**Discussion**

This study brings together many decades of MRR and dissection studies to provide new estimates of mosquito longevity. Due to the assumptions required to analyse the data, our estimates represent lower bounds on lifespan (LBL). Across both the MRR and dissection meta-analyses, the majority of estimated LBLs were less than 10 days, suggesting that relatively few mosquitoes survive to be able to transmit disease. We determined that LBL varies across species and genera with most variance explained by differences at the genus level. The MRR analysis includes experiments with sex-specific data and we estimate that, on average, females outlive males. Pre-release feeding with sugar also lengthens lifespan across all three genera, although this eﬀect is modest. In contrast to some laboratory experiments (Yang et al., 2009; Brady et al., 2013), temperature was not determined to impact lifespan. By fitting a range of survival models to the data in both meta-analyses, we found inconclusive evidence for mosquito senescence, which improved model fit for 8 of 33 species from MRR data, but only 2 out of 25 species from dissection data.

MRR data results in lower bound lifespan estimates for two reasons. First, mosquito dispersal and mortality are indistinguishable, so a high dispersal rate results downwardly biases estimates of longevity. However, we found no significant effect of recapture area with longevity, suggesting that studies tend to use a sufficiently large area to minimise dispersal bias. Second, marking mosquitoes with dye can negatively impact survival (Verhulst, Loonen, and Takken, 2013; Dickens and Brant, 2014), and unfortunately we lacked the information to determine the significance of this effect. We conducted an *in silico* Monte Carlo study to determine how accurately mosquito lifespan can be estimated in an ideal MRR experiment, where mosquitoes do not disperse away from the study area and are not harmed by marking (see SOM). This indicated that the short study durations and small release sizes of most experiments results in high uncertainty in lifespan estimates (Fig. S12), underlining the value of pooling data across studies.

Unlike MRR data which is used to estimate chronological lifespan, dissection data is used to estimate physiological lifespan which is measured in units of the number of gonotrophic cycles a female undergoes (this method can only be applied to females). In this meta-analysis we have used dissection studies that recorded the number of ovariolar dilations of wild-caught females, an approach that dates back to the 1940s (Polovodova, 1948). This method results in lower bound lifespan estimates because most ovarioles have fewer dilations than the true number of gonotrophic cycles (Fox and Brust, 1994; Hugo et al., 2008), an issue that worsens with age (Fox and Brust, 1994). The alternative dissection-based approach of Detinova (Detinova, 1962), based on dichotomous categorisation of female mosquito specimens as ‘parous’ or ‘nulliparous’ relies on fewer assumptions, and is also widely used. However, this method provides less information on the age structure of a population than Polovodova’s. To estimate physiological age from either type of dissection data, it is also necessary to assume that the population is neither growing nor shrinking, and that collected individuals are random samples from the population. To minimise the role of population growth or decline to our estimates, we aggregated capture data across collections occurring at different timepoints for each site. The trapping methods that were used by the constituent studies of our meta-analysis are varied, and the extent to which they have yielded unbiased samples is difficult to determine. There is some evidence that samples under-represent nulliparous females (Gillies and Wilkes, 1965) yet there is also contrasting evidence that these females are over-represented (Clements and Paterson, 1981). To determine the significance of this uncertainty we excluded data with a large deficit of nulliparous individuals and re-ran the analyses to estimate physiological lifespan as presented above. Posterior predictive checks showed that this model fitted the data well across all age classes, suggesting the assumption of random sampling is reasonable (see SOM).

The exchange rate between physiological age and chronological age is the duration of a gonotrophic cycle, which is predominantly estimated by two methods: MRR studies , where marked mosquitoes are recaptured and dissected to determine the number of gonotrophic cycles occurring since release (e.g. Gillies and Wilkes, 1965); and dissections of specimens from laboratory colonies (e.g. Afrane et al., 2005). In our analysis, laboratory studies indicated the longer gonotrophic cycle of the two approaches, which was somewhat surprising given that, in the wild, mosquitoes must additionally locate hosts to blood-feed and aquatic habitats in which to oviposit (Fig. S9). The literature does not however favour one experimental method over another, and so to convert physiological age into chronological age we pooled data from both sources.

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In benign laboratory conditions, mosquitoes are expected to live longer than in wild populations, and laboratory lifespans can thus be considered upper bounds on lifespan. A large cage experiment using *Ae. aegypti* mosquitoesdetermined that females lived 32 days on average (Styer et al., 2007), and a similar study with female *A. stephensi* determined a median lifespan between 31 and 42 days (Dawes et al., 2009). These estimates are several multiples of the modal estimates from either of our analyses but without a gold standard method to measure mosquito lifespan in the field, it is diﬃcult to quantify the gap that exists between field and laboratory populations. The development of additional methods to estimate mosquito age such as ‘Near-Infrared Spectroscopy’ (Mayagaya et al., 2009; Sikulu et al., 2011; Lambert et al., 2018) if they are proven to work in the field, may be of considerable worth here.

In our analysis of the MRR data, we considered the effect of air temperature, sex and pre-release feeding status on lifespan. There is evidence mainly from laboratory studies that temperature modulates mosquito ecology and behaviour (Yang et al., 2009; Brady et al., 2013; Murdock et al., 2012; Beck-Johnson et al., 2013). The locations and times of year when the MRR studies were conducted encompassed a large range of average air temperatures, from approximately 10 oC to 35 oC yet we found no relationship between lifespan and temperature when pooling all series (Fig. S5) or for those individual species with the most data (Fig. S6). It is possible that by considering a raw average of air temperatures across the month and ignoring rainfall (whose historical data is likely less reliable for a given location), we obscured more complex interactions between temperature and lifespan. The observed laboratory relationship between lifespan and temperature, however, may not be as robust in the field if mosquitoes adjust their behaviour in reaction to changes in temperature (for example by seeking shade). As with laboratory studies (Styer et al., 2007; Dawes et al., 2009) our analysis indicates that females outlive male mosquitoes, although the magnitude of this difference is not as large in absolute or percentage terms. Ethical concerns mean it is now more common than historically for MRR experiments to release males opposed to females (Fig. SM2). Since differences in lifespan exist between the sexes, it is possible that other ecological parameters that can be determined by MRRs also differ, highlighting the need for field methods that directly measure these characteristics of wild females. Our estimates of lifespan indicate that mosquitoes sugar-fed prior to release lived longer than unfed individuals (Fig. S4) which may partly explain recent successes of vector control methods reducing access of the insects to sugar or using toxic sugar baits (Müller, Kravchenko, and Schlein, 2008; Müller, Junnila, and Schlein, 2010; Müller et al., 2010a; Müller et al., 2010b; Beier et al., 2012).

It is encouraging that our pooled estimates of lifespan from the MRR (6.0 days) and dissection (5.5 days) analyses are comparable and that there was a positive (although insignificant) correlation between corresponding species-level estimates. Across genera, the greatest discrepancy in estimates was for *Aedes*, with 8.1 days estimated from the MRR studies compared to 3.5 days from the dissection analysis. This was followed by *Culex* (2.9 days from the MRRs versus 4.9 days fromdissection) with the smallest discrepancy for *Anopheles* (6.8 versus 6.4 days). Some of the diﬀerences in estimates between the two approaches are likely due to environmental and genetic diﬀerences between mosquitoes included in this analysis. However, we believe that part of the discrepancy can be explained by the assumptions required to analyse each field method and speculate that diﬀerences in dispersal rate may be responsible. Both *Anopheles* and *Culex* mosquitoes are generally thought to fly farther than *Aedes* [Charles, do you have a reference here?], meaning that the estimates from MRR-based approaches will be most downwardly-biased for these genera. This is supported by our results since the dissection-based estimates (themselves not reliant on assumptions about dispersal) are similar or exceed the MRR estimates for *Anopheles* and *Culex* mosquitoes, but not for *Aedes*.

Our conclusion that mosquito senescence is apparent in only a minority of cases across both experimental approaches contrasts with evidence from some laboratory studies (Styer et al., 2007; Dawes et al., 2009) and field experiments (Harrington et al., 2014). To determine if experimental characteristics were responsible for our inability to detect senescence, we conducted a power analysis of MRR experiments (see SOM). This work indicated that power to detect senescence senescence strongly depends on study length (Fig. S11B) but is insensitive to release size (Fig. S11C). Clements and Patterson (1981) conducted a meta-analysis of MRR and dissection field experiments and determined that mortality increased with age at a rate comparable to the ‘mild’ senescence case population we consider in the power analysis (see SOM). In this case, detecting senescence with a power of 80% required a study length of at least 18 days. Since the median study duration for experiments included in our analysis was 10 days (Table SM2) this could partly explain our failure to detect senescence at the species level. It is possible however that laboratory studies overstate the magnitude of senescence since colony mosquitoes may survive long enough to experience physiological decline not felt in the wild. To our knowledge the MRR study of Harrington et al., (2014) on *Aedes* aegypti in Thailand has been the sole field experiment aiming to detect senescence and further studies are clearly needed.

In this work, we applied modern statistical methods to combine precious field data collected by entomologists past and present to produce lower bound estimates of mosquito lifespan. Although our approach to estimating mosquito lifespan is novel, its importance for disease transmission has long been recognized since even before 1957, when George Macdonald formulated his mathematical model of malaria transmission. Indeed, the recent declines in malaria prevalence in Sub-Saharan Africa were mainly due to interventions (insecticide-treated bednets and indoor residual spraying) that aim to reduce mosquito lifespan (Bhatt et al., 2015). Yet, there is ample evidence that mosquito resistance to pyrethroid insecticides has spread throughout the continent (World Health Organization, 2018) which may erode or reverse recent gains. A direct way to assess the performance of existing vector control methods is to estimate how mosquito lifespan responds to changes in measured resistance. The diﬀerent nature of the assumptions underpinning analysis of MRR and dissection studies means they oﬀer complimentary information on mosquito survival and lacking a gold standard method to estimate this quantity, we foresee continued reliance on these longstanding field entomological methods.

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