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ORIGINAL ARTICLE

Lowering the cost of citizen science: can we reduce the number of sampling visits in a constant ringing effort-based monitoring program?

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Abstract
Volunteer-based (i.e., citizen science) monitoring schemes constitute a basic piece for the long-term monitoring of bird populations. This work aims to determine whether we can reduce the sampling effort, in terms of number of sampling journeys per yearly campaign, of a long-term breeding bird monitoring ringing scheme in Spain. With that goal, we test to what extent a progressive decreasing number of journeys (from the original effort of seven visits in a season to four visits) will have an impact on indices of adult abundance and/or productivity. Reducing the number of visits did not affect the estimate of abundance of adults, either if we consider a full-period population change index which takes into account the numbers of the last survey year in relation to the first one in the series, or if we consider annual trends (with a yearly index which is referred to a reference value—1—fixed for the first survey year). By contrast, the estimation of productivity was severely affected by a reduction of the sampling effort. We attribute this result to the fact that juveniles were captured late in the season and, therefore, eliminating the last sampling journeys produced biased estimates. It is proposed that the program can reduce the effort from seven to six visits (i.e., one visit per fortnight from May to July) with little impact on the estimation of abundance and productivity. Additionally, the program may admit sites with a sampling effort of four visits, from May to June, useful to estimate trends on abundance of adults and their survival rates (but not on productivity). With this dual option, we expect to increase the spatial coverage of the program and the robustness and representativeness of at least two of the indices calculated through the program, since we might both increase the number of participants (i.e., sites) and the type of habitats covered.

Keywords Citizen science · Conservation status · Monitoring schemes · Passerines

Zusammenfassung
Kostensenkung bei „citizen science“: Kann die Anzahl von Besuchen zur Probenentnahme in einem Beobachtungsprogramm mit konstanter Beringung reduziert werden?
Beobachtungsprogramme mit Hilfe von freiwilligen Amateuren („citizen science “) sind ein wesentlicher Bestandteil der Langzeitbeobachtung von Vogelpopulationen. Ziel unserer Untersuchung war es festzustellen, ob der jährliche Aufwand, also die Anzahl von Fangtagen pro Saison im Rahmen eines langfristigen Beringungsprogramms für Brutvögel in Spanien reduziert werden könnte. Zu diesem Zweck testeten wir, inwieweit eine allmählich abnehmende Anzahl von Fahrten in das Beobachtungsgebiet (von ursprünglich sieben in einer Saison auf vier Besuche) einen Einfluss auf einen (oder beide) Indikatoren für das Vorhandensein adulter Tiere und/oder ihre Produktivität haben würde. Die Verringerung der Anzahl der Besuche hatte keinen Einfluss auf die Schätzung, wie viele adulte Tiere vorhanden waren, weder für die Annahme eines

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globalen Index für die Veränderung der Population über den gesamten Zeitraum, der die Zahlen des letzten Erhebungsjahres im Verhältnis zum ersten Jahr der Reihe berücksichtigt, noch bei der Betrachtung möglicher jährlicher Trends (mit einem jährlichen Index, der sich auf einen für das erste Erhebungsjahr festgelegten Referenzwert -1- bezieht). Aber die Einschätzung der Produktivität wurde durch eine Verringerung des Probenahmeaufwands stark beeinträchtigt. Wir führen dieses Ergebnis darauf zurück, dass die Jungtiere erst spät in der Saison gefangen werden und daher das Weglassen der letzten Stichprobenfahrten zu verzerrten Schätzungen führte. Wir denken, dass in dem Programm der Aufwand von sieben auf sechs Fangtage (d.h. von Mai bis Juli einer alle zwei Wochen) reduziert werden kann, ohne dass sich dies auf die Einschätzung des Vorkommens und der Produktivität auswirkt. Darüber hinaus könnten in das Programm Standorte mit einem Beprobungsaufwand von vier Besuchen von Mai bis Juni aufgenommen werden, die zur Trendberechnung der Abundanz von Altvögeln wie ihrer Überlebensraten nützlich wären, nicht aber für die Produktivität. Mit dieser doppelten Möglichkeit könnte unseres Erachtens die räumliche Abdeckung des Programms sowie die Belastbarkeit und Aussagekraft von mindestens zwei der im Rahmen des Programms errechneten Indikatoren erhöht werden, da wir damit sowohl die Anzahl der Teilnehmer (d. h. der Standorte) als auch die der einbezogenen Habitattypen steigern könnten.

Introduction

Volunteer-based (i.e., citizen science) monitoring schemes constitute a basic piece for the long-term monitoring of bird populations (Greenwood 2007; Jiguet et al. 2012; Knaus et al. 2018; Peach et al. 1996). Constant effort site (CES) bird ringing schemes provide standardized data on individually marked individuals of known age, which therefore allow the estimation of not only annual indices of abundance based on adult captures, but also of productivity and apparent survival (Kampichler and van der Jeugd 2011; Morrison et al. 2021; Peach et al. 1991; Ralph and Dunn 2004; Robinson et al. 2009). CES networks, therefore, play a role for the long-term monitoring of bird populations (mostly involving common passerines), and have great value to disentangle the demographic causes underlying trends (or changes) in population sizes (Baillie and Peach 1992; Peach et al. 1999; Ralph and Dunn 2004).

The implementation of a new CES is always a challenging issue, since ringers must look not only for a set of logistical and ecological aspects (including finding a habitat as stable as possible), but also have in mind that once a site is decided and the station starts to run they should keep a personal commitment to maintain the sampling effort (e.g., in terms of number of sampling visits) as long as they can, since the value of a CES is based on long-term monitoring (Baillie 1990, 2001; Julliard et al. 2004). The amount of sampling effort that every observer would invest annually to keep a CES is, therefore, crucial. The entities coordinating this kind of monitoring programs must find a balance between obtaining the highest statistical power, often associated to higher sampling effort (with either increasing sampling effort per unit of time and/or the number of sampling journeys), and reducing the sampling effort as much as possible (to make the program sustainable for the largest number of volunteers).

When focusing on breeding bird populations, CES schemes must be adjusted to those periods of time when most (ideally, all) captures would be local breeders and their offspring (although the interpretation of 'local' can be somewhat flexible, because productivity indices for instance can include offspring from beyond the immediate site boundary—because of post-fledging dispersal—but are still representative of 'local' productivity of a wider area). This is not easy due to the existence of different phenological patterns, so overall the breeding period in the northern hemisphere spans from late winter to mid-summer (depending on location). At the end, and depending on regions, CES protocols try to select a temporal window covering the 'core' of a breeding season, theoretically adjusted to capture both adults and juveniles. The Aranzadi Ringing Scheme (Spain) launched a common breeding bird monitoring CES-based protocol in 2010 (Arizaga et al. 2013). From experience of other existing CES programs in Spain (e.g., Bermejo 2004), the protocol was set up under the basis of 7 sampling journeys, once per fortnight, starting in May. In this protocol, (1) April was not included due the existence of very strong, active migration in this month (which would then add a lot of transients in the sample) (Tellería et al. 1999); (2) the sampling was extended up to August with the aim of including offspring of late breeding species, especially thinking in those populations which breed in northern Spain, and that may have a delayed breeding season as compared to populations from southern Spain. After a 10 year period, however, some sites show signs of fatigue (due to concerns received from some ringers), and the risk of losing CES is always challenging. That is why a review of the protocol can be positive, especially if we can reduce the sampling effort without losing statistical power (Kampichler and van der Jeugd 2011). Reducing this effort could also reduce the amount of missing visits (though in our case this is not a big problem, with just 2% of the visits missed).

This work aims to determine whether we can reduce the sampling effort, in terms of number of sampling journeys per yearly campaign, of a long-term breeding bird monitoring program of a network of ringing sites based on constant-effort standardized sampling protocol in Spain. Although this question is not new (e.g., Kampichler and van der Jeugd 2011; Peach et al. 1996; Ralph and Dunn 2004), every protocol shows its own particularities, given the amount of CES involved, number of visits previewed, number of habitat types covered, etc., which overall needs from specific evaluations. Beyond CES projects, the analyses run in the present article may be also of interest to other conceptual frameworks where monitoring demographic parameters is needed. For instance, this may be the case of specific studies focused on one or a few target species or on communities linked to specific habitats (Ralph and Dunn 2004). With that goal, we test to what extent a progressive decreasing number of journeys will have an impact on indices of adults abundance and/or productivity. Since juveniles appear later within the season, as compared to adults, it can be predicted that reducing the number of sampling journeys at the end of the season will have a deeper impact into the estimation of productivity, as compared to adults' abundance.

Material and methods

Study area and data collection

Ringing data used in this work come from a data set of ten sampling years obtained from the common breeding bird monitoring program (abbreviated in Spanish as EMAN) of the Aranzadi Ringing Scheme. The EMAN program is based on a CES protocol, where the birds are captured during 7 subsequent sampling journeys, one per fortnight, starting in May (Arizaga et al. 2013). Even though Spain shows a wide reproductive phenological spectrum from a bird perspective, overall it can be admitted that for most passerines the breeding period goes from March to July/August. Within this broad time frame, the resident and migratory pre-Saharan birds start to breed from March/April (some even earlier), while those of trans-Saharan origin would do so in May. Moreover, in March and April (also in May for some trans-Saharan) there is still a relevant migratory passage, with a strong impact on the number of captures at CES. It is for all this that we considered that the Aranzadi CES protocol should start in May. It is true that in southern Spain this protocol should start one month earlier, but the CES stations used in this work were all situated in the northern half of Spain.

Within each site, the nets are open at dawn and kept active during a period of 6 h. Nets remain in the same location within the season and among years, so the sampling effort is constant at each site. Ringers are called to look for places with stable habitats, so that the observed population trends cannot be assigned to local habitat changes.

The analyses run in this work were obtained from a network of 24 sites, mainly distributed in northern Spain (Fig. 1). Birds captured at each CES were identified at the species level, ringed (or the ring was read if the bird had a ring) and aged either as adults (birds in their second-calendar year or older; EURING code 4) or juveniles (birds in their first calendar year; EURING code 3). The age was determined after the examination of plumage, focusing on aspects that vary species-specifically, usually concerning details of the wearing and/or colour patterns of the wing and tail (Svensson 1996).

Statistical analyses

The analyses were focused on the ten most abundant species captured in the EMAN program during the period 2010–2019 (comprising 67.6% of all captures). These have been listed (together with the same main statistics) in Electronic Supplementary Material Annex 1. This was done to ensure a sufficient sample size of both adults and juveniles.

First, we calculated for each species both the full-period population change (index of the difference from 2019 in relation to 2010) and the annual index—trend—of their abundance (for which the captures of adults is considered only) and productivity. We used the 'cesr' package (Robinson 2014), for the software R (R Core Team 2020), designed to estimate abundance, productivity and survival with ringing data from CES programs. This package estimates the abundance and productivity indices considering the standard BTO method (Peach et al. 1996; Robinson et al. 2007). Overall, (1) abundance at each site is calculated as the sum of captures of adults, and (2) productivity is the proportion of captures of young birds over the total catch at each site. This method also takes into account the missing visits, which are taken into account from an analytical perspective. These analyses were repeated after reducing sequentially from the end of the season the number of visits (starting in the last one, i.e. considering visits 1–6, 1–5…) up to a minimum of 4 visits (we considered that a lesser number of visits is too low, and may result in too small sample sizes to for the estimation of other parameters like survival). These analyses were also done considering a reversed scenario (i.e., removing visits starting in the first one: visits 2–7, 3–7…).

After obtaining such indices, we calculated pairwise Pearson regression coefficients (R^2) for the combinations of 7–6, 7–5 and 7–4 visits, both for the change and the annual index for both abundance and productivity. Correlations with an R^2 value equal or higher than 0.8 were interpreted as indicating similar results of the reduced data set as compared to the original sampling effort with 7 visits per season (Cohen 1969).

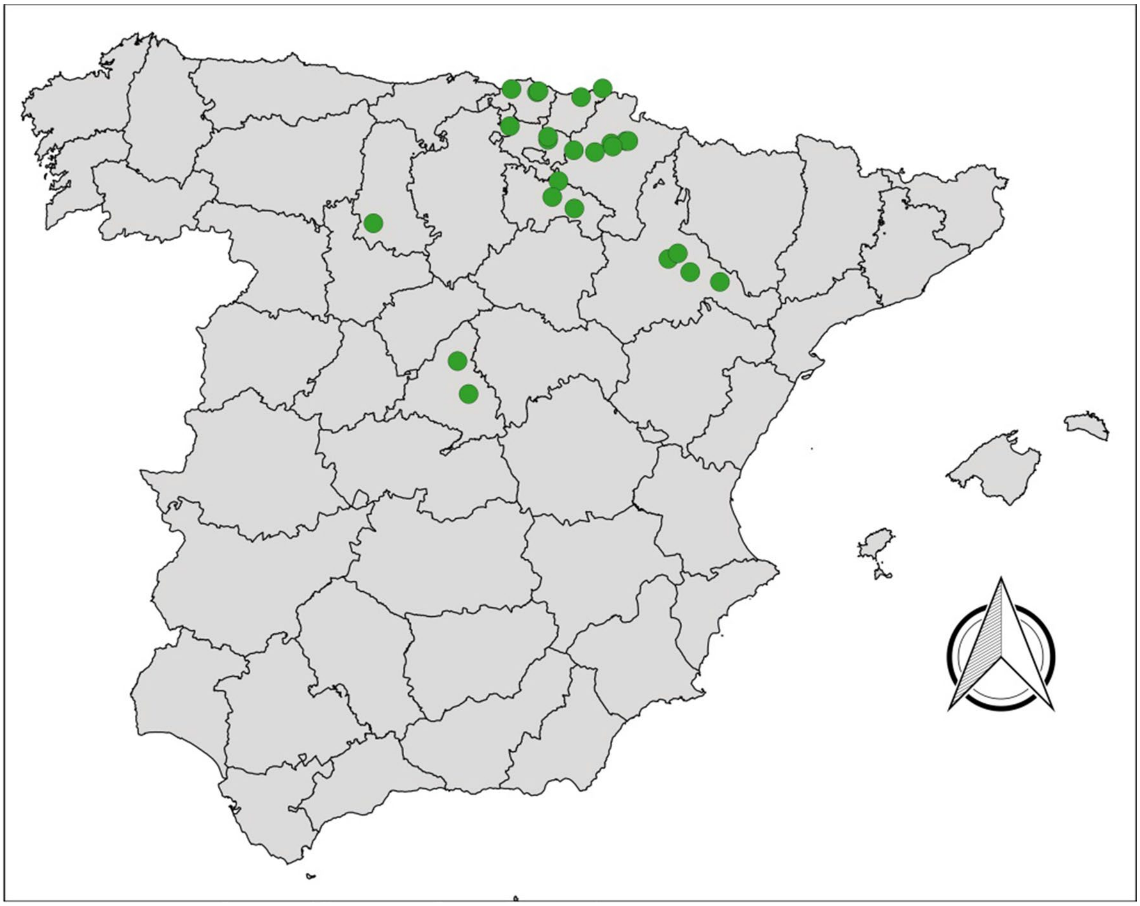

Fig. 1 Geographic distribution of the CES operating for the EMAN program of the Aranzadi Ringing Scheme from 2010 to 2019

Results

Full-period (2010–2019) population change index

Change in abundance of adult birds using the data set considering 7 visits showed a very high correlation with values obtained after reducing the data set to 6 ($R^2 = 0.994$), 5 ($R^2 = 0.990$) or even 4 visits ($R^2 = 0.958$; $P < 0.001$ for all cases) indicating that, overall, a decreasing sampling effort from 7 to 4 visits showed a negligible effect on full-period population change estimations. In a reversed scenario where removals were progressively done from visits 1st to 4th, however, the correlations were much weaker (6 visits: $R^2 = 0.686$, $P = 0.003$; 5 visits: $R^2 = 0.750$, $P = 0.001$; 4 visits: $R^2 = 0.426$, $P = 0.041$).

Regarding productivity, the full-period population change from the data set considering 7 visits showed a weaker correlation with values obtained after reducing the data set to 6 visits ($R^2 = 0.662$, $P = 0.014$), and yet this correlation was worse after reducing the data set to 5 ($R^2 = 0.360$, $P = 0.116$) or 4 visits ($R^2 = 0.536$, $P = 0.040$). In a reversed scenario, however, the correlation was very good for the removals that retained 6 and 5 visits ($R^2 = 0.974$ and 0.969, respectively, $P < 0.001$), but much weaker when we only considered 4 visits ($R^2 = 0.765$, $P = 0.001$).

Annual trends

The mean coefficient of correlation of the annual index of adult abundance considering 7 visits tended to decrease with decreasing number of visits (ANOVA of repeated measures: $F = 3.94$, $P = 0.038$; Fig. 2), though the difference was non-significant after Wilcoxon pairwise comparisons with Bonferroni corrections ($P > 0.05$ for all pairwise comparisons). In the reversed scenario, however, the decrease was also significant even after Wilcoxon pairwise comparisons ($F = 16.16$, $P < 0.001$; Fig. 2; pairwise: 6–5 visits, $P = 0.085$; 6–4 visits, $P = 0.020$; 5–4 visits, $P = 0.020$).

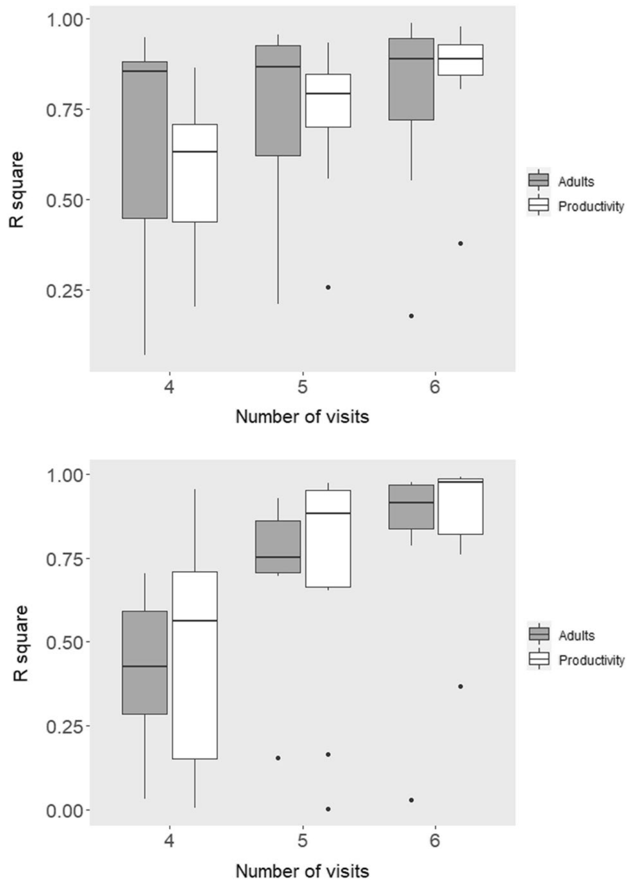

Fig. 2 Mean (±95% CI) correlation R^2 values (sample size = 10 species) obtained after plotting the annual index of adult abundance or productivity (period 2010–2019) of the original set (with 7 sampling journeys in a year) with new data sets where the number of sampling journeys were progressively reduced up to 4 journeys. Above: from-the-end removal; Below: onwards removal

By contrast, the mean coefficient of correlation of the annual productivity index considering 7 visits tended to decrease with decreasing number of visits (ANOVA of repeated measures: $F = 12.26$, $P = 0.008$; Fig. 2); the difference was significant for the 7–6 versus 7–5 ($P = 0.035$) and 7–6 versus 7–4 ($P = 0.035$) comparison, but not for the 7–5 versus 7–4 comparison ($P = 0.128$), indicating that, on average, the annual trends obtained using a data set with 7 or 6 visits did not differ statistically as they were significantly correlated, but differed when such data set was reduced to either 5 or 4 visits (see also for further details Electronic Supplementary Material Annex 2 and 3). In the reversed scenario, the decrease was also significant ($F = 8.30$, $P = 0.002$; Fig. 2), with the Wilcoxon pairwise tests being significant only for the 7–6 versus 7–4 comparison ($P = 0.009$).

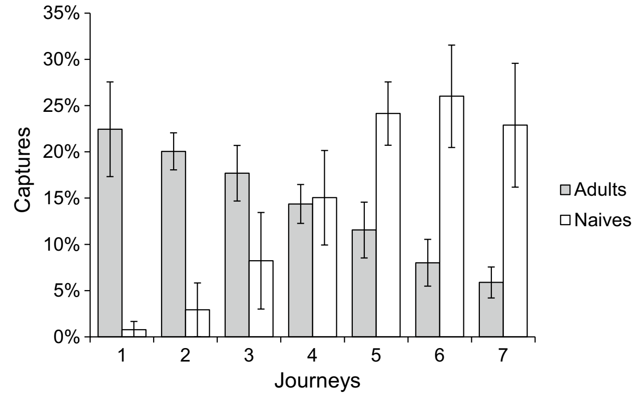

Fig. 3 Percentage of captures (mean ± 95% CI) of adults and juveniles during the 7 journeys (visits) run for the EMAN program (1 = 1–15 May). Data averaged for the ten most abundant passerines captured in all CES for the whole study period

Season variation in proportion between age classes

The percentage of adult and juvenile individuals varied substantially across the season, with a progressive decrease in the percentage of adults (on average 22.5% of captures of adults were caught during the first visit but just 6% during the last one), and a progressive increase of juveniles (on average < 1% of juveniles were caught during the first visit and from 22 to 26% during the visits 5th to 7th) (Fig. 3).

Discussion

The common breeding bird monitoring program of the Aranzadi Ringing Scheme (Spain), based on a constant effort site protocol scheme, originally previewed 7 visits per season to guarantee a reasonably good temporal cover for the whole breeding season, allowing us to capture both adult birds and their offspring. Reducing the number of visits from the original stated effort of 7 visits per season to 4 visits did not affect the estimate of abundance of adults when the removal was done ‘backwards’ (i.e., when we retain visits 1st to 4th), either if we consider a change index which takes into account the numbers of the last survey year in relation to the first one in the series, or if we consider annual trends (with a yearly index which is referred to a reference value—1—fixed for the first survey year). In a reversed scenario, when we remove visits 1st up to 3rd (so we retain visits 4th to 7th), the impact on the results was, however, critical, with correlations with an R^2 value below 0.75. This is expectable given that most adults tend to be captured early within the season. These results suggest, therefore, that we could reduce the sampling effort from 7 to 4 visits (retaining visits 1st to 4th) without losing our capacity to detect the trends that we had with the original sampling effort. For a network of 24 stations, with a 6 h-based sampling effort per day, this would allow us to save 432 h per year, apart from other costs like transport, etc. If we assign a theoretical cost of 100 € per day, this measure would save 4320 € in a year (43,200 € for the 10 year period in which the program was run).

Regarding productivity, however, we observed that reducing the number of sampling visits per season showed dramatic consequences on the estimation of trends when we retain visits 1st to 4th. We attribute this result mainly to the fact that most juveniless were captured late in the season and, therefore, eliminating the last sampling journeys from the data set (especially journeys 5th to 6th) produced biased estimates due to the infra-representation of this fraction of the population when assessing productivity. On average more than 70% of juveniles were caught during the months of July–August (visits 5th to 7th). By contrast, the impact was less dramatic when the removal was carried out 'onwards' (so we retain up to visits 4th to 7th), especially if we only remove visits 1st and 2nd.

Overall, therefore, it is proposed that the program can reduce the effort of sampling from 7 to 6 journeys (i.e., one journey per fortnight from May to July) with little impact on the estimation of abundance and productivity. It is important to note here that CES projects also allow obtaining other measures, such as survival or phenology, in which case losing visits with adult captures would certainly be bad. Adult captures, however, are not affected by the sampling effort decrease proposed in this study, which then presumably has a null or little impact on other parameters such as survival or part of the phenology. Further reductions in sampling effort, however, would have fatal consequences to estimate productivity (with biased estimates due to the loss of many captures of juveniles). Alternatively solutions, such as removing visits 1st or even 1st and 2nd would have little impact to estimate productivity, but would be fatal for all those parameters which consider the captures of adults. From the Program perspective, this may not be desirable. Additionally, it can be proposed that, for those who may not attend a CES with a sampling effort extended up to July, but that may however assume lower effort, the program may admit sites with a sampling effort of 4 journeys, from May to June, useful to estimate trends on abundance of adults and their survival rates. With this dual option, we expect to increase the spatial coverage of the program and the robustness and representativeness of at least two of the indices calculated through the program, since we might both increase the sampling size and the type of habitats covered.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10336-022-02019-7.

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