# Use of highway underpasses by Florida panthers and other wildlife

*Melissa L. Foster and Stephen R. Humphrey*

**Wildlife, including endangered Florida panthers, successfully used constructed underpasses. Conservation implications are reviewed.**

Collision with motor vehicles is a major cause of mortality of the endangered Florida panther (*Felis concolor coryi*), accounting for 49% of documented deaths (Maehr et al. 1991). Demand for transportation infrastructure conflicting with endangered species protection could prevent highway construction unless mortality can be prevented. One such conflict was the proposed upgrade of 2-lane State Road 84 (Alligator Alley) to a 4-lane Interstate Highway (I-75) in southwestern Florida. This road traverses the range of the Florida panther (Fig. 1) and is the site of 5 panther roadkills (Maehr et al. 1991). Anticipated increases in traffic speed and volume on the upgraded highway were expected to increase hazards to panthers and motorists unless large animals could be excluded from the right-of-way by fencing. However, fencing alone would have divided the panther population into 2 smaller populations. Accordingly, fencing and wildlife underpasses were incorporated into the plan to upgrade the highway.

Most research on the use of highway underpasses by wildlife has focused on ungulates (e.g., Reed et al. 1975, Singer and Doherty 1985). Whether wildlife crossing structures reliably prevent mortality and population fragmentation of large predators has not been established. Ratcliffe (1974) reported that no highway mortality of European badgers (*Meles meles*) occurred within a single badger territory after installation of fences and an underpass. Black bears (*Ursus americanus*), gray wolves (*Canis lupus*), lynx (*Lynx canadensis*), and coyotes (*Canis latrans*) crossed a fenced segment of the Trans-Canada Highway at will but used underpasses where

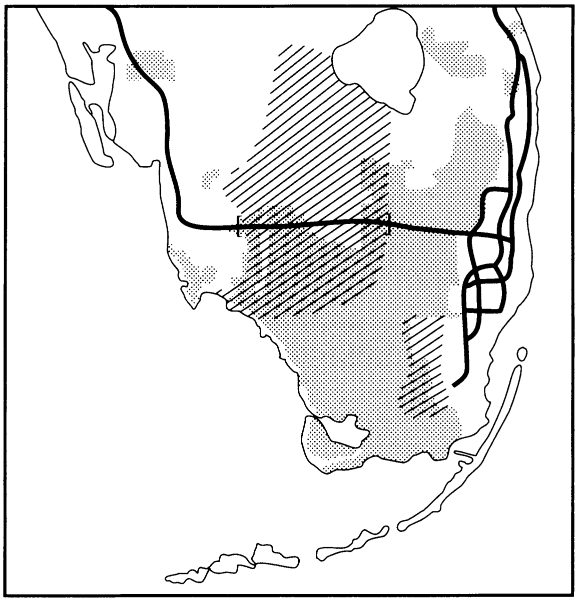

Fig. 1. Four-lane or larger highways (bold lines), public lands for conservation (shaded), and the distribution of Florida panthers (diagonal lines, after Maehr 1992) in southern Florida, 1992. Twenty-four wildlife underpasses and fencing were installed along the 64-km portion of Interstate 75 marked with brackets.

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**Key words:** Alligator, *Alligator mississipiensis*, black bear, bobcat, *Felis concolor coryi*, Florida panther, highway, *Lynx rufus*, *Odocoileus virginianus*, *Procyon lotor*, raccoon, road mortality, underpass, *Ursus americanus*, white-tailed deer

they were convenient; wolves and coyotes learned to herd deer against the highway fencing (Waters 1988). The purpose of our study was to determine whether the combination of fencing and underpasses constructed for the upgrade of I-75 effectively allowed panther movement across the road while preventing panthers from being hit by cars.

## Underpass design and monitoring

Design of wildlife underpasses along I-75 was based on panther biology and literature on use of highway underpasses by other species. Twenty-four underpasses were installed along a 64-km fenced portion of I-75 traversing Big Cypress National Preserve, Fakahatchee Strand State Preserve, and the Florida Panther National Wildlife Refuge in Collier County, Florida (Fig. 1). Distances between adjacent underpasses for the first 8 underpasses built, including the 4 studied here, ranged from 0.73-1.86 km and averaged 1.43 km. Each underpass consisted of 2 bridges under a 4-lane divided highway. Each bridge was constructed of concrete, configured as 2 lanes plus shoulders, 36.6 m long and 13.1 m wide. Eastbound and westbound lanes were separated by a 22.3-m median that was open overhead (not bridged). Three of the 4 underpasses monitored were (from the crossing animal's orientation) 21.2-25.8 m wide at grade level (fence to fence) and 48.5 m long, including the open median and both bridges, or 13.1 m long for each bridge. A 3.0-m high chain-link fence made of galvanized steel topped with 3 strands of barbed wire was installed along the entire 64 km to exclude animals from the highway right-of-way. This elaborate system of wildlife underpasses and fencing was experimental, because reducing road mortality of large carnivores had not been attempted before and because seasonal flooding of the flat terrain imposed severe constraints on construction.

The substrate of wildlife underpasses was distinctly unlike native habitat, consisting mostly of bare sand and gravel with sparse grasses and other herbaceous plants (Fig. 2). Vegetation approaching the underpasses was herbaceous plants characteristic of disturbed sites. Habitats of the flat study area were a mosaic of forests, marshes, and disturbed areas (Duever et al. 1979). Forests included hardwood swamps, slash pine (*Pinus elliottii* var. *densa*) flatwoods, and common baldcypress (*Taxodium distichum*) forests or savannas. Disturbed habitats were mostly roadsides and agricultural fields. Some of the habitat bordering the highway was already public land managed as wildlife refuges or preserves. As part of the highway development, additional land bordering the road was purchased to provide panther protection.

Underpasses were monitored by digital event recorders (game counters) and cameras with automatic flash units triggered by infrared-light sending and receiving units (Trailmaster 1500 Game Counters, P.O. Box 3497, Shawnee, KS 66203). Anything interrupting the light beam caused an event to be recorded and a picture to be taken. Four wildlife underpasses were monitored for approximately 2, 10, 14, and 16 months. We monitored the underpasses most likely to be used by panthers, as judged by tracks and telemetry data.

Game counters were strapped to a wooden platform with a flat plywood base. Because of the width of the underpasses and limited resolution of night-time photography, 3 counters were required to span each underpass. Although counters were in place nearly continually, monitoring was interrupted occasionally by cameras running out of film, vandalism, or depleted batteries.

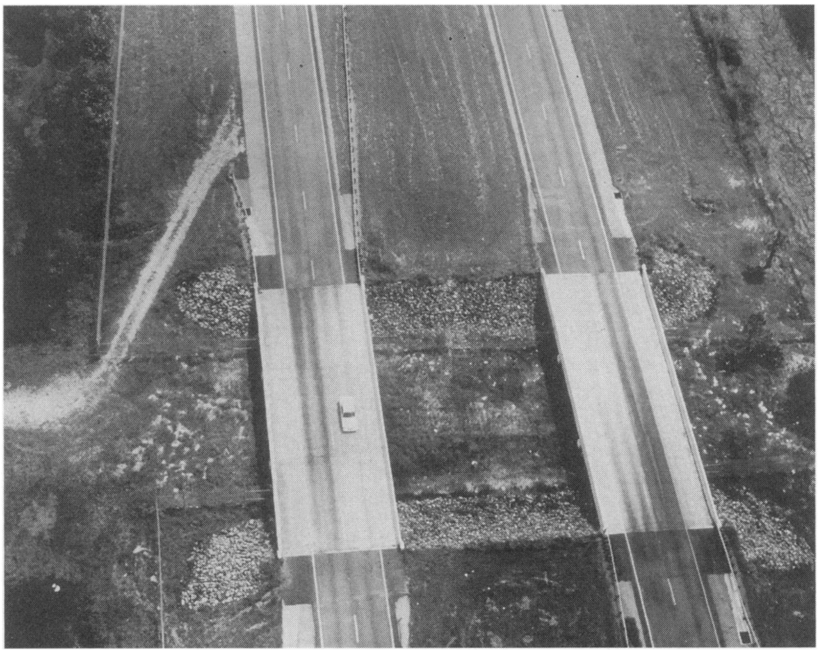

Fig. 2. Typical wildlife underpass and fencing at Interstate 75, southern Florida, 1992.

## Detections and difficulties

Cameras took 837 photographs of 1 or more animals at the 4 underpasses monitored during the study (Fig. 3). Photographs recorded 10 crossings by panthers, 133 by bobcats (*Lynx rufus*), 361 by deer (*Odocoileus virginianus*), 167 by raccoons (*Procyon lotor*), 9 by alligators (*Alligator mississippiensis*), and 2 by black bears. Telemetry data on radio-collared Florida panthers indicated that the 10 panther crossings were by 2 individuals, 1 using 2 different underpasses a total of 8 times and 1 using 1 underpass twice (D. S. Maehr, Florida Game and Fresh Water Fish Comm., Naples, pers. commun., 1992). Additionally, panther tracks were seen at unmonitored underpasses. The level and frequency of underpass use by panthers varied with location and configuration of panther home ranges and individual movements. Similarly, radio-collared bobcats often were photographed moving from 1 side of the highway to the other repeatedly within a single night.

The 4 crossing structures appeared to differ in their use by wildlife (Fig. 4). Most of the deer and raccoon photographs were taken at crossing 8. Most panther photographs were taken at crossing 12. Most wading birds (numerically) were photographed at crossing 4. Deer were the most commonly photographed animals at all underpasses except 12. Most photographs obtained at underpass 12 were of humans, with bobcats ranking second.

Eighty-five photographs were taken of humans and human-related objects (e.g., vehicles, dogs). Most were taken at underpass 12, which was vandalized in October 1990 and again in February 1991, when all equipment there was stolen. Replacement equipment was moved to underpass 10 because of continued trespass at underpass 12. At underpass 8, 1 camera was twice knocked off its support into a pool of water.

Different species used the underpasses at different times of day (Fig. 5). Panthers crossed exclusively at night. Raccoons and bobcats usually crossed from dusk to dawn. Deer were photographed most often during the day, particularly morning. The only wading birds photographed at night were yellow-crowned night herons (*Nycticorax violaceus*) and 1 little blue heron (*Egretta caerulea*). All other wading birds were photographed from 0500–1815.

We evaluated reasons for underpass use based on radiotracking data for panthers and bobcats, photographs of crossing animals, and prior knowledge of the species' behavior. Panthers, bobcats, and black bears used underpasses mainly to travel to portions of their home ranges separated by the highway. One bobcat photographed carrying a hispid cotton rat (*Sigmodon hispidus*) in its mouth may have been

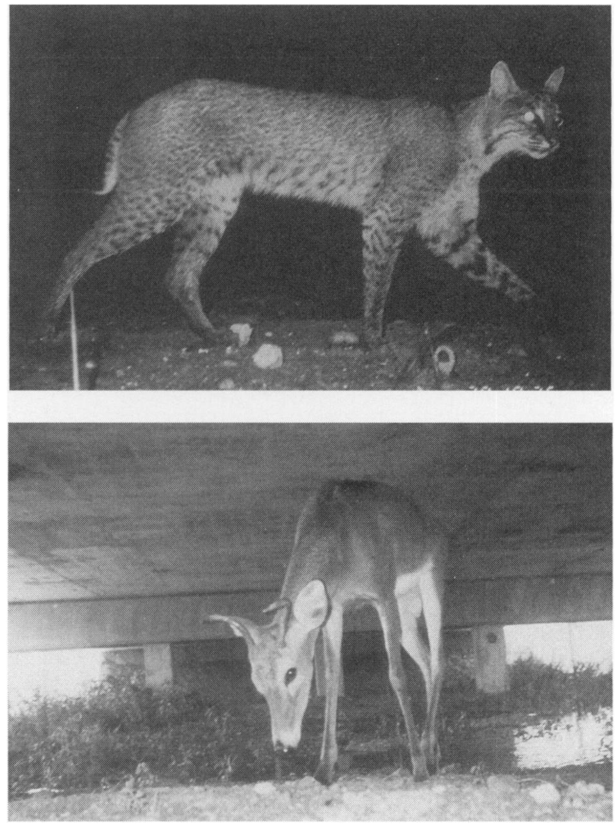

Fig. 3. Photographs of a bobcat at night and a white-tailed deer in the daytime taken by infrared game counters and cameras in wildlife underpasses under Interstate Highway 75, southern Florida, 1992.

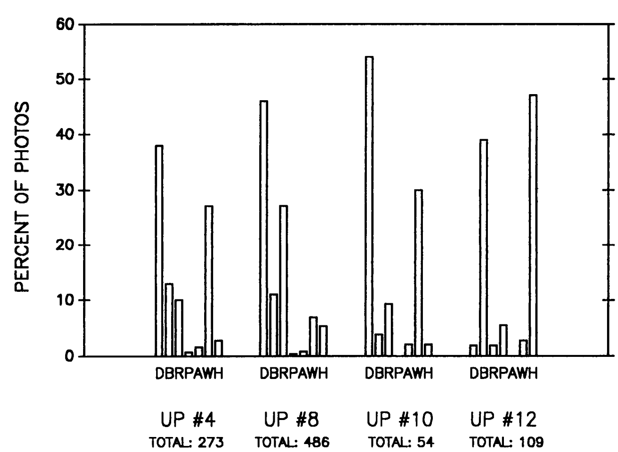


Fig. 4. Use of underpasses by wildlife at 4 underpasses (UP) monitored with infrared game counters and cameras in southern Florida, 1992. D = deer, B = bobcats, R = raccoons, P = panthers, A = alligators, W = wading birds, and H = humans.

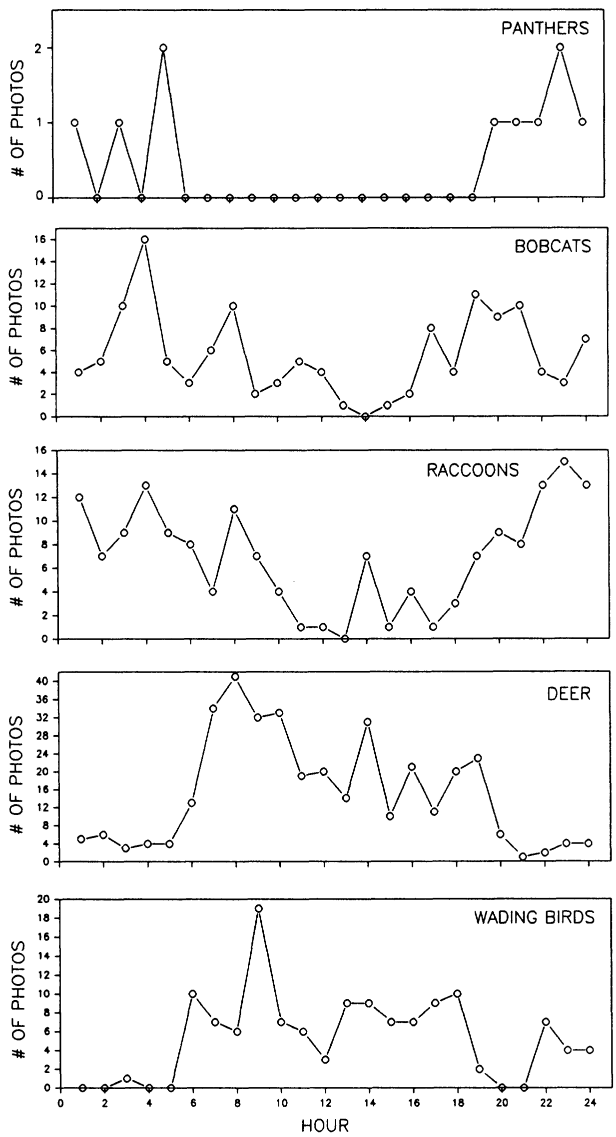


Fig. 5. Time of day of underpass use by wildlife at 4 underpasses monitored with infrared game counters and cameras in southern Florida, 1992.

foraging in the underpass. Deer probably also used underpasses mainly for travel, but numerous individuals were photographed grazing there. Raccoons probably used underpasses for travel and feeding; numerous raccoons were photographed in pools of water. Wading birds probably used underpasses mainly for feeding. Barred owls (*Strix varia*) also may have used underpasses for feeding; several were photographed apparently swooping down on prey.

## Planning implications

Our observations showed that panthers and other wildlife used the underpasses. These animals (except for individuals of some species attracted to floodwater for foraging) would have been vulnerable to collision with vehicles if they had been traveling across the road rather than under it. Thus we infer that the underpasses reduced mortality for some species, preventing the highway from becoming a demographic sink (Pulliam 1988). The underpasses also reduced fragmentation of animals' home ranges encompassing both sides of the highway. However, full evaluation of the latter effect requires analysis of movement patterns. Such analysis is the subject of separate studies for panthers (D. S. Maehr, Florida Game and Fresh Water Fish Comm., Naples, pers. commun., 1992) and bobcats (M. L. Foster, unpubl. data).

Certain species seemed to favor certain underpasses, probably for several reasons. First, frequency of crossings may have been affected by a few individuals repeatedly using the same underpass, as was the case for panthers. Second, disparate densities of certain species could have influenced relative numbers of photographs in different areas. Third, use of underpasses for foraging may have caused raccoons and wading birds to use wetter underpasses; deer and bobcats mainly used the drier ones. Fourth, infrequent photographs of some species at particular underpasses might have resulted from interspecific interactions. For example, perhaps deer avoided underpass 12 because it was often used by panthers, bobcats, and humans (Fig. 4).

***Design of underpasses and fencing.*** The lowest-cost solution to the problem of wildlife-vehicle collisions is to fence the highway without providing for animal movement across the road, but this fragments wildlife populations. Providing wildlife underpasses without fencing the right-of-way fails to solve collision problems. Thus a more comprehensive solution is a combination of wildlife underpasses and fencing. Selecting an effective design with an acceptable cost requires consideration of underpass placement, dimensions of the crossing structure, and configuration and design of fencing.

Effective placement of wildlife underpasses for deer species depends on location of traditional wildlife trails and acceptable distance between crossing points. Underpasses should be located where wildlife naturally cross roads (Klein 1971; D. R. Jensen, Idaho Transp. Dep., Pocatello, unpubl. rep., 1977; Hanna 1982, Singer and Doherty 1985, Waters 1988). Hanna (1982) found that crossing structures placed without regard to traditional paths failed; adding fences failed to direct deer to these crossings. Extensive prior knowledge of panther movements from radio-tracking enabled placement of wildlife underpasses along I-75 at all identified panther crossing points. These crossing locations appeared to be associated with forested habitats and existing human-made trails (Maehr 1989). We believe that underpass placement based on knowledge of actual travel routes is more important in determining underpass use than other factors such as structural dimensions. Ford (1980) and Ward et al. (1980) found that deer used underpasses placed 1.61 and 1.77 km apart, respectively. An application placing crossing structures 2.69 km apart (D. R. Jensen, Idaho Transp. Dep., Pocatello, unpubl. rep., 1977) was only partially successful; some deer evidently could not find the underpasses.

***Dimensions.*** Suitability of various underpass designs is better known for deer than for other wildlife, but minimum acceptable dimensions are not clearly established. Dimensions are also important because they determine cost of the structure. Most researchers have concluded that animals using an underpass should have an unobstructed view of the habitat or horizon on the far side of the underpass. This feature probably is more important than the exact width and height of the underpass. For divided highways, the median probably should be open (as in the I-75 crossings) rather than bridged, because a covered median is more costly and makes the underpass resemble a tunnel. Flat terrain and frequent flooding made it difficult to provide sufficient headroom over a dry substrate in the I-75 crossings. Bridges were designed to provide clearance of 2.4 m, but only 2.1 m was achieved at several underpasses. Although we do not know whether vertical clearance affected animal crossings, certainly many animals used the underpasses. The open median and substantial width of the I-75 underpasses may have compensated for the low headroom.

Reed et al. (1979) recommended an openness ratio (opening width x height)/(length of crossing) for underpasses for mule deer >0.6 when calculated in meters. The panther underpasses exceeded this guideline (openness ratio = 0.92–1.12). Underpasses used by deer have been as narrow as 12.2 m at bridge level and 6.1 m at ground level (Ford 1980, Ward et al. 1980). Most deer underpasses have been built in natural ravines, where the physical configuration dictated high bridges. However, our finding that 2.1-m headroom sufficed for white-tailed deer and panthers indicated that greater height may be unnecessary and that it may be incorrect to assign equal weight to width and height in the openness formula. Another question, in cases where the median is not covered, is whether wildlife perceptions justify using single-span or double-span length of the crossing in the denominator of the openness formula. Given such uncertainties, we think that each application should be viewed as experimental. Thus, each application should be carefully documented to ascertain minimum acceptable dimensions.

Storer and True (1931) found that deer jumped over standard 1.2-m-highway fences but could be induced by deer-proof fencing to use underpasses. Two types of fences were suitable. One was upright, at least 2.1 m high (preferably 2.4 m high) and made of woven wire or (preferably) chain link. The other was a sloping or "outrigger" fence of lesser height, designed to prevent deer from approaching the fence close enough to jump over it. To counter the climbing ability of panthers, the fence along I-75 is taller than most wildlife fences. It is unlikely, though conceivable, that a panther could climb the I-75 fence or climb an adjacent tree and jump over.

Previous studies offer no clear guidance on how long wildlife-excluding fences should be. A length of 12.4 km (Ward et al. 1980) and lengths averaging 3.5 km (Reed et al. 1975) failed to prevent "end runs" by deer. Animals that enter a fenced right-of-way from the end are trapped by the fencing and are likely to be hit by vehicles. Reed et al. (1979) recommended that fences extend 0.8 km beyond deer concentration areas, but the general lesson is that longer is better. The 64-km span of fencing along I-75 is long relative to other studies (except for landscape-scale wildlife fencing in Africa and Australia; e.g., McKnight 1969). We believe the ends of the fencing extend far enough beyond occupied panther range to prevent end runs.

Numerous wildlife fences failed because of gaps under the fence from improper construction, crawl holes dug by animals, soil eroded by water, and unrepaired damage from vehicular accidents, vandalism, falling trees, and cows (McKnight 1969;, D. R. Jensen, Idaho Transp. Dep., Pocatello, 1977; Falk et al. 1978, Ford 1980, Ludwig and Bremicker 1982, Waters 1988). Right-of-way fencing requires frequent inspection and repair of all components to installation standards, because wildlife quickly exploit breaks in the fence.

***Maintenance.*** We believe the I-75 mitigation will provide panthers and other large-bodied mammals a safe and acceptable means of travel under the highway if fencing and underpasses are maintained properly. Trespass by humans at the wildlife underpasses should be reduced; considering panther refuge and preserve policies, trespassers may be poachers. In other contexts, however, non-lethal human activities such as passage of farm or ranch equipment and livestock or use of suburban greenways for human recreation may be compatible with underpass use by wildlife. Highway right-of-ways should be mowed to facilitate inspection of the fence at regular intervals. All holes and gaps remaining or developing along the fence should be repaired promptly. A contingency plan should be developed to rescue a panther caught within the fence.

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## Literature cited

Duever, M. J., J. E. Carlson, J. F. Meeder, L. C. Duever, L. H. Gunderson, L. A. Riopelle, T. R. Alexander, R. L. Myers, and D. P. Spangler. 1979. The Big Cypress National Preserve. National Audubon Soc., New York, N.Y. 444pp.

Falk, N. W., H. B. Graves, and E. D. Bellis. 1978. Highway right-of-way fences as deer deterrents. J. Wildl. Manage. 42:646–650.

Ford, S. G. 1980. Evaluation of highway deer kill mitigation on SIE/LAS-395. Final report no. FHWA/CA/TP-80-01. Calif. Dep. of Transp., Sacramento. 45pp.

Hanna, P. 1982. The impact of Interstate Highway 84 on the Sublette-Black Pine migratory deer population. A 12-year summary, with recommendations for mitigation of identifiable adverse impacts. Final report, Project W-160, Idaho Dep. of Fish and Game. 97pp.

Klein, D. R. 1971. Reaction of reindeer to obstructions and disturbance. Science 173:393–398.

Ludwig, J., and T. Bremicker. 1982. Evaluation of 2.4-meter fences and one-way gates for reducing deer-vehicle collisions. Minn. Wildl. Res. Q. 42(1):1–14.

Maehr, D. S. 1989. Florida panther road mortality prevention. E-1-13 Annual performance report, Florida Game and Fresh Water Fish Comm., Tallahassee. 10pp.

Maehr, D. S. 1992. Florida panther. Pages 176–189 *in* S. R. Humphrey, ed. Rare and endangered biota of Florida. Vol. I. Mammals. Univ. Press of Florida, Gainesville.

Maehr, D. S., E. D. Land, and M. E. Roelke. 1991. Mortality patterns of panthers in southwest Florida. Proc. Annu. Conf. of Southeast. Assoc. Fish and Wildl. Agencies 45:201–207.

McKnight, T. L. 1969. Barrier fencing for vermin control in Australia. Geogr. Rev. 59:330–347.

Pulliam, H. R. 1988. Sources, sinks, and population regulation. Am. Naturalist 132:652–661.

Ratcliffe, E. J. 1974. Wildlife considerations for the highway designer. J. Inst. Municipal Eng. 101:289–294.

Reed, D. F., T. N. Woodard, and T. D. I. Beck. 1979. Regional deer-vehicle accident research. U.S. Dep. Transp. Fed. Highway Adm. Rep. No. FHWA-RD-79-11. National Tech. Inf. Serv., Springfield, Va. 61pp.

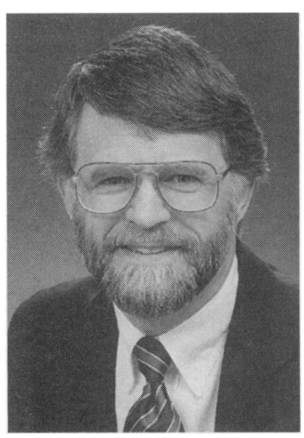
Reed, D. F., T. N. Woodward, and T. M. Pojar. 1975. Behavioral response of mule deer to a highway underpass. J. Wildl. Manage. 39:361–367.

Singer, F. J., and J. L. Doherty. 1985. Managing mountain goats at a highway crossing. Wildl. Soc. Bull. 13:469–477.

Storer, T. I., and G. H. True, Jr. 1931. Deer proof fences in California. Calif. Fish and Game 17:263–269.

Ward, A. L., N. E. Fornwalt, S. E. Henry, and R. A. Hodorff. 1980. Effects of highway operation practices and facilities on elk, mule deer, and pronghorn antelope. U.S. Dep. Transp. Fed. Highway Adm. Rep. No. FHWA-RD-79-143. National Tech. Inf. Serv., Springfield, Va. 48pp.

Waters, D. 1988. Monitoring program, mitigative measures, Trans Canada Highway twinning, km 0–11.4. Final report. Environment Canada, Banff National Park, Canada. 57pp.



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