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Letter to the editor

The trap of hidden processes: Why 'quick & dirty' methods to estimate mortality are not always good. A comment to De Pascalis et al. (2020)

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Live and dead encounters of animals in natural populations represent only a glimpse of the survival and mortality processes because not all individuals alive are seen and not all corpses can be found. Capture-Mark-Recapture and -Recovery models (CMRR) have been developed to provide an analytical framework to estimate mortality accounting for detection and recovery failures (Williams et al., 2002). CMRR models can be difficult to build and many conservation biologists are tempted to shortcut them for simpler, 'quick & dirty', methods, trading difficulty with the lack of precision. In some particular cases, it is a winning trade, however, in most cases, it is a very hazardous practice. De Pascalis et al. (2020) provided an analysis of the observed mortality patterns in six species of raptors using a CMRR dataset spanning more than a century. Bird mortality was estimated as a binomial proportion from last-seen observations, coded "1" for dead an "0" for alive. Animals seen only at marking were discarded. They concluded that mortality decreased over time and that mortality causes have shifted from those related to human persecution to those related to collisions with artificial infrastructures. The results are sound and confirmed previous approaches with data from rescue centres (Martínez-Abraín et al., 2009). Conditional analyses, like the one used by De Pascalis et al. (2020), however, have the risk to overlook important hidden processes. The proportion of animal seen alive *vs* those seen dead depends, by definition, on the detection probability, p, that an animal alive is detected and on the probability, λ, that a dead animal is found or retrieved (c) and the tag reported (r), with $\lambda = c^*r$ (Williams et al., 2002). In CMRR, p and λ relate the observations to the latent mortality processes governed by the survival probability, S. The estimate of mortality during a given time interval based only on observations makes the implicit assumption that $p = \lambda = 1$ (Catchpole et al., 2004). However, this assumption is in most cases unrealistic. The danger of a conditional approach when p and λ are different from 1 can be illustrated through simulations. We consider a hypothetical CMRR study of 15 occasions in which 50 individuals are released at the beginning of each time interval. The first set of data has been simulated assuming constant parameters and considering three values for S, p, and λ (S: 0.8, 0.6 and 0.2, p: 0.7, 0.4 and 0.3, λ: 0.2, 0.1 and 0.01, respectively, 27 datasets). A second dataset was built assuming constant survival and recovery probabilities (0.6 and 0.1, respectively), while recapture probability was increasing linearly over time (from 0.1 to 0.8). For each dataset, we estimated mortality using the Burnham's joint capture-recovery model (Williams et al., 2002, hereafter 'CRMM mortality', noted 'μ_{CMRR}', Fig. 1) and the conditional method based on last observations only, as proposed by De Pascalis et al. (2020, hereafter 'conditional mortality', noted 'μ_C'). The conditional mortality, μ_c, changes according to the ratio between recovery and recapture probability (Fig. 1). Specifically, when $p \gg \lambda$ the conditional mortality is low whereas it is large when $p \ll \lambda$. The analysis of the second dataset showed how the conditional mortality abates over time simply due to an increase in the detection probability, unrelated to mortality processes (Fig. 1). Further scenarios can be explored through an R shiny application (Chang et al., 2020) that we provide together with the R-scripts at https://github.com/oliviergimenez/bias_recovery.

Finally, the relative importance of each mortality cause, if estimated directly from recoveries, is also misleading because based on the assumption that λ does not depend on the cause of death. As we recalled above, λ is the product of the probability of finding a corpse *and* the willingness to report the ring. The former clearly depends on the cause of death; a bird dead on a remote area will not be found or reported as likely as a bird electrocuted or hit by a car on a public road (Tavecchia et al., 2012).

Are results from De Pascalis et al. informative? Yes, but not in the way authors claimed to be. The metric used by De Pascalis et al., that authors called mortality but never defined, is not a mortality measure. It is the probability to found *and* report a tag from a dead bird to the one to see/capture and report a marked bird alive. This metric is difficult to interpret and it is influenced by several factors (e.g. use of plastic rings or resighting efforts). Similarly, the spatial distribution of recoveries indicates where dead animals can be detected, ignoring where they cannot be found. The temporal pattern showed by De Pascalis et al. is also consistent with an increase in the detection probability or a decrease in the reporting rate (Fig. 1). Both trends are common in long-term monitoring studies (for recoveries: Frederiksen and Bregnballe, 2000; for recapture: Tavecchia et al., 2005).

The problem of assuming p and λ equal to 1 when they are not, goes beyond the study of mortality pattern (Gimenez et al., 2008) and

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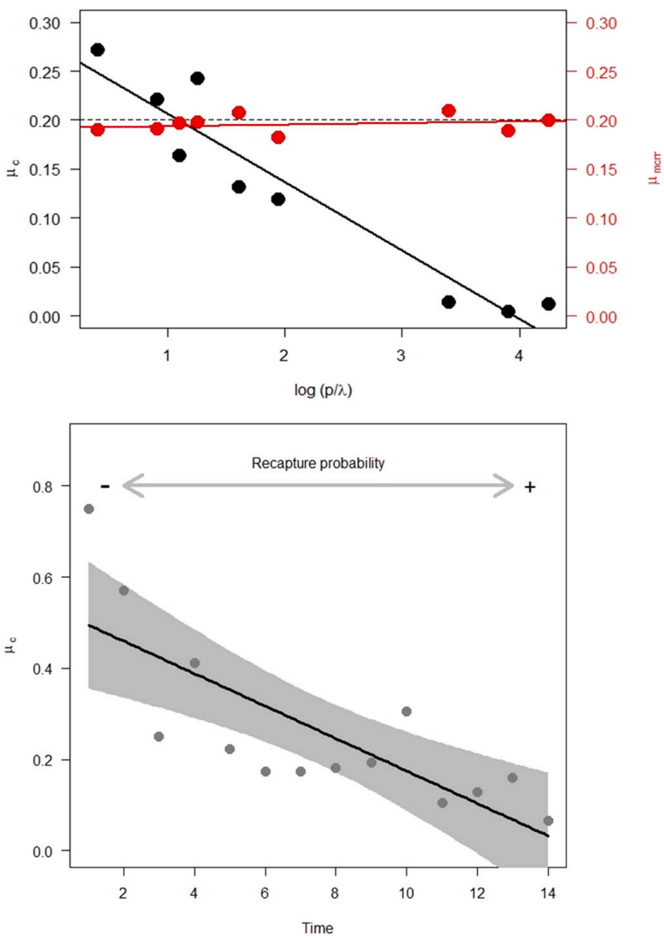

Fig. 1. Mortality measures from simulated datasets (only $\mu = 0.2$ are represented for the sake of simplicity). Top: The conditional measure of mortality, μ_c, changes with the ratio p/λ (log-transformed) while μ_{CMRR} does not. Dashed lines indicate the true value. Bottom: When μ and λ are kept constant, the conditional mortality abates over time if detection probability increases.

certainly, it is not confined to the method used by De Pascalis et al. (2020). Estimating detection and/or recovery probabilities is a central issue in the estimate of almost any demographic parameter of natural populations (Williams et al., 2002; Gimenez et al., 2008; Kellner and Swihart, 2014).

Are conditional approaches always wrong? No. Conditional approaches can be a good alternative to CRMM if used with caution, e.g. when p can be assumed equal or close to 1 or when the ratio p/λ is known (Catchpole et al., 2004). Do hidden processes prevent the analysis of large CMRR datasets? Certainly not. There are many studies of large datasets that account for multiple effects on detection and recovery processes. The analyses are complicated but large datasets offer the unique opportunity to address fine questions that otherwise remained unanswered. Even if appealing, quick & dirty methods are seldom the solution. Raptor mortality might be less than it used to be and mortality causes might have shifted from human-induced to accidental, but the results from the conditional approach used by De Pascalis et al. (2020) might as well tell a different story. We do not claim that conditional approaches are wrong, but they rely on assumptions that should be assessed. Ignoring what we do not see might lead to unreliable results.

Declaration of competing interest

None.

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