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# Widespread Decline of Ground Beetles in Germany

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**Received:** 13 January 2025 | **Revised:** 21 August 2025 | **Accepted:** 16 October 2025

**Editor:** Boris Leroy

**Funding:** This work was supported by Deutsche Forschungsgemeinschaft, DFG-FZT 118, 202548816.

**Keywords:** citizen science | insect conservation | insect decline | insect monitoring | long-term change | occupancy detection model | trend analysis

## ABSTRACT

**Aim:** Many insect species are facing existential crises, primarily due to diverse human activities. Most insect assessments, however, are based on relatively short time series or some iconic species. Here, we assess how the occupancy of ground beetles has changed in Germany over the last 36 years.

**Location:** Germany.

**Methods:** In close collaboration with taxonomic experts from natural history societies, we compiled the best available occurrence data for ground beetles in Germany, estimated the changes in species occupancy over time, and related these changes to species traits and characteristics.

**Results:** We obtained trends for 383 species and found that 52% of species significantly declined, and 22% significantly increased in site occupancy over the last 36 years. The remainder of the species (26%) all showed a mean negative trend, albeit nonsignificant. Species classified as non-threatened in the German red list declined at a similar rate as threatened species, with 64% of the Near Threatened species experiencing significant declines (highest among all red list categories). Across all traits, we found that large (compared to medium-sized) and omnivore (compared to predator) species declined less.

**Conclusions:** Since ground beetles are key predators in many natural and agricultural ecosystems that play an important role in pest control and the food chain, their decline should raise concerns. Thus, we urgently plead for more harmonised and systematic monitoring of this insect group.

## 1 | Introduction

We are currently in the midst of a biodiversity crisis (Dirzo et al. 2014; Leclère et al. 2020). Human activities, particularly habitat destruction and alteration, have caused a precipitous decline in many species across various taxa (Butchart et al. 2010; Bellard et al. 2012; Haddad et al. 2015; Eichenberg et al. 2021; Jandt et al. 2022). The Living Planet Report revealed a shocking 69% drop in the population abundance of vertebrates over the last 49 years (WWF 2022). Despite the fact that insects are "the little things that run the world" (Wilson 1987), there are significantly fewer conservation assessments on insects than on vertebrates (Samways et al. 2020; Di Marco et al. 2017; Chowdhury, Jennions, et al. 2023; Dove et al. 2023; Ledger et al. 2023). This disparity is also evident in species extinction risk assessments: only 8% of the assessed species in the IUCN Red List are insects (IUCN 2024), even though insects comprise over 80% of animal species on Earth (Stork 2018). The massive underrepresentation of insects in the global extinction risk assessments is primarily due to insufficient data on the occurrence of most species (Didham et al. 2020; Chowdhury, Zalucki, et al. 2023). For example, about 66% of the species occurrence data in the Global Biodiversity Information Facility (GBIF) are for birds, while ~8% are for insects (data accessed on October 10, 2025). Although insect occurrence data have surged over the last one and a half decades, mostly due to citizen involvement (Heberling et al. 2021), these new data are usually spatially and taxonomically biased and cannot be compared to previous decades of specimen-based collections.

Insect decline is a global issue (Dirzo et al. 2014; Eisenhauer et al. 2019; Turin et al. 2022; Martínez-Núñez et al. 2024; Boyle et al. 2025; Sharp et al. 2025). Dunn (2005) estimated that if the extinction rate of insects is similar to that of birds, nearly 44,000 insect species have already gone extinct, yet only 70 insect extinctions have been documented. Recent studies have revealed that many insect species are declining dramatically worldwide (Didham et al. 1996; Van Klink et al. 2024; Wagner 2020; Wagner et al. 2021). For example, over 75% of insect biomass has declined in some protected areas in Western Germany (Hallmann et al. 2017), over 80% of butterfly species have declined in the Netherlands over the last century (Van Strien et al. 2019), and 29% of odonate species have declined from 1980 to 2016 in Germany (Bowler et al. 2021). Although many threats are interactively impacting species conservation status and trends, anthropogenic climate change and habitat change by intensive agriculture are seen as the main drivers of global insect declines (Dieker et al. 2011; Halsch et al. 2021, 2025; Raven and Wagner 2021; Outhwaite et al. 2022).

From all these underrepresented invertebrates, carabid beetles are one of the most frequently sampled taxa and are used in ecological studies about drivers and planning assessments (Rainio and Niemelä 2003; Avgın and Luff 2010; Kotze et al. 2011). Carabids are often used as a bioindicator group (Koivula 2011). They play important ecosystem functions, from predators and biological control agents to prey for birds and small mammals. There is a good knowledge of the ecological requirements/niches of most of the prominent species (Rainio and Niemelä 2003; Avgın and Luff 2010; Kotze et al. 2011). Many studies on long-term trends in carabid beetles have reported a decline in species richness or abundance of ground beetles (UK: Brooks et al. 2012; Pozsgai and Littlewood 2014; Pozsgai et al. 2016; Germany: Homburg et al. 2019; Weiss et al. 2024; the Netherlands: Hallmann et al. 2020; Turin et al. 2022). However, not all studies reported a decline (e.g., Saska et al. 2021). While decline appears to be widespread among carabid beetles, not all habitats appear to be affected similarly, although, for a similar habitat, both decline and increase have sometimes been reported (e.g., forests: Homburg et al. 2019; open habitat: Pozsgai and Littlewood 2014; Pozsgai et al. 2016; Saska et al. 2021). Comparative studies have shown that body size, habitat specialisation, and dispersal power appear to be the main traits shaping the species' response (Kotze and O'hara 2003; Nolte et al. 2019; Weiss et al. 2024). In Germany, the latest national Red List reported 35% of carabid species as either threatened or already extinct (Schmidt et al. 2016). Here, by compiling carabid data using various approaches, we analyse the long-term trends of carabid beetles in Germany for the past 36 years and assess if the changes in the number of occupied sites are related to species traits and national threatened status.

To meet the Kunming-Montreal global biodiversity framework targets (CBD 2022), acting on insect conservation is now a priority. Identifying the state of species, the pattern and reasons for decline is crucial. Although long-term systematically collected data are the gold standard for detecting population trends, such data are unavailable from most taxa and in most of the world. Instead, there is a large amount of heterogeneous data, collected either opportunistically or with unknown methods that can be leveraged for estimating species trends. While different types of statistical models exist to analyse population trends using heterogeneous data, the occupancy detection model is the most reliable (Isaac et al. 2014; Outhwaite et al. 2019; Bowler et al. 2021).

Based on almost 1 million records of occurrences of 554 carabid species collected by German volunteers and carabid experts, we assessed the changes in occupancy of carabid beetles in Germany over the last 36 years (1988–2023). Using single-species multi-season occupancy models (Isaac et al. 2014; Doser et al. 2022), we investigated the changes in occupancy patterns. We further collated species attributes to compare whether changes in species occupancy were associated with conservation status or morphological and ecological traits. This is the first-ever national-scale statistical assessment of carabid beetle trends in Germany, highlighting the potential impact on policy and helping Germany meet the global biodiversity framework obligations.

## 2 | Methods

### 2.1 | Occurrence Data

We collated species occurrence data in direct collaboration with German carabid experts. We compiled the data in two steps. First, we obtained species occurrence data from the ColeoWeb (https://www.coleoweb.de/) database (Bleich et al. 2024). This is the most comprehensive database for German beetles, which includes data on carabid beetles that originate mostly from systematic pitfall trapping, supplemented by data from hand collecting and opportunistic observations. This initial data collation included 586,292 occurrence records for 554 species. Because this dataset did not contain the most recent data that carabidologists have collected, we attended the annual meeting of the German Carabid Society (GAC, http://www.angewandte-carabidologie.de/) in February 2024 in Göttingen. We requested the members to share their unsubmitted observations within 3 months (by May 2024) with the ColeoWeb database. This way, we updated the dataset to 953,230 occurrence records for 554 species.

## 2.2 | Data Cleaning

Once we obtained the compiled data, we cleaned the dataset following several approaches. First, we harmonized species names and removed records without location information (longitude and latitude), date (day, month and year), duplicate records, and imprecise coordinates (records in the ocean or outside German borders).

We only included occurrence records for the last 36 years (from 1988 to 2023). We chose 1988 as the first year because the occurrence records were substantially fewer in the earlier years. The yearly species occurrence records were low for many species, so we grouped years into 2-year bins, resulting in 18 bins for the 36-year study period (1988–2023). After a peak in observations around the year 2000, the number of observations has fallen again in recent years (Figure 1b). We grouped occurrence records into survey quadrants with an edge length of 10 min longitude and 6 min latitude, which is approximately 11 × 11 km (German Ordnance Map, Meßtischblatt, MTB). The number of survey quadrants has increased over time (Figure 1c). We discussed this issue with the experts, who suggested that this reflects a change in observer behavior, with many observers now exploring new areas rather than visiting the same sites. To estimate the changes in 2-year bins, we only included survey quadrants visited at least twice in the last 36 years (Outhwaite et al. 2018; Bowler et al. 2021). Our final cleaned dataset included 602,054 occurrence records for 549 species with a median of 346 occurrence records per species (ranging from 1 to 9372; Figure 1a; Table S1). The number of occurrence records was low for many species: 71 with < 10 and 173 with < 100; however, the occurrence records were well distributed across the entire study period. For example, we had data from 7 year-bins from at least 50% of the survey quadrants.

While we understand the potential of species occurrence data from the Global Biodiversity Information Facility (GBIF), our compiled data is much more comprehensive in the given area. A search in GBIF (GBIF 2024) indicates that, except for *Cicindela campestris* (4590 vs. 3816), our data contained more species occurrence records (an additional 95% observations, ranging between 16% and 100%) for all species than GBIF.

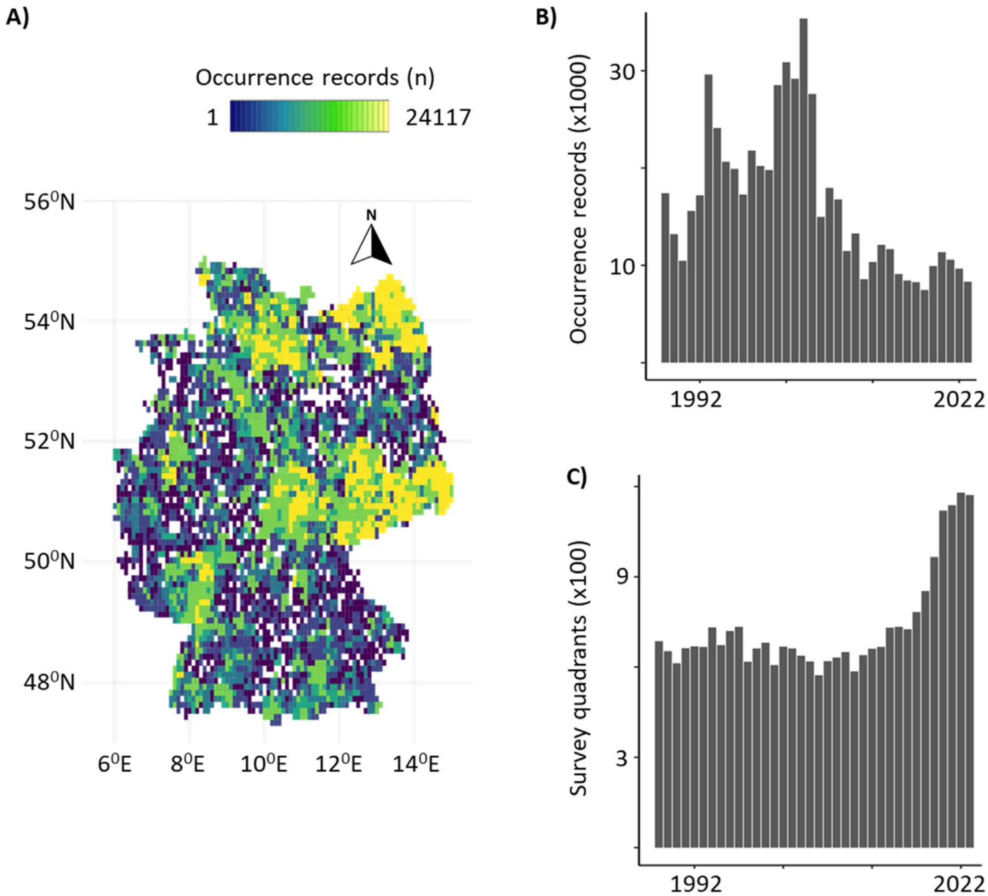


**FIGURE 1** | The patterns of distribution records of carabid beetles in Germany (1988–2023). (A) is the spatial distribution of records for all species and years (colours reflect the number of records in each MTB grid cell, where 'white' indicates no data from that grid); (B) is the number of species occurrence records per year; and (C) is the number of survey quadrants per year with at least one species record.

## 2.3 | Trend Estimation

To estimate the changes in the occupancy of carabid beetles in Germany, we fitted single-species multi-season occupancy detection models. As the unit of the detection model, we aggregated observations into those likely to be collected on the same survey visit. A visit was defined by species observations collected on the same date in the same survey quadrant (Van Strien et al. 2019; Bowler et al. 2021). We inferred the absences of species (non-detections) based on observations of other species during a given visit (Outhwaite et al. 2022), similar to the commonly used target-background method used in species distribution models (Ranc et al. 2017; Barber et al. 2022). Since some sites were sampled much more than others, we subsampled at most 10 visits per year at any specific site (i.e., survey quadrant). We built models for species with at least 50 occurrence records (76% of species in the dataset).

We modelled occurrence probability as a function of site and year variation. Here, the year variation was modelled by including the 2-year bins (due to data sparsity in some years) as a fixed continuous effect and site variation as a random effect to account for mean spatial variation in occupancy. We modelled the detection probability for each visit to a given quadrant in a 2-year bin. Survey effort was included in the detection model using list length as a proxy variable (Outhwaite et al. 2019). Specifically, list length was the number of species reported on a visit (categorical variables with three levels: a single list (1 species, 53% visits), a short list (2–3 species, 21% visits) or a longer list (4 or more species), 26% visits, set as the reference level). We separately fit the model for each species. The observed detection data for a given species on each visit were assumed to be derived from a Bernoulli distribution conditional on the presence of the species in that survey quadrant and a 2-year bin.

We fit the model using the spOccupancy package (Doser et al. 2022) in R (R Core Team 2022; Version 4.2.0), which implements a hierarchical Bayesian occupancy-detection inference using Markov chain Monte Carlo simulation. Specifically, we used the tPGOcc() function, which models species occurrence as a function of environmental and random effects while accounting for imperfect detection using detection covariates. The occupancy process is modelled with a logit link, and the detection process is separately parameterised to distinguish true absences from non-detections. We used vague priors and 3 chains with 150,000 iterations, discarding the first three-quarters as burn-in. We assessed model convergence using Rhat statistics and trace plots. We carried out posterior predictive checks by calculating a Bayesian $p$-value with a Freeman-Turkey fit statistic. In the end, we obtained trends for 383 species (69% of 549 initial species). The model convergence/performance is good when the Rhat value is $<1.1$, and the Bayesian $p$-value ranges between 0.1 and 0.9 (Doser et al. 2022). Based on this, the model performance was sufficient in our case, with a mean Rhat value of 1.012 (median 1.007) and a mean Bayesian $p$-value of 0.45 (median 0.45). Four German carabid experts also thoroughly examined the predicted trends for each species to check for plausibility. Specifically, once we obtained the trend data, results were shared with taxonomic experts and they carefully went through each species and discussed them. Overall, the experts agreed with the trends found for the vast majority of the species for which it was available based on their regional and national knowledge.

To test whether the survey bias impacted our results, we ran three sensitivity analyses. First, we removed the two data-dense states (Mecklenburg-Vorpommern and Saxony) from the cleaned dataset and ran the single-species multi-season occupancy model following the method described above. Second, we ran the same models, but changed the minimum biennial survey requirement from two to five. Finally, we changed the maximum survey limit from 10 to 15. Both numbers were chosen randomly. We discussed the results in the results section and added the figure in the supplementary section (Figure S1). We further assessed if the timing of the surveys was similar across the year. We found no substantial difference in timing, with most visits taking place between March and October, thus covering well the main activity period of ground beetles, which is from April to September (Figure S2). This aligns with the previous paper finding little effect of changes in phenology/sampling on trend estimates of German dragonflies (Bowler et al. 2021). Experts also verified the trends and broadly reflect their opinions about the state of carabid communities in Germany.

## 2.4 | Species Attributes

To explain variation in the trends of different species, we collated two types of trait data. First, we obtained the threat status of each carabid species from the German Red List (Schmidt et al. 2016). Second, we combined species traits from the ColeoWeb database and Nolte et al. (2017). Specifically, we collated species information on mean body size (numerical), wing types (categorical; short-winged, dimorphic and long-winged), trophic level (categorical; herbivore, mycetophag, omnivore and predator), and habitat preference (categorical: coastal, eurytopic, forest, mountain, open, riparian, special habitat and wetland). These traits were chosen based on previous studies that showed a link between these traits and the occupancy trends or extinction risk. Body size is considered a key driver among them, being positively linked with species decline for numerous groups of insects (e.g., Staab et al. 2023; Coulthard et al. 2019), including, ground beetles (e.g., Kotze and O'hara 2003; Nolte et al. 2019). Similarly, relationships between dispersal ability linked with wing development, food, and habitat specialisation and ground beetle species decline have also been found (Kotze and O'hara 2003; Nolte et al. 2019; Homburg et al. 2019; Weiss et al. 2024). In general, species with large body size, poor dispersal ability, narrow dietary requirement, and high habitat specialisation decline disproportionately when compared to small-bodied, good-dispersing, omnivorous, generalist species.

To test if the trend was significantly associated with any of the species attributes, we fitted a linear model considering species trend with all attributes, calculated using the occupancy–detection model, as the response variable and species attributes as the explanatory variables.

## 3 | Results

Of the 383 species for which we obtained occupancy trends (i.e., biennial changes in the number of occupied survey quadrants), the trend was negative for 78% of species (298 species) and positive for 22% of species (85 species). Based on whether the 95% CI of trend overlapped zero, 52% of species (200 species) significantly declined, and 22% (85 species) significantly increased, while the trend was insignificant (or stable) for the other 26% of species (98 species) (Figure 2). We obtained very similar results ($r=0.94$ after removing two data-dense states, $r=0.98$ in both cases when we changed minimum biennial surveys from two to five and maximum biennial surveys from 10 to 15) in the sensitivity analysis, meaning that the survey bias did not have a significant impact on our findings (Figure S1).

Among the species that had significantly declined, the trend was steepest for *Trechus pulchellus* (trend estimate: −0.31; 95% CI = −0.46, −0.18). It corresponds to a reduction to approximately 0.42 by the end of the time series—a ~15% relative decrease, or ~0.2% per year. Conversely, for species that had significantly increased, the trend was highest for *Elaphropus diabrachys* (trend estimate: 0.25; 95% CI = 0.19, 0.33), representing a relative increase in occupancy probability of ~13% over the same period. The mean and median trend for the significantly decreasing species was −0.1 and −0.09, respectively, while the median trend for the significantly increasing species was 0.04. For 98 species with non-significant trends, all showed slightly negative trends and were very close to zero (except for one species, *Stenolophus teutonus*; trend: −0.13; Figure 2).

The 383 species for which we could calculate trends contained 278 non-threatened species, 104 threatened species, and only one species, listed as Data Deficient in the German Red List (*Philorhizus quadrisignatus*). The overall changes in the proportion of occupied sites were similar among the threatened and non-threatened species. Of the 278 non-threatened species, 53% (148 species) significantly declined, 23% (63 species) significantly increased, and the trend was non-significant for 24% (67 species). Similarly, among the threatened species, 50% (52 species) significantly declined, 21% (22 species) significantly increased, and the trend was non-significant for 29% (30 species) (Figure 3). Among the species that had significantly declined over the last 36 years, the percentages were the highest for the Near Threatened species (64%; 32 of 50 species) and lowest for the Rare species (40%; 2 of 5 species). However, the changes in occupied sites between the threatened and non-threatened species were non-significant (Estimate: −0.01, SE: 0.08, $Z = -0.21$, $p = 0.83$; generalised linear model).

The median biennial changes in the proportion of occupied sites were somewhat similar across wing types (Figure 4A), whereas, for trophic level status, the median trend was slightly less declining among omnivorous species compared with herbivores (median trend: −0.02 vs. −0.05) (Figure 4B). Beetle species with larger body sizes were more often associated with positive trends, whereas smaller species had slightly worse negative trends (Figure 4C). In contrast, regarding habitat preference, the species associated with coastal habitats showed the most negative trends (median trend −0.1), and forest-dwelling species were the least declining (median trend −0.03) (Figure 4D).

While the short-winged species had a worse negative trend, the long-winged species had a less negative trend compared to the dimorphic species, but both were non-significant (Figure 5). In contrast to predatory species, both herbivore and omnivore species were increasing, but the association was only significant for the omnivore species (Estimate = 0.04, SE = 0.02, $Z = 2.4$, $p = 0.02$; Figure 5). Among different habitat preferences, coastal species experienced significantly more negative trends (Estimate = −0.06, SE = 0.02, $Z = -2.68$, $p = 0.008$), while species with other habitat preferences experienced more positive but non-significantly different trends compared to the open-habitat species (Figure 5). Compared to medium-sized species, both small and large-bodied species had more positive trends, but the difference was only significant for the large species (Estimate = 0.04, SE = 0.01, $Z = 3.75$, $p = 0.0002$; Figure 5).

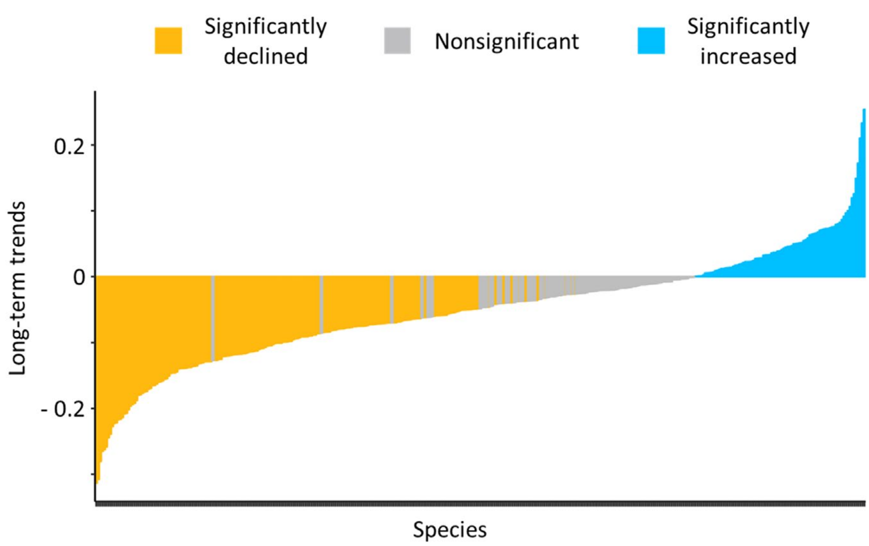


**FIGURE 2** | The biennial changes in the number of occupied survey quadrants of carabid beetle occupancy in Germany over the last 36 years. Here, each bar represents one species.

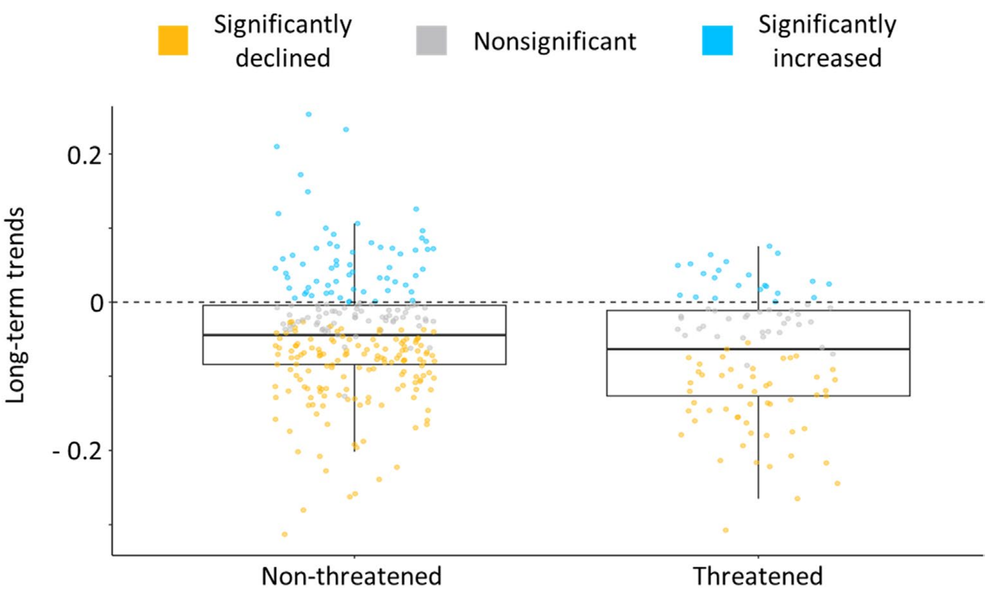


**FIGURE 3** | Trends of German carabid beetles based on their national threat status. Each point shows a species, colored by its trend classification. The boxplot shows the median, interquartile range and range of the species trends. There was no significant difference between the trends of threatened and non-threatened species, albeit the trends were more negative for the former.

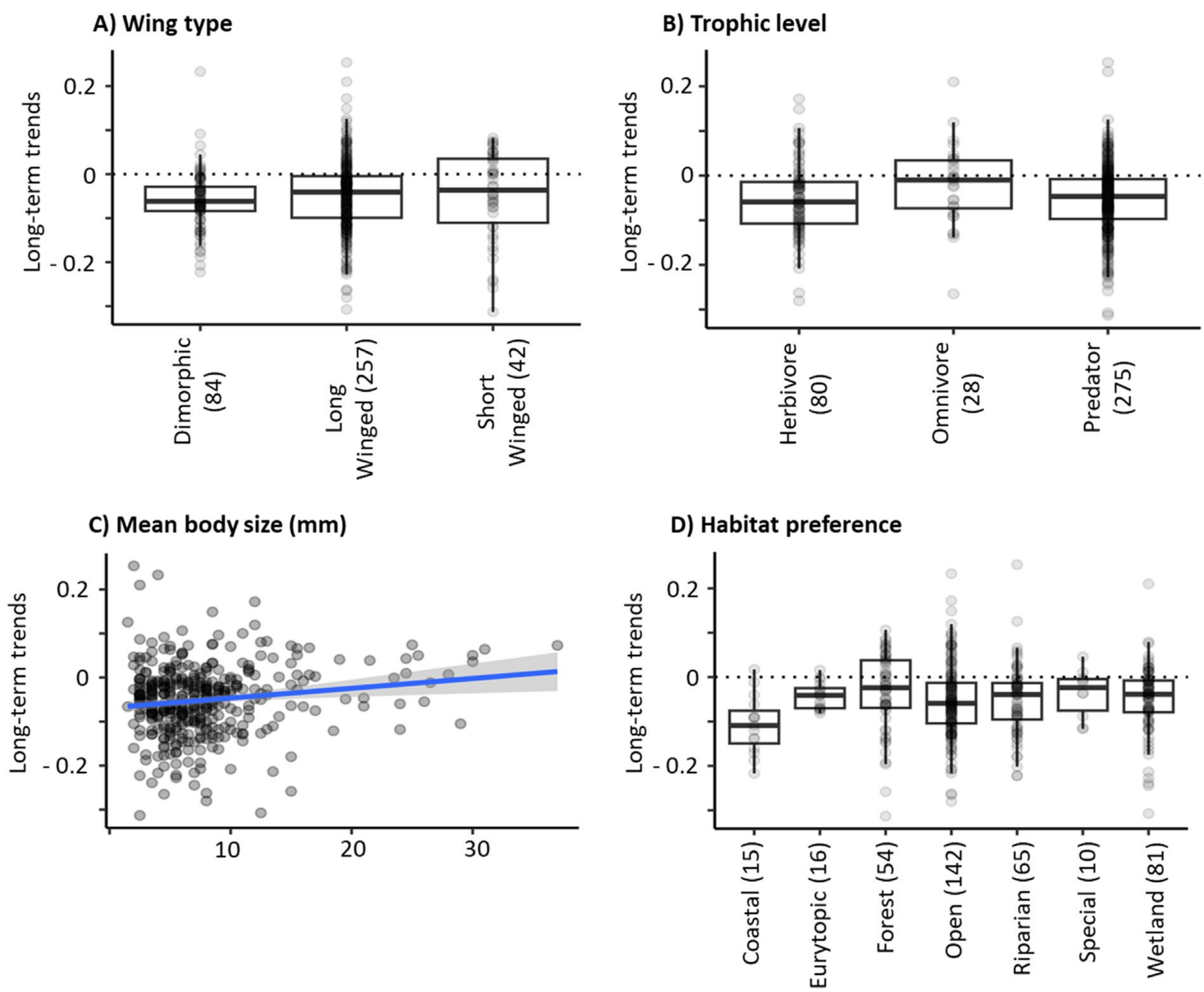


**FIGURE 4** | Trends of German carabid beetles based on different traits. (A) shows the boxplots of the trends split by wing type; (B) split by trophic level; (C) by body size (each point shows a species) and (D) split by habitat. Here, the horizontal dotted line in each plot indicates no changes.

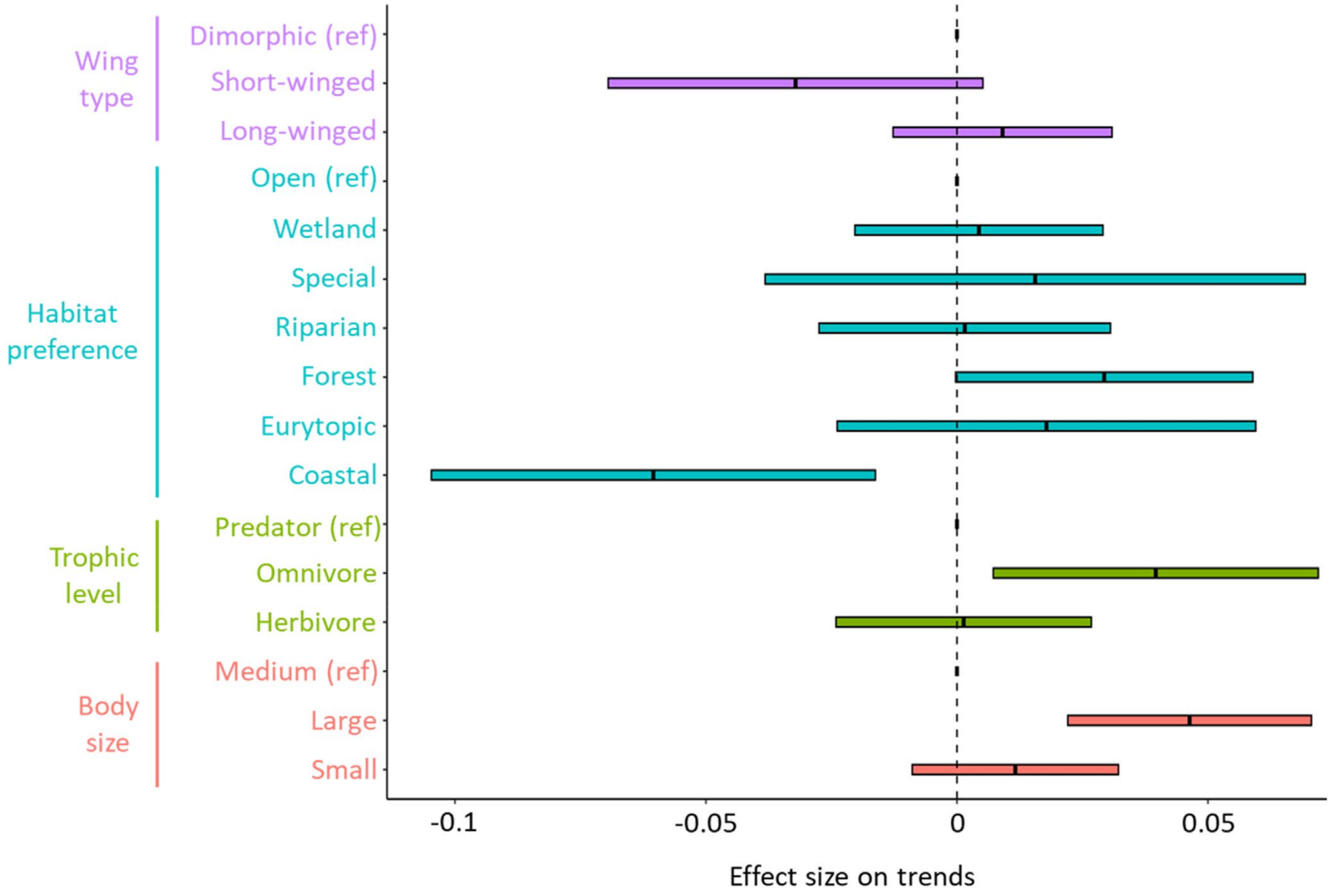


**FIGURE 5** | Effect of species attributes on their long-term trend, where the reference groups were shown as points. We fitted a generalised linear model to calculate the effect size. Here, the effect size was assessed by comparison to the trends of reference groups (marked as *ref* in the *y*-axis, with dimorphic for wing types, predator for trophic level, medium for mean body size, and open habitats for habitat preference), selected by discussing with the carabid experts. For mean body size, we converted the continuous values to three categories: Small (1.9–4.5 mm), medium (> 4.5–10.5 mm) and large (> 10.5–37 mm).

## 4 | Discussion

Using the last 36 years (1988–2023) occurrence data of German carabid beetles, we show that over half (52%) of the species have significantly declined. In contrast, only one-fourth of species have increased significantly. Our results of the declining trends are similar to the ones observed in several other insect taxa: 37% of butterflies, dragonflies, and orthopterans have declined in occupancy in Bavaria (Engelhardt et al. 2023), caterpillars and parasitoid richness and diversity have significantly declined at the La Selva Biological Research Station in Costa Rica (Salcido et al. 2020), and 80% of the flies have declined in abundance in northeast Greenland (Loboda et al. 2018). Our observed changes in species occupancy are quite similar across national threat status classes. While the mean trend of threatened species was slightly lower than that of non-threatened species, the association was non-significant. Among the non-threatened group, 64% of Near Threatened species have declined by a mean amount of 8% of their occupied sites. For species with non-significant trends, all showed declines in occupancy, which is probably linked to data limitation. More data from data-poor areas are needed for robust trend analyses for these species.

Species traits are widely considered an important factor in determining species' extinction risk, and changes in species occupancy are associated with species attributes (e.g., Nolte et al. 2019). For example, analyzing carabid beetles from Belgium, the Netherlands, and Denmark, Kotze and O'hara (2003) showed that larger, habitat specialist, short-winged and long-winged species declined more significantly than others. Dimorphic species are usually less prone to extinction because of their ability to disperse and establish rapidly large populations (Turin and Den Boer 1988; Kotze and O'hara 2003). We found that the median trends among different wing types were similar, also observed by Nolte et al. (2019). This suggests that even species with a greater capacity for dispersal—typically considered more resilient—are not experiencing significantly different long-term occupancy trends than poor dispersers. In the current configuration of German landscapes, where suitable habitats are already isolated and embedded in unfavorable matrices (e.g., intensive agriculture or urban areas), even the winged species may be unable to relocate or colonize new habitat patches effectively. This challenges the assumption that high dispersal ability is sufficient for persistence in fragmented systems. Instead, it highlights that dispersal must be matched by the availability, accessibility, and quality of habitat and that landscape-level connectivity and restoration efforts are likely critical for safeguarding carabid beetle diversity under ongoing environmental change. The trend was slightly better among omnivore species, which tended to decline less than herbivorous or predatory ones. This contrasts with previous studies, which showed, particularly for forest species, that higher trophic levels, such as predators, were at higher risk of extinction or declined more strongly following severe drought events (Nolte et al. 2019; Weiss et al. 2024). The flexibility of omnivorous species may come to be advantageous when fluctuating environmental conditions may strongly alter the availability or quality of the food source within the species' habitat.

Among the habitat types, coastal species were the most vulnerable, whereas forest species were the least vulnerable. This result is similar to those found by Nolte et al. (2019), with forest species having the lowest risk of decline while coastal species exhibiting some of the highest risks of decline. Similarly, in the Netherlands, forest species showed only a slight decline in abundance (Turin et al. 2022) and even an increase in forest species in the southern UK (Brooks et al. 2012). Information on trends for coastal habitat is limited (Turin et al. 2022), although a relatively stable trend was reported by Kotze and O'hara (2003). As pointed out by the later authors, coastal habitats experience ever-increasing anthropogenic pressures while, at least in Europe, the situation of forest habitats has notably improved, with forests occupying larger areas and their management having improved. Thus, the negative trend displayed by many coastal species is likely driven by the anthropogenic pressure experienced by those habitats. The smaller number of declining species in forest habitats is certainly linked to both the recent increase in forest cover and the improved management of those forested areas, even if there is still a need for further improvement (Nolte et al. 2017; Staab et al. 2023). Future studies could analyse the changes in spatial and temporal occupancy by considering climate, land cover and other features as well as their changes and how species attributes modify their responses to these variables.

We found that smaller species declined more than larger species. This appears to be in strong contrast with numerous studies on insect decline, which reported the opposite trend (e.g., Homburg et al. 2019). However, numerous studies on ground beetles have reported that while larger species are often at higher risk, this notably depends strongly on the habitat considered (Kotze and O'hara 2003; Nolte et al. 2019). In particular, forest species appear to be the main exception to this global trend (Homburg et al. 2019). Within our species pool, most of the larger species are forest inhabitants, likely driving the observed pattern.

The general decline in ground beetle species found, combined with the lack of relationship with any of the species' life history traits or their habitat preferences, indicates that the drivers of such decline are likely acting at a large scale. Some authors documented that changes in habitat features induced by a changing climate and land use could have a significant impact on species trends (Desender et al. 2010; Purtauf et al. 2005; Chamberlain et al. 2020; Liu et al. 2021; Skarbek et al. 2021; Martínez-Núñez et al. 2024). While anthropogenic climate change and land use change affect all habitats, some habitat types, such as coastal areas, experience stronger pressures than others. In this regard, the situation of forest habitats, which has notably improved, suggests that appropriate local-scale conservation efforts could contribute to improving species trends. Weiss et al. (2024) found that large carabid beetles in forested areas still declined strongly following severe drought events despite the buffering capacity of such habitats. With such extreme events likely to increase in frequency, targeted conservation action may not suffice.

We followed a crowdsourcing approach to access more data, which increased the data by nearly 40%. We also discussed our results with many carabid experts (some of whom are co-authors) to understand if the biennial changes in occupancy matched their expectations and revised the analysis accordingly (e.g., we removed very rare species from the analysis). Despite the various challenges with the data, the trend estimates were broadly in line with the expectations of the experts. Our approach highlights the value of data mobilization, integration and community involvement for assessing species trends at large scales (Moersberger et al. 2024). However, it should be noted that to be conservative, we only considered expert-verified data, and we did not consider data from GBIF (see Heberling et al. 2021) or social media data (see Chowdhury, Aich, et al. 2023; Chowdhury et al. 2024) that may not have been expert validated but might further improve our assessment. Additionally, the number of survey quadrants increased with time, reflecting the change in observer behavior, with many observers now exploring new areas rather than visiting the same sites. However, occupancy detection models are well-equipped to handle such bias (Isaac et al. 2014; Outhwaite et al. 2018). Our analysis is also limited by the lack of metadata to explain how individual data were collected, so we could not fully model the likely sampling variability. We used the list length as a proxy for the sampling effort, but this is an imperfect proxy since list length also depends on local species richness (Outhwaite et al. 2018). Nonetheless, as we noted above, our trend estimates passed our expert assessment.

Insect decline is a widespread issue. Our study is another example that provides further evidence. Following expert-driven data compilation and analysis, we show that most ground beetles in Germany have severely declined over the last 36 years. Alarmingly, the number of non-threatened species is declining at a rate similar to that of threatened species. Conservation efforts over the last decades have been insufficient to reverse this trend, and substantial efforts are needed for habitat restoration, which is in line with the new EU Restoration Law. Overall, our study also highlights the importance of recording efforts of natural history societies and citizen scientists as a backbone for biodiversity assessments, and their efforts need further support, especially given the ongoing carabid beetle declines.

## Author Contributions

S.C., D.E.B., H.B., F.J., R.K., M.W., and A.B. conceptualised the idea and developed the method; S.C. and D.B. did the analysis; everyone contributed to the analysis; S.C. wrote the paper; everyone contributed to the writing.

## Acknowledgements

We are grateful to the many volunteers involved in data recording over the last four decades, and we thank all taxon experts involved in co-developing and critically reviewing this research. Funding was provided through the sMon project of the German Centre for Integrative Biodiversity Research (iDiv) funded by the German Research Foundation (DFG-FZT 118, 202548816). Open access publishing facilitated by Monash University, as part of the Wiley - Monash University agreement via the Council of Australian University Librarians.

### Conflicts of Interest

The authors declare no conflicts of interest.

### Data Availability Statement

The occurrence data are available by MTB grids in the Supporting Information. We have provided the data file; the trend estimates, trait information and threatened status are available in the Supporting Information. All the R scripts are available in the public GitHub repository (https://anonymous.4open.science/r/occ_model_de-15DF/README.md).

### Peer Review

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/ddi.70112.

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**Supporting Information**

Additional supporting information can be found online in the Supporting Information section. **Data S1:** ddi70112-sup-0001-DataS1.xlsx. **Data S2:** ddi70112-sup-0002-DataS2.csv. **Figure S1:** The association between trends with all data and the trends from the sensitivity analysis. The trends from sensitivity analysis were obtained by (I) changing maximum survey from 10 to 15, (II) changing minimum survey from two to five, and (III) removing two data-dense states (Mecklenburg-Vorpommern and Saxony) from the cleaned dataset. **Figure S2:** The timing of the survey over time. **Table S1:** Species wise number of occurrence records.