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The jewel beetle *Chalcophora mariana* (jättepraktbagge) in the High Coast area

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The jewel beetle *Chalcophora mariana* (jättepraktbagge) in the High Coast area

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English summary

Chalcophora mariana is a beetle that is rare in Sweden and presently only occurs in a few areas in Västernorrland and Gävleborg county. We analysed recent data available for the species to better understand potential limitations for the persistence of the species.

Winter temperatures at Swedish sites of the species are unlikely to be at the extreme edge of what the species can tolerate as several sites outside of Sweden experience even colder minimum temperatures. However, the average temperature at Swedish sites between April and August is lower than at other sites the species is known to occur. This supports the prior suggestion that a sun-exposed microclimate is very important for the Swedish population.

A yearly hatching hole survey of the species in Skuleskogen national park showed a moderate decrease of hatching holes between 2011 and 2018 (rate of decrease: –(0.12-0.15). A single unusually high count early on in the monitoring period on a single deadwood item was responsible for much of the decrease. This deadwood item likely represents a highly suitable substrate in decline.

In exploratory models we found that the number of hatching holes per year was positively associated with a higher number of days with good flying conditions in the year of hatching and an earlier occurrence of the first day with good flying conditions in the year of hatching and six years prior to hatching (roughly the assumed larval period). We also found that deadwood items receiving higher radiation values produced a larger number of hatching holes. However, these results are based on data with a narrow temporal and spatial extent and do not support the inference of robust conclusions. Therefore, the results should be regarded as tentative and will need to be confirmed, rejected or refined when more data become available. We give recommendations for the collection of additional data.

Svensk sammanfattning

Jättepraktbagge *Chalcophora mariana* är en i Sverige sällsynt skalbagge med aktuell förekomst på ett fåtal lokaler i Västernorrlands och Gävleborgs län. Vi har analyserat data som samlats in under de senaste åren för att försöka förstå vad som begränsar artens fortlevnad på de kända lokalerna

Vintertemperaturen på de svenska lokalerna är sannolikt inte någon begränsande faktor då arten i andra delar av sitt utbredningsområde lever i områden med lägre minimitemperaturer. Däremot är medeltemperaturen under perioden april–augusti på de svenska lokalerna lägre än i andra områden där arten förekommer. Detta stöder tidigare antaganden om att solexponerade miljöer med ett extra gynnsamt mikroklimat är mycket viktiga för den svenska populationen.

Årliga inventeringar i Skuleskogens nationalpark visar på en måttlig nedgång i förekomsten av nya kläckhål mellan 2011 och 2018 (minskning 0,12–0,15/år). En närmare analys av data visar att det kläckte stora mängder jättepraktbagge från en enskild stock under 2011 och att minskningen till stor del kan förklaras utifrån denna enda stock. Troligtvis har denna stock blivit mindre optimal.

Våra analyser visar på ett positivt samband mellan antalet kläckhål och antalet dagar med goda flygförhållande under kläckningsåret samt en tidig sommar (mätt som första dagen med bra flygväder) under såväl kläckningsåret som sex år tidigare (förmodad larvperiod). Analyserna antyder dessutom att mera solexponerade stockar producerar fler kläckhål. Det ska dock påpekas att dessa resultat baseras på data med en smal tidsmässig och rumslig upplösning och stöder inte robusta slutsatser. Av denna anledning är det nödvändigt med fortsatta studier för att kunna bekräfta, avvisa eller utveckla resultaten från vår analys. Rapporten innehåller ett antal rekommendationer när det gäller insamlingen av ytterligare data.

Introduction

The presence of *Chalcophora mariana* in the High Coast area, Ångermanland, Sweden was unknown until 2007 when the species was discovered for the first time (Marklund & Marklund 2010). Today, the species is known to be reproducing in the Skuleskogen national-park, on the island Mjältön about 6 km from the sites in the park, and on the peninsular Fanön, 7 km from the park. The conservation of the species is guided by the species action plan (Ehnström & Bader 2013). One action has been to put out substrate, pine logs, with a helicopter in the park and on Mjältön, which for example has given information about the species larval development time at this latitude.

The aims of this study were to analyse currently available data of the species, to identify data or knowledge gaps impeding a population viability analysis and to give recommendations for future data collection. Specifically, we carried out the following data analyses:

1. We compared the climate the species is exposed to in Sweden against the climate the species experiences outside of Sweden. This facilitates a better understanding of a possible limitation by climate of *Chalcophora mariana* in Sweden as the species is described as preferring sun-exposed logs and the distribution of the species is assumed to be limited by cold climate (Brechtel & Kostenbader 2002).
2. We estimated the population trend from the number of fresh hatching holes recorded by the yearly survey carried out by Länsstyrelsen Västernorrland.
3. We carried out an exploratory analysis to identify possible factors that may affect the population trend of the species.
4. We investigated a possible relationship between microclimate and the number of hatched *Ch. mariana*.
5. We carried out an exploratory analysis of a 2018 hatching hole survey, commissioned by Länsstyrelsen Västernorrland in the Skuleskogen national park, Fanön and Mjältön to better understand local variation in the number of *Ch. mariana* hatching holes in the High Coast area.

Jewel beetle *Chalcophora mariana*.
PHOTO: JONAS SALMONSSON

Data and methods

Species records in Sweden and abroad

Direct observations of *Chalcophora mariana* and records of hatching holes in countries other than Sweden were downloaded from the Global Biodiversity Information Facility (GBIF, www.gbif.org) on 13th November 2018 (Fig. 1). *Ch. intermedia* and *Ch. massiliensis* occur in Spain and along the Mediterranean and were formerly regarded as *Ch. mariana* (Brechtel & Kostenbader 2002). We excluded records from the Iberian Peninsula and near the Mediterranean due to uncertainty in the species identity. Records for Sweden were downloaded from the Swedish Species Observation System (www.artportalen.se) via the Analysis Portal (www.analysisportal.se, Leidenberger *et al.* 2016) on 21st November 2018 (Fig. 1).

The Swedish data contained 419 observations recorded between 1963 and 2018, 416 of which were recorded after 2001. However, for observations of hatching holes it will often not be known in which year the individual hatched. The records are from the current coastal distribution areas and from historical sites, which include some inland sites. The non-Swedish observations, excluding those with uncertain species identity, contained 209 records, of which 79 were undated and 110 were recorded after 1993. Most records were from central and eastern Europe (Fig. 1).

Climate data

We obtained climate data for the period 1970–2000 as monthly averages from the global Worldclim Version 2.0 dataset (Fick & Hijmans 2017). The data consisted of minimum, maximum and average temperature (°C), solar radiation (kJ m^{-2} day^{-1}), wind speed (m s^{-1}) and precipitation (mm) at a spatial resolution of ca. 1 km^2. Additionally, we obtained predicted average monthly minimum and maximum temperature (°C) for the year 2050 for three downscaled global climate models (GCM) for a radiative forcing of 4.5 and 8.5 W/m^2 (RCP4.5 and 8.5) from the global Worldclim Version 1.4 dataset (Hijmans et al. 2005), also at a spatial resolution of ca. 1 km^2. Worldclim datasets were downloaded from www.worldclim.org.

For the climate data 1970–2000 and each occurrence observation, we extracted minimum, maximum and average temperature, solar radiation, wind speed and precipitation and plotted kernel density estimates of the climate data per month and region. As regions we used: Poland, Norway, Turkey, Baltic (Estonia, Latvia, Lithuania), Russia/Ukraine, Austria and adjacent areas (including records from Italy and the Czech Republic as those were located close to the Austrian border), Germany and adjacent areas (including French records close

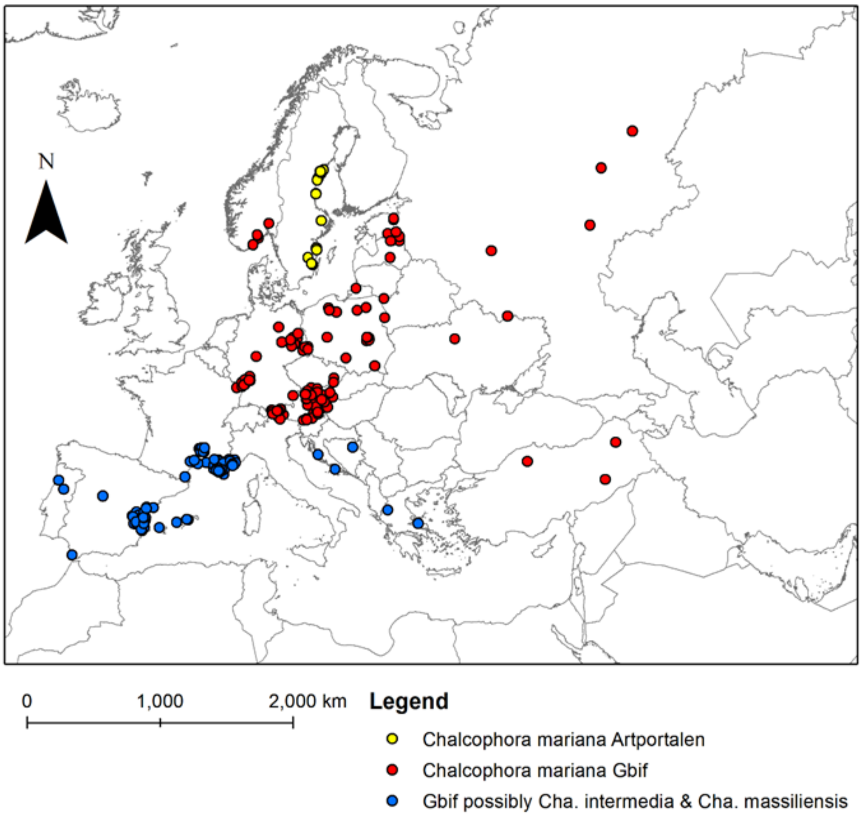


Fig 1: Occurrence records for *Chalcophora mariana* in Sweden (yellow) and elsewhere (red and blue). *Ch. intermedia* and *Ch. massiliensis* occur in Spain and along the Mediterranean and were formerly regarded as Ch. mariana. Records in these areas are shown in blue to highlight a possible uncertainty in species identity, and have not been included in the analyses. Swedish records were obtained from the Swedish Species Observation System (Artportalen) and all other records from the Global Biodiversity Information Facility (GBIF).

Fig 1: Fynd av praktbaggar av släktet *Chalcophora* i Europa. Rapporter om fynd av jättepraktbagge *Ch. mariana* är hämtade från Artportalen (gula prickar) samt från Global Biodiversity Information Facility (GBIF) (röda och blåa prickar). Fynden på Iberiska halvön och i Medelhavsområdet (blå prickar) utgörs möjligtvis av det nyligen utskilda artparet *Ch. intermedia* respektive *Ch. massiliensis* och har inte inkluderats i analyserna.

to the German border). A kernel density estimate plot shows how frequent certain values of a variable occur in the data. In other words it shows the distribution of the data and can be seen as a smoothed version of a histogram. For the predicted climate data for the year 2050, we extracted minimum and maximum temperature for each Swedish occurrence observation and plotted kernel density estimates per GCM.

Population trend based on the yearly hatching hole survey

A hatching hole survey in four survey areas (4.6 ha) located in Skuleskogen national park has been carried out yearly since 2011 (Areas A–C, F in Fig 2) by Länsstyrelsen Västernorrland. Two additional survey areas were added in 2012 (Areas D–E in Fig. 2) resulting in a total survey area of 6.2 ha. Several experimental logs added in 2009 have been surveyed for hatching holes since 2011 and the first hatching hole was found in 2016.

In the hatching hole surveys all lying deadwood items and snags over approximately 5 cm diameter had been inspected in late summer / early autumn, after the summer hatching period of the species. Fresh hatching holes can be recognized by the sharp edges and the lack of wood discolouration and all fresh holes found had been marked and recorded. Deadwood pieces with hatching holes had been numbered and their location recorded with a GPS.

We used program TRIM (Trends and Indices for Monitoring data), developed by Statistics Netherland, to estimate the population trend based on the hatching hole data. We chose TRIM to enable consistency with estimations of population trends in the future as TRIM has a user-friendly structure.

We estimated the population trend for 1) the six survey areas, 2) the six survey areas plus five experimental log sites in the vicinity of the survey areas, 3) the six survey areas plus all experimental log sites. We treated the cluster of logs per experimental log site as one site as hatching holes were recorded per cluster. Missing values (deadwood pieces that were not surveyed in a given year), can be imputed based on the population trend observed in other years and on other deadwood pieces (see Fig. 3 for an example). We always imputed values for the year 2011 for survey areas D & E, which were added in 2012 and for experimental logs not in the vicinity of the survey areas. It is unclear whether or not hatching holes on experimental logs in the vicinity of survey areas are part of the survey area population (i.e. the individuals hatching on experimental logs would otherwise have hatched in the survey areas A–F). Therefore, we estimated the population trend twice when we included experimental logs. For the five experimental log sites in the vicinity of the survey areas a) we assumed that the experimental logs are part of the survey area population and we fixed the number of hatching holes at experimental logs pre-2016 to zero and b) we imputed the number of hatching holes for years before 2016, thereby treating experimental logs as an enlargement of the survey area.

Hatching holes. PHOTO: UTE BRADTER

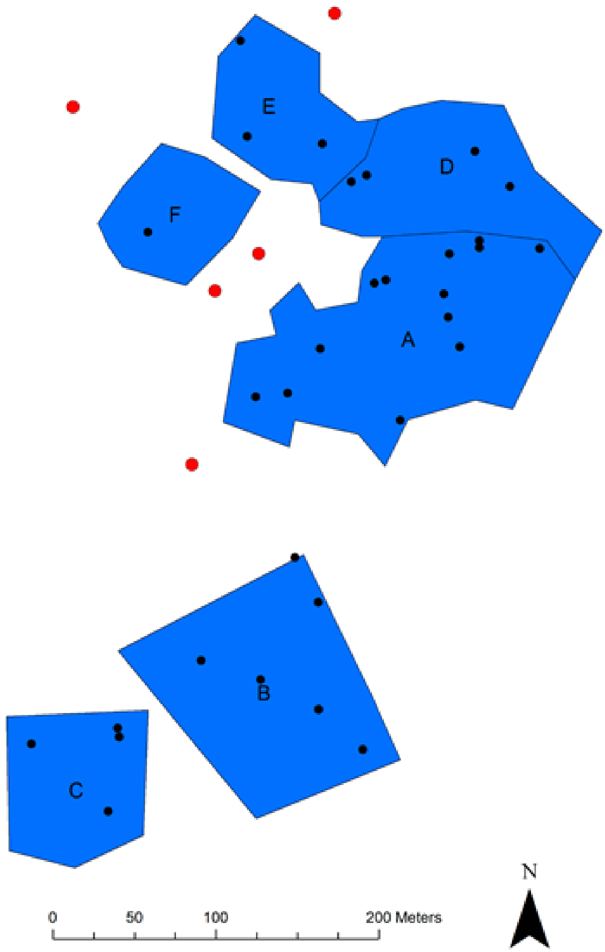


Fig. 2: The survey areas (blue) of the yearly hatching hole survey, the deadwood pieces (black) on which hatching holes had been recorded and the location of the five nearby experimental pine log assemblages (red).

Fig. 2: Områden som undersökts i samband med de årliga inventeringarna av kläckhål, högstubbar och stockar med färska kläckhål (svart) och placeringen av fem grupper av tallstockar som lagts ut i experimentellt syfte (rött).

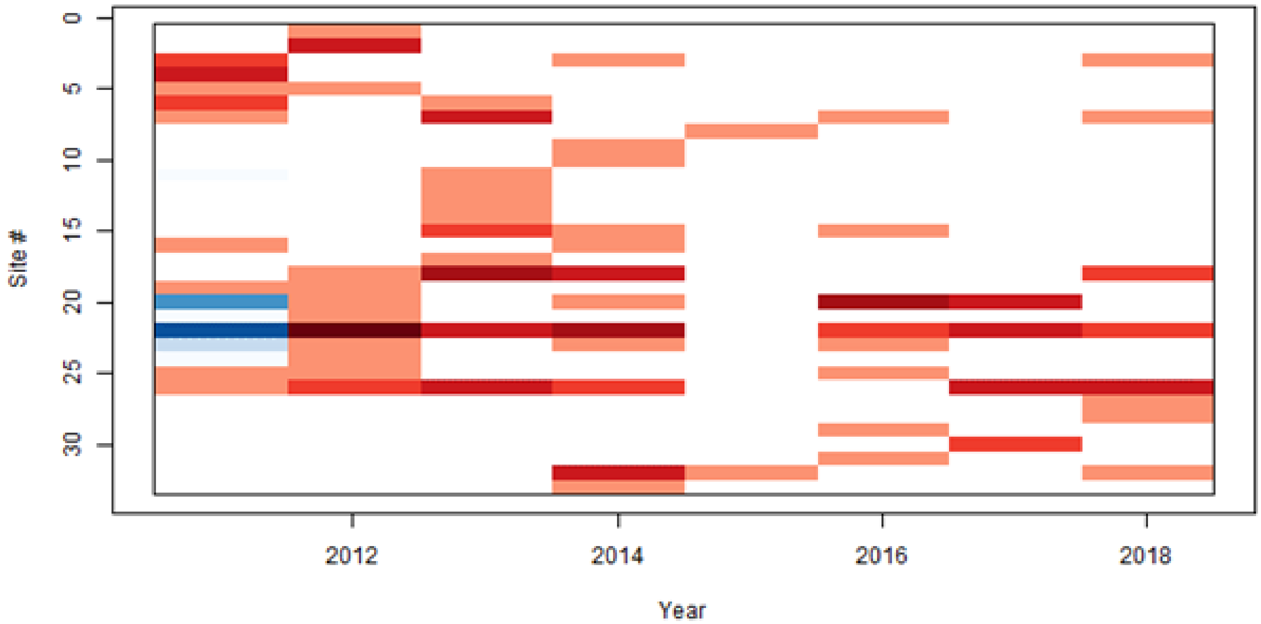


Fig. 3: Heatmap of hatching holes per site for the six hatching hole survey areas (A–F) in Skuleskogen national park. Each row denotes a deadwood item (Site #: the identification number per deadwood item). Red: recorded hatching holes; blue: imputed hatching holes for survey areas D & E added in 2012. Darker colours denote a higher number of hatching holes.

Fig. 3: Sammanlagt antal kläckhål för de olika undersökningsområdena (A–F) i Skuleskogens nationalpark. Varje rad (Site # anger stammens id-nummer) visar antalet kläckhål per stam under perioden 2011–2018. Rött: funna kläckhål; blått uppskattat antal kläckhål i områdena D och E före år 2012. Mörkare färg anger ett högre antal kläckhål.

We allowed populations to vary across sites (deadwood pieces in this case), but assumed the same growth rate between sites and constant growth rates during specific time intervals (piecewise linear, Model 2 in TRIM) (Pannekoek, Bogaart & van der Loo 2018). To identify time intervals with a constant growth rate, we carried out a stepwise selection of change points (options changepoints = "all" and stepwise = TRUE in TRIM). We allowed for overdispersion, but not for serial temporal autocorrelation as the larval development period covers several years and the number of hatching holes in one year is not thought to affect the number of hatching holes in the following year.

Potential causes of population change

The yearly hatching hole survey data could form the basis for a population viability analysis if the factors that affect the variation in the number of hatching holes can be reliably identified. The current data from the hatching hole survey is unlikely to be sufficient to investigate the environmental influences on the variation in the number of hatching holes robustly. However, we performed an analysis, which should be viewed as exploratory, to see if the current data set allows for tentative findings of potential causes of population change. To confirm, reject or refine these tentative findings, the analysis will have to be repeated, once more data are available.

We modelled the number of hatching holes in the six Skuleskogen survey areas and on the five nearby experimental log sites as a function of weather covariates. We used the hatching hole count data obtained from TRIM (see above), which included imputed hatching holes on deadwood pieces in study areas D & E, and with the count for hatching holes on experimental logs pre-2016 fixed to zero.

The following weather data were obtained from SMHI (http://opendata-download-metobs.smhi.se/explore/#) on 29th November 2018 for the weather stations SkagsuddeA (on the coast east of Örnsköldsvik, lat & long: 63.1885 & 19.0194) and VästmarkumA (north west of Docksta, lat & long: 63.1251 & 18.2555): maximum and minimum temperatures within 12 h periods and precipitation within 24 h periods. To describe weather conditions suitable for flying imagos, for each year of the hatching hole survey we calculated the number of 12 hour periods in which the maximum temperature was above 18.5 °Celsius at both weather stations and no precipitation were recorded. We also calculated the first day of the year on which these conditions occurred. These covariates were motivated by the description that imagos in the High Coast area had been observed in sunny conditions when the temperature was at least 19 °Celsius (Marklund & Marklund 2010). To describe weather conditions suitable for larvae, we calculated the number of 12 hours periods and the cumulative temperature above a threshold temperature within the six years (approximately the expected larval period in Sweden) prior to the year of hatching. With these covariates we aimed to quantify the foraging opportunities for larvae as many beetle species stop feeding below a certain temperature (Brechtel & Kostenbader 2002). As we had no information on the temperature below which *Ch. mariana* larvae cease to feed we considered 9, 11, 13 and 15 °Celsius.

Jewel beetle *Chalcophora mariana*. PHOTO: JONAS SALMONSSON

We modelled the number of hatching holes using a negative binomial distribution and a log link. To account for repeated measurements from the same deadwood item, we used a generalized linear mixed model and used the unique deadwood item identifier as random effect. We included year as a fixed effect to account for variation not captured within the weather covariates. The negative binomial distribution was chosen after initially comparing how the data fitted a poisson, negative binomial, zero-inflated poisson and a zero-inflated negative binomial distribution using AIC (Akaike information criterion, Burnham & Anderson 2004; Zuur & Ieno 2016). Selection of covariates was carried out by comparing alternative models using AIC.

Microclimate selection

To identify a possible relationship between microclimate and the number of hatching holes, we used data recorded in autumn 2018. Hatching holes were recorded in nine survey areas, three in Skuleskogen national park (4.1 ha), three on the Fanön peninsula (2.9 ha) and three on the island of Mjältön (3 ha). All deadwood items with a diameter of at least 10 cm were inspected and their location was recorded with a GPS. For each item, the number of hatching holes (including zero counts) in three age classes was recorded. The assignment of hatching holes to age classes was approximate and the accuracy of the ageing is unknown. It was assumed that the three classes distinguished between hatching in 2017–2018 (new), hatching less than ten years ago, but not in 2017–2018 (old), hatching earlier than ten years ago (very old). Deadwood items that were no longer suitable as substrate because they had disintegrated were also recorded.

To describe microclimate at deadwood locations we calculated average solar radiation (direct and indirect radiation), curvature of the terrain and the total volume of living trees. Curvature was included, because the shape of the terrain (concave or convex) can influence microclimate. Tree volume was included because denser forest produces more shading. We calculated radiation and curvature from a digital terrain model (DTM, GSD-Höjddata, grid 2+, spatial resolution: 2 m) obtained from http://maps.slu.se/get on 7th December 2018. Tree volume was extracted from the SLU Skogskarta with a spatial resolution of 25 m for the year 2005 (https://www.slu.se/centrumbildningar-och-projekt/riksskogstaxeringen/statistik-om-skog/slu-skogskarta/). We calculated solar radiation as the cumulative radiation between the period 1st May to 10th September, using sampling intervals of seven days for the whole period and 30 min per day. Curvature was calculated at the spatial resolution of the DTM (2 m). For solar radiation we chose a coarser spatial resolution of 10 m assuming that this would better reflect local temperatures due to air circulation. Note, that the survey areas were already selected to be in areas of higher solar radiation and in areas of more open forest.

To identify a possible relationship between microclimate and the number of hatching holes per deadwood item we modelled the number of hatching holes of any age using a negative binomial distribution and a log link. To account for the clustering of deadwood items within the three areas (Skuleskogen Fanön, Mjältön), we used a generalized linear mixed model and used area as random effect. We chose the negative binomial distribution after initially comparing how the data fitted a poisson, negative binomial, zero-inflated poisson, zero-inflated negative binomial distribution and a hurdle model using AIC. Variable selection for the microclimatic covariates was carried out using AIC.

Software

Radiation and curvature was calculated in ArcGIS 10.4.1. All other analyses were carried out with the software R.3.5.1 (R Core Team 2018) using packages sp (Bivand, Pebesma & Gómez-Rubio 2008), rgdal (Bivand, Keitt & Rowlingson 2016), raster (Hijmans 2016), rtrim (Bogaart, van der Loo & Pannekoek 2018), glmmTMB (Brooks et al. 2017), MuMIn (Barton 2018) and DHARMa (Hartig 2018).

Results

Climate

In comparison with other regions in which *Ch. mariana* was recorded, the minimum temperature in winter (January and February) in Sweden was low (Fig. 4, see Appendix 1 for additional months). However, the species has been recorded at sites in the Baltic, Russia/Ukraine and Turkey with lower minimum temperatures than in Sweden (Fig. 4). There are few sites in Russia/Ukraine and Turkey and for clarity, additional plots comparing these regions with Sweden are provided in Appendix 2.

The average temperature at Swedish *Ch. mariana* sites from April to August was lower than, and mostly outside the range of temperatures experienced by other popula–tions (Fig. 5, see Appendix 1 for additional months and Appendix 2 for plots focusing on Russia/Ukraine and Turkey versus Sweden). Swedish sites received some of the highest solar radiation in June and some of the lowest in winter, early spring and autumn compared to sites outside of Sweden (Fig. 6, Appendix 1 & 2).

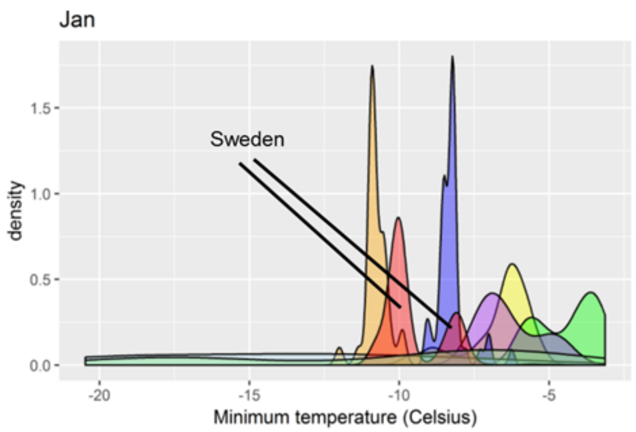
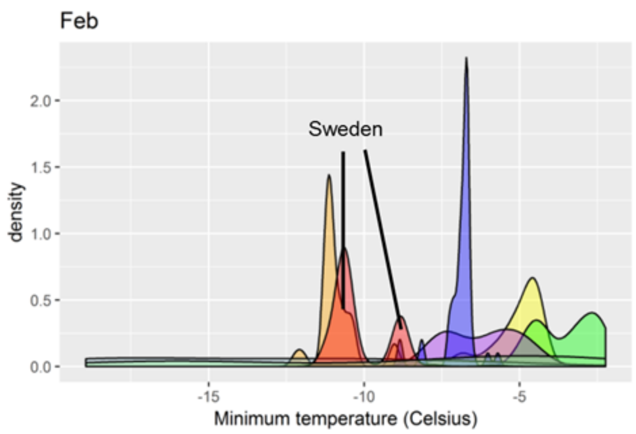


Fig. 4: Plots of kernel density estimates of minimum temperature for January and February per region for sites at which *Ch. mariana* was recorded. Kernel density estimates show the distribution of the data. For example for Sweden in January, most *Ch. mariana* sites experience average minimum temperatures around -10 °C, while a smaller proportion of sites experience temperatures around -8 °C.

Fig. 4: Fördelning av minimitemperaturer (kernel density) på lokaler med förekomst av jättepraktbagge under januari och februari uppdelat på olika regioner. Det visar temperaturintervall för respektive region; t.ex. är medelminimitemperaturen under januari för de flesta svenska lokalerna kring -10 °C, medan den för ett mindre antal lokaler ligger kring -8 °C.



Region

- Austria and adjacent areas
- Baltic
- Germany and adjacent areas
- Norway
- Poland
- Russia/Ukraine
- Sweden
- Turkey

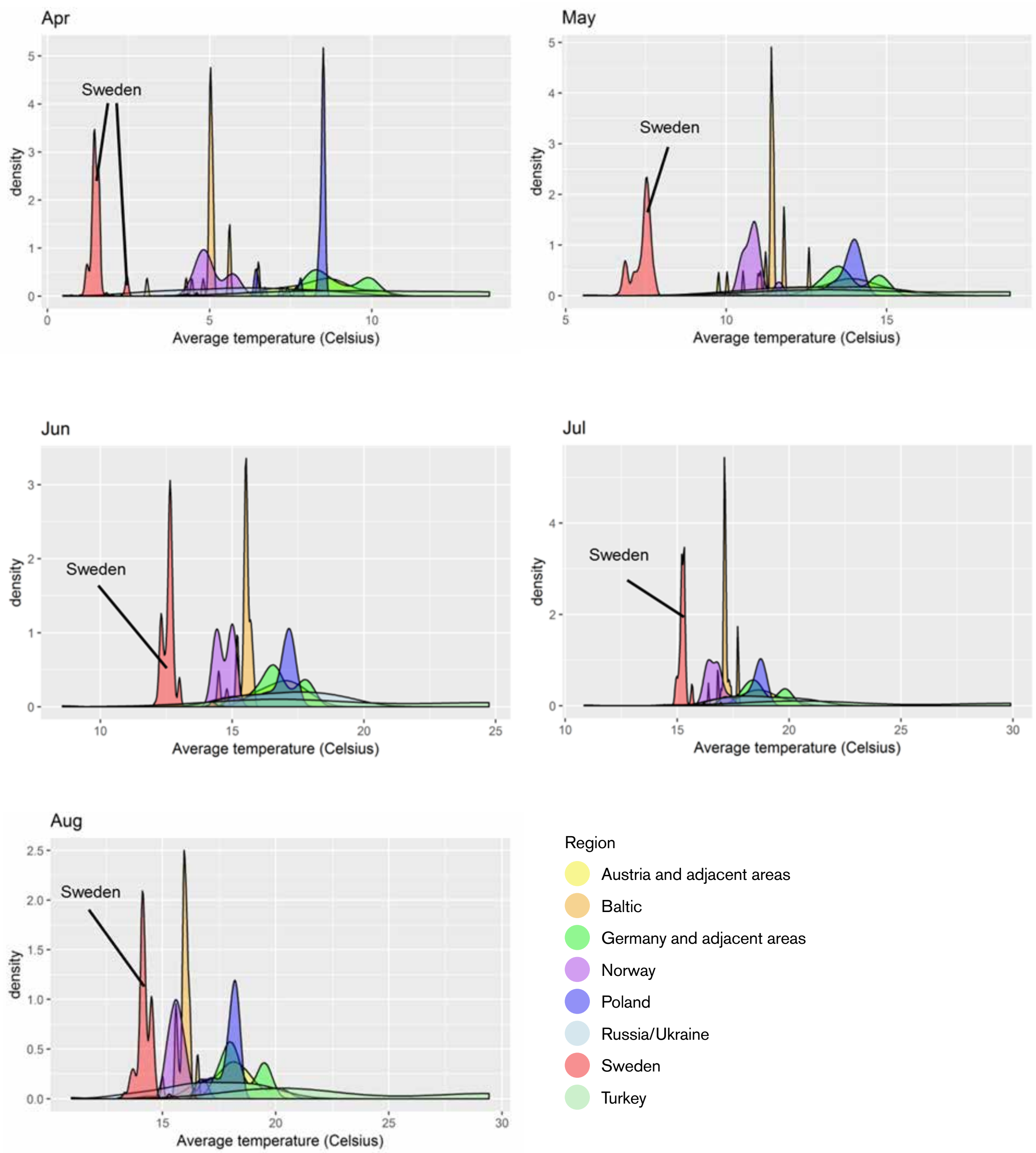


Fig. 5: Plots of kernel density estimates of average temperature for April to August per region for sites at which *Ch. mariana* was recorded.

Fig. 5: Fördelning av medeltemperaturer (kernel density) på lokaler med förekomst av jättepraktbagge under perioden april till augusti uppdelat på olika regioner.

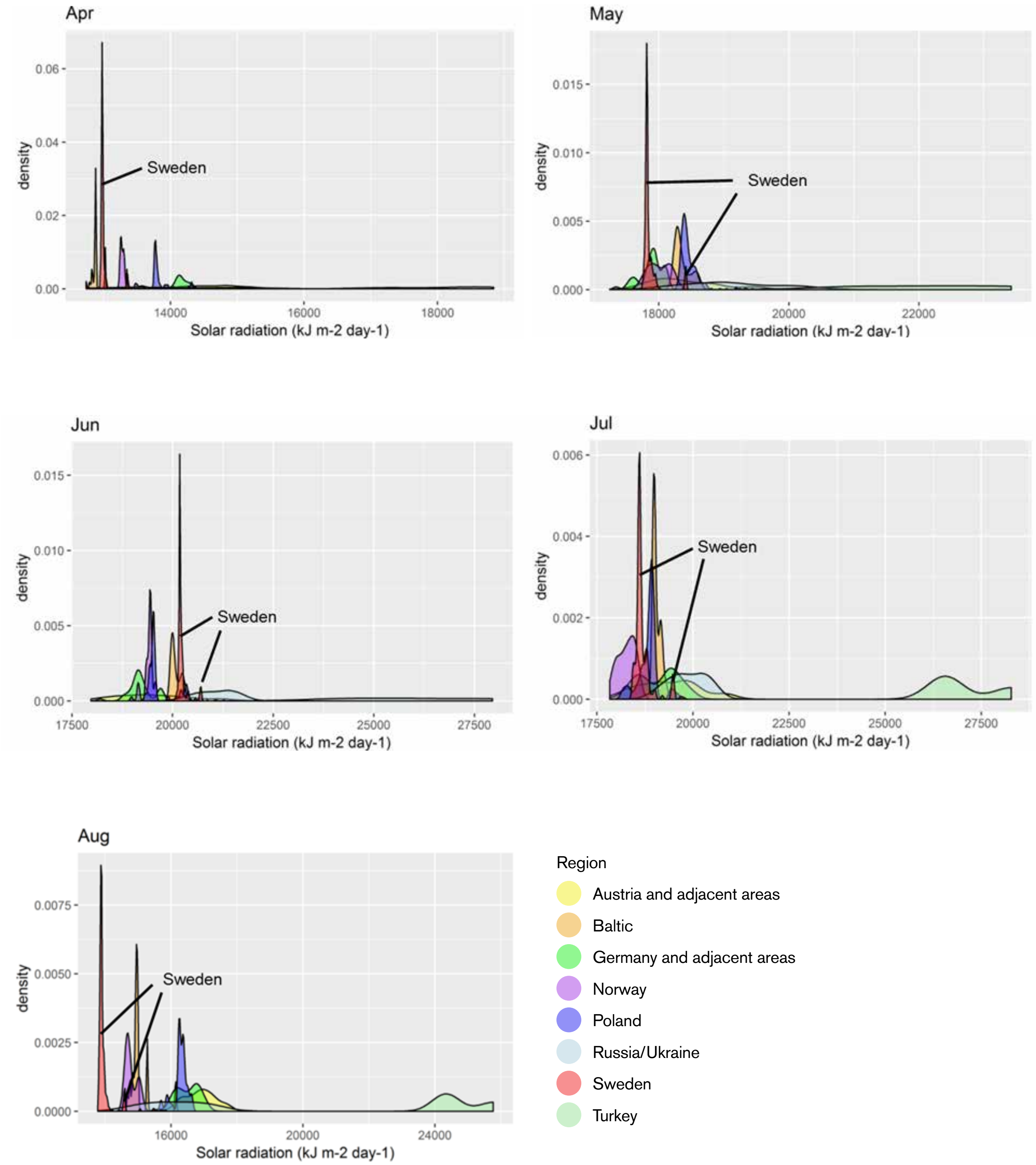


Fig. 6: Plots of kernel density estimates of solar radiation for April to August per region for sites at which *Ch. mariana* was recorded.

Fig. 6: Solinstrålning (kernel density) på lokaler med förekomst av jättepraktbagge under perioden april till augusti uppdelat på olika regioner.

Experimental logs. PHOTO: UTE BRADTER

Predicted minimum and maximum temperatures at Swedish sites for the year 2050 vary between the GCMs (Appendix 3 and 4). Several GCMs for a radiative forcing of 4.5 (Appendix 3) predict that Swedish sites will experience temperatures that are more similar or even exceed temperatures currently experienced at Baltic sites in some spring and summer months. For a radiative forcing of 8.5 W/m2 predicted temperatures are even higher (Appendix 4).

Population trend based on the yearly hatching hole survey

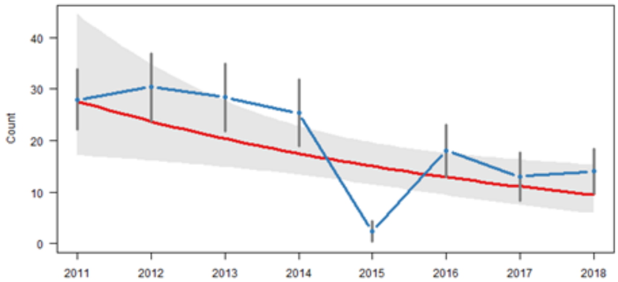
All models estimated a significant moderate decrease in the number of hatching holes for the period 2011-2018 (Fig. 7). For models in which we had fixed the pre-2016 counts on experimental logs nearby the survey areas to zero, the rate of decline was -0.12 (se: 0.04, $p < 0.05$). For all other models, it was -0.15 (se: 0.05, $p = 0.02$). For all models, the population growth rate was constant and showed no significant trend during the period 2011 – 2014 and also during the period 2016 – 2018 (Fig. 7).

Within the largest of the six survey areas (Site A, Fig. 2), the number of hatching holes showed no significant trend between 2011-2018 (Fig. 8a). The data was insufficient to estimate the population trend for each of the other areas. For the five other areas combined (sites B – F, Fig. 2) the population trend showed a moderate decrease with a slope of -0.21 (se: 0.07, $p = 0.03$, Fig. 8b). Notably, on the deadwood item with ID 13 in area D, 11 hatching holes were recorded in 2012, five more than on any other deadwood item. In later years at most five hatching holes were recorded on this item, which strongly affects the population trend.

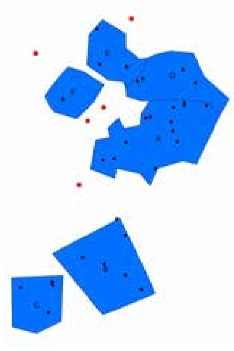
Potential causes of population change

In our exploratory model of potential causes of population change, we tentatively found that the number of hatching holes increased with a higher number of dry 12 hour periods with a minimum temperature of 19 °Celsius in the year of hatching and decreased the later the first such day occurred in the year of hatching and six years prior. The covariate year was also retained in the model and was negatively associated with the number of hatching holes.

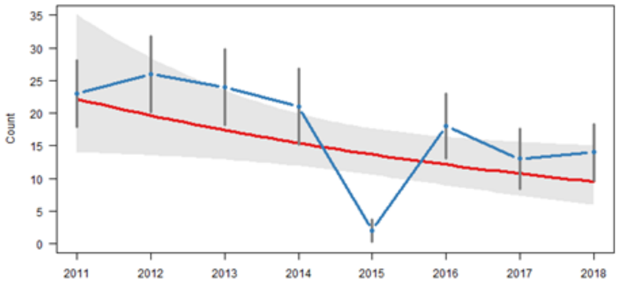
a) Sixa survey areas and nearby experimental logs; with imputation for experimental logs pre-2016



a) and b)

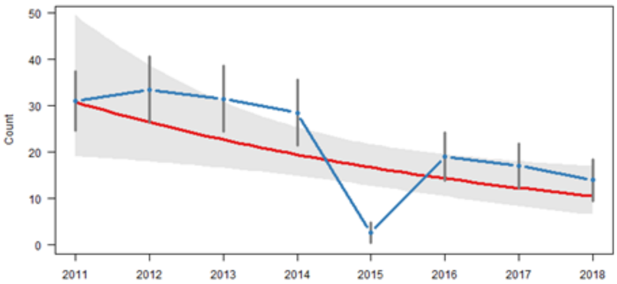


b) Six survey areas and nearby experimental logs; no imputation for experimental logs

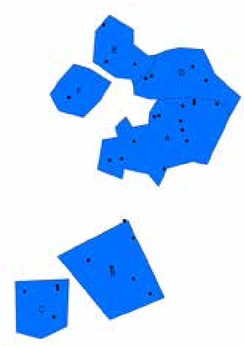


c) and d)

c) Six survey areas and all experimental logs; with imputation for experimental logs pre-2016

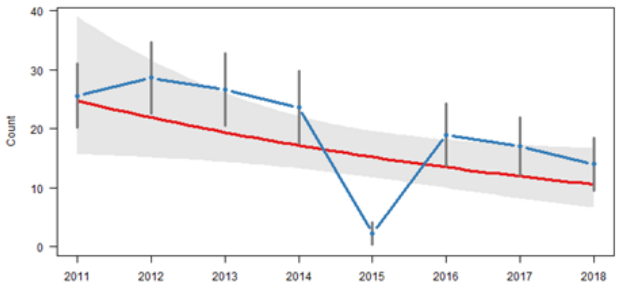


e)



Experimental logs: red. For full legend, see Fig. 2.

d) Six survey areas and all experimental logs; no imputation for experimental logs near study areas



e) Six survey areas

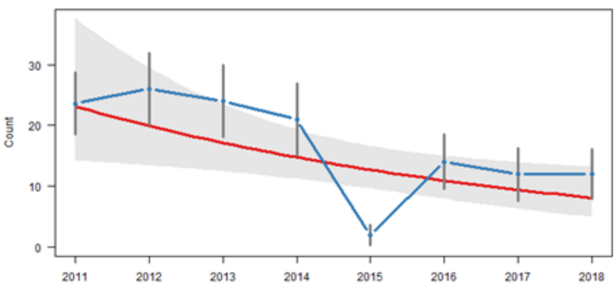
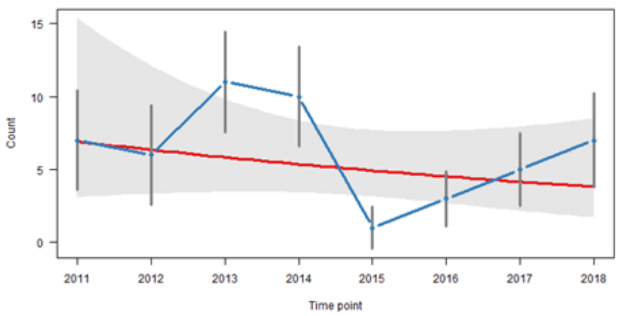


Fig. 7: The trend of the number of hatching holes within the survey areas and nearby experimental logs (a, b), the survey areas and all experimental logs (c, d) and the survey areas (e). The number of hatching holes for experimental logs near the survey areas were imputed pre-2016 for plots (a, c), but not for plots (b, d). The plots show the overall hatching hole trend 2011–2018 (red line), its 95% confidence band (grey polygon), the number of fresh hatching holes per year (blue line) and their 95% confidence intervals (grey bars).

Fig. 7: Förändring av antalet kläckhål inom undersökningsområdena och de närbelägna experimentstockarna (a,b), undersökningsområdena och samtliga utlagda experimentstockar (c,d), samt enbart inom undersökningsområdena (e). Antalet kläckhål i experimentstockarna före 2016 (beräknat utifrån TRIM-modellen) är inkluderat i figurerna (a,c), men inte i figurerna (b,d). Figurerna visar den generella utvecklingen av färska kläckhål 2011–2018 (röd linje) med 95 % konfidensintervall (grått fält), samt antalet färska kläckhål enskilda år (blå prickar) med 95 % konfidensintervall (staplar).

Habitat. PHOTO: UTE BRADTER

a) Area A



b) Areas B–F

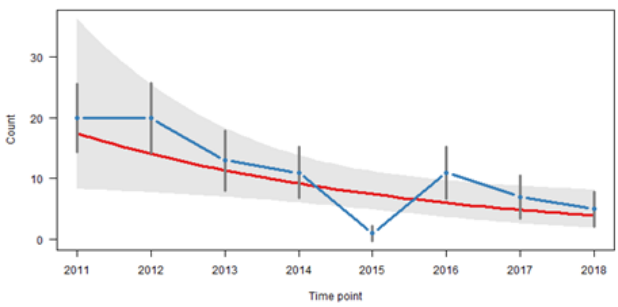
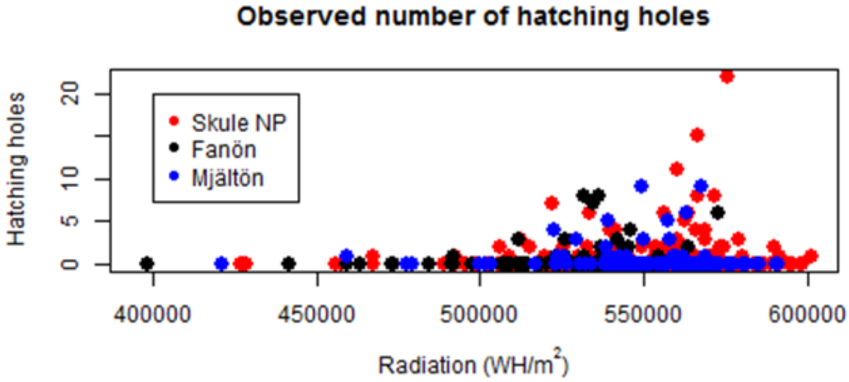


Fig. 8: The trend of the number of hatching holes within the largest of the six survey areas (a), and in the remaining survey areas (b) (see Fig. 2). The plots show the overall fresh hatching hole trend 2011–2018 (red line), its 95% confidence band (grey polygon), the number of fresh hatching holes per year (blue line) and their 95% confidence intervals (grey bars).

Fig. 8: Förändring av antalet kläckhål inom det största undersökningsområdet (a) samt övriga undersökningsområden (b) (se Fig. 2). Figurerna visar den generella utvecklingen av färska kläckhål 2011–2018 (röd linje) med 95 % konfidensintervall (grått fält), samt antalet färska kläckhål enskilda år (blå prickar) med 95 % konfidensintervall (staplar).

Microhabitat selection

The number of hatching holes in the 2018 survey data from Skuleskogen, Fanön and Mjältön was positively associated with solar radiation (Fig. 9). Solar radiation was the only covariate retained in the final model. Note however, that most observations were collected on deadwood items receiving higher radiation values. Such sampling bias can affect the model outcome.



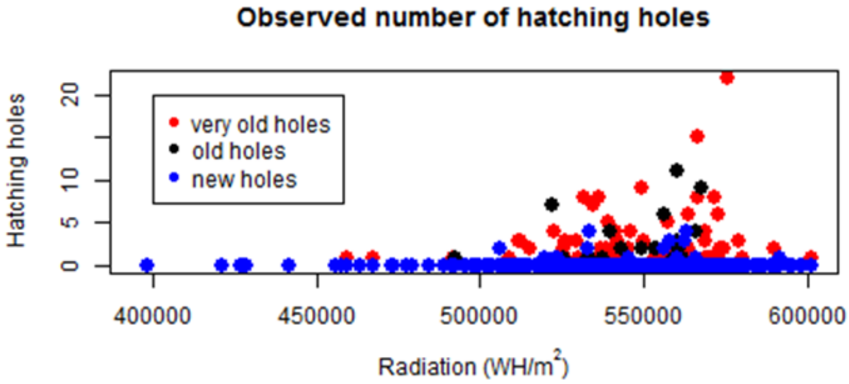


Fig. 9: The observed number of hatching holes per deadwood item and the global radiation the logs received per study area (above) and per age class (below). Data from 2018.

Fig. 9: Antalet observerade kläckhål per stam i förhållande till den genomsnittliga instrålningen per studieområde (ovan), respektive antalet kläckhål av olika ålder i förhållande till den genomsnittliga instrålningen per studieområde (nedan). Data från 2018.

The study areas Skuleskogen, Fanön and Mjältön of the 2018 survey

Few of the deadwood logs on Fanön were exposed to the higher radiation values received by some of the logs in Skuleskogen and on Mjältön (Fig. 10). The percentage of intact (not disintegrated) deadwood logs was particularly high on Mjältön (Fig. 11). The number of logs with hatching holes per ha was higher in Skuleskogen than on Fanön or Mjältön (Fig. 12). In the Fanön study sites only one hatching hole was recorded among those assumed to have hatched within the last ten years (new and old hatching holes; Fig. 12).

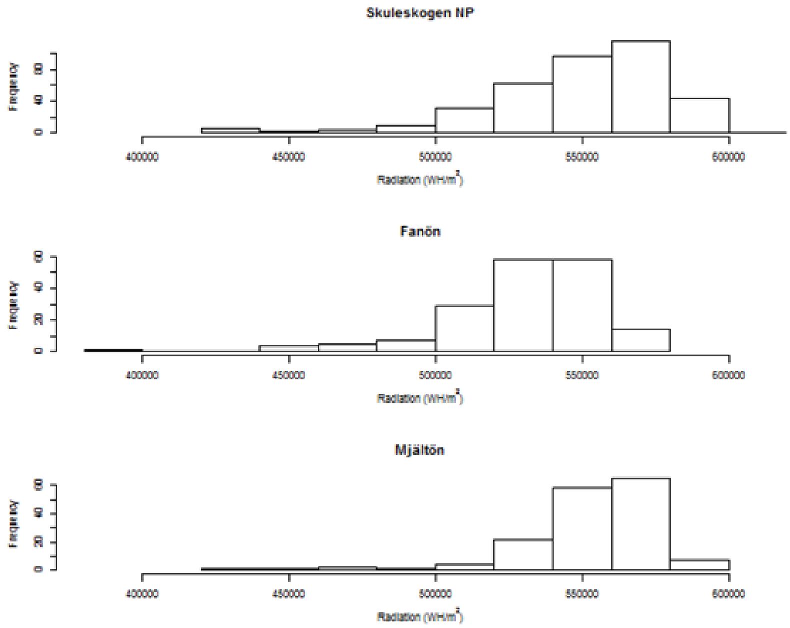


Fig. 10: Histograms of the radiation (Wh/m²: Watt hours per m²) received by deadwood logs (recorded in the 2018 survey) in Skuleskogen national park, Fanön and Mjältön.

Fig. 10: Instrålning (Wh/m², watt timmar per m²) per stam i de tre undersökningsområdena: Skuleskogens nationalpark, Fanön och Mjältön. Data från 2018.

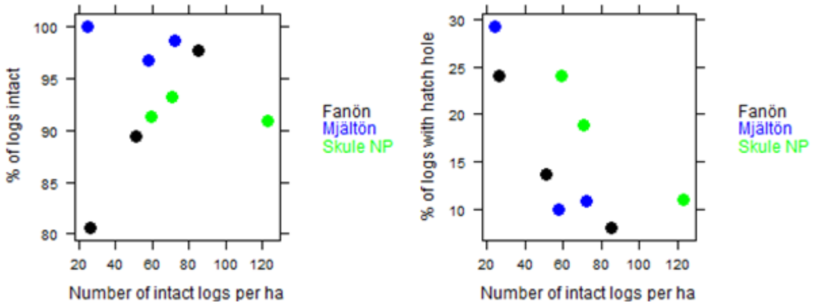


Fig. 11: The percentage of intact (not disintegrated) deadwood logs (left) and of logs with hatching holes (right) plotted over the number of intact logs per ha. Data from 2018.

Fig. 11: Andelen intakta (ej nedbrutna) stammar (t.v.) samt andelen stammar med kläckhål (t.h.) i förhållande till antalet intakta stammar per hektar i de tre undersökningsområdena. Data från 2018.

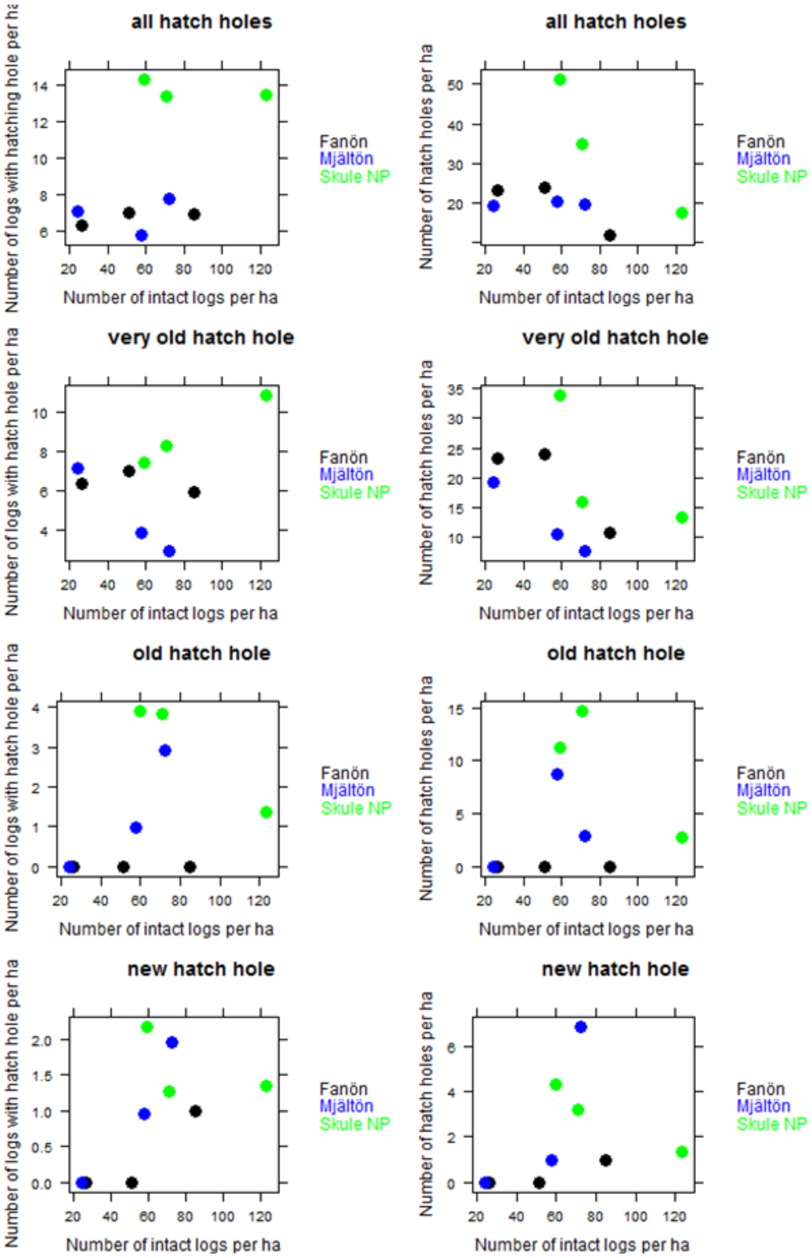


Fig. 12: Left column: The number of logs with hatching holes per ha plotted over the number of intact (not disintegrated) deadwood logs per ha. Right column: The number of hatching holes per ha plotted over the number of intact logs per ha. Rows from top to bottom: all hatching holes, very old hatching holes (assumed to be older than 10 years in 2018), old hatching holes (assumed to be between 2 and 10 years old in 2018), new hatching holes (assumed to be from 2017 or 2018). Data from 2018.

Fig. 12: Till vänster: antalet stockar med kläckhål per hektar i förhållande till antalet intakta (ej nedbrutna) stockar per hektar. Till höger: antalet kläckhål per hektar i förhållande till antalet intakta stockar per hektar. Uppifrån och ned: samtliga hål, mycket gamla hål (förmodat > 10 år), gamla hål (2–10 år) samt nya hål (1 år gamla). Data från 2018.

Discussion

The results and conclusions in this report should be treated as indicative only, due to the relatively narrow temporal and spatial extent of the data, which does not support the inference of robust conclusions on population trend, population viability or habitat selection. Re-evaluations should be carried out when more data become available.

Climate

Descriptions of the ecology of *Ch. mariana* emphasize the preference for warm and sun-exposed conditions (Brechtel & Kostenbader 2002). Winter temperatures in Sweden are unlikely to be at the extreme edge of what the species can tolerate as sites in the Baltic, Russia/Ukraine and Turkey experience even colder minimum temperatures. While it is unknown if these populations have a stable trend, winter snow cover of low lying deadwood will likely also insulate *Ch. mariana* from the most extreme winter temperatures.

The average temperatures at *Ch. mariana* sites in Sweden between April and August are lower than at other sites the species is known to occur. In contrast, solar radiation in June at Swedish sites is higher and precipitation lower than at most other known sites. This supports the suggestion that a sun-exposed microclimate is very important for the Swedish population (Marklund & Marklund 2010). In the High Coast area such conditions occur due to the sparse forest cover on rocky ground. It has also been suggested that the distribution of the current population along the coast is due to the increase in sunshine hours close to the coast compared to the inland of Sweden (Marklund & Marklund 2010).

The long-term chances for persistence of the species in Sweden will likely improve with climate change, particularly if the long-term lack of sufficient suitable substrate (deadwood) in many areas is addressed. Climate change is predicted to raise spring and summer temperatures at Swedish sites likely to within the range currently experienced by populations abroad. However, in addition to, on average, increasing temperatures, climate change may also lead to other changes (e.g. cloud cover), which may also have a negative impact on the population. Climate change may also lead to increased forest growth and denser forest, potentially decreasing the number of sun-exposed locations.

Population trend based on the yearly hatching hole survey

The number of hatching holes showed a moderate decrease between 2011 and 2018. Assuming that the experimental logs belong to the same population as the long-term survey areas, the overall rate of decrease was -0.12, otherwise it was -0.15.

Of note is that a single deadwood item was responsible for much of the observed decline. In 2012, eleven fresh hatching holes were recorded on this item, far more than on any other deadwood item (max: 6) or in a later year on the same item (range: 0–5). The 2012 count is assumed to be correct (and not for example the combined count for 2011 and 2012 due to poor conditions for the correct identification of fresh hatching holes in 2012) and it is likely that this log represents an exceptionally suitable substrate in decline. Photographs of the deadwood item support the 2012 count figure and show an overall high number of hatching holes on this deadwood item (Wörler & Bader 2019, pers. comm.). Of note is also, that the population trend estimate is based on data from one area in Skuleskogen and may therefore not be representative for the whole population.

Potential causes of population change

In exploratory models we found that the number of hatching holes was positively associated with a higher number of days with good flying conditions and an earlier occurrence of the first day with good flying conditions in the year of hatching. We also found that the number of hatching holes was positively associated with an earlier occurrence of the first day with good flying conditions six years prior to hatching. As previously emphasized, these results are tentative, because they are based on little data and would need to be confirmed, rejected or refined once more data is available.

Microhabitat selection

Deadwood items receiving higher radiation values produced on average a larger number of hatching holes. However, we could not consider the effect of shading by trees or of wind chill on temperatures. Nor could we consider the length of time dead wood items had been available as substrate. Survey sites were already in areas with low tree density. Consequently, this effect could not fully be considered. Furthermore, only few observations were available from deadwood items receiving lower radiation values. Hence these results should be regarded as preliminary and further data should be collected to confirm or reject these results.

Given the small extent of the current known population of the species, it is prudent to consider the possible importance of source-sink dynamics and environmental stochasticity for the species. Sources are self-sustainable populations that produce emigrating surplus individuals while sinks are areas that are not self-sustainable and rely on immigration (Pulliam 1988). Few source areas can sustain a sink population in a much larger area (Pulliam 1988). For the *Ch. mariana* population in the High Coast area it is possible that suitable deadwood items in micro-climatically favourable locations form source habitat while deadwood items in micro-climatically less favourable locations may form sink habitat. In small populations like the High Coast population, by chance few deadwood items may be located in micro-climatically favourable conditions. If such deadwood items are indeed those sustaining the population, a below average availability of such substrate could have a strong negative effect on the viability of the population.

Recommendations for future monitoring, research and conservation

▪ Population trend monitoring

Monitoring the number of hatching holes represents a convenient way to monitor the population trend of the species and a continuation of the yearly hatching hole survey is therefore valuable. However, the current hatching hole survey sites are concentrated in one area while the known distribution area of the currently reproducing population is larger and consists of three distinct areas. Moreover, it is unclear if there are further areas with a currently reproducing population in the vicinity of the known areas. The population trend based on the yearly hatching hole survey may therefore not be representative for the High Coast population.

We recommend that areas suitable for the species (open forests receiving high solar radiation) in the vicinity of the known current distribution of the species (such as other areas of Skuleskogen national park) are surveyed to gain a better understanding of the current distribution of the species. Such surveys could potentially be carried out by skilled volunteers, who should be encouraged to delineate the areas they searched, record the location of surveyed deadwood items (GPS co-ordinates including of deadwood items on which no hatching holes were found) and record the number of fresh and old hatching holes per deadwood item. Such data could then be used not only as a basis to establish a more representative hatching hole monitoring program, but also to get a better understanding of substrate selection and the potential distribution area of the species (see below).

Until it is known if there are further areas in the vicinity of the currently known population in which the species currently reproduces, we recommend that the yearly hatching hole survey is continued as before (Area F could be omitted to save effort, and if necessary, area D could be halved), but that sites on Mjältön are included in the yearly survey.

Once a better understanding of the distribution of the currently reproducing population in the vicinity of Skuleskogen is obtained, we recommend assessing how representative the current survey sites are for this population by assessing how different the current distribution of study sites is compared to a random or regular distribution of sampling sites. Random or regular sampling tends to produce the most representative and robust results (Sutherland, Newton & Green 2004). Due to the patchy nature of the distribution area of the species, random sampling is likely easier to implement whereby sampling units are selected randomly over the distribution area. For example the distribution area can be divided into grid cells of the size of sampling units and cells are drawn randomly. The size and number of sampling units should be chosen to achieve a good compromise between a wide spread of sampling units and practicability (the time it takes to move from one sampling unit to the next).

Should this comparison find that the current distribution of sampling sites is not representative, a re-design of survey sites may be necessary. As several years of survey data already exist, we suggest to incorporate as much of the existing survey areas in the new design as is possible without compromising representativeness to enable the collection of longer time-series data. If such a re-design will be necessary, it will be important to initially survey new and old sampling units in parallel to ensure data continuity before a final switch to a more representative distribution of sample sites.

We suggest to re-estimate the trend in the number of hatching holes every 1 (-2) years to monitor the development of the population.

▪ Substrate selection

A good understanding of substrate selection by the species is important if efficient management measures to benefit the species are to be carried out. We found an association between the number of hatching holes on a deadwood item and microclimate (however, the data and subsequently the model had limitations, see above). A dedicated study could overcome these limitations; for example an MSc project in which temperature is measured over a prolonged period (e.g. via temperature loggers at a sample of the deadwood items surveyed since 2011). Such a study could take into account the effect of shading by trees and wind chill, which our study couldn't and also collect data representatively (i.e. not undersampling deadwood logs receiving lower radiation values as in the data we had available). To gather representative data the choice of sample sites (deadwood items) could be stratifying by the number of fresh hatching holes recorded between 2011 and the latest survey (including zero counts). Within each stratum deadwood items could be randomly selected which should ensure a wide spatial spread.

If an association between the number of hatching holes and microclimate is confirmed by such a study, the temperature logger data could potentially be used to produce a microclimate map if suitable LiDAR data are available, that would allow taking the effect of shading by trees and potentially wind chill into account. This map could then be used for a possible conservation action: the moving of deadwood items from less sun-exposed locations into micro-climatically more suitable locations.

Currently, little is known about the requirements of the species on its substrate. Deadwood items with larger diameters were preferred over smaller diameters (Sandberg & Malm 2012). We had little data on substrate characteristics available for the deadwood items in our data and therefore did not include substrate characteristics in this study. We recommend that for the deadwood items of the yearly hatching hole survey (and for the deadwood items of a temperature logger study if it should take place), substrate characteristics such as deadwood dimensions and decomposition state are recorded to enable an inclusion of such characteristics in a future analysis.

▪ Hotspots of suitable habitat / Potential future distribution area

The information that the species was searched for, but not found, is important information. Such information is very useful for species distribution models, which can be used to produce maps of the distribution of a species outside of survey sites. Hence they can highlight areas of particularly suitable habitat for the species and give a better idea of the potential distribution area of the species (which may be occupied if the population increases and spreads).

Therefore, we recommend that whenever sites are being searched for hatching holes of the species, not only positive findings of the species are recorded, but also non-detections (e.g. a GPS location of a surveyed deadwood item with a record of the number of fresh / old hatching holes or the information that no hatching holes were found).

▪ Potential population viability analysis

Representative yearly hatching hole survey data can be used to empirically estimate the population viability of the species if the variation in the trend can be explained by environmental variation and / or biotic factors, such as local population density. Given the long generation time of the species, a relatively long time series of data will be needed for a robust estimate. Our exploratory analysis of potential causes of population change showed that with the currently available data, no robust association with environmental variation can yet be established. We recommend that this analysis is repeated in 4-5 years' time, or earlier if considerable changes in the number of yearly hatching holes are observed in the meantime.

Information on the size of other small isolated populations and their population trend, or of the density of fresh hatching holes in other populations may also give insight into the viability of the Swedish population. We suggest publishing a call for information in an entomological journal commonly read by entomologists in countries hosting populations of the species as more data may already have been collected than is available in the peer-reviewed literature.

▪ Potential conservation action and further knowledge gaps

Recommendations for the conservation of the species outside of Sweden are available for south-west Germany and include to maintain and increase areas of open and old pine forest aiming for a high density of large dimensional deadwood of old pine. Recommendations for the final felling of pine trees are to cut some distance above ground-level, not at ground-level, thus leaving stumps (Brechtel & Kostenbader 2002).

We have suggested a study to better evaluate the association between the number of hatching holes and microclimate. Conservation action to follow a positive confirmation of this association could be the moving of deadwood items from climatically unfavourable to more favourable conditions. The success (or lack thereof) of such action should be monitored, by comparing the trend in hatching hole numbers on the items in their old location versus the trend in the new location. The yearly number of hatching holes in the vicinity of the locations should also be recorded to be able to account for effects of varying population density.

If conservation measures, such as the provision of additional substrate are taken, their success should also be monitored by matching treatment areas (with additional substrate) with control areas (no additional substrate) and comparing the population trend before the addition of substrate with the population trend after the addition of substrate between both areas. Treatment and control sites need to be far enough apart, so that the addition of substrate in treatment sites does not (or only little) affect the beetle population at control sites. Due to the small overall size of the population, the number of independent treatment and control sites will be small. Ideally, treatment and control sites should also be paired, so they experience similar conditions (e.g. sun exposure, local population density), which will also be limited by the small extent of the population. Statistical testing of results may therefore be infeasible. Still, a comparison of the population trend between treatment and control sites can be informative, even without the possibility for robust statistical testing.

Little is known about what attracts the species to suitable sites although fires and tree felling have been suggested (Marklund & Marklund 2010). Behavioural observations in controlled experiments (e.g. where Ch. mariana in enclosures are given the choice between different items of substrate) may enhance our knowledge. Such studies with individuals from a small, threatened population may have a negative influence on the population, but it may be possible to collaborate with researchers abroad and to study such questions with individuals from a less threatened population.

There is also a lack of knowledge as to the mechanistic effect of cool, cloudy summers on hatching of the species. An important question is whether this delays hatching or whether individuals due to hatch die before hatching. This could also be studied in experiments with individuals from a less threatened population.

References

Barton, K. (2018) MuMIn: Multi-Model inference. R package version 1.42.1. https://CRAN.R-project.org/package=MuMIn.

Bivand, R., Keitt, T. & Rowlingson, B. (2016) rgdal: Bindings for the Geospatial Data Abstratction Library. R package version 1.4-3. http://CRAN.R-project.org/package=rgdal.

Bivand, R.S., Pebesma, E.J. & Gómez-Rubio, V. (2008) *Applied spatial data analysis with R*. Springer, New York.

Bogaart, P., van der Loo, M. & Pannekoek, J. (2018) rtrim: Trends and Indices for Monitoring Data. R package version 2.0.6. https://CRAN.R-project.org/package=rtrim.

Brechtel, F. & Kostenbader, H. (2002) *Die Pracht- und Hirschkäfer Baden-Württembergs*. Ulmer.

Brooks, T.M., Kristensen, K., van Benthem, K.J., Magnusson, A., Berg, C.W., Nielsen, A., Skaug, H.J., Maechler, M. & Bolker, B.M. (2017) glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. *The R Journal*, 9, 378-400.

Burnham, K.P. & Anderson, D.R. (2004) Multimodel inference : Understanding AIC and BIC in model selection. *Sociological Methods & Research*, 33, 261-304.

Ehnström, B. & Bader, P. (2013) Åtgärdsprogram för jättepraktbagge, 2013-2017. Rapport 6584, Naturvårdsverket.

Fick, S.E. & Hijmans, R.J. (2017) Worldclim 2: New 1-km spatial resolution climate surfaces for global land areas. *International Journal of Climatology*, 37, 4302-4315.

GBIF.org (13th November 2018) GBIF Occurrence Downlaod. https://doi.org/10.15468/dl.eyls2g.

Hartig, F. (2018) DHARMa: Residual diagnostics for hierarchical (multi-level / mixed) regression models. *R package version 0.2.0. http://CRAN.R-project.org/package=DHARMa.*

Hijmans, R.J. (2016) raster: Geographic Data Analysis and Modeling. R package version 2.8-19. https://CRAN.R-project.org/package=raster.

Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G. & Jarvis, A. (2005) Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology*, 25, 1965-1978.

Leidenberger, S., Käck, M., Karlsson, B. & Kindvall, O. (2016) The Analysis Portal and the Swedish LifeWatch e-infrastructure for biodiveristy research. *Biodiversity Data Journal*, 4, e7644.

Marklund, D. & Marklund, S. (2010) Inventering av jättepraktbagge Höga kusten Ångermanland. Länsstyrelsen Västernorrland avdelningen för Miljö och Natur.

Pannekoek, J., Bogaart, P. & van der Loo, M. (2018) Models and statistical methods in rtrim. pp. 1-34. Statistics Netherlands, The Hague, Netherlands.

Pulliam, H.R. (1988) Sources, sinks, and population regulation. *The American Naturalist*, 132, 652-661.

R Core Team (2018) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Sandberg, E. & Malm, Y. (2012) Skuleskogens hällmarkstallskogar - Jättepraktbaggens livsmiljö. Mittuniversitetet.

Sutherland, W.J., Newton, I. & Green, R.E. (2004) *Bird ecology and conservation*. Oxford University Press, Oxford.

Zuur, A.F. & Ieno, E.N. (2016) *Beginner's guide to zero-inflated models with R*. Highland Statistics Ltd., Newburgh, UK.

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Most of the work conducted at SLU Swedish Species Information Centre fits into Swedish University of Agricultural Sciences program for Environmental Monitoring and Assessment, focusing on the long term goals of sustainable development expressed by the Parliament in, e.g., the Swedish Environmental Objectives. We work with commissions from the Government and other authorities within the field of Swedish biodiversity, frequently in cooperation with various NGOs. We also conduct research in the fields of Ecology and Conservation.

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