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**Appendix S1. Accounting for bias in estimates of survival.**

One of the fundamental assumptions underlying capture-recapture methods is that marks are not lost, overlooked, or misidentified (Williams, Nichols, & Conroy, 2002). This assumption can be violated, however, when photographic data are used to identify and “recapture” individuals. If false rejection errors occur (here, failing to recognize that two partial spot maps are from the same frog), the number of encounter histories will exceed the number of individuals observed, which will bias estimates of survival negatively (Morrison, Yoshizaki, Nichols, & Bolger, 2011). Although false acceptance errors might occur (here, incorrectly assuming features were from the same frog when in fact, they were part of spot patterns from two different frogs), these types of errors tend to be rare (Morrison et al., 2011; ERZ, *unpublished data*), therefore we did not account explicitly for this potential source of bias.

**METHODS**

We identified three strategies to address potential bias associated with false rejection errors. First, we could assume false rejection errors occurred rarely and elect not to account for such errors (i.e., use all encounter histories, based on all survey occasions and photosets). Although a tenuous assumption, most capture-recapture studies that rely on photographic data have adopted this strategy, ignoring the potential for bias (but see Hiby et al., 2013; McClintock, Conn, Alonso, & Crooks, 2013; Morrison et al., 2011). Second, we could restrict analyses to only those encounter histories associated with individuals whose spot patterns were mapped completely (i.e., features mapped over all three body regions). Although this strategy might reduce or even eliminate identification errors, sample sizes would be reduced and estimates of survival could nevertheless be biased if the individuals associated with those encounter histories were not representative of the larger population. Third, we could censor the initial observation of all individuals and partial spot maps, thereby excluding capture histories associated with individuals or partial spot maps that were observed only once. This approach was developed by Morrison et al. (2011) to address false rejection errors resulting from low-quality photographic images and was based on the assumption that low-quality images are likely to result in superfluous histories, each with a single encounter. When false rejection errors result from incomplete information rather than poor image quality, as in our study, censoring initial encounters may reduce but not eliminate this potential bias, as partial spot maps could be encountered more than once and retained in analyses. Lastly, we considered whether methods developed recently for “bilateral” data (Corkrey et al., 2008; Hiby et al., 2013; Link, Yoshizaki, Bailey, & Pollock, 2010; McClintock et al., 2013; Wilson, Hammond, & Thompson, 1999) could be extended to photographic studies where identification was based on patterns or markings on three regions of the body (dorsum, left flank, right flank). We determined that for our study, with three body regions and >240 survey occasions, model likelihoods would be prohibitively complex, therefore we did not pursue this alternative.

To compare how methods to account for bias could affect parameter estimates, we implemented each of the three strategies detailed above to estimate survival of post-metamorphic leopard frogs. Specifically, we created three sets of encounter histories: 1) histories for all individuals and partial spot maps that included all observations (uncensored), 2) histories for only those individuals whose spot patterns were mapped completely, including all observations of each individual (uncensored), and 3) histories for all individuals and partial spot maps, excluding the initial observation (censored; Table S1). For each set of encounter histories, we estimated apparent monthly survival with an intercept-only model (i.e., constant survival and recapture probability) and a model that allowed survival to vary with surface-water availability, temperature, dew point, and perimeter groundcover and allowed recapture probability to vary with surface-water availability, temperature, humidity, wind, perimeter groundcover, and year (see Methods section for description of covariates).

**RESULTS AND DISCUSSION**

As expected, estimates of survival based on censored encounter histories were slightly higher and less precise than estimates based on uncensored encounter histories of all individuals and partial spot maps (Table S1). Estimates based on censored histories were also 4% lower than estimates based on only those individuals whose spot patterns were mapped completely. Methods used to account for bias did not seem to affect inferences about the factors governing variation in survival over space and time, as regression coefficients from analyses that used censored encounter histories were similar to regression coefficients from both analyses that used uncensored encounter histories (Table S1).

Although our use of in-situ photographs introduced the possibility of identification errors, we viewed these costs as reasonable given that non-invasive methods allowed us to survey frogs multiple times per year, providing valuable insights about the factors that govern seasonal variation in survival of lowland leopard frogs. Among the strategies that could be used to account for these errors, censoring methods reduced potential sources of bias while incurring minimal costs associated with precision of parameter estimates. Although surely imperfect, this approach seemed preferable to those that ignored known sources of bias or used only a subset of individuals that may not have been representative of the larger population.

**LITERATURE CITED**

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**Table S1.** Parameter estimates (and 95% confidence intervals) from models evaluating post-metamorphic survival of lowland leopard frogs based on three sets of encounter histories: 1) all individuals and partial spot maps, uncensored; 2) only those individuals with spot patterns that were mapped completely, uncensored; and 3) all individuals and partial spot maps, with the initial observation of each spot map censored. We report estimates of monthly apparent survival, , and associated coefficients of variation (CV) from an intercept-only model, and regression coefficients (β) relating monthly apparent survival to surface-water availability (Water), temperature, dew point, and perimeter groundcover on the logit-scale from a more general model. All covariates were standardized relative to their means and standard deviations.

|  |  |  |  |
| --- | --- | --- | --- |
|  | All individuals and partial spot maps, uncensored | Only individuals with spot patterns mapped completely, uncensored | All individuals and partial spot maps,  censored |
| No. encounter histories | 352 | 215 | 205 |
|  | 0.81 (0.79, 0.83) | 0.86 (0.84, 0.88) | 0.82 (0.80, 0.85) |
| CV() | 1.4% | 1.2% | 1.6% |
| β.Water | 0.17 (–0.17, 0.51) | 0.28 (–0.15, 0.70) | 0.19 (–0.25, 0.63) |
| β.Water2 | –0.31 (–0.53, –0.10) | –0.28 (–0.53, –0.03) | –0.36 (–0.63, –0.10) |
| β.Temperature | 0.33 (–0.05, 0.70) | 0.42 (–0.02, 0.86) | 0.58 (0.06, 1.11) |
| β.Dew point | –0.38 (–0.78, 0.01) | –0.49 (–0.95, –0.03) | –0.69 (–1.24, –0.14) |
| β.Groundcover | 0.01 (–0.13, 0.15) | 0.09 (–0.07, 0.26) | –0.05 (–0.23, 0.13) |