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USE OF ARBOREAL NESTS OF TREE VOLES (*ARBORIMUS* SPP.) BY AMPHIBIANS

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***Abstract.*—We describe occupancy of arboreal nests of Tree Voles (*Arborimus* spp.) by four amphibian species in western Oregon and northern California, including Clouded Salamanders (*Aneides ferreus*), Arboreal Salamanders (*Aneides lugubris*), Pacific Tree Frogs (*Pseudacris regilla*), and a California Giant Salamander (*Dicamptodon ensatus*). These observations suggest that occupancy of the canopy of Douglas-fir (*Pseudotsuga menziesii*) forests by arboreal amphibians may be a more common phenomenon than is generally known. We suggest that salamanders and Pacific Tree Frogs may be attracted to occupied vole nests because they support large populations of invertebrate prey and provide a damp microenvironment. Tree Voles may benefit from the presence of amphibians in their nests because the amphibians feed on mites and other arthropods that commonly infest vole nests. We suggest that more detailed studies are needed to determine the extent of arboreal activity by salamanders in Douglas-fir forests.**

Key Words.—Aneides ferreus, Aneides lugubris, Arboreality, *Arborimus*, *Dicamptodon ensatus, Pseudacris regilla,* Tree Vole

INTRODUCTION

Most *Aneides* salamanders are at least partly arboreal (Ritter 1903; Van Denburgh 1916; Nussbaum et al. 1983; Jones et al. 2005; Staub and Wake 2005a,b). A recent study by Spickler et al. (2006) revealed that some large old Redwood Trees (*Sequoia sempervirens*) are occupied by relatively large numbers of Wandering Salamanders (*Aneides vagrans*) that live high in the forest canopy for at least part of the year. At least occasionally, *A. vagrans* also lay their eggs in fern mats in Redwood Trees (Welsh and Wilson 1995). The amount of arboreal activity by Clouded Salamanders (*A. ferreus*) in the Douglas-fir forests of western Oregon is poorly documented, but several records of *A. ferreus* in squirrel nests (Spickler et al. 2006), or in snags or trees (Van Denburgh 1916; Leonard et al. 1993; Jones et al. 2005; Spickler et al. 2006), indicate that this species at least occasionally inhabits the forest canopy.

Tree Voles (A*rborimus* spp.) are small arboreal rodents that are endemic to western Oregon and the coastal forests of northern California (Howell 1926; Hayes 1996). They are unique among voles in that they live in the forest canopy where they feed on conifer needles and bark from conifer twigs. They live in nests (Fig. 1) that they construct from twigs, conifer needles, lichens, and the resin ducts that they remove from conifer needles when feeding (Maser 1998). Their nests range in size from small structures no larger than a softball to large brood nests that are 50-80 cm wide and 30-40 cm deep. While conducting studies of Red Tree Voles (*A. longicaudus*) in Oregon in 2000-2007, we found *A. ferreus* and Pacific Tree Frogs (*Pseudacris regilla*) living in Tree Vole nests in Douglas-fir trees. This led us to search the unpublished field notes of earlier biologists who had studied Tree Voles to determine if there were additional records of amphibians in Tree Vole nests. We were surprised to find a fairly large number of records in which earlier researchers observed *Aneides* salamanders or Pacific Tree Frogs in Tree Vole nests. To our knowledge, none of these observations have been published, and the use of Tree Vole nests as micro-habitats by amphibians in Douglas-fir forests is largely unknown. Herein, we describe our observations of amphibians in vole nests in western Oregon, and summarize the previously unpublished records of other researchers.

FIGURE 1. Nest of an adult female Red Tree Vole (*Arborimus longicaudus*) in the deformed top of a Grand Fir (*Abies grandis*) in a mixed forest of Douglas Fir (*Pseudotsuga menziesii*) and Grand Fir. This nest was occupied by at least two Clouded Salamanders (*Aneides ferreus*). Scale indicated by the 8 cm pocket knife.

MATERIALS AND METHODS

In 2000-2007, we examined 1,401 Tree Vole nests in Oregon, and recorded any amphibians that we observed while inspecting nests. These nests were located by walking or driving through forest areas and climbing trees to examine nests that were first observed from the ground, or by climbing trees to locate radio-collared voles (Swingle 2005; Forsman and Swingle 2006). We identified nests as Tree Vole nests based on observation of voles (n = 217 nests), or signs of occupancy by voles such as fecal pellets, resin ducts, or fresh cuttings of conifer branches stored on top of nests (n = 1,184). Nests of Tree Voles are easy to identify even when the voles are not present because of the presence of resin ducts and fecal pellets (Howell 1926; Maser et al. 1981). In addition, occupied nests are usually covered by a layer of freshly cut conifer twigs, which the voles harvest at night and consume during the day (Fig. 1). We examined intact nests by gently probing them with a stiff piece of wire to determine if they were occupied by voles (Swingle 2005). If a nest was occupied this usually caused voles to run out of the nest and jump to the ground, where we caught them in nets or in our hands. Although we sometimes tore nests apart or probed the entry tunnels with our fingers, we generally avoided tearing nests apart, as most of our studies involved in-situ observations in which we captured voles and then released them at the nest after collecting tissue samples or installing radio collars (Bellinger et al. 2005; Swingle 2005). We did not keep a record of the degree to which each nest was probed or opened up, so we were only able to report the number of nests in which we found amphibians, as opposed to the proportion of nests that were actually occupied by amphibians. However, we estimate that < 5% of the nests examined were opened up to examine the interior of the nest.

In 2006-2007, we used an infrared video camera (Sentinel Magnum-4 DVR System, Sandpiper Technologies, Inc., Manteca, California, USA.) to continuously observe three vole nests from 36-117 days (Table 1). We kept records of any amphibians that were observed on the nests.

Concurrent with our field studies, we also visited 13 of the 16 museums in North America that had ≥10 Tree Vole specimens, and searched their archived field notes for references to amphibians in vole nests. We also obtained original field notes from Donald Roberts and William Hamilton, III, in which they described their observations of amphibians in nests of Sonoma Tree Voles (*A. pomo*) in California in 1956-1960. Based on these sources, we constructed a summary of all previous observations of amphibians in Tree Vole nests.

RESULTS

In western Oregon, we documented nine cases of single *A. ferreus* in Tree Vole nests in Douglas-fir trees, and one case of at least 2 *A. ferreus* in a Tree Vole nest in a Grand Fir (*Abies grandis*) (Table 1). Six of the ten cases were in nests simultaneously occupied by voles, three were in nests with evidence of recent occupancy by voles, and one was in an old, unoccupied vole nest. Seven of the nests were in young forest (35-45 yrs old), and three were in old forest

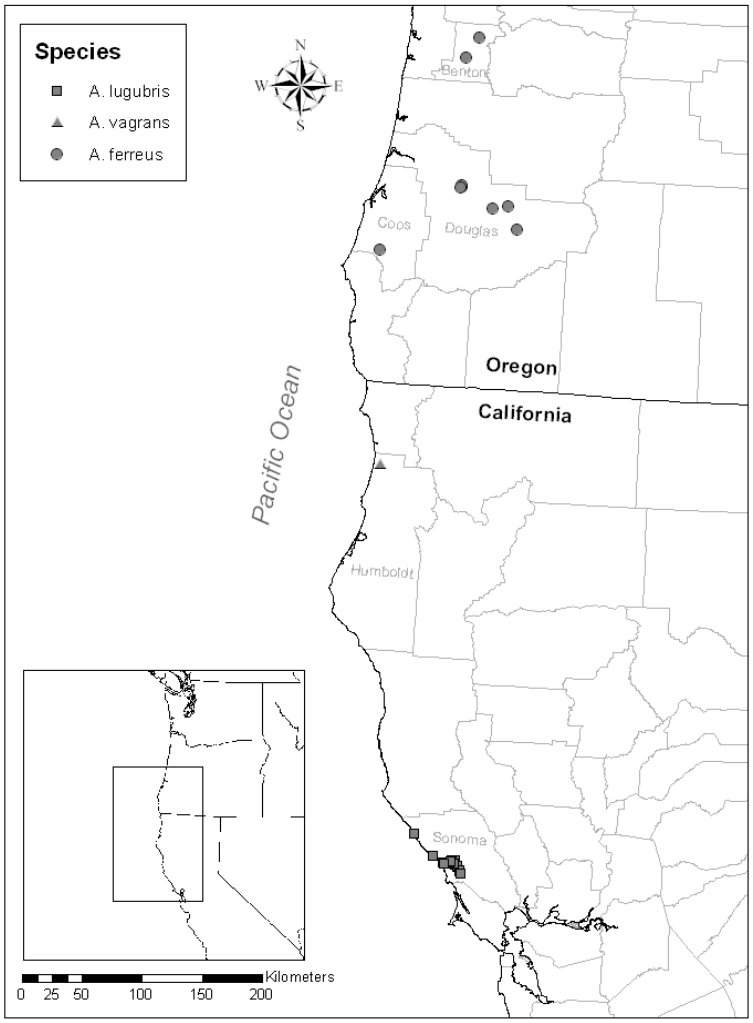

FIGURE 2. Locations of *Aneides ferreus* and *A. lugubris* found in nests of Tree Voles in Oregon and California, USA. Also shown is the location where Spickler et al. (2006) studied *A. vagrans* living in the canopy of old-growth Redwoods (*Sequoia sempervirens*).

TABLE 1. Species, collection dates, locations, and nest heights of amphibians found in nests of Tree Voles (*Arborimus* spp.) in Oregon and California, USA.

Species	Source[1]	Date	Number Observed	Location	UTM coordinates[2]		Nest ht (m)
					Easting	Northing	
Aneides ferreus	1	11/21/1971	1	Broadbent, Coos Co., OR	403686	4759285	14.0
	2	4/5/2002	1	Rock Creek, Douglas Co., OR	507670	4803100	3.3
	2	4/11/2002	1	Gassy Creek, Douglas Co., OR	494371	4800453	8.9
	2	11/15/2002	1	Gallegher Ridge, Douglas Co., OR	467900	4816804	9.0
	2	1/3/2003	1	Gallegher Ridge, Douglas Co., OR	467780	4816797	12.6
	2	5/14/2003	1	Taft Creek, Douglas Co., OR	516097	4784200	20.1
	2	6/13/2003	1	Gallegher Ridge, Douglas Co., OR	468063	4817331	7.3
	2	6/18/2003	1	Gallegher Ridge, Douglas Co., OR	466882	4815946	11.7
	2*	11/20/2006	1	Greasy Creek, Benton Co., OR	463828	4923050	5.1
	2*	Feb-May 2007	2	Oak Creek, Benton Co., OR	473451	4940642	14.3
Aneides lugubris	3	12/13/1930	1	Bohemian Grove, Sonoma Co., CA	500787	4258131	
	3	2/1/1931	1	Occidental, Sonoma Co., CA	505037	4250050	9.2
	3	2/1/1931	1	Occidental, Sonoma Co., CA	505037	4250050	18.3
	3	3/1/1936	6-8	Monte Rio, Sonoma Co., CA	497846	4258693	
	3	3/1/1936	1	Monte Rio, Sonoma Co., CA	500922	4254763	
	3	11/25/1937	1	Jenner, Sonoma Co., CA	491690	4255350	
	4	2/14/1944	2	Camp Meeker, Sonoma Co., CA	503358	4253380	
	5	3/4/1957	1	Jenner, Sonoma Co., CA	492374	4255470	
	5	3/4/1957	1	Jenner, Sonoma Co., CA	492374	4255470	9.2
	5	3/24/1957	3	Jenner, Sonoma Co., CA	490284	4256020	6.1
	5	2/16/1958	2	Camp Meeker, Sonoma Co., CA	502428	4253919	9.2
	5	3/2/1958	1	Occidental, Sonoma Co., CA	505014	4250366	7.6
	5	3/2/1958	1	Monte Rio, Sonoma Co., CA	500012	4256025	9.2
	5	3/9/1958	1	Duncans Mills, Sonoma Co., CA	495874	4256005	4.6
	5	2/11/1959	3	Duncans Mills, Sonoma Co., CA	497305	4257594	10.7
	6	6/20/1966	8-10	Jenner, Sonoma Co., CA	491685	4255367	6.1
	6	2/24/1967	2	Stewarts Point, Sonoma Co., CA	465658	4278244	7.6
	6	2/21/1969	1	Freestone, Sonoma Co., CA	506499	4247466	12.2
	6	2/22/1969	1	Fort Ross, Sonoma Co., CA	482019	4261304	9.2
	6	2/23/1973	1	Freestone, Sonoma Co., CA	506499	4247466	9.8
Dicamptodon ensatus	5	3/4/1957	1	Jenner, Sonoma Co., CA	492374	4255470	2.4
Pseudacris regilla	7	7/16/1913	1	Mendocino City, Mendocino Co., CA	432185	4352502	
	3	11/25/1937	1	Jenner, Sonoma Co., CA	491690	4255350	
	5	3/9/1958	1	Duncans Mills, Sonoma Co., CA	495827	4255610	4.6
	1	11/21/1971	1	Broadbent, Coos Co., OR	403686	4759285	12.2
	2	8/11/2000	1	South Myrtle Cr., Douglas Co., OR	499024	4770151	20.0

[1] Sources of data were: 1 = Chris Maser field notes at University of Puget Sound Slater Museum (UPS); 2 = Forsman and Swingle personal observations (*video observation) ; 3 = Seth Benson field notes at University of California Museum of Vertebrate Zoology (MVZ); 4 = Walter Dahlquest field notes at MVZ; 5 = William Hamilton, III and Donald Roberts field notes at UPS; 6 = Murray Johnson field notes at University of Washington Burke Museum; 7 = Walter Taylor field notes at MVZ.
[2] Universal Transmercator Coordinates of observations in NAD27.

(> 110 yrs old). Two of the 10 cases were discovered with video cameras and eight were found when resin ducts or fresh cuttings of Douglas-fir were lifted off the top of vole nests, exposing salamanders under the cuttings or inside the tunnels constructed by the voles. Mean height of all nests occupied by *A. ferreus* was 10.6 ± 5.0 m SD (range = 3.3-20.1 m; n = 10). Seven of the nests were against tree trunks on branch whorls, two were in forked tree tops and one was in a cavity in the side of a tree. In four cases, we observed salamanders in the same nest on multiple occasions spanning periods of 1-8 months. We were unsure if these were the same or different individuals because we did not mark them.

The two nests in which we detected salamanders with video cameras were 5.1 and 14.3 m above ground, respectively (Table 1). At one of these nests, which was located in a Grand Fir, we observed salamanders foraging on top of the nest or on limbs adjacent to the nest on 50 out of 101 nights between 6 Feb-18 May 2007, including one night in which we saw two salamanders foraging on top of the nest at the same time. We saw four close interactions between salamanders and voles at the latter nest. In one case, the vole seemed unaware of the salamander as she nearly ran over it, and on three occasions the vole sniffed at the salamander and then ignored it. The salamanders always turned and crawled away when closely approached by a vole.

We found 20 historic records of Arboreal Salamanders (*A. lugubris*) in nests of Tree Voles, all in Sonoma County, California (Table 1, Fig. 2). These included 13 nests with one salamander, three nests with two salamanders, two nests with three salamanders, one nest with 6-8 salamanders, and one nest with at least 8-10 salamanders (Table 1). Of the 20 nests, 16 (80%) were simultaneously occupied by voles and four (20%) had evidence of vole occupancy in the recent past, including one nest that contained two dead juvenile voles and no sign of their mother (Hamilton and Roberts, unpubl. data - field notes on file at University of Puget Sound Slater Museum). There were 10 cases in which the position of the nest in the tree was specified in the notes. Of these, seven (70%) were built against the trunk of the tree on limb whorls, two (20%) were 3.0-6.1 m out on branches, and one (10%) was under loose bark on a dead Douglas-fir. Except for the latter case, all nests were in live Douglas-fir. For cases in which it was provided, mean nest height was 9.1 ± 3.3 m SD (range = 4.6-18.3 m; n = 14), and mean tree diameter was 61.0 ± 8.7 cm SD (range = 46-76 cm; n = 7). In most cases, stand age was not mentioned in field notes and could not be analyzed.

We found one unusual case in which a "very large" California Giant Salamander (*Dicamptodon ensatus*) was found in a nest that contained two neonate Sonoma Tree Voles, but no adult vole (Hamilton and Roberts, unpubl. data). This nest was 2.4 m above ground in a deformed, windswept Douglas-fir that had live limbs that nearly touched the ground.

We documented five cases of Pacific Tree Frogs in Tree Vole nests, including one observation of our own, and four cases described by others (Table 1). Four of these were in nests that were simultaneously occupied by voles, and one was in a nest that had evidence of recent vole occupancy. One nest was simultaneously occupied by a Pacific Tree Frog, an Arboreal Salamander, and a female Tree Vole with two young (Seth Benson, field notes at University of California Museum of Vertebrate Zoology). Nests occupied by Tree Frogs averaged 10.8 ± 5.6 m SD above ground (range = 4.6-15.5 m; n = 3).

DISCUSSION

Based on the above records, we suspect that use of Tree Vole nests by amphibians may be a fairly common occurrence in Douglas-fir forests. Tree Vole nests provide unique microenvironments in the forests of western Oregon and northern California (Howell 1926; Maser et al. 1981). Inside these nests, the compacted mass of resin ducts, fecal pellets, twigs, lichens, and conifer needles gradually decompose into a soil-like material that is occupied by a variety of invertebrates, including mites, ticks, spiders, isopods, beetles, flies, and their eggs and larvae (Maser 1965). Most amphibians that we located were in occupied or recently occupied vole nests, which are typically characterized by a combination of damp, decomposing vegetation and many invertebrates. These conditions are probably ideal for amphibians because they provide a rich source of food; as well as, a microhabitat that remains damp, even during the dry summer months. It is possible that the presence of *Aneides* salamanders in vole nests may benefit the voles as well, because these salamanders are known to feed on mites and dipterans (Staub and Wake 2005a,b), some of which may be parasites of the voles (Whitaker and Maser 1979).

Although it is well known that *A. lugubris* is arboreal in oak forests (Ritter 1903; Storer 1925), and that *A. vagrans* is highly arboreal in redwood forests (Spickler et al. 2006), there is comparatively little data on the amount of arboreal activity of amphibians in Douglas-fir forests. Spickler et al. (2006) reported *A. ferreus* in three squirrel nests in western Oregon, and records of *A. ferreus* 61 m up in a dead tree (Jones et al. 2005), and 30 m up in a large old-growth Douglas-fir (Spickler et al. 2006) indicate that *A. ferreus* occasionally ventures high into the forest canopy. Our observations show that both *A. lugubris* and *A. ferreus* frequent the canopies of Douglas-fir trees, utilizing vole nests up to at least 20 m high in the forest canopy. Whether they occupy these unique microhabitats year-round is unknown. Spickler et al. (2006) found that marked *A. vagrans* lived for extended periods in fern mats in Redwoods, and estimated that a single large Redwood could be occupied simultaneously by as many as 29 individuals.

The observation of a *D. ensatus* 2.4 m above ground in a Tree Vole nest is the only record of arboreality in this species. The field notes for that day indicate only that the vole nest was in a "…windswept distorted fir…" (Hamilton and Roberts, unpubl. data), so it was unclear if the salamander gained access to the nest by climbing a leaning tree trunk or by crawling up a limb that touched the ground. Adult *D. ensatus* feed on large prey, including mice (Bury 1972), and a nest with neonate voles would probably be an attractive target in the rare case where it was easily accessible to the normally terrestrial *D. ensatus*. Although the female vole was missing from the nest, it was unclear if she had fled the nest or had been eaten by the salamander.

If anything, the use of Tree Vole nests by salamanders and Tree Frogs is probably more common than is indicated by our observations because we usually did not tear nests apart. It is also likely that our estimates of the mean height of nests used by salamanders and Tree Frogs were biased low because the majority of Tree Vole nests examined in our study, and all previous studies, were found by climbing to nests that were first detected from the ground.

Because it would be unethical to destroy large numbers of Tree Vole nests to determine if they are occupied by amphibians, we suggest that one option for estimating the proportion of vole nests occupied by salamanders would be

to use infrared video cameras on a sample of nests. Our experience with only three nests suggests that, if salamanders are present, they can usually be detected fairly quickly with a video camera, because they emerge on a fairly regular basis at night to forage among the debris on top of the nest. Drawbacks to this method are that it will probably not detect all of the salamanders that are present, and it is extremely labor-intensive. Another option for estimating the number of salamanders in vole nests would be to use mark-recapture techniques similar to those used by Spickler et al. (2006).

Old forests with deep crowns, heavily fissured bark, large numbers of cavities, and limbs covered with thick mats of moss, lichens and ferns probably provide a wealth of arboreal microhabitats for amphibians (Spickler et al. 2006). In young forests, where such structures are less common, it is possible that other types of structures—such as Tree Vole nests—may provide alternative habitats for arboreal amphibians. More studies are needed to better document these relationships and to better document the amount of arboreal activity by amphibians in Douglas-fir forests.

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