Research waste in applied ecology and conservation

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"Research waste" is a well established concept in medical research (1). Research is wasted when its outcomes cannot be used for the benefit of society (2). Waste can occur at any of the four stages of research (as defined by 2); question setting; methods; accessibility; and reporting. In recent years there has been an increased focus in ecology on methods (e.g. 3; 4) which have called for methodological improvements in individual studies. Open science is fast becoming mainstream in ecological publishing which is vastly improving accessibility (5). Evidence synthesis approaches such as systematic review and meta-analysis have become stalwarts of ecology and conservation research (6) leading to improved reporting for the benefit of decision-makers. Despite these advances research waste still occurs in ecology and here we focus on a critical area where ecology and conservation can make large steps forward in research waste reduction.

Chalmers & Glasziou (2009) separate what we suggest is part of the same research stage across the reporting and question setting stages. Namely, that new studies do not take in to account the body of evidence that have taken place prior to them (categorised as reporting by 2) and that low priority questions are being asked. A low priority question may be one that is not relevant to stakeholders (and 2 suggest that stakeholders be apart of the research commissioning process). Alternatively a low priority question may be one that has already been sufficeintly addressed in the literature so that any further studies are a waste of resources and should be avoided.

In medicine, one way in which this particular type of research waste has been identified is by looking at cumulative meta-analysis. A cumulative meta-analysis typically describes the accumulation of evidence (e.g., about the effectiveness of an intervention) as the available estimates are added to the analysis in chronological order (7). By carrying out this approach a researcher or funder can show the point at which there is sufficient evidence to be confident that a reported effect is true and thus new trials are no longer required.

As an example of the approach we can look at the potential of autonomous acoustic recorders to replace human observers in wildlife sampling and monitoring, which now has a long history in the ecological literature (starting from at least 8). Technological advances over the last two decades have allowed this potential to be explored fully. Well over 150 field studies have been carried out that address this issue either directly or indirectly and seek to address the question of whether acoustic recorders can replace human observers in wildlife surveys. Darras et al. (2018) explored the pooled effect of these types of studies using a meta-analysis. They concluded that when human observers (using point counts) and sound recorders sample areas of equal size then there is no difference between estimates of bird species richness. Despite this, using their search terms in a Web of Science search identifies another 14 papers that have been published after Darras et al. (2018) was submitted. By using a cumulative meta-analysis we can answer the question "Do we need another study quantifying the difference between acoustic recorders and human observers for bird survey point counts?" In addition, we can show the historical point at which studies into this topic could have been stopped and research waste (in a restricted sense) could have been avoided.

A worked example of cumulative meta-analysis to identify research waste

We extracted the data and R code from 9 to recreate their analysis. Building on their random effects meta-analysis we ran a cumulative meta-analysis using the "cumul" function in the "metafor" package (10) in R. The cumulative meta-analysis was ordered by publication year and plotted using the "forest" function. To assess the point at which there is sufficient evidence and no further investigations are required we plotted the z-curve in relation to the cumulative sample size. The thresholds for significance was a z value of 1.96 or -1.96. When the z curve crosses this threshold then the level of evidence is considered sufficient. This

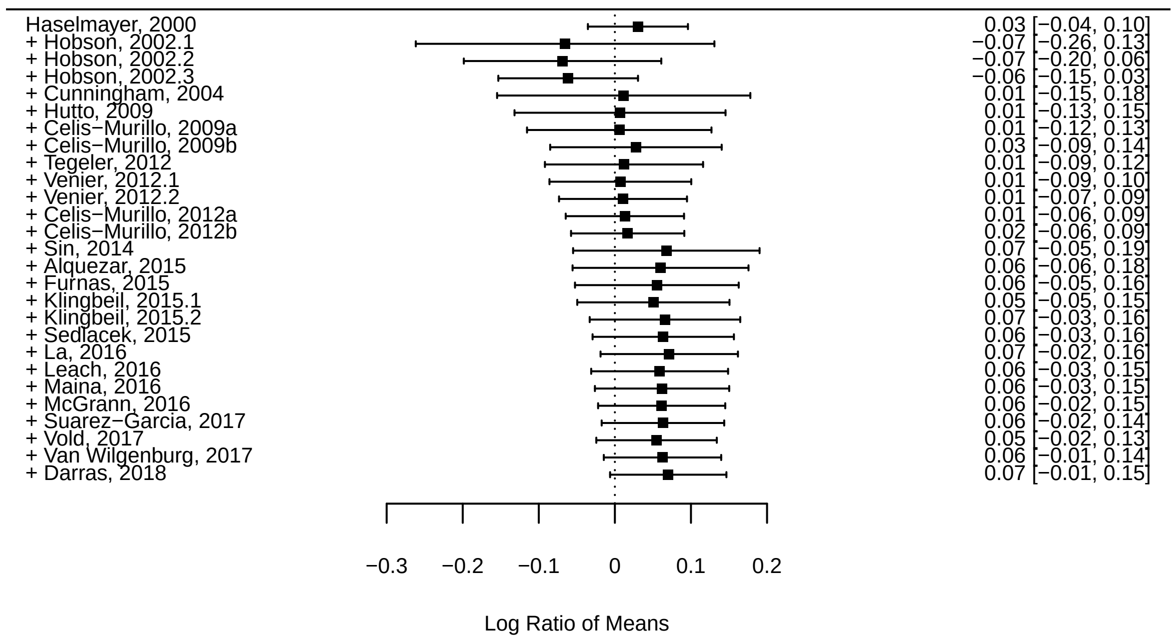

Figure 1: Cumulative forest plot of the meta-analysis of Darras et al. (2018) on the difference between human observers and acoustic recorders in terms of species richness.

approach (known as "trial sequential analysis") is well developed in medicine (wetterslev2008trial). Plots were produced using ggplot2 in R (11).

The effect size of studies investigating the difference between autonomous acoustic recorders and human observers in terms of bird species richness estimates was consistently close to 0 in each study (Figure 1). Trial sequential analysis shows that an evidence threshold was reached in 2015. This suggests that studies undertaken post 2015 were a waste of research resources.

"We need less research, better research, and research done for the right reasons" (Altmann, 1994).

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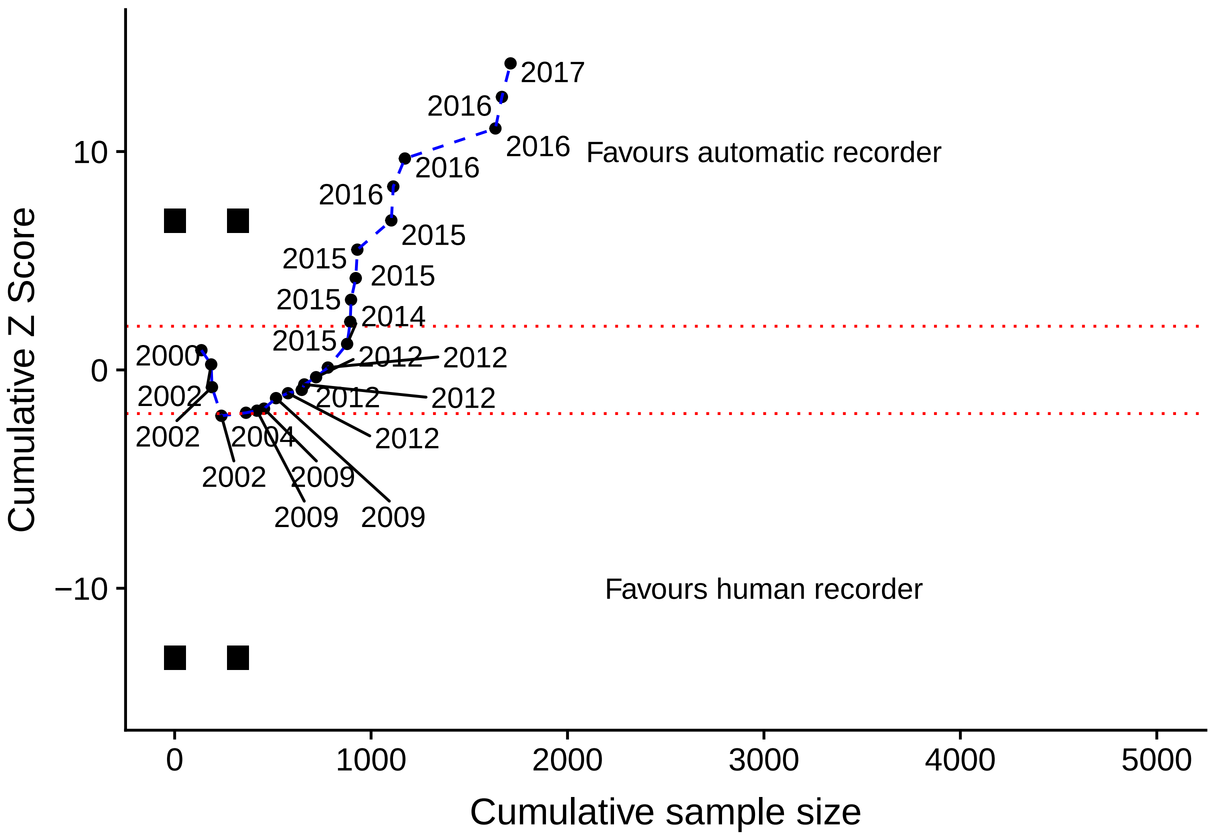

Figure 2: Trial sequential analysis. The red dashed lines indicate the significance threshold (between -1.96 and 1.96). When the z-curve crosses the red line then there is sufficient evidence and no new trials are required.

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