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COMMENTARY

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Miniaturization of biologgers is not alleviating the 5% rule

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Abstract

1. The use of biologging technology has increased exponentially over the last decade, allowing us to study animal behaviour at a level of detail not previously possible.
2. It is clear from recent meta-analyses that the attachment of such devices can have negative effects on individual animals, particularly their behaviour and physiology. In recognition of this, a commonly applied rule is to ensure that devices borne by flying animals weigh less than 5% of their body mass. Over time, the continuing miniaturization of devices should facilitate the deployment of devices that are an ever-decreasing fraction of animal mass.
3. Despite these considerations regarding device mass, here we show that there has been no apparent reduction in the relationship between body mass and the mass of logging devices over the last 48 years.
4. Using a meta-analytical approach, we demonstrate that the ongoing miniaturization of animal-borne devices has resulted not in a decrease in the relative device mass borne by animals, but instead has prompted researchers to measure smaller and smaller species.
5. We recommend that researchers better exploit the ongoing miniaturization of devices to reduce the relative mass of the devices borne by animals, and avoid blind adoption of the 5% or any other arbitrary rule when designing research programs.

KEYWORDS
accelerometry, avian, biologging, GPS

1 | INTRODUCTION

The deployment of animal-borne devices has provided the opportunity to understand aspects of animal physiology, ecology and evolution that were not previously possible before the invention of such technology (Wilmers et al., 2015). These miniaturized devices have revealed incredible animal migratory feats (e.g. Bishop et al., 2015; Klaassen, Alerstam, Carlsson, Fox, & Lindström, 2011), demonstrated physiological and aerodynamic energy-saving mechanisms (e.g. Handrich et al., 1997; Portugal et al., 2014; White, Grémillet, Green, Martin, & Butler, 2011), monitored the movements of critically endangered and range-expanding species (e.g. Block et al., 2011; Sims et al., 2008; White, Green, Martin, Butler, & Grémillet, 2013), and sampled environmental parameters in inhospitable locations (Roquet et al., 2017; White et al., 2011). The number of studies published that use biologging technology on vertebrates now encompass many thousands of individuals (e.g. www.movebank.org). Studies utilizing biologging technologies typically apply a general rule that the device must weigh less than 5% of the total body mass of swimming or flying animals (Kenward, 2001), to minimize the impact that the logging device has on behaviour. The exact evidence-based origin of this value is not entirely clear (Barron, Brawn, & Weatherhead, 2010; Gessaman & Nagy, 1988), however, and the "rule" is often broken (see below). Applying a meta-analytical approach, recent studies of birds have shown that externally attached devices can have negative effects on nesting productivity, clutch size, offspring quality, flying ability, energy expenditure and survival rate (Barron et al., 2010; Bodey et al., 2017; White et al., 2013). In addition, the effects of logging devices may be exacerbated in volant and diving animals, where the devices create additional drag and thus increase the energetic costs of transport (White et al., 2013). There are, therefore, considerations to be taken into account when deploying biologging devices, particularly on free-roaming wild animals. Recently, Bodey et al. (2017) used a phylogenetically informed meta-analytical approach to reiterate significant negative effects of logger deployments on a variety of life-history traits in birds. Moreover, the authors demonstrated significant interactions between the effects of logger deployments on different traits, thus suggesting that there may be cumulative effects of logger deployments that will not be apparent in studies focusing on just one trait in isolation (Bodey et al., 2017). Given the conclusive nature of these studies (Barron et al., 2010; Bodey et al., 2017; White et al., 2013), it is clear that the miniaturization of biologgers is a technological step that needs continuing development. Here, we aimed to establish if there was a continuing trend over time for the miniaturization of biologging devices, to ameliorate any of the potential negative consequences of attaching logger devices—and their additional mass—to birds.

2 | MATERIALS AND METHODS

To investigate how loggers have changed in mass over time, particularly with respect to the device mass/animal body mass ratio, we deployed a meta-analytical approach based on a systematic search of the literature. Our goal was not to compile every study that made use of animal-borne devices, but to collect an unbiased sample of studies to quantify the size of devices deployed on birds and examine how this has changed through time. Data for the masses of devices borne by birds were compiled by expanding upon a previous meta-analyses of device impact (White et al., 2013). White et al. (2013) analysed data for 39 studies of 36 species, but their analysis was restricted to studies that quantified at least one effect of device carriage with a direction that could be unambiguously interpreted as detrimental, that provided data for groups with and without devices, and that provided both sample size and an estimate of variance (*SD*, *SEM* or 95% CI). For the present study, we followed the search methodology of White et al. (2013) to identify studies of device impact that reported the mass of the devices that were employed, the first year in which these devices were deployed, and also searched those studies that cite recent meta-analyses of device impact to identify more recent studies that satisfied the same criteria (Barron et al., 2010; White et al., 2013). We identified a total of 132 studies published from 1972 (Boag, 1972; Ramakka, 1972) to 2017 (Snijders et al., 2017), a substantial increase on the 89 studies considered by Barron et al. (2010) and the 39 studies considered by White et al. (2013). The earliest deployments began in 1968 (Johnson & Berner, 1980) and the latest began in 2013 (Blackburn et al., 2016; Chivers, Hatch, & Elliott, 2016). Species names were checked against the taxonomic reference associated with the online tree of life (Hinchliff et al., 2015) using the rotl package (Michonneau, Brown, & Winter, 2016) of R (R Core Team 2016). Where no body mass was specified in a study from which device mass data were extracted, mean body masses were obtained from the CRC Handbook of Avian Body Masses (Dunning, 2007). In total, our database includes 202 records for 102 species (Table S1). Data for device mass, animal mass and relative device mass (= device mass divided by animal mass) were analysed using quantile regression implemented in the quantreg package (Koenker, 2016); data for device mass and animal mass were log transformed for analysis. Quantile regression fits were computed using the Barrodale and Roberts algorithm (Koenker & d'Orey, 1987, 1994). Significance of quantile regression parameter estimates was determined on the basis of 95% confidence intervals calculated based on inversion of a rank test (Koenker, 1994).

3 | RESULTS AND DISCUSSION

Our meta-analysis, using a quantile regression approach to test for temporal trends in the 0.75th and 0.25th quantiles, showed the 0.75th quantile exhibited no trend with deployment year for both device mass (Figure 1a) and body mass (Figure 1b). The 0.25th quantile decreased significantly with deployment year for both device mass (Figure 1a) and body mass (Figure 1b). These patterns in device size and body size combine such that there is no temporal trend in both the 0.75th and 0.25th quantiles of relative device mass (Figure 1c), especially if only deployments occurring after 1990 are considered. It is noteworthy, however, that small animals typically bear relatively heavier devices than large ones (Figure 1d), and the 0.25th and 0.75th quantiles for relative device mass both decrease significantly with deployment year if the relationship between relative device mass and $\log_{10}$(body mass) is accounted for. These relationships are not significant if only those devices deployed since 1990 are considered, however. Thus, we conclude that the miniaturization of animal-borne devices initially resulted in a modest decrease in the relative device mass borne by animals, but over more recent decades, the continuing miniaturization has instead prompted researchers to measure smaller and smaller species. Such an outcome is effectively encouraged by blind adoption of the "5%" rule, or any other rule based on the ratio of device size to body mass, rather than guidelines based on empirical examination of the presence or absence of negative effects of device deployment determined for the species, device size and deployment duration required for a particular study.

Although the negative effects of animal instrumentation have been investigated for decades, meta-analyses suggest that researchers have become no better at reducing these effects with time (Barron et al., 2010; Bodey et al., 2017). Our data provide a possible explanation for this: there has been, at best, only a small reduction in the mean ratio of device mass to body mass over the last 44 years, and the ratio has now been approximately static for

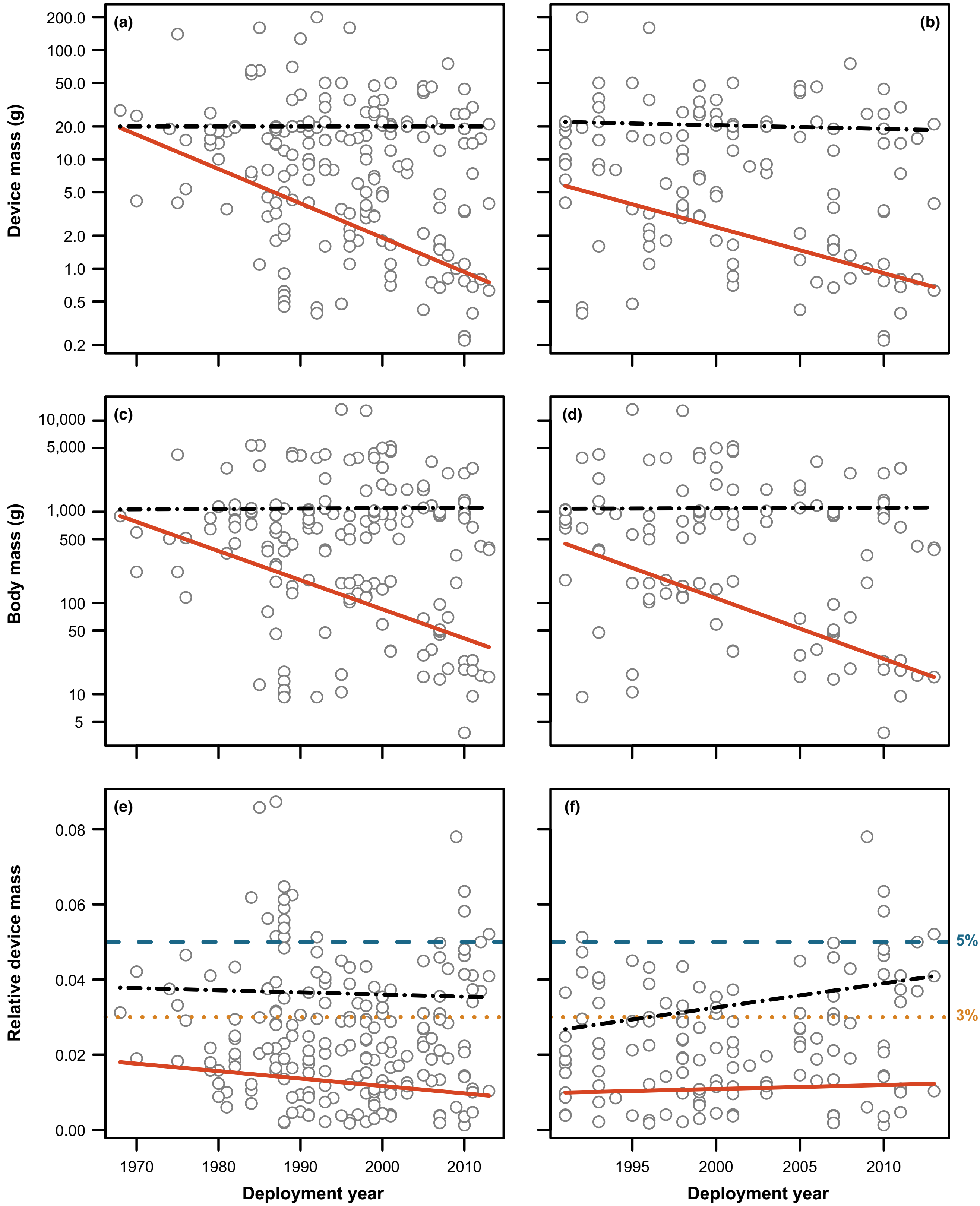

FIGURE 1 Temporal trends in (a) device mass, (b) body mass and (c) relative device mass (= device mass divided by body mass) for birds instrumented with a range of biotelemetry and biologging devices, and (d) the relationship between relative device mass and body mass. The solid lines in (a), (b) and (c) are the 0.75th and 0.25th quantile regressions; the 0.25th quantile regression is significant in both (a) and (b), whereas the 0.75th quantile regressions are not. The *y*-axis is a log scale, but the non-log-transformed values are shown. Both quantile regressions in (c) are not significant. The dashed and dotted lines in (c) correspond with devices weighing 5% and 3% of body mass, respectively, which have been proposed as maximum reasonable device masses, but are regularly exceeded

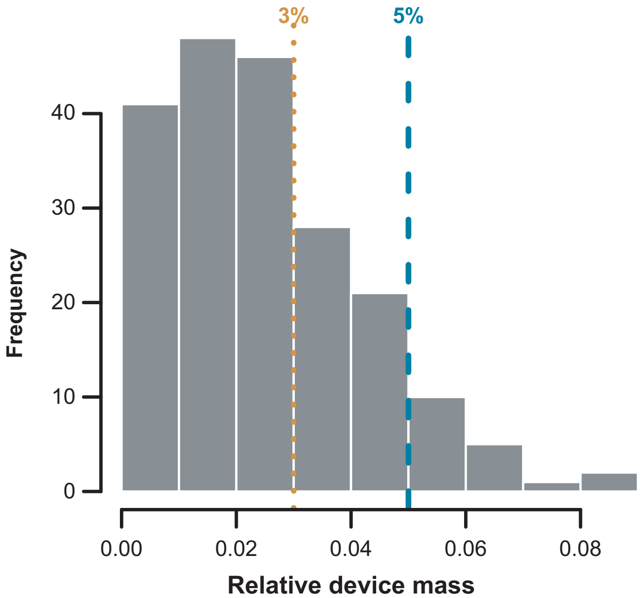

FIGURE 2 Frequency distribution of relative device masses (= device mass divided by body mass) for birds instrumented with a range of biotelemetry and biologging devices. The dashed blue and dotted orange lines correspond with devices weighing 5% and 3% of body mass, respectively, which have been proposed as maximum reasonable device masses, but are regularly exceeded

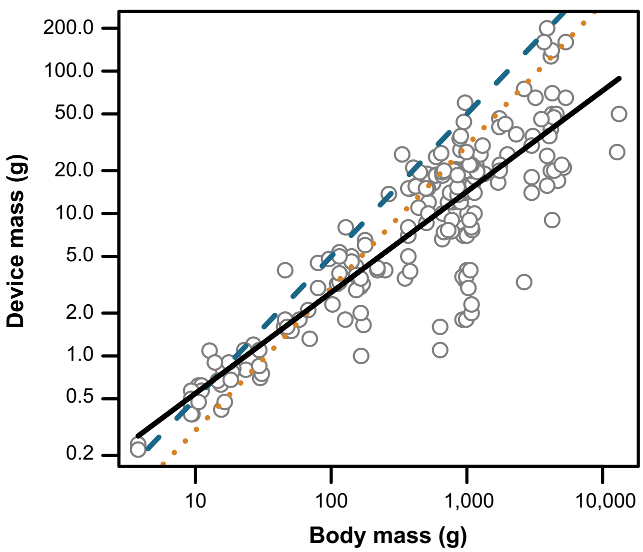

FIGURE 3 The relationship between device mass and body mass for birds instrumented with a range of biotelemetry and biologging devices, shown on a log scale with non-log transformed values plotted. The solid black is the scaling relationship between device mass (*D*) and body mass (*M*), $D = 0.11\ M\ 0.71$. The dashed blue and dotted orange lines correspond with devices weighing 5% and 3% of body mass, respectively, which have been proposed as maximum reasonable device masses, but are regularly exceeded

decades (Figures 2 and 3). Biologging seems likely to become more widespread as device cost continues to decrease and the power of the approach becomes widely appreciated. Furthermore, it is likely that the implications for logger attachment will be greater for long-term deployments on wild birds, as opposed to short-duration (<1 day) deployments on captive animals. Based on these observations, we make two recommendations. (1) As a general principle, we encourage researchers to better exploit the ongoing miniaturization of devices to reduce the relative mass of the devices borne by animals. (2) We suggest that researchers make decisions about the appropriate size of device to be used for a particular species and deployment duration based on the findings of recent meta-analyses of device impact (Barron et al., 2010; Bodey et al., 2017; White et al., 2013) or based on empirical examination of device impact, rather than by strict adoption of the 5% or any other arbitrary rule.

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CONFLICT OF INTERESTS

We have no competing interests.

AUTHORS' CONTRIBUTIONS

Conceptualization, S.J.P. and C.R.W.; formal analysis, C.R.W.; resources, S.J.P. and C.R.W., writing, S.J.P. and C.R.W.

DATA ACCESSIBILITY

All data are available in the manuscript and Supporting Information and are deposited in the Dryad Digital Repository (https://doi.org/10.5061/dryad.jt48n1c) (Portugal & White, 2018).

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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