Introduction and Critical Literature Review

Citations and a brief summary of all literature related to deer-vehicle collision reduction strategies that we reviewed are available online as an annotated bibliography at: http://www.forestry.uga.edu/h/research/wildlife/devices/GADOTLiteratureReview.pdf.

After our review of the literature, several prominent themes were evident: (1) Of the mitigation technologies previously studied, fencing of adequate height combined with the proper wildlife-crossing structures was the most effective method for reducing deer-vehicle collisions while providing a semi-permeable road/landscape interface. (2) Areas in need of improvement on an international level included: monitoring of deer-vehicle collision rates; scientifically rigorous evaluation of reduction strategies; and communication and cooperation among governments, wildlife researchers, highway managers, motorists, and others involved in the issue of deer-vehicle collisions.

To develop solutions aimed at reducing the occurrence of deer-vehicle collisions, we must enhance our understanding of the factors that result in hazardous encounters between deer and motorists. This requires a unique cooperative effort among disciplines to design, implement successfully, and refine mitigation techniques. Ultimately, we should possess a collection of strategies that were developed with consideration for the specific behavioral and physiological traits of deer and motorists alike.

Fences and wildlife-crossing structures

Roadside fencing was arguably the most-studied device implemented to reduce the incidence of deer-vehicle collisions. Most research indicated that fences were not an absolute barrier to deer and only served to reduce the number of animals entering the roadway. Conventional wire fencing must be at least 2.4 m high to limit the ability of deer to jump over it. Alternative low-in-height fence designs, such as solid-barrier fencing and non-traditional configurations of electric fencing, may provide a less-expensive fencing option to exclude deer from roadways and other areas. Construction of fencing is prohibitively expensive for many applications and regular maintenance is both costly and necessary for effectiveness. Gaps created by weather events, humans, and animals are quickly exploited by deer, and may create “hotspots” for deer-vehicle collisions when deer enter the roadway corridor and are unable to locate an escape point. Although fencing is not a complete barrier to deer, its presence may severely limit the natural movements and gene flow of deer populations and other wildlife. Fencing coupled with a variety of underpasses, overpasses, road-level crosswalks, one-way gates, and other strategies were tested to allow animals to cross roadways at controlled areas along fenced highways. Crossing structures were most successful when used where traditional migratory routes of mule deer, elk, and other migratory species intersect highways. An intimate understanding of the proper physical design, location, and integration into the habitat of crossing structures at a particular location is necessary to encourage utilization by the targeted wildlife species.
Wildlife-warning reflectors

Studies of wildlife-warning reflectors have been based on a diversity of testing methods and various levels of scientific validity, which ultimately have resulted in a limited understanding of reflector efficacy. Most reflector evaluations were based on counts of deer-vehicle collisions within test sections either pre- and post-installation of reflectors; when reflectors were covered versus uncovered; or within reflectorized sections as compared to adjacent control sections. Such methods failed to consider changes in deer densities, seasonal movements, or traffic patterns. Further, studies evaluating reflector effectiveness have been hampered by small sample sizes that limited statistical inferences on efficacy. Little is known about how deer react to reflector activation or if individual animals become habituated to the devices over time. Studies that used counts of deer carcasses along roadways to assess reflector effectiveness rarely used data quality controls such as video surveillance of test sections or driver surveys to account for deer-vehicle collisions that resulted in injured deer wandering from the roadside. Beyond differences in experimental design, comparison of results among different reflector studies was confounded further by the variety of reflector models tested and the distinct spectral properties of those devices.

Motorist-warning devices

Active and passive driver-warning devices were largely ineffective at reducing vehicle speeds and deer-vehicle collisions. Drivers ignored the common “deer crossing” sign, perhaps because of its overuse. Reduced vehicle speed was the most common method used for assessing warning-device effectiveness, even though this response was not the primary desired effect of warning drivers about site-specific dangers associated with wildlife crossings. No studies to date assessed driver alertness or other changes in driver behavior relative to warning devices through surveys directed at motorists actually exposed to such strategies. The effectiveness of recently developed active-warning systems, which only alert drivers when animals are present near the roadway, was unclear despite the high cost of such devices. Research indicating that non-redundant command-type messages impact driver behavior more than notification-style messages, which suggests that educating drivers during periods when they are most likely to encounter roadway dangers (i.e., during the fall and spring when deer-vehicle collisions are most common) may be most effective. Such techniques should be evaluated through direct communication with drivers.

Alternative mitigation strategies

No “alternative strategy” proved effective in reducing vehicle collisions with white-tailed deer. Intercept feeding for migratory mule deer (*Odocoileus hemionus*) proved marginally effective. However, successful adaptation of this technique to white-tailed deer in the eastern U.S. is unlikely. Other alternative approaches included variations of highway lighting and even placing imitations of deer with raised tails along roadways. Although not successful in reducing deer-vehicle collisions, such approaches provided evidence that deer-vehicle collision-reduction research may require a departure from typical study designs.

Time and location of deer-vehicle collisions

Most research indicated that peaks in deer-vehicle collision rates occurred late in the evening, at night, and in the early morning on a diurnal basis, and seasonally in the spring and fall. Modern analyses of deer-vehicle collision sites typically involved Global Information Systems (GIS) technology combined with regression modeling to identify areas likely to experience an elevated deer-vehicle collision rate. GIS modeling also was used to select areas for implementation of mitigation strategies based on landscape and economic feasibility, along with many other criteria.

Human dimensions associated with deer-vehicle collisions

The general public greatly values deer as a public resource. Surveys showed, however, that public opinion about deer management and deer-vehicle collision mitigation was affected significantly by human perception of personal risk and cost of implementation. Human-dimensions researchers suggested that professionals involved with wildlife management and roadway management should combine public risk-assessment data with biological data to make decisions about alternative management strategies.

Deer hearing

Information on white-tailed deer hearing abilities and their response to sound-frightening devices was limited. Previous research on deer hearing was preliminary in nature and investigations of the efficacy of sound deterrents employed along roadways were of poor experimental design. Several studies indicated that deer likely have hearing abilities similar to humans, thus suggesting that “ultrasonic” sound-deterrent devices would be ineffective for deer.

Deer vision

Electrophysical examination and behavioral research established that white-tailed deer are capable of limited color vision. During the day, deer likely can discriminate in the color range of blue to yellow-green, and at night in the blue to blue-green color range. Little else is known about how white-tailed deer visually perceive the world. Information on deer visual acuity and depth perception was lacking.

Conclusions and recommendations

Although many aspects of deer biology were well studied, we lack a basic understanding of the anatomy and physiology related to the hearing and visual capabilities of deer, information which may prove integral to the invention of economically effective strategies to minimize deer-vehicle collisions. Furthermore, our knowledge of deer behavior relative to roads is inadequate. Limiting our evaluations of deer-vehicle collision-mitigation devices to comparisons of deer road-kill statistics, for example, tells little about the complex interaction of deer and motorist behavioral traits that
leads to collisions. When conducting future tests, we should make detailed observations of deer behavior relative to the implementation of mitigation techniques and, when possible, also document motorist awareness and response to the strategies. Such data may be used to improve strategies during the design and planning stages, rather than as a basis for critique after mitigation strategies are widely instituted or enter the manufacturing process.

At present, fences of the appropriate height may be the most effective method to exclude deer from roads. However, transportation and wildlife managers have an ethical responsibility to consider the potential ecological impacts of fencing on animal populations. Traditional fence designs may severely limit gene flow among populations separated by fenced roads. Fencing also may restrict wildlife access to resources critical to their survival. Crossing structures within fenced roadway corridors may provide partial habitat connectivity for some wildlife species and were more successful when used where traditional migratory routes of mule deer, elk (Cervus elaphus), and other migratory species intersected highways. However, white-tailed deer generally do not make mass seasonal migrations and are more likely to cross roads within their home ranges on a daily basis. Over a single kilometer, a roadway may be intersected many times by the home ranges of different white-tailed deer in an area. Previous reports rated wildlife-crossing structures as cost prohibitive for most applications. Considering the road-crossing behavior of white-tailed deer and the cost of wildlife-crossing structure installation, reliance on fencing to prevent deer-vehicle accidents likely is not a feasible option.

Currently there is no simple, low-cost solution for reducing the incidence of deer-vehicle collisions. Like fencing, other devices, including wildlife warning reflectors and motorist warning systems, were used where deer regularly cross roads. Only instituting collision-reduction techniques at select areas or “hotspots” will not guard against non-habitual deer road crossings, which typically occur during the peak seasons for deer-vehicle collisions (breeding and fawning). To guard against these collisions and to provide the most effective system for minimizing deer-vehicle collisions, we have three general conclusions and recommendations:

1. Vehicle-mounted deer warning systems may have the best potential for minimizing deer-vehicle collisions; however, to date none of these systems has been designed in accordance with the senses of deer. Therefore, future research and development of vehicle-mounted deer warning systems must be based on detailed knowledge of deer vision, hearing, and behavior.

2. Every year, motorist awareness of the danger of deer-vehicle collisions can decline over time. Therefore, agencies should develop and routinely implement education programs and/or highway warnings to enhance motorist awareness prior to and during the seasons of greatest danger for deer-vehicle collisions (breeding and fawning).

3. Deer overabundance can increase the potential for deer-vehicle collisions. Therefore, agencies and municipalities should implement proper deer-herd management programs designed to control deer abundance.

Our Research Project

Project objectives
Based on our review of the literature, we designed our research project to accomplish the following objectives:

1. Investigate the visual physiology of white-tailed deer to determine their visual acuity, their ability to discern patterns and shapes, and to gain new insight on deer color and night vision.

2. Investigate the auditory physiology of white-tailed deer to determine the range of their hearing capabilities.

3. Determine roadway behavior of deer and test the effect of wildlife-warning reflectors and auditory deterrents in altering deer roadway behavior.

4. Use new information on deer senses and roadway behavior to improve on existing technologies and develop new strategies to reduce the incidence of deer-vehicle collisions.

Deer vision
We are utilizing a combination of laboratory techniques and behavioral testing to determine white-tailed deer visual capabilities, which were not documented previously. We are training captive-raised deer through discrimination learning to select positive visual targets in a range of spatial frequency gratings, patterns, and shapes. We are calculating visual-acuity scores based on the spatial grating of the highest frequency that the animal is able to discern. Likewise, we will reduce the size of shapes and increase the complexity of patterns to determine those which are most reliably perceived by our trained deer. We are using immunohistochemistry to label rod and cone photoreceptor cells fluorescently and staining to visualize ganglion cells in the deer retina. We are developing spatial-density maps of cells across the retina to provide better understanding of light-signal processing by the deer visual system. Using our estimates of ganglion-cell densities, we also will be able to infer deer visual-acuity limits.

Deer hearing
We are conducting auditory brainstem response testing to estimate deer-hearing capabilities. While sedated, we expose their hearing system to a range of frequencies from 250 Hz to 30,000 Hz at intensities up to 90 dB. We will analyze auditory electrical potentials evoked from the deer’s brainstem to estimate the lowest threshold at which the
deer’s hearing system can detect sounds throughout the range of tested frequencies. Our preliminary results on 13
deer indicate that deer hearing is less sensitive than that of humans at lower frequencies. At moderate to high frequen-
cies, deer hearing appears to be more sensitive than human hearing and may extend to at least 30,000 Hz. We are
performing subsequent trials to determine the behavioral response of deer to auditory cues.

**Behavioral field experiments**

Our research approach to evaluate the effectiveness of deer-vehicle collision reduction techniques will consider
roadway behavior of deer relative to such techniques. This experimental design differs from most other studies of
similar purpose, which traditionally have used counts of deer carcasses along test sections of road. We will use a
forward-looking infrared camera to monitor deer behaviors at night when negative deer-vehicle interactions are most
likely to occur. We will assess deer-behavioral responses to normal vehicle traffic as compared to deer responses
to vehicles when reduction techniques are activated. Our experiments will determine the effectiveness of reduction
techniques currently available and will provide basic information on deer roadway behavior, which is integral to the
development of effective and economically feasible strategies to minimize deer-vehicle collisions.

**Acknowledgments:** We gratefully acknowledge funding provided by the Georgia Department of Transportation through the Governor’s
Office of Highway Safety and the National Highway Traffic Safety Administration. We also thank ICOET for providing travel funding for
presentation of our poster at the 2005 conference.

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TIDAL MARSH RESTORATION AT TRIANGLE MARSH, MARIN COUNTY

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Abstract: The California Department of Transportation (Caltrans) provided funding to help restore and enhance 0.48 hectare (ha) (1.19 acre (a)) of tidal marsh, 0.56 ha (1.39 a) of native wetland and upland habitat, and improve public access at Triangle Marsh in Corte Madera, Marin County, California. This restoration work mitigates for impacts to 0.015 ha (0.038 a) of wetland/tidal marsh habitat resulting from the Highway 101 widening at nearby Corte Madera Creek. The goals of this restoration are to increase the habitat for marsh-dependent species such as the California clapper rail and the salt marsh harvest mouse and to provide wildlife-viewing opportunities for the public while maintaining a suitable buffer from the restored tidal marsh.

In 2000, the Marin Audubon Society (MAS) purchased the 13 ha (31 a) Triangle Marsh, which is located along Paradise Drive in Corte Madera adjacent to San Francisco Bay. Triangle Marsh is a remnant of a larger area of historical marsh of the Marin Baylands. At some unidentified time within the past 100 years, a portion of Triangle Marsh was filled, creating large upland areas with pockets of wetlands where differential settling of fill material occurred. This restoration occurred within three areas of the site: the eastern, middle, and western. Upland areas were excavated to tidal marsh elevations. An upland berm was constructed along the boundary between the marsh and Paradise Drive to provide a physical barrier between the public pathway and the middle restoration site. In the larger eastern section, this berm has more gradual slopes on its northern (restored marsh) side to provide wetland-upland transitional refugia habitat. The existing levee in the western section was lowered to provide additional transitional refugia habitat.

Grading and contouring of the site began in January 2004 and was completed by January 2005. MAS began planting the upland areas with native species after the grading was completed.

Caltrans biologists obtained pre-restoration information on plants and wildlife and took photographic records of the Triangle Marsh in January 2004 before the site was graded and contoured. Caltrans biologists will take photographic records in the same locations annually during the five-year monitoring period to document the restoration progress. Caltrans biologists will conduct spring and summer plant surveys to detect early and late-seasonal species and will map the extent of the vegetation cover using a Global Positioning System (GPS). Surveys will include a minimum of 20 vegetation sample plots, each measuring 3 x 3 meters (m) (10 x 10 feet (ft)), to estimate plant coverage and dominance in the tidal marsh and upland areas. Caltrans biologists will measure wildlife usage of Triangle Marsh on an opportunistic basis.

During the June 2005 monitoring, biologists observed pickleweed, marsh gumplant, and California cordgrass naturally recruiting into the margins of the graded and contoured tidal marsh sections. At the end of the five-year monitoring period, Caltrans expects that the restored areas will have at least 70% coverage of native species typical of local tidal marsh habitats and native wetland and upland areas.

Introduction

The California Department of Transportation (Caltrans) provided mitigation for widening work on Highway 101 that resulted in 0.015 ha (0.038 a) of impacts to wetland/tidal marsh habitat at Corte Madera Creek, in the City of Larkspur, Marin County, California (figure 1).

Figure 1. Project location.
Caltrans provided funding and assistance to the Marin Audubon Society (MAS) with monitoring work for the restoration of 0.48 ha (1.19 a) of tidal marsh habitat (figure 2). The restoration occurred within three areas of the site: the eastern and middle portions of the site along Paradise Drive and the levee along the western property boundary. Upland areas were excavated to tidal-marsh elevation while existing tidal marsh and transitional high marsh atop manmade land (fill) were left undisturbed. An upland berm was constructed along the boundary between the marsh and Paradise Drive to provide a physical barrier between the public and the middle site. In the larger, eastern restoration area, this berm has more gradual slopes on its northern (restored marsh) side to provide wetland-upland transitional refuge habitat. The existing western berm was lowered to provide additional transitional refuge habitat. An estimated 8,158 cubic meters ($m^3$) (10,670 cubic yards (cy)) of soil was excavated, 1,869 $m^3$ (2,445 cy) were used on site for berm construction, and 6,289 $m^3$ (8,225 cy) were removed for off-site disposal.

The topographic features were delineated using GPS after grading and contouring of the site (February 3, 2005). Future tidal-marsh areas (green outline), wetland-upland transition areas (yellow outline), and upland areas planted with native vegetation (orange outline) are shown. A channel was excavated at the eastern section (blue) to allow tidal inundation. Public viewing and access is shown in black. Numbers represent points where ground photos were taken (January 9, 2004 and January 13, 2005).

Functions and values of habitat to be created

The Triangle Marsh Mitigation Project will result in high-quality tidal marsh. Success is primarily dependent on establishment of the planted native marsh vegetation. Success criteria will include adequate hydrology of the marsh area after excavation and establishment of a self-sustaining tidal marsh.

The fundamental goals of this project are to enhance shorebird and waterfowl habitats and associated tidal marsh wildlife and plant communities. This restoration plan seeks to meet four specific ecological goals for tidal marsh and their associated wetland-upland transition areas.

**California Clapper Rail**

One goal of this plan is to increase habitat suitable for use by the federally endangered California clapper rail (*Rallus longirostris obsoletus*). Clapper rails utilize tidal marshes in the San Francisco Estuary. Individuals of this species have been observed at the site (Barbara Salzman pers. comm.), although no survey has been performed to determine the extent or breeding success of their populations.

Appropriate habitat for the California clapper rail includes tidal marsh with a predominance of pickleweed-vegetated (*Salicornia virginica*) marsh plains and cordgrass-vegetated (*Spartina* sp.) lower marsh, as well as access to other high marsh plants. Other habitat requirements for clapper rail establishment are marsh area, relative distance between the site and other marshes, size of buffer between marsh and upland, and low human disturbance.

**Salt Marsh Harvest Mouse**

Another goal of this plan is to increase habitat suitable for use and occupation by the federally endangered salt marsh harvest mouse (*Reithrodontomys raviventris*). The salt marsh harvest mouse (SMHM) can be found in salt marshes around San Francisco, San Pablo, and Suisun Bays. Populations of SMHM are present in salt marshes near the site, such as Corte Madera Ecological Reserve, and may already be present at Triangle Marsh. SMHM habitat requirements are the pickleweed and peripheral halophyte zone in mid-to upper marsh areas.
Other Plant and Wildlife Resources
The third ecological goal of this plan is to provide habitats suitable for use and occupation by tidal marsh and wetland-upland transition dependent plant and wildlife species.

Wetland/Upland Transitional Refuge
The fourth ecological goal of this plan is to provide wetland-upland transitional habitats along the margins of restored tidal marsh. This transitional zone consists of gently sloping topography across which microhabitats can establish provides refuge from extreme high-tide events, as well as tall native cover vegetation such as marsh gumplant (Grindelia stricta) and salt marsh baccharis (Baccharis douglasii) for predator avoidance.

Mitigation Site

Location and size of mitigation area
The Triangle Marsh property is 13 ha (31 a) and is bounded by Paradise Drive on the south, San Francisco Bay on the north, the Marin Country Day School on the east, and a narrow band of tidal marsh and the Mariner’s Cove housing subdivision on the west. It lies immediately north of the Ring Mountain Nature Preserve, separated by Paradise Drive. The Corte Madera Ecological Reserve lies northwest of Triangle Marsh, separated by the housing subdivision.

Existing site features at Triangle Marsh include tidal marsh and tidal pannes on the western and central portions of the site, upland fill in the southeastern portion of the site adjacent to Paradise Drive and a remnant berm along the western site boundary. Central San Francisco Bay lies on the northern boundary, which includes intertidal mudflats and shallow open water. San Clemente Creek empties into the Bay a short distance west of the site.

Implementation Plan

Rationale for expecting mitigation success
Collection and analysis of data in this area by MAS combined with the fact that historically, all of Triangle Marsh was a part of a larger tidal marshland in the Marin Baylands, led to the determination that additional tidal marshland can be created at this site. This rationale was determined by analysis of tidal datum, storm water flow, soils, current ecosystem types, and existing vegetation within the Triangle Marsh area.

Vegetation planting will be limited to species that occupy the margins of the tidal marsh and may not necessarily colonize rapidly, including marsh gumplant, alkali heath (Frankenia salina), and jaumea (Jaumea carnosa). Planting will also include native species in the wetland-upland transition area and will include salt marsh baccharis.

Public access for this project aims to balance the needs of wildlife protection with opportunity for wildlife-sensitive viewing opportunities. The berm constructed parallel to Paradise Drive has a crest elevation 0.9 m (3 ft) above the roadway and is intended to discourage public entry into the restored marsh while maintaining viewing corridors for pedestrians, bicyclists, and motorists. Signs will be installed discouraging public entry and a small fence may be considered.

Along the eastern section of the new berm, a point-access location is also provided. This point access will consist of a 6 m (20 ft) diameter semicircle earthen platform located atop the eastern berm. The access will be reached via an earthen path up the berm slope. No additional improvements or interpretive signs for this access are planned as part of this project. This access point will allow open views to the existing and restored marsh and beyond to San Francisco Bay.

Construction occurred in upland areas and avoided areas dominated by pickleweed and other native marsh vegetation that may potentially provide habitat for the salt marsh harvest mouse. Clapper rails have been observed on the site in previous surveys, although locations were not documented. Therefore, it is inferred that clapper rails could be present at any location on the site. Cooper Crane and Rigging, contractors for MAS, began grading and contouring the site in January 2004. To avoid potential impacts to the California clapper rail, the contractor did not resume grading and contouring of the site until September 2004. Grading and contouring work was completed in January 2005 and MAS began planting the upland areas with native plant species.

Monitoring Plan

Monitoring methods
Caltrans biologists will take photographic records of the same locations annually during the five-year monitoring period to monitor the progress of the restoration work (figure 2). Figures 3, 4, and 5 are representative of the photographic records taken at the site.

Caltrans biologists will conduct plant sampling in the spring and summer to detect early and late-seasonal species. This plant monitoring includes measuring the trend analysis for vegetation at the restoration areas (eastern section, middle section, and western section). Caltrans biologists will map the extent of the vegetation cover using a Global Positioning System (GPS). Annual reports submitted to MAS, California Department of Fish and Game, U.S. Army Corps of Engineers, San Francisco Bay Conservation and Development Commission, and the California Regional Water Quality Control Board will include the initial extent of vegetation coverage in the area, the types of species in the area, and an
estimation of the dominant types of vegetation present. The annual report will document the percentage of change in plant coverage from the previous year. Caltrans biologists will use a minimum of nine random vegetation sample plots to estimate plant coverage and dominance in each zone.

To obtain the sample plots, a grid with 3 x 3 m (10 x 10 ft) quadrats was placed over an aerial photo of the site. Each section was divided into three zones to provide an equal representation from different elevations. The upper zone contains mostly upland plants installed by MAS, the middle zone represents a transition between upland and tidal zones, and the lower zone represents the tidal marsh. Caltrans biologists will randomly choose a minimum of one quadrat from each zone to monitor percent cover change of vegetation from year to year. The objective is to conduct a random sampling of approximately 10% of the project area.

Caltrans biologists will record wildlife usage of Triangle Marsh when they are observed during field surveys.

At the end of the five-year monitoring period in 2009, Caltrans expects that the restored areas will have at least 70% coverage of native species typical of tidal marsh habitats and native wetland and upland areas.

**Results**

**Post-restoration survey**
Caltrans biologists Michael Galloway, Hal Durio, Tami Schane, and Chuck Morton conducted post-restoration surveys of Triangle Marsh on January 13, 2005, and June 7, 2005. Dominant plants and wildlife within the three restoration areas (eastern, middle, and western sections) were surveyed. The biologists photographed each restoration area at the same points where pre-restoration photographs were taken (figure 2). Figures 3, 4, and 5 are representative of the photographic records taken at the site. Caltrans biologists delineated the plant coverage of each of the three restoration areas by GPS to determine success of natural recruitment. Table 1 is a listing of the vegetation observed on June 7, 2005, for the eastern, middle, and western sections of the site.

**Eastern section**
Because the January 13, 2005, survey occurred shortly after the grading and contouring of the site was completed, not many plants were observed growing in the eastern section (figure 3). The upland berm of the eastern section was sparsely planted with California sagebrush (*Artemesia californica*), marsh gumplant, coyote brush (*Baccharis pilularis*), toyon (*Heteromeles arbutifolia*), and coast live oak (*Quercus agrifolia*). Pickleweed, marsh gumplant, and California cordgrass (*Spartina foliosa*) were growing at the margins of the eastern section adjacent to the tidal marsh.

Caltrans biologists observed least sandpipers (*Calidris minutilla*) and killdeer (*Charadrius vociferus*) in the excavated areas of the eastern section. Caltrans biologists also observed American crows (*Corvus brachyrhynchos*) and a turkey vulture (*Cathartes aura*) flying near the project area. Deer tracks (*Odocoileus hemionus*) and droppings and raccoon (*Procyon lotor*) tracks were observed throughout the eastern section.

A second plant survey was conducted on June 7, 2005, after MAS completed the installation of upland native plants. During this survey, Caltrans biologists determined plant coverage in quadrats sampled randomly in the eastern section.

Plant coverage in the randomly sampled plots in the tidal zone ranged from 0% to 51% with native marsh plants such as pickleweed, spearscale (*Atriplex triangularis*), and saltgrass (*Distichlis spicata*) recruiting from the adjacent tidal marsh into the restoration area (Table 1). Plant coverage in the randomly sampled plots in the wetland-upland transition zone ranged from 31% to 100%, showing much more recruitment into these areas of tidal marsh plants, especially those directly adjacent to the tidal zone while those areas directly adjacent to the upland zone showed a recruitment of non-native plant species such as birdfoot trefoil (*Lotus corniculatus*) and perennial ryegrass (*Lolium perenne*).

Plant coverage in the randomly sampled plots in the upland zone ranged from 35% to 70%. The majority of plants establishing in the upland area consists of non-native plants such as birdfoot trefoil, perennial ryegrass, and rabbit’s foot grass (*Polypogon monspeliensis*). Plants installed by MAS were found in 8 (73%) of the 11 random upland quadrat samples. The coverage of installed plants ranged from 2% to 15% of the sampled areas and consisted of California sagebrush, coyote brush, blue-eyed grass (*Sisyrinchium bellum*), creeping wildrye (*Leymus triticiodes*), meadow barley (*Hordeum brachyantherum*), and bee plant (*Scrophularia californica*). Table 1 lists the plants observed in the sampled quadrats of the eastern section.
Photos taken before restoration work (January 9, 2004) are shown on the left. Photos taken after grading and contouring of the site (January 13, 2005) are shown on the right.

Table 1. Post-Restoration Plants Observed at Triangle Marsh (June 7, 2005)

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
<th>Habitat-community</th>
<th>Section</th>
<th>Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anagalis arvensis</td>
<td>Scarlet pimpernel</td>
<td>Non-native upland plant</td>
<td>E, M</td>
<td>U, W-U</td>
</tr>
<tr>
<td>Artemisia californica included</td>
<td>California sagebrush</td>
<td>Native upland shrub</td>
<td>E</td>
<td>U</td>
</tr>
<tr>
<td>Atriplex triangularis</td>
<td>Spearscale</td>
<td>Native marsh plant</td>
<td>E, M</td>
<td>TM, U, W-U</td>
</tr>
<tr>
<td>Avena barbata</td>
<td>Slender wild oats</td>
<td>Non-native upland grass</td>
<td>E, M, W</td>
<td>W-U</td>
</tr>
<tr>
<td>Baccharis pilularis included</td>
<td>Coyote brush</td>
<td>Native upland shrub</td>
<td>E, M</td>
<td>U</td>
</tr>
<tr>
<td>Bromus diandrus</td>
<td>Rigid grass</td>
<td>Non-native upland grass</td>
<td>M</td>
<td>U</td>
</tr>
<tr>
<td>Conula coronopfollia</td>
<td>Brass buttons</td>
<td>Non-native marsh plant</td>
<td>E</td>
<td>TM, U, W-U</td>
</tr>
<tr>
<td>Cuscuta sp.</td>
<td>Dodder</td>
<td>Native marsh plant</td>
<td>E, M</td>
<td>W-U</td>
</tr>
<tr>
<td>Distichlis spicata included</td>
<td>Salt grass</td>
<td>Native marsh plant</td>
<td>E, M, W</td>
<td>TM, W-U</td>
</tr>
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<td>Eryngium sp.</td>
<td>Coyote thistle</td>
<td>Native plant</td>
<td>E</td>
<td>W-U</td>
</tr>
<tr>
<td>Frankonia salina</td>
<td>Alkali heath</td>
<td>Native marsh plant</td>
<td>E</td>
<td>W-U</td>
</tr>
<tr>
<td>Grindelia stricta included</td>
<td>Marsh gumplant</td>
<td>Native marsh plant</td>
<td>E</td>
<td>W-U</td>
</tr>
<tr>
<td>Hordeum brachiyantherum included</td>
<td>Meadow barley</td>
<td>Native upland grass</td>
<td>E, M, W</td>
<td>U</td>
</tr>
<tr>
<td>Juncus carnosus included</td>
<td>Juncus</td>
<td>Native marsh plant</td>
<td>M</td>
<td>U</td>
</tr>
<tr>
<td>Leymus triticeoides included</td>
<td>Creeping wildrye</td>
<td>Native upland grass</td>
<td>E, M, W</td>
<td>U</td>
</tr>
<tr>
<td>Lolium perenne</td>
<td>Perennial ryegrass</td>
<td>Non-native upland grass</td>
<td>E, M, W</td>
<td>U, W-U</td>
</tr>
<tr>
<td>Lotus corniculatus included</td>
<td>Birdfoot deerweed</td>
<td>Non-native upland plant</td>
<td>E, M</td>
<td>U, W-U</td>
</tr>
<tr>
<td>Melilotus officinalis</td>
<td>Yellow sweetclover</td>
<td>Non-native upland plant</td>
<td>E, M, W</td>
<td>U</td>
</tr>
<tr>
<td>Parapholis scabra</td>
<td>Sickle grass</td>
<td>Non-native marsh plant</td>
<td>E</td>
<td>U</td>
</tr>
<tr>
<td>Phalaris aquatica included</td>
<td>Harding grass</td>
<td>Non-native wetland grass</td>
<td>E</td>
<td>W-U</td>
</tr>
<tr>
<td>Planagro lanceolata</td>
<td>English plantain</td>
<td>Non-native upland plant</td>
<td>M</td>
<td>U, W-U</td>
</tr>
<tr>
<td>Polygogon monspeliensis</td>
<td>Rabbit’s foot grass</td>
<td>Non-native wetland grass</td>
<td>E, M</td>
<td>U, W-U</td>
</tr>
<tr>
<td>Salicornia virginica included</td>
<td>Pickleweed</td>
<td>Native marsh plant</td>
<td>E, M, W</td>
<td>TM, W-U</td>
</tr>
<tr>
<td>Salsola soda included</td>
<td>Alkali Russian thistle</td>
<td>Non-native marsh plant</td>
<td>E, M</td>
<td>TM, W-U</td>
</tr>
<tr>
<td>Scrophularia californica included</td>
<td>Bee plant</td>
<td>Native upland plant</td>
<td>E</td>
<td>U</td>
</tr>
<tr>
<td>Spartina foliosa</td>
<td>California cordgrass</td>
<td>Native marsh plant</td>
<td>M</td>
<td>TM, W-U</td>
</tr>
<tr>
<td>Stipa trichotum bellum included</td>
<td>Blue-eyed grass</td>
<td>Native upland grass</td>
<td>E</td>
<td>U</td>
</tr>
<tr>
<td>Tritium aestivum</td>
<td>Wheat</td>
<td>Non-native upland grass</td>
<td>E</td>
<td>U</td>
</tr>
</tbody>
</table>

1. E = Eastern, M = Middle, W = Western.
2. TM = Tidal Marsh, W-U = Wetland-Upland Transition Area, U = Upland.
3. Plants installed by the Marin Audubon Society.
4. Plants observed in the area during the pre-construction period (January 9, 2004).
5. Salsola soda was manually removed from site where feasible.
Middle section
The middle section, like the eastern section, did not have many plants growing in the area as of the January 13, 2005, survey because this section was recently graded and contoured (figure 4). The upper berm of the middle section was also sparsely planted with toyon, coyote brush, marsh gumplant, California sagebrush, and bee plant. Caltrans biologists observed kildeer and deer tracks in the middle section.

A second plant survey was conducted on June 7, 2005, after MAS completed the installation of upland native plants. During this survey, Caltrans biologists determined plant coverage in quadrats sampled randomly in the middle section.

Plant coverage in the randomly sampled plots in the tidal zone ranged from 10% to 30%, with native marsh plants such as pickleweed, spear scale, marsh gumplant, and salt grass recruiting from the adjacent tidal marsh into the restoration area. Plant coverage in the randomly sampled plots in the wetland-upland transition zone range from 35% to 55%, showing much more recruitment into these areas of tidal marsh plants, especially those directly adjacent to the tidal zone while those areas directly adjacent to the upland zone showed recruitment of non-native plant species, such as perennial rye grass and yellow sweet clover (*Melilotus officinalis*). Plant coverage in the randomly sampled plots in the upland zone ranged from 36% to 70%. The majority of plants establishing in the upland area consist of non-native plants such as yellow sweet clover, perennial rye grass, and rabbit’s foot grass. Plants installed by MAS were found in three (75%) of the four random upland quadrat samples. The coverage of installed plants ranged from 0% to 7% of the sampled areas and consists of coyote brush, creeping wild rye, meadow barley, and jaumea. Table 1 lists the plants observed in the sampled quadrats of the middle section.

![Point 4](image)

![Point 5](image)

![Point 6](image)

Figure 4. Middle restoration section.

Photos taken before restoration work (January 9, 2004) are shown on the left. Photos taken after grading and contouring of the site (January 13, 2005) are shown on the right.
Western section
The western section was also recently graded and contoured down to marsh elevations (figure 5). Pickleweed and marsh gumplant were growing at the margins of the western section adjacent to the tidal marsh on the January 13, 2005, survey. As natural recruitment of the area is expected to occur, the western section was not planted.

Caltrans biologists observed a dead deer, a turkey vulture, and kildeer near the western section. Caltrans biologists identified a California red-sided garter snake (*Thamnophis sirtalis infernalis*) at the edge of the western section in the pickleweed.

A second plant survey was conducted on June 7, 2005, after MAS completed the installation of upland native plants. During this survey, Caltrans biologists determined plant coverage in quadrats sampled randomly in the western section.

The tidal zone in the western section was completely submerged during the survey and no plant coverage in this area was observed. Plant coverage in the randomly sampled plots in the wetland-upland transition zone ranged from 24% to 55%, showing recruitment into these areas of tidal marsh plants such as pickleweed and saltgrass from the adjacent tidal zone. Plant coverage in the randomly sampled plot in the upland zone was 95%, consisting mostly of non-native plants such as yellow sweetclover, perennial rye grass, and slender wild oats (*Avena barbata*). MAS planted creeping wildrye in this area and it was found in 10% of the sampled area. Table 1 lists the plants observed in the sampled quadrats of the western section.

Photos taken before restoration work (January 9, 2004) are shown on the left. Photos taken after grading and contouring of the site (January 13, 2005) are shown on the right.
Conclusions

At the eastern section, Caltrans expects that 0.412 ha (1.019 a) of the 0.781 ha (1.929 a) area of land that was contoured and graded will become tidal marsh habitat, 0.084 ha (0.207 a) will become wetland-upland transition areas and 0.285 ha (0.704 a) will become upland habitat after five years.

The quadrats sampled in the tidal marsh of the eastern section show an average of 3% total plant coverage. Because biologists conducted a plant survey of the area only five months after the area was recontoured, this survey does not adequately represent annual plant growth in the area. Plant surveys scheduled for January 2006 will provide a better estimate of annual plant growth in the tidal-marsh area.

The quadrats sampled in the upland-wetland transition areas of the eastern section show an average of 80% total plant coverage. The transition areas directly adjacent to the marsh show recruitment of native marsh plants. Approximately half of the transition area directly adjacent to the upland berm shows recruitment of non-native plant species, MAS will determine whether to control the spread of non-native upland plant materials that have established in the area.

The quadrats sampled in the upland areas of the eastern section show an average of 54% total plant coverage, but only 13% of total plant coverage is represented by plants installed by MAS. MAS will determine whether to install more native plants or to implement weeding methods to control the spread of non-native upland plant materials that have established in the area.

At the middle section, Caltrans expects that 0.057 ha (0.141 a) of the 0.182 ha (0.451 a) area of land that was contoured and graded will become tidal marsh habitat, 0.021 ha (0.053 a) will become wetland-upland transition areas and 0.104 ha (0.257 a) will become upland habitat after five years.

The quadrats sampled in the tidal marsh of the middle section show an average of 21% total plant coverage. The tidal area in the middle section may have more plant coverage than the eastern section because of differences in tidal inundation, differences of elevation of the sampled areas, or differences in how the quadrats were sampled. Plant surveys scheduled for January 2006 will provide a better estimate of annual plant growth in the tidal-marsh area.

The quadrats sampled in the upland-wetland transition areas of the middle section show an average of 46% total plant coverage. The transition areas directly adjacent to the marsh show recruitment of native marsh plants. Approximately 21% of the transition area directly adjacent to the upland berm show recruitment of non-native plant species. MAS will determine whether to control the spread of non-native upland plant materials that have established in the area.

The quadrats sampled in the upland areas of the middle section show an average of 54% total plant coverage, but only 4% of total plant coverage is represented by plants installed by MAS. MAS will determine whether to install more native plants or to implement weeding methods to control the spread of non-native upland plant materials that have established in the area.

At the western section, Caltrans expects that 0.014 ha (0.034 a) of the 0.081 ha (0.200 a) area of the levee that was contoured and graded will become tidal marsh habitat and 0.067 ha (0.166 a) will become wetland-upland transition areas after five years.

The quadrat sampled in the tidal marsh of the western section did not show any plant coverage. This area is constantly submerged, which may inhibit plant growth or prevent plants in the area from being identified. Future plant surveys may identify plants growing in this area.

The quadrats sampled in the upland-wetland transition areas of the western section show an average of 39% total plant coverage. Because this transition area is located directly adjacent to the marsh, it shows recruitment of a high percentage of native marsh plants.

The quadrats sampled in the upland area of the western section show approximately 95% total plant coverage, but only 10% of total plant coverage is represented by plants installed by MAS. MAS will determine whether to install more native plants or implement weeding methods to control the spread of non-native upland plant materials that have established in the area.

Acknowledgments: The authors would like to thank Barbara Salzman of the Marin Audubon Society for her assistance in the development of this site. We would also like to thank Fred Botti, California Department of Fish and Game (retired) for his thoughts and suggestions on the mitigation opportunities within the Highway 101 corridor.

Biographical Sketches: Chuck Morton is a district branch chief for the California Department of Transportation in the Oakland office. His area of responsibility encompasses Marin, Sonoma, Napa, Solano, and Contra Costa Counties and includes over 700 miles of roadway. He holds a B.S. in biology and marine science and a M.S. in environmental planning.

Michael Galloway is currently employed as a biologist for Caltrans. He graduated from San Francisco State University in 2001 with an M.A. degree in marine biology. His master’s thesis focused on Pacific harbor seal (Phoca vitulina richardii) haul-out behavior at a haul-out site in the San Francisco Bay. He is currently monitoring several Caltrans restoration projects in the San Francisco Bay area, including this project, and the Triangle Marsh Restoration Project in Corte Madera, California.
References
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USE AND SELECTION OF HIGHWAY BRIDGES BY RAFINESQUE’S BIG-EARED BATS IN SOUTH CAROLINA

Frances M. Bennett (Phone: 513-556-9730, Email: bennetfm@email.uc.edu), University of Cincinnati, P.O. Box 210006, Cincinnati, OH 45221-0006

Abstract

Rafinesque’s big-eared bats (Corynorhinus rafinesquii) occur throughout the South and into some Midwestern states. However, they are rare throughout their range and are considered to be a species of special concern in every state in which they occur. Previous studies have documented the use of bridges by Rafinesque’s big-eared bats in Louisiana, Mississippi, and North Carolina, but information on bridge use across the range is lacking. Furthermore, two of the three studies on bridge use were conducted in national forests. Thus, our objective was to determine the use and selection of bridges as day roosts by Rafinesque’s big-eared bats on all public roads in South Carolina.

We surveyed 1,129 bridges within all 46 counties from May to August 2002. During the summer of 2003, we monitored 236 bridges in previously occupied areas of the state one to five times to evaluate bridge-roost fidelity. Colonies (including maternal groups) and solitary big-eared bats were found beneath 38 bridges in 2002 and 55 bridges in 2003. Occupancy in both years was strongly influenced by bridge size ($P < 0.001$) and construction type ($P < 0.001$); bats selected large, concrete-girder bridges and avoided flat-bottomed, slab bridges. Rafinesque’s big-eared bats occupied bridges in the Upper and Lower Coastal Plain, but were absent from bridges in the Piedmont and Blue Ridge Mountains. Big-eared bats demonstrated a high degree of roost fidelity (65.9 percent). We also found that checking bridges three times at two-week intervals ensured the detection of bats, but checking more than three times did not increase detection probabilities.

The high degree of fidelity and use by maternal groups suggest that highway bridges are important roosting sites for Rafinesque’s big-eared bats in the South Carolina Coastal Plain. Our results also suggest that if repair or maintenance work is planned for girder bridges during the summer, they should be inspected three times over a four to six week period. Because other studies have shown that Rafinesque’s big-eared bats rarely use bridges during winter, delaying work on occupied bridges until that time will aid in the conservation of this rare species.

Biographical Sketch: Frances Bennett completed an honor’s degree in biology from the University of Saskatchewan in 1999, after which she worked as a field biologist for three years in eastern Canada for provincial and federal agencies and Acadia University. She attended Clemson University to complete a master’s degree in environmental/wildlife toxicology from 2002-2004, where she conducted a statewide survey for Rafinesque’s big-eared bats in South Carolina and also carried out an assessment of metal exposure in these bats. Ms. Bennett attends the University of Cincinnati, where she plans to continue her research into the effects of environmental contaminants on insectivorous bats.
USING REMOTE-SENSING CAMERAS AND TRACK SURVEYS TO ASSESS WILDLIFE MOVEMENT THROUGH A PROBABLE WILDLIFE LINKAGE BISECTED BY TWO MAJOR HIGHWAYS

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Charles Barclay, Manager, Natural Resources Management Section, Arizona Department of Transportation, 1444 W. Grant Road, MD T862, Tucson, AZ 85745-1403

Abstract

The Arizona Department of Transportation, Natural Resources Management Section (NRMS), and Sky Island Alliance, a non-profit conservation organization, are collaborating on a project utilizing a combination of motion-sensing cameras and track surveys to assess wildlife activity and movement between the Dragoon and Whetstone Mountains in southeastern Arizona. The study investigates the distribution of wildlife across the landscape as it relates to wildlife utilization of different crossing structures on two major highways.

Through its Wildlife Monitoring Program, Sky Island Alliance identifies at-risk landscape-level wildlife corridors within the region and conducts long-term monitoring and data collection within those corridors. Sky Island Alliance is particularly concerned with the movement of four large, wide-ranging mammals: Ursus americanus (black bear), Puma concolor (mountain lion), Pantera onca (jaguar), and Canis lupus baileyi (Mexican gray wolf). Top predators were chosen based on their large spatial requirements and reliance on wildlife corridors connecting the region’s mountain ranges. In the Sky Island region, the importance of wildlife corridors is magnified due to the numerous, relatively small mountain ranges separated by valleys varying from 16 to 40 km in width. In addition, data are collected on two smaller species: Lynx rufus (bobcat), Nasua narica (coati). The region between the Whetstone and the Dragoon Mountains was identified as containing possible critical wildlife-movement routes threatened by the increase of habitat fragmentation in the form of road expansion, subdivision of private land, and loss of open space. The area is bordered on the west by the Whetstone Mountains and on the east by the Dragoon Mountains. The San Pedro River, flowing northward out of Mexico, as well as two high-speed four-lane highways, bisects the study area. These three features, one natural and two human-made, are possible deterrents to wildlife movement across the valley.

Wildlife activity is monitored by conducting “track surveys” along pre-established transects. Tracking volunteers, trained by Sky Island Alliance, search for and document incidences of wildlife sign such as tracks, scat, scratches, scrapes, or kill sites. Occurrence of wildlife sign indicates the presence of that species on the transect. Volunteers record species, type of sign, UTM map coordinates for the location of sign and direction of travel (if applicable). Sign from any of the six species of concern are photo documented. Other species are noted, but not assigned data points or UTM coordinates. Sky Island Alliance has been conducting track surveys in the Dragoon/Whetstone corridor since 2001, concentrating efforts in the area east of State Route (SR) 80 and west of the Dragoon Mountains.

Tracking transects are located in four major drainages: Stronghold Canyon and Slavin Wash (which converge before crossing under SR 80) and Smith and Clifford Washes (which converge east of SR 80). Information gathered from tracking surveys is plotted on a map using the ArcView Geographic Information System to determine the location and distribution of wildlife activity. In addition to the tracking transects, Tucson NRMS recently installed remote cameras under two bridges and three culverts along a 10-km stretch of SR 80 in direct relation to the tracking transects. This section, which is located south of the town of St. David, has been identified as having high levels of wildlife activity and roadkill incidence. Tucson NRMS facilitates film replacement and camera maintenance and the management of collected photographic data.

To date, trackers have documented two focal species–bobcat and mountain lion–on all transects within the project area. In addition, Tucson NRMS personnel documented mountain lion tracks outside one of the culvert sites. Sky Island Alliance verified the species identification. Inspection of the first round of remote-camera photographs reveal travel through the culverts and bridges by deer, javelina, cattle, and domestic dog, as well as humans on horseback, ATVs, or foot. To further test the feasibility of using remote cameras under highways, NRMS has installed four cameras along SR90. Future research will expand tracking surveys throughout the Dragoon/Whetstone corridor, specifically in relation to the camera sites on SR 90. Using tracking data in combination with data from the remote cameras, NRMS biologists and Sky Island Alliance will examine characteristics of wildlife corridors in relation to major roadways, in addition to evaluating wildlife use of different crossing structures and how roadway dynamics influence wildlife movement.
**Abstract**

Instream projects—whether for habitat enhancement, culvert and bridge replacements, mitigation for fisheries or aquatic habitat impacts, or bank protection—often occur in altered streams in altered watersheds. For this paper, we will use the term “enhancement” to include all forms of “restoration” and “rehabilitation.” Infrastructure typically interrupts watershed geomorphic processes and places constraints from both physical and legal liability viewpoints. Stakeholders can bring constraints in the form of biased perceptions and interests. Raw materials that may have been historically available for habitat-forming features are likely greatly reduced or even wholly unavailable to the stream, especially lower in the watershed. As a result, these natural materials can be unavailable to sustain or construct enhancement projects, or conversely, may be available to excess. While we often recognize that watersheds are altered, we frequently do not apply that information in the context of individual project development and implementation. As a result, inappropriate project design results from a lack of consideration of the entire project context (both project and watershed scale) and from circumventing a detailed constraints analysis early in the process.

Practitioners often try to improve instream and riparian habitats with the goal of restoring “natural” functions without recognizing the larger context of the existing altered conditions in the watershed. This nearly ubiquitous state of alteration requires us to recognize that the altered state of urban, and even many wildland streams, is unlikely to support historic habitat functions without structural intervention. Elements that formed instream habitat in the undisturbed stream may not work or may require adaptation in the new urban or disturbed environment. If “natural” defines the undisturbed stream, the obvious question is how “non-natural” do our design options need to be in the new urban or disturbed environment?

Our interdisciplinary design team and project management approach mirrors most of what defines the Context Sensitive Design (CSD) approach. We find that CSD applies a balanced approach in order to maximize natural, self-sustaining, low-maintenance elements that provide more long-term habitat functions, while still realizing the immediate creation or enhancement of missing habitats to provide needed functions to keep imperiled species viable. We share a common goal to create successful, natural, and self-sustaining stream-enhancement project designs that contribute to species and ecosystem recovery. This approach is usually more acceptable to the regulatory and environmental community. We are able to apply the reliability and stability of engineered features that may best provide short-term habitat functions, while larger-scale natural processes are allowed to re-establish.

We have identified a list of project and watershed elements that define project context as it relates to CSD and stream enhancement projects. Project context goes beyond site-specific or watershed condition assessment to include:

- Regulatory drivers, expectations and requirements
- Temporal constraints and goals, (short-term and long-term functions and processes)
- Physical/spatial constraints and goals, including landowners and infrastructure
- Liability considerations
- Cost
- The scope and scale of multi-level planning processes and stakeholder involvement.

We will compare the risks and benefits of different project approaches (CSD versus traditional) relative to ecological processes and professional liability. We will discuss natural vs. engineered/non-natural adaptations and new components in terms of:

- Long-term vs. short-term habitat functions and processes
- Symptoms vs. root problems
- Techniques/methods/materials
- Perceptions of stakeholders applied to all of the above

We will present project case studies in the Lower Columbia and Willamette River basins in Washington State and Oregon. Some interesting differences will be noted that resulted from both applying CSD early on, versus applying CSD late in the design process. These projects will illustrate ways to identify and define the watershed and project...
context, prioritize structural and non-structural project elements, and develop and choose from a toolbox that includes the maximum range of methods, techniques, materials, and approaches. We will address pre- and post-project monitoring as a critical (but often overlooked and underfunded) element in the successful adaptive management of dynamic resources. Finally, we will reaffirm the message that CSD has great applicability in the future development and prioritization of stream- and river-enhancement projects to improve the success of species and ecosystem recovery on a large scale.
Abstract

Many highways wind their way through excellent wildlife habitat. Florida's highways slice through rare black bear habitat. Alaska struggles with moose-vehicle collisions. Grizzly bears in the northern Rockies are killed on highways or avoid crossing them, limiting them to smaller areas.

Solutions are available, but the information is widely scattered. The Wildlife Crossings Toolkit gathers information in one location on proven solutions and lessons learned.

Who can use the toolkit?

Professional wildlife biologists, engineers, and transportation planners can use the toolkit to work together to create innovative solutions for wildlife-friendly highways and railways.

Features:

1. Case Histories
   - Fully searchable database of case histories
   - Highlights projects from around the world
   - Provides examples of solutions used in planning or retrofitting to prevent highway-caused impacts to wildlife
   - Demonstrates collaboration of engineers and biologists
   - Includes sections on alternative approaches and suggested modifications
   - Includes engineered drawings and photos

2. Resources
   - Summary articles by experts on wildlife habitat connectivity, highway impacts, and solutions
   - Extensive illustrated glossary to facilitate a common lexicon between engineers and biologists
   - Links to other pertinent resources including ICOET proceedings and international information

3. Training and Workshops

The USDA Forest Service has developed associated training sessions to complement the information in the Wildlife Crossings Toolkit.

Biographical Sketch: Sandra L. Jacobson, wildlife biologist/research and management liaison, Pacific Southwest Research Station, Redwood Sciences Laboratory, Arcata, California. Education: B.A. in zoology (1983), Humboldt State University, Arcata, California; M.S. in natural resources/wildlife (1986), Humboldt State University. Jacobson has served as a wildlife biologist for the USDA Forest Service since 1980, working on three national forests at the district and forest levels in California and Idaho. She has worked for the USDI Fish and Wildlife Service, California Department of Fish and Game, and the USDA Soil Conservation Service. As the district wildlife biologist for the Bonners Ferry Ranger District on the Idaho Panhandle National Forests for 13 years, she managed grizzly bears, woodland caribou, and other threatened or endangered wildlife in an interagency and international setting. Ms. Jacobson is the lead biologist for the Wildlife Crossings Toolkit website. She is a charter member of the Transportation Research Board's Task Force on Ecology and Transportation and a team member for NCHRP 25-27's Evaluating the Effectiveness of Wildlife Crossing Structures. She is a member of the University of California-Davis Road Ecology Center’s Scientific Advisory Committee. Currently, Ms. Jacobson is providing project-level technical expertise and training on wildlife and highway issues for several agencies around the country while acting as a research/management liaison at the Pacific Southwest Research Station.
WILDLIFE HOT SPOTS ALONG HIGHWAYS IN NORTHWESTERN OREGON

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Abstract: Determining locations where wildlife movement and highway operation conflict is an essential first step in making highways safer for motorists and animals. Using an expert-opinion approach, we identified 86 conflict areas (hot spots) for wildlife along state-maintained roads in the Oregon Department of Transportation’s Region 1. Of the 757 miles of highway analyzed, 22% were identified as wildlife hot spots by expert teams, suggesting that the scope of this problem is substantial. Most of these hot spots were locations with frequent deer-vehicle collisions, although some were crossing locations for deer and elk that did not have frequent animal-vehicle collisions. Some hot spots were identified for non-focal species, including northwestern pond turtle, western painted turtle, coyote, bobcat, black bear, and beaver. Hot spots generally were associated with topographic features that directed animals towards highways, the presence of habitat adjacent to highways, or food resources that attracted animals. Six hot spots were considered high priority. The expert-opinion approach employed for this analysis was effective in rapidly assessing many miles of state-maintained highway for the presence of wildlife hot spots and may prove useful in addressing conflicts between wildlife and highways in other locales or on a statewide basis. Not all of the hot spots warrant mitigation, although we suggest that the areas identified in this analysis be examined more carefully during development of projects that may affect wildlife passage.

Introduction

Nearly all human communities in North America are connected via roads. The movement of goods and people allowed by this unprecedented connectivity is fundamental, both economically and socially, to our society. However, while connecting human communities, the modern road network has fragmented the natural environment, leaving animal populations isolated from one another and thus at greater risk of extinction from genetic (Keller and Largiader 2003) or demographic factors (Lande 1988). Animal-vehicle collisions are one of the primary causes of fragmentation, because dispersing individuals that attempt to cross roads suffer elevated rates of mortality due to collisions with motor vehicles (e.g., Lode 2000). Animal-vehicle collisions thus can affect population viability both directly through increased mortality rates and indirectly through the demographic and genetic effects of population fragmentation.

The human costs of animal-vehicle collisions are also substantial, especially when involving large animals such as deer (Odocoileus spp.) and elk (Cervus elaphus). For example, Conover et al. (1995) estimated that 1.5 million collisions between motor vehicles and deer occur annually in the United States, killing 211 people, resulting in 29,000 human injuries, and causing $1 billion in property damage annually. When insurance costs, lost productivity due to human injury, and value of the animal killed are accounted for, the annual economic cost of collisions between deer and motor vehicles likely exceeds $2 billion (Danielson and Hubbard 1998). As populations of deer in North America continue to swell, the number of collisions and associated costs will continue to rise. In the United States, white-tailed deer (for example) numbered approximately 500,000 in 1900 and climbed to over 20,000,000 in 1996 (Hughes et al. 1996).

Numerous methods exist for allowing safe passage of animals across highways, ranging from relatively inexpensive efforts to modify the behavior of motorists (e.g., warning signs) or animals (e.g., reflective lights, repellents, or intercept feeding) to expensive construction of new infrastructure (e.g., wildlife overpasses or underpasses). However, the success of these measures is strongly influenced by their placement (Clevenger and Waltho 2000, Gloyne and Clevenger 2001, Ng et al. 2004), and thus any effort to maintain safe passage for wildlife and reduce animal-vehicle collisions must first identify the location of problem areas, or hot spots. In addition, the high cost of many passage solutions requires that efforts be prioritized to produce maximum returns on any investment in mitigation. Developing a comprehensive and efficient strategy for addressing the environmental, economic, and social costs of animal-vehicle collisions therefore must be predicated on an understanding of where conflicts between wildlife and highway operation are most severe.

Here, we detail the application of a rapid-assessment process (Ruediger and Lloyd 2003) that can be used to identify potential hot spots quickly for wildlife along highways. Our study area was a portion of the state of Oregon that includes mountainous, agricultural, and highly urbanized landscapes. We chose the study area as a test case to determine the value of the rapid-assessment process for conducting statewide analyses of potential hot spots. Throughout Oregon, collisions between wildlife (especially deer and elk) and motor vehicles have been identified as a significant problem in Oregon (ODFW 2003a, b). However, efforts to address the problem are hampered by a lack of information, most notably the location of areas where wildlife-vehicle collisions are most frequent and wildlife passage most limited. To address this information gap, we conducted a study to identify and prioritize wildlife hot spots along state-maintained highways within Region 1 of the Oregon Department of Transportation (ODOT). We focused on mule deer (O. hemionus hemionus), black-tailed deer (O. hemionus columbianus), and elk (Cervus elaphus) because of public concern for these species and because they pose the greatest risk to motorists when involved in collisions with motor vehicles. We also collected ancillary data about additional species.
Methods

Wildlife hot spots are generally identified using data on the distribution of animal-vehicle collisions (Malo et al. 2004), predictive models of wildlife habitat (Clevenger et al. 2002), or by expert opinion (Clevenger et al. 2002, Ruediger and Lloyd 2003). We chose to use an expert-opinion approach because the data necessary for empirical modeling of wildlife hot spots is lacking for our study area and because expert opinion is faster and generally produces results equivalent to those obtained via empirical modeling (Clevenger et al. 2002, Ruediger and Lloyd 2003).

The study area consisted of the state-managed highway system within northwest Oregon (ODOT Region 1, including the counties of Multnomah, Washington, Clackamas, Columbia, and Hood River, as well as portions of Clatsop County and Tillamook County), including state routes, U. S. highways, and interstate highways. Prior to assembling expert teams, we split the study area into eight subregions, based approximately on the boundaries of maintenance units. Expert teams, comprised of local ODOT maintenance workers, local and regional biologists, and others with knowledge of local conditions, were then established for each subregion. In establishing these teams, we attempted to ensure that each was composed of members with detailed, site-specific information about the location of animal-vehicle collisions (e.g., staff of ODOT Maintenance) as well as members with broader-scale perspectives about the movements and habitat requirements of the focal species (e.g., wildlife biologists from Oregon Department of Fish and Wildlife (ODFW) and the U. S. Forest Service (USFS)).

Expert teams were provided with GIS-based, paper maps of the subregion that presented information on topography, land ownership, location of streams and other waters, location of parks and open space, location of highways, and highway mileposts. To help team members accurately identify potential hot spots, expert teams were also provided with interactive, computer-projected GIS maps that included all of the layers provided on the paper maps as well as high-resolution (2-feet pixels), color-infrared digital photography of the entire study area. When a potential hot spot was identified, the team member provided a rationale for identifying the area as a hot spot. The hot spot was only recorded if the expert team reached unanimous consensus.

To ensure accurate representation of hot spots, each was mapped directly into a GIS database once the expert team had reached consensus. This allowed all team members to verify that the location was accurately described. Each hot spot was assigned a record number based on subregion and sequential identification number (e.g., the first hot spot identified in Subregion 8 was identified as 08-01). The following information was collected about each hot spot identified:

1. Basis for nomination.
2. Description of location, including highway mile markers and distinguishing topographic features.
3. Presence of any existing features that facilitate or encourage animal movement across the road.
4. Other species that may use this area as a road crossing.
5. Future threats to the value of the area as a wildlife crossing.
6. Priority to ODOT.

The priority of each hot spot was based on the judgment of the expert team. In general, expert teams considered areas with an unusually high frequency of animal-vehicle collisions, documented or suspected crossings by sensitive or rare species, or deer and elk migratory routes. Medium-priority hot spots generally had lower rates of animal-vehicle collisions than high-priority hot spots or, in several cases, had no documented animal-vehicle collisions but were used frequently as a crossing location for wildlife. Low-priority hot spots typically had only scattered reports of animal use. We visited all of the hot spots identified as high priority by the expert teams, all of the hot spots used as road crossings by rare or sensitive species, and a randomly selected subset of the medium-priority hot spots to document site conditions, establish a photographic record of site conditions, and verify the information received.

Results

Overall

The total length of highways considered in this analysis was 757 miles (Table 1). Of the total highway miles considered, 170 miles, or 22%, were identified as wildlife hot spots. The expert teams identified 86 hot spots in Region 1. Most of these (44) were identified based on frequent deer-vehicle collisions. Elk crossings (10) and areas where both frequent elk crossings and frequent deer-vehicle collisions occurred (15) were also commonly noted by expert teams. Elk-vehicle collisions were not identified as a problem at any hot spot, and only one area was identified as a deer crossing without frequent deer-vehicle collisions. The remaining 17 hot spots identified included 15 areas noted for frequent collisions between motor vehicles and non-focal species (for example, coyote (Canis latrans), beaver (Castor canadensis), and northwestern pond turtle (Emys marmorata marmorata), two areas without frequent animal-vehicle collisions that were used as crossings by non-focal species, and one area with existing underpasses (cattle crossings) that might be used by wildlife.

The size of hot spots varied considerably. Most were greater than one mile long. The mean length of a hot spot was 2.3 miles (Table 1). However, the mean length was biased upwards by the inclusion of several extraordinarily long hot spots (e.g., a 15.5-miles long hot spot along I-84 in Subregion 5). The average median length of hot spots in each subregion
was 1.7 miles. Median hot-spot length tended to be greater in the eastern portion of the study area, including the foothills of the Cascade Range (Subregions 7 and 8), Mount Hood and the Hood River drainage (Subregion 6), and the Columbia River Gorge (Subregion 5).

The number of hot spots identified in each subregion did not correspond with the total length of state-maintained highway in each subregion. Western subregions, especially those in the Coast Range (Subregions 1 and 2), had more hot spots identified than did eastern subregions (Subregions 6-8). Rural subregions tended to have longer hot spots and a greater percentage of highway miles in hot spots. For example, the two most urbanized subregions, Portland-Sylvan and Portland-Flanders, had only 10% and 16% of highway miles in hot spots, with an average length of 1.3 miles and 1.9 miles, respectively. In contrast, hot spots in the more rural Clatskanie, Cascade Locks, and Government Camp subregions accounted for more than 30% of total highway miles, and the average length of hot spots was greater (averaging 3 miles). Suburban subregions, such as Sandy and Estacada, were intermediate both in the percentage of highway miles in hotspots and the average length of hot spots.

Table 1. Summary statistics for wildlife hot spots identified along state-maintained highways in Region 1 of the Oregon Department of Transportation

<table>
<thead>
<tr>
<th>Subregion name (Subregion number)</th>
<th>Total miles of highway analyzed</th>
<th>Percentage of miles in hot spots(^1)</th>
<th>Number of hot spots identified</th>
<th>Average length of hot spots (miles)</th>
<th>Median length of hot spots (miles)</th>
<th>Range of hot-spot lengths (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clatskanie (1)</td>
<td>91</td>
<td>36</td>
<td>18</td>
<td>1.8</td>
<td>0.75</td>
<td>0.2 – 11</td>
</tr>
<tr>
<td>Manning (2)</td>
<td>98</td>
<td>16</td>
<td>17</td>
<td>0.9</td>
<td>0.9</td>
<td>0.4 – 1.4</td>
</tr>
<tr>
<td>Portland-Sylvan (3)</td>
<td>161</td>
<td>10</td>
<td>12</td>
<td>1.3</td>
<td>1.0</td>
<td>0.3 – 1.3</td>
</tr>
<tr>
<td>Portland-Flanders (4)</td>
<td>142</td>
<td>16</td>
<td>11</td>
<td>1.9</td>
<td>1.5</td>
<td>0.5 – 6</td>
</tr>
<tr>
<td>Cascade Locks (5)</td>
<td>74</td>
<td>39</td>
<td>7</td>
<td>4.0</td>
<td>2.5</td>
<td>1 – 15.5</td>
</tr>
<tr>
<td>Government Camp (6)</td>
<td>82</td>
<td>33</td>
<td>9</td>
<td>3.1</td>
<td>3.0</td>
<td>0.3 – 7</td>
</tr>
<tr>
<td>Sandy (7)</td>
<td>38</td>
<td>29</td>
<td>4</td>
<td>2.5</td>
<td>2.1</td>
<td>1 – 5</td>
</tr>
<tr>
<td>Estacada (8)</td>
<td>72</td>
<td>23</td>
<td>8</td>
<td>2.6</td>
<td>1.6</td>
<td>0.1 – 7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>757</strong></td>
<td><strong>22</strong></td>
<td><strong>86</strong></td>
<td><strong>2.3</strong></td>
<td><strong>1.7</strong></td>
<td><strong>0.1-15.5</strong></td>
</tr>
</tbody>
</table>

\(^1\) Calculated as total length of highway/total length of hot spots.

**Subregional summary**

Of the 86 hot spots identified by the expert teams, six were considered high priority. Three high-priority hot spots occurred in the Portland-Sylvan subregion (Subregion 3), which includes the western side of the greater Portland metropolitan area. Two of these were segments of State Highway 217 in which amphibians, small mammals, and birds are frequently killed while attempting to cross the highway; the third was on U. S. Highway 26 and was noted for collisions between motor vehicles and deer, waterfowl, and raptors. A high-priority hot spot was identified on State Highway 213, near Milk Creek in the northern Willamette Valley (Subregion 4), based on the frequency of collisions between deer and motor vehicles. In the Cascade Locks subregion (Subregion 5), a high-priority hot spot for several species, including deer, elk, beaver, and several reptiles and amphibians, was identified along Interstate 84 in the Columbia River Gorge. Roadkilled animals are common in this hot spot, which is associated with an extensive wetland complex near Multnomah Falls. The sixth high-priority hot spot was located on State Highway 35 (Government Camp, Subregion 6) where the highway bisects an important migration corridor for deer and elk.

Many of the hot spots in the coastal mountains (Subregions 1 and 2) included moderately long stretches of highway, reflecting the fairly continuous forest cover adjacent to the highways in these subregions. Many hot spots in Subregions 1 and 2 appeared to be connected with ephemeral features of the landscape, such as aging clearcuts that provide foraging opportunities for deer and elk, although the expert teams also identified several hot spots that were influenced by topographic features. No high-priority hot spots were identified in these subregions. Indeed, the most significant hot spots in the coastal mountains of northwest Oregon appear to lie outside the western boundaries of the study area on the west slope of the Coast Range, where larger elk populations exist (D. Nuzum, ODFW, pers. comm.).

The two urban subregions (subregions 3 and 4) contained slightly lower proportions of hot spots than the more rural or mountainous subregions (all others) and also had hot spots that were significantly shorter in length than other subregions (Table 1). Many of the hot spots identified in Subregions 3 and 4 were associated with wetland features and were identified based on the frequency of collisions between motor vehicles and some combination of deer, small mammals, and waterfowl. Hot spots for deer were also associated with areas of remnant open space or other suitable, disturbed environments, such as golf courses and plant nurseries. Elk hot spots were uncommon in these subregions, mainly due to the lack of large blocks of suitable habitat.
Two high-priority hot spots occurred in the City of Beaverton, one of which was located near an area of open space along State Highway 217 (Site 03-04 and 03-05). Both sites are flanked by wetlands and pockets of natural habitat in an otherwise developed area. Good habitat, including wetlands and a golf course adjacent to the highway, exists for migratory birds and small mammals. However, the area immediately adjacent to the highway in both sites is heavily developed. Beaver, nutria (Myocastor coypus), raccoon (Procyon lotor), and birds are frequently killed in collisions with motor vehicles. The jersey barrier that runs through this section likely represents a significant barrier to most species that attempt to cross and may increase the risk of collision for animals that attempt to cross over the roadway.

Not all hot spots were associated with animal-vehicle collisions. For example, a hot spot was identified near a wetland complex because northwestern pond turtles and western painted turtles (Chrysemys picta), both listed as Sensitive-Critical by ODFW, are thought to cross in this section. The site is located adjacent to the Burlington Bottoms Wildlife Area, just northwest of Portland (Site 03-08). It was ranked as a medium-priority site because the expert team had no information on whether roadkill was occurring at this hot spot. However, no culverts exist to allow animals to cross beneath the roadway, and thus any movement across the highway requires crossing four lanes of traffic. In addition, railroad tracks lie parallel and adjacent to the roadway on both sides, although several small culverts and a bridge allow passage beneath the railroad tracks. Collisions between ducks and motor vehicles are known to occur at this hot spot.

One hot spot in the northern Cascade Mountains, in the Government Camp Subregion (Site 06-07), was singled out by the expert teams as the most important in the study because it encompasses a section of road that crosses an area used during migration by deer and elk. Although expert teams were asked only to prioritize hot spots within their respective subregion, expert team members who contributed to multiple subregions agreed that this hot spot was the most significant in Region 1. The highway in this hot spot, which is three miles long, is curvy and clear zones are limited, resulting in frequent deer-vehicle collisions. Although this hot spot includes a significant elk-migration route, elk-vehicle collisions are rare at present. The only mitigation measure employed within this hot spot is a deer-crossing sign near the turnoff to Cooper Spur Ski Area. The functionality of this hot spot may be threatened by the proposed expansion of Cooper Spur Ski Area, which would significantly increase traffic through this hot spot.

Discussion

Region 1 wildlife hot spots

Collisions between animals and motor vehicles are a significant problem in Oregon. Of the 757 highway miles analyzed in this study, approximately 22% were included in hot spots identified by the expert teams. The extent of these conflict areas suggests that allowing wildlife to move safely across Oregon’s highways will yield substantial economic and environmental benefits. In particular, reducing the risk of collisions between motor vehicles and animals will mean fewer human injuries and fatalities, less money spent on vehicle repair and insurance costs, and reduced mortality in wildlife populations.

In addition, allowing safe passage for wildlife will also ensure that animals have access to all necessary habitats and resources and that connectivity among different populations is maintained. The necessary first step towards this goal is to identify those areas where conflicts between wildlife movement and highway operation are most severe. The results of the analysis presented here provide this information for Region 1 of ODOT.

Although deer-vehicle collisions were the basis of most of the identified hot spots, expert team members also identified crossing areas used by deer and elk in which collisions are not an issue, as well as hot spots used by a variety of other species, including black bear (Ursus americanus), bobcat (Felis rufus), river otter (Lutra canadenensis), beaver, small mammals, birds, red-legged frogs (Rana aurora aurora), northwestern pond turtles, and western painted turtles. Hot spots generally resulted from one of three factors: topography that directed animals towards the road, suitable habitat in close proximity to the road, or food resources that attracted animals. Understanding the nature of hot spots is important, as it will influence the likelihood that animals continue to use the area in a similar fashion in future years. For example, hot spots resulting from topography or hot spots that include historical migration routes are likely to remain hot spots indefinitely.

In contrast, hot spots for deer that exist due to attractive foraging opportunities created by timber harvest may receive less use as the forest ages and food availability declines. Hot spots that are associated with ephemeral resources are unlikely to remain stable through time, and thus may be a relatively low priority when considering mitigation. Considering how forest practices may influence animal movement is especially important in the western parts of Region 1, where much of the land adjacent to state-maintained highways is subject to timber harvest.

The frequency, size, and extent of hot spots varied among subregions. Variation in the length and extent of hot spots likely reflects differences in the amount and configuration of habitat available in each subregion. In the urban subregions, the amount of available habitat is low and tends to be highly fragmented, and animals are concentrated into remaining islands of habitat. Hot spots generally occurred wherever roads bisected remnant habitat patches, thus producing the observed pattern of many short, distinctive hot spots in the urban subregions. With more available habitat and fewer artificial edges to focus movement, animals in the rural subregions may be less likely to encounter the highway at discrete locations, leading to longer hot spots that account for a greater percentage of total highway miles.
Regional differences in the size and frequency of hot spots may also be related to corresponding variation in the behavior and life history of the focal species. For example, black-tailed deer and elk from the Coast Range and the west slope of the Cascade Range either do not migrate at all or undertake much shorter seasonal migrations than mule deer and elk from the east side of the Cascade Range, where deep snow accumulations and cold temperatures often drive significant seasonal migrations (Verts and Carraway 1998). When roads intersect traditional migration routes, which tend to follow well-defined and narrow corridors, short and discrete hot spots with frequent animal-vehicle collisions are likely to result.

In contrast, west of the Cascade Range hot spots probably reflect the proximity of habitat to roads and the local population density of the focal species. In these areas, the animal-vehicle collisions that help define hot spots may reflect the movement of individual animals within a home range, rather than large-scale migratory movements, and the resultant hot spots may be longer and less pronounced. This may be especially true in areas where roads bisect large blocks of habitat that support locally dense populations of the focal species.

Differences among subregions may also be due to the differences in the perceptions of members of expert teams. For example, maintenance crews in some subregions maintain written records of the location of many animal-vehicle collisions, allowing crews to provide more precise information about potential hot spots. In contrast, in subregions where maintenance crews did not record data on animal-vehicle collisions, expert team members were forced to rely on recollection and, in many cases, to approximate the location of hot spots. Thus, hot spots may appear to be longer in certain subregions simply because written records of animal-vehicle locations were not available.

In addition, because we did not establish strict criteria for identifying hot spots and instead relied on the best judgment of the expert teams, some variation may occur among subregions because perceptions of what constitutes a hot spot varied among expert team members. We attempted to minimize this bias by giving examples of what conditions might constitute a hot spot (e.g., unusually high rate of animal-vehicle collisions or frequent observations of animals crossing), but ultimately the opinion of the assembled experts dictated the identification of hot spots.

Efficacy of the approach

Despite the necessarily subjective nature of expert-opinion approaches, the approach outlined here proved a useful template for broader application throughout the state. Because the expert-opinion approach to identifying hot spots relies on existing information, it is far less expensive and time consuming than conducting field studies of animal movement. Few transportation projects operate on sufficiently long timelines to allow the multiple years of data collection and analysis necessary to achieve robust results. Habitat modeling can be used to predict hot spots along highways (e.g., Clevenger et al. 2002), but in most cases the detailed data necessary to build predictive models are lacking, as was the case for this study. For example, the landscape-level information available to predict the distribution of the focal species would have ruled out the presence of hot spots within the Portland metropolitan area, as urban areas are considered non-habitat. However, Portland does support urban-dwelling wildlife, including black-tailed deer, and animal-vehicle collisions are an important local issue.

The expert-opinion approach is also valuable because it draws on the vast, yet largely untapped, pool of local knowledge regarding wildlife and their movements. Although relying on local experts introduces an element of subjectivity, local ecological knowledge is used widely to address resource management issues, especially in remote and undeveloped areas where baseline empirical information is lacking (e.g., Mallory et al. 2003). The study area for this analysis is neither remote nor undeveloped, but baseline information on the location of wildlife hot spots is generally unavailable, both within the study area and throughout the state. Because this approach defines the scope and extent of the conflict between wildlife movement and highway operation, it may be especially useful as a first step in developing a comprehensive strategy for addressing wildlife movement along highways statewide.

One drawback of this approach is that it is difficult to apply to smaller species (such as amphibians and reptiles) that may experience high rates of roadkill but that are rarely observed by maintenance staff or other highway users. More detailed follow-up studies, including field surveys and habitat modeling, may be useful in refining information about the use of hot spots by these species. In addition, because the expert-opinion approach relies largely on observations of roadkilled animals, it does not identify sections of highway in which animals are prevented from crossing but in which animal-vehicle collisions are rare. This may be especially problematic when considering species that exhibit road-avoidance behaviors, including elk (Lyon 1979).

Recommendations for Future Study

The hot spots identified in this analysis should not be considered a definitive list of areas where wildlife crossings are a concern, nor are the results appropriate as the basis for mitigation planning. Rather, the results presented here should help to focus future research and provide guidance during the scoping and planning phases of transportation projects. Research should be directed at the hot spots identified as high priority by the expert teams to better quantify existing conditions at each location. Collecting additional data on animal-vehicle collisions and conducting surveys to determine which species are using these hot spots, and with what frequency, will help in determining whether any mitigation efforts are needed, and if so, what form mitigation should take.
Although the priority hot spots should be the focus of additional work, all of the hot spots identified in this analysis should be considered during project development. Early scoping during project development has been identified as the most effective way to address wildlife hot spots. To facilitate this, the hot spots identified in this study will be added to the other environmental-data sources that are evaluated during project scoping for Region 1. Early identification of these potential conflict areas within a project site may allow the opportunity to budget for further evaluation of hot spots. Although specific mitigation measures will not be known until further analyses have been conducted, costs can be estimated for conceptual-mitigation strategies based on basic project and site information, such as type of hot spot, animals involved, adjacent land use (existing and foreseen future), and type of proposed project (pavement preservation vs. bridge rehabilitation, for example). In addition to project development and construction budgets, other avenues of funding further research and construction of mitigation measures are available, including Federal Highway Administration (FHWA) enhancement grants, wildlife agency grants, or possibly safety or maintenance funds.

Possible mitigation strategies include structural approaches, such as adding fencing or building dedicated wildlife overpasses or underpasses (reviewed in Evink 2002). For those hot spots associated with bridges, mitigation opportunities might include relatively minor modifications to the existing structure, such as adding a bench for wildlife passage on the fill slopes beneath the bridge. Changes to the management of roadside vegetation may also be useful, especially because many of the hot spots identified in this study appear to be related to the presence of food and cover adjacent to the road. Eliminating habitat features that attract deer and elk to the roadside has proven effective in other areas (Rea 2003). Intercept feeding, in which attractive food sources are created that draw animals away from the road, may also help to reduce the frequency of collisions at hot spots (Wood and Wolfe 1988). In general, reflectors, repellents, and warning signs are of little value in reducing animal-vehicle collisions, especially on high-volume highways (Romin and Dalton 1992, Reeve and Anderson 1993, Gordon et al. 2004).

Finally, developing a standardized system for recording and collecting data on the location and nature of animal-vehicle collisions would prove invaluable in addressing wildlife passage problems on major highways. Roadkill or animal-injury records are important data for the development of empirical models that could be used to refine the results of expert-opinion analyses. Currently, the decision to collect data about the location of animal-vehicle collisions and the species involved is left at the discretion of each ODOT maintenance district. The degree to which collision data are collected varies greatly. In some cases, no data are collected at all. Although expert opinion is useful in conducting rapid assessments for potential hot spots, it cannot be used to quantify the severity of a problem in any particular hot spot (e.g., the frequency of animal-vehicle collisions), and thus cannot be used as baseline information for evaluating the effects of mitigation. Implementing a standardized, agency-wide system for collecting data on animal-vehicle collisions will be useful in justifying any investments made in mitigation. Expert opinion is a useful tool for rapidly assessing a highway system, but empirical data, if properly collected, are more reliable and also allow for fully parameterized cost-benefit analyses.

Biographical Sketches: John Lloyd is a biologist with Mason, Bruce & Girard, Inc. He received a Ph.D. in wildlife biology from the University of Montana in 2003, after which he worked as a post-doctoral associate on the USDA Forest Service Highway 93 Wildlife and Fish Habitat Linkage Analysis project. In addition to road ecology, John has expertise in avian ecology, statistics and experimental design, and wildlife-habitat relationships.

Melinda Trask is a biologist in Region 1 of Oregon Department of Transportation and has been with ODOT for over 5 years. Her undergraduate degree was in environmental biology with an emphasis in wildlife ecology from California Polytechnic State University. Ms. Trask has a master of science degree from Oregon State University in rangeland resources and a master of science degree from Washington State University in environmental planning. Her main duty at ODOT is to help the agency maintain compliance with federal and state endangered-species acts. In addition to preparing biological assessments and conducting monitoring on a variety of projects, Ms. Trask coordinates and manages peregrine falcons for many ODOT bridges and has developed a region-wide system for tracking wildlife roadkills.

Alexis Casey is a biologist with Mason, Bruce & Girard, Inc. She has a bachelor of science degree in resource management with an emphasis in forest resources from the University of California Berkeley (2002). In addition to her work on wildlife crossings in Oregon, she has experience with forest management and rare plant studies in California, Oregon, and Washington. She is currently working on a variety of projects to assess the anticipated impacts of development activities on ESA-listed wildlife, fish, and plant species.

References

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