

# UC Agriculture & Natural Resources

## Proceedings of the Vertebrate Pest Conference

### Title

Invasion, Damage, and Control Options for Eastern Fox Squirrels

### Permalink

<https://escholarship.org/uc/item/5g95r9v2>

### Journal

Proceedings of the Vertebrate Pest Conference, 24(24)

### ISSN

0507-6773

### Authors

Krause, Sara K.  
Kelt, Douglas A.  
Van Vuren, Dirk H.

### Publication Date

2010

### DOI

10.5070/V424110494

# Invasion, Damage, and Control Options for Eastern Fox Squirrels

Sara K. Krause, Douglas A. Kelt, and Dirk H. Van Vuren

Dept. of Wildlife, Fish, and Conservation Biology, University of California, Davis, California

**ABSTRACT:** Fox squirrels are an emerging urban, suburban, and agricultural vertebrate pest in California. They cause a diversity of damage to vegetation and property. Multiple introductions of fox squirrels into California have led to a rapid expansion of their range in the state. Fox squirrels at the University of California, Davis increased from none to an estimated 1,609 between 2001 and 2009. Damage due to the dense population of fox squirrels is increasing. There are several population control options available, but social considerations may limit the viable options to non-lethal methods. This paper provides an overview of the impacts of the introduced fox squirrel in California and on the University of California, Davis campus.

**KEY WORDS:** damage, efficacy, fox squirrel, GonaCon™, *Sciurus niger*, wildlife birth control, wildlife contraception

Proc. 24<sup>th</sup> Vertebr. Pest Conf. (R. M. Timm and K. A. Fagerstone, Eds.)  
Published at Univ. of Calif., Davis. 2010. Pp. 29-31.

## INTRODUCTION

Fox squirrels (*Sciurus niger*) are found throughout the United States in urban, suburban, rural, and wild areas. They are native to the eastern and southern United States, as well as some areas of the southwestern United States. They have been introduced to many areas of the western United States. Their ability to adapt readily to diverse ecological conditions, combined with a lack of natural predators in urban and suburban habitats, has led to high fox squirrel densities in these areas. Human attitudes towards fox squirrels range from appreciation to dismay at squirrel-caused damage. Thus, control methods in urban and suburban areas can be controversial.

A review of damage caused by fox squirrels, potential control methods, and rate of population expansion in their introduced range could provide needed information for management of these populations. We provide a review of the current literature, coupled with resident interviews and findings from over 600 hours of observations on fox squirrels that were recently introduced to the University of California, Davis (UCD) main campus. Our study focuses on fox squirrels at two sites on the UCD campus containing over 200 uniquely marked (with ear tags and fur dye) individuals. Observations occurred January 2009 through January 2010.

## CURRENT DISTRIBUTION AND INVASION

Introductions of eastern fox squirrels into California occurred deliberately throughout the 20<sup>th</sup> century, usually for aesthetic reasons, as many people enjoy watching them in their yards (Byrne 1979). Fox squirrel introductions into California were banned in 1933 (CDF&G Code Section 2118), which put an end to the import of new individuals. However, despite the fact that relocations are also illegal without written consent of the California Department of Fish and Game (CDF&G Code Section 671.6a[2],[3]), several documented relocations have occurred by well-meaning citizens who relocated fox squirrels from one area to another in order to minimize damage without having to kill the animals (King 2004). In the Los Angeles area, the range of eastern fox squirrels has been expanding at a rate of 6.84

km/year (King 2004). In the San Francisco Bay area, we have seen them in nearly all city and county parks, educational campuses, open space preserves, state parks, and national recreation areas. Populations within California occur along the coast from Sonoma County to San Diego County, and inland from Lake and El Dorado Counties to Kern County. There are also reports of populations in Shasta County in northern California (Hoeffler and Harris 1990).

The expansion of fox squirrels in Davis, California has been consistent with population expansions elsewhere. Interviews with local residents indicate that fox squirrels arrived on the UCD campus circa 2001 and not prior to 2000. A likely source for the campus population is a small population, which according to local residents, persisted prior to 2001 in south Davis, a section of town separated from the main city of Davis by a 6-lane divided freeway. The completion of a pedestrian tunnel underneath the I-80 freeway in 1998 may have allowed fox squirrels to disperse to the UCD campus and the main city of Davis. Although the arrival of the fox squirrels to UCD was noted by two of us (DAK and DHVV), the population was not monitored until 2009.

By 2009, the fox squirrel population had expanded throughout the city of Davis, which surrounds the UCD campus on three sides, involving dispersal 4-6 km to the north, east, and west. Residents report that fox squirrels were present throughout Davis by 2006, suggesting an expansion rate of approximately 1 km/year. Assuming that the initial founding population was small and that immigration from the south side of the freeway was uncommon, the initial increase in population size during 2002 and 2003 was probably slow, an assumption supported by anecdotal observations. Most of the invasion of the fox squirrels into Davis probably occurred post-2004. If this assumption of the latency of invasion is correct, the population expansion rate was closer to 3 km/year. This is a slower rate than reported by King (2004) in Los Angeles, but King (2004) noted that several Los Angeles residents had admitted to relocating squirrels, and that rehabilitation centers may have increased expansion rates by releasing fox squirrels

within 8 km of their origin rather than at the origin.

The rate of increase in density of invading fox squirrel populations has not been studied. We estimated fox squirrel numbers on the UCD campus during April and May 2009 using distance sampling methods (Thomas et al. 2010). Using a detailed map of the campus, we established 131 parallel transects of variable length with 80-m spacing totaling 20.5 km; transects were established at a random bearing that did not correspond with any regularly occurring features of the landscape. Where large buildings obstructed the path, transects were separated into multiple sections. Two observers walked each transect at a rate of 15 m/min. The distance and compass angle of each sighted squirrel from the transect line was measured and recorded. The transects were stratified into 2 groups: viable habitat was defined as transects that passed through areas containing trees >5 m tall, and non-habitat was defined as transects lacking such trees. Since no squirrels were seen in the non-habitat strata, the area and all associated transects were excluded from the analysis. Distance sampling analysis followed Buckland et al. (2001). The best model was selected using Akaike's information criteria.

We estimated the fox squirrel population at 1,609 (95% CI: 1,307 - 1,981) individuals in 2009, 8 years after the first squirrel sighting. The UCD campus has about 240 ha of suitable habitat resulting in an average density of 6.6/ha, a much higher density than the 0.82-3.66/ha found in woodlots in their native range (Uhlig 1957) but not as high as the highest densities found of 12/ha (Koprowski 1985). Density across campus is highly variable, however.

## DAMAGE CAUSED

### Impact on Native Squirrels

The expansion of fox squirrels into natural areas along the coast of California may pose a threat to the western gray squirrel (*Sciurus griseus*), which is native to California, Oregon, and Washington. Although western gray squirrels are aggressively dominant to eastern fox squirrels (King 2004), the latter have replaced the former in some habitats (Muchlinski et al. 2009), although they may coexist for long periods in other habitats (Byrne 1979, Gilman 1986, King 2004). Anecdotal observations suggest that western gray squirrels, never common in Davis, may have disappeared from the city about the time that fox squirrels invaded. Although fox squirrels are not behaviorally dominant, they may become numerically dominant because of their reproductive ecology. Fox squirrels may reproduce twice per year with an average litter size ranging 1.97 - 3.35 (Koprowski 1994), whereas western gray squirrels reproduce only once per year with an average litter size ranging 2.2 - 3.0 (Carraway and Verts 1994).

### Crop Damage

Although fox squirrels are known agricultural pests in a variety of crops, including citrus, avocado, walnut, and almonds (Salmon et al. 2006), no studies have documented the extent of fox squirrel damage. We have witnessed fox squirrels feeding on pomegranates, persimmons, figs, strawberries, apples, tomatoes, and many

other garden vegetables and fruits.

## Property Damage

Eastern fox squirrels, particularly in high density populations, also may cause a variety of property damage. Squirrels in urban and suburban settings are known to damage nut trees and gardens by feeding, cause power outages or fires by short-circuiting electrical wires, and pose a safety concern because of aggression towards humans with food (Wolf and Roest 1971, Flyger and Gates 1982, Hamilton et al. 1989, Vu 2007, Lee 2009). Their gnawing can also sever phone lines and damage wooden buildings, and they may invade attics (Salmon et al. 2006).

On the UCD campus, fox squirrels cause extensive damage by gnawing, especially on various items made of hard plastic. Damaged fixtures include sprinkler heads, utility covers, outdoor grill handles, benches, picnic tables, and the dashboards of utility vehicles used by UCD groundskeepers. Damage to sprinkler heads is so widespread that nearly all sprinkler heads across campus must be replaced. The economic cost of control for California ground squirrels (*Spermophilus beecheyi*) on the UCD campus is significant, and this species is much less abundant than fox squirrels have become; hence, the cost of control likely will be even higher for fox squirrels.

## CONTROL OPTIONS

Efforts to control fox squirrels and their associated damage have traditionally been limited to exclusion, habitat modification, repellents, trapping, shooting, and recreational hunting (Salmon et al. 2006). Fox squirrels are classified as a game species and can be controlled at any time in accordance with California hunting regulations or if causing property or crop damage, and they can be shot year-round where hunting is permitted. Since relocation of fox squirrels is not permitted, the use of commercially available lethal traps is recommended over live traps (Salmon et al. 2006). The use of poisons for tree squirrel control is not legal (Salmon et al. 2006).

The available exclusion, habitat modification, and lethal control methods are not always effective, practical, or socially acceptable tools in urban and suburban communities. Exclusion and habitat modification options often are undesirable in a landscaped setting. Although removing trees would be effective at reducing the squirrel population, the presences of trees is often strongly preferred in landscaped settings. Repellents are often ineffective. Lethal options can be prohibitively controversial.

A newly emerging option for pest control is the use of contraception. On the UCD campus, we are testing GonaCon™, an immunocontraceptive vaccine that was developed by researchers at the USDA National Wildlife Research Center (NWRC) (Miller et al. 2004). Wildlife contraception is increasingly a preferred method of controlling wildlife populations (Fagerstone et al. 2006), especially where lethal methods may be socially unpopular or logistically challenging. The NWRC is developing multiple types of wildlife birth control that may be an option for controlling fox squirrel populations in urban and suburban areas (Killian et al. 2006). For fox

squirrels, birth control in comparison to lethal removal might be particularly effective because the removal of resident females can increase density due to a resultant increase in immigration (Hansen and Nixon 1985). One concern with the use of GonaCon™ is that animals must be captured to administer the vaccine. However, we experienced consistently high trap success (>75%) using pre-baiting for 2-5 days with whole walnuts.

## CONCLUSIONS

Eastern fox squirrels are an emerging vertebrate pest in their introduced range, particularly in California, and can cause a diversity of damage. They are also a threat to the native western gray squirrel. Eastern fox squirrels reach particularly high densities in urban areas resulting in increased urban damage. Thus, control measures are needed to reduce population density in some areas. Although several control methods are available, most of them are not practical in urban and suburban areas. Efficacy studies on wildlife birth control methods may result in availability of such methods for eastern fox squirrel studies. Additional studies on how to successfully implement contraceptive methods for population reduction are still needed.

## ACKNOWLEDGMENTS

We would like to thank all of our colleagues at NWRC for their continued support and assistance, and all of the many undergraduates who have put in countless hours of volunteer time watching squirrels.

## LITERATURE CITED

- BUCKLAND, S. T., D. R. ANDERSON, K. P. BURNHAM, J. L. LAAKE, D. L. BORCHERS, and L. THOMAS. 2001. Introduction to Distance Sampling: Estimating Abundance of Biological Populations. Oxford University Press, Oxford, UK. 432 pp.
- BYRNE, S. 1979. The distribution and ecology of the non-native tree squirrels *Sciurus carolinensis* and *Sciurus niger* in northern California. Ph.D. dissertation, Univ. of Calif., Berkeley. 190 pp.
- CARRAWAY, L. N., and B. J. VERTS. 1994. *Sciurus griseus*. Mammalian Species 474:1-7.
- FAGERSTONE, K. A., L. A. MILLER, K. S. BYNUM, J. D. EISEMANN, and C. YODER. 2006. When, where and for what wildlife species will contraception be a useful management approach? Proc. Vertebr. Pest Conf. 22:45-54.
- FLYGER, V., and J. E. GATES. 1982. Fox and gray squirrels. Pp. 209-229 in: J. A. Chapman and G. A. Feldhamer (Eds.), Wild Mammals of North America. The Johns Hopkins Univ. Press, Baltimore, MD.
- GILMAN, K. N. 1986. The western gray squirrel (*Sciurus griseus*), its summer home range, activity times, and habitat usage in Northern California. M.S. thesis, Calif. State Univ., Sacramento, CA. 71 p.
- HAMILTON, J. C., R. J. JOHNSON, R. M. CASE, and M. W. RILEY. 1989. Assessment of squirrel-caused power outages. Pp. 34-41 in: K. A. Fagerstone and R. D. Curnow (Eds.), Vertebrate Pest Control and Management Materials, 6<sup>th</sup> Vol. ASTM STP 1055, American Society for Testing and Materials, Philadelphia, PA.
- HANSEN, L. P., and C. M. NIXON. 1985. Effects of adults on the demography of fox squirrels (*Sciurus niger*). Can. J. Zool. 63:861-867.
- HOEFLER, G., and J. HARRIS. 1990. M078 Eastern fox squirrel. Pp. 148-149 in: D. C. Zeiner, W. F. Laudenslayer Jr., K. E. Mayer, and M. White. (Eds.), California Statewide Wildlife Habitat Relationships System. Calif. Dept. of Fish and Game, Sacramento, CA.
- KILLIAN G. N., K. DIEHL, L. MILLER, J. RHYAN, and D. THAIN. 2006. Safety and toxicity evaluation of three contraceptive approaches for population control of wild horses. Proc. Vertebr. Pest Conf. 22:67-71.
- KING, J. L. 2004. The current distribution of the introduced fox squirrel (*Sciurus niger*) in the greater Los Angeles metropolitan area and its behavioral interaction with the native western gray squirrel (*Sciurus griseus*). M.S. thesis, California State Univ., Los Angeles, CA. 112 pp.
- KOPROWSKI, J. L. 1985. Fox squirrel population trends and regulation in a southern Illinois woodlot. M.A. thesis, Southern Illinois Univ., Carbondale, IL. 85 pp.
- KOPROWSKI, J. L. 1994. *Sciurus niger*. Mammalian Species 479:1-9.
- LEE, H. K. 2009. Clumsy squirrel sparks fire near Rossmoor. News article in San Francisco Chronicle, Sept. 3, 2009, SFGate online: [http://articles.sfgate.com/2009-09-03/bay-area/17207193\\_1\\_squirrel-fire-injury](http://articles.sfgate.com/2009-09-03/bay-area/17207193_1_squirrel-fire-injury). [Accessed Feb. 24, 2010].
- MILLER, L. A., J. RHYAN, and G. KILLIAN. 2004. GonaCon™, a versatile GnRH contraceptive for a large variety of pest animal problems. Proc. Vertebr. Pest Conf. 21:269-273.
- MUCHLINSKI, A. E., G. R. STEWART, J. L. KING, and S. A. LEWIS. 2009. Documentation of replacement of native western gray squirrels by introduced eastern fox squirrels. Bull. So. Calif. Acad. Sci. 108(3):160-162.
- SALMON, T. P., D. A. WHISSON, and R. E. MARSH. 2006. Wildlife Pest Control around Gardens and Homes, Second Ed. University of California Agriculture and Natural Resources Publication 21385, University of California, Oakland, CA. 122 pages.
- THOMAS, L., S. T. BUCKLAND, E. A. REXSTAD, J. L. LAAKE, S. STRINDBERG, S. L. HEDLEY, J. R. B. BISHOP, T. A. MARQUES, and K. P. BURNHAM. 2010. Distance software: Design and analysis of distance sampling surveys for estimating population size. J. Appl. Ecology 47:5-14.
- UHLIG, H. G. 1957. Gray squirrel populations in extensive forested areas of West Virginia. J. Wildl. Manage. 21:335-341.
- VU, T. 2007. Squirrel attacks occur again in Mountain View Park. News article, Feb. 23, 2007. CBS 5 Broadcasting, <http://cbs5.com/local/2.452734.html> cbs5.com. [Accessed Nov. 21, 2009.]
- WOLF, T., and A. ROEST. 1971. The fox squirrel (*Sciurus niger*) in Ventura County. Calif. Fish Game 57:219-220.