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Population Ecology

Monitoring Site Occupancy for American Mink in Its Native Range

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ABSTRACT American mink (*Neovison vison*) are secretive, semi-aquatic carnivores that often require noninvasive methods based on field signs such as tracks and scat for determining their spatial distribution. Most previous assessments of survey methods for American mink have been conducted in the United Kingdom where mink are an invasive species. We evaluated survey techniques for American mink in riparian habitat in its native range in the midwestern United States. We used occupancy modeling to compare detection rates between walking surveys and mink raft surveys, and we evaluated the potential for environmental covariates and observer bias to influence detectability from walking surveys. Per-survey detection probabilities were greater for walking surveys (0.72) than for mink rafts (0.39). Walking surveys also were cheaper and easier to conduct in small streams prone to flooding when compared to mink raft surveys. However, detection probabilities from walking surveys were affected by observer bias, recent rainfall, substrate, and date. We recommend walking surveys for determining the distribution of American mink in riparian habitat in the Midwest if occupancy modeling is applied to adjust for environmental and observer effects on detectability. We used such an approach to demonstrate occupancy dynamics of mink were related to variable water depths, which has implications for how this carnivore might be influenced by climate change. Mink rafts standardize the substrate for recording mink tracks and reduce the likelihood of observer effects. For studies using many volunteers, we recommend mink rafts for determining site occupancy by American mink.

KEY WORDS American mink, detectability, Illinois, mink raft, *Neovison vison*, observer bias, occupancy modeling, riparian.

Reliable data on the spatial distribution of species are needed for monitoring programs and for habitat models to predict species responses to current and future environments. Noninvasive survey methods to determine presence–absence have been effectively applied to elusive carnivores (Gompper et al. 2006; Long et al. 2008, 2011), which often occur at low densities and are difficult to capture with traditional methods (Eagle and Sargeant 1985). The American mink (*Neovison vison*) is a secretive, semi-aquatic carnivore that has been studied in North America primarily using harvest data to examine predator–prey dynamics (Erb et al. 2001, Haydon et al. 2001, Shier and Boyce 2009) and impacts of feral mink (Bowman et al. 2007, Nituch et al. 2011). Relatively few studies of habitat use by American mink have been conducted within the native range of the species (e.g., Arnold and Fritzell 1990, Ben-David et al. 1995, Stevens et al. 1997, Loukmas and Halbrook 2001). In contrast, most recent research on survey techniques and habitat selection by American mink has been conducted outside of North America because mink are a consequential invasive species in Europe and South America (Bonesi and Palazon 2007, Melero et al. 2008, Reynolds et al. 2010, Bryce et al. 2011, Fasola et al. 2011).

In the midwestern United States, most remaining mink habitat is associated with streams and drainage ditches because of extensive loss of wetlands (Suloway and Hubbell 1994, McCauley and Jenkins 2005). Two noninvasive methods mainly have been used to determine site occupancy of riparian habitat by mink—walking surveys to locate sign such as tracks and scat (Loukmas and Halbrook 2001, Bonesi and Macdonald 2004, Reynolds et al. 2004, Harrington et al. 2008), and mink rafts (Reynolds et al. 2004). The mink raft was developed in the United Kingdom as a standardized device for monitoring invasive American mink (Reynolds et al. 2004, 2010). In the United Kingdom, mink rafts are considered to be more effective than walking surveys for determining occurrence of American mink (Reynolds et al. 2004, Harrington et al. 2008), but mink rafts have not been tested in North America. Occupancy modeling approaches that quantify detection rates using multiple sur-

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veys of sites (MacKenzie et al. 2006, Long et al. 2011) only have been applied individually to walking surveys (Bonesi et al. 2006) or mink rafts (Reynolds et al. 2010). Estimates of detectability from occupancy modeling for the 2 survey methods have not been directly compared in the same study.

Mink sensitivities to hydrology are important for understanding current constraints to habitat use, and for predicting how this mesocarnivore might be affected by climate change. Projections for the Midwest include increased precipitation during winter, spring, and autumn; but lower precipitation during summer combined with increased annual temperatures (Hayhoe et al. 2010). These climate changes could decrease mean annual streamflow and increase variability of daily streamflow (Risley et al. 2011). Extreme precipitation events are expected to be more common (Hayhoe et al. 2010). Collectively, riparian mink will likely be exposed to increased variability of water levels at multiple time scales. Such effects of climate change could be heightened in urbanized and intensively drained agricultural regions (Changnon and Demissie 1996).

Our main objective was to compare noninvasive survey techniques for determining site occupancy by American mink in its native range in the midwestern United States. We used occupancy modeling to test whether detection rates were greater for mink rafts than for walking surveys. We also evaluated environmental covariates and observer bias (Evans et al. 2009, Fitzpatrick et al. 2009) that might affect detectability estimates from walking surveys. We also determined how mink respond to water levels of streams that vary in space and time.

STUDY AREA

We conducted our research in the Grand Prairie Region of central Illinois within a 7,854-km^2 area centered on Champaign, Illinois (40°05′N, 88°15′W) that contained portions of 5 watersheds (Sangamon, Moultrie, Embarras, Wabash, Vermilion). Streams ranged from first-order headwater streams to a fifth-order stream (Sangamon River) in which stream order refers to the hierarchy of tributaries upstream (e.g., fifth-order stream is formed by joining of 2 fourth-order streams). Elevations ranged from 188 m to 236 m, and stream gradients typically were <1%. The wetted width of stream channels varied from <1 m to 30 m. Land cover in the Grand Prairie Region was dominated by row crop agriculture (80%, primarily corn and soybeans), forest (5%), and pasture and grassland (4%). Dominant riparian vegetation included reed canary grass (*Phalaris arundinacea*) and smooth brome grass (*Bromus inermis*). Total precipitation for July–October (our survey period) averaged 346 mm (SE = 10) from 1907 to 2007. Precipitation for July–October was below average in 2007 (261 mm) and above average in 2008 (503 mm; Illinois State Water Survey 2008).

METHODS

Sampling Design

We surveyed 200-m reaches of wadeable streams (hereafter sites). We chose this spatial extent to approximate the average linear home range of riparian muskrats (*Ondatra zibethicus*) for a concurrent study (Cotner and Schooley 2011). At this scale, a site represented a resource patch to American mink given their expected home-range size in riparian areas (Yamaguchi and Macdonald 2003, Melero et al. 2008). Hence, we investigated detection rates and site occupancy for mink at a scale corresponding to habitat use instead of population or metapopulation dynamics (MacKenzie et al. 2006). We used a stratified random sampling design to select 90 sites; 50% were located within a 2-km radius of incorporated towns (>2,500 people), and 50% were located outside of these urban buffers (Cotner and Schooley 2011). The median nearest-neighbor (Euclidean) distance between sites was 2.5 km. The stream orders for the 90 sites included 54 first-orders, 13 second-orders, 12 third-orders, 3 fourth-orders, and 8 fifth-orders.

We used presence of tracks and scat to indicate site occupancy (Loukmas and Halbrook 2001, Bonesi and Macdonald 2004, Bluett et al. 2006, Bonesi et al. 2006, Harrington et al. 2008). Field identification of American mink scat can be difficult in areas where mink co-occur with other medium-sized mustelids (Harrington et al. 2010, but see Harrington et al. 2008). We based detections of mink mainly on tracks for both walking surveys (tracks only = 73%, tracks plus scat = 20%, scat only = 7%; $n = 201$ detections) and mink raft surveys (tracks only = 93%, tracks plus scat = 7%, scat only = 0%; $n = 28$ detections). River otters (*Lontra canadensis*) are uncommon in our study area and have substantially larger tracks than do mink (Rezendes 1999). Other mustelids (long-tailed weasel [*Mustela frenata*], least weasel [*M. nivalis*], badger [*Taxidea taxus*]) and mephitids (striped skunk [*Mephitis mephitis*]) that could occur in the study area have distinct tracks or differ considerably from mink in size. Long-tailed weasels are the most common mustelid but males weigh 160–450 g and the width of their front feet is ≤1.9 cm, whereas female mink weigh 550–1,000 g and the width of their front feet is 3.2–4.5 cm (Rezendes 1999, Kays and Wilson 2002). Hence, false positives for mink were unlikely. We acknowledge that our non-invasive survey methods are not able to distinguish wild, feral, and hybrid mink (Bowman et al. 2007, Nituch et al. 2011) so our inferences regarding detectability and occupancy apply to the species as a whole.

Walking Surveys

We conducted occupancy surveys for mink at the 90 sites between mid July and late October in 2007 and 2008. For each survey, 1 trained observer walked along both sides of the 200-m stream reach and searched for sign within 5 m of the water's edge. In 2007, 6 different observers conducted surveys, but 2 main observers performed most surveys (78%). In 2008, 3 observers conducted all surveys. Two observers independently surveyed each site during 1 visit. We surveyed each site 2–4 times per year with walking surveys using a removal design (MacKenzie and Royle 2005, MacKenzie et al. 2006) in which we did not revisit sites where we detected mink during either of the first 2 surveys. We completed 464 surveys (248 in 2007, 216 in 2008).

Mink Rafts

Reynolds et al. (2004) provide a detailed description and schematic for construction of a mink raft. In general, a raft consisted of a floating base (122 cm × 610 mm) made of a sandwich of 6-mm plywood with a 25-mm polystyrene filling. We placed a tracking cartridge (236 mm × 152 mm × 66 mm plastic basket) in a cut-out, central area of the base so that the top of the cartridge was flush with the surface of the raft. A layer of floral foam in the bottom of the cartridge wicked water up from the stream to moisten the tracking medium, which was a clay–sand mixture. We covered the tracking cartridge with a 6-mm plywood tunnel (each panel was 610 mm × 239 mm) and vegetation, and then tethered the mink raft to a stake or tree on the streamside.

We conducted surveys with mink rafts from 8 August to 31 October 2008. We randomly selected 42 of the 90 study sites to evaluate effectiveness of mink rafts. We removed 3 sites from the data set (1 because of vandalism of rafts, and 2 because of flooding and loss of rafts). Thus, our analysis included data from mink rafts at 39 sites. One survey for each site consisted of placing rafts at the 50-m and 150-m points along the 200-m stream reach, then checking the 2 rafts for sign after 2 weeks. We combined data between the 2 rafts at a site because we assumed rafts separated by 100 m were not independent (Reynolds et al. 2010). Hence, site occupancy was indicated by mink sign on either raft during 2 weeks. The 39 sites received either 2 surveys ($n = 34$ sites) or 1 survey ($n = 5$ sites) using mink rafts. Sites that received only 1 survey with mink rafts had $\geq$1 raft disturbed by flooding or raccoons (*Procyon lotor*).

Comparison of Detection Probabilities

We compared detection rates between walking surveys and mink rafts using data from the 39 sites sampled by both methods in 2008. We used an occupancy modeling approach to estimate per-survey detection rate (P) and site occupancy (ψ) using data from multiple surveys of each site (MacKenzie et al. 2006, O'Connell et al. 2006). We constructed a detection history for each site that included 3–6 surveys (2–4 walking, 1–2 mink rafts). Detection of mink by either survey method indicated site occupancy. Occupancy modeling effectively copes with missing data (MacKenzie et al. 2006). The estimation approach assumes there are no false positives. We conducted all modeling in program PRESENCE (Version 2.2, www.mbr-pwrc.usgs.gov/software/presence.html, accessed 2 Dec 2008). We used an information-theoretic approach to rank candidate models based on Akaike's Information Criteria (AIC; Burnham and Anderson 2002). For this analysis, the 3 models in the candidate set included a constant occupancy probability, but models differed in how they treated detection probability. Models included a constant per-survey detection probability that did not differ between survey methods [ψ(.), P(.)], a detection probability that differed between walking surveys and mink rafts [ψ(.), P(methods)], or a detection probability that differed between walking surveys and mink rafts and also between the first and second survey by mink rafts [(ψ(.), P(methods, raft)].

Detection Covariates for Walking Surveys

We used multi-season occupancy models in PRESENCE to evaluate detection covariates for walking surveys using all data for 2007 and 2008. We kept occupancy, colonization (γ), and extinction (ε) constant but varied the parameters for per-survey detection probability (P). We examined 3 covariates that could affect detection rates of mink: observer, recent rainfall, and survey date. We considered observer variability because detection could depend on innate abilities or effort during searching. For this analysis, we separately coded for the 2 main observers for 2007 (121 and 72 surveys) and the 3 observers for 2008 (107, 69, and 40 surveys). One observer was in common between years. We grouped the 3 additional observers for 2007 and coded them as 1 observer (75% of these 55 surveys were conducted by 1 observer) to avoid over-parameterization of models. Hence, there were 5 observers for the 2 years. Recent rainfall could remove mink sign or raise water levels to hide sign, so we did not conduct surveys for 2 days following a rainfall event of >1 cm. We summed total rainfall (cm) during the 7 days prior to each survey and used this value as a covariate to test for effects of precipitation on detection probability. To evaluate any temporal trends in detection rates within our sampling season, we considered Julian date of survey as a covariate. We used AIC to rank the 9 models in our candidate set. Models included constant detection [P(.)] or the 3 covariates (observer, rain, Julian) singly, in pairs, or all together.

During surveys in 2007, we realized detection probabilities could be related to availability of substrates suitable for collecting identifiable mink tracks. In 2008, we recorded substrate for each survey as the percentage of the stream bank covered by sand bars and mud flats. Two observers visually estimated the substrate variable and then averaged their estimations. We could not include substrate as a detection covariate in our multi-season models because values were missing for 2007. Instead, we used a single-season occupancy model with data for 2008 to determine whether substrate affected detection probability.

Occupancy Dynamics and Water Depth

We measured maximum water depth (thalweg depth) at 5 stations located 0 m, 50 m, 100 m, 150 m, and 200 m from the downstream end, and then averaged these measurements to obtain 1 estimate of water depth for each site each year. We used walking survey data from 2007 and 2008 and multi-season occupancy modeling to evaluate effects of water depth on site occupancy and colonization by American mink. We used the most supported model for detection (see Results). We then constructed models that included water depth in 2007 as a covariate for occupancy, water depth in 2008 as a covariate for colonization, and both water depth in 2007 as a covariate for occupancy and water depth in 2008 as a covariate for colonization. We ranked these 3 models plus the intercept-only model using AIC.

RESULTS

In 2008, naïve occupancy (i.e., proportion of sites with detections) was greater for walking surveys than for mink raft surveys: first walking survey = 0.64, second walking survey = 0.71, first mink raft survey = 0.29, and second mink raft survey = 0.49. We did not compare naïve occupancy for the third and fourth walking surveys because of our removal design.

We compared unique detections between survey methods by restricting the contrast to sites with 2 raft surveys ($n = 34$) and again using only the first 2 walking surveys. Hence, the comparison involved 2 walking surveys versus 2 raft surveys. Mink were detected by only 1 of the 2 survey methods at 20 sites. Unique detections were more likely for walking surveys (14/20 = 70%) than for mink raft surveys (6/20 = 30%).

Two models of detection probability were competitive (ΔAIC ≤ 2; Table 1). The highest-ranked model included heterogeneity in detection related to survey method (walking vs. raft) and to differences between the 2 mink raft surveys. The second-ranked model included only detection heterogeneity related to survey method (Table 1). Based on parameter estimates from the top model, site occupancy by mink was high in 2008 ($\psi = 0.93$, SE = 0.03), and the per-survey detection probability was highest for walking surveys ($P = 0.72$, SE = 0.03), lowest for the first mink raft survey ($P = 0.30$, SE = 0.08), and moderate for the second mink raft survey ($P = 0.50$, SE = 0.09). The cumulative detection probability (i.e., likelihood of detecting mink at least once when the species was present at site) can be calculated as $1 - (1 - P)^k$, in which k is the number of surveys (MacKenzie et al. 2006). Using detectability estimates ($P_{\text{walking}} = 0.72$, $P_{\text{raft}} = 0.39$) from the second-ranked model that included only differences due to survey methods (Table 1), obtaining a 99% cumulative probability of detecting mink would require 4 walking surveys or 9 mink raft surveys (Fig. 1).

Using data for both years, the key covariate affecting detection probabilities for walking surveys was observer identity (Table 2). The observer variable was included in all multi-season models with any weight of evidence. With observer 1 who conducted surveys in 2007 and 2008 coded as the baseline, detection rates were less for the other 2 observers in 2007 (observer 2, $\beta = -1.10$, SE = 0.52; observer 3, $\beta = -0.86$, SE = 0.50) and greater for the 2 other observers in 2008 (observer 4, $\beta = 0.65$, SE = 0.36; observer 5, $\beta = 1.58$, SE = 0.46). The observer effect was exemplified by differences among the 3 observers in 2008 (Fig. 2A). Observer 1 had a similar mean detection rate for 2007 ($n = 121$ surveys, $P = 0.58$, SE = 0.06) and 2008 ($n = 40$ surveys, $P = 0.55$, SE = 0.09). Recent rainfall had a negative effect on detection (Table 2, Fig. 2A). The estimated coefficient (on a logit scale) for rainfall from the second-ranked model was -0.2299 (SE = 0.1444). Detection also was related to Julian date (Table 2, Fig. 2B) with detection probability increasing over time ($\beta = 0.0071$, SE = 0.0054; estimated from second-ranked model). Despite variation in detection probability due to observer bias and environmental conditions, only 10.2% (22/216) of the walking surveys in 2008 had a detection probability less than the mean detection probability for rafts (0.39).

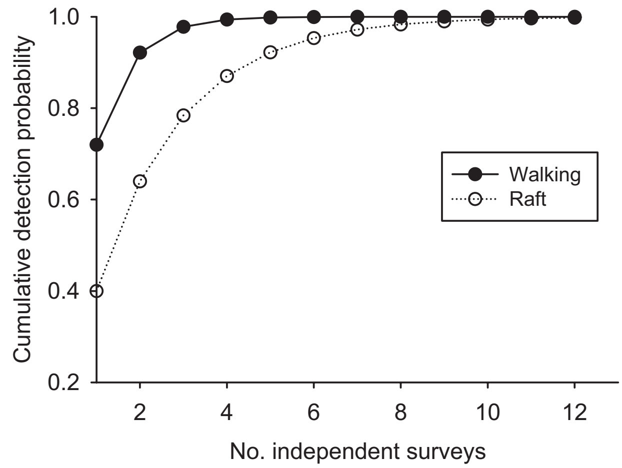

Figure 1. Probability of detecting American mink at a site in Illinois, 2008, in relation to number of independent surveys using 2 methods based on sign, walking surveys and mink raft surveys. Per-survey detection probabilities ($P_{\text{walking}} = 0.72$, $P_{\text{raft}} = 0.39$) are estimates from the model holding occupancy constant and allowing variable detection probability between methods.

Substrate also was an influential detection covariate based on the single-season model for 2008 (Table 2). Detection probability was related positively to the cover of sand and mud on stream banks ($\beta = 0.0174$, SE = 0.0059).

Water depth at most sites was greater in 2008 than in 2007 (Fig. 3A). Based on the multi-season occupancy model that included 3 detection covariates (observer, rainfall, Julian date), the initial probability of site occupancy in 2007 was 0.439 (SE = 0.067), probability of site colonization between years was 0.876 (SE = 0.050), probability of local extinction was 0.012 (SE = 0.032), and the derived estimate of site occupancy for 2008 was 0.926 (SE = 0.032). Site occupancy more than doubled from 2007 to 2008. The most supported model included water depth in 2007 as a covariate for occupancy and water depth in 2008 as a covariate for colonization (Table 3). Sites with deeper water were more likely to be occupied ($\beta = 2.89$, SE = 2.37) and colonized

Table 1. Ranking of models to compare detection rates between 2 survey methods for American mink (walking surveys and mink rafts) in Illinois, 2008. Occupancy (ψ) was held constant in all models. Per-survey detection probability (P) was constant (.), differed between walking surveys and mink raft surveys (methods), or differed between the 2 surveys by mink rafts (raft). K = no. estimable parameters, L = likelihood of model, AIC = Akaike's Information Criteria, ΔAIC = AIC$_i$ − minimum AIC, and w_i are Akaike weights.

Model	K	-2Log (L)	ΔAIC	w_i
ψ(.), P(methods, raft)	4	360.31	0.00	0.63
ψ(.), P(methods)	3	363.37	1.06	0.37
ψ(.), P(.)	2	386.00	21.69	0.00

Table 2. Evaluation of covariates for per-survey detection probability (P) for American mink from walking surveys at 90 sites in Illinois. Multi-season models for 2007–2008 included [$\psi(.)$, $\gamma(.)$, $\varepsilon(.)$] where ψ = occupancy, γ = colonization, and ε = extinction. Single-season models were for 2008 only and included $\psi(.)$. Observer was the person recording occupancy based on sign. Rain was rainfall (cm) during 7 days prior to the survey. Julian was Julian date of the survey. Substrate was recorded only in 2008 and measured the percentage of bank suitable for collecting mink tracks. For each model type, a 95% confidence set is presented plus the constant detection model. K = no. estimable parameters, L = likelihood of model, AIC = Akaike's Information Criteria, ΔAIC = AIC$_i$ – minimum AIC, and w_i are Akaike weights.

Model	K	-2Log (L)	ΔAIC	w_i
Multi-season$_{2007–2008}$				
P(observer, rain)	9	454.53	0	0.32
P(observer, rain, Julian)	10	452.81	0.28	0.28
P(observer, Julian)	9	455.25	0.72	0.22
P(observer)	8	457.69	1.16	0.18
P(.)	4	485.56	21.03	0.00
Single-season$_{2008}$				
P(observer, rain, substrate)	6	237.51	0	0.32
P(observer, substrate)	5	239.55	0.04	0.31
P(observer, rain, Julian, substrate)	7	236.87	1.36	0.16
P(observer, Julian, substrate)	6	239.00	1.49	0.15
P(substrate)	3	248.77	5.27	0.02
P(.)	2	262.37	16.86	0.00

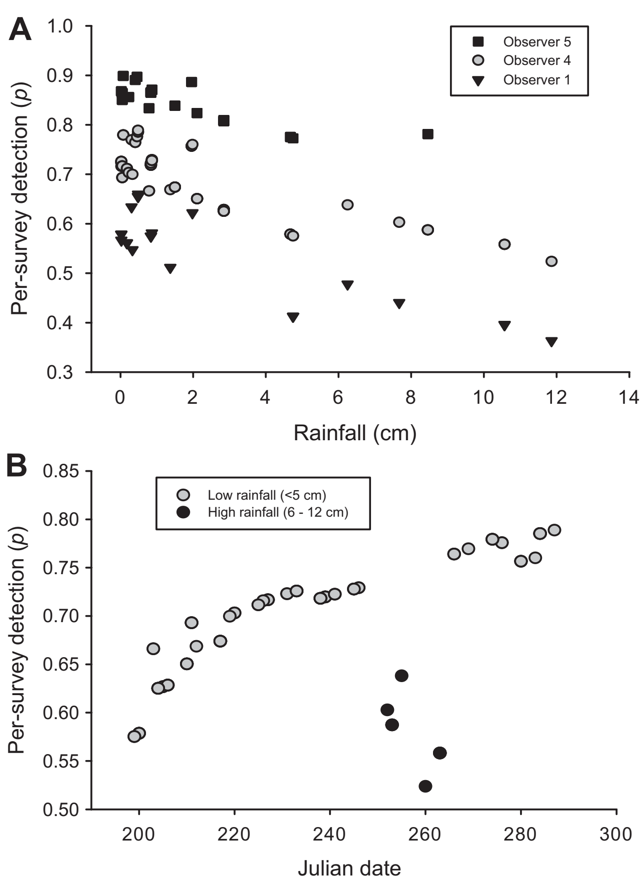

Figure 2. Effects of covariates on detection probabilities for walking surveys for American mink in Illinois, 2008. Values are estimates for individual sites based on the multi-season model holding occupancy, colonization, and extinction constant and allowing for variable detection related to observer, rainfall, and Julian date. (A) Effects of observer and rainfall on detection. Rainfall was summed for 7 days prior to the survey date. Symbols are overlapping because multiple surveys were conducted by the same observer on the same day with identical summed rainfall. (B) Effect of Julian date on detection. Data are for observer 4.

(β = 13.02, SE = 8.37; Fig. 3B). A competitive model included only water depth in 2007 as a covariate for occupancy but had a poorer fit (Table 3). We did not evaluate covariates for local extinction because few sites changed from occupied to unoccupied between years.

DISCUSSION

Comparison of Survey Methods

Per-survey detection of American mink was greater for walking surveys than for mink rafts in riparian habitat in Illinois. Our results contradict those from previous studies in the United Kingdom in which patterns for raw detection rates and unique detections indicated greater detection probabilities for mink rafts than for walking surveys (Reynolds et al. 2004, Harrington et al. 2008). What factors could cause these differences between studies? We used rafts similar to those designed by researchers in the United Kingdom (Reynolds et al. 2004), and all studies used 2-week check intervals. We combined data from 2 rafts per site, which should favor mink rafts in our study relative to Harrington et al. (2008) who employed only 1 raft per site. Harrington et al. (2008) only used scats to indicate mink presences in their walking surveys, however, which could explain their lower detection rates for walking surveys. We detected mink tracks much more often than scats while conducting walking surveys (see also Bonesi and Macdonald 2004). Differences in environmental conditions among studies also might have contributed to the dissimilar outcomes. Our study sites were small streams and agricultural ditches, whereas study sites in the United Kingdom were larger streams and rivers (Reynolds et al. 2004, Harrington et al. 2008). Natural substrates suitable for collecting identifiable mink tracks could have been more abundant in our area.

Detection rates for mink rafts in our study were less than those reported in the United Kingdom (Reynolds et al. 2004, 2010). We speculate that this result could reflect greater densities of American mink in the United Kingdom where

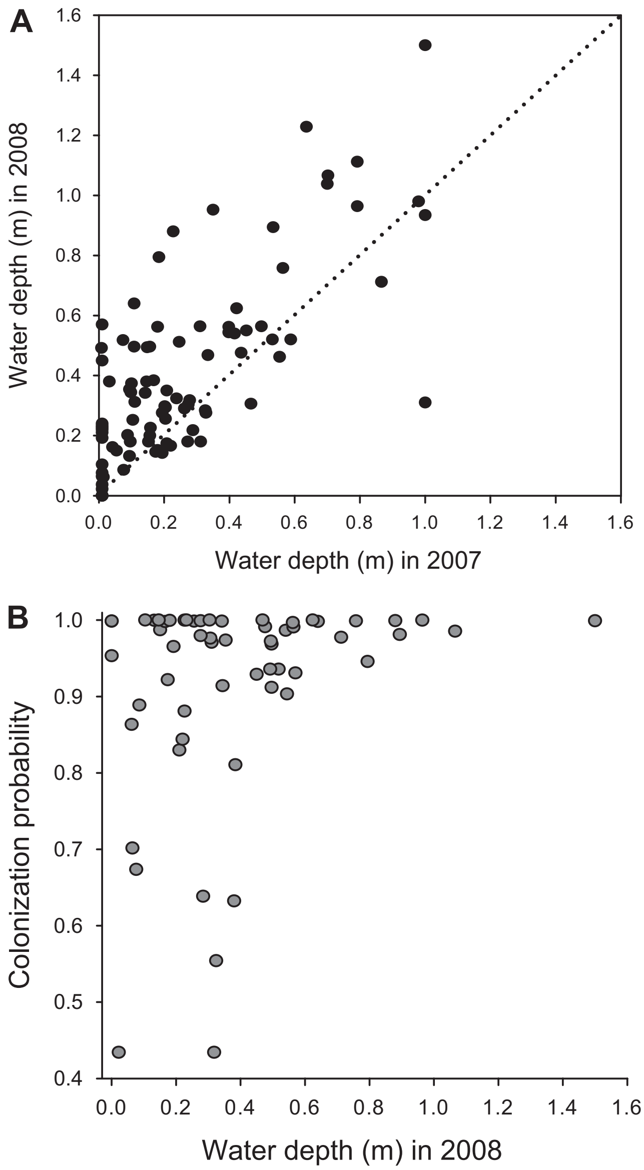

Figure 3. (A) Changes in maximum water depth between 2007 and 2008 at 90 stream sites in Illinois where we conducted occupancy surveys for American mink. (B) Relationship between the probability that a site was colonized by American mink in 2008 and water depth that year. Colonization probabilities are based on the top-ranked model including water depth in 2007 as a covariate for occupancy, water depth in 2008 as a covariate for colonization, constant extinction, and detection related to observer, rainfall, and Julian date.

it is an invasive species supported by naïve prey (Bonesi and Palazon 2007, Harrington et al. 2008). Capture rates from livetrapping in the United Kingdom (51 individuals in 4,336 trap-nights = 1.18%; Yamaguchi and Macdonald 2003) and in our study area (26 individuals in 3,497 trap-nights = 0.74%; A. Ahlers, University of Illinois, unpublished data) also suggest greater densities of American mink in the United Kingdom than at our sites.

Logistical and financial considerations also favor walking surveys over mink rafts in our region. Mink rafts were developed for streams and rivers with fairly constant water levels, and rafts might not be appropriate for riparian systems with variable water depths and high sensitivity to rainfall events (Reynolds et al. 2004). Indeed, we not only lost rafts during flooding events, we often had to visit rafts between the scheduled 2-week checks to verify rafts were in place and functioning properly. Although a comprehensive cost analysis was beyond our scope, our experience indicated walking surveys cost less when compared with mink raft surveys. Walking surveys required that 2 technicians visit a site only once to conduct 2 surveys, which took a total of approximately 30 min to complete. In contrast, 2 surveys with mink rafts required an initial visit by 2 technicians to deploy 2 rafts that took roughly 30 min (roadside access often was limited), at least 1 visit by 1 technician to check rafts after 2 weeks, and a final visit by 2 technicians to check and retrieve rafts after 4 weeks. Mink rafts not only required more labor in the field, rafts had to be constructed and materials cost approximately \$25 US per raft.

We identified several factors that can affect detection probabilities when surveying for mink using walking surveys, including issues that prompted the initial development of the mink raft (Reynolds et al. 2004, 2010). Observer bias was evident in both years of our walking surveys despite what we considered to be adequate training and supervision of observers. Individuals likely differ in innate abilities to locate and recognize field sign, especially sparse tracks (Evans et al. 2009), and individuals might differ in motivation to search for sign along heavily vegetated streambanks. The potential effects of observer bias (false absences and false positives) in occupancy modeling are receiving increased attention (Fitzpatrick et al. 2009, McClintock et al. 2010, Jeffress et al. 2011). We also detected a negative effect of recent rainfall on detection probabilities for walking surveys, even though we avoided conducting surveys within 2 days of a substantial rain event (>1 cm). Rainfall likely increased water levels of streams enough to hide scats and substrates

Table 3. Effects of water depths of streams on occupancy dynamics of American mink in Illinois, 2007–2008. Rankings are for multi-season models that included occupancy (ψ), colonization (γ), and local extinction (ε). We recorded water depths in 2007 (depth07) and 2008 (depth08). Per-survey detection probability (P) included 3 covariates: observer, cumulative rainfall for previous 7 days, and Julian date. K = no. estimable parameters, L = likelihood of model, AIC = Akaike's Information Criteria, ΔAIC = AIC$_i$ − minimum AIC, and w_i are Akaike weights.

Model	K	−2Log (L)	ΔAIC	w_i
ψ(depth07), γ(depth08), ε(.), P(observer, rain, Julian)	12	443.86	0	0.50
ψ(depth07), γ(.), ε(.), P(observer, rain, Julian)	11	446.87	1.01	0.30
ψ(.), γ(depth08), ε(.), P(observer, rain, Julian)	11	448.28	2.42	0.15
ψ(.), γ(.), ε(.), P(observer, rain, Julian)	10	452.81	4.95	0.04

that hold mink tracks or remove sign existing at the time of the rain event, which otherwise might have been counted. Substrate also affected detectability of mink in 2008; we found a positive relationship between detection and abundance of sand bars and mud flats (see also Bonesi and Macdonald 2004). Mud substrates also increase detectability of river otters relative to other substrates (Jeffress et al. 2011).

In contrast, mink rafts standardize the substrate available for collecting mink tracks and greatly reduce the potential for observer bias. Variation in search effort among observers is removed because each observer must simply check the tracking cartridge for mink tracks. Moreover, if there is uncertainty by an observer about particular tracks, species identity can be verified by showing the tracks to the project coordinator by switching out the tracking cartridge.

Occupancy Dynamics and Water Depth

Our region received substantially more precipitation during 2008 compared to 2007, which affected water levels of streams. Mink evidently responded to this environmental variation and were more widely distributed in 2008 (93% occupancy) than in 2007 (44% occupancy). We cannot rule out an increase in density of mink between years as a possible driver of the greater occupancy in 2008. A more likely explanation, however, is that habitat use by individuals expanded under the more favorable conditions. That is, more sites in 2008 were suitable for hunting aquatic prey because of adequate water levels. The probability of a vacant site being colonized between years was variable if 2008 water depths were $\leq$0.4 m, but consistently high if water depths were $>$0.4 m (Fig. 3B). This strong tracking of water levels by mink suggests the species could be sensitive to hydrologic shifts resulting from climate change (Risley et al. 2011), urbanization, or agricultural practices. Future modeling of site occupancy by riparian mink in its native range should determine the relative impact of water depths and flow regime, stream vegetation (Yamaguchi et al. 2003), and landscape context including the degree of urbanization (Melero et al. 2008).

MANAGEMENT IMPLICATIONS

In general, we recommend walking surveys for determining the spatial distribution of American mink in riparian habitat associated with small streams with variable water levels. Walking surveys are easier, cheaper, and have greater per-survey detection rates when compared to mink rafts. However, walking surveys are most beneficial only if multiple surveys of each site are conducted within a season so that occupancy modeling (MacKenzie et al. 2006) can be used to adjust for observer and environmental effects on detectability. Such an approach enabled us to detect dynamic patterns of habitat use by mink in relation to stream water levels. Mink rafts have distinct advantages over walking surveys including standardizing substrate for tracks and effort among observers. For studies using many volunteers including citizen scientists (e.g., Bryce et al. 2011), or those conducted in riparian systems lacking adequate natural tracking substrates, we recommend use of mink rafts for determining site occupancy by American mink.

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