



H. T. HARVEY & ASSOCIATES
Ecological Consultants
50 years of field notes, exploration, and excellence

Alma Bridge Road-Related Newt Mortality Study

Project #4301-02

Prepared for:

Julie Andersen
Midpeninsula Open Space District
330 Distel Circle
Los Altos, CA 94022

and

Neal Sharma
Peninsula Open Space Trust
222 High Street
Palo Alto, CA 94301

Prepared by:

H. T. Harvey & Associates

November 12, 2021

Executive Summary

A survey started by community scientist Anne Parsons in 2017 demonstrated that a large number of newts were being killed by vehicles using Alma Bridge Road during the winter season. An analysis of the data provided by her winter 2018/2019 survey suggested that these newts were being killed while crossing Alma Bridge Road during their annual breeding migration to breed in Lexington Reservoir. In order to help determine the effect of this road-based mortality on the Lexington Reservoir newt population, we conducted a drift fence/pitfall trap array study in an attempt to estimate the number of adult newts of two species, California newt (*Taricha torosa*) and rough-skinned newt (*Taricha granulosa*), attempting to cross Alma Bridge Road during a migration to breed in Lexington Reservoir and the percentage that were killed by vehicular strikes in the 2020/2021 breeding season. Six drift fence/pitfall trap arrays were installed at locations that experienced various levels of road mortality in the 2018/2019 survey in order to capture a range of mortality levels in the study area. At these arrays, daily surveys of the road segments for newt carcasses and the pitfall traps for live newts that crossed or attempted to cross the road were conducted from November 4, 2020 to March 31, 2021. Traffic and precipitation data were also recorded during this survey period. Concurrently, a community scientists group conducted road carcass surveys over the entire study area, excluding those areas covered by this study to avoid duplication of efforts and double counting of carcasses.

Because the vast majority of newts captured in the pitfall traps were California newts (2,256), with only a relatively very low number of rough-skinned newts captured (45), we only analyzed the data to calculate the number of adult California newts attempting to cross Alma Bridge Road at the arrays and the road-based mortality rates. Then, with road mortality data provided by the community scientists conducting road carcass surveys over the entire study area during the same survey period, we estimated the number of adult California newts attempting to cross the road and the mortality rates over the study area during the survey period. We then modeled whether this road-based mortality rate might, if left unabated, lead to a reduction in, and possibly the eventual extirpation of, the local population of California newts breeding in Lexington Reservoir.

Based on the results of the surveys and analyses, we estimated that approximately 13,786 adult California newts attempted to cross Alma Bridge Road in order to migrate to Lexington Reservoir from upland habitat to breed during the survey period. We also calculated a 39.2% road-based mortality rate during this migration to the reservoir and the reverse migration to the upland after breeding. Using these parameters in a population growth model, we predicted that this road-based mortality level may result in a reduction of the population to possibly becoming extirpated in approximately 57 years.

Table of Contents

Figures

Tables

Appendices

List of Preparers

Steve Rottenborn, Ph.D., Principal-in-charge
Jeff Wilkinson, Ph.D., Senior Herpetologist
John Romansic, Ph.D., Herpetologist
Abra Kaiser, B.A., GIS Specialist

List of Surveyors

Steve Carpenter, B.S., Herpetologist
Matt Louder, M.S., Wildlife Ecologist
Christian Knowlton, B.S., Wildlife Ecologist
Will Lawton, B.S., Wildlife Ecologist
Emily Malkauskas, B.S., Wildlife Ecologist
Jane Lien, B.S., Wildlife Ecologist
Craig Fosdick, M.S., Wildlife Ecologist
Zach Hampson, B.S., Wildlife Ecologist
Jazmine Jensen, B.S., Wildlife Ecologist
Stephen Peterson, M.S., Wildlife Ecologist

Section 1. Introduction

Roads and traffic have long been known to have major impacts on animal populations and communities (Stoner 1925; Trombulak and Frissell 2000; Forman et al. 2003). One study estimated that one million vertebrates are killed each day on roads in the United States (Lalo 1987), and another emphasized that road-kill is a factor in the overall decline of amphibians (Glista et al. 2007). The negative effects of roads and traffic on amphibian populations are well known (Beebee 2013), and although road mortality may not have a substantial effect on very large populations, it can have an impact on populations of threatened or endangered species over time (Glista et al. 2007). For this reason, three threatened and endangered amphibian species with ranges in or near the Bay Area have received much attention with respect to the negative impacts of roads: the California tiger salamander (*Ambystoma californiense*), which is listed under both the Federal and California Endangered Species Acts as threatened, with the Sonoma and Santa Barbara County populations listed federally as endangered (Bain et al. 2017); the Santa Cruz long-toed salamander (*A. macrodactytum croceum*), which is federally and state listed as endangered (Hobbs 2013); and the California red-legged frog (*Rana draytonii*), which is federally listed as threatened, and state listed as a species of special concern. This attention has had some influence on how roads are currently constructed and used within the ranges of these species, with some road designs incorporating measures such as barriers to over-the-road movement coupled with undercrossings to allow amphibians to safely cross the roads (Bain et al. 2017). In some areas, compensatory mitigation is required to reduce the impacts of new road construction on these species through land conservation (e.g., USFWS 2005).

A recent study by Brehme et al. (2018) ranked species of amphibians and reptiles in California based on the risk of roads to their survivorship. Each species was given a road risk score based on movement distance, frequency of movement, habitat preference, road use, movement speed, fecundity, proportion of population at risk, size of range or amount of isolation, and conservation status, and then grouped into five broad categories of very high risk, high risk, medium risk, low risk, and very low risk. Thirty-three and 34 species were placed into the very high risk category and high risk category, respectively. Of the 33 species in the very high risk category, eight were amphibians and 25 were reptiles. Of the eight amphibian species in this category, the top four were salamanders: red-bellied newt (*Taricha rivularis*) with a score of 561, California newt (*T. torosa*) with a score of 532, then California tiger salamander and Sierra newt (*T. sierrae*), which both received a score of 437.

The placement of the California tiger salamander in the very high risk category is understandable, given its threatened and endangered status as mentioned above. However, the placement of the red-bellied newt and the California newt above, and the Sierra newt at the same level as, the California tiger salamander is less intuitively obvious, as the red-bellied newt and the California newt are listed only as California species of special concern (only the southern California populations of the California newt are listed as such), and the Sierra newt has no special listing status. Everything being equal, the California tiger salamander should have a higher risk factor than these other species because of its threatened and endangered status. Therefore, these rankings must be reflecting higher individual-level and population-level risk scores due to the other factors in the risk model, such as longer movement distances and higher frequency of movement than other species, which would increase their chances of crossing (and encountering risk) on a road.

Another interesting finding of Brehme's analysis is the placement of the rough-skinned newt (*T. granulosa*) within the high risk category along with the Santa Cruz long-toed salamander, with road risk scores of 304 and 308, respectively. The rough-skinned newt has no federal or state protective status, and has a relatively large range of four or more states and four geographic regions within California, whereas the Santa Cruz long-toed salamander is restricted to the southern Santa Cruz and northern Monterey Counties (USFWS 2004). Again, these rankings must be reflecting similarly high individual-level and population-level risk scores to those of the California newt.

Both the rough-skinned newt and the California newt are found in the mountainous parts of the San Francisco Bay Area, but they are mostly absent from the lower elevations primarily due to loss of habitat due to development. The distribution of the rough-skinned newt extends south along the San Francisco Peninsula to southern Santa Cruz and southwestern Santa Clara counties. The California newt on the other hand has several disjunct distributions, from Mendocino County south to southern California, one of which is along the San Francisco Peninsula similar to the rough-skinned newt; the California newt also occurs east of the bay in the hills and mountains of western Contra Costa and Alameda counties, south to southern Santa Clara and southwestern San Joaquin counties. Both the rough-skinned newt and California newt are found in sympatry within San Mateo, western Santa Clara, and Santa Cruz counties (Stebbins and McGinnis 2012).

Even though these two species do not have state or federal protective status in the Bay Area, there is some recognition that development (including roads) is having an impact on their survivorship, and some measures have been introduced to protect the species from road mortality. For example, each year the East Bay Regional Parks District initiates a road closure program of South Park Drive in Tilden Park from November to March in order to protect California newts crossing the road during the winter rainy season from vehicle strikes (https://www.ebparks.org/civica/press/display.asp?layout=11&Entry=484), and volunteers in Marin have formed a newt brigade to assist newts in safely crossing Chilleno Valley Road (https://www.pressdemocrat.com/article/news/newt-brigade-shuttles-salamanders-to-safety/).

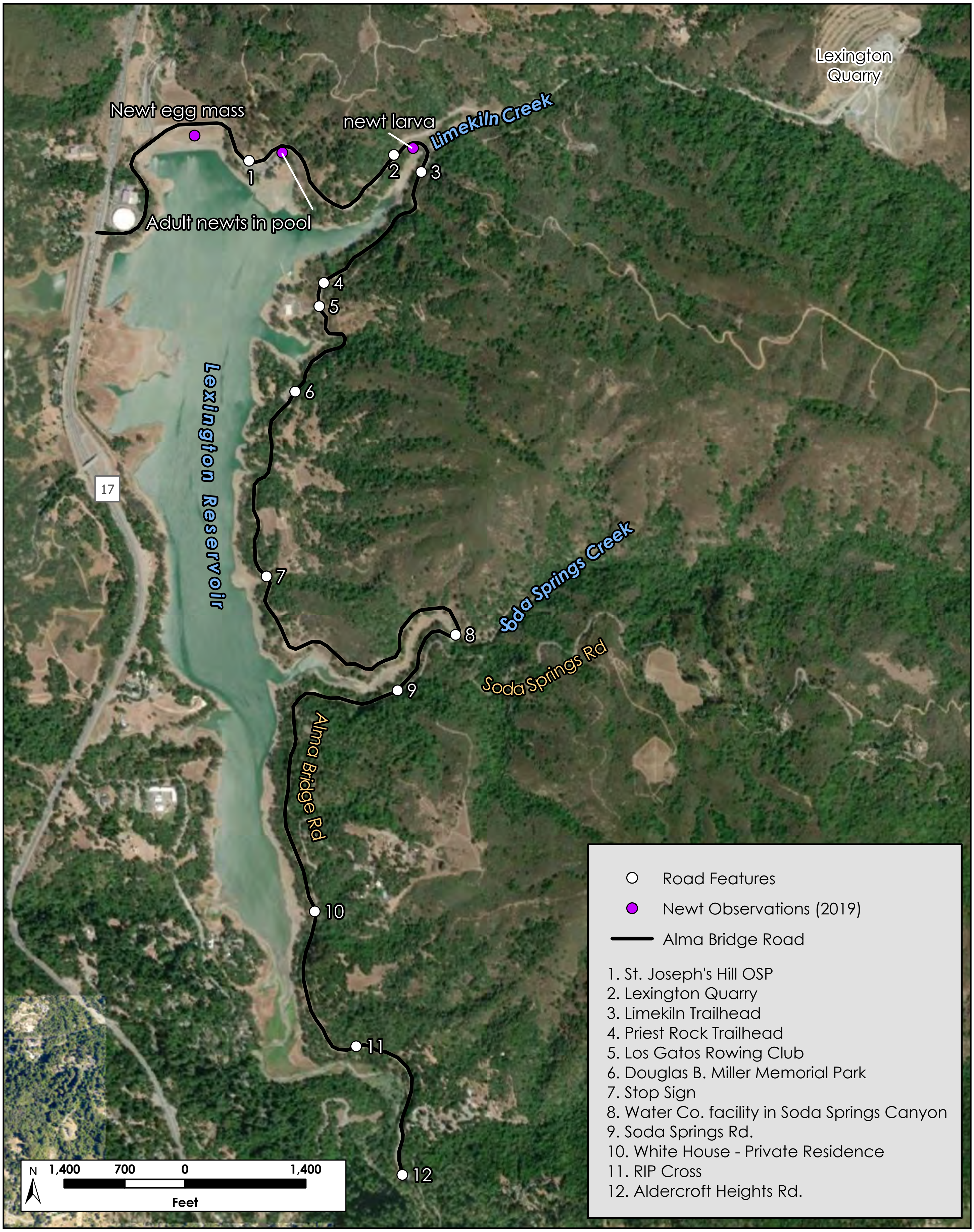
Similarly, due largely to the survey efforts of community scientist Anne Parsons since 2017 (Parsons 2021), the issue of newt mortality has come to light along Alma Bridge Road in western Santa Clara County generating media interest; prompting further interest in an investigation regarding potential impacts of traffic mortality on the local newt population (https://www.openspace.org/visit-a-preserve/plants-wildlife/newts); and prompting interest in two multi-stakeholder grant proposals to the California Wildlife Conservation Board to mitigate the impact, with one receiving support from the County. Alma Bridge Road is a 4.6-mile (mi) long, two-lane road along the east side of Lexington Reservoir (Figure 1). The northern section of the road is used by trucks that are transporting sandstone from the Lexington Quarry (Vulcan Materials Co.) to the east, recreationalists (hikers, boaters, and bicyclist) that use the road for travel and parking in Lexington Reservoir County Park to access the park and surrounding open space preserves, and private residents that have property to the south and east. The road is also used by commuters that choose to bypass a section of Highway 17, especially during times of high congestion. Observations of high newt mortality on Alma Bridge Road suggest that, if left unchecked, such traffic impacts could have an impact on this population.[1]

1.1 Results of Prior Investigation

Strategies to reduce wildlife road mortality have become a component of many conservation efforts. However, their success depends on knowledge of the temporal and spatial patterns of mortality. To determine the potential effects of newt mortality along Alma Bridge Road on newt populations and investigate the feasibility of measures to reduce mortality, in 2019 the Peninsula Open Space Trust (POST) commissioned H. T. Harvey & Associates to conduct an investigation of the temporal and spatial patterns of this high newt mortality on the road in a single breeding season based on information provided by community scientists efforts initiated by Anne Parsons and attempt to determine the degree to which this newt mortality is adversely affecting the local newt population.

The study area for our 2019 investigation was determined largely based on the roadkill data collected by the community scientists, who had uploaded observations of newts dead on the road (DOR) to iNaturalist (https://www.inaturalist.org/projects/pacific-newt-roadkill-main-project-lexington-reservoir). The study area encompassed the section of Alma Bridge Road from the Saint Joseph Hill Open Space Preserve (OSP) trail (Point 1; 37.200364°, -121.987036°) to the junction of Aldercroft Heights Road (Point 12; 37.168124°, -121.980288°) as illustrated on Figure 1. This section of road mostly separated the eastern shore of Lexington Reservoir from the adjacent expanse of upland habitat that is a mixture of public open space and private property. Prior to the start of our 2019 investigation, the community scientists had tallied over 3,000 newts DOR since 2017, and an additional 1,500 or more newts DOR over the two-month period from December 2018 through January 2019 (Neal Sharma, pers. comm.). A total of 4,892 newts DOR were eventually recorded in the 2018/2019 winter season (https://www.inaturalist.org/projects/pacific-newt-roadkill-2018-2019-lexington-reservoir).

[1] The local population of California newts on which this study focuses is the population breeding in Lexington Reservoir. Because our study area only included Alma Bridge Road, our quantitative analyses only include the newts that reside in the upland habitat east of Lexington Reservoir, breed exclusively in Lexington Reservoir, and must cross Alma Bridge Road in order to breed. We acknowledge that some newts breeding in the reservoir may use upland habitat to the southwest (e.g., south of the reservoir or between the reservoir and Highway 17). It is also our understanding that the extension of Lexington Reservoir in Lyndon Canyon west of Highway 17 is not freely connected to the reservoir proper under Highway 17 but instead water between this extension and the reservoir must pass through a high-water Lexington Culvert under the highway north of Black Road that would restrict adult newts and preclude larval newts from freely crossing under Highway 17 between the extension and the reservoir. Therefore, due to residential development southwest of the reservoir and the presence of Highway 17 (a barrier to newt dispersal) to the west, it is our opinion that population dynamics in Lexington Reservoir as a whole are driven primarily by the newts that were explicitly included in our study. Therefore, our references to "population" in this report refer interchangeably to the group of newts that were explicitly included in our study and the overall population breeding in the reservoir.



N:\Projects4300\4301-01\02\Reports\Newt Mortality Study\Newt Mortality Study.aprx

H. T. HARVEY & ASSOCIATES
Ecological Consultants

Figure 1. Alma Bridge Road
Alma Bridge Road Newt Mortality Study (4301-02)
November 2021

1.1.1 Identifying Potential Breeding Sites

Based on this high DOR count, we suspected that the newt mortality on Alma Bridge Road was a result of adult newts crossing the road from upland habitat to aquatic breeding habitat during annual breeding migrations. However, the types and locations of breeding habitats for these newts was not confirmed at the time. During a preliminary investigation of the area, portions of Limekiln Creek and Soda Springs Creek on the reservoir side of Alma Bridge Road were suggested as potential breeding sites for the newts, as no other aquatic habitat was present in the area other than Lexington Reservoir itself. We were uncertain at the time whether large numbers of newts were breeding successfully in Lexington Reservoir itself due to the potential for predation of newt eggs and/or larvae by fish. However, a review of the literature indicated that newts may actually breed in reservoirs (Kuchta 2005, Thomson et al. 2016), and that egg masses are most likely toxic (Kuchta 2005), and thus unpalatable to fish. We therefore planned to conduct presence/absence larval surveys in March and May 2019 in Limekiln Creek and Soda Springs Creek on the reservoir side of Alma Bridge Road and the reservoir proper. During the March survey, Limekiln Creek was completely inundated by the reservoir to Alma Bridge Road. We therefore searched along the edge of the reservoir from the dam face to within Limekiln Creek arm, where accessible. We observed one newt egg mass attached to floating woody debris along the edge of the reservoir at the dam (Photo 1 and Figure 1). In May, we surveyed with dip nets along the edge of the reservoir within the Limekiln Creek arm. One larva (Photo 2) was captured near the culvert under Alma Bridge Road (Figure 1). Our intent of the survey was to document presence and relative abundance of larvae. However, due to limited access in this area because of the inundation, it would have been difficult to conduct more extensive sampling needed to quantify relative abundance of larvae. We therefore did not continue sampling after confirming presence that breeding was occurring.

Photo 1. California newt egg mass observed on floating woody debris in Lexington Reservoir.

Photo 2. California newt larva observed in Lexington Reservoir at Limekiln Canyon Creek area downslope of Alma Bridge Road.

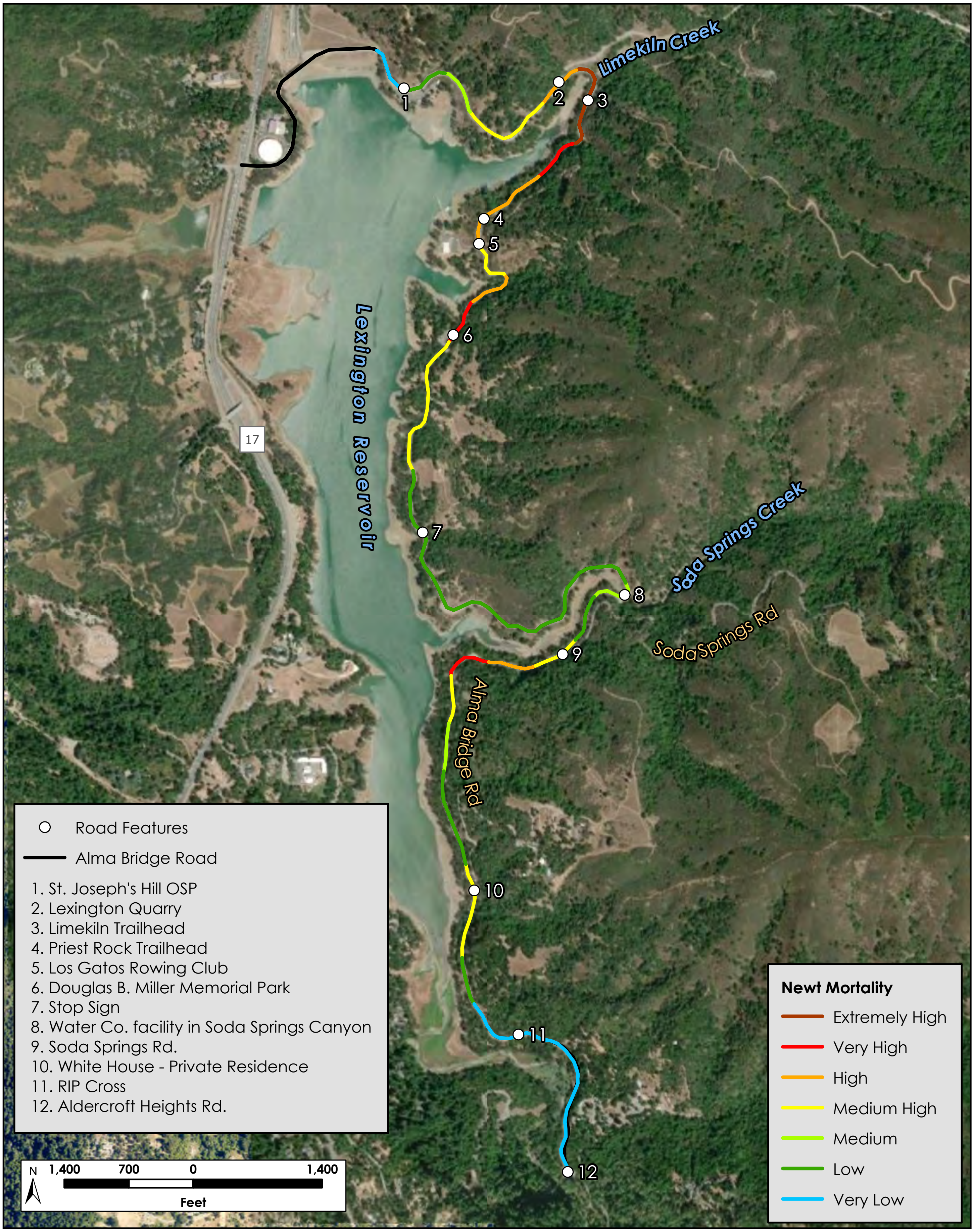
1.1.2 Analysis of iNaturalist Data and Identification of Potential Hotspots

Prompted by Anne Parsons' compilation of iNaturalist DOR data, POST requested that we review those data for the period of November 25, 2018 through April 8, 2019 to determine if hotspots (areas of concentrated newt mortality) and hot moments (times of concentrated newt mortality) were apparent during this period. We also compared the data to the record of survey effort provided by Ms. Parsons to determine if these hotspots and hot moments were independent of, or correlated with, the spatial and temporal level of survey effort (i.e., the sections of Alma Bridge Road surveyed and the dates surveyed, respectively).

The DOR data provided geocoordinates, dates, and times of observations of newt carcasses on Alma Bridge Road. Based on these data, we calculated that 4,047 dead newts were detected on the stretch of Alma Bridge Road within the study area during 37 survey days from November 25, 2018 to April 8, 2019. We mapped the geocoordinates in order to observe the distribution of DOR observations. We then divided Alma Bridge Road within the study area into forty-two 0.1-mi sections. We tallied the number of observations per section, then graphed a distribution of sections based on the median number of observations per section. Based on this graph, we color-coded each section based on its distribution of DOR around the median as follows: extremely high (over 300), very high (200-300), high (150-199), medium high (90-149), medium (70-89), low (25-69), and very low (below 25), as illustrated in Figure 2. This figure indicates that two adjacent sections of Alma Bridge Road that span Limekiln Creek between just east of the turnoff to the Lexington Quarry and the Priest Rock Trailhead experienced the highest newt mortality (769 newts killed in both sections combined). This was followed by several adjacent sections of very high, high, and medium high newt mortality both north beyond the turnoff to the Lexington Quarry and south to approximately midway between Limekiln Creek and Soda Springs Creek. A second group of four sections of Alma Bridge Road along the south side of Soda Springs Creek also experienced medium high to very high newt mortality, and finally, two sections south of Soda Springs Creek spanning road feature #10 "White House - Private Residence" experienced medium high newt mortality (Figure 2).

The graph in Figure 3 illustrates the survey effort per stretch as measured by days surveyed as documented by Anne Parsons. The stretch between Limekiln Trailhead and the Priest Rock Trailhead (stretch 3 of Figure 2) was surveyed the most, at 32 days, followed by the stretch between the Priest Rock Trailhead and the Los Gatos Rowing Club (stretch 4), at 30 days. The two stretches that received the least amount of survey effort were between "White House - Private Residence" and the junction with Aldercroft Heights Road (stretches 10 and 11), at 12 days, each.

Comparing Figure 2 with Figure 3 indicated that assessment of newt mortality levels is confounded by unequal survey effort among segments, and that the level of newt mortality detected in various stretches of the road could be a function of survey effort to some extent. For example, the two sections that experienced the highest observed newt mortality were also within two stretches that received high survey effort (e.g., stretch 3 with the most days of survey effort of 32 days), whereas the stretches that received the least days of survey effort of 12 also had the lowest observed newt mortality. Therefore, even though there appeared to be a hotspot of newt mortality from the turnoff to Lexington Quarry to just beyond the Limekiln Trailhead, this may be a result of a more concentrated survey effort along this stretch than at other stretches. With this qualification, there appeared to be a rise in observed newt mortality on the sections along the south side of Soda Springs Creek (Figure 2) that did not correlate with the lower level of survey effort (15 days) for that stretch of road (stretch 9 of Figure 3). We therefore created a second map for which the numbers of DOR observed per section were divided by the number of days those sections were surveyed as a way to better standardize the DOR numbers



N:\Projects4300\4301-01\02\Reports\Newt Mortality Study\Newt Mortality Study.aprx

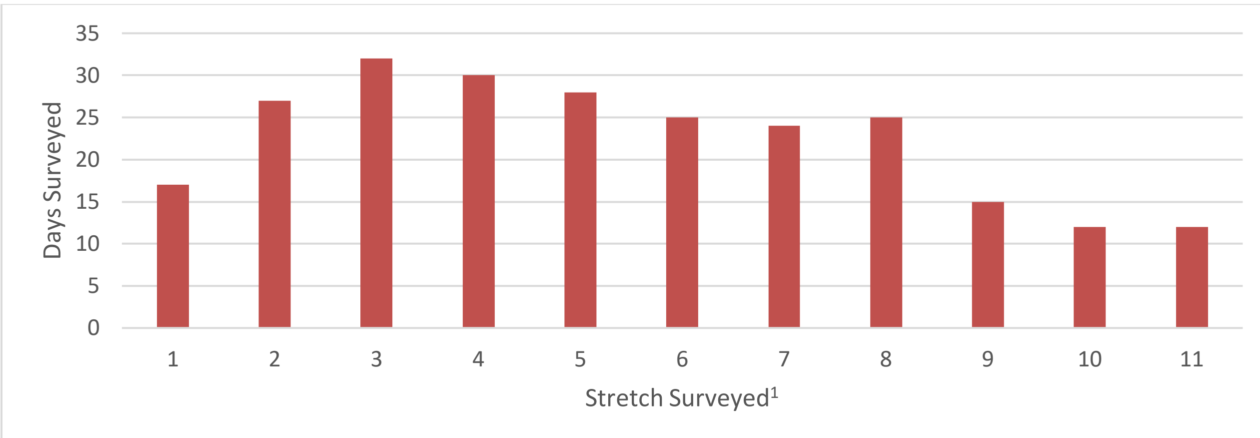
H. T. HARVEY & ASSOCIATES
Ecological Consultants

Figure 2. Level of Newt Mortality (Based on Raw Numbers) - 2019 Analysis

Alma Bridge Road Newt Mortality Study (4301-02)
November 2021

observed (Figure 4). We categorized the sections in terms of number of DOR observed per days surveyed as follows: extremely high (over 14), very high (10-11), high (7-9), medium high (4-6), medium (3), low (2), and very low (0-1). Though similar to Figure 2, this map better shows the possible hotspots of mortality as the section just east of the culvert over Limekiln Creek and the section along the south of Soda Springs Creek where the creek joins the reservoir proper (Figure 4).

Figure 3. Graph of Number of Days Surveyed per Stretch of Alma Bridge Road from Data Received from Anne Parsons (2018-2019).

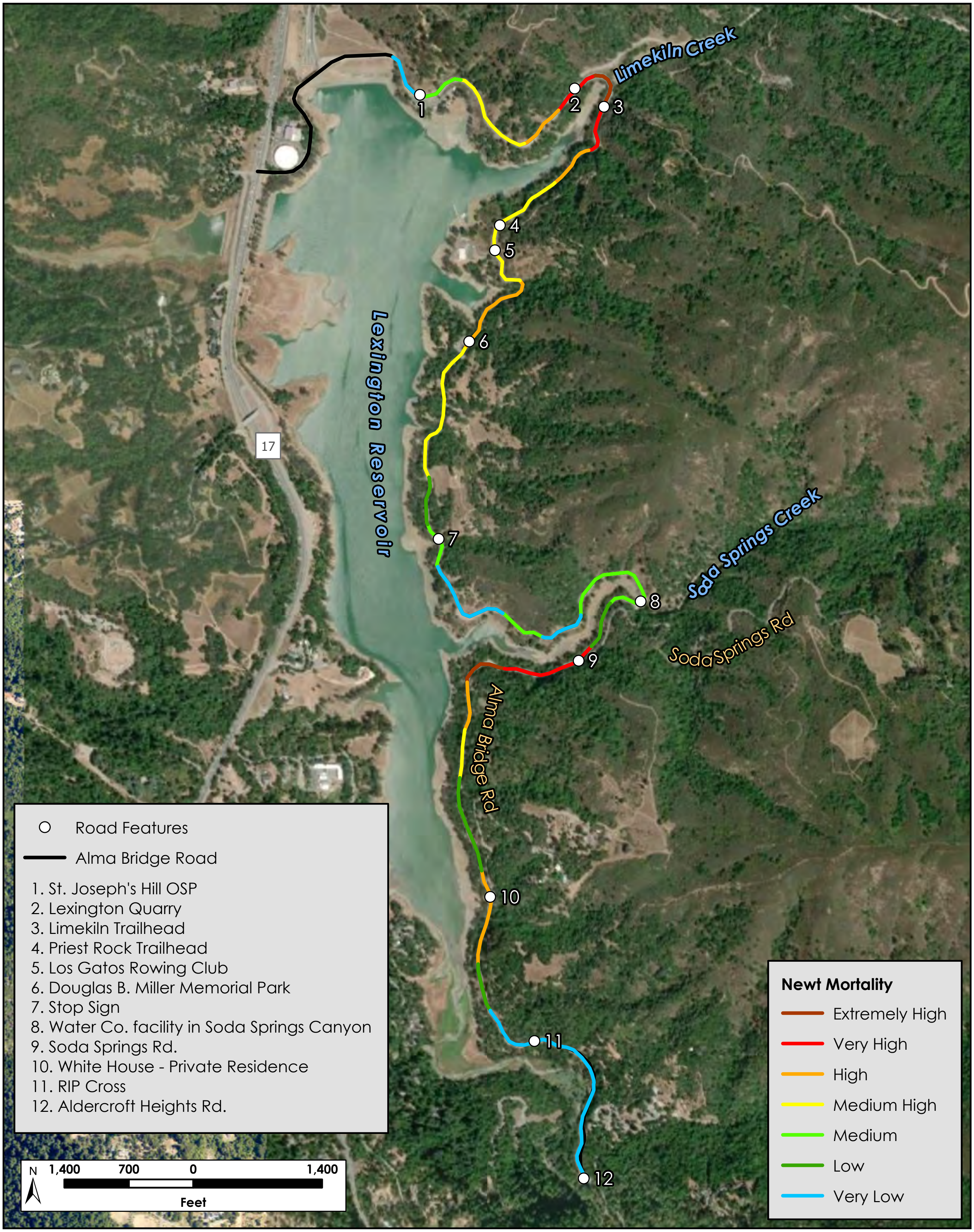


[1] Stretches surveyed from points shown on Figure 1 as follows: 1 = St. Joseph's Hill OSP to Lexington Quarry, 2 = Lexington Quarry to Limekiln Trailhead, 3 = Limekiln Trailhead to Priest Rock Trailhead, 4 = Priest Rock Trailhead to Los Gatos Rowing Club, 5 = Los Gatos Rowing Club to Douglas B. Miller Memorial Point, 6 = Douglas B. Miller Memorial Point to Stop Sign, 7 = Stop Sign to Water Co. facility in Soda Springs Canyon, 8 = Water Co. facility in Soda Springs Canyon to Soda Springs Rd., 9 = Soda Springs Rd. to White House - Private Residence, 10 = White House - Private Residence to RIP Cross, 11 = RIP Cross to Aldercroft Heights Rd.

It was also difficult to determine hot moments of newt mortality beyond general trends (i.e., weekly or monthly totals) because the surveys were not conducted daily but instead varied in their timing, with three surveys conducted the day following the previous survey, nine surveys conducted two days after the previous survey, 10 surveys conducted three days after the previous survey, six surveys conducted four days and five days after the previous survey, three surveys conducted six days after the previous survey, and one survey conducted 13 days after the previous survey. We assume the timing of the surveys coincided with rain events, based on the assumption that more newts would be moving during these events. However, a regular systematic survey effort would have better provided a correlation between dates, times, and weather conditions and newt movement (and non-movement). This being said, observations of DOR were highest in January (1,578) and March (1,510), followed by February (1,122), then December (584); two survey dates, on January 12 and February 2, resulted in the most newt mortality observations in a single survey, with over 440 mortalities on each day. These two dates were either during or following rain events (Anne Parsons pers comm.).

1.1.3 Initial Population Growth Model to Determine Threshold Level

Based on an initial review of the data on newt mortality on Alma Bridge Road, it was unclear whether such mortality was sufficient to pose a risk to the viability of the local newt population. The numbers of DOR newts seemed high, and we assumed the loss of breeding adults would result in a decrease in metamorph recruitment.



N:\Projects4300\4301-01\02\Reports\Newt Mortality Study\Newt Mortality Study.aprx

H. T. HARVEY & ASSOCIATES
Ecological Consultants

Figure 4. Level of Newt Mortality (Standardized by Effort) - 2019 Analysis

Alma Bridge Road Newt Mortality Study (4301-02)
November 2021

However, Alma Bridge Road has been present for 67 years, and while traffic levels have almost certainly increased in recent years/decades, a population of newts has persisted despite road mortality, so the threshold at which such mortality would be great enough to risk long-term population viability was unclear. However, even low levels of road mortality have been shown to reduce population viability in other species (e.g., Row et al. 2007, Winton 2018, Howell and Siegel 2019), and the level of mortality at this location is unusually high in comparison to others in the United States and Europe (e.g., Mazerolle 2004, Coleman et al. 2008, Heigl et al. 2017). Contributing factors include that they are long-lived (12 to >20 years), have delayed sexual maturity (3-5 years), females may not breed every year, they are slow moving, and are required to make long migratory movements (up to over 2 miles) for breeding (Kuchta 2005). In fact, newt species are often the first to disappear in fragmented landscapes (Gibbs 1998, Trenham 1998). We therefore used a model of population growth that incorporated parameters of newt road mortality in order to investigate the impact of this road-related mortality on the local newt population (Gibbs and Shriver 2005).

We identified the parameters and input data that were required to construct this model of population growth to determine the threshold level specific for the population at Alma Bridge Road. Some of the data were available from the literature, but other data would need to be obtained through additional fieldwork or by making assumptions.

The model from Gibbs and Shriver (2005) is $N_{a,t+1} = N_{a,t} * \sigma_a + \sigma_m (K_l - N_{e,t}) K_l * \sigma_j$, where $N_{a,t}$ is the number of adults in the current year, $N_{e,t+1}$ is the number of eggs produced in a given year, σ_a is the adult annual survival rate, σ_m is the survival rate from egg to metamorphosis, σ_j is the survival rate of juveniles through their first winter, and K_l is the carrying capacity of larval habitat.

The number of eggs produced in a given year is calculated as $N_{e,t} = N_{a,t} * \sigma_a \phi_m$, where ϕ_m is the average eggs produced per individual, calculated by multiplying the number of eggs per mass by the number of masses laid per year, and multiplying this number by the breeding probability per year divided by 2 (for both sexes).

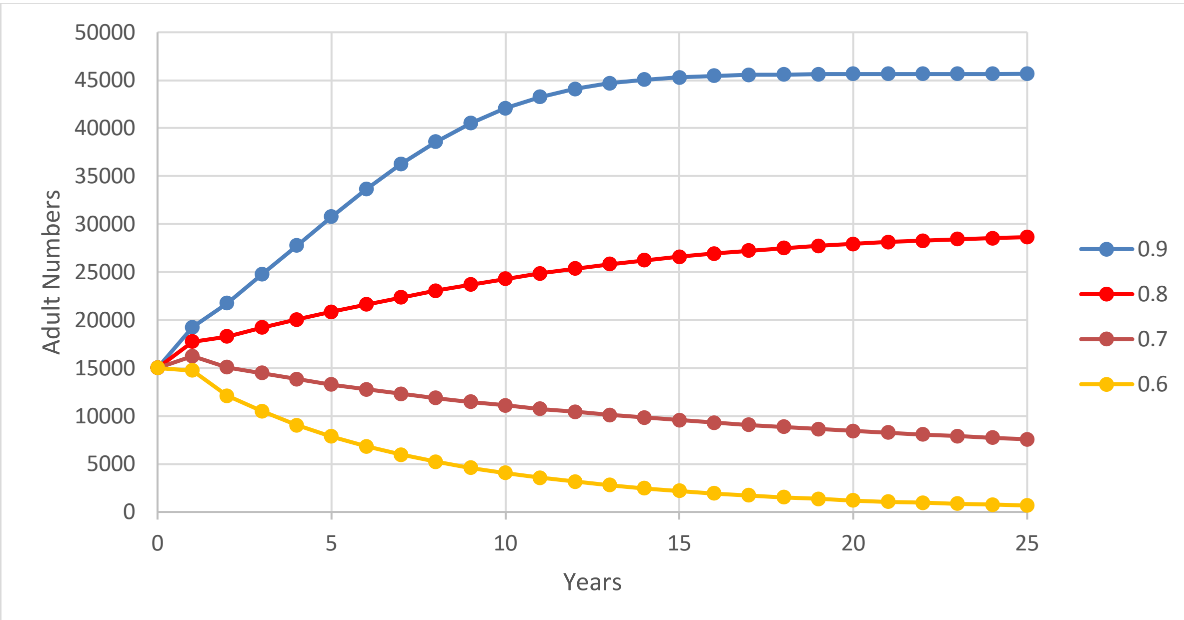
The starting adult population (or current population during a given year) would need to be determined from field work. This may be calculated by conducting a pitfall trap or camera trap study along a section of Alma Bridge Road, calculating the number of newts attempting to breed, and also calculating a ratio of newts successfully crossing the road as opposed to those being killed on the road. From this, a starting average number of eggs ϕ_m can be calculated by multiplying the number of individuals with the average clutch size and the average number of clutches per year. For the California newt, this average number of eggs was not found in the literature; instead the literature provided a range of 7-47 eggs per egg mass, and a range of 3-6 egg masses laid by a female during the breeding season (Brame 1968) and an ovarian count range of 130-160 per female (Thomson et al. 2016). We therefore made the assumption that the average number of egg masses laid is 4.5, with an average number of eggs per egg mass of 32.2, to arrive at a midrange ovarian count of 145. It is also unknown whether females lay eggs every year or skip years; therefore to be conservative, we assumed that they skip years as is documented for the red-bellied newt (Twitty 1961, 1964). Because we were unable to find a previously reported survival rate from egg to metamorphosis in the literature at the time of the analysis, we considered using a proxy of 0.04, as has been provided for other salamander larvae (Petranka 1998). However, we then considered the potential effects of predation by fish. Crayfish and mosquitofish (*Gambusia affinis*) are known to prey on newt larvae (Gamradt and Kats 1996), which do not retain the toxin present in the egg mass after yolk absorption (Twitty and Johnson 1934, Twitty 1937). Fish predators, such as native rainbow trout (*Oncorhynchus mykiss*) and nonnative green sunfish (*Lepomis cyanellus*), have been found in streams devoid of newts, indicating that these fish may exclude newts (Kuchta 2005). These species are present in Lexington Reservoir (https://www.sccgov.org/sites/parks/Activities/Boating-Fishing/Pages/Fishing.aspx), suggesting that the egg-to-metamorphosis survival rate for this population could be lower than 0.04. To be conservative, we halved the 0.04 larval survival rate for other salamander species to 0.02. Also, we could not find the survival rate of juveniles through their first winter from the literature at the time of the analysis, but instead used a proxy of 0.6 based on data from other salamander species (Petranka 1998). The carrying capacity of the reservoir for newts is unknown. Due to the size of the reservoir, one could assume that the carrying capacity is very large (e.g., into the millions of larvae). However, carrying capacity depends on the abundance of aquatic invertebrate food source for the larvae in the reservoir, which may be quite small, as reservoirs are considered less productive than other natural waterbodies of the same size typically due to a limited littoral zone (Moss 2008). Finally, the adult annual survival rate is unknown but may be quite high due of the presence of a skin toxin that prevents or inhibits predation (Brodie et al. 1974). As a proxy, we used 0.9 based on data from the red-bellied newt (Twitty 1961).

We ran a version of the model based on the following parameters for the California newt only, under the assumption that the vast majority of the newts observed DOR were of this species rather than rough-skinned newt:

> Starting Na,t of 15,000 (an arbitrary starting number, which is approximately 3.7 times the number of newts observed killed on Alma Bridge Road in the 2018-2019 breeding season);
>
> Starting number of eggs of 543,375, based on the starting Na,t multiplied by the ϕm, which was calculated as 36.225 by multiplying 32.2 (average clutch size) with 4.5 (average clutches laid per year), and 0.5 (probability of breeding per year), divided by 2 (for the two sexes);
>
> Starting adult annual survival rate of 0.9, without mortality from vehicular strikes when crossing Alma Bridge Road (proxy from red-bellied newt);
>
> Survival rate from egg to metamorphosis of 0.02 (proxy of half of other salamander species in the literature);
>
> Survival rate of juveniles through their first winter of 0.6 (proxy from other salamander species in the literature); and
>
> Carrying capacity of the reservoir as the larval habitat of 2,000,000 (an admittedly speculative number estimated as four times the starting number of eggs).

This model run determined that in the absence of road mortality, the adult number plateaus at 45,665 after 27 years (Figure 5). If the adult annual survival rate is reduced to 0.8 by road mortality, the adult population size plateaus at 29,323 after 74 years. If the survival rate is reduced to 0.7, the adult population size steadily declines to 7,415 by year 25 (Figure 5), to 2,101 by year 200, and may eventually become extirpated. If the adult survival rate is reduced to 0.6, then the adult population drops quickly to 2,094 individuals by year 15 (Figure 5) and is essentially extirpated by year 88. So, a reduction of 10% in survival rate (from 0.9 to 0.8) as a result of road mortality allows for the population to be maintained, but a reduction of 20% results in a steady decline in, and possible extirpation of, the local population based on these parameters.

Figure 5. Population Growth Model with Levels of Adult Survival Rate[1] Due to Road Mortality



[1] 0.9 = adult survival rate in the absence of road mortality, 0.8 – 0.6 = from 10 to 30 percent decrease in adult survival rate due to road mortality.

1.1.4 Additional Information to be derived from Systematic Study

We consider over 4,000 newts killed on Alma Bridge Road in the 2018/2019 breeding season to be a high number. Since our review of the data for the 2018/2019 breeding season, an even higher mortality number (5,294) was recorded by community scientists in the following 2019/2020 breeding season (https://www.inaturalist.org/projects/pacific-newt-roadkill-main-project-lexington-reservoir). However, without a more systematic study allowing for a more accurate estimate of the adult breeding population of both the California newt and rough-skinned newt, proportion of adults successfully crossing Alma Bridge Road to breed, carrying capacity of Lexington Reservoir, and other parameters in the population growth model, we could not confidently predict the effect of this mortality on the local newt population. A better assessment of the impacts of road mortality on this population, preferably for each of the two newt species present, was requested by POST and the Midpeninsula Regional Open Space District (Midpen). Working with POST and Midpen, along with assistance and input from Santa Clara County Parks, Santa Clara County Roads and

Airports, the Santa Clara Valley Water District, U.S. Geological Survey, community scientists, and several volunteers, we conducted a drift fence/pitfall trap array study in an attempt to estimate the number of adult newts of each species attempting to cross Alma Bridge Road to breed in Lexington Reservoir and the percentage that were killed by vehicular strikes during a single breeding season (2020/2021), with the purpose of characterizing this percentage relative to long-term impacts to the local population of each species. The remainder of this report describes that 2020/2021 study, its results, and its implications for population modeling of the Lexington Reservoir newt populations.

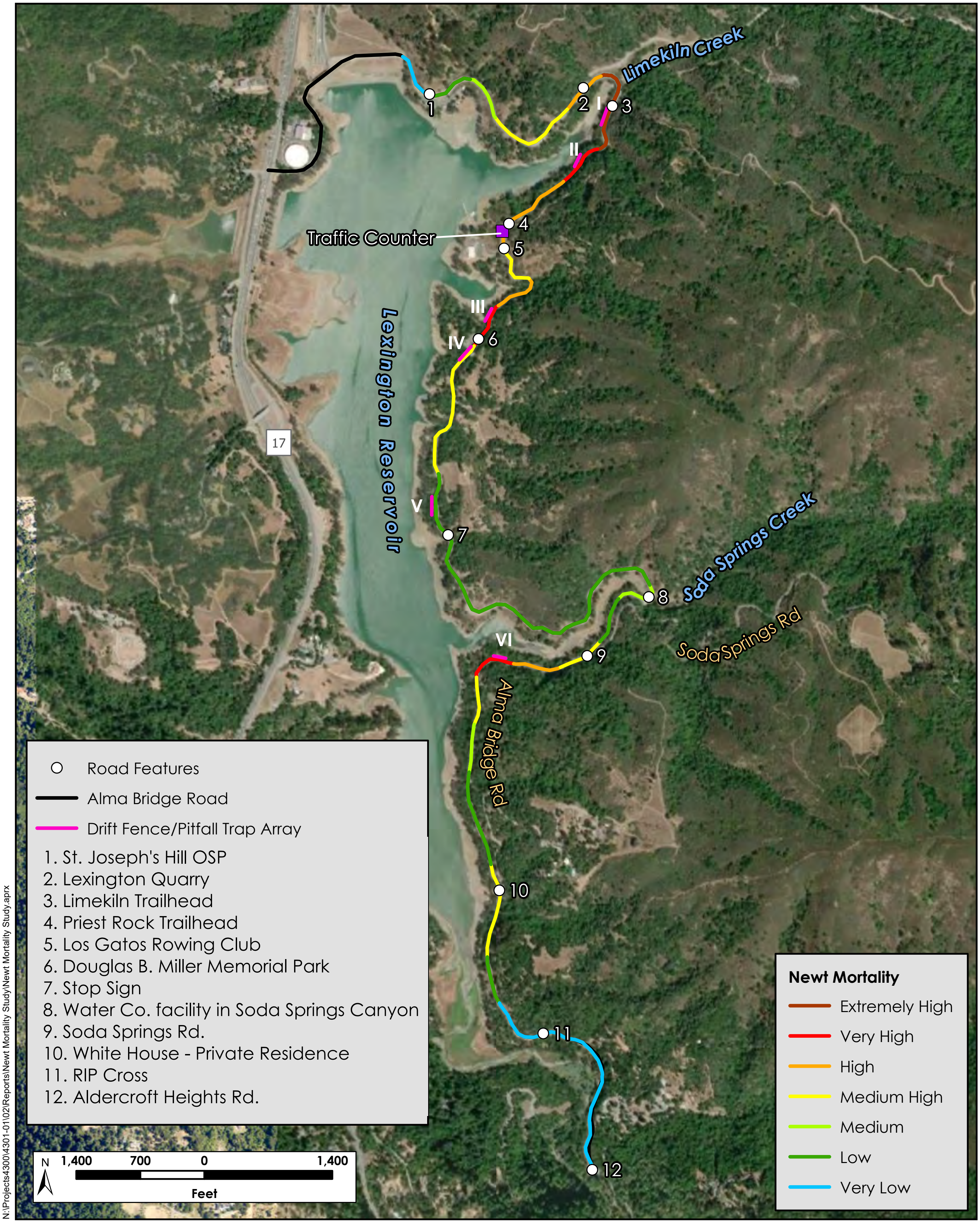
Section 2. Methods

2.1 Drift Fence/Pitfall Trap Array

In late October and early November 2020, with assistance from Santa Clara County Parks staff, we installed six drift fence/pitfall trap arrays at the following locations: I) along a road segment just south of Point 3 (Limekiln Trailhead), which was considered to have extremely high mortality based on the 2019 study; II) along a road segment south of the first array, which was considered to have very high mortality, III) along a road segment just north of Point 6 (Douglas B. Miller Memorial Point), which was also considered to have very high mortality; IV) along a road segment just south of Point 6, which was considered to have medium-high mortality; V) along a road segment just north of Point 7 (stop sign), which was considered to have low mortality; and VI) along a road segment on the south side of Soda Springs Canyon, which was considered to have very high mortality in 2019 (Figure 6). The purpose of placing the arrays along these six road segments was to determine whether the percentage of newts killed versus successfully crossing the road is similar among segments that have varying (extremely high to low) levels of mortality. If these percentages were similar (i.e., similar mortality rates) among the arrays then we would expect to be able to apply an overall mortality rate across the mortality level categories when calculating results for the entire road length using the 2019 DOR data.

In addition, the six arrays are distributed across four spatial blocks (1-2 arrays per block). These blocks were identified to distinguish potential differences in road use by the public and thus differences in traffic volume. Blocks are separated by three destinations along Alma Bridge Road. Block 1 extends from Point 1 (the Saint Joseph Hill OSP trail) to Point 5 (the Los Gatos Rowing Club) and includes the road segments at Arrays I and II; Block 2 extends from Point 5 to Point 6 (the entrance of the Miller Point Parking Lot) and includes the road segment at Array III; Block 3 extends from Point 6 to Point 9 (Soda Springs Road junction) and includes the road segments at Arrays IV and V; and Block 4 extends from Point 9 to Point 12 (the intersection of Alma Bridge Road and Aldercroft Heights Road) and includes the road segment at Array VI (Figure 7). Mortality rates are expected to differ between the four blocks due to differences in various aspects of vehicular traffic including the number of vehicles and the timing of travel with respect to newt activity. For example, we expect that most of the traffic to and from the Los Gatos Rowing club comes from Highway 17, which could cause differences in traffic patterns between Block 1 and the other blocks. Although we did not have differences in traffic volume between blocks, it is likely that they are largely responsible for the between-block differences we detected in newt mortality rates (see below), although other factors might also contribute to the between-block differences.

We placed each array at the downslope (reservoir) side of Alma Bridge Road to intercept and capture newts that moved from the uplands, and that successfully crossed the road, towards the reservoir. The barrier consisted of silt fence buried at least six inches below ground and extending 24 inches above ground. All arrays were initially planned to be of equal length, but due to site-specific limitations (e.g., the lack of a sufficiently



H. T. HARVEY & ASSOCIATES
Ecological Consultants

Figure 6. Array Locations
Alma Bridge Road Newt Mortality Study (4301-02)
November 2021

N:\Projects4300\4301-01\02\Reports\Newt Mortality Study\Newt Mortality Study.aprx

H. T. HARVEY & ASSOCIATES
Ecological Consultants

Figure 7. Spatial Blocks on Alma Bridge Road
Alma Bridge Road Newt Mortality Study (4301-02)
November 2021

wide shoulder in which to construct the arrays), the arrays ranged in length from approximately 130 to 190 ft as follows: Array I at 130 ft, Array II at 190 ft, Array III at 190 ft, Array IV at 170 ft, Array V at 120 ft, and Array VI at 120 ft. We installed a series of paired pitfall traps at each array; at each pair, one trap was on the upslope side (front trap) and the other trap was on the downslope side (back trap) of the array (Photo 3). The outermost pairs of pitfall traps were located 5 ft from the ends of each array, with intervening pairs of traps spaced at 10-ft intervals. There were a total of 24 traps (12 pairs) at Array I, 36 traps (18 pairs) at Arrays II and III, 32 traps (16 pairs) at Array IV, and 22 traps (11 pairs) at Arrays V and VI. This placement was designed to intercept both newts traveling to the reservoir to breed and newts traveling from the reservoir back to the uplands upslope of the road after breeding. The pitfall traps were flush with the array (Photo 4) so that a newt would fall into the trap as it was walking along the array in an attempt to cross to the other side. Each pitfall trap was numbered.

Photo 3. Array V showing pairs of traps on the upslope and downslope side of the array.

Photo 4. Pitfall trap at Array V flush with ground and against the array.

To provide information on vehicular activity within the study area, we also installed a TRAFx vehicle counter (provided by Midpen) on a guard rail post at 37.196278° -121.984222° between Arrays II and III. The counter was able to take hourly counts of vehicles in both directions over the survey period. We received these data from Midpen, who monitored the counter. We tabulated the hourly counts into daily totals corresponding to the periods in which newt observations were tallied (i.e., the 24 hr period from 9 a.m. of the previous day to 9 a.m. of the day of each newt survey).

2.2 Surveys

We began the surveys on November 4, 2020, conducting daily inspections of the arrays and adjacent road segments at the arrays, ending the surveys on March 31, 2021. California and rough-skinned newts breed during the wet season, moving from upland refugia to breeding waterbodies after the fall/winter rains begin and breeding before moving back into upland areas (Stebbins and McGinnis 2012). Therefore, we expected that the period of early November through March would encompass the breeding season for the newts and would allow us to determine the peak(s) of newt movement across the road. During each daily inspection, we inspected each road segment adjacent to an array for newt carcasses, and the road segment 50 ft to the north and 50 ft to the south of the array ("wings"). As a newt carcass was identified on the road, it was photographed, georeferenced, and then removed from the road so that it was not counted subsequently. We did not attempt to identify dead newts to species, sex, or life stage, as this would have been difficult for all newts observed DOR due to the poor condition of most individuals. We conducted the inspections at the same time each morning to standardize results (with a starting time of 9 a.m. at Array I). At each array, after inspecting the adjacent road segment and its "wings", we then inspected the pitfall traps for newts. We counted and categorized each newt (i.e., species, age-class, and sex) in each pitfall trap on the upslope (road) side of the array (front trap) and released the newt to the nearest suitable habitat on the downslope (reservoir) side of the array, under the assumption that newts captured in the front (road side) traps were moving toward the reservoir when they encountered the array. We then repeated this procedure for newts in the pitfall traps on the downslope (reservoir) side of the array (back trap), releasing the newts to the nearest suitable habitat on the upslope side (across the road) under the assumption that these newts were moving away from the reservoir.

We also took daily rainfall data from the National Ocean and Atmospheric Administration Lake Kittridge, CA KDGC1 station, approximately 1.6 mi west of the study area. The period of recorded precipitation associated with a date of newt observations was from 9:15 a.m. of the previous day to 9:00 a.m. of the date of newt survey.

We tabulated data from field data forms onto a spreadsheet; such data included the daily numbers of newts found in each pitfall trap, newts found DOR on the segments at each array, daily traffic volume, and daily rainfall totals.

2.3 Data Analysis

2.3.1 Determining Mortality Rates and Numbers of Adult California Newts Attempting to Cross Alma Bridge Road at Arrays

The main purposes of this study were to determine the influence of road mortality during annual breeding seasons on the mortality rate of breeding adults in the Lexington Reservoir population of each newt species and whether this mortality rate is expected to have an adverse effect on these populations. For this purpose it is important to accurately measure the mortality rates of each species at the arrays and apply them in a statistically rigorous manner to derive overall mortality results for the populations using Lexington Reservoir as a breeding site.

When initially planning this study, we did not know whether community scientist-led surveys for newts DOR would be conducted during the 2020/2021 breeding season. We therefore planned to use the results of the 2018/2019 surveys to help us estimate mortality for this population as a whole, under the assumption that if the ratio of newts killed on the road to total number of newts attempting to cross was similar between the road segments at the arrays, and if these segments were relatively similar in mortality levels to those recorded during the 2018/2019 survey. Then we would be able to extrapolate these ratios to the entire road within the study area. We would also have needed to arrive at a single ratio of newts killed on the road to the total number of newts attempting to cross the road during the breeding migration. We would then include this ratio into the overall mortality rate for the population in a population growth model.

Fortunately, a continuation of the DOR survey since 2017 was conducted by community scientists, and led by Merav Vonshak of San Jose State University, during the 2020/2021 breeding season concurrently with our pitfall trap surveys (https://www.inaturalist.org/projects/pacific-newt-roadkill-main-project-lexington-reservoir). Having newt DOR data from the 2020/2021 breeding season facilitated our study in two ways. First, these data allowed for a comparison between the two seasons (2018/2019 and 2020/2021) to determine whether spatial patterns of mortality (e.g., mortality levels on the same road segments) were similar between years or varied considerably between years. Second, having DOR data from the same year as our study allowed us to combine the 2020/2021 DOR data with our 2020/2021 pitfall trap results to estimate an adult newt breeding number and overall road-based mortality rate of the newts crossing Alma Bridge Road to breed in Lexington Reservoir. The two studies were closely coordinated to avoid duplication of efforts, to avoid double counting of carcasses, and to better inform both studies.

Based on the pitfall trap results (see Section 3) indicating that the vast majority of newts crossing Alma Bridge Road were California newts, we decided to restrict our further analysis to the California newt, even though the rough-skinned newt is also important to consider. Furthermore, we revised our plan of analysis to consider potential differences in mortality rates among different parts of the road (blocks) when calculating the overall mortality rate for the entire road.

Prior to analyzing the data, we made the following assumptions based on our understanding of California newt breeding biology, breeding migration, array position, survey methodology, and model requirements:

1. The potential mortality of juveniles on the road is not so important to the population growth model that they needed to be considered in order to determine the impact of road mortality on the population. The total effect of road mortality on the population can be accurately described by focusing on the road effects on survival of breeding adults (males and females). This assumption is based on the natural history of the juvenile life history stage. California newt larvae metamorphose and leave the aquatic breeding site for the terrestrial environment during the dry season (summer and fall) (Kuchta 2005), likely travelling at night, when temperatures and risk of desiccation are lowest. Traffic levels should also be lower at night, resulting in low risk of vehicular strike for juveniles attempting to cross Alma Bridge Road during the dry season (see Section 3.2). Conversely, adult newts travelling to breeding sites have been observed during both daytime and nighttime hours, primarily during wet months of the year (Stebbins and McGinnis 2012). Our trapping data indicates that relatively few juvenile California newts attempted to cross the road during the 2020/2021 wet season; juvenile captures accounted for only 9% of all California newt captures at the trapping arrays. This runs counter to expectation, based on observations of another drift fence/pit fall trap study result on California tiger salamanders in Alameda County (H. T. Harvey & Associates 2004), where juveniles outnumbered adults in the captures, suggesting that the juveniles we captured represent only a small fraction of the total number of juveniles in the Lexington Reservoir population. The juveniles we captured likely emerged from underground retreats to continue migrating away from the reservoir or forage for prey at the surface. It is assumed that the road mortality of this small component of the juvenile stock is likely to have only negligible effects on the population compared to road mortality of the adults.

2. There are two times during a single breeding season when a breeding adult newt will cross the road. These times are when a breeding adult is traveling to the reservoir from upland areas to breed and then when that individual is traveling back to the uplands from the reservoir post-breeding. We assumed that each individual newt only attempts to cross the road once in each direction per breeding attempt.
3. Adult newts DOR at the arrays or captured in the front (road side) traps were adult newts traveling to the reservoir from the uplands to breed during this breeding season regardless of when observed during the survey period. Conversely, adult newts captured in the back (reservoir side) traps were adult newts traveling from the reservoir to the uplands after breeding either during the previous breeding season or this breeding season. Thus, all adults attempting to cross the road were considered breeding adults.
4. At each array, the mortality rate of individuals attempting to cross the road in the upland-to-reservoir direction, calculated over the entire survey period, is equal across species, life history stages (adult versus juvenile), and sexes, of the two newt species no matter the context. This assumption was necessary because newts DOR often could not be accurately identified to species, life stage, or sex.
5. No newts were killed (during the study period) attempting to cross the road from the reservoir side to the upland side at the arrays, because they were captured in the pitfall traps and then safely transported across the road by the surveyors.
6. At any particular array on a particular day of the survey period, the theoretical mortality rate that would have been experienced by individuals attempting to cross the road in the reservoir-to-upland direction had they not been safely transported across the road by the surveyors is equal across species, life stages, and sexes, and equivalent to the mortality rate of all newts (all species, life stages, and sexes combined) traveling in the opposite direction at that array on that day. This assumption allows us to indirectly estimate mortality rates in the reservoir-to-upland direction using a regression model (the "array" model), which predicts the odds of mortality for newts travelling in the results for the upland-to-reservoir direction at the arrays on each particular day of the study (see Sections 2.3.3 and 3.4.1.2); we assume that the rate for the reservoir-to-upland direction each particular day/array combination is equal to the upland-to-reservoir rate predicted by the model for that day/array. This assumption is logical because we would expect the speed at which newts travel in each direction, and therefore the amount of time each newt spends on the road, to be the same on any particular day regardless of the direction of travel. We also do not expect the time of day in which newts move across the road to differ between newts travelling in opposite directions on any particular day. Therefore, newts traveling in each direction on any one day of the study would have the same probability of being struck by vehicles. However, the model suggests that the mortality rate on any particular day is related to the traffic level (the number of vehicles we detected on Alma Bridge road the day of attempted crossing), day (day number on a continuous numerical scale, independent of traffic level), and block (see Section 3.4.1.2). The model takes into account all three of these factors when making predictions; therefore the model controls for differences in timing and location of road-crossing attempts between the two directions of travel. Because traffic level potentially varied seasonally, and newts travelling in one direction do not necessarily attempt to cross the road at the same time of year as newts travelling in the other direction, overall rates calculated for the entire survey period might differ considerably between the two directions. Our approach accounts for differential risk arising from differences in the timing and

location of road crossing attempts between the two directions of newt travel. A more direct method of measuring mortality rate in the reservoir-to-upland direction was not possible because we did not install trapping arrays on the upland side of the road and we did not allow newts traveling in the reservoir-to-upland direction at the arrays to be killed by traffic.

7. Within each direction of travel, individual crossing attempts are independent events. In other words, the outcome of a newt's crossing attempt is independent of the outcome of any other newt's crossing attempt.

With these assumptions, we calculated the number of adult California newts attempting to cross the road ($A_{at, ur}$) at each array to breed in the reservoir with the following equation:

$$A_{at, ur} = T_{at, ur} + D_{ur} * C_{at, ur} \quad (1)$$

where $T_{at, ur}$ is the number of adult California newts captured in the front traps (traps on the upland side of the array), D_{ur} is the number of newts DOR at the array, and $C_{at, ur}$ is the proportion all newts (including both species, both sexes, and all life stages) captured in the front traps that were adult California newts. This equation applies Assumption 4.

$C_{at, ur}$ is calculated separately for each array using the following equation:

$$C_{at, ur} = T_{at, ur} / (T_{at, ur} + T_{jt, ur} + T_{ag, ur} + T_{jg, ur}) \quad (2)$$

where $T_{jt, ur}$ is the number of juvenile California newts, $T_{ag, ur}$ is the number of adult rough-skinned newts, and $T_{jg, ur}$ is the number of juvenile rough-skinned newts captured in the front traps. We then calculated the survival rate of breeding adult California newts crossing the road at each array to breed in the reservoir ($S_{at, ur}$) with:

$$S_{at, ur} = T_{at, ur} / A_{at, ur} \quad (3)$$

The corresponding mortality rate ($M_{at, ur}$) was calculated thus:

$$M_{at, ur} = 1 - S_{at, ur} \quad (4)$$

The number of adult California newts that died attempting to cross the road in the upland-to-reservoir direction ($D_{at, ur}$) was estimated as:

$$D_{at, ur} = M_{at, ur} * A_{at, ur} \quad (5)$$

We were able to directly calculate the number of adult California newts attempting to cross the road in the reservoir-to-upland direction after breeding in the reservoir ($A_{at, ru}$) at each array by totaling the number of adult California newts captured in the back traps (traps on the reservoir side of the array) over the entire survey period. However, because the arrays prevented newts from crossing the road at the arrays, and surveyors transported newts captured in the back traps across the road, we used an indirect method to calculate the mortality rate of adult California newts crossing the road after breeding in the reservoir as follows.

We first divided the survey period into 144 one-day periods; as described above, this was done to control for potential differences in mortality rate between directions arising from daily variation in traffic levels and differential timing and location of newt movement between the two directions. Although the survey period lasted 148 days (21 weeks and one day), we excluded the first four days because traffic counts necessary for the regression modeling of newt mortality did not begin until the fifth day, and no newts were observed in the traps or on the road at the arrays during the initial four-day period. Each one-day period began after the morning check and lasted to the end of the morning check on the following day.

For each combination of day and array, we obtained a prediction of the mortality rate of all newts (all species, life stages, and sexes) attempting to cross the road in the upland-to-reservoir direction on that particular day at that particular array ($M_{\mathrm{d,\,ur}}$) using the array model (see Sections 2.3.2 and 3.4.1.2).

We then applied Assumption 6, wherein we assumed that the mortality rate for adult California newts attempting to cross the road at an array in the reservoir-to-upland direction on a particular day ($M_{\mathrm{d,\,ru}}$) would be equal to $M_{\mathrm{d,\,ur}}$ (the mortality rate predicted by the array model for that particular array on that particular day). Next, for each day/array combination, we multiplied the number of adult California newts captured in the back traps by the appropriate $M_{\mathrm{d,\,ru}}$ value to estimate how many would have been killed on that part of the road that day if the array was not present (i.e., "rescued" adult California newts). For day/array combinations in which no adult California newts were captured in the back traps, the number of rescued adult California newts was zero.

For each array, we summed the number of "rescued" adult California newts across all 144 day periods to derive the total number of "rescued" adult California newts ($R_{\mathrm{at,\,ru}}$). We then calculated the estimated mortality rate for the array over the study period for the reservoir-to-upland direction ($M_{\mathrm{at,\,ru}}$) by dividing $R_{\mathrm{at,\,ru}}$ by the total number adult California newts attempting to cross the road in that direction (total number of adult California newts captured in the back traps) ($A_{\mathrm{at,\,ru}}$).

2.3.2 Statistical Modeling of Array Mortality Rates

We used logistic regression to investigate factors potentially associated with mortality of newts attempting to cross the road at the arrays and build an "array" model of road mortality in the upland-to-reservoir direction based on direct observations. We then used the array model to obtain day- and block-specific mortality rates, which we used to estimate the number of "rescued" adult California newts that would have died attempting to cross in the reservoir-to-upland direction at the arrays if they had not been safely transported across the road (see Section 2.3.1). Furthermore, we used the array results, combined with the community-scientist data from the same season (2020/2021), to estimate the number of adult California newts attempting to cross Alma Bridge Road in the entire study area when migrating to Lexington Reservoir to breed and the number killed during this breeding migration to, and the reverse migration from, Lexington Reservoir due to vehicular strikes.

Because the arrays represent only a portion of Alma Bridge Road, we used the logistic regression results to select the best approach for applying the array-based mortality rates to the other parts of the road. Although our study is focused on adult California newts, the logistic regression analyses were performed using data from all newts, including juvenile California newts as well as adult and juvenile rough-skinned newts. This approach follows Assumptions 4 and 6 and maximizes the sample sizes and statistical power of the regressions to detect factors that predict road mortality.

The logistic regression analyses investigated array mortality rates separately for each direction (newts moving to and from the reservoir) and tested whether the probability of mortality from vehicular strike for newts attempting to cross the road was associated with several environmental factors: block, day, number of vehicles counted on Alma Bridge Road that day, amount of precipitation that day, vegetation, slope, and aspect in the array immediately adjacent to the road. We reasoned that the probability of mortality could potentially depend on environmental conditions experienced by migrating newts immediately before they attempt to cross the road, as well as variation in traffic patterns between days and among the four spatial blocks. We measured the number of vehicles at one location on Alma Bridge Road (the traffic counter in Block 1). Thus, the actual number of vehicles at the other blocks is probably different than the number of vehicles counted at Block 1. However, any differences in probability of mortality resulting from variation in the number of vehicles across blocks would be controlled for by our inclusion of the block factor in the logistic regression. We also included day per se (day number) in the analyses because probability of mortality might also vary seasonally, independent of traffic level and block. For example, newts might experience a lower risk of mortality when crossing the road later in the year, all else (daily number of vehicles, block, etc.) being equal, if the warmer temperatures and drier ground conditions later in the season cause them to shift their movements to nighttime hours when vehicle traffic is lighter. We further reasoned that consideration of statistically significant predictors of mortality would increase the accuracy of mortality rate estimates for the entire road (whole-road estimates for each direction of travel) compared to a simpler but less ecological realistic approach that assumes constant mortality rates over the entire road (a constant rate for each direction). The regression results for the upland-to-reservoir direction were used to make predictions of mortality rate for each array on each day of the study, which were used to estimate mortality rates and number of "rescued" adult California newts for upland-to-reservoir direction as describe above (see Section 2.3.1). Thus, the dependent variable in the dataset used for the reservoir-to-upland model direction is based, in part, on the results of the upland-to-reservoir regression. Nevertheless, we include a regression analyses of the reservoir-to-upland direction because differential timing of newt movements in the reservoir-to-upland direction relative to the other direction might influence which independent variables are statistically significant predictors of mortality.

To perform logistic regression we built separate binomial data sets for each direction of travel, including an outcome of "died" or "survived" for each newt attempting to cross the road. For the upland-to-reservoir direction, the number of newts (all species, life stages, and sexes) successfully crossing the road and the number attempting to cross the road in that direction at each array were defined as T_{ur} and A_{ur}, respectively. T_{ur} was measured directly (it is the sum of all newt captures in the front traps of the array) and A_{ur} was calculated by adding the number of newts observed DOR at the array to T_{ur}. T_{ur} and A_{ur} represent array-specific totals across the entire study period and were used to produce a binomial database consisting of a "survived" or "died" outcome for all newts attempting to cross in the upland-to-reservoir direction across all six arrays.

For the reservoir-to-upland direction, we analyzed the probability of mortality that newts (all species, life stages, and sexes) would have experienced had they not been transported across the road by the surveyors. This analysis is necessary to investigate the factors associated with our estimates of mortality in the reservoir-to-upland direction and, ultimately, apply the results to the non-array areas of the road where some newts travelling in the reservoir-to-upland direction are killed by traffic. For each array, the number of newts (all species, life stages, and sexes) attempting to cross in this direction and the number that would have successfully crossed without intervention by the surveyors were defined as A_{ru} and 1 - R_{ru}, respectively. A_{ru} was calculated as the sum of all newt captures in the back traps of the array. R_{ru} (the number of "rescued" newts, including all species, life stages, and sexes) was calculated in the same manner as $R_{at,\,ru}$ (see Section 2.3.1.), except that all newts were considered, not just adult California newts. Specifically, we applied Assumption 6 to set the mortality rate for all newts attempting to cross the road at an array in the reservoir-to-upland direction ($M_{d,\,ru}$) equal to $M_{d,\,ur}$ (the mortality rate predicted by the array model for that particular array on that particular day). Next, for each day/array combination, we multiplied the number of newts (all newts) captured in the back traps by the appropriate $M_{d,\,ru}$ value to estimate how many would have been killed on the road that day on that part of the road if the array was not present (i.e., "rescued" newts). For day/array combinations in which no newts were captured in the back traps, the number of rescued newts was zero. For each array, we summed the number of "rescued" adult newts across all 144 days to derive the total number of "rescued" adult newts (R_{ru}). Because logistic regression requires discrete units of replication (also known as experimental units), we rounded our estimates of R_{ru} to the nearest whole number. A_{ru} and R_{ur} and represent array-specific totals across the entire study period and were used to produce a binomial database consisting of a "survived" or "died" outcome for all newts attempting to cross in the reservoir-to-upland direction across all six arrays.

Next, for each array, we drew three polygons adjacent to the road: (1) one polygon adjacent to the downslope (reservoir) side of the road and extending 82 feet (ft) (25 meters [m]) towards the reservoir; (2) one polygon adjacent to the upslope side of the road and extending 82 ft away from the reservoir (small upslope polygon); and (3) one polygon adjacent to the upslope side of the road and extending 164 ft (50 m) away from the reservoir (large upslope polygon) (Figure 8). Polygons of two sizes were created on the upslope side to allow consideration of a small or large area of environmental influence on probability of mortality. Only one size of polygon was used on the downslope side because at some arrays the reservoir itself occupies most of the area more than 82 ft downhill from the road. The polygons were "squared-off" with lines perpendicular to the road and passing through the array endpoints. For each polygon, we measured cover of three variables involving vegetative cover using aerial imagery from September 26, 2020, supplemented with aerial imagery from May 9, 2018 when shadows in the more recent images obscured vegetation (Google 2021): percent cover of canopy (trees and shrubs), percent cover of uncanopied grassland, and percent cover of uncanopied bare ground. Average slope and average aspect (rounded to the nearest 8-point compass direction – north, northeast, east, southeast, south, southwest, west, or northwest) were also measured for each polygon using a 10-meter digital

N:\Projects4300\4301-01\Reports\Newt Mortality Study\Newt Mortality Study.aprx

Figure 8. Polygons at Each Array Alma Bridge Road Newt Mortality Study (4301-02)
November 2021

H. T. HARVEY & ASSOCIATES
Ecological Consultants

elevation model (U.S. Geological Survey 2021). However, for each set of polygons (downslope, small upslope, and large upslope), percent cover of bare ground and percent cover of canopy were strongly, negatively correlated (Pearson correlation coefficient less than -0.7). Therefore we excluded the bare ground variables to prevent confounding of independent variables during regression.

For the reservoir-to-upland direction, we first tested for differences in probability of mortality between blocks using a simple logistic regression model (block-only model). Significance of the block term was tested using a maximum likelihood ratio test. Next, we tested for the potential influence of block and other environmental variables (day, vehicles (number of vehicles recorded that day), precipitation (amount of precipitation recorded that day), percent cover of uncanopied grassland, percent cover of canopy, average slope, and average aspect in the downslope polygon). Because percent cover of uncanopied grassland, percent cover of canopy, average slope, and average aspect were confounded with block, they were initially excluded. We then performed a stepwise backward elimination procedure, starting with a full model containing block, day, vehicles, and precipitation. At each step, we evaluated the significance of independent variables using maximum likelihood ratio tests (with χ^2 as the test statistic), and if any variables were not statistically significant ($p > 0.05$), we eliminated the variable with the highest *p*-value. The procedure ended once all nonsignificant variables were eliminated, resulting in the "complex model". We then repeated the stepwise backward elimination procedure, this time excluding block and starting with a full model containing day, vehicles, and precipitation, percent cover of uncanopied grassland, percent cover of canopy, average slope, and average aspect. The resulting "non-block model", the complex model, the block-only model, and a null model of constant odds probability of mortality were then compared using the Akaike information criterion (AIC), with a penalty of 2 for each parameter (independent variable), to inform ultimate model selection. Differences in AIC value (ΔAIC) of 2, the standard benchmark for distinguishing models of differing quality, was used to rank models according to their value for predicting mortality rates (lower AIC values connote greater predictive value).

For the upland-to-reservoir direction, we used the same block-only logistic regression and stepwise backward elimination procedures, except that we adjusted our investigation of vegetation (percent cover of uncanopied grassland, percent cover of canopy) and topographic (average slope and average aspect) variables. Instead of using a single full model to investigate the potential influence of these variables to derive a non-block model, we built two separate full models, one including vegetation and topographic variables for the small upslope polygons and one including these variables for the large polygons, resulting in two different non-block models. This dual approach was used because we did not know *a priori* which size of polygon was best for examining the potential influence of the vegetation and topographic variables. For each set of polygons (small and large), percent cover of uncanopied grassland was strongly correlated with other variables (Pearson correlation coefficient greater than 0.7 or less than -0.7) and thus was excluded to prevent confounding of independent variables in the regression. The resulting non-block, complex, block-only model, and null models were then compared using the AIC to inform ultimate model selection as above. The model with the lowest AIC value was selected as the "array model" and was used to estimate mortality rates for adult newts traveling in the reservoir-to-upland direction (see Sections 2.3.1 and 2.3.3) and to build the binomial dataset for that direction.

2.3.3 Determining Mortality Rates and Numbers of Adult California Newts Attempting to Cross Alma Bridge Road in the Entire Study Area

We used the array results, combined with the community-scientist data from the same season (2020/2021), to estimate the number of adult California newts attempting to cross Alma Bridge Road in the entire study area when migrating to Lexington Reservoir to breed and the number killed during this breeding migration to, and the reverse migration from, Lexington Reservoir due to vehicular strikes. Because the arrays represent only a portion of Alma Bridge Road, we employed a statistical analysis to (1) investigate factors potentially associated with mortality of California newts attempting to cross the road at the arrays, and (2) select the best approach for applying the array-based mortality rates to the other parts of the road.

2.3.3.1 Calculation of Overall Results

We estimated overall, whole-road mortality rates for adult California newts attempting to cross Alma Bridge Road in each direction and the number of adult California newts attempting to breed by combining array results (reported in Section 3.3) with the results of community-scientist observations of DOR newts in road areas outside of the arrays. Based on the analysis of array mortality rates, the complex and non-block models were selected for describing mortality of newts attempting to cross the road in the upland-to-reservoir and reservoir-to-upland directions, respectively, in preference over the other models, including null models of constant risk of mortality (see Section 3.4.1). Ideally, we would apply the complex and non-block models to the community-scientist observations to estimate mortality rates for the non-array road areas. However, this approach was impossible because both models included day and number of vehicles (a daily count) as explanatory variables, but these variables are absent from the community-scientist dataset, as their observations were not made every day. Thus, we applied the block-only models, which outperformed the non-block models and did not require day or daily number of vehicles as model inputs (see Section 3.4.1).

We applied the block-only models to estimate mortality rates in road areas outside of the arrays by using mortality rates that were specific to block as well as the newts' direction of travel (see Section 2.3.1). For blocks 2 and 4, each of which contained only one array, $M_{\text{at, ur}}$ and $M_{\text{at, ru}}$ (see Section 2.3.1) were used as the mortality rates for the upland-to-reservoir and reservoir-to upland directions, respectively. For blocks that contained two arrays, the mortality rate in the upland-to-reservoir direction for the block ($M_{\text{at, ur, b}}$) was calculated by combining the results from both arrays according to the following equation:

$$M_{\text{at, ur, b}} = (D_{\text{at, ur, a1}} + D_{\text{at, ur, a2}}) \ / \ (A_{\text{at, ur, a1}} + A_{\text{at, ur, a2}}) \qquad (6)$$

where $D_{\text{at, ur, a1}}$ is the estimated number of adult California newts that died attempting to cross the road at the first array, $D_{\text{at, ur, a2}}$ is the estimated number of adult California newts that died attempting to cross the road at the second array, $A_{\text{at, ur, a1}}$ is the estimated number of adult California newts that died attempted to cross the road at the first array, and $A_{\text{at, ur, a2}}$ is the estimated number of adult California newts that died attempted to cross the road at the second array (all variables are for the upland-to-reservoir direction).

Similarly, for newts traveling in the reservoir-to-upland direction, the mortality rate for blocks that contained two arrays ($M_{at, ru, b}$) was calculated by combining the results from both arrays as follows:

$$M_{at, ru, b} = (R_{at, ru, a1} + R_{at, ru, a2}) / (A_{at, ru, a1} + A_{at, ru, a2}) \quad (7)$$

where $R_{at, ru, a1}$ is the number of "rescued" adult California newts for the first array, $R_{at, ru, a2}$ is the number of "rescued" adult California newts for the second array, $A_{at, ur, a1}$ is the number of adult California newts attempting to cross the road at the first array, and $A_{at, ur, a2}$ is the number of adult California newts attempting to cross the road at the second array (all variables are for reservoir-to-upland direction).

We used the iNaturalist data of DOR detections during the 2020/2021 survey period in combination with the block-specific and direction-specific mortality rates to estimate the number of adult California newts that attempted to cross the road, as well as the number that succeeded and the number that died in the attempt, for each direction of travel, in the areas located outside of the arrays. However, due to the condition of many newts DOR and the lack of information on their direction of travel, many of these newts DOR (including those in the iNaturalist data as well as the DOR survey data collected for our study) could not be identified to species or life stage reliably, nor could their direction of travel be determined reliably. Therefore, use of iNaturalist data to derive estimates specific to adult California newts traveling in a specific direction required the following additional assumptions about the composition (species and life stage) and direction of travel of newts DOR:

8. The proportion of newts DOR outside of arrays that were adult California newts traveling in the upland-to-reservoir direction ($C_{m, ur}$) (as opposed rough-skinned newts, juvenile California newts, or adult California newts travelling in the other direction) was homogenous across all non-array areas of the road and equal to the average of $C_{m, at, ur}$ across n = 6 arrays, where $C_{m, at, ur}$ at each array is the proportion of all dead or rescued newts (including all species, life stage, and sexes) that were adult California newts traveling in the upland-to-reservoir direction (see Appendix A-1, which describes the series of equations used to calculate $C_{m, at, ur}$).
9. The proportion of newts DOR outside of arrays that were adult California newts traveling in the reservoir-to-upland direction ($C_{m, ru}$) (as opposed to rough-skinned newts, juvenile California newts, or adult California newts travelling in the other direction) was homogenous across all non-array areas of the road and equal to the average of $C_{m, at, ru}$ across n = 6 arrays, where $C_{m, at, ru}$ at each array is the proportion of all dead or rescued newts (including all species, life stage, and sexes) that were adult California newts traveling in the reservoir-to-upland direction (see Appendix A-1, which includes the series of equations used to calculate $C_{m, at, ru}$).

Prior to using the iNaturalist data, we snapped each data point representing the locality of an individual DOR observation to the nearest center line of the road. This was necessary because even though a majority of the data points were within the width of the road, the geocoordinates for many data points were several feet from the road in the nearby uplands even though they were clearly from the road based on the accompanying photos. We also excluded the array sections of the road from the iNaturalist data, because community-scientist counts of DOR newts were affected by a study artifact (i.e., the other, array-based surveyors removed DOR newts at the arrays every morning). Because array-based surveyors also removed DOR newts in the "wing" sections (50 ft before and after each array), we also used the array-based surveyor counts, rather than iNaturalist data, for the wing sections. Nevertheless, the wings were located in non-array areas of the road and thus the wing counts were added to the iNaturalist data from non-array road segments outside the wings to derive the total number of DOR newts in non-array areas.

We then applied $C_{m, ur}$ (the proportion of newts DOR outside of arrays that were adult California newts traveling in the upland-to-reservoir direction; see Assumption 8 above) and $C_{m, ru}$ (the proportion of newts DOR outside of arrays that were adult California newts traveling in the reservoir-to-upland direction; see Assumption 9 above) to estimate, for each block, the number of adult California newts that died attempting to cross the road *outside of the arrays* in each direction, using the following equations:

$$D_{at, ur, na} = D_{b, na} * C_{ur} \quad (8)$$

$$D_{at, ru, na} = D_{b, na} * C_{ru} \quad (9)$$

where $D_{at, ur, na}$ is the estimated number of adult California newts that died while crossing the road in the upland-to-reservoir direction, $D_{b, na}$ is the number of dead newts (all species, life stages, and sexes) found on the road outside of the arrays, and $D_{at, ru, na}$ is the estimated number of adult California newts that died while crossing the road in the reservoir-to-upland direction (all variables are specific to the particular block).

Using these DOR estimates ($D_{at, ur, na}$ and $D_{at, ru, na}$), and block- and direction-specific mortality rates, we calculated, for each block, the number of adult California newts that attempted to cross the road *outside of the arrays* in each direction according to the following:

$$A_{at, ur, na} = D_{at, ur, na} \ / \ M_{at, ur, b} \quad (10)$$

$$A_{at, ru, na} = D_{at, ur, na} \ / \ M_{at, ru, b} \quad (11)$$

where $A_{at, ur, na}$ is the estimated number of adult California newts that attempted to cross the road in the upland-to-reservoir direction, $M_{at, ur, b}$ is the block-specific mortality rate for newts attempting to cross the road in the upland-to-reservoir direction, $A_{at, ru, na}$ is the estimated number of adult California newts that attempted to cross the road in the reservoir-to-upland direction, and $M_{at, ru, b}$ is the block-specific mortality rate for newts attempting to cross the road in the reservoir-to-upland direction (all variables are specific to the particular block).

Then, for each direction of newt travel, we totaled the array and non-array estimates of dead and "rescued" adult California newts across all four blocks to obtain an entire-road estimate of overall adult California newts that died on the road. Thus, "rescued" adult California newts were counted as dead, in order to best estimate what the overall mortality would have been without intervention. We also, for each direction of newt travel, totaled the array and non-array results for number of adult California newts attempting to cross the road across all four blocks. We then calculated an overall mortality rate and an overall survival rate (1 – overall mortality rate) for each direction of newt travel from the entire-road estimates of the number of adult California newts that died on the road and the number that attempted to cross the road. The overall mortality rate for the 2020/2021 breeding season was calculated by subtracting the product of the survival rates in each direction from one.

We then applied the estimated number of adult California newts attempting to cross Alma Bridge Road in the upland-to-reservoir direction in order to breed in Lexington Reservoir and the overall mortality rate as two parameters from this study to be used in the aforementioned population growth model under the following assumption:

10. The local population of California newts that reside in the upland habitat at Lexington Reservoir consists of individuals that exclusively breed in Lexington Reservoir and are required to cross Alma Bridge Road in order to breed.

In reality, our study area only included Alma Bridge Road, and therefore our quantitative analyses only include the newts that reside in the upland habitat east of Lexington Reservoir, breed exclusively in Lexington Reservoir, and must cross Alma Bridge Road in order to breed. We acknowledge that some newts breeding in the reservoir may use upland habitat to the southwest (e.g., south of the reservoir or between the reservoir and Highway 17). It is also our understanding that the extension of Lexington Reservoir in Lindon Canyon west of Highway 17 is not freely connected to the reservoir proper under Highway 17 but instead water between this extension and the reservoir proper must pass through a high-water Lexington Culvert under the highway north of Black Road that would restrict adult newts and preclude larval newts from freely crossing under Highway 17 between the extension and the reservoir proper. Therefore, due to residential development southwest of the reservoir and the presence of Highway 17 (a barrier to newt dispersal) to the west, it is our opinion that population dynamics in Lexington Reservoir as a whole are driven primarily by the newts that were explicitly included in our study. Therefore, our references to "population" in this report refer interchangeably to the group of newts that were explicitly included in our study and the overall population breeding in the reservoir, even though our analysis only included those that cross Alma Bridge Road.

2.3.4 Projecting the Impact of Road-Based Mortality on the Lexington Reservoir California Newt Population using a Population Growth Model

After performing our initial model runs and preparing a draft of this report, we obtained feedback from project partners suggesting that we consider using the parameters in the Jones et al. (2017) study on California newt population dynamics for populations in southern California in our model. As a result, we updated our values for the parameters in the Gibbs and Shriver (2005) model (see Section 1.1.3) by examining this study by Jones et al. (2017). This study used an adult California newt survival rate of 91% based on a study on red-bellied newts by Twitty (1966), a survival rate of 2.5% from egg to metamorphosis based on a study on tiger salamanders (*Ambystoma tigrinum*) by Sever et al. (1986), and calculated a higher annual juvenile survival rate of 79.17% from the results of their study. Therefore, we updated the adult California newt survival rate (σa) from 90% to 91%, the egg to metamorphosis survival rate (σm) from 2% to 2.5%, and the juvenile survival rate (σj) from 60% to 79.17%.

The Jones et al. (2017) study also used a much lower average of 60 eggs (24 eggs in 2.5 egg masses) laid per female during a breeding season. They base this average 60 eggs laid per female on Kats et al. (2013) who state in the introduction that "after breeding, female newts remain in the streams to deposit small (2-3 cm diameter, 15-30 embryos each) egg masses…"; and on Brame (1968) who referenced Ritter (1897) stating that the average number of eggs produced at any one laying… "seems to be about sixty for each female, these being distributed in three or four of the masses". Yet, Brame in the same study observed one female laying six egg masses, with an average of 22.1 eggs per mass for a total of 133 eggs, and suggested that his higher counts may reflect differences in geographic regions between his observations and those of Ritter. We however, consider our average of 145 eggs (32.2 eggs per 4.5 egg masses) to be a better indicator of average number of eggs laid by females based on an egg mass range of 3-6 egg masses and an ovarian count range of 130-160 per female as provided in Thomson et al. (2016). Therefore, we kept our average number of 145 eggs per female instead of the much lower 60 eggs per female.

Jones et al. (2017) also suggested that females migrate to breeding sites annually and breed through most of their adult lives. However, Thomson et al. (2016) state that it is unknown whether females breed every year or skip years, and Stebbins and McGinnis (2012) state that "individual newts probably do not breed every year". Therefore, to be conservative, we decided to keep our value for this parameter of females breeding every other year instead of annually until more information becomes available.

We then used the number of adult California newts attempting to cross the road in the upland-to-reservoir direction as the number of adults in the current year (Na,t), and an adult survival rate calculated by subtracting the overall road-based mortality rate (see Section 3.4.2) from the adult survival rate (91%) as the parameters in the population growth model of Gibbs and Shriver (2005).

Finally, we recalculated a juvenile survival rate by subtracting the road-based mortality rate in the reservoir to upland direction (see Section 3.4.2) from the aforementioned juvenile survival rate of 79.17% under the following assumption:

11. A juvenile newt will cross the road at least once when dispersing back to the upland from the reservoir after metamorphosis.

Section 3. Results

We captured a total of 2,302 newts in the pit fall traps: 1,333 newts in the upslope or road side (front) traps, and 969 newts in the downslope or reservoir side (back) traps. We also counted 376 newts DOR at the arrays and an additional 402 newts DOR at the wings. Of the newts captured in the traps, 2,256 (98%) were California newts and 45 (2%) were rough-skinned newts. Of the California newts captured, 956 (42%) were adult males, 1,098 (49%) were adult females, and 202 (9%) were juveniles (individuals that were under 2.5 inches total length and lacked breeding adult characteristics such as smooth skin and flattened tail in both sexes, and enlarged tailfin, swollen cloaca, and nuptial pads on finger tips in males). Of the rough-skinned newts captured, 18 (40%) were adult males, 20 (44%) were adult females, and 8 (16%) were juveniles. A breakdown of the numbers of newts observed DOR and captured at each array is provided in Table 1.

Table 1. Number of Newts Captured and Observed DOR at Arrays.

	Front (Road Side) Traps						Back (Reservoir Side) Traps								
	TT			TG			TT			TG			DOR		
Array	**M**	**F**	**J**	**M**	**F**	**J**	**M**	**F**	**J**	**M**	**F**	**J**	**Array**	**W1**	**W2**
I	160	83	18	6	2	0	38	75	10	1	3	1	92	61	84
II	121	126	25	5	2	0	75	171	22	0	2	2	92	38	31
III	209	164	34	3	9	0	94	173	53	0	0	0	91	27	26
IV	85	45	13	1	0	0	28	37	8	0	0	0	47	16	23
V	18	30	0	0	0	0	14	30	3	0	0	0	12	11	5
VI	81	82	5	1	2	3	33	82	11	1	0	2	42	36	44
Total	**674**	**530**	**95**	**16**	**15**	**3**	**282**	**568**	**107**	**2**	**5**	**5**	**376**	**189**	**213**

TT = *Taricha torosa* (California newt), TG = *Taricha granulosa* (rough-skinned newt), M = male, F = female, J = juvenile, DOR = dead on road, W1 = north wing, W2 = south wing at each array.

Because the arrays differed in length, we standardized the results for each array by multiplying the number of individuals capture at that array and DOR at that array by 190 (the length of the longest array in feet) divided by the length of the target array. These standardized numbers are provided in Table 2.

Table 2. Standardized Numbers of Newts Captured and Observed DOR at Arrays.

	Front (Road Side) Traps						Back (Reservoir Side) Traps								
	TT			TG			TT			TG			DOR		
Array	**M**	**F**	**J**	**M**	**F**	**J**	**M**	**F**	**J**	**M**	**F**	**J**	**Array**	**W1**	**W2**
I	234	121	26	9	3	0	56	110	15	1	4	1	134	89	123
II	121	126	25	5	2	0	75	171	22	0	2	2	92	38	31
III	209	164	34	3	9	0	94	173	53	0	0	0	91	27	26
IV	95	50	15	1	0	0	31	41	9	0	0	0	53	18	26
V	29	48	0	0	0	0	22	48	5	0	0	0	19	17	8
VI	128	130	8	2	3	5	52	130	17	2	0	3	67	57	70
Total	**816**	**639**	**108**	**19**	**17**	**5**	**330**	**672**	**121**	**3**	**6**	**6**	**455**	**246**	**283**

TT = *Taricha torosa* (California newt), TG = *Taricha granulosa* (rough-skinned newt), M = male, F = female, J = juvenile, DOR = dead on road, W1 = north wing, W2 = south wing at each array.

These standardized numbers appear to better reflect the results of the 2019 analysis of the 2018/2019 survey, with Array I (in the extremely high mortality road segment) with the highest DOR counts, followed by Arrays II and III (very high mortality road segments), then Array VI (in a very high mortality road segment), Array IV (in a medium-high mortality road segment), and Array V (in a low mortality road segment).

Other species of vertebrates captured during the study are one Santa Cruz black salamander (*Aneides flavipunctatus*, which is a California species of special concern), 59 California slender salamanders (*Batrachoseps attenuatus*), two arboreal salamanders (*Aneides lugubris*), three ensatinas (*Ensatina eschscholtzii*), 12 western fence lizards (*Sceloporus occidentalis*), 11 western skinks (*Plestiodon skiltonianus*), two southern alligator lizards (*Elgaria multicarinata*), one deer mouse (*Peromyscus maniculatus*), and three shrews (*Sorex* sp.). We also observed one arboreal salamander DOR at one of the arrays. The community scientists also observed amphibian and reptile species DOR during this and prior survey efforts, including five American bullfrogs (*Lithobates catesbeiana*), 10 aquatic garter snakes (*Thamnophis atratus*), 20 arboreal salamanders, six California slender salamanders, one coast night snake (*Hypsiglena ochrorhyncus*), one ensatina, 13 Pacific tree frogs (*Psuedacris regilla*), four ring-necked snakes (*Diadophis punctatus*), one Santa Cruz black salamander, two sharp-tailed snakes (*Contia tenuis*), three southern alligator lizards, 31 western fence lizards, five western skinks, 41 western toads (*Anaxyrus boreas*), and one western whiptail (*Aspidoscelis tigris*) (https://www.inaturalist.org/projects/other-roadkill-lexington-reservoir).

3.1 Correlation of Newt Movement with Precipitation

Of the 148 days of the survey period, 45 days received precipitation. These "rain days" were distributed as 11 single days, four pairs of consecutive rain days, three groups of three, three groups of four, and a single group of five consecutive rain days, interspersed with days of no measurable precipitation "dry days". The longest period of consecutive dry days was a 22-day period from November 20 to December 11, 2020, followed by two 13-day periods from January 9 to January 21, 2021 and from February 21 to March 4, 2021, and a 10-day period from March 22 to the end of the survey period of March 31, 2021.

As expected, the majority of newt capture and newt DOR observations at arrays occurred during and after rain days, and the counts of newt capture and/or DOR observations decreased (with a few exceptions) as the period of consecutive dry days lengthened. The longest string of consecutive days with counts of newt captures and DOR is 34 days from January 22 to February 24, 2021, with a total count of 1,287 newts. This period also contained 18 rain days, with two of four consecutive rain days (January 27 and 28) receiving 2.96 and 4.21 inches of rain, respectively, the highest single-day rain totals in the survey period. This period also contained the only five consecutive rain day period from February 12 to February 16, 2021.

The highest single-day count of newts captured and DOR was March 6, 2021 at 278. This date was near the beginning of a 26-day string of consecutive days with counts of newt captures and DOR, totaling 836. This period also contained nine rain days (three single rain days, one pair of consecutive rain day, and one group of three consecutive rain days) interspersed with 18 dry days. In fact, 59 newts were captured and observed DOR in the 10 consecutive dry day period that extended to the end of the survey period (Figure 9), indicating that newts continued to move until the end of the survey period (and since) even though major rain events were over for the season.

Approximately half of the newts were observed crossing the road at the arrays (i.e., observed captured in traps and/or DOR at arrays and wings) during just 12 of the 148 days (8%) of the survey period, all associated with rain events (only one of these 12 days was immediately before a rain event). If we were to include all rain events plus two dry days after the last rain day in order to include a lag time of newt movement after a rain event, this would encompass 81 days (or 55% of the survey period) and, 91% of newt movement across the road at the arrays. So, approximately 50% newt movement occurred during 8% of the survey period, and 91% occurred during 55% of the survey period, associated with rain events.

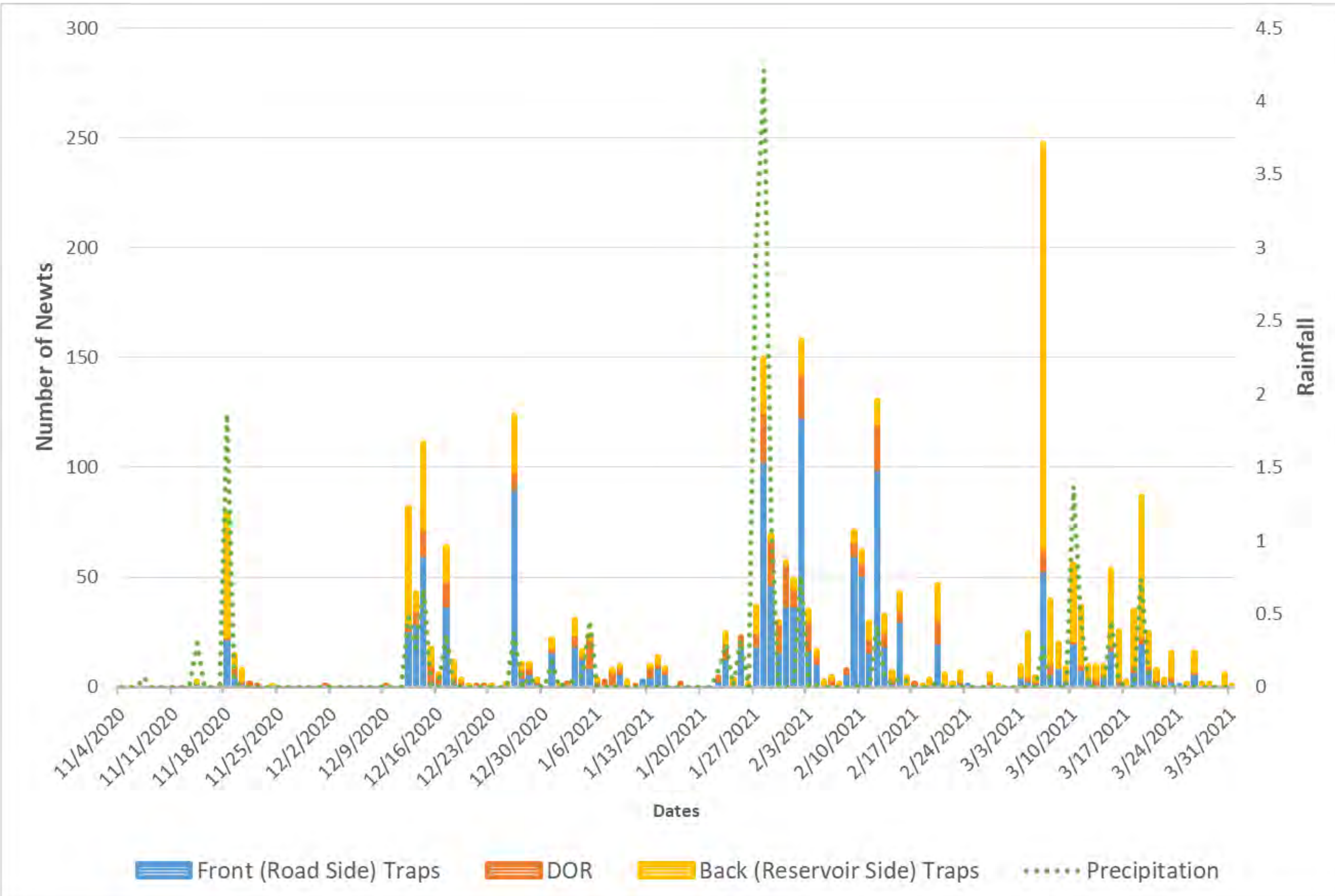
There also appeared to be a switch in the relative abundance of newt movement from one direction to the other at the beginning of the survey period and near the end of the survey period during the last week in February. During the initial rain events from November 2020 to December 12, 2020 more newts were captured in the back (reservoir side) traps than DOR at the arrays and/or captured in the front (road side) traps (Figure 9). Then from December 13, 2020 to February 20, 2021, more newts were typically recorded DOR at the arrays and/or captured in the front (road side) traps than captured in the back (reservoir side) traps (Figure 9). After that, from February 21, 2021 to the end of the survey period on March 31, 2021, more newts were typically captured in the back (reservoir side) traps than DOR at the arrays and/or captured in the front (road side) traps (Figure 9).

We interpret these patterns as follows:

1. Newts were moving in both directions and crossing the road throughout the rainy season;
2. However, from the initiation of rain events in the fall to December 12, 2020 (day 39 of the survey period), most newts crossing the road were adult newts that most likely bred in the previous year and may have been continuing to migrate away from the reservoir to the upland;

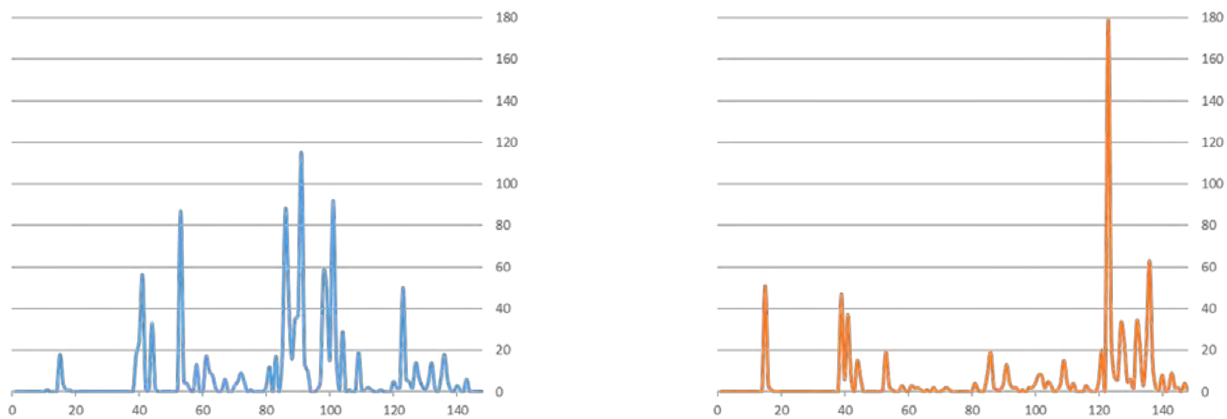
3. Then from December 13, 2020 (day 40) to February 20, 2021 (day 109) most newts crossing the road were adults migrating from the upland to the reservoir to breed during this breeding season, with the peak of this migration occurring around February 2, 2021 (day 91);

Figure 9. Graph of Newt Capture and DOR at Arrays in Relation with Precipitation



4. From February 21, 2021 (day 110) to the end of the survey period (day 148), most newts crossing the road were adults migrating from the reservoir to the uplands after having bred during this breeding season, with a peak of this reverse migration occurring on March 3, 2021 (day 121; Figure 10).

Figure 10. Graph of Numbers of Adult Newts Caught in Front (road side) Traps (blue) versus Back (reservoir side) Traps (orange) over the 148-day Survey Period

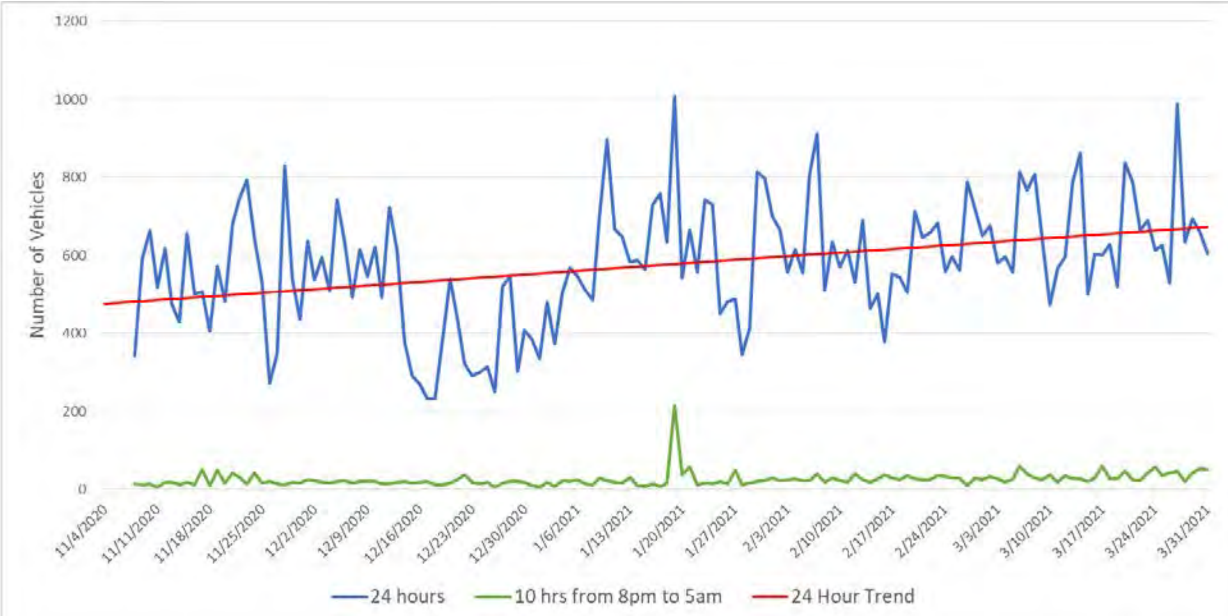


3.2 Traffic Volume during Survey Period

The traffic counter tallied 83,757 vehicles on Alma Bridge Road from November 8, 2020 to March 31, 2021. The average 24-hour vehicle count was 577. The maximum 24-hour vehicle count was 1,008 from 9:00 am on January 18 to 9:00 am on January 19, 2021, and the minimum 24-hour vehicle count was 233 from 9:00 am on December 17 to 9:00 am on December 18, 2020.

However, the daily traffic volume dropped off substantially in the evening. For example, the average 10-hour vehicle count from 8:00 pm to 5:00 am was 27, with a maximum count of 231 during the same time period between January 18 and January 19, 2021, and a minimum count of six vehicles during the same time period between November 10 and November 11, 2020, December 25 and December 26, 2020, and December 31, 2020 and January 1, 2021. There also appeared to be a reduction of traffic from mid-December to the end of that month, but a general trend of increasing traffic during the survey period (Figure 11). This increase in traffic likely resulted in an increase in impacts to newts crossing Alma Bridge Road particularly during the reverse migration in the spring. For example, the peak of newt reverse migration on March 3, 2021 had a high traffic count of 815 vehicles, most likely resulting in the high newt DOR count of 279 on March 6 and 7, 2021 (the closest DOR surveys to March 3, 2021 by community scientists) from the iNaturalist data.

Figure 11. Graph of Vehicular Traffic over the 148-day Survey Period



3.3 Adult California newt Crossing Attempts and Road Crossing Mortality Rate at Arrays

Table 3 provides the estimates of the number of adult California newts attempting to cross Alma Bridge Road at the arrays in the upland-to-reservoir direction and the mortality rate due to vehicular strikes. These adult California newt numbers and mortality rates are directly calculated by the number of adult California newts captured in the front traps, contribution to all newts captured in the front traps, and newts DOR at each array (also provided in Table 3). The mortality rates are relatively similar between the six arrays (range of 18 to 25 percent) but are higher at Arrays I, II, and IV than at Arrays III, V, and VI. The higher mortality rates at Arrays I, II, and IV, even though the total number of newts crossing the road at Array III is the highest among all arrays, indicate that the road segments at Arrays I, II, and IV were possibly experiencing higher vehicular use due to their locations at or near recreation-associated parking areas (which are not present in the other segments). We expect that mortality rates for adult rough-skinned newts were similar to those calculated for California newts due to similar relative numbers captured among the arrays (relatively higher numbers captured in Arrays I, II, III, and VI than in Arrays IV and V; Tables 1 and 2) and similar capture patterns in the traps (most rough-skinned newts were captured during rain events, as was the case with California newts).

Table 3. Number of Adult California Newts Caught in Front (Road Side) Traps, Contribution to All Newts Caught in Front (Road Side) Traps, Estimated Number Attempting to Cross Alma Bridge Road in Upland to Reservoir Direction at Each Array, Survival Rate, and Mortality Rate.

Array	Number in Front (Road Side) Traps	Contribution	Total Number	DOR	Survival Rate	Mortality Rate
I	243	0.90	326	83	0.75	0.25
II	247	0.89	328	81	0.75	0.25
III	373	0.89	454	81	0.82	0.18
IV	130	0.90	172	42	0.75	0.25
V	48	1.00	60	12	0.80	0.20
VI	163	0.94	202	39	0.81	0.19

Table 4 provides the number of adult California newts attempting to cross Alma Bridge Road at the arrays in the reservoir-to-upland direction based on the number of adult California newts captured in the back (reservoir side) traps, and the estimated number of "rescued" adult California newts based on the day-specific rates of mortality from vehicular strikes for newts attempting to cross the road predicted by the array model. Estimated mortality rates for Arrays I, IV, V, and VI were very similar, falling within a range of 6 percentage points (19-25%). Estimated mortality rate was relatively high at Array II (27%) and relatively low at Array III (16%) because of two factors: (1) the directly observed mortality rates for the upland-to-reservoir direction were relatively high at Block 1 arrays (Arrays I and II) and relatively low at the single array in Block 2 (Array III), which heavily influenced the array model upon which the reservoir-to-upland estimates were based; and (2) newts attempting to cross the road in the reservoir-to-upland direction at Arrays II and III happened to time their crossings on days that also happened to be relatively high and relatively low, respectively, in risk of road mortality. Nevertheless, mortality rates for the reservoir-to-upland direction were fairly consistent; all rates for this direction fell within a range of 11 percentage points (16 to 27%).

Table 4. Number of Adult California Newts Caught in Back (Reservoir Side) Traps, Estimated Number of "Rescued Adult California Newts", and Mortality Rate at Each Array for Adult California Newts Attempting to Cross Alma Bridge Road in Reservoir-to-Upland Direction.

Array	Number in Back (Reservoir Side) Traps	Total Number of Rescued Adult California Newts	Estimated Mortality Rate
I	113	29	0.25
II	246	65	0.27
III	267	44	0.16
IV	65	14	0.22
V	44	10	0.23
VI	115	22	0.19

3.4 Adult California Newt Crossing Attempts and Overall Mortality Rate

3.4.1 Statistical Analysis of Array Mortality Rates

3.4.1.1 Reservoir-to-Upland Models

For the reservoir-to-upland direction, the non-block model, which contained day, vehicles, and percent of uncanopied grassland as independent variables, had the lowest AIC value among competing models (Table 5). According to the non-block model, risk of mortality declined over time (as day number increased) ($\chi^2 = 8.908$, d.f. = 1, $p = 0.0028$; odds of mortality decreased by 9.4% every 10 days, all else being equal). This pattern suggests that the factors contributing to mortality of newts attempting to cross the road in the reservoir-to-upland direction abated slightly over the study period. Perhaps road-crossing attempts shifted somewhat to nighttime hours when vehicle traffic was relatively light. The non-block model also suggests that mortality correlated positively with number of vehicles ($\chi^2 = 13.721$, d.f. = 1, $p = 0.0002$; odds of mortality increased by 30.7% for every increase of 100 vehicles in daily traffic count, all else being equal). This correlation is consistent with our expectation that increases in traffic levels cause increases in road mortality (Beebee 2013). Mortality also correlated positively with percent cover of uncanopied grassland in this model ($\chi^2 = 4.837$, d.f. = 1, $p = 0.0279$; odds of mortality increased by 47.4% for every 10 percentage-point increase in the amount of uncanopied grassland cover, all else being equal). However, interpretation of this correlation is difficult because the grassland variable is confounded with block. The statistically significant correlation between uncanopied grassland and mortality might be a reflection of between-block differences in factors such as traffic patterns rather than a result of differences in the amount of grassland cover per se.

Table 5. Comparison between Models of Adult California Newt Mortality at Arrays. Within Each Direction of Travel, Models Are Listed in Order of Increasing AIC Values

Direction of travel	Model	Predictors[1]	d.f.	AIC	ΔAIC
Reservoir-to-upland	Non-block	-0.010*Day + 0.003*Vehicles +3.881*Canopy[2] –2.909	4	530.97	0
	Complex	-0.013*Day + 0.003*Vehicles -2.036	3	533.81	2.84
	Block-only	-0.857*Block 2 -1.040*Block 3 -0.452*Block 4 -1.283	4	544.02	13.05
	Null	-1.660	1	551.94	20.97

Direction of travel	Model	Predictors[1]	d.f.	AIC	ΔAIC
Upland-to-reservoir	Complex	-0.428*Block 2 - 0.057*Block 3 - 0.293*Block 4 -0.007*Day +0.001*Vehicles -1.246	6	1790.41	0
	Non-block (small polygons)	-0.007*Day + 0.001*Vehicles -1.313*Canopy[3] – 0.313	4	1790.45	0.04
	Non-block (large polygons)	-0.007*Day + 0.001*Vehicles -1.313*Canopy[4] – 0.553	4	1792.04	1.63
	Block-only	-0.436*Block 2 - 0.089*Block 3 - 0.324*Block 4 -1.091	4	1797.96	7.55
	Null	-1.265	1	1802.53	12.12

[1] Predictors of ln(*P*/1- *P*), the log odds ratio, where *P* = probability of mortality

[2] Percent cover of uncanopied grassland in the downslope (reservoir side) polygon

[3] Percent canopy cover in the small upslope (upland side) polygon

[4] Percent canopy cover in the large upslope polygon

The model with the second-lowest AIC value was the complex model. Similar to the non-block model, it contained day and vehicles as independent variables. Probability of mortality decreased over time (as day number increased) ($\chi^2 = 19.223$, d.f. = 1, $p < 0.0001$) and was positively correlated with number of vehicles ($\chi^2 = 13.357$, d.f. = 1, $p = 0.0003$). Block was eliminated from the model due to nonsignificance ($p > 0.05$).

The block-only model had an AIC value that was significantly higher than both the non-block and complex models (ΔAIC values > 2), indicating that the non-block and complex models better explained the variation in odds of mortality. However, the block-only model showed a statistically significant block effect (i.e, significant differences between blocks in probability of mortality for newts attempting to cross the road) ($\chi^2 = 13.916$, d.f. = 3, $p = 0.0030$). Furthermore, the block-only model outperformed the null model of constant odds of mortality (ΔAIC = 7.92), and thus the block-only model was used to estimate mortality rates outside of the arrays, as the non-block and complex models were incompatible with the community-scientist observations in these areas (see Section 2.3.3). Although comparison of AIC values revealed that the block-only model was not the best explanation of mortality at the arrays, the AIC values also indicated that the block-only model was a statistically significant improvement over the null model, which ignores between-block differences and follows the naïve approach of assuming a constant, average mortality rate over the entire road. The block-only model is also desirable due to our strong expectation that differences in traffic patterns between blocks influence mortality rates.

3.4.1.2 Upland-to-Reservoir Models

For the upland-to-reservoir direction, the complex model, which contained block, day, and vehicles as independent variables, had the lowest AIC value among competing models (Table 5) and thus was selected as the array model (i.e., the model used to estimate reservoir-to-upland mortality at the arrays; see Section 2.3.2). Both non-block models had AIC values that were indistinguishable from the AIC value of the complex model (ΔAIC < 2), but were nonetheless deemed inferior because their AIC values were numerically higher than the AIC value of the complex model and because of our strong expectation that between-block differences in traffic patterns influenced mortality rates. According to the complex model, odds of mortality for newts attempting to cross the road in the upland to reservoir direction differed significantly between blocks (χ^2 = 10.031, d.f. = 3, p = 0.0183). The complex model suggests that mortality of these newts decreased over time (as day number increased) (χ^2 = 7.267, d.f. = 1, p = 0.0070; odds of mortality decreased by 6.3% every 10 days, all else being equal). This pattern, which was also detected for all newts travelling in the reservoir-to-upland direction (see Section 3.4.1.1), suggests that the factors contributing to road mortality of newts attempting to cross the road in the upland-to-reservoir direction were ameliorated slightly over the study period. For example, road-crossing attempts might have shifted somewhat to nighttime hours that have relatively light traffic levels. The complex model also found that mortality of newts correlated positively with number of vehicles (χ^2 = 13.721, d.f. = 1, p = 0.0002; odds of mortality increased by 13.4% for every increase of 100 vehicles in daily traffic count, all else being equal). This correlation is consistent with our expectations that increased traffic levels result in increased road mortality.

The non-block models had the second- and third-lowest AIC values among the five competing models (Table 5). Each non-block model contained day, vehicles, and percent canopy cover within the polygons used by the model (small or large upslope polygons). Matching the complex model, the non-block models suggest that mortality decreased over time (as day number increased; $p < 0.05$) and increased with increasing number of vehicles ($p < 0.05$). Both non-block models also suggest that mortality was negatively correlated with percent canopy cover ($p < 0.05$). However, interpretation of these correlations involving canopy cover is difficult because the canopy cover variables are confounded with block. The negative association between canopy cover, and mortality, evident for both polygon sizes, might be a reflection of between-block differences in factors such as traffic patterns rather than a result of differences in the amount of canopy cover per se.

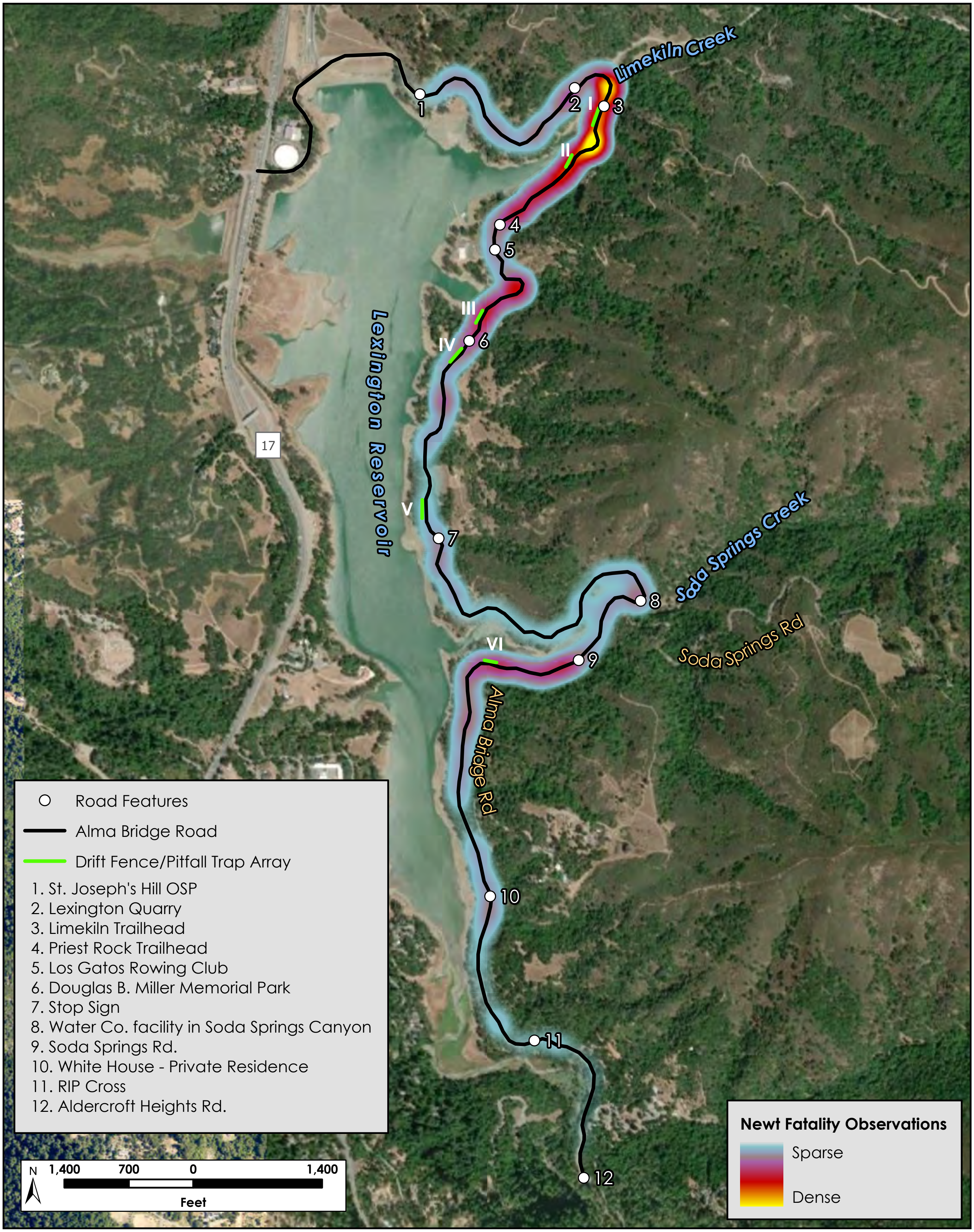
The complex model had an AIC value that was significantly higher than the block-only model and both non-block models (ΔAIC values > 2), indicating that the complex models better explained the variation in odds of mortality. However, the block-only model was well-supported. It showed a statistically significant block effect (i.e, significant differences between blocks in probability of mortality for newts attempting to cross the road) (χ^2 = 10.569, d.f. = 3, p = 0.0143). Furthermore, the block-only model outperformed the null model of constant odds of mortality (ΔAIC = 4.57), and thus was used to estimate mortality rates outside of the arrays, as the complex model was incompatible with the community-scientist observations in these areas (see Section 2.3.3). Although comparison of AIC values revealed that the block-only model was not the best explanation of mortality at the arrays, the AIC values nevertheless indicated that the block-only model was a statistically significant improvement over the null model, which ignores between-block differences and follows the naïve approach of assuming a constant, average mortality rate over the entire road. The block-only model is also desirable due to our strong expectation that differences in traffic patterns between blocks influence mortality rates. This expectation was supported by the fact that the complex and block-only models both detected between-block differences in mortality rates.

3.4.1.3 Justification for Use of Block-Specific Mortality Rates

AIC values indicated that, for each direction of travel, the null model of constant probability of mortality was outperformed by the block-only model, suggesting that assigning mortality rates according to block (see Sections 2.3.1 and 2.3.3) is a better approach than assuming a constant, average mortality rate over the entire road. We decided to apply block-specific mortality rates for both directions when calculating mortality rates for the arrays as well as road areas outside the arrays in order to capture what we believe are real differences between blocks in mortality rates. These differences likely arise because some motorists turn off from the road at specific destinations, and then return in the opposite direction, rather than traveling the entire study segment of the road. Such driving patterns would result in differences between road sections (blocks) in the number of vehicles, which should influence newt mortality rates.

3.4.2 Overall Estimates of Adult California Newts Attempting to Cross Alma Bridge Road and Direction Specific Mortality Rates

Based on our analyses, which use the newt capture results from the arrays in combination with observations of newts DOR at the arrays and segments of Alma Bridge Road located outside of the arrays (see Section 2.3), we estimate that at least 13,786 adult California newts attempted to cross the entire Alma Bridge Road in the study area in order to migrate to Lexington Reservoir to breed during the survey period. This number is the sum of our estimates of the number of adult California newts that attempted to cross the road at each array and the number that attempted to cross at the road segments of the four different blocks that are outside of the arrays (see Section 2.3.2.2). The actual number may have been higher, because it was possible that the DOR counts recorded on the road by the community scientists did not capture all of the newts DOR, as a percentage may have been removed by subsequent vehicle strikes, rain, or predators before the DOR surveys were conducted on certain road segments (M. Vonshak, pers. comm.). Applying the mortality rates estimated for each array and each non-array road segment, we also estimate that 3,066 adult California newts died on the road due to vehicular strikes during this migration, for a road-based mortality rate of 22.2%. Also, based on our captures of newts moving in the reservoir-to-upland direction, in combination with DOR observations from the non-array road segments, we estimate road-based mortality rate for this return migration to be 21.9%. These estimates indicate that of the 13,786 adult California newts migrating from the upland across Alma Bridge Road to the reservoir to breed, 10,720 adult California newts successfully crossed and potentially bred in the reservoir. We presume that a large proportion of these adult California newts then attempted to cross Alma Bridge Road on the return migration back to the uplands, though many were likely still on the reservoir side of the road at the end of the survey period. It is likely that these adult California newts will continue to migrate back to the uplands as conditions allow during the summer and fall, for example, during rain events in the summer and through the fall and winter, or during periods of high humidity at night (i.e., foggy nights) throughout the year (see interpretations of correlation of newt movement pattern in Section 3.1). Some of these adult newts may be subject to mortality before they can successfully migrate back to upland areas; such mortality may result from dehydration or predation (even though newts are toxic to most predators as mentioned previously, they can still be injured or killed by predation attempts).



N:\Projects4300\4301-01\02\Reports\Newt Mortality Study\Newt Mortality Study.aprx

H. T. HARVEY & ASSOCIATES
Ecological Consultants

Figure 12. Newt Mortality Density Map
Alma Bridge Road Newt Mortality Study (4301-02)
November 2021

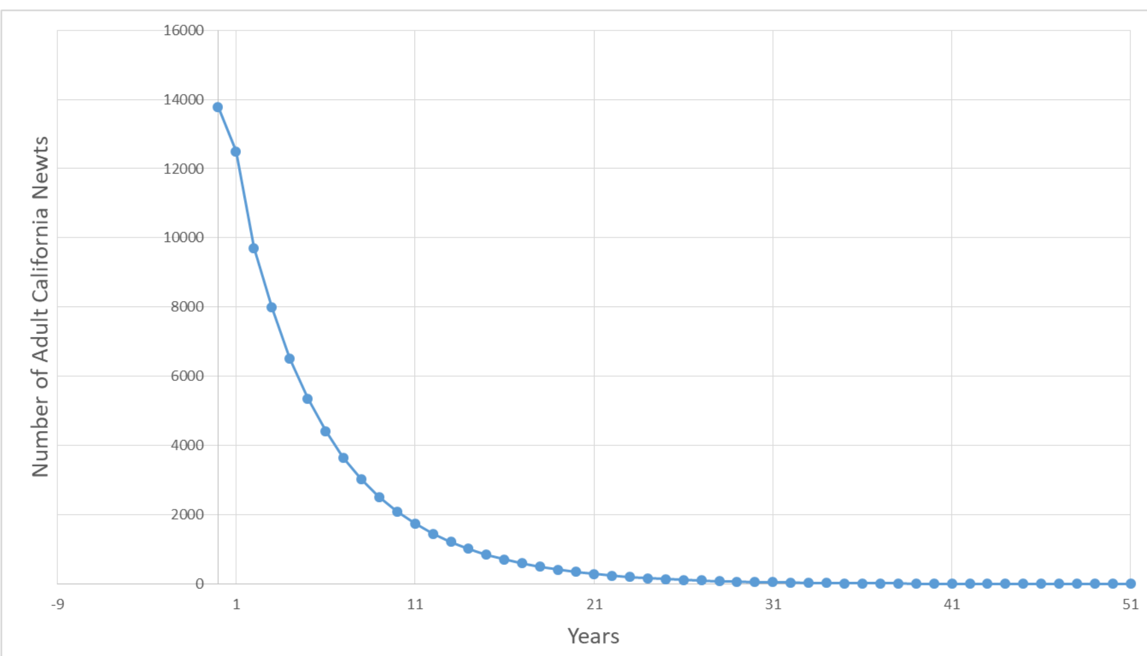
Similar to the results from the DOR observations in 2018/2019 (see Section 1.1.2), the areas of high mortality in the 2020/2021 breeding season, shown in Figure 12, were at the sections of Alma Bridge Road from Limekiln Creek south to the Priest Rock Trailhead (Point 4), then from south of the Los Gatos Rowing Club (Point 5) to before the Miller Point parking lot (Point 6), and from the junction with Soda Springs Road (Point 9) westward along the south side of Soda Springs Creek, with hotspots of very high mortality on either side of the Limekiln Trailhead (Point 3) (Figure 12). Because an adult breeding California newt is required to cross the road twice to successfully survive a round trip migration; it is subject to an upland-to-reservoir mortality and a reservoir-to-upland mortality. We calculated the roundtrip survival rate of crossing the road to be 60.8% percent and therefore estimate the overall road mortality rate for migrations in both directions during the survey period to be 39.2%.

3.5 Population Growth Model and Expected Impact of Road Mortality on the Lexington Reservoir California Newt Population

We inserted these values of adult California newts attempting to cross the road in the upland-to-reservoir direction (13,786) and the overall mortality rate (39.2%) for the parameters of the population growth model of Gibbs and Shriver (2005), with all other values in the previous investigation (see Section 1.1.3) being the same except for the updated values presented in Section 2.3.4, in order to determine how the Lexington Reservoir California newt population is expected to change given these new model inputs.

The graph in Figure 13 illustrates the results. As indicated in this graph, the population is predicted to quickly decline to under 1,000 adult California newts in 15 years and may be extirpated in 57 years.

Figure 13. Population Growth Model with Starting Adult California Newt Number and Mortality Rate from Current Study



Section 4. Discussion

The results of the population growth model indicate that the local California newt population using Lexington Reservoir for breeding may be extirpated in 57 years. However, Alma Bridge Road has been in use for approximately 67 years. Therefore, it is important to discuss why this population is still extant with such a potentially high road-related mortality rate.

One reason may be that the road-based mortality rate was much lower in the past and has increased due to increased traffic volume on Alma Bridge Road. This increase in traffic volume may have resulted from the start of and increased operations of the Lexington Quarry, increased recreational traffic with the opening of the Los Gatos Rowing Club and trails and park through the open space, and an expansion of private development in the south. The road may also have received increased overflow traffic from Highway 17 when it has become congested over the years. We have very little historical data on traffic using this road since its construction. For example, one set of data over a three-day period from October 13 through 15, 2015 that we have examined (internal records from Santa Clara County via POST provided by Neal Sharma on June 15, 2021) gives an average daily count of 194 vehicles. This count is below the lowest daily count in our study (233). Another more recent two-day count from March 15 through March 16, 2019 has an average daily count of 289 (internal records from Midpen provided by Julie Andersen on June 3, 2021). If more data are available and show that traffic volume has steadily or dramatically increased over the decades then it is conceivable to assume that the road-based mortality rate has also increased in concert with this increased traffic volume.

Another possibility of why the newt population is extant is a higher annual breeding potential of the females than we used in the model. If we were to re-run the population growth model, increasing the probability of breeding each year from 0.5 (as assumed in our original model) to 1.0 (breeding annually) the adult population size would be sustained at approximately 5,488. The study by Jones et al. (2017) assumed that females attempt breeding annually, the success of which is due to limitations in habitat for egg laying, particularly in the streams they were investigating, which would decrease during drought conditions. We assume that in the case of Lexington Reservoir, there is not a limitation in egg-laying habitat, as the reservoir will maintain the littoral zone that newts would use regardless of annual rainfall, and therefore would be available every time a female attempts to breed and lay eggs. Therefore, it is possible that adult female California newts could breed annually, given that Lexington Reservoir is available to them for breeding and egg laying each year, and that this breeding frequency is sufficient to sustain the population (though at a lower number) despite the high mortality rates we estimated. However, if we were to decrease the average number of eggs per female to 60 as in the Jones et al. (2017) study, then the model results would be similar to those in Figure 13, with the population becoming extirpated in 54 years. This exercise illustrates the importance of knowing these other parameters, particularly the average annual reproductive output of the female – yet obtaining such basic life history information is currently very challenging.

The model is also conditioned on Lexington Reservoir being the only breeding source for this population and the adult newts in this population crossing Alma Bridge Road to breed (see Assumption 10 in Section 2.3.2.2). However, it is possible that there are adult newts in other upland areas around Lexington Reservoir that are breeding in the reservoir without crossing Alma Bridge Road. We suspect though that the number of newts in these other areas (i.e., areas south and west of Lexington Reservoir) is much lower than those in the upland east of Lexington Reservoir, on the other side of Alma Bridge Road, due to the relatively limited amount of upland habitat available to these newts for dispersal and refugia as a result of more residential development and Highway 17 in these areas. Also, there may be other breeding sources for this population besides Lexington Reservoir. For example, newts may breed in the upper reaches of Limekiln Creek (approximately 10 miles of creek upstream of Alma Bridge Road) and Soda Springs Creek (approximately 12 miles of creek upstream of Alma Bridge Road). If newts are breeding in Lexington Reservoir without crossing Alma Bridge Road or are also breeding in these other locations, annual recruitments from Lexington Reservoir or these other sources might be sustaining or supplementing the population, even though the high mortality rate of crossing Alma Bridge Road to breed in Lexington Reservoir would represent a population sink for the overall metapopulation. However, if these other breeding sources do exist, they may become less reliable in the future due to increased drought conditions as a result of climate change (Jones et al., 2017).

Assuming that all parameters and assumptions for the population growth model are correct, resulting in a possible extirpation of the local California newt population at Lexington Reservoir in 57 years as illustrated in Section 3.5, then reducing the road-based mortality rate from the current 39.2% to 20% would allow the population to continue at over 4,700 adults in 200 years (though there would be a steady slow decline in population size). If the road-based mortality rate were reduced to 19%, the population would be reduced to over 8,600 adults in 200 years, with a much slower decline in size, and if reduced to 17.667%, the population would be sustained at its current size after 200 years. These road-based mortality rates should therefore be considered when examining potential corrective measures to reduce the negative impact of this road-based mortality on this population.

4.1 Potential Corrective Measures

In 2020, prior to commencement of this study, the Road Ecology Center at the University of California Davis, with support from the U.S. Geological Survey, Audubon Society, Sierra Club, Peninsula Open Space Trust, Midpeninsula Regional Open Space District, County of Santa Clara, and Valley Water, applied to the Wildlife Conservation Board to plan and design dedicated newt passage for a portion of Alma Bridge Road. The proposal was to evaluate three methods including: 1) an at-grade amphibian crossing embedded in the road surface, 2) retrofitting existing culverts to enhance newt movement, and 3) an elevated road section to allow passage of migrating newts beneath the roadway. While the 2020 grant proposal was not successful, these agencies remain committed to exploring these and/or other corrective means that would effectively reduce newt mortality. It is our understanding that Midpeninsula Regional Open Space District plans to release a request for proposals in 2021 to evaluate alternatives intended to reduce newt mortality on this road. While these measures are being developed, an interim approach could be to initiate an assisted movement of the newts across the road between Points 2 and 4, Points 5 and 6, and westward from Point 9 (hot spots; see Figure 12) during and one or two days after rain events at least during the peak movement periods of the newts, which for the 2020/2021 survey period were in early February and early March (hot moments; see Figures 9 and 10), with the overall goal of this assisted movement to be to reduce the road-based mortality rate to 20% or less. This assisted movement could consist of multiple teams of 2 to 3 personnel (e.g., volunteers) at these stretches of road, capturing newts as they observe them entering the road and moving them to appropriate habitat on the opposite side of the road. We understand and appreciate that protocols for such a measure would require adequate considerations and review by the County regarding safety in order to be implemented.

The results of the traffic volume data indicate a dramatic daily decrease in traffic volume between 8pm and 5am. Therefore, we infer that capturing and moving newts in the daytime during the much higher traffic volume levels would reduce the number of newts DOR based on the assumption that newts migrate regardless of time of day if other conditions are appropriate, such as high humidity (i.e. during rain events) as is noted in the literature (see, Stebbins and McGinnis 2012) and based on our observations. Therefore, an assisted movement team could continue to take daily newt DOR data as part of the assisted movement protocol to compare with data in prior years and to evaluate whether adjustments should be considered in the assisted movement protocol. For example, if capturing and moving newts during the day does not result in a reduced level of newts DOR at those road segments compared to previous years, this would indicate that the timing of the assisted movement is incorrect. The team could assume from this that the newts are preferentially moving at night and are being struck by the relatively fewer vehicles traveling on the road during the same time period. The team would then need to adjust the assisted movement protocol to include a nighttime assisted movement component to reduce the DOR counts, taking into account the increased safety concerns of conducting nighttime activities on a road such as this one. Assisted movement efforts have inherent safety hazards of volunteers being on the road, especially during nighttime or rainy weather. If volunteers participate in this effort, any efforts for directional fencing, pitfall traps, or moving newts will need to be reviewed by the County as the underlying road owner. This type of assisted movement has been, and is currently being, conducted for California newts in Marin County (https://www.pressdemocrat.com/article/news/newt-brigade-shuttles-salamanders-to-safety/) and other amphibians experiencing high road-based mortality rates such as the natterjack toad (*Epidalea calamita*) (https://www.froglife.org/what-we-do/toads-on-roads/) and the great crested newt (*Triturus cristatus*) https://www.ringwood.gov.uk/toad-patrol-and-great-crested-newts/) in Great Britain.

4.2 Summary and Conclusions

In summary, based on the results of this study, over 13,700 adult California newts attempted to cross Alma Bridge Road during the 2020/2021 winter season in order to breed in Lexington Reservoir, experiencing a 39.2% road-based mortality rate. Our population viability model indicates that this road-based mortality rate is having a negative impact on the population using Lexington Reservoir to breed, and if unmitigated may cause this population to become reduced and possibly extirpated in 57 years. This model-derived estimate could be high or low, but is based on the best available data to inform the model parameters. Further investigation of demographic parameters for the Lexington Reservoir California newt population could be used to refine the model in the future. These investigations could include:

- A detection probability factor based on the results of a carcass persistence study, as such a factor may influence both the overall road-based mortality rate and the population size in the model, and may direct future survey efforts to include more frequent surveys (e.g., twice a day);

- An extended drift fence/pitfall trap array survey period throughout the year to capture newts dispersing during the non-breeding season, for example juvenile newts and non-migrating adult newts, to arrive at a more accurate road-based mortality rate for these life stages and seasons; and

- Multiple years of similarly procured capture and mortality data to reflect possible differences in numbers of newts migrating during drought years as opposed to years of average or above average rainfall, which would better estimate the adult breeding population.

It is likely that adult rough-skinned newts experienced similar rates of mortality during their migrations to and from the Lexington Reservoir breeding site. However, only 38 adult rough-skinned newts were observed in the traps compared to 2,054 adult California newts, indicating that the rough-skinned newt population breeding at the reservoir is far smaller than the corresponding California newt population, perhaps because this locality is near the southernmost limit of the rough-skinned newt's range. High levels of mortality on the road combined with a small population size might make the rough-skinned newt population more susceptible to potential extirpation in the near term than California newt. Although we did not estimate overall population size and mortality rates for rough-skinned newts in this report due to the very low number of captures, such estimates based on a larger survey effort, combined with the same quantitative population modeling approach applied to the California newt population, may provide more information on the risk of extirpation to the rough-skinned newt population and how long it would take such extirpation to occur without intervention. Regardless, our study results indicate that temporary and permanent actions should be implemented to help preserve the local populations of these two species.

Section 5. Acknowledgements

The basis for this study was identified through the considerable efforts of Anne Parsons, surveying for road-killed newts along Alma Bridge Road and entering the data into iNaturalist. We would like to thank Blair Pagano, Dana Page, Jackson Bramham, Jared Bond, Mason Hyland, Michael Rhoades, and Vanessa Clayton of the Santa Clara County Parks Department for assisting with the installation of the drift fence/pitfall trap arrays and coordinating with the volunteers. We would also like to thank Anderson Wang, Ariel Starr, Chuck Wilson, Freya Prissberg, Joan Pinder, Kevin Yokoo, Marika Powers, Marisa Dobkins, Mojgan Mahdizadeh, Pam Hansen, Sadie Hine, Matt Bozzo, Shawn Lockwood, Thomas Wang, K. Perry, and Vanessa Roy, who, as volunteers, partnered with H. T. Harvey & Associates biologists to conduct the daily surveys during the survey period. We would also like to thank Merav Vonshak of the BioBlitz Club and San Jose State University and her team of community scientists, particularly Robin Agarwal, who performed the surveys for newt mortalities along Alma Bridge Road and coordinated closely with our efforts during the 2020/2021 breeding season to ensure that our data were complementary rather than overlapping, inconsistent, or confounding. Finally, we would like to thank Neal Sharma of POST, Julie Andersen, Brian Malone, Jane Mark, Tina Hugg, Alex Casbara, and Kirk Lenington of Midpen, Harry Freitas and Ananth Prasad of Santa Clara County Roads and Airports, Jared Bond, Jeremy Farr of Santa Clara County Parks, Jae Abel and Shawn Lockwood of Valley Water, Merav Vonshak, Shani Kleinhaus of the Santa Clara Valley Audubon Society, Cheryl Brehme of the U.S. Geological Survey, Tiffany Yap of the Center for Biological Diversity, Fraser Shilling of the University of California at Davis Road Ecology Center, Terris Kasteen of the California Department of Fish and Wildlife, and Dashiell Leeds of the Sierra Club for participating in the multiple discussions on the study, analytical methods, and our results and conclusions, and for providing comments on a draft of this report.

Section 6. References

Bain, T. K., D. G. Cook, and D. J. Girman. 2017. Evaluating the effects of abiotic and biotic factors on movement through wildlife crossing tunnels during migration of the California tiger salamander *Ambystoma californiense*. Herpetological Conservation and Biology 12:192-201.

Beebee, T. C. 2013. Effects of road mortality and mitigation measures on amphibian populations. Conservation Biology 27:657-668.

Brame, A. H., Jr. 1968. The number of egg masses and eggs laid by the California newt, *Taricha torosa*. Journal of Herpetology 2:169-170.

Brehme, C. S., S. A. Hathaway, R. N. Fisher. 2018. An objective road risk assessment method for multiple species: ranking 166 reptiles and amphibians in California. Landscape Ecology 33:911-935.

Brodie, E. D., Jr., J. L. Hensel, and J. A. Johnson. 1974. Toxicity of the urodele amphibians *Taricha*, *Notophthalmus*, *Cynops*, and *Paramesotriton* (Salamandridae). Copeia 1974:506-511.

Coleman, J. L., N. B. Ford, and K. Herriman. 2008. A road survey of amphibians and reptiles in a bottomland hardwood forest. Southeastern Naturalist 7:339-348.

Forman, R. T. T., D. Sperling, J. A. Bissonette, A. P. Clevenger, C. D. Cutshall, V. H. Dale, L. Fahrig, R. France, C. R. Goldman, K. Heanue, J. A. Jones, F. J. Swanson, T. Turrentine, and T. C. Winter. 2003. Road Ecology: Science and Solutions. Island Press, Washington, D.C.

Gamradt, S. C., and L. B. Kats. 1996. Effects of introduced crayfish and mosquitofish on California newts. Conservation Biology 10:1155-1162.

Gibbs, J. P. 1998. Distribution of woodland amphibians along a forest fragmentation gradient. Landscape Ecology 13:263-268.

Gibbs, J. P., and W. G. Shriver. 2005. Can road mortality limit populations of pool-breeding amphibians? Wetlands Ecology and Management 13:281-289.

Glista, D. J., T. L. DeVault, and J. A. DeWoody. 2007. Vertebrate road mortality predominantly impacts amphibians. Herpetological Conservation and Biology 3:77-87.

Heigl, F., K. Horvath, G. Laaha, and J. G. Zaller. 2017. Amphibian and reptile road-kills on tertiary roads in relation to landscape structure: using citizen science approach with open-access land cover data. BMC Ecology 17:24.

Hobbs, M. T. 2013. Amphibian mortality on roads: A case study in Santa Cruz Long-toed salamander habitat. Thesis presented to the Faculty of the Department of Environmental Studies, San Jose State University.

Howell, H. J. and R. A. Seigel. 2019. The effect of road mortality on small, isolated turtle populations. Journal of Herpetology 53:39-46.

H. T. Harvey & Associates. 2004. Dublin Ranch West California Tiger Salamander Survey and Salvage Report, Winter 2003/2004. Prepared for Ms. Jennifer Lin c/o Martin Inderbitzen. August 20, 2004.

Jones, M. T., W. R. Milligan, L. B. Kats, T. L. Vandergon, R. L. Honneycutt, R. N. Fisher, C. L. Davis, T. A. Lucas. 2017. A discrete stage-structured model of California newt population dynamics during a period of drought. Journal of Theoretical Biology 414:245-253.

Kats, L. B., G. Bucciarelli, T. L. Vandergon, R. L. Honeycutt, E. Mattiasen, A. Sanders, S. P. D. Riley, J. L. Kerby, R. N. Fisher. 2013. Effects of natural flooding and manual trapping on the facilitation of invasive crayfish-native amphibian coexistence in a semi-arid perennial stream. Journal of Arid Environment 98:109-112.

Kuchta, S. R. 2005. *Taricha torosa*. In Lannoo, M. J. (ed.): Amphibian Declines: The Conservation Status of United States Species. University of California Press, Berkeley, CA.

Lalo, J. 1987. The problem of road-kill. American Forests 50:50-52.

Moss, B. 2008. The kingdom of the shore: achievement of good ecological potential in reservoirs. Freshwater Review 1:29-42.

Mazerolle, M. J. 2004. Amphibian road mortality in response to nightly variations in traffic intensity. Herpetologica 60:45-53.

Parsons, A. 2021. Mass mortality of Pacific newts at Lexington Reservoir: Bearing witness to the decimation of two populations. Summary of four migration seasons (Nov. 2017 – May 2021). June 5, 2021.

Petranka, J. W. 1998. Salamanders of the United States and Canada. Smithsonian Institution Press. Washington, D.C.

Ritter, W. E. 1897. *Diemyctylus torosus* Esch.: the life-history and habits of the Pacific coast newt. The Academy, San Francisco.

Row, J. R., G. Blouin-Demers, P. J. Weatherhead. 2007. Demographic effects of road mortality in black ratsnakes (*Elaphe obsolete*). Biological Conservation 137:117-124.

Sever, D. M., S. A. Kramer, S. Duff. 1986. The relation between ovum variability and larval growth in *Ambystoma tigrinum*, amphibia: urodela. Proceedings of the Indiana Academy of Science 96:594.

Stebbins, R. C. and S. M. McGinnis. 2012. Field Guide to Amphibians and Reptiles of California. University of California Press.

Stoner, D. 1925. The toll of the automobile. Science 61:56-57.

Storer, T. I. 1925. A synopsis of the amphibia of California. University of California Publications in Zoology 27:1-342.

Thomson, R. C., A. N. Wright, and H. B. Shaffer. 2016. California Amphibian and Reptile Species of Special Concern. University of California Press, Berkeley, CA.

Trenham P. C. J. 1998. Demography, migration, and metapopulation structure of pond breeding salamanders. Ph.D. Dissertation, University of California, Davis.

Trombulak, S. C. and C. A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14:18-30.

Twitty, V. C. 1937. Experiments on the phenomenon of paralysis produced by a toxin occurring in *Triturus* embryos. Journal of Experimental Zoology 76:67-104.

Twitty, V. C. 1942. The species of Californian *Triturus*. Copeia 1942:65-76.

Twitty, V. C. 1961. Experiments on homing behavior and speciation in *Taricha*, in Blair, W. F. (ed.) Vertebrate Speciation. University of Texas Press, Austin, TX.

Twitty, V. C. 1964. *Taricha rivularis* (Twitty) red-bellied newt. Catalogue of American Amphibians and Reptiles 9:1-2.

Twitty, V. C. 1966. Of Scientists and Salamanders. W. H. Freeman and Company, Stanford University.

Twitty, V. C. and H. H. Johnson. 1934. Motor inhibition in *Amblystoma* produced by *Triturus* transplants. Science 80:78-79.

[USFWS] U.S. Fish and Wildlife Service. 2004. Draft revised recovery plan for the Santa Cruz long-toed salamander (*Ambystoma macrodactylum croceum*). U.S. Fish and Wildlife Service, Portland, Oregon.

[USFWS] U.S. Fish and Wildlife Service. 2005. Santa Rosa Conservation Strategy. https://www.fws.gov/sacramento/es/Recovery-Planning/Santa-Rosa/santa-rosa-strategy.php

U.S. Geological Survey. 2021. USGS 1/3 Arc Second n38w123 20210301. https://apps.nationalmap.gov/downloader/#/. Accessed on May 17, 2021.

Vonesh, J. and O. de la Cruz. 2002. Complex life cycles and density dependence: assessing the contribution of egg mortality to amphibian declines. Oecologia 133:325-333.

Winton, S. A. 2018. Impacts of road mortality on the western rattlesnake (*Crotalus oreganus*) in British Columbia. M.S. Thesis in Environmental Science, Thompson Rivers University.

Personal Communications

Anne Parsons email communication with Jeff Wilkinson on April 15, 2019 in which she shared her spreadsheet on the newt project.

Merav Vonshak email communication with Jeff Wilkinson on November 2, 2021 concerning a carcass persistence study conducted on Alma Bridge Road during the same period as the road-related mortality study for this report.

Appendix A. Additional Equations Required in Analyses

The proportion of newts DOR outside of arrays that were adult California newts traveling in the upland to reservoir direction ($C_{m, ur}$) and proportion of newts dead on the road outside of arrays that were adult California newts traveling in the reservoir-to-upland direction ($C_{m, ru}$) were calculated by applying a series of equations separately for each array and then averaging results across arrays as follows.

Within-array Equations

The proportion of all dead or rescued newts (including all species, life stage, and sex) that were adult California newts traveling in the upland-to-reservoir direction ($C_{m, at, ur}$) was calculated according to:

$$C_{m, at, ur} = D_{at, ur} / (D_{ur} + R_{ru})$$

where ($D_{at, ur}$) is the number of adult California newts that died attempting to cross the road in the upland-to-reservoir direction, D_{ur} is the number of newts (all species, life stages, and sexes) detected dead on the road at the array, and R_{ru} is the total number of "rescued" newts (all species, life stages, and sexes) traveling in the reservoir-to-upland direction (i.e., our estimate for the *theoretical* total number of newts that would have died on the road without the intervention). Although rescued newts were prevented from dying on the road, at least on the particular trip that resulted in their capture, estimates of the number of such rescues are important for estimating analyzing the parts of the road outside of the arrays, where there was no intervention to prevent newts from being killed by vehicles.

R_{ru} was derived using the same day-long time periods used to determine $R_{at, ru}$ (the total number of "rescued" adult California newts. For each, we calculated $R_{d, ru}$ as:

$$R_{d, ru} = M_{d, ru} * A_{d, ur}$$

where $M_{d, ru}$ is the *theoretical* mortality rate of newts (all species, life stages, and sexes) attempting to cross the road in the reservoir-to-upland direction; this rate is predicted by the array model and is specific to the particular day and array (see Section 2.3.1). $A_{d, ur}$ is the number of all newts (all species, life stages, and sexes) captured in the back traps that day at that array (i.e., the total number of newts that attempted to cross the road in the reservoir-to-upland direction that day at that array).

$R_{d, ru}$ values were totaled across all 144 days of the array survey period to provide R_{ru}.

The proportion of all dead or rescued newts (including all species, life stage, and sex) that were rescued adult California newts traveling in the reservoir-to-upland direction ($C_{m, at, ru}$) was calculated according to:

$$C_{m, at, ru} = R_{at, ur} / (D_{ur} + R_{ru})$$

where $R_{at, ur}$ is the total number of "rescued" adult California newts (see Section 2.3.1).

Averaging Across Arrays

$C_{m, ur}$ was calculated by averaging $C_{m, at, ur}$ values across all six arrays. Similarly, $C_{m, ru}$ was calculated by averaging $C_{m, at, ru}$ values across all six arrays.