Radiotelemetry error : factors affecting bearing error and the ultimate effects of triangulation error on determining habitat use

by Kevin Michael Podruzny

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University

Abstract:
Precision of estimated locations via radiotelemetry depends on the quality of estimated bearings. Therefore, I identified factors affecting bias and precision of radiotelemetry bearings. I placed transmitters at known locations throughout a study area, crew members estimated bearings to the transmitters without knowing their actual locations, I measured bias and precision of estimated bearings, and I measured possible correlates to bearing error. Overall, estimated bearings to transmitters differed from true bearings by -6.13° to 7.84° (SD = 1.63°). Identified sources influencing bearing bias included: transmitter, receiving-station location, transmission lines, distance from transmitter to receiver, location attempt, time, temperature, and humidity. Identified sources influencing bearing precision included: transmitter, transmission site, habitat, receiving-station location, transmission lines, distance from transmitter to receiver, observer, day, time, humidity, and cloud cover/precipitation.

Radiotelemetry triangulation is routinely used to estimate locations of animals for determining habitat use. However, radiotelemetry locations have associated error and only provide estimates of actual locations. Therefore, I compared MLE point-estimates and 95% error ellipses by examining their effects on classification of habitats, accuracy of observed habitat-use patterns, and efficiency of tests for detecting habitat selection. I then evaluated effects of precision of location estimates (error-ellipse size) on correct classification of habitats, observed habitat-use patterns, and efficiency of tests for habitat selection, using each location-estimation method. I placed transmitters at known locations throughout 2 study sites and crew members estimated bearings to the transmitters without knowing their actual locations. I then estimated locations to the transmitters from the recorded bearings and examined effects of subsequent radiotelemetry triangulation error on determining habitat use and detecting habitat selection using MLE point-estimates and 95% error ellipses. In each study site, point estimates correctly classified more habitats (70.1% and 68.7%) than error ellipses (62.2% and 64.6%). Point estimates were more accurate, but less precise, at determining patterns of habitat use, and more efficient, but less precise, at determining habitat selection, than error ellipses in both study sites. The ability of each method to correctly classify habitats, to correctly identify habitat-use patterns, and to correctly identify habitat-selection increased as ellipse sizes decreased relative to habitat-patch sizes.

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

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Radiotelemetry triangulation is routinely used to estimate locations of animals for determining habitat use. However, radiotelemetry locations have associated error and only provide estimates of actual locations. Therefore, I compared MLE point-estimates and 95% error ellipses by examining their effects on classification of habitats, accuracy of observed habitat-use patterns, and efficiency of tests for detecting habitat selection. I then evaluated effects of precision of location estimates (error-ellipse size) on correct classification of habitats, observed habitat-use patterns, and efficiency of tests for habitat selection, using each location-estimation method. I placed transmitters at known locations throughout 2 study sites and crew members estimated bearings to the transmitters without knowing their actual locations. I then estimated locations to the transmitters from the recorded bearings and examined effects of subsequent radiotelemetry triangulation error on determining habitat use and detecting habitat selection using MLE point-estimates and 95% error ellipses. In each study site, point estimates correctly classified more habitats (70.1% and 68.7%) than error ellipses (62.2% and 64.6%). Point estimates were more accurate, but less precise, at determining patterns of habitat use, and more efficient, but less precise, at determining habitat selection, than error ellipses in both study sites. The ability of each method to correctly classify habitats, to correctly identify habitat-use patterns, and to correctly identify habitat-selection increased as ellipse sizes decreased relative to habitat-patch sizes.

CHAPTER 1

INTRODUCTION

Radiotelemetry triangulation is a technique commonly used to estimate locations of animals. From such location estimates, researchers often attempt to distinguish habitats that are selected or preferred by the radiomarked animals, i.e., identify habitats that are used in greater proportions than their availabilities. Thus, it is critical that triangulation techniques accurately measure locations with respect to habitats. However, radiotelemetry locations are only estimates of true locations and have associated error. As a result, estimated locations may be erroneous and detect animals in habitats they are not actually using. Therefore, we must first consider ways to minimize such errors, i.e., increase their precision, and second, choose location-estimation methods that maximize the quality of radio-location estimates.

The precision of estimated locations is dictated by 3 factors: the distances from the animals to the receivers; the angles at which triangulated bearings intersect; and the variances around estimated bearings. Once attempts have been made to position receivers nearer to animals with bearings intersecting at optimal angles, the precision of location estimates depends on the accuracy and precision of estimated bearings. Yet, bearing bias and precision are not as easily controlled. Because researchers have limited influence over bearing error, there is a need to document situations in which frequent errors have occurred, record circumstances that produced the most biased and imprecise bearings, and avoid those situations and circumstances where errors are more likely to occur.

Even if attempts are made to minimize bearing errors, calculable bearing-errors still exist. Consequently, location estimates from intersections of several triangulated bearings have measurable error, i.e., the magnitude of location error can be quantified by constructing confidence ellipses around estimated locations. Thus, estimated locations can be treated as both points and areas. Still, point estimates and error ellipses can produce erroneous location-estimates, which could lead to misclassification of habitat use. Inaccurate point-estimates may simply be in wrong habitats. Given imprecise locations with larger error-ellipses, it may be difficult clearly identify used habitats, i.e., if an error ellipse overlaps >1 habitat type, it is not clear to which habitat type the location estimate should be assigned because the actual location may be within any of the habitats covered by the ellipse. Although triangulation error is known to exist, very few studies have addressed the effects of habitat misclassification on determining habitat-use patterns or testing for selection, or compared the quality of estimated locations between point estimates and error ellipses.

In CHAPTER 2, I attempted to maximize the quality of bearings by identifying potential sources of bearing error. Knowledge of potential sources of error can allow researchers to avoid situations where they are more likely to occur and, possibly, to correct any systematic or predictable errors. Therefore, I designed a first study with the following objectives: (1) to identify factors that affect radiotelemetry bias and/or precision and (2) to develop recommendations for reducing triangulation bias and increasing triangulation precision.

In CHAPTER 3, I examined the effects of 2 location-estimation methods on the quality of location estimates. The abilities of point estimates and 95% error ellipses may differ at correctly classifying habitat use, determining use patterns, and detecting habitat selection at different levels of precision and under varying habitat arrangements. Therefore I designed a second study with the following objectives: (1) to compare the abilities of 2 location-estimation methods at correctly classifying habitats in 2 study sites; (2) to assess the abilities of the same 2 methods to accurately determine habitat use patterns in 2 study sites; (3) to judge the abilities of the 2 methods to detect habitat selection in 2 study sites; and (4) to evaluate the effects of precision of location estimates, i.e., error-ellipse size, on correct-classification rates, determination of habitat-use patterns, and detection of habitat selection using 2 methods of estimating locations, within 2 study sites.

CHAPTER 2

FACTORS AFFECTING RADIOTELEMETRY BEARING ERROR

Introduction

Radiotelemetry triangulation is a technique commonly used to estimate locations of animals. It can generate many locations with relatively little effort and without disturbing marked animals. However, radiotelemetry locations are only estimates of true locations and have associated error (Springer 1979). Erroneous location-estimates may lead to incorrect conclusions about the biology and behavior of marked animals. Therefore, we must consider ways to minimize such errors and increase the precision of location estimates. It has often been argued that the best measure of precision for location estimates is the area of associated error polygons or confidence ellipses (Nams 1989, Saltz and White 1990, White and Garrott 1990:57, Saltz 1994). The 3 major factors that govern precision of location estimates via radiotelemetry are: (1) the distances from transmitters to receivers; (2) the intersection angles of bearings; and (3) the variances around the bearings (Springer 1979, Saltz 1994).

The above 3 factors, although often difficult to control, can be manipulated by researchers. Garrott et al. (1986) stated that in practice, animal locations relative to receivers are generally manageable. Distances and the angles at which triangulated bearings intersect are often dictated by movements of the radiomarked animals. However, researchers can influence these 2 factors by taking bearings from towers at optimized locations (White 1985, White and Garrott 1986) or by moving the receiving station throughout a study area, i.e., vehicle-mounted tracking system (White and Garrott 1990:90). Once all attempts have been made to position receivers nearer to animals with bearings intersecting at optimal angles, the precision of location estimates depends on the accuracy and precision of estimated bearings. Yet, bearing bias and precision are not as easily controlled (Garrott et al. 1986).

Because researchers currently have limited influence over bearing error (bias and precision), it is very important to document situations where frequent errors have occurred, record circumstances that produced the most biased and imprecise bearings, and avoid those situations and circumstances when possible. Hypothesized sources of radiotelemetry bearing error include differences by: observer, day, weather conditions, radiotelemetry system (including antenna type and height, receiver, transmitter, and signal modulation), distance from transmitter to receiver, topography/terrain, vegetation, and animal movement (Cederlund et al. 1979, Springer 1979, Macdonald and Amlaner 1980, Sargeant 1980, Hupp and Ratti 1983, Lee et al. 1985, Garrott et al. 1986, Hegdal and Colvin 1986, Anderka 1987, Pace 1988, Schmutz and White 1990). Unfortunately, the inferences that can be drawn from several of these sources (Macdonald and Amlaner 1980, Sargeant 1980, Hegdal and Colvin 1986, Anderka 1987) are limited: although potential causes of bearing error were stated, specific ranges of bias or precision were not provided.

Given the importance of precision in estimating locations of animals, researchers must maximize the quality of bearings that provide those location estimates. An important step in improving the quality of estimated bearings is to identify potential sources of bearing error and understand how such sources may reduce bias and increase precision. Knowledge of potential sources can allow researchers to avoid situations where these errors are more likely to occur and possibly correct any systematic or predictable errors. Therefore, I designed this study to: (1) identify factors that affect radiotelemetry bias and/or precision and (2) develop recommendations for reducing triangulation bias and increasing triangulation precision.

Study Area

I conducted this investigation in the lower Flathead Valley of western Montana, approximately 80 km north of Missoula, on the Flathead Indian Reservation (Fig. 1). The study area was approximately 8 km west of the Mission Mountains and 20 km east of the Flathead River and foothills. Lokemoen (1966) likened the region to pothole habitat in the prairie-pothole region of Canada. Terrain was flat to gently rolling glacial moraine. Average pothole density was $65.3/km^2$, and most potholes were <0.1 ha (Lokemoen 1966). Specific sites were located on approximately 317 ha of state-owned Wildlife Management Areas (WMAs) adjacent to the Ninepipe National Wildlife Refuge.

The Montana Department of Fish Wildlife and Parks manages the WMAs to provide habitat and food for local wildlife and has created a mosaic of native and agricultural habitats. Upland land use on WMAs included: idle grassland, mowed grassland, planted cropland (wheat or barley), fallow cropland, and planted hedgerow. I classified habitats on the study areas into 8 broad categories: open water, vegetated wetland, grassland, cropland, fallow, scrub or hedgerow, woodland, and roads or trails.