ABSTRACT

Documenting whether variation in demographic parameters such as births, deaths, and movements exists, and how temporal and spatial environmental variability influences demography, is critical to understanding and affecting changes in animal populations. Natural populations often exhibit variation in demographic parameters, and while the examination of temporal variation has long been a central theme in population ecology, spatial variation among or within populations of the same species has received much less attention. Although the vast majority of the world's ungulate species live in the tropics and sub-tropics, few studies have investigated the demography of large, tropical herbivores. Giraffe (*Giraffa camelopardalis*) are believed to be declining rapidly, as their habitat throughout Africa has been lost and fragmented, thus the fragmented Tarangire Ecosystem in Tanzania was representative of much of the remaining landscape for these iconic megaherbivores. The goal of this study was to fill this knowledge gap by examining whether spatial variation in demography of giraffe existed in a fragmented ecosystem, and how key demographic parameters of reproduction, adult and juvenile survival, and movements of a large tropical ungulate were affected by spatial variation in land use, poaching (illegal hunting), and predation. I also assessed the source-sink structure of the study area and examined the implications of sub-population demography and movements for metapopulation dynamics. Finally, I examined temporal seasonal variation in reproduction and calf survival, and whether observed patterns fit specific theories of synchronous and asynchronous reproduction.

My research used data from 1,857 individually identified giraffe at 5 sites within the Tarangire Ecosystem to estimate site-specific population size, probabilities of

reproduction, calf survival, adult survival, and movements among sites to understand a suspected declining overall population trend. My research was organized around three questions: 1) How does survival, reproduction, and population growth rate vary among sites? Does spatial variation in land management, giraffe density, lion density, or poaching affect adult survival, calf survival, and reproduction? Do patterns of spatial variation reflect the paradigm of ungulate population dynamics from studies of temporal variation?; 2) How does movement link the sub-populations in this fragmented landscape? Does land management, predation, or density explain movement rates? How do differences in demography and movement among sub-populations affect the metapopulation?; and 3) How do reproduction and juvenile survival vary by season? Do observed seasonal patterns in reproduction and survival relative to changes in vegetation quality and/or predation pressure fit specific theories of synchronous and asynchronous reproduction?

I found significant spatial variation in adult female survival, reproduction, movements, and density existed. Only adult female survival was significantly correlated with a spatial covariate (positively correlated with anti-poaching efforts). A matrix population model using site-specific estimates of survival and reproduction showed adult female survival was the highest elasticity parameter, and thus had the greatest proportional effect on population growth rate (*lambda*).

Population growth rate also varied significantly by site, and was best explained by the spatial covariate of distance to Mtowambu, the main bushmeat market town in the area. Population growth rate was $\geq$ 1.0 (indicating a growing sub-population) only in Tarangire National Park (TNP), but *lambda* at all other sites was less than 1.0 indicating decreasing sub-populations. A decreasing metapopulation ($\lambda^M \approx 0.99$) was estimated by two methods of computing the metapopulation growth rate. TNP was identified as the dominant engine of metapopulation growth, but movement of individuals out of TNP and into "attractive sink" sites, where more poaching of adults occurs, is the most likely explanation for the shrinking metapopulation. However, these movements are also responsible for preventing extirpation of giraffe sub-populations in the smaller sites.

I also examined how temporal variation affected calving and calf survival. I found significant seasonal variation in proportion of births, with more births in the short rains and dry seasons relative to the long rains, and calf survival was affected by season of birth in accordance with both the "phenological match" theory of reproductive synchrony and the "temporal resource partitioning" theory of asynchrony. Calf survival also was positively correlated with the seasonal abundance of migratory herds of zebra and wildebeest, the local abundance of which apparently reduced predation pressure on young giraffe.

Based on my results, for conservation of the species and the large-scale processes of giraffe interactions across the landscape, I recommend efforts to disrupt bushmeat markets and expand anti-poaching patrols such as those employed in the Tanzanian national parks, to bring down harvest rates of adult females to sustainable levels, while simultaneously maintaining or improving linkage habitat between all sites to facilitate natural movements. This should increase adult survival to the point where sink sub-populations are less of a drain on the metapopulation, and having multiple linked, healthy sub-populations reduces the risk of total extinction. Additionally, conservation of migratory herds by protecting their calving grounds and migration routes would maintain their indirect benefit to giraffe calf survival.

Identifying source and sink habitats using the methods described herein is superior to monitoring via abundance or density estimates alone because when managers understand movements, population growth rates, and metapopulation dynamics, they can effectively prioritize actions to ensure the security of sources while addressing the causes of sinks.