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TECHNIQUES FOR ESTIMATING COYOTE ABUNDANCE

SCOTT E. HENKE, Caesar Kleberg Wildlife Research Institute, Campus Box 218, Texas A&M University-Kingsville, Kingsville, TX 78363

FRED F. KNOWLTON, USDA-APHIS Denver Wildlife Research Center, Utah State University, Logan, Utah 84322-5295

Abstract: Knowledge of coyote abundance is needed to make intelligent management decisions. Several methods have been devised to ennumerate coyote (*Canis latrans*) population size. We review several techniques and attempt to identify biases associated with each method. Once biases are understood, recommendations can be made to minimize their impact on data collection processes and yield better estimates of coyote population trends.

Enumeration of population status (i.e., density, trends) is important in research and management of wildlife. Management of coyote populations has typically involved population control (Beasom 1974). Ranchers may be interested in the number of coyotes in an area to assess the potential severity of livestock losses (Scrivner et al. 1985). Wildlife managers sometimes attempt to reduce the density of coyotes to aid recruitment of game species (Beasom 1974, Garner et al. 1978, Hamlin et al. 1984). Assessing population size has been 1 method to judge the success of such management programs. Unfortunately, estimation of coyote population size is difficult because of species' secretive behavior and low densities.

Coyote population size can be expressed as density or relative abundance. However, these terms are sometimes confused and used erroneously. Population density is the number of individual animals per unit area, for example, the number of coyotes per square mile. Relative abundance refers to the ranking of populations according to their population size. For example, Ranch A has more coyotes than Ranch B. Often, relative abundance is derived from an index or an indicator of population size.

Researchers of coyotes often rely on population indices because of the difficulty in obtaining adequate data to estimate population size. However, because the relationship between the index and the true population size is often unknown, the use of indices should be restricted to measures of relative abundance between populations of different areas during the same time period, or between populations on the same area over time.

Methods used to estimate coyote population size, density, and relative abundance have included scent stations (Linhart and Knowlton 1975, Roughton and Sweeney 1982), vocalization responses (Okoniewski and Chambers 1984), scat counts (Andelt and Andelt 1984), mark-recapture (Clark 1972), removal (Zippin 1958), radioisotope markers (Crabtree et al. 1989), aerial surveys (Nellis and Keith 1976), and radiotelemetry (Andelt 1985). However, all methods provide variable results and none give a complete census of coyote populations (Spowart and Samson 1986). A census is a complete count of every animal within the population. Obviously, because of the behavior of coyotes, a census is not practical.

Our purpose here is to identify methods which can be used to assess coyote abundance and to identify some merits and problems of each. While not an exhaustive treatment of the subject, this report provides a general assessment of our current understandings.

Density estimates

Aerial Counts: Aerial surveys are commonly used to sample animals or animal signs (e.g., nest colonies) visible from the air. Aerial counts can be conducted from either a fixed-wing plane or helicopter. Normally, a pilot and 1 or 2 observers are required to conduct aerial surveys. A Global Positioning System (GPS) is useful in maintaining flight patterns (R. Curnow, Denver Wildl. Res. Center, pers. commun.). Surveys should be conducted when there is adequate visibility during the early morning or late afternoon hours (Beasom et al. 1981).

However, there have been few serious attempts to use aerial counts, either from planes or helicopters, to assess coyote abundance. Equipment costs may make the technique prohibitive for many situations, and biases associated with aircraft speed and height above ground, transect width, differing ground cover and terrain, differing vegetation conditions, time of day, and visual acuity of observers probably precludes this technique as a reliable procedure except under very specialized circumstances (e.g., snow cover). Use during the winter after deciduous foliage has fallen and where there is complete snow cover on the ground may improve the performance of this technique (Nellis and Keith 1976); however, little or no evaluation of the estimates obtained have been made.

Forward-Looking Infrared (FLIR) sensing shows promise as a new technique to count predators. A plane equipped with a FLIR device would fly transects as outlined above, except the infrared image of the animal would be videorecorded for later analysis. Best results from this technique are obtained from transects flown during the early morning hours (within 2 hours of sunrise) over flat, open areas. Resolution of infrared images has improved significantly in recent years and now observers can differentiate among some species (S. Beasom, Caesar Kleberg Wildl. Res. Inst., unpubl. data).

However, the FLIR technique is not without its problems. Terrain, radiated heat from the ground or other environmental heat sources, and canopy cover can obscure images (G. Henicke, Caesar Kleberg Wildl. Res. Inst., pers. comm). At the present time, FLIR technology has not progressed to a point where it appears practical to use to assess coyote abundance.

Catch-mark-release: This technique typically involves multiple captures of individual coyotes. During the initial capture the coyote must be maintained alive, after which, subsequent collections can be by lethal means. Coyotes have been live-caught by foot-hold traps, snares, boxtraps, and tranquilizer darts.

Turkowski et al. (1984) described improved foot-hold traps which resulted in coyote capture rates of over 84% and excluded smaller, non-target predators. Skinner and Todd (1990) reported that foot-hold traps resulted in a 3-fold greater coyote capture rate than foot snares. Public opposition to the use of traps exists over concern that substantial injury to the trapped animals occurs (Jotham and Phillips 1994). Linhart et al. (1981) and Zemlicka and Bruce (1991) suggested that affixing tranquilizer tabs containing propiopromazine HCl can significantly decrease foot injury to coyotes. The drug diazepam also has been used to reduce injury to coyotes caught in steel foot-hold traps (Balser 1965).

Neck snares equipped with safety stops to prevent choking have been used to reduce injury to individual animals, and capture rates are typically greater than those of foot-hold traps (Guthery and Beasom 1978), at least in areas where net-wire fences are common. Also, experience in the placement of the safety stops is required; too tight or too loose will result in killing the coyote or escape by the coyote, respectively. Coyote pups have been caught at dens in live traps (Foreyt and Rubenser 1980); however, adult coyotes seldom enter boxtraps (R. Sramek, Texas Animal Damage Control Serv., pers. commun.).

Coyotes have been darted by use of a Cap-Chur gun from the ground (Ramsden et al. 1976) and from the air (Baer et al. 1978). Dosages ranged from 8 - 21 mg/kg body weight for ketamine hydrochloride (Ramsden et al. 1976, Cornely 1979) and 2 mg/kg body weight for phencyclidine hydrochloride (Bailey 1971). Both drugs have a wide margin of safety, were easily administered by syringe, and took effect typically within 5 minutes. Recovery time for drugged coyotes can take up to 30 minutes (Pond and O'Gara 1994).

Nellis (1968) described a technique of chasing coyotes with motorized toboggans until they tired. At this point the coyote could be easily overpowered; however, he still advised using caution to avoid injury to all parties concerned. The use of ATVs could replace motorized toboggans in areas that lack sufficient snowfall. However, this technique appears to be limited to areas of open terrain which offer greater maneuverability to motorized vehicles. Death or disability can result from capture myopathy associated with over-exertion by the coyotes, especially in warm and hot conditions.

Clark (1972) estimated coyote density using a modification of the Petersen estimate (Bailey 1951). He located active coyote dens, eartagged the pups, and then trapped coyotes in the same area several months later. The proportion of eartagged coyotes among the total number of pups captured was used to estimate the density of coyote pups. This procedure appeared to yield a reliable density estimate, but it was very labor intensive.

The major problem with catch-mark-release estimators is that recovery rates of tagged coyotes is typically low (Andelt et al. 1985, Windberg and Knowlton 1990). Gionfriddo and Stoddart (1988) reported that coyotes marked with ear tags and vinyl collars were recovered at rates of 21% and 25%, respectively. Recovery rates increased to 50% if coyotes also were equipped with radio collars; however, telemetry equipment often can be cost prohibitive. Windberg and Knowlton (1990) demonstrated that coyotes are seldom captured in the areas they frequent most and are usually captured on the edges, or well outside their usual haunts.

Radioisotope markers have been used as a means to circumvent low recovery rates. Individual coyotes are intramuscularly injected with gamma-emitting radioactive isotopes, which eventually gets excreted (Pelton and Marcum 1975, Knowlton et al. 1989). The proportion of marked to unmarked feces can be used to construct a population estimate. Estimates derived from these procedures appear to be quite reliable, especially if the marked animals are equipped with radio transmitters to assess the degree to which the animals remain on the survey area, but this technique is labor intensive.

Spotlight counts: Spotlight counts have been used to estimate white-tailed deer (Harwell et al. 1979) and lagomorphs (Kline 1965, Fafarman and Whyte 1979). Few attempts have been conducted to ennumerate coyote populations by this method (Henke 1992). Spotlight surveys should begin 1 hour after sunset and should be conducted several times during the same moon phase and under similar weather conditions. The number of replicates depends upon the variability among counts as well as the precision desired. Two observers with 300,000-candlepower spotlights and a driver are required to count coyotes along each roadside. The vehicle should maintain a speed of approximately 10 mph during the survey.

Coyote densities are obtained by dividing the number of coyotes observed by the visible acreage. Henke (1992) believed that this method overestimated the coyote population in West Texas, but stated that coyote populations could be positively or negatively biased by their use of secondary roads. Coyotes preferentially use secondary roads as travel lanes (Andrews and Bogess 1978), thus causing an upward bias in density estimates. However, if coyotes were routinely hunted from vehicles at night, a learned aversion to vehicles and roads could result, resulting in underestimation of coyote density. Factors which influence animal activity might also influence counts, including time of day, season, weather conditions, and condition of roadside cover. Therefore spotlight surveys as an enumeration technique for coyotes should be viewed with skepticism until the behavioral biases are assessed.

Relative abundance indices

Catch-per-unit effort: A variety of catch-per-unit effort indices have been used with carnivores in general and coyotes in particular. Many of the trapping techniques described above also could be used as long as capture effort is recorded. Despite whether effort is measured in man-years (Cain et al. 1972, Wagner 1972) or individual "unit-nights" (e.g., trap nights) (Clark 1972, Knowlton 1972), standardization of procedures remains a major problem, particularly with regard to the manner in which different individuals use or set equipment. Biases resulting from the use of various types of equipment as well as unequal capture vulnerability of animals within various population segments need to be addressed (Windberg and Knowlton 1990).

Most catch-per-unit-effort techniques are labor intensive and many have the added disadvantage of modifying the population by removing individuals. Removal methods have been employed to estimate relative coyote population size (Henke 1992). This estimator is based on the assumption that more animals are caught during the initial effort and that the number of captures declines with subsequent efforts (Zippin 1958). However, the more intensive the capture effort in relation to the size of the area, the greater the potential impact upon the population being enumerated. Also, coyotes quickly immigrate to areas where territorial vacancies occur. Henke (1992) noted that coyote density returned to pre-removal levels in less than 3 months after the removal effort. Rapid recolonization rates can confound removal estimators.

Scent station visitation rates: Coyote visitation rates to artificial scent stations probably have been the most widely used, standardized method for indexing coyote abundance. Scent station indices also have been evaluated more critically than any other technique for indexing coyote abundance (Linhart and Knowlton 1975, Roughton and Bowden 1979, Roughton and Sweeney 1982). This technique employs a series of transects, each composed of a set of regularly-spaced stations 39 inches (1 m) in diameter. The ground surface is scarified and smoothed so that animal tracks can be recognized. Powdered clay soils are preferred for building stations.

Typically, stations are spaced at 550 yard intervals with consecutive stations located on alternate sides of a road. The basic sampling unit is a 3 mile line containing 10 stations. A standard artificial olfactory attractant is placed in the center of each station. Attractants have included plaster-of-paris disks impregnated with a scent (Roughton and Sweeney 1982) or histology tissue capsules containing scented-cotton (Henke 1992). Stations are typically set out 1 day and examined the next to determine the number of stations that have been visited by coyotes. The index of abundance normally is expressed as:

$$\frac{\textit{(No. stations with coyote visits)}}{\textit{(No. operable stations)}} \times 1000.$$

Coyote behavior can affect the number of "visits". Harris (1983) found that coyotes are more likely to visit scent-stations when they were away from areas with which they were familiar than when they were within familiar areas. Andelt et al. (1985) suggested that previous adverse experiences, such as having been trapped, reduced scent-station visitations by coyotes. Fagre et al. (1983) suggested that coyotes may become habituated to specific lures if they are repeatedly exposed to it; however, changing lures could elicit a different response.

Environmental factors such as strong winds, precipitation, and frozen ground, and biotic factors such as grazing livestock and vehicular traffic can render scent-stations unusable. Fagre et al. (1981) noted that young coyotes were more attracted to odors than adults; therefore, unequal vulnerability could result in bias.

Elicited howling responses: Sirens, bugles, broadcasting recorded coyote howls, human imitations of coyote howls, and a variety of other sound stimuli have been used to elicit responses from wild coyotes (Alcorn 1946, Wenger and Cringan 1978, Okoniewski and Chambers 1984). Locations for attempting to elicit coyote responses are identified along predetermined routes at spacings generally greater than 2.5 miles. The routes are usually driven between dusk and dawn and the number of stations with responses, or the number of responding groups per station, is used as the measure of relative coyote abundance.

Several factors have been identified which may influence the rate at which coyotes respond, irrespective of coyote abundance. Carley (1973) obtained a 4-fold difference in response rates to 3 types of sirens used to elicit the response. He also noted a bimodal response pattern during nocturnal sampling, with an absence of response in the middle of the night when animals were not active. Okoniewski and Chambers (1984) did not detect any appreciable difference between response rates elicited by siren and human voice but they did note, as did Quinton (1976) and Laundre (1981), a seasonal pattern in coyote responsiveness.

Among penned coyotes, it seems that animals not associated with "territorial groups" do not respond to other coyotes and likely would not respond to other sounds that normally elicit vocalizations. Camenzind (1978) and Bowen (1981) suggest similar behavioral differences among wild coyotes. This suggests that transients within a coyote population might be excluded from the enumeration process.

In addition to variable responsiveness on the part of coyotes, a variety of environmental factors including topography, vegetation height and density, relative humidity, wind velocity, air temperature, and presence or absence of temperature inversions can influence the range over which coyote responses can be detected (Wolfe 1974). Potentially differential auditory acuity among observers could also pose significant biases.

Scat deposition rates. This technique appears to be one of the more practical because it (a) requires only one observer with minimal training, (b) can accumulate information over a period of time without an observer in attendance (Clark 1972), and (c) does not require an artificial behavioral response on the part of the coyote. Davison (1980) and Stoddart (1984) have used the number of coyote scats deposited along 1.0 mile segments of unimproved road in a specified period of time to depict trends in coyote abundance. Each transect is walked at the beginning of the sample period and all scats detected are removed. Subsequently the transects are walked again at a later date and the number of scats recovered per mile per day is used as an index to coyote abundance.

Balcomb (unpubl. data) indicates biases associated with this technique include: (1) removal of scats may slightly reduce the number of scats deposited in subsequent days; (2) scat persistence is inversely related to the amount of vehicular traffic; and (3) failure to detect scats while walking the transects. About 30% of the scats were missed, independent of observer, each time a transect was walked, with some indication the problem was greater on transects with fewer scats. This bias can be reduced by walking transects twice, once in each direction. Also, seasonal changes in scat abundance may result from differential scat production associated with dietary changes (Andelt and Andelt 1984), suggesting comparison of scat deposition rates should not be made across seasons.

Standardized track counts. Establishing standard track counting areas may have the potential for being the most reliable technique for determining relative coyote abundance. In most situations it probably also entails the most work. This method consists of counting the number of fresh coyote tracks detected within set distances of road. In snow, sand, or soft earth it may be relatively easy, but on rocky or hard substrates it may be nearly impossible. Todd and Keith (1976) used fresh snowfall and Beasom (1973, 1974) used the sandy soils of South Texas to their advantages. However, environmental conditions, vehicular traffic, and unworkable substrates make widespread use of this technique impractical.

Road-killed coyotes. The number of coyotes killed by vehicles can be used, if standardized, to estimate relative abundance of coyotes. Henke (1992) drove the same 30 miles of highway roads every day for 2 weeks each season and recorded the number and location of freshly-killed coyotes. He estimated the relative abundance of coyotes from the equation:

$$[n/l)/V] \times 10{,}000$$

where: n = number of fresh road-killed coyotes; l = length of the road (km) surveyed; and V = average daily volume of traffic.

However, Henke (1992) reported this technique did not yield satisfactory estimates. Juveniles represented the majority of coyotes killed on the highway, suggesting a strong age bias. Differential vulnerability to vehicular traffic was also reported by Windberg and Knowlton (1990). Average vehicle speed, weather, season, and location of preferred areas may present additional biases (Downing 1980).

Harvest questionnaires and bounty payments. Many agencies use harvest data from questionnaires to estimate coyote population trends (Krause et al. 1969). However, these data are subject to biases arising from sample size, pelt prices, and honesty of respondents. Krause et al. (1969) suggested that many hunters reported they were hunting coyotes only if they happen to kill one, thus overestimating coyote harvest by underestimating effort. County bounty systems may overestimate relative coyote abundance because coyotes may be collected from nearby counties, but hunters may claim the kill occurred in the jurisdiction paying the highest bounty.

Conclusions

Developing techniques to assess the relative or absolute numbers of wild animals is an intriguing but complex process. In the case of the coyote, 2 techniques seem to have particular merit for assessing relative abundance: scent-station visitation rates and scat deposition rates. In addition, practical density estimates seem feasible through use of radioisotopes for long-term marking of feces of specific animals. However, reasons for enumerating a population, situations at hand, and resources available should be assessed before a technique is selected.

Before engaging in any attempt to detect trends or changes in coyote abundance, thought should be devoted to the sensitivity required of the estimator. How large or small a difference in abundance that can be detected will be a function of (1) the relative response level of the particular index being used, (2) variation inherent in the index method, and (3) the sampling effort. Little can be done about variation inherent in an indexing technique except to rigidly adhere to standardized methods, not only in terms of procedures but also to the conditions under which the methods are performed. The relative level of response presumably is a function of the number of animals present, and cannot be changed artificially, but expectations of the response rates to be encountered permit adjustments in the sampling intensity to achieve the degree of sensitivity desired. In short, the quality of "the answer", in terms of precision and accuracy, is closely related to the effort involved and the relative scale of that particular enumeration data.

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