Key Deer Mortality, U.S. 1 in the Florida Keys

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Abstract: Dames & Moore, Inc. was retained by the Florida Department of Transportation to develop a concept of alternative methods to reduce the mortality of Key deer (*Odocoileus virginianus clavium*) along U.S. Highway 1 on Big Pine Key, Florida. Through an intensive literature search and contacts with persons of knowledge, information was gathered on Key deer biology and distribution and timing of mortalities and methods used in other areas to reduce wildlife/motorist conflicts. Potential methods were analyzed using a fatal-flaws procedure to eliminate those methods that were unfeasible. Remaining alternatives or alternative combinations are currently being ranked as to their effectiveness.

In early 1995, the Florida Department of Transportation (FDOT) retained Dames & Moore, Inc. as a consultant to conduct a study to develop alternatives to reduce the mortality of Key deer due to vehicular collisions along U.S. 1 on Big Pine Key, Monroe County, Florida. Dames & Moore, Inc. was retained after years of initiatives by FDOT to identify, evaluate, and solve the problem of Key deer mortality on U.S. 1. Dames & Moore, Inc. was to: (1) use existing information; (2) focus on Key deer mortality along U.S. 1; (3) coordinate with other efforts to manage and protect the Key deer; (4) provide for both human and Key deer safety along the road; and, (5) submit a concept-study report recommending alternatives that were viable. Because the Key deer is listed as endangered by both Florida and the U.S. Fish and Wildlife Service, protecting the deer in accordance with the Endangered Species Act of 1973 was within FDOT's mandate.

The first phase of the study included a review of existing information regarding the biological, socioeconomic, regulatory, and engineering issues related to the problem of Key deer mortality on U.S. 1. To fully comprehend the situation, issues related to the biology of the Key deer, the socioeconomic conditions of Big Pine Key, the legal framework that would affect any option that might be selected, the engineering opportunities and constraints, and the efforts that have been carried out in other parts of the country were reviewed and evaluated.

The second phase of the study consisted of a fatal-flaws analysis, using developed criteria, of the various generated alternatives. To develop criteria and alternatives for the fatal-flaws analysis, information were gathered from existing FDOT files, an extensive search of the scientific literature on the biology of the Key deer, a literature search for approaches that have been applied to solve wildlife/motorist conflicts in other parts of the country, and discussions with persons with knowledge

about the issues.

The objectives of this paper are to: (1) examine the biology of the Key deer as to how it may affect deer/vehicle accidents; (2) relate the use of vegetation types by Key deer to the location of mortalities along U.S. 1; (3) determine seasonal and daily timing of Key deer mortalities; and, (4) discuss the conceptional development of alternatives and criteria used in the fatal-flaws analysis of possible alternatives to solve the roadkill-mortality problem.

THE PROBLEM

The Key deer is the smallest of the North American white-tailed deer and is endemic to islands in the Lower Florida Keys, from Little Pine Key to Sugarloaf Key (Hardin et al. 1984). A large portion of the overall deer population, which is estimated at about 250 to 300 deer, resides on Big Pine Key, the largest of the Lower Keys. From 1970 to 1992, a total of 1,923 mortalities was recorded of which 526 occurred along U.S. 1 on Big Pine Key. Since 1992, the number of Key deer fatalities have remained above 40 deer per year.

Despite losses due to highway mortality, the Key deer population on Big Pine Key appears to have stabilized; however, current assessments of the population size are not available. While factors other than traffic accidents may represent a bigger threat to the long-term stability of the population, FDOT is obligated to increase safety on the roads and avoid or minimize negative environmental impacts.

KEY DEER BIOLOGY

Key deer are restricted in distribution to the Lower Keys and are morphologically distinct from mainland populations (Hardin et al. 1984). Ellsworth et al. (1993) found Key deer lacked genetic variation and it could be distinguished by a unique haplotype that is closely related to haplotypes from southern Florida.

Description

The Key deer is the smallest subspecies of the North American white-tailed deer; adult males average 80 pounds (36 kg) and adult females 63 pounds (28 kg). Fawns weigh about 3.5 pounds (1.5 kg) at birth. Height at the shoulder in adults averages 27 inches (69 cm) for bucks and 25.5 inches (65 cm) for does (Hardin et al. 1984). Pelage varies from a deep reddish-brown to grizzled gray (Klimstra 1992).

The Key deer's small size and color of pelage makes them more susceptible to highway mortalities. Smaller animals are harder to see along roadside and their color tends to blend in with the environment.

Distribution

The Key deer's current range includes 37 islands from Big Johnson Key to Sugarloaf Key, in the Lower Florida Keys (Folk 1991). The National Key Deer Refuge (NKDR) encompasses much of this area. Big Pine Key, the largest of the Lower Keys (6,000 acres/2,500 ha), is the center of the deer's distribution and supports about two-thirds of the entire population (Klimstra et al. 1974). Approximately 3.5 miles of US 1 crosses Big Pine Key, separating deer habitat into sections north and south of the highway. This separation of Key deer habitat makes the deer more susceptible to roadkills.

Use of Water

The principal factor influencing distribution and movement of deer in the Keys is the location and availability of fresh surface water. Although Key deer have been observed drinking water half as salty (15 ppt) as sea water, it is doubtful that they can survive for long periods without fresh (< 5 ppt) water (Folk et al. 1991). The deer swim easily between keys and use all islands during the wet season when drinking water is available (Silvy 1975). However, extended dry periods (droughts) put considerable stress on the deer and force them to congregate on the few large islands that provide suitable drinking sources (Folk et al. 1991).

The rainy season in the Keys typically extends from May to October, followed by the dry season from November to April. Suitable drinking water is available to deer year-round on only 13 islands (Folk 1991). Other keys are used only temporarily or seasonally. Big Pine Key and No Name Key provide the most fresh water and support the bulk of the deer population.

Because the dry season (Nov-Apr) coincides with the time of year when most visitors are in the Keys, roadkills of deer can be expected to increase as deer are moving more in search of fresh water and automobile traffic is at its maximum. Big Pine Key is especially vulnerable to such kills as it supports the largest population of Key deer and, during periods when fresh water is not available on outer keys, deer return to Big Pine Key to obtain water. Thus, the deer population on Big Pine Key increases during dry periods and especially so during droughts. Deer returning to Big Pine Key for fresh water are even more susceptible to being roadkilled as they are being forced from area to area by resident deer of Big Pine as they search for fresh water. Because the breeding and fawning seasons overlap the dry season, when deer tend to be more territorial, this adds to wandering by nonresident deer. This wandering adds to the probability these deer will cross highways such as U.S. 1.

Use of Vegetation Types

Vegetation types used extensively by the deer include south Florida pinelands, hardwood hammock, buttonwood wetlands, mangrove wetlands, and open-developed areas (Silvy 1975). Pineland, which occurs in substantial stands on only 5 of the islands (Folk 1991), is most important in supplying essential freshwater resources and the variety of plant foods the deer use (Klimstra and Dooley 1990).

Because pinelands are found for only a short distance south of U.S. 1, deer south of U.S. 1 must move close to this highway to obtain fresh water, especially during droughts. This also adds to the probability of them becoming road mortalities.

Hammocks provide some foods but are more important for cover, cool shelter, and fawning and bedding (Silvy 1975). Buttonwood areas supply important herbaceous foods and loafing areas (Folk 1991). Key deer spend considerable time feeding on mangroves in tidal wetlands (Silvy 1975). Open-developed areas, such as roadsides, residential subdivisions, cleared lots, and mowed areas are used for feeding, loafing, and relief from insects (Silvy 1975). Silvy (1975) determined deer used pineland, hardwood, and hammock areas more than expected and buttonwood and open-developed areas less than expected. Whereas, mangrove areas were used at the expected level to their availability. As housing developments increase on the Keys, more open-developed areas are produced. This has led to a patch-type habitat where not all deer requirements are met in a single area; therefore, deer movements and roadkill mortality increased. U.S. 1 also runs through over a mile of pineland and hammock habitat on Big Pine Key, the very vegetation types which deer selected for over their availability (Silvy 1975). This again increases the probability of roadkill mortalities.

Fire is one of the most significant factors in the maintenance of pineland in the Keys, an essential component of Key deer habitat. Absence of fire in pineland allows browse to grow beyond the reach of deer and leads to invasion of hardwoods that shade out important herbaceous species (Carlson 1989). Regularly burned pinelands have higher nutritive value of browse and have a stable composition of fire-dependent species (Klimstra 1986, Carlson 1989). Pinelands that have been burned tend to be more open and make deer more visible to motorist. However, because of commercial development along U.S. 1, no prescribed burns are conducted along this highway; the resulting dense vegetation decreases deer visibility along this highway and may promote accidents.

Food Habits

Red *(Rhizophora mangle)* and black (*Avicennia germinans*) mangroves, constituting 24% by volume, are the most important plants in the diet of the Key deer (Klimstra and Dooley 1990). However, the deer use more than 160 other species to meet nutritional requirements (Klimstra and Dooley 1990).

Changes in seasonal food availability and nutritional requirements require the deer to move between different areas to take advantage of this availability and to meet seasonal nutritional requirements. Such movements increase the probability of accidents.

Reproduction

The reproductive output of Key deer is low when compared to other northern white-tailed deer populations in North America (Hardin 1974, Silvy 1995). This may be a result of a nutrient deficiency (possibly phosphorus) or an evolved adaptation to a restricted, insular environment. Either way, fecundity (number of fetuses/female) and rate of reproductive activity (percent of females reproducing) are low, and fetal sex ratio (males to females) and mean age of first breeding are high,

all resulting in low reproductive performance (Hardin 1974). Thus, Key deer are less able than other deer to respond rapidly to improvements in available resources. Likewise, they are less likely to recover from unnatural mortalities such as roadkills.

The breeding season begins in September, peaks in October, and declines through December and January (Hardin 1974). Yearling females breed later in the season (Hardin 1974). Yearling males only rarely do so (Hardin 1974). Young bucks are excluded by older, more aggressive males, from breeding (Klimstra 1992). Female fawns occasional breed their first year, but male fawns do not (Hardin 1974). During the breeding season, bucks are actively pursuing does is estrus and movements are greatest at this time (Silvy 1975). In addition, it is at this time of year that male fawns are separated from their mothers and begin to wander about to find suitable ranges. These increased movements by males coincides with the beginning of the tourist season and both add to roadkill mortalities at this time of year. The male-biased fetal sex ratio (1.5:1.0; Hardin 1974) adds to this problem as yearling males disperse from the maternal home range whereas, yearling females do not (Silvy 1995). It is common for male deer to disperse from their place of birth (Ellsworth et al. 1994).

Parturition occurs about 204 days after breeding and peaks in April and May (Hardin 1974). The coincidence of fawning with the rainy season ensures an ample food supply for lactating females. Open hammock and pineland are preferred fawning habitats (Silvy 1975). Twinning is infrequent, and triplets have not been documented. During the fawning season, pregnant does become highly territorial (Hardin 1994) and at this time yearling females are forced from the maternal home range until after the new fawn is born. During this separation, yearling females tend to wander about (Silvy 1975) and this increases their chance of being hit by automobiles. Also, during this time of year, adult females exclude all other deer from their birthing areas (Hardin 1974). This increases movements of all other deer, especially bucks, which leads to increased roadkills (Silvy 1975).

Social Behavior

The social structure of the Key deer is a flexible, dynamic system that varies throughout the year with the reproductive cycle (Hardin 1974). Key deer are naturally more solitary than northern white-tailed deer (Hardin 1974, Hardin et al. 1976), though feeding-induced aggregations prevalent on the human-inhabited islands have altered this tendency in recent years. Bucks associate with females only during the breeding season and will tolerate other males when feeding and bedding only during the non-breeding season. Does may form loose matriarchal groups consisting of an adult female with several generations of her offspring, but these associations are not stable (Hardin et al. 1976).

The lack of predators and different competitive and selective pressures in this island environment may have resulted in the breakdown of strong family ties and produced a social organization different from that of other white-tailed deer (Hardin et al. 1976). In northern deer, herds form seasonally in yarding areas that provide winter forage and possibly body warmth. Strong bonds allow family groups to re-associate after the seasonal migration from these yarding areas back to regular home ranges. The need for such bonds in Key deer, which neither migrate seasonally or form large groups, is less

important. Competition for limited resources may offset any strong familial bonds that do form (Hardin et al. 1976).

Average 2-year-range sizes (Silvy 1975) for adult males was 790 acres (316 ha) and for adult females about 429 acres (172 ha). Maximum 2-year-range sizes (Silvy 1975) were 1,366 acres (546 ha) for an adult male, 854 acres (342 ha) for an adult female, 1,550 acres (620 ha) for a yearling male, and 1,446 acres (578 ha) for a yearling female. Males tend to disperse from their natal range as fawns. Adult males range over much larger areas during the breeding season (Silvy 1975) and may shift to an entirely new area (Silvy 1975, Drummond 1989). Territorial behavior of bucks is limited to the defense of a receptive doe from other bucks (Hardin 1974). Does will defend birthing areas from all other deer.

Key deer are "creatures of habit", with well defined patterns of activity and habitat use (Klimstra et al. 1974). established trails, worn deep into the marl soil from years of daily use, are clearly visible in many of the deer's movement corridors. Bedding and feeding areas will be used faithfully by individuals, and "hot spot" road crossings are clearly apparent from roadkill data (Klimstra 1992).

Roadside feeding by tourists tend to congregate deer along roadsides and reduce the deer's fear of automobiles which then leads to increased road mortalities. However, little feeding occurs along U.S. 1.

KEY DEER MORTALITY

Human-related mortality, primarily roadkills, is the greatest known source of deer loss. Road mortality contributes 75-80% of all known deaths, with an average of about 44 animals per year; half of these occur on U.S. 1 (Hardin 1974, Silvy 1975, Drummond 1989).

At least 20% of fawns die before reaching 6 months of age, with most (90%) of these drowning in mosquito ditches (Hardin 1974). Up to 50% of males die before reaching 1.5 years, and 50% of females die before 2.5 years (Hardin 1974).

U.S. Highway 1 Key Deer Road Mortality 1985-94

From 1 January 1985 through 31 December 1994, 434 road-killed Key deer were examined by Refuge personnel. Additional deer may have been killed on the road which were not reported and/or not found during this period. Therefore, this number represents a minimum number of possible road deaths during this period. This represents an average of 43.4 deer deaths per year which is nearly identical to the 44 deer average reported by Drummond (1989) for 1968-88. Of the 434 deer killed, 243 (56%) were killed on U.S. Highway 1. This represents at least a 6% increase in the number of deaths recorded for U.S. 1 as Drummond (1989) noted that "nearly half" of all road kills occurred on U.S. 1 during 1968-88.

Of the 243 deer killed on U.S. 1 during 1985-94, 1987 had the most (29) kills, whereas 1985 had the

fewest. Over the 1985-94 period, more (34) deer were killed during May, whereas March had the fewest (13) deer killed. Fifty-nine percent of all deer were killed during daylight hours. Two daily time peeks occurred for road deaths, one at 0700 hours and a second at 1900 hours.

Of the 243 deer killed on U.S. 1, 158 (63%) were males, 83 (37%) were females, and 2 were of undetermined sex. It appears the percent of females killed on U.S. 1 has increased by 8% as Drummond (1989) reported a 71% male and a 29% female kill during 1968-88. Female kills peeked in July, whereas male kills were highest in May with 2 additional peeks in January and November.

Only 233 of the 243 deer killed on U.S. 1 could be classified as to adult, yearling, or fawn. Of those that could be classified, 112 (48%) were adults, 86 (37%) were yearlings, and 35 (15%) were fawns. There appears to have been a 20% decrease in the percent of adults killed, a 15% increase in yearlings killed, and a 5% increase in fawns killed when compared to 1968-88 (Drummond 1989). Drummond (1989) had noted a ratio of 68% adults, 22% yearlings, and 10% fawns killed during his study.

Only 230 of the 243 deer killed on U.S. 1 could be both sexed and classified to age. Of the females that could be classified as to age, 40 (51%) were adults, 30 (38%) were yearlings, and 9 (11%) were fawns. Of the males that could be classified as to age, 69 (46%) were adults, 56 (37%) were yearlings, and 26 (17%) were fawns.

During 1985-94, the distribution of Key deer killed along U.S. 1 have changed from kills during 1968-88 (Drummond 1989). Drummond (1989) noted 6 (0.1-mile length) hot spots (mile markers 30.8, 31.0, 31.2, 31.4, 32.8, 32.9) for kills along U.S. 1. The 1995-94 data (Fig. 5) suggest road kills averaged 1 kill per year along each 0.2-mile segment of U.S. 1 except for mile marker 32.8-32.9 which averaged over 3.5 kills per year. As noted by Drummond (1989), mile marker 32.8 represents a curve in the highway where drivers may have limited visibility. In addition, he also noted that deer traveling south to Cactus Hammock along the east side of the island will cross U.S. 1 at mile marker 32.8.

Females kills along U.S. 1 were more concentrated (12% of total kills) at mile marker 32.8 than were male kills. Although more males (8% of total kills) were killed at mile marker 32.8 than any other area along U.S. 1, kills of males were greater along the total length of U.S. 1 than were that of females. Male kills at mile marker 32.9 were only 1 deer less than kills at mile marker 32.8, whereas only 1 female was killed at mile marker 32.9.

Fifty-two percent of all female and 53% of all male Key deer were killed between mile markers 31.2 and 32.9 on Big Pine Key. This represents the non-business district along U.S. 1 on the east side of Big Pine Key (Spanish Channel Bridge to curve near St. Peter's Church).

FATAL-FLAWS ANALYSIS

A review and evaluation of the literature and other sources left us with 2 major approaches to reduce highway mortality of Key deer on U.S. 1. Either deer had to be separated from vehicles (prevent deer access to the road) or efforts had to be made to reduce the probability of deer colliding with vehicles (continue to allow deer access to road). Key factors that could be used to reduce the probability of collisions were: (1) Awareness of the deer; (2) greater visibility of the deer; and, (3) increased human reaction time. Key factors that could be used to prevent deer access to the road were existing U.S. 1 characteristics and deer behavior.

Alternative methods found that could be useful to reduce the probability of collisions included reducing vehicle speed, clearing vegetation from road right-or-way, improving lighting along road, promoting deer use of selected crossings, discouraging deer from approaching the road, and promoting public awareness through a radio advisory, signs, information, and patrolling. Methods considered that would prevent deer access to the road included moving the road off Big Pine Key, elevating the road across Big Pine Key, moving deer to one side of the road or moving deer off Big Pine Key, or excluding deer with the use of fencing, deer guards, or other similar methods.

In order for an alternative method to be viable, it had to pass through our fatal-flaws analysis which consisted of 6 major criterion. First, the method had to eliminate or reduce Key deer mortality on U.S. 1. Second, the alternative had to maintain existing deer range (habitat) and avoid or minimize behavioral modification and genetic disruption of the Key deer. Third, all alternatives had to comply with existing Federal, State, or County regulations. Fourth, alternatives had to maintain or improve human safety. Fifth, alternatives had to avoid or minimize negative effects on existing businesses (socioeconomics). Finally, the implementation of the methods had to be considered with respect to cost/benefit, engineering constraints, long-term maintenance, and land ownership constraints.

Four alternatives (by-pass Big Pine Key, elevate U.S. 1 across Big Pine Key, move the deer to one side of the road, and move the deer off Big Pine Key) were eliminated using the fatal-flaws analysis. Moving U.S. 1 off Big Pine Key or elevating U.S. 1 across Big Pine Key failed because of the additional affects on the environment (bay bottom disturbance for moving the highway off Big Pine Key and the need to destroy additional Key deer habitat to provide for frontage roads and ramps for an elevated highway). Both also failed the fatal-flaws analysis because of the negative socioeconomic effects each would have had on the local businesses. In addition, moving U.S. 1 off Big Pine Key would leave the existing road as a county road where roadkills would continue (probably somewhat reduced in numbers due to less traffic). Moving the deer to one side of the road failed to pass the fatal-flaws analysis because existing Key deer habitat would have been reduced and implementation (moving the deer) would have been costly and probably impossible because deer could swim around any constructed barrier. Moving the deer off the key failed for the same reasons (reduced habitat and implementation feasibility and excessive costs) as well as Key deer would no longer be Key deer if moved to different habitats.

Having eliminated various alternatives using our fatal-flaws analysis, we are currently ranking the

remaining alternatives or combination of alternatives for their potential to reduce Key deer mortality on U.S. 1. This process will be completed by July 1996.

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