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Abstract

Given the current pace of climate change, high temperature events will become increasingly frequent in many parts of the world. Predicting how high temperatures will impact the behavior of songbirds - highly sensitive to temperature change due to their tendency to have small size, high metabolic rate and diurnal habits - is therefore crucial and urgent. However, the behavioral impacts of high temperatures on acoustic communication in birds have rarely been studied. Responsiveness to antipredator signals is an important behavior to consider because failure to detect such signals could be lethal. We investigated whether high temperatures affect the behavioral responses of great tits (*Parus major*) to conspecific mobbing calls. We found that the emission of mobbing calls by great tits was affected by the current ambient temperature. Further, we found a significant lag effect of temperature on the approach of great tits to the speaker during the mobbing test. The results suggest that at high temperatures, great tits change their tactic from active defense to less active response. At higher temperatures, great tits produce fewer mobbing vocalizations and invest less time in response to mobbing playback. High temperatures can thus induce behavioral shifts in great tits. In the current context of increasing average temperatures, such effect of temperature on response to vital indicators such as antipredator signals could impact survival when inducing greater risk of depredation.

Keywords Acoustic communication, climate change, great tit, heat stress, mobbing calls

Significance statement

Anthropogenic climate change is causing heatwaves to increase in number and intensity. High temperatures can reduce the ability of birds to respond to vocalizations. Here, we test if high temperatures affect the ability of great tits (*Parus major*) to respond to conspecific mobbing calls - these calls generally serve to mob a predator and to recruit conspecifics and heterospecifics to join the caller. At higher temperatures, great tits produce fewer mobbing vocalizations and approach the loudspeaker broadcasting mobbing calls less often.

Introduction

The current pace of climate change is more rapid than has been experienced for the past 65 million years (Diffenbaugh and Field 2013; Kemp et al. 2015). Since climate is a major determinant of the natural distribution of species, recent poleward shifts in distribution have already been detected for a number of species from a diverse range of taxa in response to climate change (e.g. Walther et al. 2002; Parmesan and Yohe 2003; Hickling et al. 2006; Pearce-Higgins et al. 2014; Platts et al. 2019). Such rapid changes in temperatures can affect survival or reproduction of organisms and pose a serious threat to the persistence of species, particularly for species that can neither disperse nor adapt fast enough (Bale et al. 2002; Parmesan 2006; Berg et al. 2010; Bellard et al. 2012). In particular, high temperatures can have both lethal and sub-lethal effects on wildlife, resulting in mass mortality in extreme cases (Conradie et al. 2019; McKechnie et al. 2012).

Songbird species, due to their small size, high metabolic rate and primarily diurnal habits, can be highly sensitive to changes in temperature (McKechnie and Wolf 2010; du Plessis et al. 2012; Bourne et al. 2020a; Bourne et al. 2020b). To date, most studies have examined the effects of temperature on physiological changes (Dubois et al. 2016; Xie et al. 2017), but it can also induce behavioural changes in foraging (du Plessis et al. 2012; Edwards et al. 2015), cognitive performance (Soravia et al. 2021; Blackburn et al. 2022), and acoustic communication (Garson and Hunter 1979; Luther and Danner 2016; Coomes et al. 2019a; Coomes and Derryberry 2021). Recent research found that high temperatures reduce the ability of birds to discriminate between conspecific and heterospecific songs (Coomes et al. 2019a), but little is known about the effect of heat on responsiveness to other types of vocalizations. Understanding the effect of temperature on responsiveness to vocal information is important, since vocal signals are a primary form of communication for many bird species

(Bradbury and Vehrencamp 1998). Among different contexts of communication, responsiveness to alarm calls is an important behavior to consider because alarm calls are anti-predator signals that contain critical information for avoiding predation (Templeton et al. 2005; Magrath et al. 2015). The failure to discriminate the information content of these calls at high temperatures could thus lead to reduced survival.

Alarm calls are often classified as flee alarm calls, which are associated with the caller escaping while motivating other individuals to freeze or flee, or mobbing calls, which are associated with the caller approaching and vocalizing or displaying toward the predator while recruiting others to join it (Curio 1978; Magrath et al. 2015). The principal benefit of mobbing is to induce the predator to leave the area (Curio et al. 1978; Pettifor 1990). Thus, mobbing may reduce the immediate predation risk for the mobbers (Pavey and Smyth 1998) and may limit the future risk of attacks (Flasskamp 1994). Although no information is currently available on the energetic costs of mobbing (reviewed in Carlson and Griesser 2022), this behavior may be energetically expensive because it comprises repeated locomotion, movements of multiple body parts simultaneously (e.g. head bobbing, tail flagging) and vocalizations (Smith and Graves 1978; Crofoot 2012). During hot days, birds may be expected to mob less because recent evidence suggests that, similar to humans, animals can experience cognitive decline during heat stress (Coomes and Derryberry 2021; Soravia et al. 2021; Blackburn et al. 2022,). This could lead to a lower ability to perceive and respond to stimuli in the surrounding environment, such as cues of predator presence. During heat stress, individuals also have to trade-off the physiological need to offset heat against their investment in other behaviors (Cunningham et al. 2021), and hence may be less likely to invest in particular behaviors such as mobbing.

In this study, we investigated whether high temperatures affect the ability of great tits (*Parus major*) to respond to conspecific mobbing calls (Fig. 1a). Great tits are known to mob

a range of predators (Lind et al. 2005; Dutour et al. 2016; Kalb and Randler 2019), and to respond to conspecific and heterospecific mobbing calls (Randler and Vollmer 2013; Dutour et al. 2019). We predicted that great tit responses would be lower during hot days, approaching the speaker less in terms of distance when hearing mobbing calls, and emitting fewer mobbing calls. Previous studies have suggested that temperature affects the frequency of avian song both via the immediate effects of current temperature (e.g. Gottlander 1987) or by carry-over effects of prolonged high temperature events (time lag effect, e.g. Garson and Hunter 1979). Thus, both temperature states are important considerations when studying the potential effect of high temperatures on avian communication. Finally, Strauss et al. (2020) suggested that temperature might have a non-linear effect on singing, with a reduced number of songs under both cold and warm conditions, mainly because of the higher energetic demands leading to a trade-off between foraging and vocalizing. However, Strauss et al. (2020) did not find non-linear patterns in their data, perhaps because the temperature during their behavioral experiments never exceeded 20°C. We therefore expanded on these experiments by investigating the non-linear relationship between temperature and great tit behavior in response to mobbing calls overs a larger range of temperatures.

Material and methods

General methods

This study measured the response to mobbing calls of great tits at air temperatures ranging from 18°C to 36°C. The great tit's thermoneutral zone range is 15–30 °C (Broggi et al. 2005; Mathot et al. 2016). The maximum temperature of 36°C is considered a high temperature in the region where this study was conducted (see https://www.meteo-sain-bel.fr/). Data were

collected during playback tests conducted on wild great tits inhabiting mixed deciduous-coniferous forests located near Lyon (45.818992°N, 4.517753°E; France). All tests were conducted between 24 June and 4 September 2020, during a typical dry summer period (except two additional control tests conducted in early October; see hereafter). Since the focal birds were unbanded, we kept a minimum distance of at least 200 meters between experimental sites to minimize the chance of testing the same individuals more than once (as in Dutour et al. 2017; Kalb and Randler 2019). As a control, songs of common chaffinch (*Fringilla coelebs*) were played back to great tits (Fig. 1b, Kalb and Randler 2019). Chaffinches are widespread throughout the study area and great tits were assumed to be familiar with chaffinch song. A total of 92 great tit individuals were exposed to audio playback tests (mobbing calls: 60 individuals, control: 32 individuals). The playbacks (mobbing calls or control) were evenly distributed across the study period to avoid a temporal effect on the tests (see Online Resource 1).

Call collection and stimuli preparation

Mobbing calls used in the study were recorded from great tits responding to mobbing calls of conspecifics (Dutour et al. 2017; Kalb et al. 2019) or were obtained from the Xeno-Canto online database (http://www.xeno-canto.org/) with search criteria specifying the type of vocalization as “alarm call” (we reduced our selection to sound files that we could make sure were associated with a mobbing event, and most of these mobbing calls have already been used in previous mobbing studies; e.g. Dutour et al. 2021; Salis et al. 2021), quality “A” (i.e. highest recording quality), and without other bird species audible in the recording. We used mobbing calls of great tits that were composed of combinations of frequency-modulated elements followed by a string of a repeated loud broadband elements (FME-D call; Dutour et

al. 2019). From these recording files, 40 unique soundtracks of mobbing calls were built using Avisoft-SASLab software (i.e. with one calling individual per soundtrack). Chaffinch songs were obtained from the Xeno-Canto online database with search criteria specifying the type of vocalization as "song", quality "A", and without other bird species in the recording. From these recording files, 32 unique soundtracks of chaffinch songs were compiled (one calling individual per soundtrack). The song of chaffinch consists of two or three trill-like phrases, followed by an end phrase of more complex and dissimilar notes (Nottebohm 1968). On each soundtrack, low frequency noise has been systematically removed (below 1 kHz, Kalb and Randler 2019) and natural calling rates have been used for each species: great tit mobbing calls were repeated at a rate of 26 calls/min (Dutour et al. 2019), and chaffinch songs at a rate of 8 songs/min (rates observed in previous records; unpublished data). On average, the duration of a great tit mobbing call was 0.88 sec and the duration of a chaffinch song was 2.5 sec (Fig. 1). Consequently, focal great tits heard 23 sec of great tit mobbing call per minute compared to 20 sec of chaffinch song. Each sound file consisted of one minute of playback and was saved in Waveform audio file format.

Playback experiment

All playback tests were conducted between 11am and 2pm during days with cloudless sky and without strong wind or rainfall. After finding a great tit, a remotely controlled speaker (Shopinnov 20W, frequency response 100 Hz - 15 kHz) was hung from a tree at 1.5 m from the ground (Suzuki et al. 2016) and ~20 m away from the bird (Dutour et al. 2021). Before the beginning of the test, the baseline behavior of the focal individual was observed during a pre-trial period lasting one minute to ensure that the bird was not showing vigilance or antipredator behaviors. To determine the responses of the focal tit to the different playback

171 treatments (mobbing calls or control), two behaviors were measured: the number of mobbing
172 vocalizations during 1 min of playback (Carlson et al. 2017) and the minimum distance to the
173 speaker using a tape measure after the playback (Kalb et al. 2019). We considered that a
174 closer approach to the loudspeaker and a greater number of mobbing calls reflect a higher
175 mobbing response from the focal bird. All signals were broadcast with the same intensity (~80
176 dB sound pressure level, measured at 1 m from the loudspeaker, which is within the range of
177 natural mobbing calls produced by great tits; Templeton et al. 2016, and within the range of
178 songs produced by chaffinches; Brumm and Ritschard 2011). In order to limit
179 pseudoreplication (Hurlbert 1984; Kroodsma et al. 2001), each control playback was used
180 only once. For the mobbing call playbacks, 20 exemplars were used once, while the other 20
181 were used twice. Immediately after each playback, the time of the playback was recorded, as
182 well as the air temperature (T0). To investigate time lag effects of heat, the mean temperatures
183 observed for the 5, 12, 24 and 48 hours before the test were calculated for each playback test
184 (T5 to T48) from hourly records collected from the nearest weather station (< 6 km from the
185 study area; https://www.meteo-sain-bel.fr/; 45.818000°N, 4.588517°E). We calculated T5
186 over the five hours before the test to ensure a mean temperature calculated on diurnal
187 temperatures only for all the tests (T6 would have included nocturnal temperatures in some
188 tests). Humidity levels during the tests were also recorded (these levels were obtained from
189 the local weather station in the same way that temperatures were obtained).
190
191 **Statistical analyses**
192
193 To test whether the mobbing calls generated the expected mobbing response on the behavioral
194 variables tested (B1: the observed number of mobbing vocalizations and B2: the minimum
195 distance to the speaker) we checked first whether responses to the mobbing calls were

different to responses to the control. We ran (generalized) mixed models with treatment (mobbing calls or control) as a predictor term for (i) the number of mobbing vocalizations (fitted with a Poisson distribution) and (ii) the minimum distance to the speaker (fitted with a Normal distribution). In both models, the identity of the playbacks (exemplar ID) was systematically added as random effect.

Once we had confirmed that the mobbing calls generated the expected mobbing response and the control sounds triggered lower responses than conspecific mobbing calls, we analyzed the impact of temperature on the behavioral responses to mobbing call playbacks using two linear mixed models (M1 associated with B1 the number of mobbing vocalizations; M2 associated with B2 the closest distance to the speaker). In the two models, the identities of the playbacks (exemplar ID) were included as random effects. The time of day the playback test was conducted, and the temperature were included as dependent variables. As temperature scales (T0: Temperature during the test, T5-48: mean temperatures of the 5, 12, 24 and 48 hours before the test) were not independent and were highly correlated, a set of 5 mixed models were ran for each behavior (B1 and B2), each of them based on a different scale of temperatures introduced in the model as dependent variables. As temperature response curves are typically quadratic, with an intermediate optimum (Johnston and Bennett 1996; Uiterwaal and DeLong 2020), a quadratic effect of temperature was systematically included in the models. For each behavior (B1 and B2), a model selection process (AICc ranking; package *bbmle*, Bolker and Team 2017) was conducted on these five models, and an additional null model and a model without temperature effect, to compare model fit and identify the model that explained the most variation in data patterns (i.e. the model incorporating the more relevant temporal scale of temperature). The significance of each explanatory term (temperature, quadratic effect of temperature and time of day) was tested using z tests. Since high humidity can make it more difficult for birds to dissipate heat due to

evaporative cooling and may have affected behavior, and date can have an effect on mobbing behavior (Coomes et al. 2019b), the impacts of humidity and date have been controlled through additional models derivate from the final models selected, to avoid over-parametrization of the models (all details available in Online Resources 2 and 3). All statistics were carried out using R v.3.5 software (R Development Core Team 2019). All models were analyzed using the package *glmmTMB* (Brook et al. 2017), and the quality of the model estimates was monitored using Pearson residuals. For all statistical tests, the level of significance was set at $P < 0.05$.

Results

Responses to mobbing calls versus songs (control)

There was a significant difference in minimum approach to the speaker in relation to playback treatment (mobbing calls – mean distance = 12.58 or control – mean distance = 19.24, generalized linear mixed model: $\chi^2 = 23.394$, $P < 0.001$), with individuals approaching closer to the speaker during the playback of mobbing calls (Fig. 2a). Similarly, focal individuals produced significantly more mobbing vocalizations in response to the mobbing call playback (mean number of vocalizations = 5.30) than the control playback (mean number of vocalizations = 0.21) (generalized linear mixed model using Poisson family: $\chi^2 = 57.271$, $P < 0.001$; Fig. 2b).

Temperature effect on responses to mobbing calls

The different temporal scales of temperature tested (from the temperature during the tests to the mean temperature in the 48 hours before the test) showed distinct patterns with the behavioral variables. The number of mobbing vocalizations given in response to playback was best explained by temperature during the test (T0, Table 1), whereas the minimum distance to the speaker reached by focus individuals was best explained by the temperature experienced in the five hours prior to the test (T5) (Table 1). Accordingly, the final models implemented, as a temperature effect, (i) the immediate temperature during the test when considering the number of vocalizations (B1) as a dependent variable, and (ii) the mean temperatures observed for the 5 hours before the test when considering minimum distance to the speaker reached by focal individuals (B2) as a dependent variable.

The temperature during playback affected the number of mobbing calls emitted by focal individuals (Table 2; Fig. 3). This effect of the temperature was quadratic ($Y = -38.376 + 3.472X - 0.067X^2$), with individuals calling more often during mobbing call playback when the temperature averaged 25.9°C ($\text{Max}\{x\} \in R(-38.376 + 3.472X - 0.067X^2)$). At both high and low temperatures, immediate current temperature (T0) negatively correlated with the number of mobbing calls given by the focal individual. The time of day at which the playbacks were conducted did not affect calling behavior (Table 2).

The temperature during the five hours prior the playback was related to the minimum distance of approach to the speaker during mobbing call playback (Table 2; Fig. 4). This effect of the temperature was quadratic ($Y = 41.033 - 3.233X + 0.083X^2$), with individuals approaching closer to the speaker during mobbing call playback when the mean temperature in the five hours before the playback averaged 19.5°C ($\text{Max}\{x\} \in R(41.033 - 3.233X + 0.083X^2)$). At high temperatures, the mean temperature in the five hours before the playback thus negatively correlated with the approach of individuals. The time of day at which the playbacks were conducted did not affect approach behavior (Table 2).

Discussion

The approach and emission of mobbing calls by focal great tits were affected by temperatures experienced during or prior to playback. Our results suggested a significant lag effect of temperature on the approach of great tits during mobbing. This result indicates that longer term heat is a greater influence on movement response than immediate heat, perhaps because it may cause a cumulative effect of heat stress (Conradie et al. 2019; Fernandez et al. 2021).

The quadratic effect of temperature suggested that the behavioral response of great tits to mobbing calls is the strongest at temperatures of approximately 19.5°C for the approach behavior (typical average temperature in June for the region) and 26°C for calling behavior, suggesting an impact of temperature on the mobbing behavior of great tits. This result contrasts with the study of Strauss et al. (2020), where the minimum approach distance of great tits for territory defense behaviors was not affected by temperature. This could be due to the fact that temperature did not exceed 27°C in their study. Indeed, in our research, the mobbing behavior was particularly inhibited during the playback of mobbing calls at high temperatures (Fig. 3 and Fig. 4), although we cannot determine whether the lower number of calls and approach distance during high temperatures were due to behavioral flexibility in mobbing behavior (for example, a behavioral trade-off between off-setting heat and other behaviors, *sensu* du Plessis et al. 2012), or a temperature-related physiological mechanism limiting their movements. It is possible that excessive heat leads to a generalized drop in motivation to respond and that great tits were less motivated to respond to mobbing calls during high temperatures. There could also be an increase of sound attenuation during signal propagation at high temperature. Indeed, a previous study showed that air temperature affects the active space of acoustic signal (Larom et al. 1997). Nevertheless, while modification of

295 active space on long-range communication is mainly due to temperature inversions and low
296 surface wind, Harris (1966) showed that signal attenuation for frequency range between 2 and
297 5 kHz (corresponding to great tit mobbing calls) is poorly affected by temperature between 15
298 and 30 degrees (0.2 to 1 dB of excess attenuation per 100 m with a 50% humidity rate).
299 Hence, we could dismiss that our observed decrease of mobbing response could be due to the
300 fact that tested birds did not hear our soundtrack emitted at ~20 m from them.

301 High temperatures can have strong physiological effects on wildlife (Stillman 2019),
302 leading to mortality in extreme cases (Welbergen et al. 2008; McKechnie et al. 2012). In this
303 study we investigated the impact of high temperatures in the short-term, with a very short
304 latency time. Average temperatures experienced immediately during the test or during the
305 previous few hours did affect behavior, suggesting short-term impacts of temperature on
306 behavior. Short term impacts could lead to longer term effects on survival and development,
307 as have been observed in other species (Bourne et al. 2020 a and b).

308 High temperature events will become increasingly frequent under future climate
309 scenarios. Predicting how these high temperatures and heatwaves will impact animal behavior
310 is therefore crucial (Cunningham et al 2021; Soravia et al 2021). Our study suggests high
311 temperatures are likely to induce behavioral shifts in response to antipredator signals in great
312 tits. The predicted increase in summer heatwave number and intensity may alter mobbing
313 behavior perpetuation in this species in the future, and hence may impact survival rates in
314 birds because this behavior is known to repel predators in great tits (personal obs. MD) and
315 other species (Flasskamp 1994; Pavey and Smyth 1998). However, it remains unknown what
316 impact temperature will have on the behavior of great tit predators.

317 Mobbing calls are anti-predator signals that contain critical information for avoiding
318 predation (Templeton et al. 2005; Magrath et al. 2015). The failure to detect and interpret the
319 risk-based information encoded in these calls at high temperatures could thus lead to reduced

survival rates, inducing for instance a decrease in the flight initiation distance with increasing temperatures (Díaz et al. 2021). However, our results indicate that there is no evidence for complete failure to detect and interpret information encoded in mobbing calls. Indeed, such failure would have induced a complete lack of behavioral response from the targeted great tits, which is not what is observed in the present study. Our results suggest that tested birds changed their investment in approaching behavior, suggesting that high temperatures limit the movement of individuals (i.e. their approach when hearing alarm calls), as well as the calling behavior itself. There is thus a temperature-related effect on the ability of great tits to emit mobbing calls and on investment in approaching callers producing mobbing calls. This result supports the increasing body of research indicating a lower investment in behaviors at higher temperature. For example, temperate passerine birds sing earlier with rising temperatures in spring (Bruni et al. 2014), and in pied babblers (*Turdoides bicolor*) parents provision young less at high temperatures (Wiley and Ridley 2016). Our results are, to our knowledge, the first to provide experimental support that high temperatures affect the behavioral response to mobbing calls in a wild bird population. In the current context of rapid climate change, we argue that there is an urgent need to quantify the costs of heat exposure in natural populations, and to improve our understanding of the contexts in which animals change their behavior in response to climate conditions.

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Declarations

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Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval This study included no animal keeping; birds were observed in their natural habitat. All tested great tits returned to normal activity relatively quickly following playbacks, so we were confident that they were not unduly stressful. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

Consent to participate & Consent for publication: Not applicable

Availability of data and material: The datasets generated are available on the Zenodo repository; https://doi.org/10.5281/zenodo.5656901.

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Table 1. ΔAICc ranking based on the two set of models investigating behavioral response to playback of mobbing calls: M1 = number of observed vocalizations by the focal bird during playback and M2 = minimum distance to the speaker by the focal bird during playback, and comparing the null model and a model without temperature effect with models incorporating the effect of temperatures at several temporal scales (T0: temperature observed during the playback to T48: mean of the 48 hours before the playback) (N = 60). A null value indicates the model ranked as the best model; models in which the difference in AICc relative to AICcmin is < 2 can be considered to have substantial support (Burnham et al. 2011).

Model Name	Delta AICc for number of mobbing vocalizations	Delta AICc for min. distance to the speaker
Null model	53.2	9.8
No temperature	2.4	4.2
T0	**0**	6.2
T5	3.4	**0**
T12	2.2	4.1
T24	2.6	5.2
T48	2.3	6.1

Table 2. Test results and parameter estimates of the two models M1 and M2. M1 = terms influencing the number of mobbing vocalizations (R-squared = 0.105), M2 = terms influencing the minimum distance to the speaker (R-squared = 0.250). Temperature (T0 = temperature during the test, T5 = mean temperature during the 5 hours before the test), and hour when the test was performed have been used as independent variables. Signif codes: * = < 0.05.

M1: number of mobbing vocalizations

Variable	Estimate	Std. Error	z value	P. value
Intercept	-38.376	19.046	-2.015	0.044*
T0	3.472	1.441	2.409	0.016*
T0 Quad. effect	-0.067	0.027	-2.492	0.013*
Time of day	-0.033	0.626	-0.053	0.957

M2: minimum distance to the speaker

Variable	Estimate	Std. Error	z value	P. value
Intercept	41.033	16.883	2.430	0.015 *
T5	-3.233	1.545	-2.093	0.036 *
T5 Quad. effect	0.083	0.035	2.406	0.016 *
Time of day	0.957	1.062	0.901	0.367

546

547 The results were overall similar when the date (Online Resource 2) or humidity (Online
548 Resource 3) were included in the models, although the statistical power required to detect
549 significant differences was limited due to the number of factors incorporated. The humidity
550 seemed to induce an additional stress as it negatively affected both the number of
551 vocalizations and the individual approach to the speaker, but this negative effect is stronger
552 under low temperatures (see Online Resource 3 for details).

553

FIGURE CAPTIONS

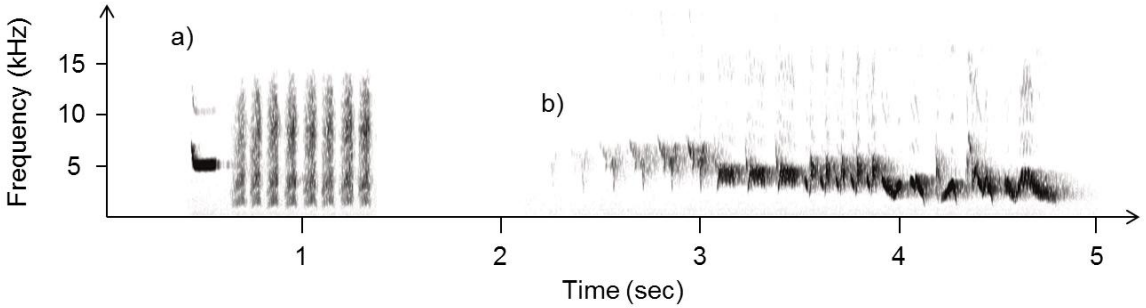
Fig. 1. Spectrogram of typical (a) mobbing call uttered by great tits, and (b) song uttered by chaffinches. The mobbing call of great tit is made of the combination of introductory note followed by broadband frequency notes (D notes). The song of chaffinch consists of two or three trill-like phrases, followed by an end phrase of more complex and dissimilar notes

Fig. 2 Great tit response to mobbing calls and control treatments (N = 92 individuals) in terms of (a) minimum distance (in meters) to the loudspeaker and (b) Number of mobbing vocalizations produced during 1 min of playback. The boxes range from Q1 (the first quartile) to Q3 (the third quartile) of the distribution and the range represents the IQR (interquartile range). The median is indicated by a line across the box. The "whiskers" on box plots extend from Q1 and Q3 to the most extreme data points. Outliers are represented as white dots. The mean and standard error for each treatment are shown in red. Different letters (a and b) indicate significant differences

Fig. 3 Relationship between the immediate temperature during the playback test and the number of mobbing vocalizations produced by the focal great tit during the playback (N = 60). The confidence band (shaded – 95% CI) and the regression line (bold) have been calculated based on the values predicted by the model

Fig. 4 Relationship between the mean temperature during the five hours before the playback test and the minimum distance between the focal great tit and the speaker reached during the playback test (N = 60). The confidence band (shaded – 95% CI) and the regression line (bold) have been calculated based on the values predicted by the model

579 **Fig. 1.**



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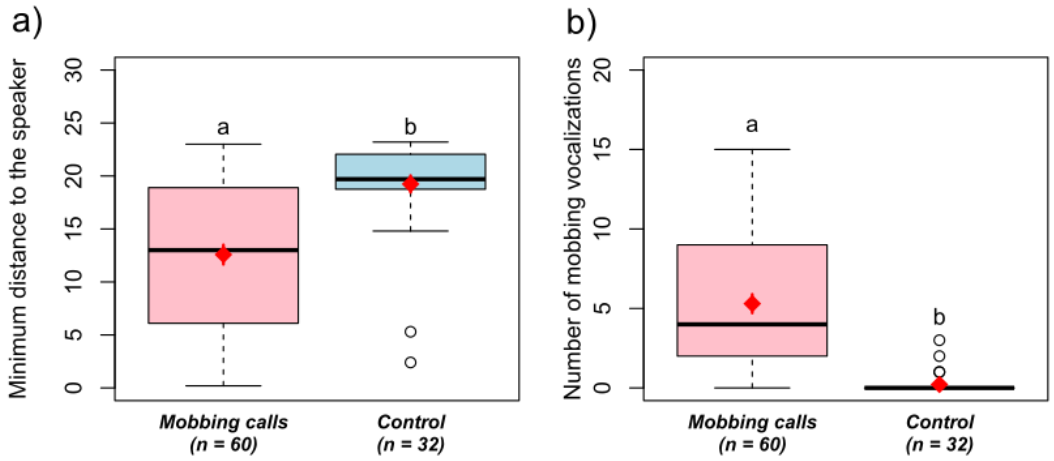
582 **Fig. 2.**



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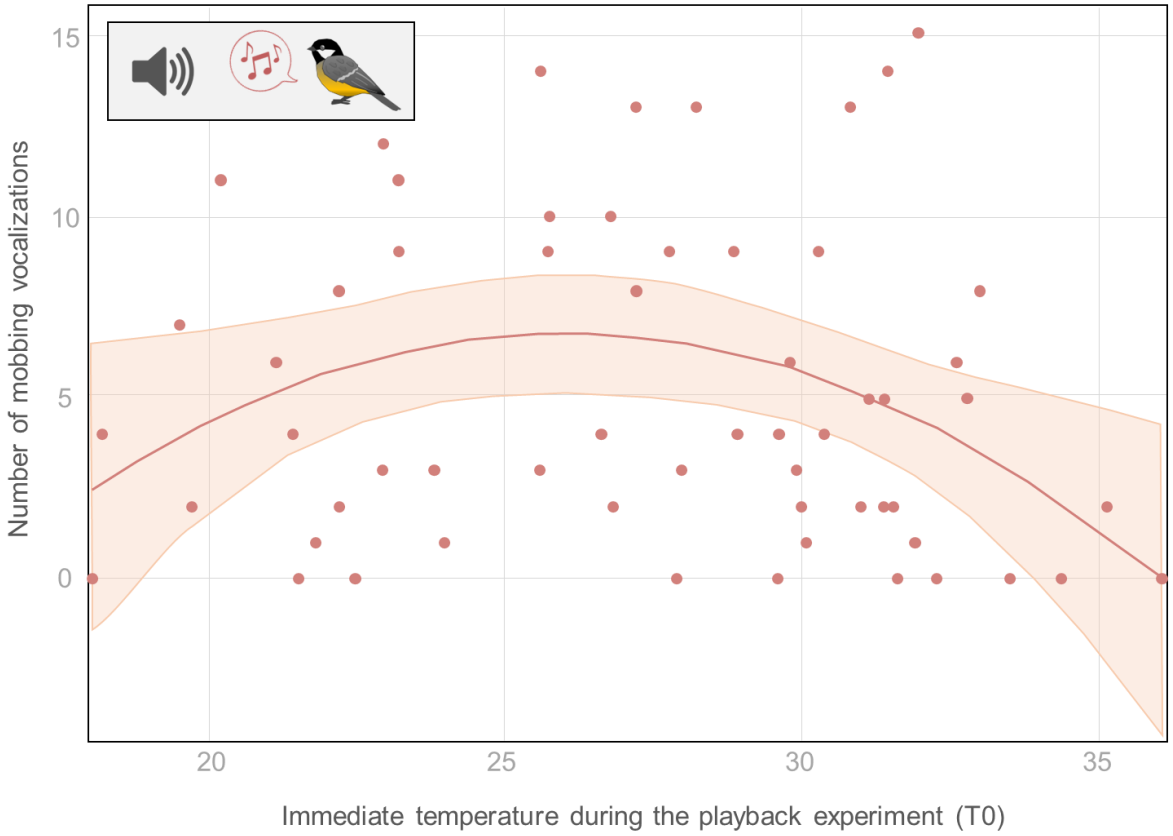
585 **Fig. 3.**



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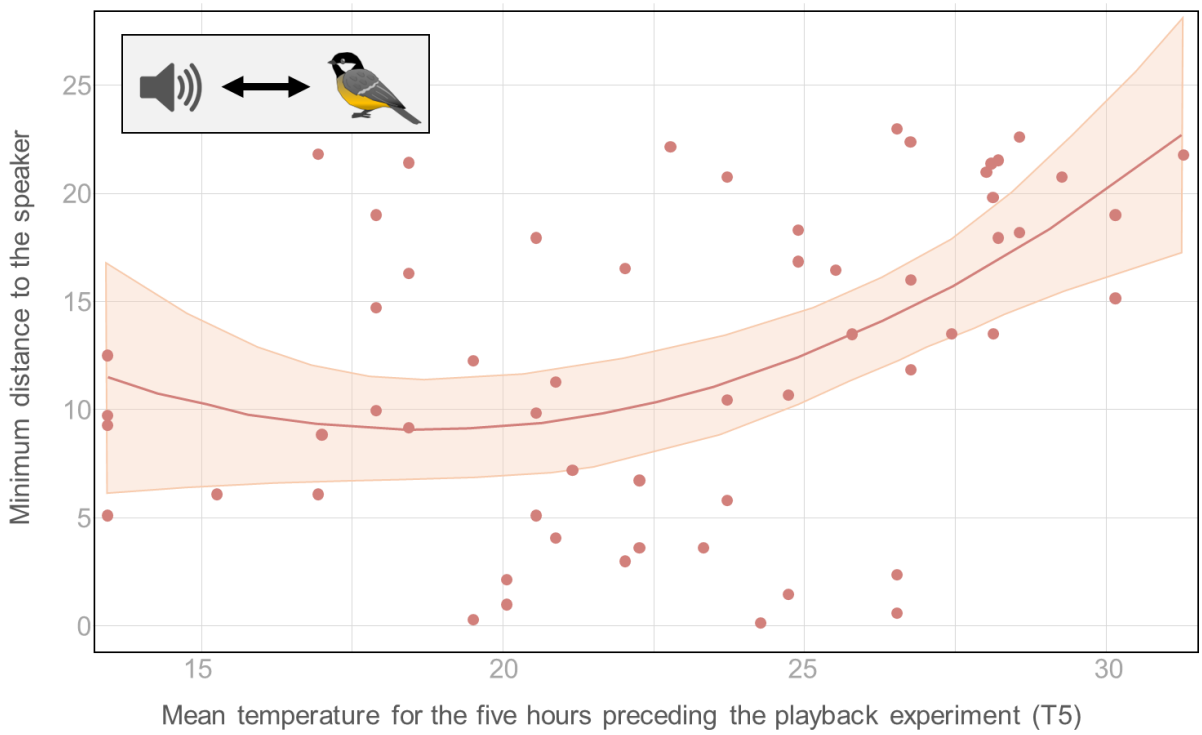
588 **Fig. 4.**


Minimum distance to the speaker
0
5
10
15
20
25
15
20
25
30
Mean temperature for the five hours preceding the playback experiment (T5)

589