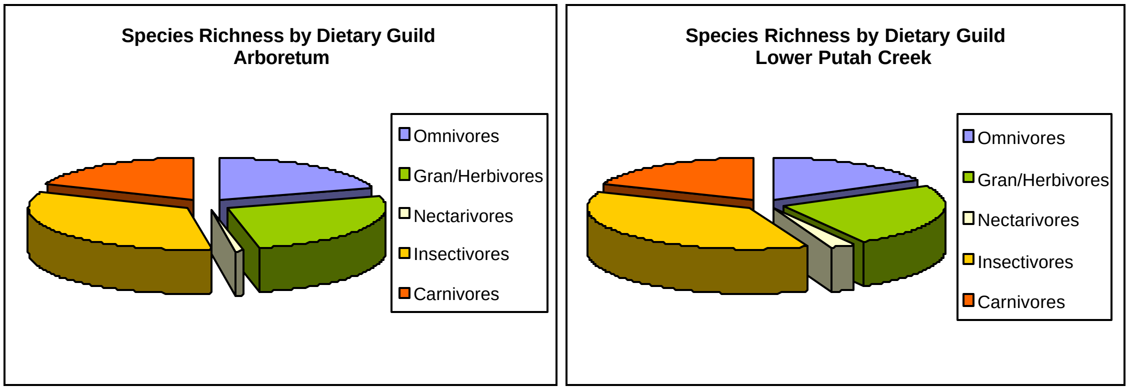


Figure 9. Percent contribution of dietary guilds to total avian species richness for UC Davis Arboretum (124 species) and lower Putah Creek (134 species). Arboretum data compiled from 1990-91, 1993-94, 1995-96, 2004-2005; Putah Creek data compiled from 2003-2004. Transects and months pooled.

2.5.3 Special Section: Shields Oak Grove Heronry

2.5.3.1 Introduction

The Shields Oak Grove, a unique collection of oak species and hybrids, is the UC Davis Arboretum's most prominent and scientifically significant taxonomic collection in terms of number of specimens and size (acreage) of display. The grove is also a resource of considerable significance to the nation. Sizeable collections of mature oaks are uncommon in botanical gardens due to space restrictions, slow growth rates, difficulties in propagation, and their propensity to hybridize. While the nation's most prominent collections of oaks are located on the East Coast and in the Pacific Northwest, many of the oaks of the arid Southwest and subtropical Central America are intolerant of these climatic conditions. The UC Davis Arboretum is thus the only institution in the United States with a large collection of mature oaks composed of species from arid climates.

Over the past decade, a heronry, a nesting congregation of colonial birds of the family Ardeidae, has become established in the Shields Oak Grove. Caretakers of the oak collection have observed that some of the trees are declining in health, possibly due to physical and chemical damage inflicted by the bird colony. Birds can damage trees by removing leaves, twigs and other foliage for nesting, and by depositing guano, which can burn leaves, reduce light absorption, and alter soil chemistry. High levels of salts and/or toxic ions affect tree health, resulting in reduced growth rates, foliar burn, dieback, and eventually death (Lichter 2003). In addition, high levels of sodium lead to reduced infiltration and percolation rates within soils.

A horticultural risk assessment (Lichter 2003) found that the pH of surface soil at various sites beneath the colony ranged from 4.8 to 5.6, compared with 6.3 to 7.7 away from the colony. In addition, electrical conductivity and levels of nitrate, ammonium, sodium, and chloride were significantly higher in soils beneath the colony. While toxicity was highest within the top inch of soil, it is expected that toxic effects will move deeper into the soil profile—and into the root zone—with continued use of the grove by the colony. Substantial leaf loss due to guano deposition has occurred in heavily used trees, directly correlated with bird density (Lichter 2003).

2.5.3.2 Methods

2.5.3.2.1 Focal Nest Monitoring

Protocols for the observation of focal nests was based on Mayfield (1961) and the Audubon Canyon Ranch North Bay Heron and Egret Project. We photographed Shield's Grove from several vantage points and identified all of the nests that were visible in each of the photographs throughout the nesting season. Each focal nest was checked approximately every three days, from a distance of thirty to sixty meters, using a spotting scope at 20x-40x magnification. We noted the nesting stage (as defined in the Audubon Canyon Ranch Protocol), number of adults, number of chicks, and any additional observations. We were not able to determine the number of eggs in each nest because the nests were monitored from the ground. Clutch initiation, incubation, hatching, and fledging dates were estimated based on behavioral cues.

2.5.3.2.2 Active Nest Monitoring

In 2005, trained student interns conducted regular counts of the number of active nests in each tree within the grove using Audubon Canyon Ranch North Bay Heron and Egret Project protocols. Each tree was labeled with a unique number for identification. All occupied nests were considered active, and the number of nests in each tree was counted individually. A comparable estimate of pressure on trees caused by nesting activity, the average peak active (APA) index, was calculated by averaging active nest counts across a peak active period, 25 April to 8 July 2005. We also determined peak active periods for each species, based on their individual nesting phenology (Table 4).

2.5.3.2.3 Evening Activity Surveys

Evening activity surveys were conducted to estimate the total number of birds using the grove and the directions from which they arrived to their nightly roosts. Directional information provides an estimate of where birds are foraging during the day and how foraging patterns change throughout the breeding season. Observers were stationed at permanent locations facing east, south, southwest, west, northwest and northeast. These directions were chosen to avoid visual obstructions and effect coverage of the entire 360-degree survey area. Recording was partitioned

into nine consecutive ten-minute intervals, so that temporal differences in activity level each evening could be determined. Birds were counted before landing; attempts were made not to double-count birds that flew away from the colony and back again.

Additional information on the methods used to study the Shields Grove heronry are presented in Appendix C.

2.5.3.3 Results

2.5.3.3.1 Species Composition

Four species nested in the Shields Oak Grove in 2005: black-crowned night-heron (*Nycticorax nycticorax*), great egret (*Ardea alba*), snowy egret (*Egretta thula*), and cattle egret (*Bubulcus ibis*). The majority of nesting birds were black-crowned night herons, with many fewer individuals of the other three species (Table 4, Fig. 10). Black-crowned night herons were the first species to arrive at the heronry, and nested earlier than the other species.

TABLE 4. RESULTS FROM THE 2005 BREEDING SEASON FOR THE FOUR SPECIES NESTING IN THE UC DAVIS ARBORETUM SHIELDS OAK GROVE.

Species	Nesting season	Date of peak nesting activity [a]	APA nests [b]	Reproductive Success [c]	Nest Stage w/ Lowest Survivorship
Great egret	15 March to 12 September	13 May	11	1.37	Nestling
Cattle egret	2 April to 12 September	27 May	49	2.23	Egg
Snowy egret	2 April to 12 September	20 June	63	2.93	Nestling
Black-crowned night-heron	9 March to 20 August	20 May	326	1.34	Egg

[a] The date when the majority of nests were counted for that species.
[b] Number of nests counted over peak nesting period, 25 April – 8 July.
[c] Number of chicks fledged per nesting attempt.

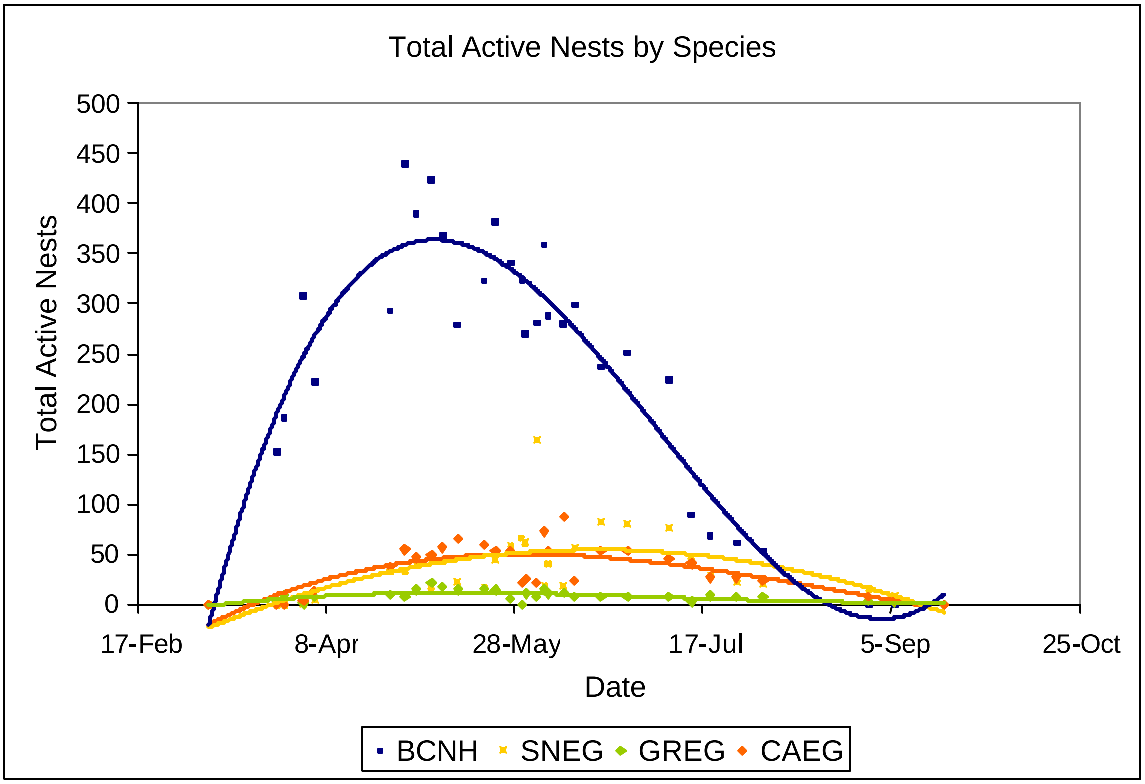


Figure 10. Total number of active nests of each species counted at each visit throughout the 2005 nesting season. Black-crowned night-heron (BCNH), snowy egret (SNEG), great egret (GREG), and cattle egret (CAEG).

2.5.3.3.2 Tree Use

The birds occupied 105 different trees, 101 of which were contained within the Shields Grove proper (Table 5). Four-hundred and forty-nine nests were active during the time of peak nesting activity. Nesting was not evenly distributed throughout the grove, however. Trees #13 and #34 were the most heavily used, with 28.3 and 25.5 APA nests respectively. Fourteen percent of the trees contained more than 10 APA nests each, 16% contained 5-10 APA nests, 30% contained 1-5 APA nests, and 45% contained less than one APA nest (this usually meant that a nest attempt was made but later failed).

We grouped trees based on differences in bird activity throughout the grove (Fig. 11). Tree groups A and B were the most heavily used (Fig. 12) and were the only trees in which great egrets, snowy egrets, and cattle egrets nested. Nesting activity in tree groups A and B peaked in early May. Trees in groups C, D, E, and F appeared to serve as overflow nesting areas for black-crowned night-herons. Nesting activity for these groups peaked in late May to early June. Of these overflow groups, nests were densest in group C, peaking at approximately 50 nests. Group

G, which also included trees outside the Grove, hosted the seasons' earliest nests. Group G included two Mexican ash trees (*Fraxinus berlandierana*) in which the seasons' first eggs were laid and which served as a staging ground for black-crowned night-herons prior to their movement into the rest of the grove. A handful of trees throughout the Arboretum contained one black-crowned night-heron nest each. Although we did not include these trees in our official results, we monitored their activity levels throughout the season.

TABLE 5. AVERAGE PEAK ACTIVE (APA) NESTS PER TREE DURING THE 2005 NESTING SEASON.

Tree	Tree Species	APA nests
13	*Quercus agrifolia*	28.3
34	*Quercus ilex*	25.5
70	*Quercus agrifolia*	17.8
44	*Quercus ilex*	17.2
53	*Quercus ilex*	16.8
41	*Quercus ilex* var. *ballota*	15.7
58	*Quercus virginiana*	15.2
15	*Quercus agrifolia*	14.9
33	*Quercus ilex*	13.4
47	*Quercus ilex*	13
23	*Quercus agrifolia*	12.8
52	*Quercus ilex*	12
48	*Quercus wislizeni*	11.2
71	*Quercus suber*	10.7
59	*Quercus coccifera* spp. *calliprinos*	9.7
66	*Quercus agrifolia* var. *oxyadenia*	9.6
35	*Quercus faginea*	8.7
12	*Quercus agrifolia*	8.6
67	*Quercus coccifera* spp. *calliprinos*	8.5
40	*Quercus ilex* var. *ballota*	8.3
46	*Quercus ilex*	7.5
68	*Quercus sinuata*	7.3
72	*Quercus agrifolia* var. *oxyadenia*	7.1
A1	*Fraxinus berlandieriana*	7
22	*Quercus agrifolia*	6.9
43	*Quercus ilex* var. *ballota*	5.8
76	*Quercus suber*	5.8
73	*Quercus agrifolia* var. *oxyadenia*	5.4
63	*Quercus coccifera* spp. *calliprinos*	5.3
14	*Quercus agrifolia*	5.2
42	*Quercus wislizeni*	4.8
A2	*Fraxinus berlandieriana*	4.6
24	*Quercus ithaburensis*	4.5
224	*Quercus engelmannii*	4.5
313	*Unknown - not on map*	3.7

TABLE 5. AVERAGE PEAK ACTIVE (APA) NESTS PER TREE DURING THE 2005 NESTING SEASON.

Tree	Tree Species	APA nests
69	*Quercus sinuata*	3.3
135	*Quercus x hispanica*	2.9
219	*Quercus vaseyana*	2.9
222	*Quercus vaseyana*	2.8
140	*Q.cornelius-mulleri* x *Q. engelmannii*	2.7
197	*Quercus turbinella X Q. lobata*	2.7
221	*Quercus vaseyana*	2.7
57	*Quercus phillyreoides*	2.6
60	*Quercus virginiana*	2.4
194	*Quercus turbinella X Q. virginiana*	2.4
220	*Quercus vaseyana*	2.3
137	*Q.cornelius-mulleri* x *Q. engelmannii*	2.2
195	*Quercus turbinella X Q. virginiana*	2.1
206	*Quercus pungens*	2.1
218	*Quercus engelmannii*	2.1
62	*Quercus agrifolia*	1.9
215	*Quercus douglasii*	1.7
229	*Quercus engelmannii*	1.7
29	*Quercus ithaburensis*	1.6
139	*Quercus engelmannii*	1.5
55	*Quercus phillyreoides*	1.4
51	*Quercus brandegei*	1.3
227	*Quercus vaseyana*	1.3
75	*Quercus agrifolia* var. *oxyadenia*	1.1
77	*Quercus agrifolia*	1.1
129	*Quercus infectoria* spp. *Veneris*	0.9
247	*Quercus trojana*	0.9
202	*Q. macrocarpa X Q. macrocarpa X Q. turbinella*	0.8
M1	*Magnolia* spp.	0.8
207	*Quercus pungens*	0.7
56	*Quercus phillyreoides*	0.6
78	*Quercus robur f. fastigiata*	0.6
80	*Quercus suber*	0.6
134	*Quercus garryana*	0.6
232	*Quercus grisea*	0.6
38	*Quercus faginea*	0.5
61	*Quercus robur f. fastigiata*	0.5
161	*Quercus robur X Q. turbinella*	0.5
240	*Quercus obtusa*	0.5
317	*Quercus dumosa*	0.5
223	*Quercus engelmannii*	0.4
28	*Quercus ithaburensis*	0.3
30	*Quercus coccifera*	0.3
32	*Quercus tomentella*	0.3
65	*Quercus suber*	0.3

TABLE 5. AVERAGE PEAK ACTIVE (APA) NESTS PER TREE DURING THE 2005 NESTING SEASON.

Tree	Tree Species	APA nests
74	*Quercus agrifolia* var. *oxyadenia*	0.3
79	*Quercus suber*	0.3
198	*Quercus turbinella X Q. lobata*	0.3
17	*Quercus robur f. fastigiata*	0.2
152	*Quercus gambelii X Q mongolica*	0.2
158	*Quercus gambellii X Quercus macrocarpa*	0.2
162	*Quercus robur X Q. turbinella*	0.2
193	*Quercus turbinella X Q. virginiana*	0.2
201	*Q. robur* x *Q. macrocarpa*	0.2
231	*Quercus engelmannii*	0.2
19	*Quercus robur f. fastigiata*	0.1
54	*Quercus phillyreoides*	0.1
115	*Q. turbinella x Q. macrocarpa*	0.1
145	*Quercus robur X Q. turbinella*	0.1
192	*Quercus robur X Q. turbinella*	0.1
196	*Quercus gambelii X (Q. gambelii X Q. havardii)*	0.1
205	*Quercus douglasii*	0.1
225	*Quercus robur X Q. turbinella*	0.1
248	*Quercus trojana*	0.1
252	*Quercus mexicana*	0.1
292	*Quercus macrocarpa*	0.1
31	*Quercus coccifera*	0.03
82	*Quercus cerris*	0.03
164	*Quercus lobata X Q. cornelius-mulleri*	0.03
233	*Quercus grisea*	0.03

Figure 11. Map of Shields Gove with tree groupings highlighted. Color chosen for each group corresponds with Figure 10.

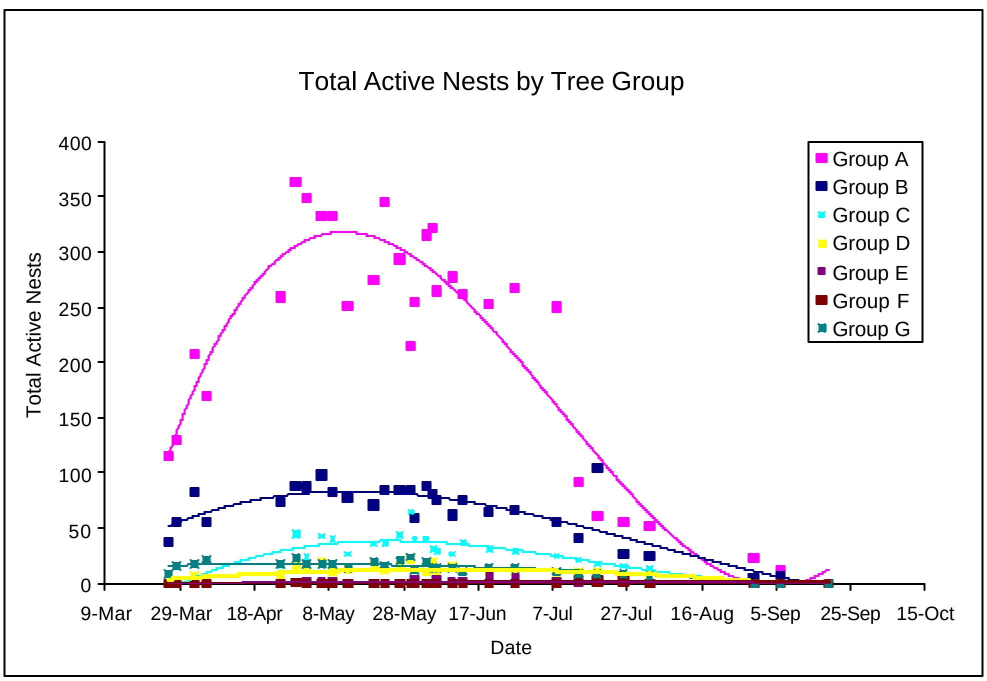


Figure 12. Total number of active nests for each of the tree groups counted at each visit throughout the 2005 breeding season

2.5.3.3.3 Roosting Behavior

In addition to the nesting colony, Shields Grove supports an active non-breeding roost during the months of March through October. While attempts to ascertain its size were conducted through evening flight surveys, the exact size could not be determined because birds flying to roosts could not be separated from those returning to active nests. Nonetheless, the evening counts did point to a sizeable non-breeding component to the rookery at Shields Grove. Most of the roosting birds appeared to be juveniles, particularly during the post-breeding months (Sept-Oct). Roosting activity appeared to be concentrated in tree groups A and B, with some black-crowned night-herons roosting in tree group C. While the roosting activities of black-crowned night-herons, snowy egrets and great egrets closely tracked their nesting activities, more cattle egrets occurred in the rookery than could be accounted for by of the number of breeding pairs. Thus many cattle egrets were probably roosting and not nesting. This was particularly obvious from July through October, when up to 650 cattle egrets, mostly juveniles, were recorded entering the Grove before sunset in both 2004 and 2005.

2.5.3.3.4 Local Significance

The Shields Grove heronry is one of only two large multi-species Ardeid colonies known to exist in Yolo County. The other Yolo County heronry occupies a large *Eucalyptus* grove on private land off County Road 103, north of Road 28. This heronry contains the same four species found in the Shields Grove colony and appears to be of equal size or larger. No quantitative assessments of species composition, number of active nests, or reproductive success have been conducted for this heronry in recent years.

Regionally, other large nesting colonies exist at Folsom Lake State Park, the Cosumnes River Preserve, Stone Lakes National Wildlife Refuge, and the Sacramento Bufferlands. These colonies contain different assemblages of species, including great-blue herons (*Ardea herodias*) and double-crested cormorants (*Phalacrocorax auritus*) in some cases (A. Engilis, Jr. personal communication, C. Swolgaard personal communication).

2.5.3.4 Discussion

Based on the high density of birds present in the colony, the amount of guano deposition, changes in soil chemistry, and the history of other large colonies throughout the world, it is likely that the Shields Grove oaks will decline in health and eventually die if the heronry is allowed to persist at current levels. While the rate of decline will depend upon factors such as local nest density, distribution, and tree health mitigation measures, significant negative effects are expected within a few years.

Negative impacts to vegetation by large aggregations of colonial birds are documented in Weseloh and Brown 1971, Wiese 1978, Gilmore *et al.* 1984, Dusi and Dusi 1987, Belzer and

Lombardi 1989, Baxter and Fairweather 1994, Mun 1997, Ligeza and Smal 2003, Telfair and Bister 2004, and Hobara *et al*. 2005. Damage mechanisms include: physical damage to trees arising from bird activity, changes in soil chemistry, and leaf loss due to accumulation of guano. Tree death has been known to occur within one to five years.

Measurable changes in soil chemistry as a result of guano deposition beneath large colonies have been correlated with significant vegetation declines over short time periods (often one nesting or roosting season) (Weseloh and Brown 1971, Wiese 1978, Gilmore *et al.* 1984, Baxter and Fairweather 1994, Mun 1997, Ligeza and Smal 2003, Hobara *et al.* 2005). In these studies, soil nitrogen, phosphorus, and potassium were significantly higher beneath colonies (Wiese 1978, Mun 1997, Ligeza and Smal 2003). Mun (1997) found elevated calcium levels and Ligeza and Smal (2003) found higher concentrations of ammonium in nesting areas. pH was high in some studies (Wiese 1978) and low in others (Mun 1997). While changes in soil chemistry beneath large colonies was often dramatic, direct cause and effect relationships between heavy bird use and tree death has not been established in controlled experiments.

There is little available information regarding the impact of mixed-species Ardeid colonies on mature oaks. Post oak (*Quercus* stellata) and blackjack oak (*Quercus marilandica*) are known to be intolerant of guano deposits and have been found to die within 1-2 years of colony establishment (Telfair and Thompson 1986 cited in Grant and Watson 1995). In one high-density colony, 85% of the mature host post oaks (*Quercus stellata*) died within three years of colony establishment (Telfair 2004). The colony then persisted at lower densities for 18 years in invasive chinaberry—more tolerant of eutrophic soils—until it too succumbed. Cork oaks at the Coto Doñana Preserve in southern Spain have also suffered serious mortalities as a result of a very large, longstanding colony of mixed Ardeids (JJ Chans, personal communication).

On the other hand, Audubon Canyon Ranch Heron and Egret Project researchers report that a large oak in Suisun Marsh, California, has supported over sixty nests over the past decade with no apparent ill effects (JP Kelly and M McCaustland, personal communication). Therefore, although there are several documented cases of tree damage and death caused by large aggregations of nesting herons and egrets, this outcome is not guaranteed. Cases in which trees have persisted are less likely to be studied and reported, and none of the aforementioned studies have attempted to alleviate the damage inflicted on the trees by the colony.

Large heronries pose a moderate to high risk of zoonotic disease transmission to humans who come into contact with them. The most common zoonotic diseases associated with rookeries and roosts are Salmonellosis, Histoplasmosis, and West Nile Virus. *Salmonella* spp., the bacteria that causes salmonellosis, is harbored by live birds, bird carcasses and guano. To avoid transmission, visitors should practice good hygiene, avoid eating near the colony, and wear gloves when handling any bird-related materials in the grove. Histoplasmosis is a respiratory disease caused by inhalation of airborne fungal spores. Although these spores are commonly found in large heronries in humid areas, no cases of histoplasmosis have been reported in California. As a precaution, workers in the grove should wear masks at all times when disturbing guano and soil beneath the colony.

This year, MWFB staff collaborated with experts from the Sacramento-Yolo Mosquito and Vector Control District to test for West Nile Virus in the Shields Grove heronry. Of the seventeen birds caught in July and August, five tested positive for West Nile Virus antibodies. This testing was conducted late in the season, so few individuals were caught. Further testing is planned for the peak of the 2006 nesting season. West Nile Virus is a mosquito-borne disease, so visitors to the grove should wear long-sleeved shirts, long pants, and insect repellent containing DEET at all times.

3. Wildlife Damage Management

Some of the species discussed in Section 2 have been known to cause serious damage to Arboretum structures and collections and may also transmit diseases to humans, pets, and other wildlife. This chapter presents management options to ameliorate the detrimental effects of nuisance wildlife. In many cases, a combination of options may be the best course of action for effective management. For each option, we present predicted outcomes (indicated with ➷).

3.1 Rats and Mice

Option 1: No action

Leave the commensal rodent population unmanaged. This is the current method for rat and mouse control in the Arboretum.

➷ Rats and mice would continue to infest the Arboretum, which would serve both as a sink and a source for colonists. Rodent-borne disease would remain a real possibility. Many predator and scavenger species would continue to benefit from the abundance of rodent food. The few native rodents present would continue to experience competition for resources. Rats would continue to exert pressure on the domestic duck population through predation on nests and ducklings. Nesting songbirds would continue to experience rat predation on eggs and chicks.

Option 2: Natural predators

Encourage natural predators, using methods described in Section 3.2 below.

➷ The outcome of this option would be similar to that described in Section 3.2.

Option 3: Baiting

Option 3a: Anticoagulant baits

This is the **method recommended by University of California Department of Integrated Pest Management (IPM)** staff for squirrel damage management (RE Marsh personal communication). Install anticoagulant baits (described under Option 3b of Section 3.2) in underground or hidden bait boxes. Bait is checked regularly and replaced when necessary. Baiting should be done on a constant basis to keep the rat population low. Field trials by Whisson *et al.* (2004) found a low likelihood of primary (consumption of bait) or secondary (consumption of poisoned carcasses) non-target hazards. In this study, bait stations were placed far enough apart to minimize effects on smaller native species, such as voles and harvest mice. In that study, opossums were observed eating carcasses, but probably did not consume enough carcasses to accumulate a lethal dose of anticoagulants (Whisson *et al.,* 2004).

- A large baiting campaign would result in a significant decrease in the Arboretum rodent population. Although rodents generally die in their burrows, rodent carcasses would likely be found throughout the Arboretum by staff and visitors. Reduction in rodent populations would lower the prey base for predators, possibly causing a dietary shift in predator take to birds and small reptiles. Songbird reproductive success might increase, but this benefit could be offset by an increase in predation pressure due to the loss of rodents. The duck population might also increase due to rat declines.

Option 3b: Rodetrol

Use Rodetrol, a new, non-poisonous bait, to control rodent populations. Use of this product and its likely outcome are described under Option 4b of Section 3.2.

Option 3c: Trapping

Conduct a trapping and removal campaign every year to reduce commensal rodent populations.

Option $3c_1$: Snap trapping

Use snap traps to kill rodents outright.

- Would kill many non-target species, including birds. The effort would be very labor-intensive. Snap traps are unsightly and can be hazardous to pets and small children. Empty and sprung traps would likely be seen by visitors.

Option $3c_2$: Live trapping

Use live traps to reduce commensal rodent populations and mortality of non-target species.

- It is virtually impossible to eliminate rodents using this method. There might be an increase in native small mammals as competitive pressure is reduced. This method would result in a detailed knowledge of the Arboretum small mammal community, but is even more labor-intensive than snap-trapping, since it requires frequent checking of the traps in order to avoid harming non-target species. There is a strong likelihood for negative publicity and confrontations with visitors since trappers would be handling live animals in public view.

3.2 Ground Squirrels

Option 1: No action

Leave squirrel population unmanaged.

- Breeding and migration from the greater regional population would cause ground squirrel populations to grow beyond the carrying-capacity of the ecosystem. Large ground squirrel burrow complexes would present hazards for visitors and undermine Arboretum structures and collections. However, burrow complexes would also create habitat for ground-dwelling wildlife. Ground squirrels would consume large quantities of plant, seed, and fruit material. The likelihood for an outbreak of plague would increase (Marsh 1987). The Arboretum population would serve as a source population of ground squirrels to the surrounding campus and community.

Option 2: Biological control

Modify Arboretum habitats to discourage squirrel use and encourage natural predators.

Option 2a: Habitat modification

Modify habitat by destroying inactive burrows to discourage ground squirrel use and uptake. Burrows would need to be ripped to a depth of at least 20 inches; simply filling them in would not be adequate (Salmon and Gorenzel 2002a, RE Marsh personal communication). Habitat modification could also include removal of large areas of rosemary and other similar types of ground-cover that support high densities of nuisance species. The rosemary shrubs provide good protection from aerial predators due to a dense impenetrable canopy, and likely exclude many larger mesocarnivores due to their many closely-spaced stems. We observed high densities of ground squirrels in this type of cover, especially when bushes were adjacent to open fields and lawns for foraging. Rosemary bushes could be replaced with other plants less supportive of dense squirrel and rabbit populations. Examining the possible relationships between ground squirrel population size and vegetation structure would create an opportunity for research and adaptive management.*

10-year plan
Need 1, 3, 5, 7
Goal 1, 3, 4

- Ground squirrel populations might be reduced through loss of habitat and increased predation. However, IPM staffers do not feel that this method alone would be effective for managing the ground squirrel problem in the Arboretum. Nevertheless, it might augment other methods and represents a holistic, non-lethal technique for wildlife damage management.

<u>Option 2b: Natural predators</u>

Encourage aerial predators of ground squirrels by installing raptor perches. Red-shouldered hawks have been observed capturing ground squirrels near Putah Creek Lodge and Swainson's hawks have been observed capturing pocket gophers in Shield's Grove. Some of the inactive gopher and ground squirrel burrows could be left open to encourage use by gopher snakes and other desirable species.

- In addition to controlling ground squirrel and other rodent populations, increased abundance of raptors would enhance the visitor experience.* Habitat for gopher snakes and other desirable species would be enhanced. IPM staff believes that this method would not dramatically decrease the squirrel population (RE Marsh personal communication), but could help to maintain stability once squirrel numbers were reduced. Volunteer monitoring and use of interpretive signage could be employed.*

10-year plan
Need 1, 3, 6
Goal 1

10-year plan
Need 2, 4, 5, 7 & 8
Goal 1, 2, 4, 5

<u>Option 3: Chemical control</u>

Use chemicals to decrease the ground squirrel population to 5-10% of current levels.

<u>Option 3a: Burrow fumigants</u>

Use burrow fumigants (aluminum phosphide) to decrease the population size to a more manageable level. This is the **IPM recommended method** (RE Marsh personal communication). The best time of year to apply this treatment is early spring after the squirrels have emerged from hibernation (February or March - see description of the squirrel annual life cycle in Section 2.4.4. At this time the soil is moist, which is necessary to activate the fumigant, and females have not yet produced young. Thus, the process is more efficient and fewer squirrels need to be killed (Marsh 1994). Young squirrels also tend to be more resistant to the fumigant (RE Marsh personal communication). Burrow use by non-target species, such as reptiles, amphibians, foxes, and burrowing owls, is lowest at this time of year.

Inactive burrows must be destroyed, unless they are being occupied by non-target species, prior to the fumigation process to avoid over-use of the poison. After the first round of fumigation, inactive burrows should be ripped to a depth of at least 20 inches and newly active burrows treated again. This process is repeated yearly until the desired population size is reached. It will likely take six or more years to reach the desired population goal of 10% of 2004 levels (RE Marsh personal communication). Afterwards, maintenance fumigation is repeated every year to keep the population under control. It is at this time that some or all of the measures in Option 2 could be implemented to assist in control of populations and enhance habitat for other desirable species. Monitoring of wildlife populations throughout this process is necessary for adaptive management and to assess impacts on non-target species.

- With diligent use, it may be possible to reduce the ground squirrel population to 5-10% of current levels. Damage to Arboretum specimens and danger to the public would be greatly reduced. There would be minimal direct negative effects (poisoning) on non-target species. Loss of the prey base could have a negative effect on raptors and mesocarnivores, but the enhancement strategies described in Option 2 could offset this effect. There is a strong likelihood of public opposition and negative publicity, as has been encountered in the past.

- The 2005 Phostoxin treatment decreased the squirrel population, though not significantly, from 2004 levels. Much greater population decreases will need to be achieved under future treatments if the desired population size is to be reached. Future treatments will be more efficacious if conducted earlier in the year, after squirrels emerge from hibernation in February and March, and if all active burrows are destroyed during treatment. Some plant collections experienced greater declines than others. Burrows are often well-hidden and/or difficult to access. Special care should be taken to find these burrows. If any burrows remain, those areas may become refugia for the surviving squirrel population. In addition, certain areas may have been missed in the 2005 treatment. For example, many squirrels were observed in the Shields Grove during the fumigation process since birds were already present, preventing treatment in that area. The grove should be thoroughly treated in February before the heron colony becomes established and access becomes limited.

Option 3b: Anticoagulant baits

This is the IPM recommended method where burrow fumigants cannot be used, such as burrow systems under occupied buildings (Salmon and Gorenzel 2002a; RE Marsh personal communication). Bait stations are placed underground, or hidden under platforms that house garbage cans or other equipment, to minimize exposure to the public and pets (RE Marsh personal communication). Carcasses are removed frequently to ensure public safety and to minimize poisoning of non-target species. Anticoagulant baiting is done in late summer and fall, after squirrels have switched to dry foods and are more likely to take bait (Salmon and Gorenzel 2002a, Marsh 1987, Marsh 1994). This technique is labor-intensive, since bait stations must be built, buried and maintained, and carcasses must be found and removed. This treatment should be repeated every year to maintain low squirrel populations.

- The squirrel population around buildings would decrease. Squirrel carcasses would need to be removed. Poisoning of non-target species could occur. There is a strong likelihood of public opposition, since carcasses and baiting activity would be visible to the public. However, this option could also be presented as a method to control rats and mice, for which there is far less public opposition.

Option 4: Novel control methods

Research and implement new and experimental methods for small mammal management*.

10-year plan
Need 5
Goals 3&4

Option 4a: Immunocontraception

Implement an immunocontraception program to test its efficacy as a wildlife damage management tool for non-lethal rodent population control. The National Wildlife Research Center has developed a contraceptive vaccine, GonaCon™ (Miller *et al.* 2004), which shows promise as a wildlife damage management tool. This vaccine was tested on a population of California Ground Squirrels in a public park in Berkeley, California, where it proved effective in lowering ground squirrel populations over the short term (Nash *et al.* 2004). Working with campus researchers, the Arboretum could initiate a study to examine the effectiveness of this vaccine in a large, open, highly-variable environment.

- This would be a long-term, labor-intensive process, since ground squirrels would need to be captured and immunized on a regular basis. The immunocontraceptive appears to last only a few years, after which squirrels must be treated again. Immigration from source populations outside the treatment area would reduce the desired effect. A non-lethal, non-poison-based program might be more acceptable to Arboretum visitors, and would promote the Arboretum as a progressive institution that seeks out new solutions to old problems.

<u>Option 4b: Rodetrol</u>

Implement a baiting program using Rodetrol, a non-poisonous, biodegradable, plant-derived product that provides no nutritive value and causes starvation (Grech *et al.* 2004). Rodetrol could be used in place of anticoagulant baits for ground squirrel management.

- Rodent mortality is complete—in very controlled circumstances where only Rodetrol is available for consumption (Grech *et al.* 2004)—but there is no evidence for efficacy in the field where animals have a large variety of more-desirable foodstuffs to choose from.

<u>Option 4c: Translocation</u>

Implement a live-trapping program with the aim of moving colonies to other areas off-campus where squirrel burrowing activities are desired, such as habitat mitigation for burrowing owls.

- Translocation of ground squirrel colonies may be a useful non-lethal management alternative in small areas if the squirrels are translocated more than 1500 meters away from the source population (Van Vuren *et al.* 1997). The Arboretum is a good candidate for a translocation study because non-lethal control methods are desired, and a campus-owned translocation mitigation site has already been identified. However, reproductive compensation and immigration of new squirrels from source populations outside the Arboretum would likely result in replacement of translocated colonies within a short time.

3.3 Rabbits

Option 1: No action.

Leave rabbit population unmanaged and employ no efforts to lessen rabbit herbivory.

- Rabbits would consume large amounts of young plantings, especially those close to open fields and cover sites. Arboretum staff would spend much time and energy re-planting and tending plants vulnerable to rabbit damage.

Option 2: Exclosures

Install wire exclosures to protect vulnerable young and/or woody plantings. This method is already employed in the Arboretum and is the **IPM recommended method** for protecting landscaping from rabbits (Salmon and Gorenzel 2002b). Chicken-wire fencing with a mesh no smaller than one inch in diameter would be placed around plantings that need extra protection. This mesh fence is buried in the ground 2-3 inches, with the bottom folded outward two to three inches underground, to deter rabbits from burrowing under the fence. Fences must be supported so that they stand away from the plant and do not allow the rabbits to access plants through the mesh (Salmon and Gorenzel 2002b).

- Building exclosures would be somewhat labor-intensive. Protection of valuable plant stock would be ensured.

Option 3: Odorous repellents

Apply odorous repellents, such as blood meal or putrescent whole egg solids, to sensitive plantings to deter rabbits from browsing on vulnerable plants (Salmon and Gorenzel 2002b).

- Might reduce rabbit browsing on target plants over the short-term, but IPM staff believe that this method is not feasible in the Arboretum where rabbits are habituated to many strange smells. There may be complaints from visitors about unpleasant smells, since the repellents work by emitting an odor that is unappetizing to rabbits. However, the repellent need not be applied any higher than two feet above the ground, so it may not be noticeable to most visitors. If the smell is found to be objectionable, a combination of exclusionary methods near paths and repellents could be installed. Repellents may also attract other unwanted pests such as rats.

Option 4: Habitat modification

Replace rabbit-friendly areas of cover, such as the large rosemary bushes in the Mediterranean Section, with other less-desirable plants. See Option 2a in Section 3.2 for further discussion of this technique.

- The cottontail and rodent populations in the Mediterranean Section may decrease due to lack of cover and browse material. However, rabbits could disperse and take up residence elsewhere.

Option 5: Natural predators

Encourage natural rabbit predators. See Option 2b in Section 3.2 for further discussion of this technique.

- Rabbit populations are very resilient to predation pressures, so the likely effect of this strategy would be an increase in the abundance of raptors utilizing the Arboretum, but little effect on the rabbit population.

Option 6: Trapping

Trap rabbits using either live or lethal traps. Traps are placed in boxes to protect children and pets. Traps are placed near cover; vegetables are used as bait. Traps need to be checked daily (Salmon and Gorenzel 2002b).

- This scenario presents several problems, not the least of which would be immense public opposition. Live traps are large and visible, though underground or contained traps would conceal trapping activity and alleviate some of the visibility problem. Rabbits would have to be euthanized, since it is not feasible to translocate them. IPM staffers do not recommend live trapping rabbits (Salmon and Gorenzel 2002b) since both lethal and non-lethal trapping are time- and labor-intensive and lethal trapping is unlikely to affect the jackrabbit population because of immigration from nearby areas. There is a strong likelihood of public opposition.

3.4 Cats

Option 1: No action.

Leave the cat population unmanaged.

- Cats would continue to inhabit the Arboretum and hunt within its confines. Cats likely exert some population control on rabbits, but also catch and kill desirable wildlife, such as amphibians, reptiles, and birds. Domestic cats from nearby residential neighborhoods may hunt and kill Arboretum wildlife. Scientific studies show that each year, cats kill hundreds of millions of migratory songbirds (Churcher and Lawton 1989, Harrison 1992, Stallcup undated, American Backyard Bird Society).

Option 2: Public Awareness Campaign

Institute a public relations campaign urging adjacent residents to spay and neuter their cats, and to keep them indoors. Residents should be informed that this benefits both wildlife and cats, since the danger to domestic cats from feral cats, coyotes and larger aerial predators in the Arboretum is very real.

- Depending upon public participation, the numbers of domestic house cats hunting in the Arboretum could decrease. Indoor cats are generally healthier and live longer.

Option 3: Live Trapping

Contract with feline welfare organizations to live-trap cats. Organizations such as the UC Davis student-based Feral Feline Organization (FFO) will trap, neuter, and release feral cats as well as adopt-out socialized feral kittens.

Feral Feline Association (FFO)
P.O. Box 4704, Davis CA 95617-4704
http://www.feralfeline.org
info@feralfeline.org
(530) 574-0817

- Source populations of feral cats should decline over time, easing pressure on Arboretum wildlife and plantings and reducing emigration and disease transmission.

3.5 Ducks and Geese

Option 1: No action

Leave the duck and Canada goose population unmanaged.

- While duck populations currently appear to be at manageable levels, it is unclear what effects the control of other species and/or habitat enhancement measures will have on future population levels. Canada goose numbers in the Arboretum are on the rise, and if not controlled, could quickly reach unacceptable levels.

Overpopulation of geese will cause fecal contamination of Arboretum grounds and waterways; aggressive encounters with humans and other species, disease transmission among birds, and erosion and grazing damage where waterfowl congregate. Other managed ecosystems, such as golf courses, are experiencing significant problems in controlling Canada goose populations. Once geese become established, it is difficult to remove them. Goose families that already have established a firm territory will defend it and are much more difficult to haze from a site.

<u>Option 2: Public relations and No Feeding Ordinances</u>

Step up public relations campaign to discourage visitors from feeding ducks and geese. Supplemental feeding encourages larger numbers of birds to remain in areas that might not otherwise support them in winter and early spring when fresh grasses are not available. An Urban Waterfowl Task Force in Wisconsin judged no-feeding ordinances a good first step in controlling goose populations (Sperling 1998). If denied sufficient food, ducks and geese will disperse. Some signage is already in place, but should be relocated to areas directly in front of major feeding areas, such as the terrace adjacent to Spafford Lake.

- The current level of public relations and signage appears to have lowered the incidence of duck feeding in the Arboretum (but see photo below). Stepping up education and enforcement should continue to lower food subsidies for ducks and geese and encourage their dispersal away from the Arboretum.

Arboretum visitors feeding ducks and geese on terrace adjacent to Spafford Lake. Photo: M. Truan

Option 3: Hazing

Institute a program of hazing to deter ducks and geese from occupying specific areas of the Arboretum, such as the area around Spafford Lake. Sonic devices and specially-trained dogs are commonly used for this purpose. In some communities, golf course managers contract with dog services to patrol the grounds and scare away flocking geese. This sort of goose hazing is especially effective if it is started in the early spring before the birds nest. Mylar helium balloons painted with eye spots that look like predators are also used.

- Hazing has garnered mixed success in other managed ecosystems. Hazing efforts must be coordinated with the arrival times of the target species and must be maintained diligently. Scare techniques are mainly effective early in the spring when adult geese are seeking secure, secluded places to nest. Noisemakers like sirens and natural gas exploders can haze geese, but the loud sounds are equally unpleasant to people. Moreover, goose flocks become accustomed to loud noises that are not accompanied by a real threat. Special permits usually need to be obtained to perform hazing.

Option 4: Interference with reproduction

Option 4a: Dummy eggs

Removing or breaking eggs merely causes birds to nest again, so they have to be fooled into remaining on a nest that will not produce hatchlings. Dummy eggs made of plaster or wood can be substituted for the natural eggs. Freshly laid eggs can be addled by shaking them vigorously, pricking the end with a sharp instrument or by coating the egg with an oily spray. Addled eggs need to be returned to the nest to allow the birds to continue incubating for at least three weeks. Thereafter, further clutches are unlikely.

- Urban Waterfowl Task Force members noted that egg addling is likely to be more acceptable to the human public than killing ducks and geese, but the practice might still be controversial (Sperling 1998). Anyone proposing to addle or replace eggs must first procure a federal permit to do so. This option would be viable only for ducks, since Canada geese do not currently nest in the Arboretum.

Option 4b: Sterilization

Some communities in other states have experimented in capturing and surgically sterilizing adult drakes and ganders. Oral contraceptives to inhibit duck and goose reproduction are not available at this time.

- Capturing and neutering males is expensive (more than $100 per bird) and time-consuming. The Urban Waterfowl Task Force concluded that "surgical sterilization is not a viable technique for widespread use in urban waterfowl control“ (Sperling 1998).

3.6 Shields Grove Heronry

Night-herons, egrets, their nests and eggs are protected under the Migratory Bird Treaty Act of 1918 (MBTA) (16 U.S.C. 703-712; Ch. 128; July 13, 1918; 40 Stat. 755), as well as under California Fish and Game Codes 3503, 3503.5, and 3513 which protect birds' nests and prevent the taking of MTBA birds. In addition, the California Environmental Quality Act (CEQA) guards against the elimination of fish or wildlife species due to man's activities, including negative effects to wildlife *habitat* (California Public Resources Code, Division 13, § 21001). Compliance with regulations pursuant to these acts must be carefully considered before any action is taken.

We have not made any specific recommendations with respect to heronry damage management options because we feel that additional consultation between Arboretum and University staff, and with consulting arborists, will be necessary to formulate an effective strategy. We do feel, however, that a coordinated approach employing a carefully-selected suite of options would be the best approach. Some management options that appear especially viable would be old nest removal and hazing early in the season to discourage birds from colonizing the grove and soil amendments to ameliorate soil acidification and salinization.

3.6.1 Options that would not negatively affect the colony or its habitat

(Compliance with MBTA, CEQA, and/or California State Fish and Game Codes not required)

Option 1: No action

- Birds will likely continue to nest in very high densities and may expand their colony to include underutilized areas. Mechanical and chemical damage to trees, roots, and soil will continue. There have been several documented cases in which high densities of nesting or roosting birds have killed their substrate trees (Weseloh and Brown 1971, Wiese 1978, Gilmore et al 1984, Belzer and Lombardi 1989, Baxter and Fairweather 1994, Mun 1997, Ligeza and Smal 2003, Telfair and Bister 2004, Hobara et al 2005, etc.). However, there is little information available regarding the impacts of large breeding colonies on mature oaks. We are aware of two cases where large mixed species Ardeid colonies killed the oaks in which they nested, and one local example where the trees appear to be healthy (see Section 2.5.3.4).

Option 2: Options to improve the overall health of the trees.

Option 2a: Use mulch to buffer the soil from guano deposition

Apply a thick layer of organic (alkaline?) mulch to the grove floor in late February, before the nesting season begins, to prevent guano-borne substances from contacting the soil surface. Remove mulch at the end of the nesting season to prevent leaching of guano-derived compounds during the rainy season. Monitor soil chemistry to test the efficacy of the treatment.

- This is an experimental technique with unknown efficacy. The mulch might serve as a sufficient buffer to insulate soil from guano-derived compounds that would otherwise alter the chemistry of the soil. Mulching would have the additional benefit of promoting healthy soil conditions and conserving moisture during the dry season. MWFB staffers have also observed lower ground squirrel activity in heavily mulched areas. However, laying and removing mulch could lead to soil compaction. For this reason, consulting Arborists do not feel this is a viable option (J Lichter, personal communication).

Option 2b: Soil Amendments

As soils acidify, certain elements, like aluminum, reach levels toxic to plants, while many critical plant nutrients become less available, including potassium, magnesium and calcium (Rich 2005). Adding specially-selected treatments to the upper layers of soil might ameliorate these changes. For example, Lee Klinger, a scientist from UC Berkeley, observes that disease in California and other Mediterranean oaks is more prevalent in trees compromised by a combination of altered soil chemistry and acidification (largely due to fire suppression in natural communities). He combats soil acidification and promotes overall tree health by “sweetening” the surface of the soil with Azomite, a mined natural crushed rock containing potash, calcium and more than 50 trace minerals (Rich 2005).

- Dr. Klinger employs this controversial technique to combat Sudden Oak Death in coastal regions of California. Its efficacy for bird remediation has not been tested, however. If compounds are suitable for the Shields Grove oaks, this technique would have a secondary benefit by improving overall soil growing conditions.

Option 2c: Pruning

Careful pruning conserves the health and structural integrity of trees. It would be necessary to prune the trees between the months of October and February to avoid disturbing the heron colony.

- Selective pruning will help to keep the trees healthy overall and may help protect them against avian nesting and roosting pressure.

3.6.2 Options with potential to negatively affect the colony, depending upon timing

(may trigger compliance with MBTA, CEQA, and/or California State Fish and Game Codes)

Option 3: Wash leaves of accumulated guano

Wash leaves periodically with an overhead sprinkling system or high-powered hose. Treatment during the non-breeding season would fully protect birds. If it is determined that treatment needs to be performed during the breeding season, an overhead watering system that simulates rain and does not produce strong streams of water would best protect nesting birds. Avoid washing leaves early in the season when eggs and nestlings are present. Avoid hitting active nests directly with streams of water.

- This technique may be effective in removing accumulated guano from leaves, thereby enhancing photosynthesis and gas exchange. However, guanotrophy (leaf death) typically occurs almost immediately following uric acid deposition. Moreover, washing the guano into the soil may increase soil toxicity. This technique may have a hazing effect on birds if it is determined that the trees must be treated frequently throughout the season in order to be effective. This technique could also damage nests or cause adults to abandon active nests, especially if high-powered hoses were used. Frequent watering may cause damage to drought-resistant oaks.

3.6.3 Options with potential to reduce the size and/or density of the colony

(may trigger compliance with MBTA, CEQA, and/or California State Fish and Game Codes**)**

Option 4: Alter the availability of nesting material

Option 4a: Remove old nest structures from the trees, and sticks from the grove floor before the start of the nesting season.

- Since returning herons and egrets prefer to refurbish old nests over building new ones (Davis 1993, Telfair 1994, Parsons and Master 2000), this action may slow the development of the colony and/or persuade individuals to find other suitable nesting locations. However, there is also a chance that this action would lead to increased physical damage to trees if birds break off new branches to build new nests. This technique should be tested in a small area first, such as the two Mexican ash trees near the Gazebo, where black-crowned night herons first established nests in the 2005 season.

Option 4b: Provide birds with sticks for nest building.

- This technique was attempted by Baxter (1996) in New South Wales. Baxter found that the egrets readily took sticks from the supplemental supply he provided if the sticks were placed on a platform within eyesight of the colony. Unfortunately, this study did not include an evaluation of the effect on the health of the trees. This technique could be combined with Option 4a above.

Option 5: Selectively prune trees to make them less attractive to nesting birds.

Assess the locations of current nest structures then prune trees to remove branches that are particularly attractive to nesting birds.

- The outcome of this option is unknown, as are the potential effects on the health and aesthetics of the trees. It may be impossible to prune the trees to be sufficiently unattractive to nesting birds, yet still maintain tree health. Colony size and/or density may decrease as birds that cannot nest in their preferred trees abandon the colony or disperse to other areas of the Arboretum. It would be prudent to test this option on a small number of trees first, perhaps trees supporting the highest nest densities.

Option 6: Limited use of exclusionary netting.

Protect selected trees with bird netting of an appropriate size. Install nets before the first prospecting birds arrive at the colony.

- This method would likely reduce bird densities in targeted areas. Would require substantial investments in money and time; installation and maintenance could damage trees. Nesting densities in non-netted trees may increase, or birds might expand into areas not currently used.

Option 7: Limited hazing at the start of the nesting season

Hazing is designed to annoy or scare birds so that they do not remain in an area. Methods for hazing are discussed in more detail later in this section. Conduct limited hazing early in the season, before any nests are established, to avoid egg loss due to abandonment.

- Hazing works well to deter some species, but not others. The potential for effectiveness with herons and egrets is moderate to high. Hazing can have both a direct effect on the birds undergoing the treatment, and an indirect effect by reducing populations of birds that serve to attract additional colonists later in the season. For best results, hazing must be timed to coincide with the period of nest-site prospecting and must be of sufficient duration and frequency to deter birds without causing habituation.

3.6.4 Options with potential to eliminate the colony

(Would likely trigger compliance with NBTA, CEQA, and/or California State Fish and Game Codes)

Option 8: Cover the entire grove with exclusionary netting.

Install netting over the entire grove before the expected arrival of prospecting birds (early March).

- This action would probably serve to prevent the colony from breeding in the grove, but would be extremely cost- and labor-intensive and might damage trees. Birds might relocate their nesting efforts elsewhere. Action would affect the aesthetics of the grove.

Option 9: Surround grove with an exclosure

An aviary-like structure could be built around the grove, or around particularly sensitive trees, to prohibit herons and egrets from gaining access.

- This action would exclude herons and egrets from the grove, as well as other species too large to fit through the exclosure fencing. This option would be visually intrusive, costly and labor intensive. Depending on its construction, herons and egrets might try to nest on the exclosure itself.

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Option 10: Comprehensive hazing to discourage the entire colony.

The colony would be hazed regularly for as long as it takes to discourage all nesting birds. Hazing methods are discussed in more detail later on in this section. This option differs from Option 7 in that hazing would continue until all birds abandoned the grove, regardless of the presence of active nests.

- Many prospecting birds would be discouraged before nests were established, but some birds might still nest. This method could result in harm to eggs or young chicks if adults abandoned active nests. The colony may continue to move throughout the grove, and management personnel would need to monitor them closely and adjust hazing methods as needed. This method might promote public opposition.

Option 11: Passive translocation of the colony.

A more suitable nesting site could be identified and attempts made to encourage the colony to relocate there. Relocation strategies include hazing and distress calls or perhaps exclusionary netting in the old location combined with decoys and attraction calls in the new location. Some efforts have gone so far as to relocate certain trees from the colony site that the birds find attractive.

- Efforts to remove heron and egret colonies have met with mixed success (Dusi 1985, Crouch et al 2002). Adjacent habitat can be identified or created elsewhere, but there is no guarantee that the birds will use it. The only way to ensure that birds do not return is to remove all the host trees. One attempt at the Port of Long Beach involved moving an entire grove of trees. A portion of the colony relocated to the new site that year, returned the following year, but dispersed the year after that. Although attempts can be made to direct birds to a suitable site, the colony may choose new areas equally undesirable to humans. If attempts are made to relocate birds, overall health, reproduction, and survivorship would need to be monitored. In addition, radio telemetry could be used to track dispersal and other movements.

3.6.5 Hazing Methods

- Pyrotechnic Devices. These devices create explosions and loud noises that scare birds. Birds quickly become habituated to them. This method is distracting to visitors and may interfere with nearby animal facilities.

- Automatic Exploder: Can be programmed to emit loud noises over regular intervals. This device should be moved often as birds habituate to the noise. This method may also interfere with nearby animal facilities.

- Alarm or distress calls: This method involves broadcasting the alarm calls of the target species to frighten them from an area. This has been shown to work with Black-crowned night herons and may be useful at the start of the season when prospecting birds first arrive. Birds habituate to the calls, so they should be played at long and irregular intervals.

- Lights: Several different types of strobe and revolving lights can be used at night to frighten birds. This may be particularly useful with the Black-crowned night herons at the beginning of the season. To avoid habituation, lights should not be used continuously.
- Water-spray Devices: Spraying the area often may deter nesting, but it may also cause injury to eggs and chicks.
- Lasers: In order for lasers to be effective, they must be systematically shined in the eyes of individual birds. Lasers should be used at night. Habituation to lasers has not been observed. Lasers are not known to cause damage to the eyes of birds.

4. Habitat Enhancement

The UC Davis Arboretum contains important plant collections and is an aesthetic resource of great value to the Davis community. It also provides valuable habitat for wildlife, including wintering birds and the western pond turtle, a state species of special concern. Potential for wildlife habitat enhancement is high, as is potential for environmental education programs to expand environmental awareness and outreach in the community.

A high level of anthropogenic disturbance, coupled with a degraded waterway and a lack of complex understory habitat are probably the greatest obstacles to biodiversity in the Arboretum. The Arboretum also hosts large numbers of nonnative or invasive species which thrive in the altered conditions and compete with native wildlife.

The compromised nature of the Arboretum's wildlife habitat is understandable, given the high levels of anthropogenic disturbance, the urban and agricultural nature of the landscape, the ubiquity and competitive nature of human commensal species, and the operational constraints of a world-class botanical garden associated with a major University. Nevertheless, we feel that enhancement of wildlife habitat in the Arboretum is possible and that an integrated, holistic perspective to ecosystem management will improve the structure and function of the Arboretum ecosystem and its resulting value to wildlife and the community.

Clearly, the Arboretum is a botanical garden and not a wildlife preserve. Therefore, management choices must always be made in the best interest of the Arboretum collections and in accordance with its mission statement: *To be a living museum connecting people with the beauty and value of plants*. However, wherever possible, the collections and resources of the Arboretum should be managed to encourage native wildlife in order to create a healthy, functioning ecosystem. In this section of the AWMEP, we present guidelines for habitat management and enhancement that may aid in the establishment of a healthy Arboretum ecosystem.

4.1 The Arboretum Waterway

4.1.1 Water quality

- Increase dissolved oxygen and decrease chemical and algal content through aeration, planting of oxygenating aquatic plants, reducing the campus sump function of the waterway, and decreasing the domestic duck population. This will lead to a more tolerable environment for native fishes and reduce the likelihood of large fish kills.*

10-Year Plan
Need 1, 3, 6
Goal 1, 2, 4

An extreme example of shaded riverine aquatic (SRA) cover. Wood ducks are frequently observed sheltering under this overhanging branch. Photo: M. Truan.

- Buffer temperature fluctuations by increasing shaded riverine aquatic (SRA) habitat overhanging the banks of the waterway. SRA cover also creates habitat for birds and other organisms, provides allochthonous (coming from outside) food material for aquatic organisms, and provides a pleasant atmosphere for visitors.*

10-Year Plan
Needs 1 & 3
Goals 1

4.1.2 Waterway design

- Modify the structure and design of the waterway to create a structurally-diverse channel, additional instream habitat, natural bank contours, backwater ponds, and areas of running water. Interpretive signage could showcase the results of these actions.*

  10-year plan
  Need 1, 2, 3, 5, 6
  Goal 1, 2, 3, 4

- Re-contour the waterway channel to enhance hydrological function (*e.g.* runs, riffles, and pools). Create backwater areas and side channels to create additional habitat and areas for planting diverse vegetation. Remove riprap and wire fencing from banks and stabilize with vegetation to create a more natural, aesthetically-pleasing environment.

- Create small backwater ponds to serve as refuges and rearing habitat for young fish, amphibians, and reptiles. The vegetated overflow channel at the west end of the waterway is currently the only place in the Arboretum where young western pond turtles are found (HB Shaffer personal communication). This area is also the most common place, other than in the Shields Grove heronry, to see juvenile black-crowned night herons in the spring.

4.1.3 Aquatic vegetation and basking material

- Plant emergent and submergent aquatic vegetation to serve as habitat for juvenile fishes, amphibians and reptiles, and to aid in oxygenating the waterway. *

  10-year plan
  Need 1 & 3
  Goal 1 & 2

- Install basking sites, such as floating logs chained to the substrate, for western pond turtles. There is currently a shortage of basking sites in the Arboretum waterway, leading to competition between turtles (Spinks *et al.* 2003). The larger non-native red-eared slider is more likely to win out in competition for basking sites because turtle competition is based on size (Spinks *et al.* 2003).*

  10-Year Plan
  Needs 1, 3, 5, 6, 7
  Goals 1, 2, 4

4.2 Terrestrial Habitats

4.2.1 Vegetation Structure and Composition

- Create complex vertical vegetative stratigraphy, representative of all height classes (grasses, shrubs, taller shrubs, and trees) to encourage biodiversity. Wherever possible, the vegetative structure should include a representative fraction of plants in each of the height classes that would naturally be found in the targeted collection. This may lead to an increase in the numbers of birds and other wildlife that are currently underrepresented in the Arboretum as compared to other local riparian habitats such as Putah Creek.* A continuous, rich structural profile throughout the Arboretum would also enhance its function as a wildlife corridor.

  10-Year Plan
  Needs 1, 3, 5, 6
  Goals 1- 4

- Plant native cultivars to encourage native wildlife. This is particularly important for butterflies and other native pollinators, since they have evolved with specific species of native plants, each depending upon the other (Shepherd *et al.* 2003). See Appendix F for a list of larval and nectar host plants that encourage native butterflies. Educational programs revolving around butterflies and other invertebrates are particularly well-suited for K-12 education (Appendix D). *

  10-Year Plan
  Needs 1- 8
  Goals 1- 5

- Retain and install snags, logs, and broken limbs to provide nesting and roosting habitat for insects, amphibians, birds and bats. Snags should be retained if they do not pose a hazard to the public. Downed woody debris provides excellent habitat for native bees, as well as amphibians and reptiles (Shepherd *et al.* 2003, HB Shaffer personal communication). The California slender salamander (*Batrachoseps attenuatus*) might be re-established in the places like the Redwood Grove and the Shields Oak Grove if downed woody debris were made available for them*

  10-Year plan
  Need 1, 3-6
  Goal 1-4

4.2.2 Water Management

- Mimic natural drought conditions to favor native species and discourage nonnative species. Irrigation subsidizes nonnative species, enabling them to survive during the hot summer months. This survival often gives them the edge they need to outcompete native species. Irrigation causes native western pond turtle eggs to swell and burst and is an especially important factor in creating conditions favorable to the invasion of the Argentine Ant, which then displaces native ants (Appendix G).*

10-Year Plan
Needs 3, 6
Goals 1-4

- Create nesting sites for native western pond turtles. Since western pond turtles evolved in a dry, Mediterranean environment, they lay hard-shelled eggs that resist desiccation. Unfortunately, when these eggs are laid in irrigated areas, they take on too much water and explode. (The non-native red-eared slider evolved in the humid southeastern United States and lays soft-shelled eggs that can tolerate swelling and shrinking) Nesting habitat for western pond turtles could be created near the waterway by planting drought resistant species that do not require irrigation (HB Shaffer personal communication).*

10-Year Plan
Needs 1, 3, 6
Goals 1-4

4.2.3 Water Gardens

- Create water gardens and small waterfalls or fountains to feed the waterway with oxygenated water, provide access to water for songbirds and other wildlife, and provide a pleasant atmosphere for visitors. Running water is extremely attractive to all wildlife, particularly birds. Installation of water gardens strategically placed throughout the length of the Arboretum, would likely spur a measurable increase in wildlife density and diversity.

Water gardens created for the purpose of attracting birds should follow a few simple guidelines (Gellner 1974):

- Water should be regularly replenished, fresh, and never frozen.
- A gradually deepening or shallow pool is necessary to provide access for all sizes of birds to drink and bathe.
- Birds are more vulnerable to predation when they are wet. Therefore, protection, such as shrubbery, should be easily accessible. However, this protection should not be so close that it provides hiding places for predators.
- Resources for creating water gardens can be found at:
    - http://www.birds-n-garden.com/water_gardening.html
    - http://www.garden-birds.co.uk/information/watergarden.htm
    - http://www.urbanext.uiuc.edu/watergarden/about.html
    - http://www.mckeegarden.org/education.html

4.3 Nesting Resources

Because the Arboretum is a highly managed ecosystem, providing nesting resources that may be otherwise lacking may be beneficial to many species.

Provide nest boxes or other structures for native bees, cavity nesting birds, and bats. Nesting structures must be monitored closely throughout the nesting season to protect nesting species. Monitoring also provides opportunities for research and environmental education*.

10-Year Plan
Needs 2-8
Goals 1-5

- Native bees nest in woody debris and snags (as well as in the soil). Downed woody debris and snags, such as currently exists in the Redwood Grove, should be retained wherever possible. Bees will also nest in nest blocks, hollow stem bundles, and nesting stakes. These structures can be built and monitored by volunteers of all ages (Appendix D; Shepherd *et al.* 2003).

- Many species of cavity nesting birds, from Ash-throated Flycatchers to Wood Ducks, will nest in man-made nest boxes. These structures are a viable conservation tool. For example, the Putah Creek Nestbox Trail has produced over 1700 birds since its inception in 2000, helping to restore western bluebird populations in the region. Nest boxes of various sizes could be installed throughout the Arboretum. Boxes for owls would be especially valuable. Nest boxes must be closely monitored to protect nesting species and ensure that nonnative species, such as European Starlings and House Sparrows, do not produce young. MWFB staffers are available to consult on the creation, installation and monitoring of bird nest boxes throughout the Arboretum (see Appendix E).

- Bats will also roost in man-made boxes. A Mexican free-tailed bat (*Tadarida brasiliensis*) colony currently exists under the California Street Bridge. Bat boxes could encourage many other valuable species, including: big brown bat (*Episticus fuscus*), *Myotis* spp., red bat (*Lasiurus borealis*), pallid bat (*Antrozous pallidus*), and hoary bat (*Lasiurus cinereus*) (see Appendix 1). Rachael Long, UC Cooperative Extension Farm Advisor, is available for consultation on the construction, monitoring and maintenance of bat boxes (See Appendix E).

4.4 Encouraging Native Wildlife

Habitat enhancement and control of nonnative species could encourage native species to use the Arboretum. Several species of fish, amphibians and reptiles that could exist in the Arboretum, but have not been found there, were named in the Current Resources Section (see Appendix A for species list). Some of these natives could be re-established given proper habitat and control of nonnative competitors. Most of the habitats in the Arboretum are so highly invaded that a control program to remove non-natives will be necessary to support native wildlife.*

10-Year Plan
Needs 3, 6
Goals 1-4

- While fishes will benefit greatly by the improvements suggested in the Waterway Enhancement Section, improvements to the waterway will also benefit non-natives, who may respond more quickly given their larger population sizes. Enhancing instream habitat with cattails and other aquatic vegetation may also benefit nonnative bullfrogs, voracious predators who consume a wide variety of prey, including larvae and juveniles of many native species. To encourage the growth and re-establishment of native populations, bullfrogs and nonnative fish, all of which are highly invasive, should be removed from the waterway. Since, historically, nonnative fish have been continually re-introduced into the waterway, a public education and removal program would need to be instituted. It is probably impossible to extirpate highly adaptable species like the common carp (*Cyprinus carpio*), but native fishes could compete if carp populations were controlled. The common carp is also of concern since their rooting disturbs aquatic vegetation that would be planted to improve the health and appearance of the waterway. Once water quality were improved and nonnative species under control, Arboretum Staff could consult with Dr. Peter Moyle on re-establishing native species (see Appendix E).*

  10-Year Plan
  Needs 2-8
  Goals 1-5

- Two native amphibian species, the California Slender Salamander and the Pacific Tree Frog might be re-established in the Arboretum, given the proper habitat (HB Shaffer personal communication). California slender salamanders (*Batrachoseps attenuatus*) need downed woody debris (discussed in the Vegetative Structure Enhancement Section) to provide protection from dry Central Valley summers. Suitable habitat for the Pacific tree frog could be created in the West End Swale. Dr. Brad Shaffer is available for consultation on improving habitat for amphibians and reptiles (see Appendix E).*

  10-Year Plan
  Needs 2-7
  Goals 1-4

- The greatest obstacles to the continued survival of western pond turtles in the Arboretum are a lack of nesting and hatchling habitat, and competition with non-native turtles. For nesting habitats, western pond turtles require areas that are not irrigated in the summer (see Water Management above). Aquatic vegetation and backwater ponds are necessary for hatchlings and juveniles to gain protection and grow to adults. Competition with non-natives can be alleviated through creation of basking sites (see Waterway Enhancement above), and by the removal of non-native turtles. These turtles could be adopted out as pets to a local turtle and tortoise club. Western pond turtles can be "headstarted" to augment current populations until nesting habitat is available. Headstarting involves raising the turtles in the lab until they are large enough to survive in the waterway (Spinks *et al.* 2003). This could be implemented as a volunteer and student intern based program. *

10-Year Plan
Needs 2-8
Goals 1-4

4.5 Reducing negative impacts of domestic animals

- Domestic dogs allowed to run off leash chase, harass and kill wildlife. They also create sanitation issues and serve as a general nuisance for Arboretum visitors. Over the course of this study, we have observed owners encouraging their dogs to harass wildlife. Leashed dogs can be a welcome part of the Arboretum experience. Leash laws are already in effect on campus and in the City of Davis. Signage describing the danger posed by dogs to Arboretum wildlife and re-stating the leash requirement should be installed. Fines for letting dogs run off-leash should be enforced. Signage should contain a phone number that Arboretum visitors can call for assistance and enforcement if they encounter nuisance dogs.*

10-Year Plan
Needs 2, 3, 5
Goals 1, 2

- Modifying habitat may also help prevent dense congregations of geese. Geese thrive in areas of low grasses adjacent to water, so steps to install rock walls and increase the height of shoreline vegetation may create a permanent, effective barrier. Shoreline strips of rocky rubble make it more difficult for geese to come ashore. Dense hedges or a 50- to 100-foot strip of stiff grasses or shrubs at least a yard high will dissuade use by geese. Shorelines that are allowed to grow over with tall grasses and shrubs are also less attractive. Artificial barrier fencing like wooden snow fence or plastic fencing at least 30 inches high with a minimum 3 x 3-inch mesh will also dissuade geese during the winter months.

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APPENDIX A: SPECIES LIST

INVERTEBRATES, AMPHIBIANS, REPTILES, AND MAMMALS

Species in boldface have been confirmed present in the Arboretum; other species expected based on range and habitat requirements.

Scientific Name **Common Name**	**Abundance**	**Conservation Status** [a]	**Natural History**
CRAYFISH: Class Crustacea (from PB Moyle personal communication)			
Procambarus clarki **red crayfish**	**Extremely abundant**	**Invasive**	**Non-native. Native to South-Central U.S. and Northeastern Mexico. Burrows may damage banks and activity increases turbidity. Carnivorous. Common prey item of herons and Egrets. (Rogers 2000, Godfrey 2004).**
BUTTERFLIES: Order Lepidoptera (from Brock and Kaufman 2003, AM Shapiro personal communication)			
Battus philenor **pipevine swallowtail**		**Riparian Indicator Species**	**Native. Frequents a variety of open habitats, open woodlands, and edges. Declining regionally. Flies Feb-Nov. 100% dependent on *Aristolochia californica*.**
Papilio zelicaon anise swallowtail	Unconfirmed, but possibly present.		Native. Late February-October. Habitat: bare hills, mountains, gardens, fields, vacant lots, and roadsides. Host plants: carrot family (Apiaceae), including sweet fennel, *Foeniculum vulgare* ("anise") and poison hemlock
Papilio rutulus **western tiger swallowtail**	**Common**		**Native. Habitat: riparian community; woodlands near rivers and streams, wooded suburbs, canyons, parks, roadsides, and oases. Flight period early spring to midsummer, in some places to late fall. Food plants: leaves of *Populus fremontii*, *Salix*, *Platanus*, *Prunus* (wild cherry), and *Fraxinus*. Nectar plants: Nectar from many flowers including thistles, abelia, California buckeye, zinnia, and yerba santa.**
Pontia protodice checkered white	Unconfirmed, but possibly present.		Native. Current decreasing trend. Habitat: open grassland; occurrence irregular, sometimes very abundant. Always subject to extreme population fluxes, but a current declining trend is noteworthy in both the eastern and western United States. Food plants: many members of Brassicaceae.
Euchloe ausonides large marble	Unconfirmed, but possibly present.		Native. Formerly common in the Central Valley, almost extinct regionally. Habitat: meadows, fields, farmlands, vacant lots, and along streamsides. Flight period Mar-Jun. Food plants: Brassicaceae: *Brassica, Raphanus*.
Pieris rapae **cabbage white**	**Ubiquitous and abundant**		**Non-native. January-December. Host plants: various members of the mustard family, Brassicaceae.**
Colias eurytheme **orange sulphur**	**Common to abundant**		**Native. Host plants: legume family, Fabaceae (various species of vetch, *Vicia*, spp.)**
Danaus plexippus monarch	Unconfirmed, but possibly present.		Native. March-December. Habitat includes fields, meadows, weedy areas, marshes, and roadsides. Host plants: narrow-leaf and broad-leaf milkweeds
Limenitis lorquini Lorquin's admiral	Unconfirmed, but possibly present.	Sensitive	Native. Habitat: along valley streams from late spring to fall; has declined catastrophically. Has been reported at North Davis Pond. Food plants: *Salix.*
Nymphalis antiopa mourning cloak	Unconfirmed, but possibly present in the Arboretum	Sensitive	Native. Regional collapse began 3 years ago, quite common previously. Over winters in Central Valley, adults emerge in Jan, 1st generation generally produced in mid May; migrate to Sierra Nevada to produce 2nd generation which migrates back to Valley in fall (primary flight season). Seen on willow catkins in early spring. Food plants: *Salix, Ulmus, Celtis.*

Scientific Name Common Name	**Abundance**	**Conservation Status [a]**	**Natural History**
Junonia coenia **buckeye**	**Common to abundant**		**Native. January-December. Habitat: open, sunny areas with low vegetation and some bare ground. Hosts: a variety of plants in the families Scrophulariaceae and Plantaginaceae, including English and broad-leafed plantains and the ground cover, common fog fruit, (Verbenaceae), *Phyla***
Vanessa cardui **painted lady**	**Often very abundant**		**Native. February-November, but often scarce or absent in July and August. Host plants: many weeds, especially members of the mallow family, Malvaceae, and various thistles, *Cirsium* sp. This is a migratory species. It enters our area late each winter from its overwintering grounds in the deserts of San Diego and Imperial Counties and Northern Mexico.**
Vanessa annabella west coast lady	Unconfirmed, but possibly present.		Native. All year. Hosts: various weedy mallows, Malvaceae and, more rarely, stinging nettle, *Urtica holosericea*
Vanessa atalanta red admiral	Unconfirmed, but possibly present.		Native. All year. Habitat: moist woods, yards, parks, marshes, seeps, and moist fields. During migrations, the Red Admiral is found in almost any habitat from tundra to subtropics. Host: stinging nettle, *Urtica holosericea*
Vanessa virginiensis American lady	Unconfirmed, but possibly present.		Native. All year, most common in Spring and Fall. Hosts: everlastings (Asteraceae), *Gnaphalium* spp. and *Antennaria* spp.
Polygonia satyrus neomarsyas satyr comma or satyr anglewing	Unconfirmed, but possibly present.	Riparian Indicator Species	Native. Habitat: riparian vegetation and understory. Stable from Winters west, sporadic east of Winters. Adults long lived, often fly on warm late-winter days. Flight period Feb-Nov; two to three broods. Food plant: *Urtica* sp. (“stinging nettle”).
Nymphalis californica California tortoise-shell	Unconfirmed, but possibly present.		Native. Except for the occasional midwinter hibernator, it is seen here only when migrating. March-June and again in late September-October. Habitat: chaparral, woodland, brush areas, forest clearings, edges. Host: California lilac, *Ceanothus* spp.
Nymphalis milberti Milbert's tortoise-shell	Unconfirmed, but possibly present.		Native. Occasionally seen in winter, otherwise March-June and, rarely, in autumn. Habitat: wet areas near woodlands, moist pastures, and marshes. Host: stinging nettle, *Urtica holosericea*
Phyciodes mylitta mylitta crescent	Unconfirmed, but possibly present.		Native. March-November. Host plants: native thistles, *Cirsium* spp., milk thistle *Silybum marianum,* and European thistles*, Carduus* spp*.*
Phyciodes campestris field crescent	Unconfirmed, but possibly present.		Native. March-October. Habitat: flats and open areas, fields, meadows, and streamsides from plains to mountains. Host: *Aster* spp.
Satyrium sylvinum sylvinum sylvan hairstreak	Unconfirmed, but possibly present.	Riparian Indicator Species	Native. Habitat: streamsides, willow thickets; in Valley and mountains. Local population at Old Davis Rd bridge extirpated by DWR vegetation clearing. Flight May-June. Food plants: various species of *Salix*, locally dependent on *Salix exigua*
Lycaena xanthoides great copper	Unconfirmed, but possibly present.	Riparian Indicator Species	Native. Resident along South Fork Preserve and in UCD Riparian Reserve. Intensely local. Habitat: grassland and open riparian woodland. Populations holding regionally. Flight period May-early July. Food plants: *Rumex* spp., including *R. pulcher*, *R. crispus*, *R. hymenosepalus*. Nectar plants: *Grindelia, Apocynum, Heliotropium.*
Glaucopsyche lygdamus silvery blue	Unconfirmed, but possibly present.	Riparian Indicator Species.	Native. Formerly widely distributed, went locally extinct in early 1970's, was reintroduced a decade later. In danger of extinction from fire, disking, herbicides, etc.Univoltine: flight period Mar-early May. Food plants: *Lupinus* spp., *Lathyrus* spp., *Vicia* spp. and other Fabaceae at Putah Creek, and *Vicia* on the valley floor.

Scientific Name Common Name	Abundance	Conservation Status [a]	Natural History
Atlides halesus great purple hairstreak	Unconfirmed, but possibly present.		Native. Flight period Mar-Oct. Habitat: canopy species (difficult to monitor). Feeds on common mistletoe (*Phoradendron flavescens*) in oaks and cottonwood. Flies in oak woodland and along stream bottoms where cottonwoods, sycamores, and ash trees grow; at times pupae may be gathered in numbers from litter beneath such trees on which mistletoe grows.
***Strymon melinus* common or gray hairstreak**	**Common**		**Native. February-November. Hosts: various weeds including mallow, (Malvaceae), Vetch, *Vicia* spp., and turkey mullein, *Eremocarpus setigerus.***
Satyrium californica California hairstreak	Unconfirmed, but possibly present.		Native. Habitat: foothill chaparral or lower mountain habitats. Often seen in large numbers at buckwheat, dogbane, and other flowers, and adults also perch on larval foodplants. Flies in late spring or summer. Host: valley oak, *Quercus* spp.
Satyrium auretorum gold-hunter's hairstreak	Unconfirmed, but possibly present.		Native. May-July. Hosts: Oaks, *Quercus* spp.
Lycaena xanthoides great copper	Unconfirmed, but possibly present.		Native. Habitat: chaparral and scrub habitats. May-July. Hosts: dock *Rumex* spp.
Lycaena helloides purplish copper	Unconfirmed, but possibly present.		Native: Habitat: open, moist (often disturbed) habitats. Once common in fields, yards, vacant lots, and marshy areas. Food plants: many members of the Buckwheat family (Polygonaceae), including dock, sorrel (*Rumex* spp.), and knotweeds (*Polygonum* spp.). In dry yards and vacant lots: Wire Grass, Yard Knotweed (*P. aviculare*). In marshy areas: Common Knotweed (*P. lapathifolium*) and many others.
Everes comyntas eastern tailed blue	Unconfirmed, but possibly present.		Native. February-November. Hosts: herbaceous legumes, especially Spanish lotus, *Lotus purshianus*
***Plebeius acmon* acmon blue**	**Common to abundant**		**Native. Flight period Feb-Oct. Host plants: many Fabaceae: *Lotus* spp. Including *L. scoparius, L. purshianus*. Also *Polygonum aviculare* and *Eriogonum spp.***
Brephidium exilis western pygmy blue	Unconfirmed, but possibly present.		Native. April-December, Rare early in Season; often very abundant in fall. Smallest butterfly in North America. Hosts: members of the goosefoot family, Chenopodiaceae, including Russian thistle (tumbleweed), *Salsola tragus*
Leptotes marina marine blue	Unconfirmed, but possibly present.		Native. March-December, Irregular. Host (locally): wild licorice, *Glycyrrhiza lepidota*
Celastrina argiolus echo echo blue	Unconfirmed, but possibly present.		Native. February-June, two broods. Hosts: various shrubs and trees, including California lilac, *Ceanothus* spp., and California buckeye, *Aesculus californica*
Pholisora catullus sooty wing	Unconfirmed, but possibly present.		Native. March-November. Host plants: pigweed family, Amarathaceae.
Erynnis tristis sad dusky-wing	Unconfirmed, but possibly present.		Native. March-October. Hosts: *Quercus* spp.
***Pyrgus communis* common checkered skipper**			**Native. Habitat: backyards, vacant lots, city parks, fields, cultivated lands, and along roadsides. US & Canada south to Argentina. Food plants: many members of the Malvaceae, including *Malvella leprosa* and the weedy Malva.**
Pyrgus scriptura little checkered skipper	Unconfirmed, but possibly present.		Native. Habitat:alkali flats, alkaline fields, usually at low elevations. In Northern California, most common in the Sacramento Delta and interior valleys. Flight period Mar-Oct. Sole food plant: *Malvella leprosa*.

Scientific Name **Common Name**	**Abundance**	**Conservation Status** [a]	**Natural History**
Paratrytone (Poanes) melane umber skipper	Unconfirmed, but possibly present.	Riparian Indicator Species.	Native. Habitat: Riparian woodland in Valley, streamsides, clearings, trails, roadsides, at low elevations. Currently extinct below Lake Solano. Numbers declining in Sacramento and possibly Vacaville foothills. Flight period Mar-Jun and Jul-Oct. Food plants: various grasses.
Polites sabuleti **sandhill skipper**	**Common**		**Native. March-November. Hosts: grasses, especially Bermuda Grass, *Cynodon dactylon***
Ochlodes sylvanoides woodland skipper	Unconfirmed, but possibly present.	Riparian Indicator Species	Native. Habitat requirements poorly understood, but associated w/ *Quercus lobata*. Flight period Jul-Oct. Food plants: various grasses, especially *Elymus* spp. The only butterfly species that nectars on the unusually shaped flower of *Trichostemma lanceolatum*.
Hylephila phyleus **fiery skipper**	**Common**		**Native. Habitat: abundant on mowed lawns. Rare in Spring, increasingly abundant from June through autumn (a few to December). Hosts: grasses, Poaceae, especially Bermuda grass, *Cynodon dactylon.***
Atalopedes campestris field skipper	Unconfirmed, but possibly present.		Native. March-November, three broods. Hosts: grasses, Poaceae, especially Bermuda grass, *Cynodon dactylon*
Lerodea eufala eufala skipper	Unconfirmed, but possibly present.		Native. Rare in Spring, common late July-early November Hosts: grasses, Poaceae, especially Johnson grass, *Sorghum halepense* and dallis grass, *Paspalum* spp.
Hemileuca eglanterina/ Pseudohazis eglanterina sheep moth			Native. Diurnal. Valley floor willow feeder. Extinct on campus. Formerly abundant near Old Davis Road bridge. Extant in Suisun and Delta and Bobelaine Sanctuary. Seen occasionally near Lake Solano. Overwinter as eggs on willow, adult emergence Sept-Oct.
FISHES: Class Osteichthyes (from Moyle 2002)			
Lavinia exilicauda hitch	Not present in waterway	watch list	Native. Widespread in warm, low-elevation, slow-moving lakes and rivers and clear streams. May be found in low numbers in urban areas with turbid water. Very high temperature tolerance. Could be encouraged with improvements in water quality and submerged vegetation.
Orthodon microlepidotus **Sacramento blackfish**	**Stable population**	**Stable or increasing**	**Native. Abundant in warm, usually turbid waters of the Central Valley floor, often in highly modified habitats. Well adapted for survival in extreme environments. Hemoglobin has a high affinity for oxygen enabling this fish to survive in hypoxic environments.**
Pimephales promelas **fathead minnow**	**Most numerous fish in the Waterway**	**Aggressive invader**	**Non-native. Habitat: pools in small, muddy streams and ponds. Tolerant of extreme alkalinity, low dissolved oxygen, high levels of organic pollution and turbidity and high temperatures. High reproductive rates. Opportunistic bottom browsers on algae, diatoms, invertebrates and organic matter.**
Cyprinnus carpio **common carp**	**Accounts for the majority of the fish biomass in the waterway**	**Widespread and stable**	**Non-native. Most abundant in warm, turbid, eutrophic water at low elevations. They can survive in high turbidity, sudden temperature changes, high temperatures, and low oxygen concentrations. They can survive in deoxygenated water by gulping air at the surface. Omnivorous bottom feeders. They often uproot plants and disturb silty bottoms while feeding, removing food and cover from other fishes and increasing turbidity. Koi, the popular ornamental pond fish, are carp, and if they escape or are released, they can establish wild populations.**

Scientific Name Common Name	**Abundance**	**Conservation Status [a]**	**Natural History**
Gambusia affinis **western mosquitofish**	**Abundant**	**Aggressive Invader**	**Non-native. Habitat: shallow, often stagnant, ponds and shallow edges of lakes and streams. Well adapted to high temperatures, extreme daily temperature fluctuations, and low dissolved oxygen concentration. Omnivorous, opportunistic top and bottom feeders. They can feed extensively on mosquito larvae and pupae, but they also feed on almost any small food or prey items available.**
Archoplites interruptus Sacramento perch	Not present in waterway	SSSC	Native. Adapted to withstand turbidity, high temperatures, high salinities and high alkalinities. Often excluded by nonnative sunfishes (Centrarchidae). Predatory, opportunistic, large individuals are piscivorous. Could be encouraged with Removal of non-native fish in the waterway. Establishment of aquatic plant beds.
Lepomis cyanellus **green sunfish**	**Common**	**Widespread and stable**	**Non-native. Habitats include small warm streams, ponds and lake edges. Able to survive, high temperatures, low dissolved oxygen concentration, and very alkaline waters. Aggressive, territorial. Opportunistic predator and competitor with native fish.**
AMPHIBIANS: Class Amphibia			
Batrachoseps attenuatus California slender salamander	Not present in the Arboretum, but have been found on Putah Creek		Native. Requires moist habitat. Found in several locations around Davis and Sacramento (DB Wake personal communication). Found above ground under leaf litter, downed logs etc. from first fall rain until the start of the dry season. Lives underground during dry times of the year. Apparently not excluded by human disturbance. (AmphibiaWeb 2005). Could be introduced to Redwood Grove if boards or logs were placed on the ground.
Pseudacris regilla Pacific treefrog	not present		Native. Seeks cover in many places, including rock fissures, under bark, in vegetation along streams, in rodent and other burrows, in nooks and crannies in buildings, and in culverts. Can be found in springs, ponds, irrigation canals, streams, and other bodies of water, but it has also been found as far as ½ mile from water (Stebbins 1951). Out of the water, it frequents habitats like grassland, chaparral, woodland, desert oases, forest, and farmland (Stebbins 1985). Could be encouraged with addition of aquatic plants and small side pools for young
Rana catesbeiana **bullfrog**	**Present, but no established breeding population**		**Non-native. Voracious eater, threatens *Pseudacris* population. By eating larvae and tadpoles. (Stebbins 2003)**
REPTILES: Class Reptilia (turtle species composition and abundance from Spinks *et. al* 2003)			
Chrysemys picta **painted turtle**	**2 individuals found and removed in 1998 and 2000 respectively**		**Non-native. Found in quiet, sluggish bodies of water with soft bottoms (Stebbins 2003). These turtles are omnivorous and will sometimes scavenge (Kipper 2002).**
Emys marmorata **western pond turtle**	**Population dominated by adults and declining in the Arboretum. Population of approx. 75 individuals.**	**SSSC**	**The only native California turtle. Aquatic, requires aquatic vegetation to for juveniles to grow. Requires basking areas. Studied extensively in the Arboretum waterway from 1994-2001. Enhancement opportunities: create basking and nesting habitat. Head start juvenile turtles to augment population. Control non-native turtles. (Spinks *et al* 2003)**

Scientific Name Common Name	Abundance	Conservation Status [a]	Natural History
Graptemys pseudogeographica **false map turtle**	**4 individuals found and removed in 1994**		**Non-native. Found in southern Canada and much of the Eastern U. S. Omnivorous, aquatic. Reproduction in Arboretum found to be limited (Spinks *et al* 2003).**
Pseudemys concinna **river cooter**	**1 female individual found and removed in 1998**		**Non-native. Found in Eastern and Southeastern U. S. Primarily a river turtle, but found in other quieter habitats. Primarily herbivorous, but can be omnivorous (Gardiner 2000).**
Trachemys scripta elegans **pond slider, red-eared slider**	**124 individuals captured and removed from 1994 to 2001**	**Invasive**	**Non-native. Native to the Mississippi River Valley (Kuhrt and Dewey 2002). Sold frequently as pets, leading to widespread introduction. Thoroughly aquatic, often seen basking alone or in groups. Prefers quiet water with aquatic vegetation (Stebbins 2003). Reproductively successful in the Arboretum (Spinks *et al* 2003).**
Glyptemys muhlenbergii **bog turtle**	**1 individual died shortly after capture in 1998**	**Federal Threatened, but not native to CA**	**Non-native. Native to swamps and bogs in the Eastern U. S. Prefers highly specific habitat that is disappearing due to natural and human-caused succession (Harding 2002). The story of this particular turtle is quite interesting (Spinks *et al* 2003).**
Apalone spinifera (pallida) **spiny softshell turtle**	**2 individuals caught and removed in 1998 and 2000, respectively**		**Non-native. Native in Central to Eastern U.S. Inhabits various freshwater systems with little aquatic vegetation and sandy or muddy bottoms with raised sandy areas for nesting. Able to breathe under water using pharyngeal linings, cloacal lining and skin. Preys on macroinvertebrates and fish (Bartholemew 2000).**
Chelydra □reganos□e **snapping turtle**	**1 individual found and removed in 1994**		**Non-native. Native to Southern Canada and North America East of the Rocky Mountains. It is currently illegal to import this turtle to California (Spinks *et al* 2003). Prefer muddy bottoms and aquatic vegetation for concealment. Omnivorous and predatory, will kill other turtles by decapitation (Bosch 2003).**
Kinosternon subrubrum **eastern mud turtle**	**1 individual found and removed in 1997**		**Non-native. This species is native to the Atlantic and Gulf Coast and the Mississippi River Valley. (Spinks *et al* 2003)**
Chinemys reevesii **Reeves' turtle**	**1 individual found and removed in 1998**		**Non-native. Found in Southern China, Korea, Taiwan and Japan. Popular in pet trade.**
Sceloporus occidentalis **western fence lizard**	**Common**		**Native. Occupies a great variety of habitats. Occasionally climbs trees, but often found on or near ground. Eats insects and spiders (Stebbins 2003).**
Eumeces gilberti Gilbert's skink	Common		Native. Varied Habitats: grassland, salt flats, high desert, open chaparral, pinon-juniper woodland, open pine forest, rocky areas near springs and streams. (Stebbins 2003)
Elgaria multicarinata southern alligator lizard	Common		Native. Found in grassland, chaparral, oak woodland, and open pine forest. Near streams with abundant plant cover, and may live in old woodpiles and trash heaps. Carnivorous, can eat black widows. (Stebbins 2003)
Contina tenuis sharp-tailed snake	Common		Native. Found in woodland, grassland, broken chaparral, pastures or open meadows, on the edge of coniferous forests, among oaks, and forests usually near streams. Keeps out of sight hidden under logs, rocks and other objects. Often found on damp soil after rains. Feeds on slugs and their eggs (Stebbins 2003)
Coluber constrictor mormon western yellow-bellied racer	Common		Native. Favors open habitats, both semiarid and moist. Ground dwelling. Feeds on reptiles, small mammals, birds ad eggs. (Stebbins 2003)

Scientific Name **Common Name**	**Abundance**	**Conservation Status** [a]	**Natural History**
Pituophis catenifer catenifer **pacific gopher snake**	**Common**		**Native. Various habitats, especially common in grassland and open brushland. Good climber and burrower. Mimics rattlesnake when disturbed.Eats rodents, rabbits, moles, birds, eggs, nestlings, lizards and insects. (Stebbins 2003)**
Lampropeltis getula common kingsnake	Common		Native. Various Habitats. Eats snakes, lizards, small turtles, reptile eggs, frogs, birds, bird eggs, and small mammals. (Stebbins 2003) Found on Old Davis Rd. near Putah Creek.
Thamnophis sirtalis fitchi valley garter snake	Common		Native. Found in grassland, woodland, scrub, chaparral, forest and city lots. Tends to stay near water, excellent swimmer. “Spirited; often defends itself energetically when cornered. When caught it often bites and smears its captor with excrement and odorous contents of anal glands” (Stebbins 2003). Eats fish, toads, frogs, tadpoles, salamanders and their larvae, birds and their eggs, small mammals, reptiles, earthworms, slugs and leeches (Stebbins 2003).
Crotalus viridis *reganos* northern pacific rattlesnake	Rare locally		Native. Found close to campus on Putah Creek. Various habitats. Produces neurotoxin, which can cause injury and death (Stebbins 2003). Not aggressive. Eat small mammals; ground nesting birds, amphibians and reptiles (ADW).
MAMMALS: Class Mammalia			
Didelphis virginiana **Virginia opossum**	**Common**		**Naturalized. Commonly photographed in West End Swale during trailmaster sessions. Habitat: cultivated and riparian areas at elevations lower than 1000m. (Wilson and Ruff 1999)**
Sorex ornatus ornate shrew	Not confirmed in Arboretum, but likely present.		Native. Restricted to the southern Pacific region. Found in Putah Creek Campus Reserve and Campus Ecosystem. Habitat: Mediteranean upland and marshland. (Wilson and Ruff 1999)
Scapanus latimanus broad-footed mole	Not confirmed in Arboretum, but likely present.		Native. Found in Putah Creek Campus Reserve and Campus Ecosystem. Habitat: favors light soils, found throughout much of the state below 2000 ft.
Myotis yumanensis **Yuma myotis**	**Colony located under California Street Bridge**		**Native. Found in Western Canada, U.S., and Mexico. Insectivorous. Colony located under the California Street bridge. (Wilson and Ruff 1999)**
Lasiurus borealis **red bat**	**Not confirmed in Arboretum, but likely present.**		**Native. Found in forested regions throughout Northern and Central America and parts of South America. Found at Briggs Hall on main campus. Insectivorous (Wilson and Ruff 1999).**
Lasiurus cinereus hoary bat	Not confirmed in Arboretum, but likely present.		Native. Widespread throughout Canada, U.S. and Central America. Found in trees near clearings including city parks. Feeds on Moths, Beetles, flies and wasps. (Wilson and Ruff 1999)
Episticus fuscus big brown bat	Not confirmed in Arboretum, but likely present.		Native. Found in North, Central, and South America as well as the West Indies. Habitat: cities, towns, and rural areas, not found in forested areas. Insectivorous. **(**Wilson and Ruff 1999)
Corynorhinus townsendii **Townsend's big-eared bat**	**In past, associated with the Myotis colony under the California Street Bridge**	**SSSC, 2nd priority**	**Native. Western U.S. through British Columbia. Uncommon in summer, often found in caves in winter months. Hibernate in caves during the winter months. Threats include disturbance, vandalism and loss of habitat. (Wilson and Ruff 1999)**

Scientific Name Common Name	Abundance	Conservation Status [a]	Natural History
Antrozous pallidus pallid bat	not confirmed in Arboretum, but likely present.	SSSC	Native. Found From Canada to Mexico. Habitat: rocky mountainous areas or open, sparsely vegetated grasslands. Roosts in buildings and rock cracks. Insectivorous, usually catiching prey on foliage or ground. Easily disturbed by humans. (Wilson and Ruff 1999)
Tadarida brasiliensis **Mexican free-tailed bat**	**Common**		**Native. Frequent campus buildings. Habitat: colonial in buildings, caves, mine shafts; migratory; found across southern US to Atlantic coast. Could be encouraged to roost in bat boxes. (Wilson and Ruff 1999)**
Canis latrans **coyote**	**Possibly one resident pair**		**Native. Found throughout North and Central America. Incredibly adaptable. Omnivorous. Usually monogamous. Breeding occurs once a year in early to mid winter with a gestation period of 63 days. Litters average six altricial pups. Coyotes live an average of 8 years in the wild. There is great variation in social structure, from individuals living alone to large packs. (Wilson and Ruff 1999)**
Canis domesticus **domestic dog**	**Common, brought by visitors**		**Domestic. No wild dogs live in the Arboretum, but domestic dogs are a common predator when brought by visitors and allowed to run off leash.**
Vulpes vulpes **red fox**	**formerly found on Arboretum,**		**Non-native. Prefer diverse habitats and edge habitats. Uncommon in Putah Creek Campus Reserve. Opportunistic hunters and scavengers. They prefer rodents, cottontails and jackrabbits, but they will also take birds, fruits and invertebrates. Principle vector and victim of rabies in the Northern Hemisphere. (Wilson and Ruff 1999)**
Felis silvestris **domestic cat**	**Common**		**Domestic. House cats and ferral cats are common predaotrs in the Arboretum.**
Erithrizon dorsatum North American porcupine	Extremely rare here		Native. Northern North America. Found once on Putah Creek Campus reserve Poor eyesight, varied herbivorous diet. They can live at least ten years. Usually solitary except in winter months. (Wilson and Ruff 1999)
Procyon lotor Northern raccoon	not confirmed in Arboretum, but likely present.		Native. North and Central America. Found in Putah Creek Campus Reserve and Campus Ecosystem. Very well developed thermoregulatory ability allows them to inhabit hot climates. Found almost everywhere near water (Wilson and Ruff 1999). We did not observe this animal on the Arboretum through any of our monitoring efforts, but it occurs on Putah Creek and within the city of Davis.
Mephitis mephitis **striped skunk**	**Confirmed near Putah Creek Lodge.**		**Native. Found throughout North and Central America except in the hottest deserts and high mountains. Often near streams and other bodies of water. Does well in Agricultural areas, common in edge habitat. Omnivorous. (Wilson and Ruff 1999)**
Sciurus carolinensis eastern gray squirrel	Not found on Arboretum, but could establish population		Non-native. Native to Southern Canada and the United States east of the Mississippi. Omnivorous scavengers. Found in many habitats. (Wilson and Ruff 1999).
Sciurus griseus **western gray squirrel**	**Rare in the Arboretum**	**Threatened in WA; sensitive in OR**	**Native. Distribution closely associated with oak-conifer woodlands. Distribution declining due to habitat loss. Herbivorous. (Wilson and Ruff 1999).**
Sciurus niger **fox squirrel**	**Common**		**Non-native. Native to the United States east of the Mississippi. Common in parks and cities (Wilson and Ruff 1999). Recently invaded UC Davis Campus, including the Arboretum.**
Spermophilus beecheyi **California ground squirrel**	**Extremely abundant**		**Native. Most common in Agricultural lands. Significant pest to agriculture. Strictly ground dwelling opportunistic forager. (Wilson and Ruff 1999)**

Scientific Name Common Name	Abundance	Conservation Status [a]	Natural History
Thomomys bottae **Botta's pocket gopher**	**Common in grassy areas**		**Native. Virtually statewide, except higher elevations and extreme Northeast corner of the state. Found in open habitats. Both sexes burrow and individuals defend their own burrow systems. Considered a pest, but also important for soil aeration and production (Wilson and Ruff 1999).**
Ondatra zibethicus muskrat	Once common in the Arboretum, appears to have been extirpated.		Native throughout North America. Semi-aquatic. Found on Putah Creek Campus Reserve.Crepuscular and nocturnal. They feed mainly on aquatic plants, but will also take animal material. (Wilson and Ruff 1999)
Microtus californicus California vole	Not confirmed in Arboretum, but likely present.		Native. The only vole in the Central Valley. Found in Putah Creek Campus Reserve and Campus Ecosystem. Lowlands and foothills in much of California up to 1500m elevation in the Sierra Nevada. Herbivorous preferring grasses, sedges, and forbs. (Wison and Ruff 1999)
Reithrodontomys megalotus western harvest mouse	Not confirmed in Arboretum, but likely present.		Native. Habitat: varies, but often in brushy areas with dense grasses and open habitats; throughout California in low and medium elevations. Found in Putah Creek Campus Reserve and Campus Ecosystem. Opportunistic forager taking seeds, insects and herbs. (Wilson and Ruff 1999)
Peromyscus maniculatus deer mouse	Not confirmed in Arboretum, but likely present.		Native. Habitat: nearly anywhere; one of the most common mammals in much of North America. Most widespread North American rodent. Found in Putah Creek Campus Reserve and Campus Ecosystem. Crepuscular and nocturnal. Opportunistic forager. Primary host of hauntavirus. (Wilson and Ruff 1999)
Mus musculus House mouse	Unconfirmed, but likely present		Non-native. Found in Putah Creek Campus Reserve and Campus Ecosystem. Commensally with humans, also invading many habitats where it may be evicting many species. (Wilson and Ruff 1999)
Rattus norvegicus **Norway rat**	**Common**	**Invasive**	**Non-native. Commensally with humans, also invading many habitats where it may be evicting many species.**
Rattus rattus **Black rat, Roof rat**	**Common**	**Invasive**	**Non-native. Commensally with humans, also invading many habitats where it may be evicting many species.**
Lepus californicus **Black-tailed jackrabbit**	**Common**	**Invasive**	**Native. Common in open fields adjacent to Garrod Rd. Found throughout most of California to about 2500m elevation.**
Sylvilagus audubonii **Audubon's cottontail**	**Common**	**Invasive**	**Native. Found throughout the Arboretum, but most abundant in large rosemary bushes of the Mediterranean Section. Very common in the southern 2/3 of California.**

[a] Conservation Status

Federal and State Designations

Threatened or Endangered: Most birds are protected under the Migratory Bird Treaty Act (16 U.S.C. 703–711). However, before a plant or animal species can receive protection under the Endangered Species Act, it must first be placed on a federal or state list of endangered and threatened wildlife and plants. An “endangered” species is one that is in danger of extinction throughout all or a significant portion of its range. A “threatened” species is one that is likely to become endangered in the foreseeable future (USFWS 2006).

> California State Species of Special Concern: “Species of Special Concern (SSSC) status applies to animals not listed under the federal Endangered Species Act or the California Endangered Species Act, but which nonetheless are declining at a rate that could result in listing, or historically occurred in low numbers and known threats to their persistence currently exist.” (CDFG 2006)

Watchlist, stable or increasing, widespread and stable, and aggressive invader classifications to indicate distribution, status and lifestyle of each fish species after Moyle (2002).

Sensitive: a species that is experiencing dramatic population declines across all or part of its range, but is not covered by federal or state protections.

Riparian Indicator Species: a species that spends all or a significant portion of its life in riparian areas and is a good indicator of riparian habitat quality. Often tied to riparian resources, such as nectar sources or larval host plants in the case of Lepidopterans, for its survival.

Invasive: a species, generally nonnative, that can outcompete native species by better exploiting resources or avoiding predation.

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Appendix B: Avian Species List

Sighting probability, conservation ranking, dietary guild, migratory status, and nest location. SPECIES IN BOLDFACE ARE probable or CONFIRMED BREEDING IN THE ARBORETUM.

	Sighting Probability [a]			Conservation ranking[b]	Dietary Guild[c]	Migratory Status[d]	Nest Location
	Surveys conducted 1990-91, 1993-94, 1995-96 by England et al.	Surveys conducted 2004-05 by Castañeda	All surveys 1990-2005				
ANATIDAE							
Greater White-fronted Goose	0.56%	0.00%	0.40%		2	3	ground
Canada Goose	3.31%	25.14%	9.73%		2	5	ground
Tundra Swan	0.56%	0.00%	0.40%		2	3	ground
Wood Duck	6.85%	17.82%	10.20%		2	5	tree
Mallard	98.19%	87.22%	97.34%		2	5	ground
Cinnamon Teal	0.00%	1.39%	0.42%		2	5	ground
Northern Shoveler	0.56%	0.00%	0.40%		2	3	ground
Canvasback	0.56%	0.00%	0.40%		2	3	water
Ring-necked Duck	0.00%	1.39%	0.42%		1	3	water
Common Goldeneye	2.54%	0.00%	1.78%		1	3	tree
Common Merganser	10.40%	0.00%	7.42%		5	3	tree
Ruddy Duck	0.69%	0.00%	0.52%		4	3	water
PHASIANIDAE							
Common Peafowl	0.00%	19.07%	5.35%		2	5	ground
ODONTOPHORIDAE							
California Quail	0.00%	1.39%	0.32%		2	5	ground
PODICIPEDIDAE							
Pied-billed Grebe	27.25%	18.29%	25.82%		5	5	aquatic
PHALACROCORACIIDAE							
Double-crested Cormorant	2.40%	15.93%	6.55%	SSSC2	5	5	ground
ARDEIDAE							
Great Blue Heron	2.13%	0.00%	1.60%		5	5	tree
Great Egret	16.24%	23.61%	18.19%		5	5	tree
Snowy Egret	12.72%	24.95%	16.10%		5	5	tree
Cattle Egret	0.00%	8.43%	2.26%		5	5	tree
Green Heron	60.59%	35.51%	55.83%		5	5	tree
Black-crowned Night-Heron	19.41%	27.18%	21.81%		5	5	tree
CATHARTIDAE							
Turkey Vulture	14.60%	12.04%	14.09%		5	5	bank
ACCIPITRIDAE							
White-tailed Kite	0.60%	2.78%	1.25%		5	5	tree
Northern Harrier	2.49%	0.00%	1.77%		5	5	ground
Sharp-shinned Hawk	1.79%	2.78%	2.07%	SSSC3	5	3	
Cooper's Hawk	6.00%	10.00%	7.29%	SSSC3	5	5	tree
Red-shouldered Hawk	8.33%	30.37%	13.77%		5	5	tree
Swainson's Hawk (former breeder)	22.04%	12.13%	20.78%	ST, RBCP, YL	5	4	tree

	Sighting Probability [a]			Conservation ranking[b]	Dietary Guild[c]	Migratory Status[d]	Nest Location
	Surveys conducted 1990-91, 1993-94, 1995-96 by England et al.	Surveys conducted 2004-05 by Castañeda	All surveys 1990-2005				
Red-tailed Hawk	15.69%	23.61%	17.42%		5	5	tree
Ferruginous Hawk	0.64%	0.00%	0.44%		5	3	tree
FALCONIDAE							
American Kestrel	3.75%	0.93%	3.05%		5	5	tree
RALLIDAE							
American Coot	16.84%	10.00%	15.22%		1	5	water
CHARADRIIDAE							
Killdeer	8.67%	12.59%	9.95%		4	5	ground
SCOLOPACIDAE							
Spotted Sandpiper	0.91%	0.00%	0.64%		4	5	ground
Long-billed Curlew	0.83%	0.00%	0.67%	RL	4	3	ground
Wilson's Snipe	0.56%	0.00%	0.40%		4	3	ground
LARIDAE							
Ring-billed Gull	1.95%	2.78%	2.23%		1	3	ground
California Gull	26.11%	10.65%	21.82%	SSSC3	1	3	ground
Herring Gull	0.00%	6.25%	1.77%		1	3	ground
Forster's Tern	0.60%	0.00%	0.60%		5	2	water
COLUMBIDAE							
Rock Pigeon	76.75%	53.52%	72.54%		2	5	ledge
Mourning Dove	39.79%	27.82%	38.16%		2	5	tree
TYTONIDAE							
Barn Owl	2.19%	0.00%	1.77%		5	5	tree
STRIGIDAE							
Great Horned Owl	0.00%	1.39%	0.42%		5	5	tree
APODIDAE							
White-throated Swift	6.66%	26.94%	12.77%	YL	4	4	bank
TROCHILIDAE							
Anna's Hummingbird	54.86%	78.75%	61.82%		3	5	tree
ALCEDINIDAE							
Belted Kingfisher	32.19%	0.00%	23.18%		5	5	bank
PICIDAE							
Acorn Woodpecker	2.22%	0.00%	1.65%	OWBCP	1	5	tree
Red-breasted Sapsucker	1.20%	0.00%	0.84%		1	3	tree
Nuttall's Woodpecker	59.56%	90.00%	69.56%	OWBCP, RL, CE	4	5	tree
Downy Woodpecker	2.45%	10.14%	4.52%		4	5	tree
Northern Flicker	40.53%	36.25%	39.07%		4	5	tree
TYRANNIDAE							
Western Wood-Pewee	0.49%	1.67%	0.81%		4	2	tree
Hammond's Flycatcher	0.60%	0.00%	0.60%		4	2	tree
Pacific-slope Flycatcher	3.73%	1.67%	3.34%		4	4	tree
Black Phoebe	51.51%	80.00%	59.69%		4	5	bank
Ash-throated Flycatcher	0.56%	2.78%	1.11%		4	4	tree

	Sighting Probability [a]			Conservation ranking[b]	Dietary Guild[c]	Migratory Status[d]	Nest Location
	Surveys conducted 1990-91, 1993-94, 1995-96 by England et al.	Surveys conducted 2004-05 by Castañeda	All surveys 1990-2005				
Western Kingbird	2.58%	1.67%	2.59%		4	4	tree
VIREONIDAE							
Cassin's Vireo	0.60%	0.00%	0.42%		4	2	tree
Hutton's Vireo	0.60%	0.00%	0.42%		4	5	tree
Warbling Vireo	2.07%	2.78%	2.52%	RBCP	4	2	tree
CORVIDAE							
Western Scrub-Jay	99.58%	89.07%	98.87%	OWBCP	1	5	shrub
Yellow-billed Magpie	78.43%	67.08%	77.57%	OWBCP, YL, CE	1	5	tree
American Crow	96.33%	90.00%	96.82%		1	5	tree
ALAUDIDAE							
Horned Lark	0.56%	0.00%	0.40%		1	5	ground
HIRUNDINIDAE							
Tree Swallow	1.59%	29.72%	9.18%	RBCP	4	5	tree
Northern Rough-winged Swallow	16.12%	1.39%	13.11%		4	4	bank
Cliff Swallow	9.99%	11.94%	11.08%		4	4	ledge
Barn Swallow	43.10%	35.19%	42.50%		4	4	ledge
PARIDAE							
Oak Titmouse	0.60%	2.59%	1.44%	OWBCP, YL, CE	4	5	tree
AEGITHALIDAE							
Bushtit	32.77%	68.70%	43.72%		4	5	tree
SITTIDAE							
Red-breasted Nuthatch	8.98%	21.11%	12.39%		4	3	tree
White-breasted Nuthatch	0.00%	0.93%	0.32%		4	5	tree
CERTHIIDAE							
Brown Creeper	2.21%	0.00%	1.56%		4	3	Tree
TROGLODYTIDAE							
Bewick's Wren	0.00%	0.93%	0.32%		4	5	tree
House Wren	2.47%	22.87%	8.29%		4	5	tree
REGULIDAE							
Golden-crowned Kinglet	0.56%	0.00%	0.28%		4	3	tree
Ruby-crowned Kinglet	46.61%	54.55%	50.58%		4	3	tree
TURDIDAE							
Western Bluebird	0.00%	17.45%	4.86%	OWBCP	1	5	tree
Swainson's Thrush	0.60%	0.00%	0.60%	RBCP	1	2	shrub
Hermit Thrush	13.65%	12.36%	13.66%		1	3	ground
American Robin	17.40%	20.19%	18.41%		1	5	tree
Varied Thrush	5.65%	0.00%	4.02%		1	3	tree
MIMIDAE							
Northern Mockingbird	34.86%	24.54%	32.88%		1	5	shrub
STURNIDAE							
European Starling	78.42%	75.74%	80.27%		1	5	tree
MOTACILLIDAE							

	Sighting Probability [a]			Conservation ranking[b]	Dietary Guild[c]	Migratory Status[d]	Nest Location
	Surveys conducted 1990-91, 1993-94, 1995-96 by England et al.	Surveys conducted 2004-05 by Castañeda	All surveys 1990-2005				
American Pipit	6.37%	15.97%	9.14%		4	3	ground
BOMBYCILLIDAE							
Cedar Waxwing	21.30%	32.50%	24.63%		2	3	tree
PTILOGONATIDAE							
Phainopepla	1.02%	0.00%	0.74%		2	5	tree
PARULIDAE							
Orange-crowned Warbler	20.03%	47.55%	28.42%		4	5	ground
Nashville Warbler	0.42%	0.93%	0.65%		4	2	ground
Yellow Warbler	7.68%	6.30%	7.69%	SSSC2, RBCP	4	4	shrub
Yellow-rumped Warbler	54.52%	52.31%	54.35%		4	3	tree
Black-throated Gray Warbler	4.69%	2.78%	4.25%		4	2	tree
Townsend's Warbler	0.49%	0.93%	0.64%		4	2	tree
Hermit Warbler	0.42%	0.00%	0.33%		4	2	tree
Common Yellowthroat	0.98%	0.00%	0.64%	RBCP	4	5	shrub
Kentucky Warbler	0.00%	0.93%	0.32%	YL	4	1	ground
Wilson's Warbler	4.64%	3.70%	4.77%	RBCP	4	2	ground
THRAUPIDAE							
Western Tanager	2.40%	0.00%	1.97%		1	4	tree
EMBERIZIDAE							
Spotted Towhee	4.83%	11.39%	6.69%		2	5	ground
California Towhee	1.47%	0.00%	1.08%		2	5	shrub
Chipping Sparrow	0.76%	0.00%	0.52%		2	2	tree
Lark Sparrow	3.10%	0.00%	2.17%		2	5	ground
Fox Sparrow	10.61%	10.42%	10.42%		2	3	ground
Song Sparrow	10.70%	9.26%	10.24%	RBCP	2	5	ground
Lincoln's Sparrow	7.49%	9.72%	8.03%		2	3	ground
White-throated Sparrow	1.57%	0.00%	1.15%		2	3	ground
White-crowned Sparrow	53.86%	49.58%	52.85%		2	3	shrub
Golden-crowned Sparrow	42.48%	35.19%	40.71%		2	3	ground
Dark-eyed Junco (Oregon)	35.74%	35.56%	35.81%		2	5	ground
Dark-eyed Junco (Slate-colored)	0.00%	2.78%	0.88%		2	5	ground
CARDINALIDAE							
Black-headed Grosbeak	1.65%	0.00%	1.35%	RBCP	2	4	tree
ICTERIDAE							
Red-winged Blackbird	1.43%	22.78%	7.57%		1	5	aquatic
Western Meadowlark	1.35%	1.39%	1.26%		1	5	ground
Brewer's Blackbird	49.21%	10.00%	40.80%		1	5	tree
Brown-headed Cowbird (former)	5.89%	0.00%	4.79%		1	5	tree
Bullock's Oriole	1.85%	0.00%	1.60%		1	4	tree
FRINGILLIDAE							
Purple Finch	15.90%	0.00%	11.31%		2	3	tree
House Finch	50.14%	65.60%	55.33%		2	5	tree

	Sighting Probability [a]			Conservation ranking[b]	Dietary Guild[c]	Migratory Status[d]	Nest Location
	Surveys conducted 1990-91, 1993-94, 1995-96 by England et al.	Surveys conducted 2004-05 by Castañeda	All surveys 1990-2005				
Pine Siskin	10.45%	0.00%	7.54%		2	3	tree
Lesser Goldfinch	17.16%	37.50%	22.90%		2	5	tree
American Goldfinch	42.87%	63.10%	48.57%		2	5	shrub
PASSERIDAE							
House Sparrow	53.88%	17.59%	45.27%		2	5	building
OTHER SPECIES OR GENERA							
Empid spp.	0.42%	0.93%	0.64%				
Gull	4.10%	0.00%	2.93%				
Selasphorus spp.	1.93%	0.00%	1.36%				
Zonotrichia spp.	0.00%	6.94%	2.02%				
Red Junglefowl	0.00%	3.06%	0.87%				
Accipiter sp.	2.58%	0.00%	1.88%				
Falco spp.	0.64%	0.00%	0.00%				
Ringed-turtle Dove	0.49%	0.00%	0.32%				
Western Flycatcher (2 Spp.)	1.09%	0.00%	0.92%				
Goldfinch	1.17%	0.00%	0.84%				
Parrot	0.49%	0.00%	0.32%				

[a] Probability of sighting calculated as number of times species was detected divided by the number of surveys
[b]Conservation Status: Federal endangered (FE), Federal threatened (FT), State endangered (SE), State threatened (ST), State Species of Special Concern 1st, 2nd, and 3rd priority (SSSC1, SSSC2, SSSC3), California Partners in Flight Oak Woodland Bird Conservation Plan Focal Species (OWBCP), California Partners in Flight Riparian Bird Conservation Plan Focal Species (RBCP), Audubon WatchList Red List (RL), Audubon WatchList Yellow List (YL), California endemic species (CE).
[c]Dietary Guild: 1=Omnivore; 2=Granivore/Herbivore; 3=Nectarivore; 4=Insectivore; 5=Carnivore.
[d]Migratory Status:1=Vagrant; 2=Transient; 3=Winter Visitor; 4=Summer Visitor; 5=Resident.

Description of Avian Conservation Rankings:

Federal and State Designations

Threatened or Endangered:

Most birds are protected under the Migratory Bird Treaty Act (16 U.S.C. 703–711). However, before a plant or animal species can receive protection under the Endangered Species Act, it must first be placed on a federal or state list of endangered and threatened wildlife and plants. An “endangered” species is one that is in danger of extinction throughout all or a significant portion of its range. A “threatened” species is one that is likely to become endangered in the foreseeable future (USFWS 2006).

California State Species of Special Concern:

“Species of Special Concern (SSSC) status applies to animals not listed under the federal Endangered Species Act or the California Endangered Species Act, but which nonetheless are declining at a rate that could result in listing, or historically occurred in low numbers and known threats to their persistence currently exist.” (CDFG 2006)

California Partners in Flight Bird Conservation Plan Focal Species:

The California chapter of Partners in Flight (CalPIF) was established in 1992 to promote the conservation of resident and migratory landbirds and their habitats in California. To facilitate a proactive approach to landbird conservation, CalPIF has developed a series of Bird Conservation Plans (BCPs), including the Oak Woodland Conservation Plan and the Riparian Conservation Plan, that identify habitats important to birds, and present a list of focal species and prescriptions for their conservation (RHJV 2004, CalPIF 2002).

National Audubon Society WatchList:

Audubon's WatchList was designed specifically to highlight those bird species that have the greatest conservation needs (National Audubon Society 2002). Audubon uses two independent assessments published by BirdLife International and Partners in Flight, respectively, to place species in one of three categories: red, yellow, or green (no conservation concern).

RED: species in this category are declining rapidly, have very small populations or limited ranges, and face major conservation threats. These typically are species of global conservation concern.

YELLOW: this category includes those species that are also declining but at a slower rate than those in the red category. These typically are species of national conservation concern

California Endemic Species:

Over millennia, California's mild climate and wealth of habitats has resulted in many distinct species and races of plants and animals, including birds (National Audubon Society 2006). Though only Yellow-billed Magpie and Island Scrub-Jay have never been recorded outside the state's borders, others like Allen's hummingbird, Nuttall's woodpecker, oak titmouse, California thrasher, wrentit, Lawrence's goldfinch and tricolored blackbird are found primarily within California and are dependent upon California's natural landscapes. Though these species are still common throughout their ranges, surveys such as the national Breeding Bird Survey have detected declines in their numbers over the past few decades (although at least one, Allen's Hummingbird, is adapting well to planted ornamental vegetation). This, along with their limited global range, is a cause for concern.

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APPENDIX C: METHODS

Shields Grove Heronry Surveys

Mapping

Colony boundaries, locations of roosting and nesting trees, and other spatial aspects of the colony were mapped using large-scale site maps provided by the Arboretum staff. These maps are available for visualization, documentation, and planning purposes associated with the project.

Activity Surveys

We performed biweekly ground-based surveys during the 90-minutes preceding nightfall on 22 July, 5 and 19 August, 1, 16, and 30 September, and 14 October 2004. Weekly surveys were performed in 2005 from 8 April to 12 October 2005. These surveys enabled us to assess the temporal and spatial dynamics of the colony, quantify species composition, distribution and abundance, and analyze crepuscular (dawn or dusk) foraging movements to and from the colony. In 2004, two to three observers conducted sweep surveys before each count. Birds were highly active and displayed strong avoidance behavior, so the results of these surveys represented only an crude estimate of abundance. For this reason, and to avoid disturbing the birds, we did not conduct sweep surveys before each evening count in 2005.

For each evening activity survey, observers sat at predetermined stations facing east, south, southwest, west, northwest and northeast. These directions were chosen to avoid visual obstructions and ensure coverage of the entire 360-degree survey area. Recording was partitioned into nine consecutive ten-minute intervals, so that temporal differences in activity level could be determined. Birds were counted before landing and attempts were made not to double-count birds that flew away from the colony and back again.

Active Nest Surveys

To obtain a preliminary assessment of the nesting phenology of the colony, visual ground-based surveys were conducted on 15 and 26 July, and on 24 August 2004. Locations of all trees containing nests or nest-like structures (large ovoid bundles of sticks) were mapped and recorded using GPS (Garmin e-trex Venture). Trees were identified by their Arboretum-assigned numbers. Species composition for all active nests was recorded. Active nests were defined as those containing adults or young, or those for which adult or juvenile birds were closely associating.

In 2005, trained student interns conducted regular counts of the number of active nests in each tree within the grove. The protocol for these counts was based on the protocol used by the Audubon Canyon Ranch North Bay Heron and Egret Project (JP Kelly and M McCaustland, personal communication). All occupied nests were considered active, and the number of nests in each tree was counted individually. During the spring quarter, James Mouton, Dinusha Maheepala, and Melanie Cullen conducted active nest counts on a biweekly schedule. During the summer (after June 10th) Melanie Cullen conducted active nest counts once per week.

Focal Nest Observation

Focal nest observations were conducted for the entire 2005 nesting season. The protocol for the observation of focal nests was based on Mayfield (1961) and the protocols of the Audubon Canyon Ranch North Bay Heron and Egret Project. We took photos of Shield's Grove from several vantage points and identified all of the nests that were visible in each of the photographs throughout the nesting season. The Audubon Canyon Ranch Protocol does not allow for the addition of focal nests after April 15th, but due to differences in species composition and phenology at our site as compared to theirs, we continued to add new nests throughout the season. Each focal nest was checked approximately every three days. We monitored the nests from a distance of thirty to sixty meters using a spotting scope at 20x-40x magnification. We noted the nesting stage (as defined in the Audubon Canyon Ranch Protocol), number of adults, number of chicks, and any additional observations. The number of eggs was not possible to determine because the nests were monitored from the ground. Clutch initiation, incubation, hatching, and fledging were determined based on behavioral cues.

Avifaunal Transect Surveys

We conducted bi-monthly systematic surveys of the avifauna on the Arboretum. These surveys were conducted for a full year from September 2004 through September 2005. These surveys were similar to those conducted by Sid England and other Audubon Society members. in 1990-91, 1993-94, and 1995-96. We walked three GPS-designated transects (Table 1) covering the length of the Arboretum waterway and recorded all birds detected. The time spent on each kilometer-long transect was one hour. Transects were performed at times of peak bird activity. Visual and audible detection were considered equivalent. We also took note of any breeding bird activity.

TABLE 1. DESCRIPTION OF AVIFAUNAL TRANSECTS

Transect	Description	Start (Lat./Long.)		Finish (Lat./Long)	
		North (degrees)	West (degrees)	North (degrees)	West (degrees)
1	Railroad tracks to Mrak Hall Drive Bridge	38.53997	121.7411	38.53561	121.7489
2	Mrak Hall Drive Bridge to Putah Creek Lodge Bridge	38.53561	121.7489	38.53138	121.7589
3	Putah Creek Lodge Bridge to West End Swale	38.53138	121.7589	38.53164	121.7593

Ground Squirrel Surveys

Due to the difficulties associated with trapping and mark-recapture techniques in such a highly public place, we conducted visual transects to map the locations of each squirrel observed. We walked throughout the entire Arboretum grounds, mapping and GPSing the location of each squirrel seen, as suggested by faculty in the Department of Wildlife, Fish, and Conservation Biology (DH Van Vuren, personal communication). The West End Swale was not mapped since the dense vegetation made it too difficult to use this visual method. However, we have not observed large numbers of ground squirrels in the West End Swale. We mapped all squirrels seen in the Arboretum during three trials in the fall (September and October) of 2004, and repeated the process again in the fall of 2005. We converted visuals counts to density estimates (squirrels per hectare) stratified by plant collection. We tested for statistical significance of differences in squirrel densities before and after fumigation treatment using one-way ANOVA on normalized data (natural log transformed). We used an alpha level of 0.10 to detect changes that might otherwise be obscured due to the small number of replicates (n=3) and the relatively low accuracy and precision inherent in the method.

Remote Camera Station (Trailmaster) Surveys

To identify nocturnal species, we used a Trailmaster model TM1500 containing an active infrared sensor with a projecting device and a receiver, connected to a Yashica T4 Super D camera. When the infrared beam was broken for approximately 0.25 seconds, the receiver registered an event and triggered the camera shutter. We set the system so that pictures would be taken no more frequently than every two minutes, to conserve film and avoid getting several pictures of the same animal.

We set up camera stations at four different locations in the Arboretum where animals were likely to frequent (Table 2). We were limited in the number of sites where we could place stations due to visibility and irrigation overspray. Stations 1 and 2 were located in the West End Swale. Station 1 was located so that the infrared beam ran perpendicular to the main path on the north bank of the overflow channel. This was the same path we followed during Avian Transect 3. Station 2 was located adjacent to a runoff stream coming from the Equestrian Center. Station 3 was located in some Oleander bushes behind the Putah Creek Lodge. Station 4 was located at water's edge in the Redwood Grove. While we were setting up Station 4, we observed a Green Heron visiting a possible nest site in the same bush. We did not see the heron at this site again during subsequent visits.

We used two different types of scent bait, fish emulsion, and a generic version of Calvin Klein's Obsession for Men shown to be attractive to cats and other mesocarnivores (A Engilis, Jr. personal communication; not referenced, see Appendix E). With the fish emulsion, we photographed opossums, a cat, rats and squirrels. With the cologne, we photographed opossums, rats, squirrels, and jackrabbits.

TABLE 2. DESCRIPTION OF TRAILMASTER STATIONS

Station	Description of location
1	West End Swale across transect 3 path
2	West End Swale near runoff stream
3	Redwood Grove, at water's edge
4	Behind Putah Creek Lodge

TABLE 3. DESCRIPTION OF TRAILMASTER SESSIONS

Station	Date and time started	Date and time removed	Hours	Number of photos	Scent
1	5/5/05 5:42 PM	5/6/05 7:30 AM	13.8	2	Fish emulsion
1	5/6/05 4:52 PM	5/8/05 1:04 PM	44.2	0	Fish emulsion
2	5/12/05 6:29 PM	5/17/05 10:55 AM	110.43	7	Fish emulsion
2	5/20/05 4:07 PM	5/24/05 9:04 AM	88.95	11	Fish emulsion
3	5/31/05 6:36 PM	6/6/05 10:00 AM	135.4	8	Fish emulsion
4	6/24/05 3:23 PM	7/1/05 2:02 PM	167.2	36	Fish emulsion
2	7/8/05 12:07 PM	8/1/05 11:47 AM	551.9	29	Cologne
4	7/8/05 12:59 PM	7/30/05 1:30 PM	506.48	36	Cologne
1	7/8/05 12:19 PM	7/29/05 7:44 AM	476.05	36	Cologne

TABLE 4. SPECIES PHOTOGRAPHED AT EACH TRAILMASTER STATION.

Station	Virginia opossum	domestic cat	California ground squirrel	fox squirrel	Norway rat	black rat	black-tailed jackrabbit	mallard	western scrub jay
1	X			X	X	X	X		
2	X		X		X	X	X		
3		X			X			X	
4	X		X	X	X			X	X

Sample Trailmaster Photos

Virginia opossum at Station 1, West End Swale

Black-tailed jackrabbit at Station 2, West End Swale

Virginia opossum at Station 2, West End Swale

Domestic cat at Station 3, Redwood Forest

Norway rat at Station 3, Redwood Forest

Fox squirrel at Station 4, behind Putah Creek Lodge

Western scrub jay at Station 4, behind Putah Creek Lodge

Domestic duck at Station 4, behind Putah Creek Lodge

Track Tunnel Surveys

The Arboretum is a difficult place to live-trap small mammals because of the high degree of visibility and the frequency of irrigation overspray. Traps must be flagged and left out a minimum of four consecutive days to trap effectively. Irrigation dislodges traps and subjects animals to exposure. For these reasons, we began searching for alternatives to trapping that would assess small-mammal abundance and diversity.

Track tunnels (or track tubes) (Glennon *et al.* 2002) involve an aboveground tunnel of some kind, usually made from pieces of plastic rain gutter. Bait is placed in the center of the tunnel. Contact paper, sticky-side up, is placed in the center of the tunnel near the bait. The outer ends of each tunnel contain a substance, usually chalk, ink or soot. As the animal walks across the chalk and contact paper to the bait, a permanent record is made of the track.

We conducted a pilot study to test the feasibility of such a technique in the Arboretum from July 28, 2005 to August 1, 2005. Again, working with the irrigation schedule was a problem, but we were able to collaborate with the grounds keeping staff so that an area of the Mediterranean Section would not be watered during this time.

For our pilot study, we used five different types of tunnels (Table 5). Five stations containing all five tunnel types were placed along the Mediterranean section every 200m. Halfway between each station, we placed an additional 1.5” diameter PVC pipe tube to survey for smaller species such as mice. We used blue marking chalk mixed with ethanol to create an ink-pad like substance that would not dry out quickly. For bait, we used oats mixed with peanut butter.

TABLE 5. MATERIALS USED FOR TRACK TUNNELS			
Tunnel shape	**Tunnel Dimensions**	**Tunnel material**	**Number of tunnels of this type**
round	1.5" in dia.	PVC pipe	9
round	2" in dia.	PVC pipe	5
rectangular	2" x 3"	brown plastic downspout	5
square	2" x 2"	brown plastic downspout	5
hexagon	3" x 4"	brown plastic rain gutter	5

The results of this pilot study were mixed. Many of the tunnels contained so many tracks that it was difficult to tell the species apart. Thus, while we were unable to identify different species, we were able to confirm that a very large population of rats and mice exists in the Arboretum, as expected. We also ran into problems with irrigation. Some of the tunnels were irrigated at the end of the study, knocking them out of position and ruining the contact paper impressions. After this attempt, we decided that this method was not a feasible alternative for small-mammal monitoring in the Arboretum.

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APPENDIX D: ENVIRONMENTAL EDUCATION AND OUTREACH OPPORTUNITIES

Opportunities for formal and informal environmental education abound in the Arboretum. These opportunities will increase as the Campus Gateway and Arboretum Waterway Improvement projects come online. Signage, docent- or guest-expert-led walks, pamphlets, and website resources could be created. Educational materials focusing on species identification, ecology and natural history, plant-animal interactions, and habitat restoration would be particularly well-suited.

Wildlife related education and outreach programs could also be designed to collect useful biological data for management and to enhance the Arboretum experience for visitors. The Davis community includes many individuals interested in local wildlife conservation issues, many of whom are well-trained in the identification of different taxonomic groups. Volunteer, citizen-scientist, and intern-based programs for formal and informal data collection will help monitor wildlife populations while providing educational and outreach opportunities.

We have identified four areas in which community resources could be tapped to monitor and enhance wildlife habitat in the Arboretum:

1) **Wildlife Website and Database:** Many people interested in wildlife observation visit the Arboretum every day. However, their valuable observations are usually not recorded for posterity. To engage visitors and to collect and catalog their observations, an Arboretum Wildlife Website could be established whereby community members and "citizen scientists" report observations into a database entry portal. While the creation of such a website would require some front-end costs, the data collected would be invaluable in tracking wildlife responses to management and habitat enhancement measures, and would create an environmental education and outreach resource.

2) **Formal heronry monitoring:** Continued monitoring of the heronry will be necessary to guide adaptive management and planning, regardless of what management actions are chosen. While certain monitoring tasks should be undertaken by wildlife professionals, many of the monitoring techniques used in the heronry by MWFB staff could be modified for use by trained, supervised volunteers. These protocols are available upon request from the MWFB.

3) **Butterfly monitoring:** Butterflies are good ecological indicators—intimately connected to the composition and health of their habitats (Sparrow *et al.* 1994)—whose species diversity is especially sensitive to development-related environmental change (Blair

1999). In contrast to birds, which respond mainly to habitat *structure*, butterflies operate at the scale of individual plants and the patches in which they grow (Fleishman *et al.* 1999). In turn, butterflies provide valuable pollination services to plants. For these reasons, and because populations of a number of species are at their lowest levels in 30 years (AM Shapiro personal communication), we recommend continuing our butterfly surveys in the Arboretum. The MWFB uses standardized protocols to monitor butterfly populations throughout the Central Valley. These are available upon request. Like the heronry monitoring program, we recommend the use of trained, supervised volunteers to implement this monitoring program. The Arboretum may well serve as an important area for conservation and monitoring of butterflies due to its abundance of flowering plants and other important resources.

4) **Nest Box Program**: Cavity nesting birds are important components of the nesting avifauna. However, some species are declining due to habitat loss and competition with nonnative species. Reproductive success along the Putah Creek Nestbox Highway has increased local populations of cavity nesting birds; western bluebirds, once extirpated from the Central Valley (Gaines 1977), are on the rebound. These and other cavity nesting species have been observed with increasing frequency in the Arboretum and may benefit from the placement of nest boxes. Wood Ducks are also spilling over into the Arboretum from breeding populations along Putah Creek and might be encouraged to breed in the Arboretum. Placement and monitoring of nest boxes for Wood Ducks, owls, and cavity nesting passerines would be a valuable conservation and habitat enhancement project that could involve Arboretum volunteers and visitors. MWFB staff can provide advice on nest box construction, placement, and monitoring.

5) **Bee Box Program**: Like cavity nesting birds, native ground and cavity-nesting bees benefit from artificial nesting sites. Detailed instructions for the construction and placement of such structures are available in the *Pollinator Conservation Handbook* (Shepherd *et al.* 2003).

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APPENDIX E: WILDLIFE EXPERTS

Name ***Area of Expertise*** **Affiliation**	**Date(s) consulted**	**Available for consultation on future projects?**	**Contact information**
Chans, J J Reserve Manager Coto Doñana National Park, Spain	24 October 2005	Yes	chans@ebd.csic.es
Eadie, John M. *Waterfowl, Wood Duck nest boxes* UC Davis Dept. of WFCB	30 September 2005	Yes	jmeadie@ucdavis.edu
Kelly, John P. *Heronries* Audubon Canyon Ranch	January 2005-August 2005	Yes	kellyjp@svn.net
Kelt, Douglas A. *Small mammals* UC Davis Dept. of WFCB	December 2004 & 30 September 2005	No	dakelt@ucdavis.edu
Lichter, John *Shields Grove Tree Health* Consulting Arborist	Throughout report preparation	Yes	john@treeassociates.net
Long, Rachael F. *Bat boxes and monitoring* UC Cooperative Extension	22 September 2005	Yes	rflong@ucdavis.edu
Marie, Jean-Philippe Putah Creek Riparian Reserve Steward	November 2005	No	jpmarie@ucdavis.edu
Marsh, Rex E. *Integrated Pest Management* UC Davis Cooperative Extension	12 December 2004 & 30 September 2005	Yes	remarsh@ucdavis.edu
Moyle, Peter B. *California Fishes* UC Davis Dept. of WFCB	4 August 2004 & 5 August 2005	Yes	pbmoyle@ucdavis.edu
Shaffer, H. Bradley *Reptiles and Amphibians* UC Davis Div. of Biology, EVE	21 February 2005 & 22 July 2005	Yes	hbshaffer@ucdavis.edu
Shapiro, Art M *Butterflies* UCD Div. of Biology, EVE	February 2005	Yes	amshapiro@ucdavis.edu
Swolgaard, Craig *Folsom Lake Heronry Monitoring* State Parks Ecologist	February 2005	No	(916) 653-6656
Truan, Melanie Allen *Songbird nestboxes* MWFB	AWMEP co-author	Yes	mltruan@ucdavis.edu
Van Vuren, Dirk H. *ground squirrel translocation* UCD dept. of WFCB	August 2004	Yes	dhvanvuren@ucdavis.edu
Wake, David B *California Slender Salamanders* UCB Dept of Integrative Bio., & Museum of Vertebrate Zoology	26 July 2005	No	wakelab@berkeley.edu
Ward, Phil S. *Ant communities* UCD Dept. of Entomology and CPB	15 September 2005	Yes	psward@ucdavis.edu

APPENDIX F: PLANT RESOURCES FOR LEPIDOPTERANS.

Prepared by Craig Thomsen from discussions with Art Shapiro (February 27, 2003). Updated to include food plant information from Shapiro and Garth & Tilden (1986).

NS=Nectar source; LHP=Larval host plant

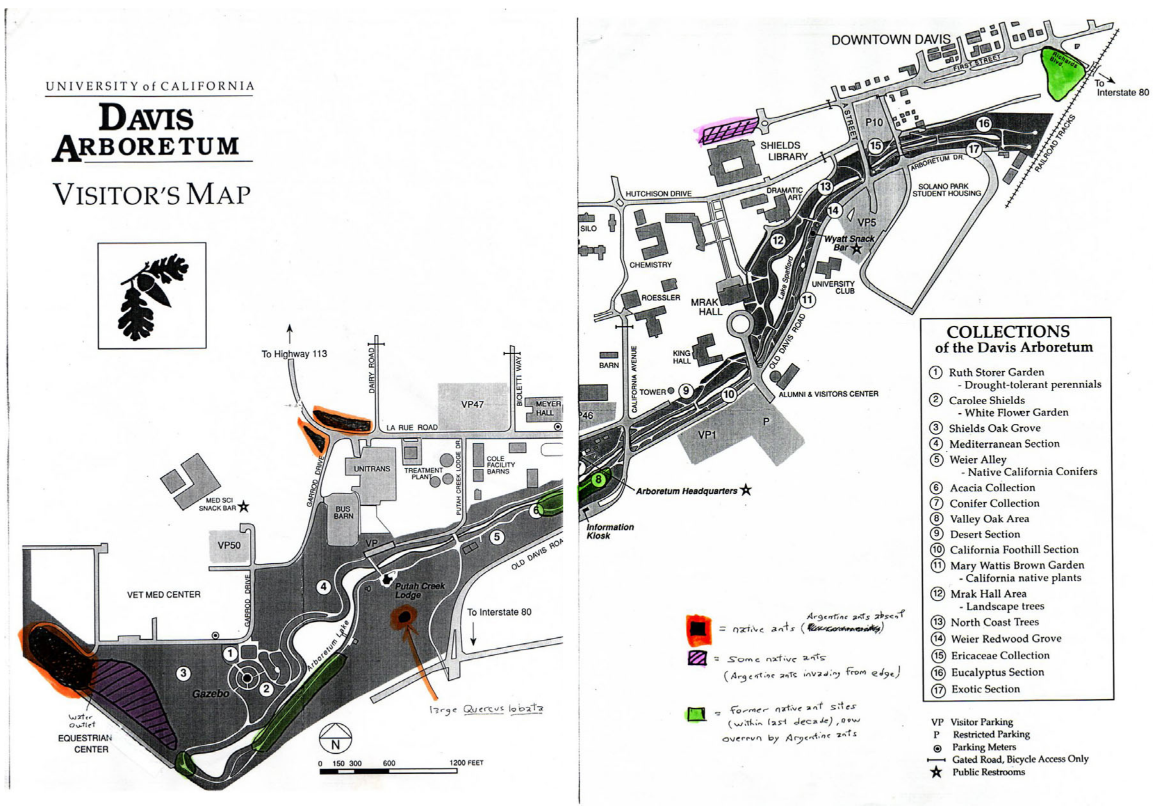
Trees	
Aesculus californica	Nectar source for many species
Alnus rhombifolia	*Papilio rutulus* (LHP)
Platanus racemosa	*Papilio rutulus* (LHP)
Salix spp.	*Satyrium sylvinum (*espec. *S. exigua)* (LHP) *Liminitis lorquini* (LHP) *Nymphalis antiopa* (On catkins; NS and LHP) *Papilio rutulus* (LHP) *Hemileuca eglanterina* (LHP)
Populus spp.	*Liminitis lorquini* (LHP) *Nymphalis antiopa* (LHP) *Papilio rutulus* (LHP)
Orchard trees (*Malus* spp.)	*Papilio rutulus* (LHP)
Orchard trees (*Prunus* spp.)	*Liminitis lorquini* (LHP)
Shrubs	
Baccharis pilularis *	
Cephalanthus occidentalis	
Cercis occidentalis *	
Rhamnus californica *	
Herbaceous perennials	
Achillea millefolium	Minor nectar source; for taxa with small probosces
Apocynum cannabinum	*Lycaena xanthoides* (NS)
Aristolochia californica	*Battus philenor* (Sole LHP)
Asclepias spp.	
Aster chilensis	
Baccharis viminea	
Deschampsia cespitosa	*Paratrytone melane* (LHP)
Dichelostemma capitatum	
Elymus spp.	*Ochlodes sylvanoides* (LHP)
Eriogonum nudum	(may not occur on lower stem of Putah Creek)
Euthamia occidentalis	
Grindelia camporum	*Lycaena xanthoides* (NS)
Heliotropium currassivicum	General nectar source for many species
Malvella leprosa	*Pyrgus scriptura* (Sole LHP)
Phoradendron macrophyllum	*Atlides halesus* (LHP)
Sidalcea malvaeflora	*Vanessa annabella* (LHP)
Solidago californica	
Triteleia laxa	*Battus philenor* (Minor NS)
Urtica dioica holosericea	*Polygonia satyrus neomarsyas* (LHP)

	Vanessa annabella (LHP)
Annuals/Biennials	
Eremocarpus setigerus	*Strymon melinus* (LHP); NS for small short-tongued spp.
Lotus purshianus	*Plebeius acmon* (LHP)
Lotus scoparius	*Plebeius acmon* (LHP)
Polygonum lapathifolium	*Lycaena helloides* (LHP)
Trichostema lanceolatum	*Ochlodes sylvanoides* (NS)
Non-native Species	
Alcea rosea	*Vanessa annabella*
Ammi sp.	Very good NS for small butterflies, but poisonous LHP to Anise Swallowtail)
Brassica nigra	*Euchloe ausonides* (LHP)
Brassica rapa	*Euchloe ausonides* (LHP)
Centaurea solstitialis	
Cynodon dactylon	*Paratrytone melane* (LHP)
Lamarckia aurea	*Paratrytone melane* (LHP)
Lippia sp.	
Marrumbium vulgare	
Polygonum arenastrum/aviculare	*Lycaena helloides, Plebeius acmon* (LHP)
Rumex crispus	*Lycaena xanthoides, Lycaena helloides* (LHP)
Rumex pulcher	*Lycaena xanthoides* (LHP)
Silybum marianum	*Vanessa cardui* (NS); *Phyciodes mylitta* (LHP)
Vicia spp.	*Glaucopsyche lygdamus* (LHP)
Family and Generic Level	
BRASSICACEAE	*Pontia protodice* (LHPl) *Euchloe ausonides* (LHP)
FABACEAE	*Glaucopsyche lygdamus* (LHP) *Plebeius acmon* (LHP)
Lathyrus spp.	*Glaucopsyche lygdamus* (LHP) *Plebeius acmon* (LHPl)
MALVACEAE	*Pyrgus communis* (LHP)
Malva spp.	*Vanessa annabella, Pyrgus communis* (LHP)
Malvella spp.	*Pyrgus communis, P. scriptura* (LHP)
POACEAE	*Ochlodes sylvanoides, P. melane* (LHP)
POLYGONACEAE	*Lycaena helloides* (LHP)
Eriogonum spp.	*Plebejus acmon* (LHP)
Rumex spp.	*Lycaena helloides* (LHP)
Polygonum spp.	*Lycaena helloides* (LHP)

APPENDIX G: ANT (FORMICIDAE) POPULATIONS IN THE ARBORETUM

Included in this Appendix:

1) A map drawn by Dr. Philip S. Ward highlighting the locations of native ant populations within the Arboretum.
2) A letter with appendices from Dr. Ward to Warren Roberts describing the ant species present in the Arboretum.



UC DAVIS: COLLEGE OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES
DEPARTMENT OF ENTOMOLOGY
AGRICULTURAL EXPERIMENT STATION
COOPERATIVE EXTENSION

2 March 2001

To: Warren Roberts
UCD Arboretum

Dear Warren,

Somewhat belatedly I am enclosing a marked-up map of the Davis Arboretum, showing the locations of native ants (Hymenoptera: Formicidae). Unfortunately, thanks to the depredations of the introduced Argentine ant (*Linepithema humile*), there are not many places left where native ants persist. The most important redoubt is at the extreme western end of the Arboretum in an area not subject to summer irrigation. In the summer-dry gully (marking the old course of Putah Creek) north of the Equestrian Center there is still a healthy community of native ants. About half-way down the old gully there is a water outlet, and from that point (marked as "water outlet" on the map) east to the Arboretum Lake the gully is infested with Argentine ants and essentially devoid of native species. The oak grove north of this—or at least that portion not receiving extensive summer irrigation—still has some native ant species, however.

Formerly there were populations of native ants in the cottonwoods along the south side of Arboretum Lake and in the valley oak area on the south side of the creek opposite the Arboretum headquarters. But within the last ten years these native populations have been extirpated by invading Argentine ants.

If we wish to maintain populations of native ants on the UC Davis campus it is essential to retain areas that are as dry as possible. The native ants are quite capable of handling a harsh Mediterranean climate—the presence of year-round water tips the balance in favor of the Argentine ant, a species that originates from riparian habitats in South America.

Best regards

Phil

Philip S. Ward
Department of Entomology

P.S. I enclose a draft list of the ant species that I have observed in the Arboretum, with information about some of these. I'd be happy to give "ant tours" of the Arboretum when the weather is warmer (April is a good time).

Ants (Hymenoptera: Formicidae) of the Davis Arboretum, Yolo Co., California

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This list of ants from the Davis Arboretum, Yolo County, California (approximately 38°33′N 121°45′W) is based on observations made by PSW over a twenty-year period. During this time there has been a steady decline in populations of native ants and an increasing dominance by the introduced Argentine ant, *Linepithema humile*. When this water-loving species invades an area it is well known to eliminate most species of native ants (Ward, 1987; Holway, 1995).

Subfamily, species	Nesting habits (A = arboreal) (G = ground)	Feeding habits (O = omnivore/scavenger) (P = predator) (S = seed-harvester)
Ponerinae		
Hypoponera opacior	G	P
Hypoponera punctatissima	G	P
Myrmicinae		
Pheidole californica	G	S (O)
Pogonomyrmex subdentatus	G	S (O)
Solenopsis molesta	G	O
Solenopsis xyloni	G	S (O)
Stenamma diecki	G	P
Tetramorium caespitum	G	O
Formicinae		
Brachymyrmex depilis	G	O
Camponotus essigi	A	O
Formica moki	G	O
Paratrechina vividula	G	O
Prenolepis imparis	G	O
Dolichoderinae		
Dorymyrmex bicolor	G	O
Dorymyrmex insanus	G	O
Liometopum occidentale	A	O
Linepithema humile	A/G	O
Tapinoma sessile	G	O

Of the preceding 18 species, 14 are native and 4 are introduced taxa (*Hypoponera punctatissima*, *Tetramorium caespitum*, *Paratrechina vividula*, and *Linepithema humile*).

Descriptions of some ant species from the Davis Arboretum

Descriptions of some of the more conspicuous or interesting ant species of the Davis Arboretum are given below. Note that the body of a worker ant is composed of three major parts: (1) the **head**, (2) a middle section called the **mesosoma**, which corresponds roughly to the thorax, and (3) a posterior part called the **gaster** (roughly corresponding to the abdomen). At the constriction or "waist" between the mesosoma and the gaster is a node-like or scale-like structure called the **petiole**. In some species a second node, called the **postpetiole**, is interpolated between the petiole and the gaster. All descriptions below apply to the worker caste; the winged males and queens are often different in appearance.

1. *Liometopum occidentale* (velvety tree ant)
Small-medium, variable in size (3-6 mm long), orange-brown, with gray gaster. Mesosoma convex in lateral profile. Petiole scale-like, postpetiole absent.

Liometopum occidentale is an arboreal species that nests in cavities in the boles of large trees such as valley oak, walnut, and cottonwood. The ants are generalist predators and scavengers, and they frequently form large foraging columns, on tree trunks and on the ground. The workers have an unpleasant but distinctive (vinegary) odor. Various other native arthropods have co-evolved with this native ant: there are parasitic phorid flies that are host-specific and attack only the workers of *Liometopum*; there are mirid bugs that mimic the workers and often co-occur with them on tree trunks; and there are specialist staphylinid beetles live in the ant nest. Thus, when *Liometopum occidentale* goes extinct as a result of invasion by the Argentine ant, we lose an entire community of associated arthropods.

2. ***Pogonomyrmex subdentatus***
Medium-large (6-8 mm long), reddish-brown; postpetiole present. Sting present.

This is a large, red seed-harvesting ant that nests in the ground. The nest entrances are usually decorated with small pebbles. Formerly more common on campus, this species survives along dry roadside verges, but does not tolerate the transformation to irrigated greenscapes.

3. *Formica moki*
Medium-sized (6 mm long), with a dark head, orange-brown mesosoma and silvery-gray gaster. Mesosoma saddle-shaped in profile. Petiole scale-like, postpetiole absent.

This species was previously more widespread in the Arboretum. It nests under stones, in rotten wood, and directly in the soil. Workers are active foragers, and their movements are fast and skittish. They look superficially like workers of *Liometopum occidentale* but they are more uniform in size and less inclined to forage in large groups.

4. *Prenolepis imparis*
Small (3-4 mm long), brown, with shiny gaster. Mesosoma saddle-shaped in profile. Petiole scale-like; postpetiole lacking.

This is a common species, whose nests are located deep in the ground. The workers are quite cold-tolerant: they forage on the ground and on vegetation throughout the winter and spring months, and then cease above-ground activity during the summer drought. During this period of aestivation, the colony apparently subsists on accumulated food-stores, including honey stored in the swollen gasters of certain workers (called "repletes"). This is one of the very few native ants that can survive in areas invaded by the Argentine ant, probably because it is underground when the Argentine ants are most active.

5. *Linepithema humile* (the Argentine ant)
Small (2.5 mm long), grayish-brown, with a thin (scale-like) petiole; postpetiole absent.

This introduced species is especially common in disturbed and irrigated areas; forages in large files; and aggressively attacks and eliminates most native species of ants. Unlike most ant species, nests of Argentine ants generally exhibit no intraspecific aggression. In fact, there are not sharp colony boundaries—all the ants in a given geographical area behave as if members of one large supercolony.

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