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FROM PRACTICE

# Stakeholders engagement as an important step for the long-term monitoring of wild ungulate populations

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## Abstract

1. Monitoring trends in animal populations is essential for the development of appropriate wildlife management strategies. However, long-term studies are difficult to maintain mainly due to the lack of continuous funding. In this scenario, the collaboration between local stakeholders and researchers can be a fruitful partnership to monitor game species for long periods and vast territories.
2. We present an experimental framework with the involvement of researchers, local hunters and game managers for the continuous monitoring of wild ungulate populations. By combining vehicle-based counts with distance sampling techniques, we implemented and validated a sampling scheme able to provide demographic information for the effective management of wild ungulate populations. Here, we used an Iberian red deer (*Cervus elaphus*) population as a model.
3. The project implementation involved 30 participants including 24 stakeholders and 6 field technicians/data analysts with experience in monitoring wild ungulates. A total of eight teams covered 29 itineraries, synchronously, in two periods of ecological relevance for red deer, early summer and early autumn. Density estimates were consistent among sampling periods and characterized by acceptable coefficients of variation (approximately 20%). Our results prove that the application of the proposed framework is feasible (three to four itineraries per team), cost- and time-effective (one week per sampling period) and produce population estimates fit for management. Being based on direct observations, the method would provide important demographic indicators (e.g. population density, age structure and fawn recruitment, and group size) about wild ungulate populations.
4. Apart from engaging interested stakeholders, the success of our proposal relies on three key actions including the theoretical and field instruction of participants, the definition of timely and unbiased survey designs and the maintenance of participants' motivation. The implementation of rigorous and standardized sampling protocols is pivotal for data integration through time and space. In the absence of

continuous funding, the voluntary collaboration between entities should be fostered to study and mitigate the potential threats to wild ungulate populations resulting from disease, unregulated hunting and environmental changes.

**KEYWORDS**
Cervidae, distance sampling, Mediterranean ecosystems, Portugal, red deer, wildlife management

## 1 | INTRODUCTION

Monitoring wildlife populations is a key issue for the effective management of natural resources. Ecological information collected systematically over time allows a deeper understanding of the individual responses to ecosystem changes, the wildlife population dynamics and the effectiveness of adaptive management measures aimed at fostering population subsistence or sustainable yield (Krausman & Cain, 2013). The ecological knowledge to answer fundamental and applied questions often relies on long-term datasets whose collection poses substantial logistical challenges and financial constraints. The lack of continuous funding and the limited commitment of government agencies are some of the main obstacles that make long-term studies difficult to maintain (Festa-Bianchet et al., 2017). This is particularly problematic when we consider species with long and complex life cycles, such as the wild ungulates.

Wild ungulates are increasingly abundant throughout the Palearctic realm. The rural exodus, the renaturalization of habitats, the definition of regulated hunting practices and the reintroduction programmes for both conservation and hunting purposes have been suggested as the main causes for the ongoing increase in the number and distribution of wild ungulates (Apollonio et al., 2010; Carvalho et al., 2018). Whether this trend represents an opportunity or a threat is context-dependent and relies on how wild ungulate impacts and damages are perceived by the different stakeholders (Valente et al., 2020a). The upsurge of wild ungulates is often seen as an opportunity to increase the genetic diversity of extant wild populations, foster the recovery of Europe's large carnivores, restore trophic interaction networks and support rural economies due to ecotourism and/or hunting harvest opportunities (Linnell et al., 2020). Conversely, the demographic burgeoning of wild ungulate populations may cause substantial damages to forestry and agriculture, imperil the conservation of endangered species, affect ecosystems processes and functions, and foster the emergence of vector-borne and zoonotic diseases (Gortázar et al., 2007; Ramirez et al., 2020; Valente et al., 2020b). The management of wild ungulate populations is, therefore, a contentious issue that should be set under the umbrella of wildlife conservation, conflicts with human activities, disease, and sustainable harvest management.

Wild ungulate populations are dynamic, affected by environmental conditions through direct and/or indirect mechanisms and subject to harvest and poaching (Owen-Smith, 2010). How biotic and abiotic factors rule the dynamics of wild ungulate populations in Mediterranean ecosystems is far from clear because its study requires well-replicated, but still scarce, datasets that span a sufficiently long-time frame (Imperio et al., 2012). Where funds are insufficient and the human resources are limited, the engagement of local stakeholders, such as hunters, and their collaboration with researchers, is envisaged as a fruitful partnership to monitor game species for long periods and vast territories (Cretois et al., 2020).

Here, we present and validate an experimental strategy with the involvement of local hunters and game managers to implement a replicable framework for the continuous assessment of red deer (*Cervus elaphus*) populations. Among the several techniques available to monitor wild ungulate populations, distance sampling is currently recognized as one of the most robust methods to estimate deer density and abundance (Valente et al., 2016). Despite some advantages (e.g. distance sampling accounts for uncertain detection and allows to model detection probability), distance sampling often requires a significant sampling effort, which may lead to the extension of field surveys over time. This should be avoided as it can be a source of bias in species with a marked phenological behaviour. By harnessing the efforts of local stakeholders, who were instructed to apply the methodology in the field, we aimed to establish and validate a cost- and time-effective framework that provides the baseline information for the effective management of wild ungulate populations.

## 2 | MATERIAL AND METHODS

### 2.1 | Study area

The project was implemented in the *Tejo International* Natural Park, Portugal (TINP; 39°38′–39°53′ N, 7°32′–6°53′ W; 26,490 hectares; Figure 1). To date, no standardized methods have been consistently applied to estimate red deer population size and trends in the TINP, and most studies were focused in particular on hunting grounds (Carvalho, 2013; Santos et al., 2018). The TINP overlaps to approximately 40 hunting areas and is characterized by a typical Mediterranean environment where hunting, disease (e.g. tuberculosis), density dependence and summer-drought have been suggested as the main drivers of population dynamics, individual survival and health (Santos et al., 2018). The red deer harvesting in the hunting grounds is based on limited scientific support. No standardized and systematic surveys have been implemented to date, which limits the adjustment of hunting quotas to population size and structure.

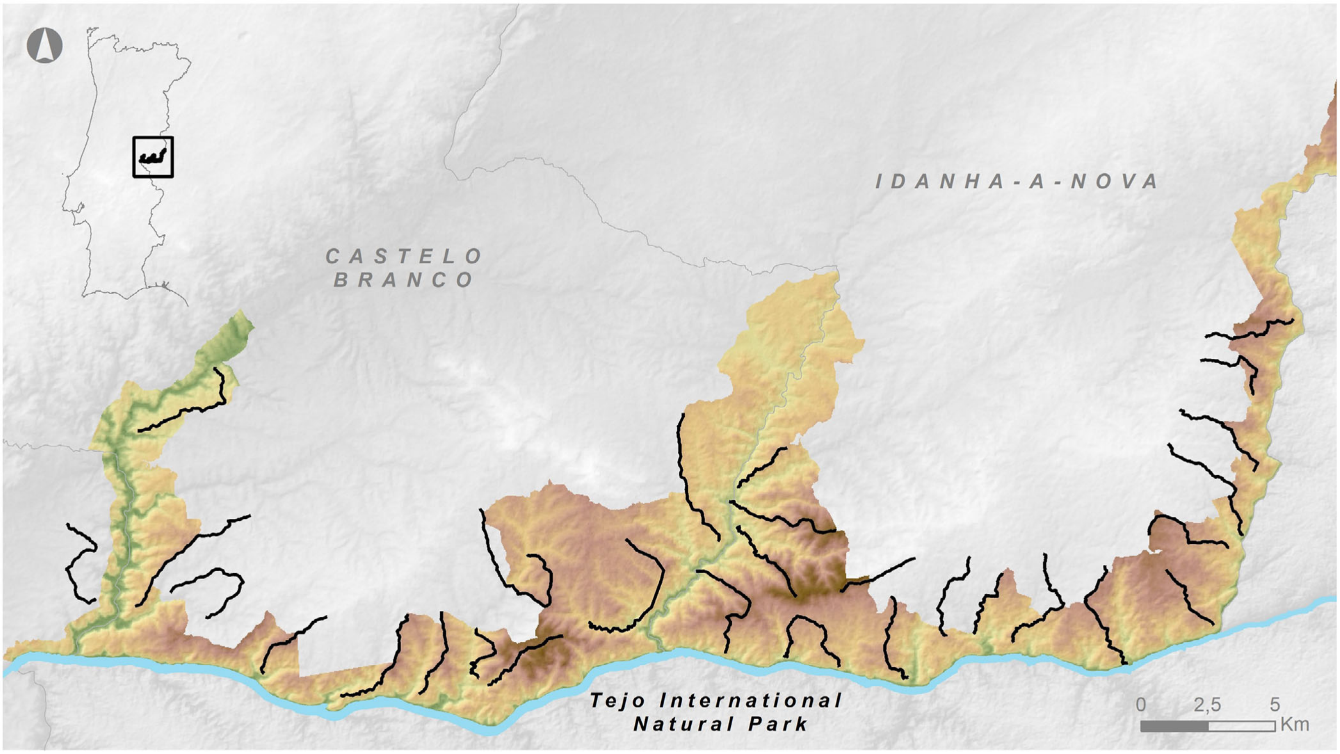


**FIGURE 1** Location of the *Tejo International* Natural Park, Portugal. The sampling design encompassed 29 itineraries (solid black lines) of variable extension evenly distributed throughout the study area

## 2.2 | Fieldwork and data collection

Project implementation followed three main steps. First, we conducted a formative session to instruct the recruited hunters and game managers about the aim of the project and the methodology specificities of distance sampling. We also aimed to assure the commitment of each participant and the logistics of conducting the field surveys. Second, the teams defined in the formative session, each led by a member with a great knowledge about the area that would be prospected, went to the field and surveyed the predefined itineraries in two periods of great relevance for red deer, the early summer and the rut season, in early autumn. Project implementation fieldwork and data analysis were carried out between May and November of 2019.

The project implementation involved 30 participants (24 stakeholders and six field technicians/data analysts with proven experience in monitoring ungulates). The sampling design encompassed 29 itineraries of variable extension (sum = 133.8 km; average = 4.6 km; min. 2.7 km; max. = 7.8 km; Figure 1) that ensured the representativeness of the main habitat types of TINP (e.g. 0.5 km/km$^2$). A total of eight teams covered 29 itineraries, synchronously. Each itinerary was surveyed twice (e.g. two mornings) in early summer (29 itineraries surveyed twice during the first week of July) and in early autumn (29 itineraries surveyed twice during the fourth week of September) by a team of at least two members. The sampling scheme and properties (e.g. number and location of itineraries, number of repetitions per itinerary, number and composition of teams) were kept unchanged for both sampling periods. Using all-terrain vehicles, each team covered the itineraries at low speed (~10 km/h; average duration = 60 min), stopping whenever a red deer group was detected. The observers recorded their position using a handheld GPS, the distance from their position to the red deer group using a range finder, the number of animals observed, the sex and the age category (fawn [0–1 year], young female [1–2 years], adult female [> 2 years], young male [1–3 years], adult male [> 4 years]) of each individual. The habitat type (dense forests, open forests, shrubs, pastures) where the red deer group was detected was also recorded. At the end of each section, the record sheets were stored, the information was compiled and standardized. Fieldwork was carried out by local stakeholders, and the data compilation was performed by local technicians from the Portuguese Institute for Nature Conservation and Forests.

## 2.3 | Data analysis

We combined vehicle-based counts with distance sampling techniques to estimate the density of the red deer population in TINP. We checked all the database records to detect and correct anomalies and inconsistencies. As previously recommended, we right-truncated the data to eliminate 5% of the farthest observations (Marques et al., 2001). We used the software *Distance 7.2* (Thomas et al., 2010) to model the detection functions and estimate the red deer population density for each sampling period. The selection of the most parsimonious model was based on the lowest Akaike's Information Criterion (AIC) value and histograms were inspected to visualize how detection

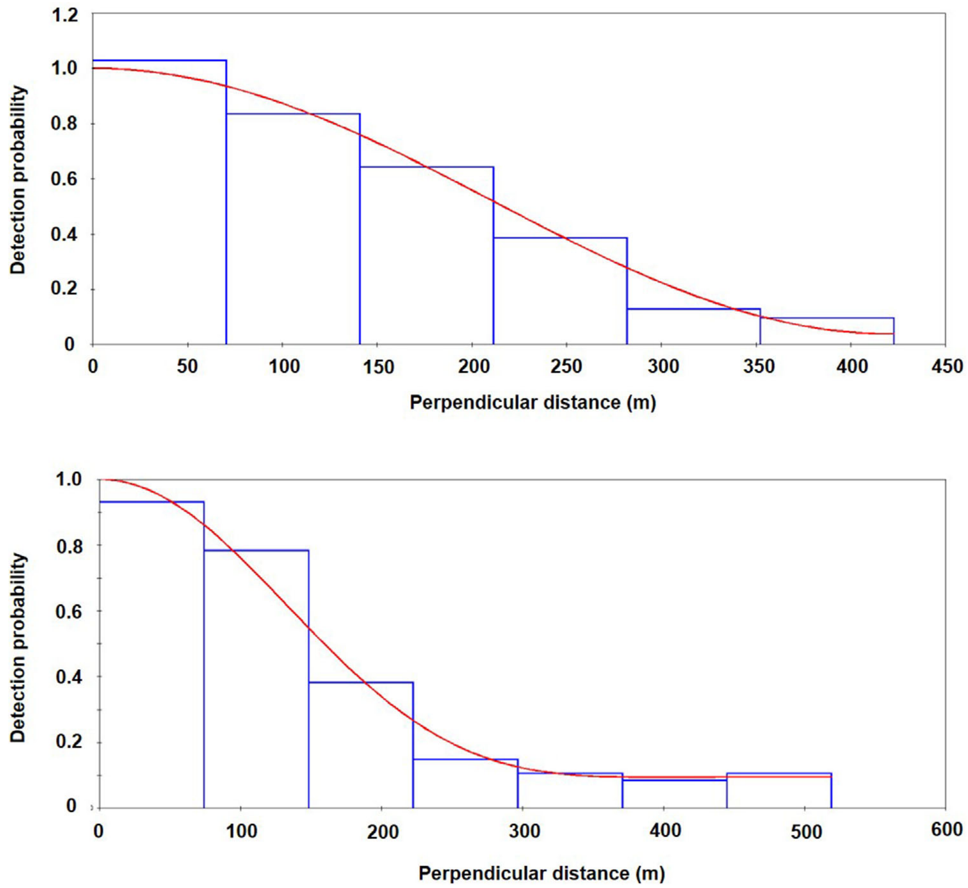


**FIGURE 2** Graphical representation of detection probability (solid red line) and histograms of perpendicular distances for the two sampling periods, early summer (upper graph) and early autumn (lower graph). We right-truncated the data to eliminate 5% of the farthest observations

functions adjusted to our data distribution. The coefficient of variation (CV) was analysed to assess if our population estimates can be considered reliable for management (Skalski et al., 2005). We started by using the conventional distance sampling (CDS, i.e. standard method where the detection probability is only modelled as a function of distance), however, as habitat type and group size may also affect detectability, we implemented the multiple covariate distance sampling (MCDS) to assess the effect of additional covariates on detection probability and model performance. We presented demographic parameters, such as age structure, adult sex ratio (the number of females divided by the number of males), fawn recruitment (number of fawns per young and adult female) and group size. These parameters are driven by phenological shifts, influenced by density-dependent processes and harvesting strategies and are considered important determinants of population dynamics (Vander Wal et al., 2013). In particular, the statistical characterization and comparison of animal group sizes are challenging because they often present aggregated and skewed distributions. We used the software *Flocker 1.1* (Reiczigel & Rózsa, 2006) to analyse and characterize group size. By recognizing that parametric statistics are not adequate to handle highly skewed distributions, the software applies a bias-corrected and accelerated bootstrap method to correct for bias and skewness of bootstrap estimates. As a resampling technique, bootstrap is deemed as an appropriate method to estimate summary statistics and confidence intervals of numeric distributions.

## 3 | RESULTS

We recorded 1360 individuals distributed by 382 red deer groups. After removing duplicates and considering the session with the highest number of observations, we considered 102 groups in early summer and 126 groups in early autumn for the density estimation of the red deer population. Encounter rates were 0.75 groups per km in early summer and 0.98 groups per km in early autumn. Detection functions are presented in Figure 2. We did not detect major discrepancies between $g(x)$ and the histograms. As expected, the probability of detecting red deer groups decreased with the increasing distance from the itinerary. We found that habitat and group size did not influence the detection function, and therefore, we modelled the detection probability as a function of distance (CDS analysis). The most parsimonious models for both sampling periods were fitted using the conventional design-based distance sampling ($AIC_{early\ summer} = 1122.49$; $AIC_{early\ autumn} = 1416.81$). We estimated a red deer density of 7.1 animals per 100 ha (95% CI [4.8, 10.6], CV = 20%) in early summer and 8.2 animals per 100 ha (95% CI [5.3, 12.7], CV = 22%) in early autumn.

**TABLE 1** Number of individuals observed per age category considering the session with the highest number of observations in two periods of ecological relevance for red deer, the early summer and the early autumn

| Age category | Early summer (*n*) | Early autumn (*n*) |
|---|---|---|
| Fawn (0–1 year) | 93 (19.2%) | 73 (19.2%) |
| Young female (1–2 years) | 38 (7.8%) | 46 (12.1%) |
| Adult female (>2 years) | 211 (43.5%) | 151 (39.6%) |
| Young male (1–3 years) | 41 (8.5%) | 40 (10.5%) |
| Adult male (>4 years) | 89 (18.4%) | 61 (16%) |
| Males (undetermined) | 5 (1.0%) | 2 (0.5%) |
| Females (undetermined) | 8 (1.6%) | 8 (2.1%). |
| Total | 485 | 381 |

These density estimates correspond to a population size of 1889 individuals (95% CI [1269, 2814]) and 2178 (95% CI [1406, 3374]), respectively. The estimated density is a variable throughout the study area; however, population size estimates remained fairly constant between the two sampling periods. Whereas young and adult females are the most representative age categories, representing approximately 53% of the whole population, males (young males ≈ 8%; adult males ≈ 19%) only represent 27%. The adult sex ratio is therefore biased towards females (1:2). These values are consistent among sampling periods (Table 1). The fawn recruitment was estimated at 0.36 (1:2.76) and 0.35 (1:2.81) in early summer and early autumn, respectively. Group size and composition varied between sampling periods. Females were observed in larger groups than males either in early summer ($\bar{x}_{♀} = 3.1$, 95% CI [2.6, 3.7]; $\bar{x}_{♂} = 2.00$, 95% CI = [1.6, 2.8]) or early autumn ($\bar{x}_{♀} = 2.4$, 95% CI [2.1, 2.9]; $\bar{x}_{♂} = 1.1$, 95% CI [1.0, 1.2]). Mixed groups were more frequent in early autumn; however, group size during this period was lower than in early summer ($\bar{x}_{\text{early summer}} = 6.9$, 95% CI [5.6, 8.4]; $\bar{x}_{\text{early autumn}} = 5.1$, 95% CI [4.3, 6.1]).

## 4 | DISCUSSION

Distance sampling is a widely used method for monitoring wild populations across time and space. By instructing local stakeholders, our work broadens the field applicability of this tool to areas where ongoing technical assistance is limited. We demonstrated that the application of this framework is feasible (straightforward, cost and time-effective) and, therefore, potentially adapted to other wildlife ungulate species (roe deer, Valente et al., 2016; fallow deer, Focardi et al., 2013; Iberian ibex, Pérez et al., 2002). Our density estimates were characterized by acceptable CV (approximately 20%, Skalski et al., 2005), that are consistent among sampling periods. The results reported in previous studies using the same technique (distance sampling based on direct observations) also support the precision of our estimates. For instance, Focardi et al. (2002) reported a CV of 21% for population density estimates of roe deer, 24% for fallow deer and 55% for wild boar. Some authors advocate that nocturnal surveys of wild ungulate populations may produce better CVs because it matches the activity rhythms of ungulate species (Focardi et al., 2013; Franzetti et al., 2012). Nocturnal activity of wild ungulates may even increase as a behavioural response to human disturbance (e.g. hunting, Kilgo et al., 1998). We did not test the performance of nocturnal surveys because our sampling did not match the hunting period. Although some studies stated that a single visit or a single itinerary survey is needed to estimate population density and abundance through distance sampling (Schmidt & Rattenbury, 2018), we strongly recommend the repetition of each itinerary on different days. Replication in the monitoring of wildlife populations allows to control for the effects of stochasticity and environmental variation on detection probability (spurious effects), to determine the underlying causes of unusual or unexpected results and to assess the consistency and robustness of population estimates (see Fraser et al., 2020). We also highlight that caution is needed when extrapolating the density estimates to all the areas. Even considering that general information on population parameters may be sufficient for management purposes (moose *Alces alces*, Solberg et al., 1999), differences in habitat and management practices may foster differences in these parameters between sampled and non-sampled areas. Therefore, we argued that game managers should perform a more detailed examination of their hunting grounds to ensure a better representativeness of the interested area and make information fit for management at a local scale.

The involvement of citizen scientists and interested stakeholders in the monitoring of wildlife and, particularly, of wild ungulates have been encouraged in other environmental scenarios because it has been proven that data recorded by instructed volunteers may produce similar population estimates than conventional and highly expensive methods (e.g. aerial strip surveys; Keeping et al., 2018). Our proposed framework would also provide important demographic information about ungulate populations, including age structure, fawn recruitment and group size. Age structure influences adult survival and population productivity, being considered an important determinant of population dynamics. By assessing systematically this parameter through direct counts, game managers are able to minimize the sex and age bias of the population and may garner support to mitigate the negative consequences of unregulated, age-specific and size-selective harvesting (Festa-Bianchet, 2017). Moreover, they become able to detect if age structure responds to differences in population density. For example, an increase in the population density of wild ungulates may lower population fecundity and increase juvenile mortality (Festa-Bianchet et al., 2003). Surprisingly, we did not detect differences in the fawn–female ratio between the two sampling periods. However, fawn mortality can be high during the summer in ecosystems experiencing Mediterranean influences (Gaillard et al., 1997). This period is often characterized by low precipitations, which may reduce the availability of food resources in populations stressed by density-dependent effects. The potential mismatch between the birth season and the survey period could be an explanation for the lack of seasonal differences in this parameter. We lack ecological and population data for further and detailed inferences.

The results reported in our study represent a solid baseline about the framework's effectiveness. Framework implementation strongly depends on the willingness and motivation of local hunters, game managers and field technicians to participate. The maintenance of stakeholders' motivation represents one of the main challenges of wildlife management and conservation initiatives and should be properly acknowledged by governments and local authorities. Noneconomic rewards such as public recognition are usually welcomed and envisaged as a way to incentive the maintenance of voluntary programmes (Leverkus et al., 2020). Fostering collaboration between hunters and game managers, and within or between institutions, will also allow to incorporate other sensitive and practical indicators for informative population assessments. Apart from engaging interested stakeholders, an important step of our framework involves the theoretical and the field instruction of participants, and the definition of timely and representative survey designs to avoid biases related to species phenology and/or habitat representativeness. As demographic data obtained from different methods (e.g. itineraries with distance sampling, camera trapping, indirect counts) are hardly combined, the definition of rigorous methodological protocols for sampling is the most welcome step towards data integration through time and space (Cretois et al., 2020; ENETWILD consortium et al., 2018). Our approach has motivated local stakeholders and game managers to use systematic population surveys to rigorously address ecological and management questions at smaller scales (e.g. hunting grounds). For instance, by using population estimates continuously and systematically collected over time, managers and researchers could understand the causes and consequences of population fluctuations and adjust hunting bags towards sustainable yield. Despite the advantages and benefits of our approach, we are aware that monitoring populations through distance sampling and ageing wild ungulates may produce inaccurate records. This source of error may introduce unintended biases in the definition of age structure and population productivity. The field instruction of participants, the level of observer experience, the seasonal-related effects (e.g. differences in species behaviour or lack of specific traits), the habitat and the topography of the study area should be taken into consideration to ensure that assumptions of distance sampling are met, to gather unbiased detection curves and to produce accurate population estimates (Le Moullec et al., 2017).

The long-term monitoring of wild ungulate populations will provide a consistent time series of population estimates (e.g. population density, population structure and productivity) to determine how hunting, disease, density dependence and climate rule the population dynamics. The close collaboration between entities may allow to overcome the lack of financial resources while providing the evidence-based support to mitigate the potential threats to the conservation and management of wild ungulate populations.

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## CONFLICT OF INTEREST

Nothing to declare.

## AUTHORS' CONTRIBUTIONS

JC, CF and RTT conceived the study. JC, PL, AMV compiled and analysed the data. JC, PL and RTT wrote the manuscript. All authors contributed to the development of ideas and approved the final version of the manuscript.

## DATA AVAILABILITY STATEMENT

Data available from the Dryad Digital Repository: https://doi.org/10.5061/dryad.fj6q573v6 (Carvalho et al., 2021).

## PEER REVIEW

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