Wildlife responses to drone noise: an integrated approach for single- and dual-drone flights

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Drones are increasingly being deployed to study wildlife; however, growing evidence indicates that drone noise and presence can alter animal behavior and confound ecological data. Few studies have quantified how acoustic exposure affects the observed behavioral responses of wildlife. Here, we present a field-based protocol that integrates in-situ real-time acoustic monitoring with standardized behavioral scoring to identify species-specific disturbance thresholds in African megafauna. In Ol Pejeta Conservancy, Kenya, we monitored how flight altitude, singular or dual drone flights, and flight path affected plains zebras (Equus quagga) and reticulated giraffes (Giraffa reticulata). We conducted single and dual drone flights at 75 m to 20 m altitude with two DJI quadcopter drones (Mavic 3Pro and 3T). A linear microphone array at ground level recorded drone noise, and observers used a detailed ethogram to log vigilance and escape behaviors. Drone noise declined predictably with increasing flight altitude, while dual-drone operations introduced a disproportionate increase in acoustic exposure. This increase was non-linear and reflected overlapping rotor harmonics and prolonged exposure rather than a simple doubling of noise. Bootstrapping of behavioral scores showed a robust directional effect, with dual-drone flights producing mean disturbance responses approximately 3 points higher than single-drone flights (95% bootstrap CI: 2–4). Behavioral responses differed between species. Zebras showed consistent, qualitatively dose-dependent increase in vigilance and displacement behaviors below approximately 50 m, particularly during dual-drone operations and in mixed-species herds. Giraffes primarily exhibited prolonged head-up vigilance without fleeing. These findings provide preliminary, context-specific disturbance indicators for the species and open savannah habitat studied and show how coupling real-time acoustic measurements with behavioral observations enables a more mechanistic interpretation of drone disturbance than behavioral data alone. This approach moves beyond simple altitude-based assumptions and supports the evaluation of emerging operational configurations, such as multi-drone flights.