Demographic Estimates from a Muskrat Population in the Flint Hills

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Abstract - Apparent declines in *Ondatra zibethicus* Linnaeus (Muskrat) populations across North America necessitate information regarding key demographic parameters. In the Flint Hills ecoregion in Kansas, USA, Muskrat habitat is generally characterized by man-made wetlands used for ranching operations. The relative quality of these habitats for Muskrat populations is poorly understood. We marked and recaptured Muskrats (2020–2022) in the Flint Hills to quantify daily rates in apparent survival. Trap success was low, resulting in a small sample size for inference (n = 22). Our most-supported Cormack-Jolly-Seber model suggested daily recapture probabilities were greater in 2021 ($p = 0.67$) than in 2022 ($p = 0.36$). Daily apparent survival rates ($\Phi = 0.92$, 95% CI = 0.75–0.98) were lower than reported in other studies, suggesting poorer habitat conditions for Muskrats in the Flint Hills. We did not capture or detect kits during our study, possibly revealing drought-induced Allee effects in a low-density Muskrat population.

Introduction

Ondatra zibethicus Linnaeus (Muskrat) are small semiaquatic mammals (0.7–1.8kg; Willner et al. 1980) that are ecologically (Bomske and Ahlers 2021), culturally (Straka et al. 2018, Turner et al. 2018), and economically important species (Ahlers et al. 2016). Although widely distributed across North America, recent evidence suggests Muskrat populations have declined across much of their native range (Ahlers and Heske 2017, Greggory et al. 2019, Roberts and Crimmins 2010, Sadowski and Bowman 2021). A mechanistic explanation for observed population declines remains unknown. However, several hypotheses are plausible. For example, wetland loss, wetland isolation, and changing patterns in hydrology may be affecting key population demographic parameters such as survival and population growth (Ahlers and Heske 2017).

Muskrat survival and population growth are affected by both biological and environmental factors. Extreme fluctuations in hydrology, such as drought and flooding, can negatively affect Muskrat populations (Ahlers et al. 2010b, Errington 1939, 1963). Climate change is increasing the frequency and duration of extreme precipitation and drought events (Dai 2013, Easterling et al. 2000), likely posing increased risks for Muskrat populations (Ahlers et al. 2015). Receding water levels during drought conditions can expose burrows to predators, resulting in greater adult and kit mortality rates (Errington 1963). Predation of Muskrats within burrows or lodges has generally been attributed to *Neogale vison* Schreber (American Mink; Errington 1943, 1963), though *Canis latrans* Say (Coyote) predation is also a significant cause of mortality (Ahlers et al. 2010b). Muskrats occurring in drought-affected wetlands are reluctant to move into upland areas and search for other good-quality habitats (Errington 1939). Space use by Muskrats is largely restricted to within-water areas (Ahlers et al. 2010a, Ganoe et al. 2021, Matykiewicz et al. 2021), and individuals using terrestrial areas can incur greater

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mortality risks (Ahlers et al. 2015). Muskrat population abundances are dynamic (Ahlers et al. 2021, Erb et al. 2000), though little is known about survival rates or population growth.

Wetlands occurring in the Flint Hills, Kansas, USA, are largely man-made and designed for water retention to support *Bos taurus* Linnaeus (Cattle) ranching operations. Historically, wetlands large enough to support Muskrat populations in the Flint Hills ecoregion were relatively rare outside of naturally occurring riparian areas. Constructed wetlands now support wetland-obligate biodiversity in the Flint Hills (Swartz and Miller 2021), including semiaquatic mammals such as Muskrat. Relative habitat quality of these wetlands and survival rates of Muskrat occurring in them are unknown. We conducted a mark-recapture study of a Muskrat population occurring in isolated wetlands in the Flint Hills from 2020–2022 to quantify apparent survival estimates. Our goal was to estimate daily Muskrat apparent survival rates to provide insight on the relative quality of these habitats to Muskrat populations.

Materials and Methods

All trapping and handling methods were approved by Kansas State University Institutional Animal Care and Use Committee (Protocol #4074) and were consistent with guidelines provided by the American Society of Mammalogists (Sikes et al. 2016). Our study occurred in the Flint Hills tallgrass prairie ecosystem, near Manhattan, Kansas, USA (39°11′N, −96°35′W). The Flint Hills represent one of the largest remaining tracts of tallgrass prairie landcover in North America and are characterized by shallow, rocky soils overlaying layers of limestone and flint. Our study area (Fig. 1) ranged from 300–500 m in elevation, and landcover was dominated by native tallgrass prairie (~45%). However, landscape change is prevalent, and much of the landcover now includes agriculture (21%) and woody encroachment (7%; Hamilton et al. 2000, Ratajczak et al. 2012). During our study, monthly precipitation ranged from 20–184 cm (mean 105 cm) and the temperature ranged from -14°–37° C (mean 23° C). All wetlands included in our study were human-made retention ponds constructed for watering cattle (average depth = 3.3 m, range = 0.5–10 m). Emergent plant species included Cattail (*Typha* sp.), Spikerush (*Eleocharis* sp.), Milfoil (*Myriophyllum* sp.), Pondweed (*Potamogeton* sp.), Sedges (*Cyperus* sp.), Arrowhead (*Sagittaria* sp.), Knotweed (*Polygonum* sp.), Bullrushes (*Schoenoplectus* sp.), and Duckweed (*Lemna* sp.). Woody encroachment was also prevalent and characterized by *Juniperus virginiana* Linnaeus (Eastern Redcedar), *Rhus glabra* Linnaeus (Smooth Sumac), and *Cornus drummondii* Mey (Roughleaf Dogwood). Potential Muskrat predators in our study area included American Mink, *Buteo jamaicensis* Gmelin (Red-tailed Hawk), Coyotes, and *Bubo virginianus* Gmelin (Great Horned Owl), among others. Landowners confirmed that Muskrat trapping was not occurring on their properties during the duration of our study and that Muskrat trapping was

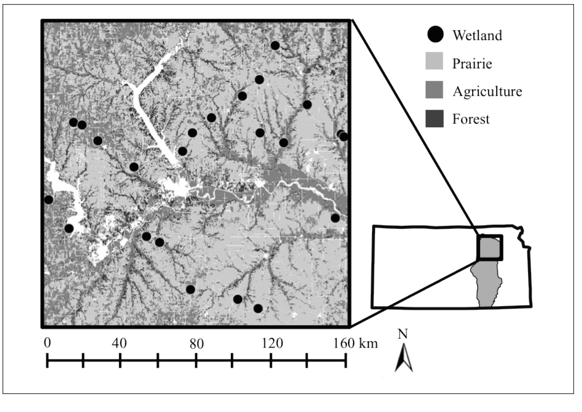

Figure 1. Study area in the northern Flint Hills of Kansas, USA, where we quantified apparent survival estimates for Muskrats (*Ondatra zibethicus*) from 2020–2022. Black dots (not to scale) represent 23 wetlands from which we captured and marked individual Muskrats. The spatial extent of the Flint Hills ecoregion is highlighted in gray in the inset map of Kansas.

rare at their wetlands after 2010. Average spatial separation from sampled wetlands was 7.74 km (range: 1.63–23.89 km), and average wetland area was 5,234 m^2 (range: 278–25,424 m^2).

Captures and marking

We live-trapped Muskrats using single-door, collapsible traps (Tomahawk Live Trap Inc., Hazelhurst, WI; Model 202) at wetlands throughout our study area. We chose wetlands based on probability of Muskrat occupancy the previous fall (information we collected during a concurrent study) and likelihood of Muskrat occurrence at the time of trapping (determined by presence of Muskrat signs at that time). We attempted to target wetlands with the greatest likelihood of Muskrat capture, as our preliminary work suggested Muskrat population abundances were depressed in the region following severe drought. We conducted trapping from 2 November–11 December 2020, 1 March–9 April 2021, and 14 March–10 June 2022, dependent upon temperature and precipitation. We did not trap when daily low temperatures were forecasted ≤ 0°C or during rain events. We fastened live-traps to floating rafts (modified track boards; Larreur et al. 2020, Matykiewicz et al. 2021, Reynolds et al. 2004, Schooley et al. 2012) kept buoyant by Styrofoam sandwiched between two plywood sheets (122 × 61 × 4 cm). We floated trap boards along wetland edges near active Muskrat burrows or in areas with Muskrat signs (e.g., Muskrats, tracks, scat, clippings) and tethered them to sturdy vegetation or structure (e.g., rocks, Eastern Redcedar trees or stumps, Cattails). We covered traps with local vegetation to conceal them and provide cover from adverse weather and direct sunlight (Matykiewicz et al. 2021). We baited traps with apple (e.g., Ahlers et al. 2010a) and checked twice daily, once in the morning and again in the evening. All unmarked individuals were immediately transferred to a handling bag and marked with a 10-mm passive integrated transponder (PIT) tag (Biomark, Boise, Idaho) inserted subcutaneously between the shoulders. We recorded unique identity of all recaptured individuals using a handheld PIT tag reader (Biomark, Boise, Idaho) passed along the outside of the trap or handling bag.

We measured weight (g) of all captured Muskrats (average = 1.25 kg, range = 0.82–1.93 kg) and determined sex, though we could not identify sex with complete certainty in all individuals (see Results). All Muskrat handling was done at the wetland edge without use of anesthesia (< 5 min per individual), and marked and recaptured individuals were released at the point of capture.

Survival analyses

We used Cormack-Jolly-Seber models (Program MARK ver. 9.0; White and Burnham 1999) to estimate apparent daily survival rates (Φ) of Muskrats. Apparent survival rates were estimated over 10 days each year. We considered single and additive effects of 'Sex' (male = 1, female = 0) and 'Year' (2022 = 0, 2021 = 1) on recapture probabilities (p) resulting in four models in this candidate set (Sex, Year, Sex + Year, Null). Because of our small sample size, we did not consider time-dependent effects in either Φ or p, nor did we consider models including interactions. We also did not model covariate effects on Φ as not to overfit models. We ranked models using Akaike's Information Criterion (AIC), corrected for small sample sizes (AICc), and assessed model-support using an information-theoretic approach (Arnold 2010, Burnham and Anderson 2002). We considered models with ΔAICc < 2.00 as competitive.

Results

From 2020–2022, we attempted to live trap Muskrats at 23 wetlands (2020 = 11, 2021 = 12, 2022 = 14) resulting in 1,766 trap nights (2020 = 290, 2021 = 640, 2022 = 836). Overall trap success was 0.03/trap night but varied by year (2020 = 0.003, 2021 = 0.04, 2022 = 0.02). We caught and individually marked 22 Muskrats across all years (2020 = 0, 2021 = 14, 2022 = 8). A single Muskrat caught in 2020 escaped the handling bag prior to being marked. Sex could not be determined with complete confidence for 10 individuals, thus our sample included 8 males and 4 females with remaining individuals' sex unknown. All captured Muskrats were adults and we did not capture or detect kits at wetlands. Average recaptures per individual was 0.86 (range = 0–5) and varied between years (2020 = 0; 2021 = 0.86, range = 0–5; 2022 = 0.88, range = 0–2). We did not recapture any individual Muskrats in multiple years, including at wetlands where we marked Muskrats in previous years. Our top model indicated Muskrat recapture probabilities varied by year ($\beta = 1.12$, $SE = 0.70$; 2021 = 0.67, 2022 = 0.36; Table 1). Our null model was also competitive, though it had poorer model fit (Table 1). After accounting for differences in recapture probabilities between years, daily apparent survival rates were 0.92 (95% CI = 0.75–0.98).

Discussion

Our study provides information on survival rates of Muskrats in the Flint Hills ecoregion—a key demographic that was previously unknown. Our estimated daily apparent survival rates, when extrapolated to weekly survival rates (0.56), were lower than those reported by other studies (e.g., Ahlers et al. 2010b, Ganoe et al. 2021, Kanda and Fuller 2004, Matykiewicz et al. 2021). Further, we did not catch or detect signs of Muskrat kits or lactating females at any of our wetlands in 1,766 trap nights across 3 years. This suggests reproductive success is limited or absent, and highlights potential demographic Allee effects (Stephens and Sutherland 1999) in a low-density Muskrat population. If species' populations fall below an abundance threshold average, fitness of individuals within that population can decrease (Allee 1931). Allee effects may reduce Muskrat population fitness for many reasons, including if Muskrats are dispersing away from already low-density populations, mate limitation at wetlands, or inbreeding depression. Future work should focus on identifying mechanistic explanations for reduced population fitness in low-density Muskrat populations including assessing the potential for Allee effects to impede population growth or recovery.

Large areas of the Great Plains in North America experienced significant drought conditions prior to our study (summer and fall 2018). In the Flint Hills ecoregion in Kansas, USA, drought was severe (Palmer drought severity index -3 to -3.99), resulting in substantial wetland drying across the region (e.g., Hopper 2019). Additionally, streams and other riparian areas had reduced or no water flow during this time (e.g., Hopper et al. 2020). These drought conditions could have negatively affected Muskrat populations during our study, though we could not empirically test this hypothesis with our data. Extreme hydrological events are becoming

Table 1. Ranking of Cormack-Jolly-Seber models estimating recapture probability (p) for Muskrats (*Ondatra zibethicus*) occurring in isolated wetlands in the Flint Hills ecoregion, Kansas, USA (2021–2022). Model parameters include apparent survival (Φ) and recapture probability (p). All models of Φ only include an intercept term (.), and we allowed p to either vary by year (2021 or 2022) and sex or held constant (.). ΔAICc = change in Akaike's Information Criterion corrected for small sample sizes (AICc) relative to model with lowest AICc, ω = model weight, k = number of estimable parameters, and $-2l$ = -2*Log(Likelihood).

Model	ΔAICc	ω	*K*	*-2l*
$\Phi(.)p(\text{Year})$	0.00	0.40	3	85.38
$\Phi(.)p(.)$	0.18	0.37	2	87.91
$\Phi(.)p(\text{Sex + Year})$	2.41	0.12	4	85.30
$\Phi(.)p(\text{Sex})$	2.53	0.11	3	87.91

more frequent and intense (Dai 2013, Easterling et al. 2000), with potential to negatively affect Muskrat populations (Ahlers et al. 2015). Subsequent studies assessing resilience of man-made wetlands in the Flint Hills to extreme flooding and drought events are warranted, especially as it relates to conservation of wetland-obligate species occurring in the area.

Prior to wetland construction, it is likely Muskrats did not occur in the Flint Hills except in riparian areas or limited naturally occurring wetlands. Based on our results, our sampled wetlands likely only offer marginal-quality habitat to support Muskrat populations. Human-constructed wetlands in the Flint Hills that retain sufficient water levels may provide temporary refugia for Muskrats during drought (e.g., to escape predation) or act as stepping stones between good-quality habitat for dispersing individuals. These hypotheses, however, need to be rigorously evaluated. Unfortunately, we could not assess the importance of local- (e.g., wetland size, amount of vegetation) and landscape-scale (e.g., amount of agriculture or woody encroachment) habitat quality on apparent daily survival rates of Muskrats because of our limited sample size. We did not recapture marked Muskrats between sampling years or at wetlands where they were not initially marked. Studies examining the spatial ecology of Muskrats in the Flint Hills will likely provide insight into factors affecting wetland colonization and extinction of Muskrat populations. Additionally, studies incorporating known-fate survival and population abundance information would likely reveal the relative importance of these wetlands to Muskrat population fitness.

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