# Analysis of the regional distribution of epigeic arthropods 2. Evaluation of models for ground beetles

Ulrich Strothmann, Claus Döring und Michael Judas


## Synopsis

In an area of continuous beechforests on limestone the distribution of carabid beetles was investigated in a study area of c. 4 km$^2$ by pitfall sampling. A distribution model was developed predicting the occurrence of 2 species, namely *Pterostichus madidus* and *P. melanarius* in 3 abundance classes. This study describes the evalution of the distribution models by independent sampling in the original study area and in a different region to which the model was transferred. For both species the models were validated in the original study area, with 56–59% correctly predicted catches and only one extreme mismatch (3%) with a difference of two classes. The model did not predict the catches in the other region which can be attributed to differences in fundamental habitat properties.


*Carabidae, Pterostichus madidus, Pterostichus melanarius, distribution, modelling, GIS*

## 1 Introduction

The development of valid distribution models is a central problem in ecogeography and nature conservation (MILLER 1994). We adressed this question on a medium spatial scale by selecting a study area of c. 4 km$^2$ situated in a larger area of continuous beechforests on limestone for which good faunistic information on ground beetles is available (DORNIEDEN 1997). Distribution patterns were described in an extensive survey (DORNIEDEN & al. 1996) and models were developed predicting the distribution from habitat factors available for the entire study area (cf. JUDAS & al. 1998). This paper describes the crucial step of model evaluation in the case of two carabid species, namely *Pterostichus madidus* (FABRICIUS) and *P. melanarius* (ILLIGER). For this purpose a test sampling scheme was derived from the model predictions for both the original study area and a different region.

The analysis of medium- to large-scale distribution patterns is much facilitated by the use of geographic information systems (GIS). This technology allows a spatially explicit representation of well-known or supposed habitat associations of species and was used as an essential tool in this study.

## 2 Material and Methods

### 2.1 Base data and distribution models

Carabid beetles' distribution patterns were investigated in a 3.8 km$^2$ area of continuous beechforests forming part of a larger forest area on limestone (DORNIEDEN & al. 1996). The study area is part of the forestry district of Reinhausen-Wittmarshof, which is situated SE of the town of Göttingen in central Germany. A number of habitat parameters of potential biological significance were available for the entire sudy area. These data were handled and processed with two geographic information systems, namely ARC/INFO and TopoL, the former due to its capabilities, the latter for its ease of use. Habitat parameters were derived from a digital topographic landscape model, forestry inventory data (»Forsteinrichtung«), and a soil status evaluation (»Standortkartierung«). Four factors classified into three classes each were used to predefine habitat types for sampling. These factors were soil humidity, slope, aspect, and age of canopy trees. Combinations of these classified factors were evaluated using GIS, and potential sites for sampling were identified under the condition of a minimum size of 2500 m$^2$ of homogeneous habitat type as defined by the above factor combinations, and under the condition of a minimum distance of 25 m to internal and external forest edges. For 69 realized factor combinations a total of 189 sites was chosen for sampling. Carabid beetles were caught in pitfall traps for 1 year in 1994/95. Traps were operated with ethylene glycole and exchanged in intervals of 14 days. Results from pitfall sampling represent a measure of activity density (TRETZEL 1955) which may be correlated to true densities.

The distribution patterns derived from this base sampling varied between species (cf. DORNIEDEN & al. 1996). In a statistical analysis not only the predefining habitat parameters but also the array of other data available were used to derive models to describe species' distribution patterns. This process is detailed for ground beetles by JUDAS & al. (1998) and for spiders by ROTHLÄNDER & al. (1998). Two carabid species were chosen to test the respective models, namely those for *Pterostichus madidus* and *P. melanarius.* These species were caught with an intermediate frequency (62% and 39%, respectively) and contrasted in their distribution patterns with higher densities in the southern or northern part of the base study area. Parameters describing the distribution pattern of *P. madidus* were soil humidity and a differentiation of the area into a northern and a southern part. In the case of *P. melanarius* the model parameters were the same area differentiation plus aspect and elevation (cf. STROTHMANN & al. 1997). Spatial representations of the factorial models were produced with a GIS. Predicted densities were classified as low, medium, or high.

## 2.2 Evaluation of distribution models

In the area of base data sampling, the distribution models for the two carabid species, i.e. *Pterostichus madidus* and *P. melanarius*, were tested in 1996 by independent pitfall sampling. 37 traps were placed in the area under the condition of 50 m minimum distances to former traps, forest edges, and the borders delimiting the predicted areas of low, medium or high abundances.

The possibility to transfer the distribution model to a different region was tested with 15 traps in the same forestry district, c. 1.5 km south of the base study area and separated from it by a rural district with two small villages. This c. 2.1 $km^2$ region is more heterogeneous with stands dominated by beech, ash, or spruce, and substrate ranging from medium and upper sandstone to limestone. Also, the topography is more varied, with numerous small valleys mainly in parts of medium sandstone. Compared to the base model no area differentiation was possible and the prediction was based on the factorial model for the southern part of the base study area. This procedure was justified by the similarity in short distances to edges of the forest and in general aspect orientation. These parameters may best characterize differences between the two parts of the base model area.

Traps were operated in both regions from 1st July through the end of October, in the base study area sampling continued until 2nd December. Thus the catches from both regions may be directly compared as they cover the same main activity period.

## 3 Results

### 3.1 Intraregional evaluation

Due to differences in overall catches, the definition of abundance classes was different between the base study and this test study (cf. STROTHMANN & al. 1997). In the base study area, the distribution models were by and large validated. *P. madidus* catches were correctly predicted for 56% of the 37 traps, and there was only 1 trap with an extreme deviation where no catch was predicted and the actual catch was in the high abundance class (Table 1). In the case of *P. melanarius* correct abundance classes were predicted for 59% of the traps and there was no extreme deviation of more than 1 class from the prediction (Table 2). Both models are significant and the contingency coeffients ($\gamma$) are for both species > 0.8.

### 3.2 Interregional model transfer

The transfer of the distribution models for *P. madidus* and *P. melanarius* failed for both species, the sampling results did not match the predicted distribution patterns. No specimens of *P. madidus* were trapped, and only 4 of *P. melanarius*. These were recorded at two sites in Melico-Fageta on medium sandstone:

Table 1
***Pterostichus madidus* pitfall catches in 1996 compared to predicted local abundances in the base study area.**

| predicted catch-classes | actual catch-classes 0 | 1 | 2 | no. of traps (model classes) |
|---|---|---|---|---|
| 0 | 11 | 2 | 1 | 14 |
| 1 | 6 | 2 | 1 | 9 |
| 2 | 0 | 5 | 9 | 14 |
| no. of traps (actual classes) | 17 | 9 | 11 | 37 |

The 3 classes of actual and predicted catches are defined as 0, 1–5, and ≥6 specimens, respectively.
$\chi^2$ test: P = 0.001, $\gamma$ = 0.82.

Table 2
***Pterostichus melanarius* pitfall catches in 1996 compared to predicted local abundances in the base study area.**

| predicted catch-classes | actual catch-classes 0 | 1 | 2 | no. of traps (model classes) |
|---|---|---|---|---|
| 0 | 17 | 2 | 0 | 19 |
| 1 | 7 | 0 | 2 | 9 |
| 2 | 0 | 4 | 5 | 9 |
| no. of traps (actual classes) | 24 | 6 | 7 | 37 |

The 3 classes of actual and predicted catches are defined as 0, 1, and ≥2 specimens, respectively.
$\chi^2$ test: P = 0.001, $\gamma$ = 0.85.

one trap with 3 specimens in a moist valley, and one trap with 1 specimen on a dry SW facing slope close to the edge of the forest (c. 60 m).

There are some differences and some similarities in the carabid faunas of the two regions (Table 3). Comparing the sampling results despite a short difference in operating time, more than twice as many specimens were caught per trap in the northern region on limestone compared to the southern one which is more heterogeneous and largely on sandstone. The specimens from both surveys represented 23 species of which 13 were recorded from both regions. From the 2 species that were sampled in 1996 in the southern region only, one was not recorded during the base study also (cf. 3.1). Despite the lower species number, the diversity in the southern compared to the northern region is the same or slightly higher due to higher evenness (Table 3). In both regions the dominant species from pitfall traps are *Pterostichus burmeisteri* and *Abax parallelepipedus*, but the northern codominant *P. madidus* is missing from the southern region. *P. melanarius* contributes 2% to the catches in the latter region which is comparable to 3% in the base area evalution study (1996) and 1% in the original base study (1994/95).

## 4 Discussion

Although the match of prediction and sampling results in the base study area was not perfect, it showed a high degree of correspondence and was statistically significant. Taking into account that the model parameters are but rough correlates of proximate habitat factors and that many confounding effects are to be expected in a sampling program of this extent, the models were well validated for *Pterostichus madidus* and *P. melanarius* and provide a good representation of these species' distribution in the study area. The failure of transferring the model to a close but in many respects different region demonstrates that a distribution model is primarily area-specific. A potential success of applying the model in other areas may depend on a similarity in important habitat characteristics like geologic substrate and canopy tree species. Therefore another model transfer will have to be tested in areas of beechforest on limestone.

The general research strategy to derive distribution models is outlined in Fig. 1. GIS-based habitat parameters are used to construct a statistical or narrative model explaining the qualitative or quantitative distribution pattern of one to many species in a study area. If the model parameters are available a distribution map can be produced. This represents a spatially explicit model of the species' habitat associations which can be tested by independent sampling. A successful validation of the model allows to derive data for further applications and to transfer the model to other areas. If the model predictions cannot be confirmed the model may be modified or must be rejected. A transfer to an unsampled region starts the process of model evaluation and possible modification once again.

The proximate aim is to develop a valid representation of distribution patterns in a particular study area, the ultimate goal is to use such models for valid predictions in other areas. These in turn offer valuable applications e.g. in conservation, faunistics, or autecology. Modern concepts in nature conservation like population viability analysis and target species (VOGEL & al. 1996), or gap analysis (PRIMACK 1995) require a spatially explicit description of species distributions often on a large scale, e.g. for

Table 3

**Characteristics of the ground beetle faunas of two model evaluation regions sampled in 1996.**

| | northern region (beechforests on limestone) | southern region (heterogeneous landscape) |
|---|---|---|
| number of traps | 37 | 15 |
| total catch per trap | 34.2 | 13.9 |
| species number | 21 | 15 |
| diversity | 1.96 | 2.09 |
| evenness | 0.64 | 0.77 |
| dominant species | *Pterostichus burmeisteri* (32%) | *Pterostichus burmeisteri* (23%) |
| (% of total catch) | *Abax parallelepipedus* (20%) | *Abax parallelepipedus* (22%) |
| | *Pterostichus madidus* (17%) | *Carabus problematicus* (21%) |
| | ... | ... |
| | *Pterostichus melanarius* (3%) | *Pterostichus melanarius* (2%) |

Diversity (Shannon-Wiener index, log-base e) and evenness computed after Mühlenberg (1993).

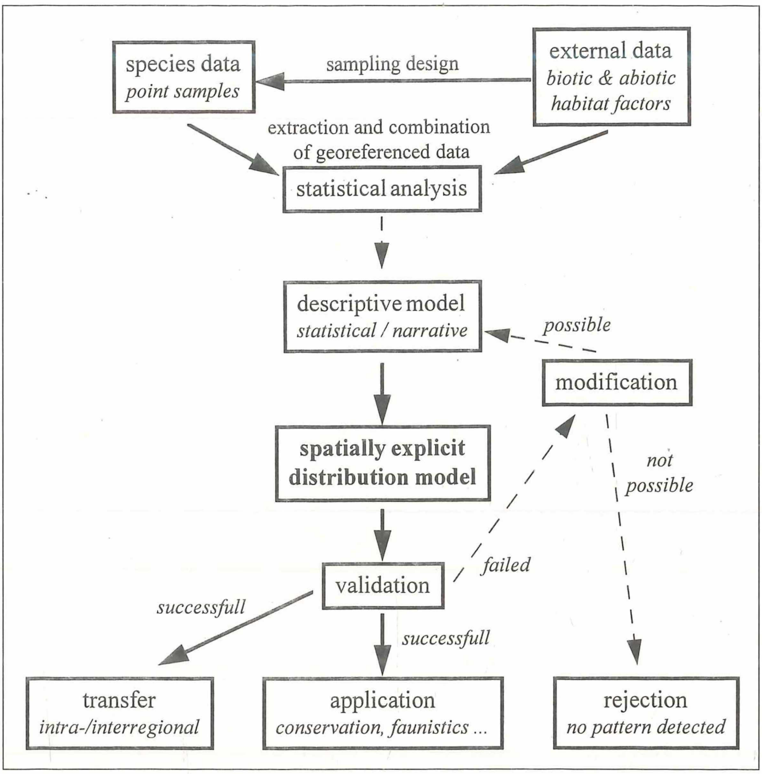


Fig. 1
**GIS-based modelling of distribution patterns as applied to epigeic arthropods. Solid bold arrows indicate steps that require the application of geographic information systems.**

risk analysis or for the identification of areas to be protected.

Powerful tools for these purposes are geographic information systems that allow the rapid processing of large quantities of digitized information (HAINES-YOUNG & al. 1993, MILLER 1994). GIS programs are useful both for basic data storage and handling, for the production of thematic maps, and above all for the extraction of new spatially defined information from the combination of different data sources. Problems arising from different resolutions of the data layers, inaccurate digitizing, and artefacts produced by the combination of data layers have to be considered very carefully (DÖRING 1996). While on the one hand the construction of spatial distribution models depends on the quality of the external data, these models are on the other hand operational only if the model parameters are available for a target area. The latter problem was encountered by the area differentiation in the base study model. This locally specific factor cannot be transferred to other regions. In the context of the present study this problem was solved by using a partial dstribution model for an interregional transfer. In a subsequent modification of the original model another factor combination was derived (cf. JUDAS & al. 1998) that allows a transfer to other regions where the model parameters are available (namely soil moisture and topographic classifications).

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## Address

Ulrich Strothmann (ustroth@gwdg.de)
Dipl.-Biol. Claus Döring (cdoerin@gwdg.de)
Dr. Michael Judas (mjudas@gwdg.de)
Institut für Zoologie und Anthropologie
Abt. Ökologie
Berliner Str. 28
D-37073 Göttingen
Germany