

1 The Individualised Niche in Motion; quantifying 2 individualised niches with movement data

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9 Abstract

10 Individuals of the same species often differ consistently in their use of resources, their
11 responses to environmental gradients, and their movement decisions. Between-individual
12 variation across niche axes has been shown to have important ecological consequences. Yet
13 practical frameworks that translate modern tracking data into operational, comparable
14 measures of niche individual specialisation remain limited. Rather, the individualised niche
15 concept has inherited the plasticity of the ecological niche concept and its quantification has
16 been considered an unfeasible goal. Here I present a workflow that estimates realised and
17 potential individualised niches from movement data using mixed-effects selection functions.
18 The workflow combines resource selection models with random intercepts and slopes with
19 relative selection probabilities and ecological niche indices. Individualised niches are quantified
20 using niche breadth and pairwise niche overlap are derived from hypervolume representations
21 in environmental space and provide interpretable measures of specialisation. In addition, I use
22 repeatability estimates, which capture consistent among individual differences in the use of
23 single environmental axes and allow direct comparisons between realised and potential niche
24 components. The workflow is implemented in exclusively in the programming language R. A
25 case study using publicly available northern lapwing (*Vanellus vanellus*) tracking data
26 illustrates how the workflow can be applied across multiple environmental variables

27 (earthworm abundance, human population density, cropping intensity, application rates of
28 glyphosates and propiconazole, air temperature, precipitation, wind speed, soil water index,
29 human footprint, organic carbon, soil bulk density, soil nitrogen, crop type and NDVI) to
30 characterise individualised niches.

31 **Keywords**

32 individual specialisation, mixed effects models, reaction norms, niche partitioning, remote
33 sensing, landscape ecology, biotic interaction, Jaccard similarity, niche width, coexistence,
34 limiting similarity, rewilding, translocation

35 Introduction

36 The ecological niche is a foundational concept in the field of ecology, central to understanding
37 species interactions and environmental relationships. Over time, its definition has evolved,
38 reflecting shifts in ecological theory and perspective. Early uses of the term were imprecise,
39 often referring generally to a species' ecological position, habitat, or requirements. The first
40 formalized definitions of the niche were proposed by Elton (1927) and Grinnell (1928). Elton
41 (1927) conceptualized the niche as the functional role of a species within a community,
42 emphasizing its interactions with other species, which is an interpretation widely employed in
43 community and functional ecology. In contrast, Grinnell (1928) defined the niche as the
44 physical space to which a species lives, the habitat or the spatial position of a species within
45 the environment. These foundational definitions laid the groundwork for subsequent theoretical
46 developments. The most commonly used definition of the ecological niche was introduced later
47 (Hutchinson, 1957), defining the concept as a hypervolume in an n -dimensional environmental
48 space. Moreover, Hutchinson distinguished between biotic and abiotic variables,
49 which roughly correspond to biotic and abiotic factors.

50 Literature reviews of the niche concept appeared relatively early in ecological literature
51 (Hutchinson, 1978), and the definition has remained a subject of considerable debate. Hurlbert
52 (1981) compiled a list of over 20 different definitions of the ecological niche, which was
53 extended recently with additional conceptual approaches (Takola and Schielzeth, 2022).
54 Although some definitions exhibit minor distinctions, they can generally be categorized into two
55 major groups: environment-based and function-based. Environment-based definitions
56 characterize the niche either as the habitat or physical environment occupied by a species
57 (Dice, 1952; Gauze, 1934; Grinnell, 1928, 1917; Odum and Barrett, 2005) or as an abstract
58 environmental space defined by multiple axes of environmental conditions (Hutchinson, 1957;
59 Macfadyen, 1973; Root, 1967). Function-based definitions, on the other hand, focus on the
60 ecological role or trophic position of a species within a community (Clarke, 1954; Elton, 1950,
61 1927; Weatherley, 1963). Some more integrative approaches combine these perspectives,

62 defining niches in terms of both environmental conditions and their influence on resource
63 availability (Chase and Leibold, 2003). However, there is one common characteristic that most
64 definitions have in common and that is their species-level (or above-species-level) focus, with
65 the exceptions of Roughgarden (1972) and Hutchinson (1957).

66 Historically, intraspecific variation was considered as noise around an ecological 'optimum'.
67 However, recent technological and methodological advancements have shed light on the
68 ecological importance of intraspecific variation. We now know that many species exhibit many
69 distinct phenotypes that are linked to age, sex or behavioural differences. The study of between
70 individual-level variation is necessary to better understand the dynamics of ecological systems
71 and facilitate causal inference in global-change dynamics and conservation biology (Jeltsch et
72 al., 2025).

73 Individuals differ in their genetic composition, morphology, life strategies, dietary habits or their
74 behaviour. Multiple studies have focused on examining the behavioural phenotypes (also
75 known as personalities) of different animals and the characteristics of each phenotype. The
76 field of behavioural ecology is focusing on examining these phenotypes. Consistent individual
77 behavioural differences have been observed in cognition (Bračić et al., 2022), antipredator
78 behaviour (Hahn et al., 2023; Winter et al., 2023), breeding behaviour (Gladow et al., 2025),
79 infochemical composition and responses towards infochemicals (Müller et al., 2020). Individual
80 niche variation has consequences for inter- and intra-specific dynamics (Dingemanse et al.,
81 2004; Enne et al., 2026; Moran et al., 2022; R et al., 2024).

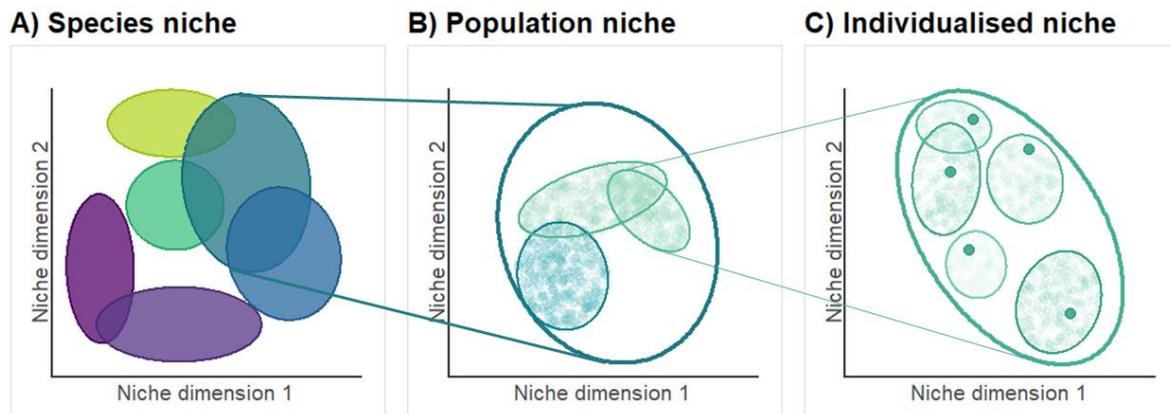
82 The term individualised niche emerged in the beginning of 2010's, to describe niche individual
83 specialization or individual niche differences (Fig. 1). Following Hutchinson's distinction
84 between fundamental and realised ecological niche, an individualised niche can be
85 distinguished in realised or potential individualised niche (Takola and Schielzeth, 2022).
86 Behaviour is an integral part of the individualised niches and can predict resource use in voles
87 (Erixon et al., 2025). Individualised niches emerge through three mechanisms; niche choice,
88 niche construction or niche conformance (Krüger et al., 2026; Trappes et al., 2022).

89 Experiments have shown the prevalence of these mechanisms across multiple animal groups
90 (Singh et al., 2024). For example, early-life experiences shape the individualised niche of
91 guinea pigs, zebra finches and fire salamanders at later developmental stages through (social)
92 niche conformance (Liebermann-Lilie et al., 2025; Lilie et al., 2022; Mutwill et al., 2023; Oswald
93 et al., 2020; Rystrom et al., 2024; Schulte et al., 2025). Many insect species are known for
94 their niche construction strategies (Jakobs et al., 2019; Lo et al., 2025; Schulz et al., 2025),
95 while niche choice has been observed in common voles, salamanders and insects (Erixon et
96 al., 2025; Nabutanyi et al., 2025; Petruzzi et al., 2006). In addition, morphological and
97 developmental variation can give rise to niche choice variation (Cabon et al., 2025).
98 Individualised niches can emerge through intrinsic factors (e.g. condition) or external factors,
99 such as social environment, ecological opportunity or interspecific dynamics (Araújo et al.,
100 2011; Kaiser et al., 2024; Moran et al., 2022; Winter et al., 2023) and have important
101 consequences for the indefinite persistence of the species (Bolnick et al., 2003).

102 Various attempts have been made to quantitatively estimate individualised niches. Depending
103 on the purpose of the study, researchers draw on a varipraxis of analytical methods and
104 approaches to quantify individualised niches (Lowe and Ingram, 2023; Trappes et al., 2025).
105 Tracking data shed light on new scientific questions (Trappes, 2023) and step selection
106 functions are particularly useful for studying individual specialisation (Carlson et al., 2021).
107 More broadly, individual differences in habitat selection have been studied with the use of
108 resource selection functions, mixed-effects models, reaction norms and repeatability analysis,
109 showing that the in some species individuals choose consistently different habitat types (Cuscó
110 et al., 2018; Dingemanse et al., 2010; Dingemanse and Dochtermann, 2013; Leclerc et al.,
111 2016; Northrup et al., 2022 but see Hertel et al., 2019). In addition, individual variation
112 increases when resources are unequal quality (Kikuchi and Reinhold, 2021).

113 The aim of this paper is to provide an operationalisation of the individualised niche concept
114 based on movement data. I provide a workflow to estimate the realised and potential
115 individualised niches in practice. Quantitative frameworks that systematically analyse

116 intraspecific variation can help to build cross-scale conceptual bridges. I demonstrate the
117 workflow by using movement data of northern lapwings (*Vanellus vanellus*) in western Europe.



118

119 **Figure 1.** Heuristic representation of the different niche levels. A) A community can be
120 represented as a set of species where each one occupies a different niche. B) A species can
121 be represented as a set of meta-populations with different niches. C) A population consists of
122 multiple individuals with different individualised niches (potential niche is shown with
123 transparent dots, realized niche is shown with bold dots).

124

125 **Box 1.** Definition of realised and potential individualised niche (Takola and Schielzeth, 2022).

126 The realised individualised niche is the place in environmental space in which a particular
127 individual is found and has an expected lifetime reproductive success of ≥ 1 surviving offspring.

128 The realised individualised niche can be quantified empirically.

129 The potential individualised niche is the volume in environmental space in which a particular
130 individual could be found with an expected lifetime reproductive success of ≥ 1 surviving
131 offspring. The potential individualised niche cannot directly be quantified, but significant parts
132 of the niche space can usually be statistically inferred.

133

134 A proposed workflow to estimate individualised niches

135 Overview

136 I here propose a workflow to quantify individualised niches by integrating mixed-effects
137 resource selection functions (RSFs) with summaries of realised (used) and potential (available)
138 environmental space. The workflow has four components: (i) data preprocessing and definition
139 of candidate environmental dimensions, (ii) RSF modelling incorporating individual variation,
140 (iii) computation of within-individual relative selection scores and repeatability to identify high-
141 selection conditions (and thus high expected lifetime reproductive success) and account for
142 availability, and (iv) quantification and visualization of individualised niches via niche overlap,
143 and niche breadth indices.

144 Data structure and preprocessing

145 The input of the workflow should be a dataset in which each row corresponds to a (used or
146 available) step of an individual, in the same vein as most movement ecology analyses, along
147 with information about turning angle and step length. Environmental predictors should be
148 measured, inferred or calculated (usually with the aid of remote sensing tools) for each location
149 and then grouped based on resource type (food, soil, weather etc).

150 Step 1: Mixed-effects RSFs with random slopes per individual

151 After compiling the dataset, the first step is to implement a mixed-effects resource selection
152 function (RSF) per resource type group using a binomial model with logit link with the
153 glmmTMB (McGillcuddy et al., 2025). The response variable of all models should be binary
154 (available vs used steps) and each model should contain the predictors that are relevant to the
155 corresponding resource type, along with random intercepts and random slopes for each
156 individual. The random intercepts are used to capture baseline differences among individuals,
157 whereas the random slopes are used to account for individual variation in responses.

158 Whenever possible, it is possible to include a nested random intercept with step ID. The model
159 results represent the (i) population-average effects that describe selection and (ii)
160 individualised deviations that quantify consistent among-individual differences in selection
161 along specific environmental axes.

162 Step 2: Relative selection probabilities (RSPs)

163 The result of Step 1 is a set of coefficients for each predictor. For each row, the coefficient is
164 multiplied by the raw value of this predictor producing a “score” for each step, which is an
165 individual-level selection score. The score of all predictors are then summed, producing one
166 score (*eta*, η) per resource type. The *eta* score can then be exponentiated and turned into a
167 scale that is suitable for individualised niche estimation. The exponentiated score is a relative
168 selection probability (RSP) for each row and scale the scores within each individual, to ensure
169 comparability between individuals.

$$170 \quad RSP_i = \exp(\eta_i) , \quad (1)$$

171 Where RSP_i is the relative selection probability that each resource type (food, soil, weather
172 etc.) will be chosen by an individual i and η_i is an individual's score of the corresponding
173 resource type. The RSP is then scaled within each individual (the used point is part of the
174 realized niche and therefore has a probability of 1 and the other points are scaled based on
175 this).

176 The definition of individualised niche incorporates the condition of an expected lifetime
177 reproductive success of at least one surviving offspring. Admittedly, calculating an individual's
178 expectation is even harder than estimating fitness outcomes (but see Bračić et al., 2025).
179 However, there have been multiple studies that link habitat preferences to survival (Catlin et
180 al., 2019; DeCesare et al., 2014) and fitness outcomes, which justify the connection of high
181 RSPs to high expected lifetime reproductive success (Gaillard et al., 2010; Uboni et al., 2017).
182 For pragmatic reasons, I here assume that highest quartile of the probability of selection

183 (>0.65) is associated with a high expected fitness. This assumption is a heuristic threshold and
184 it is used here arbitrarily to express the fact that the individualised niche can be a subset of the
185 used environment. The following steps contain only the subset of the environmental space
186 where RSP (for used or available points) is over 0.65.

187 Step 3: Visual diagnostics of individualised niches in the environmental 188 space

189 For each resource type, it is possible to visualise individualised niche structure by plotting all
190 pairwise combinations of predictors, coloured by individual ID (*sensu* Fig. 1 in Takola and
191 Schielzeth, 2022). The realised individualised niche (used steps) is displayed with high opacity
192 and the potential individualised niche (available steps) with low opacity to ensure visibility. To
193 summarise the occupied region of environmental space per individual in each facet, a convex
194 hull polygon can be drawn around that individual's points (semi-transparent fill with a thin
195 outline). These plots serve as a diagnostic of (i) separation among individuals, (ii) the degree
196 of overlap among realised conditions, and (iii) whether high-selection subsets are concentrated
197 or diffuse in environmental space. To quantify the niche breadth of each individual we used
198 the R package hypervolume (Blonder et al., 2013).

199 Step 4: Quantifying individualised niches: overlap, and breadth

200 Individualised niches can be quantified using complementary metrics that map directly onto
201 the conceptual distinction between realised and potential niche components. This step borrows
202 tools from niche theory, namely niche breadth (Moulatlet et al., 2025) and niche overlap
203 (Jaccard, 1901).

204 For each individual and resource type, the environmental predictors are standardised (as
205 described in Step 2) and projected into principal component (PCA) space. I then use the first
206 two principal components (PC1 and PC2) to construct a convex hull polygon, which serves as

207 a two-dimensional representation of that individual's occupied environmental space in the focal
208 domain.

209 Niche breadth is the area of the convex hull (or niche hypervolume) that includes all the filtered
210 points of individualised niche (realised and potential) using the first two principal components
211 (PC1-PC2). The breadth is calculated separately for realized and potential niches. Here, niche
212 breadth is quantified as a 2D polygon area in PCA space, not as a full n-dimensional
213 hypervolume estimate to facilitate readability and interpretability, but this step can be easily
214 extended to include more dimensions. Smaller realised breadth relative to potential breadth is
215 consistent with stronger specialization; conversely, similar breadth suggests realised use
216 broadly mirrors availability.

217 The individualised niche overlap can be calculated for each pair of individuals, based on their
218 realised and potential individualised niches. To quantify how similar individuals are in
219 multivariate environmental space, we construct individualised niche polygons and compute
220 pairwise overlap with the Jaccard index (Jaccard, 1901) on convex hull polygons in the PCA
221 space. Overlap matrices can then be visualised as heatmaps for realised and potential niches,
222 enabling direct comparison of individual specialization.

223 **Step 5: Repeatability of individual resource use**

224 Repeatability is a useful metric that quantifies the proportion of behavioural heterogeneity that
225 can be attributed to between- and within-individual variance (Nakagawa et al., 2026; Schielzeth
226 and Nakagawa, 2022). I here use the R package rptR (Stoffel et al., 2017) to quantify the
227 repeatability of the realised and potential individualised niche, using 1,000 bootstrap replicates
228 and 1,000 permutations to obtain empirical 95% confidence intervals. Comparing repeatability
229 for used (realised) versus available (potential) conditions provides a standardized test for
230 individualised niche expression: higher repeatability in realised than potential conditions
231 indicates stronger individual differentiation in use than expected from availability alone.

232 Implementation notes and limitations

233 I here list the most important assumptions behind the workflow.

- 234 i) Individuals move in landscape that (on average) match their phenotype. There is
235 no extensive phenotypical mismatch. In other words, an individual is (on average)
236 making most of the steps based on maximised expected reproductive success of
237 at least one surviving offspring.
- 238 ii) Relative selection probability is positively associated with the expected lifetime
239 reproductive success.
- 240 iii) Individualization is supported when realised niches show greater among-individual
241 structure than potential niches, reflected by higher repeatability, reduced overlap,
242 and narrower breadth in realised relative to available environmental space.

243 Case study; the individualised niche of northern lapwings 244 (*Vanellus vanellus*) in western Europe

245 Dataset

246 The dataset used in the present study to showcase the proposed workflow is the same dataset
247 that was used in a previous study (Esguerra et al., 2025). The northern lapwing movement
248 data are publicly available for Europe through the MoveBank database (dataset ID:
249 1448409403, curator: Jelle Loonstra). The data cover an area across the Netherlands,
250 Belgium, England, France, and Spain (Fig. 1) and the tracking period extends from April 2021
251 to March 2023. The number of observations per individual ranges from 28 to 1,266 steps.

252 The environmental variables used to characterise the individualised niche of northern lapwings
253 are the following: temperature, precipitation, wind speed, Normalized Difference Vegetation
254 Index (NDVI), crop type, cropping intensity, soil water index, soil organic carbon, soil organic
255 carbon stock, soil nitrogen, pesticide application rates, resource abundance, population
256 density, human footprint, and earthworm abundance. An important note is that the earthworm

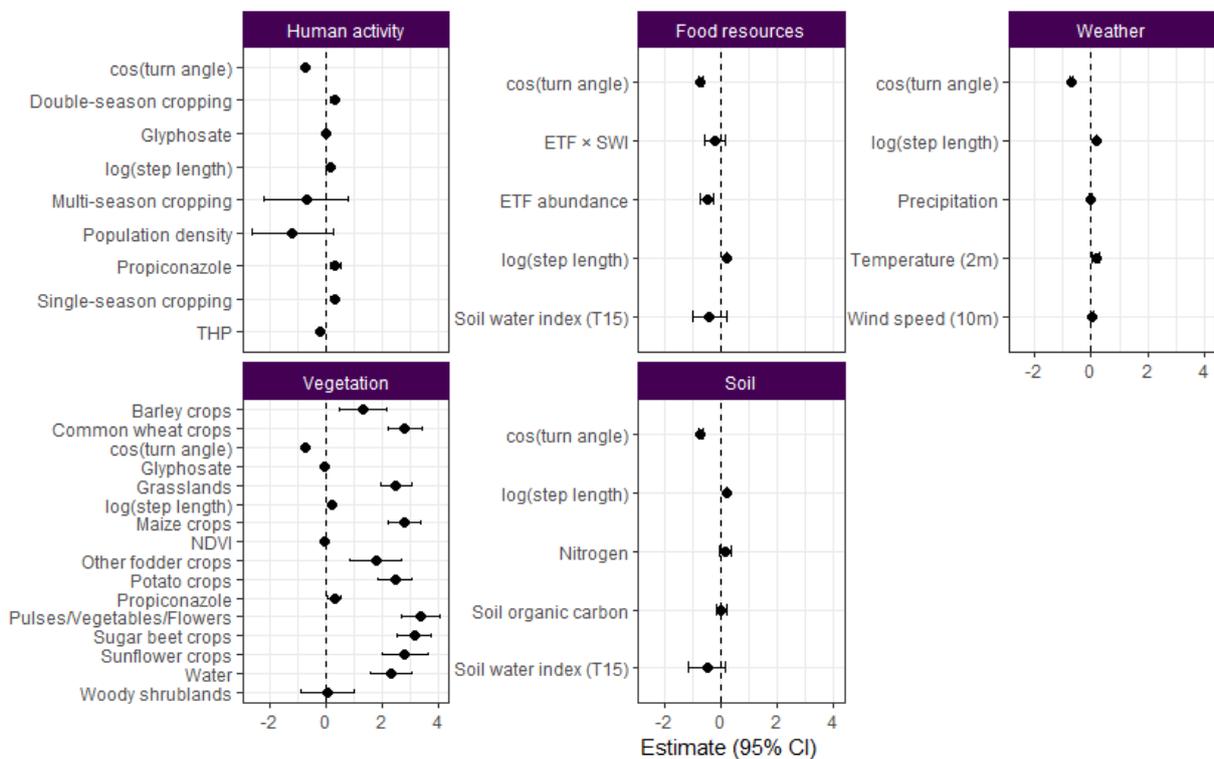
257 abundance is here quantified as an earthworm abundance factor (ETF). The higher the factor
 258 value, the lower the earthworm abundance.

259 Workflow implementation

260 *Step 1: Mixed-effects RSFs with random slopes per individual*

261 The mixed-effects resource selection functions per resource type show that northern lapwings
 262 avoid densely populated areas and frequently cropped fields but show strong preferences for
 263 certain crop types, water and high earthworm abundance (Fig. 2).

264

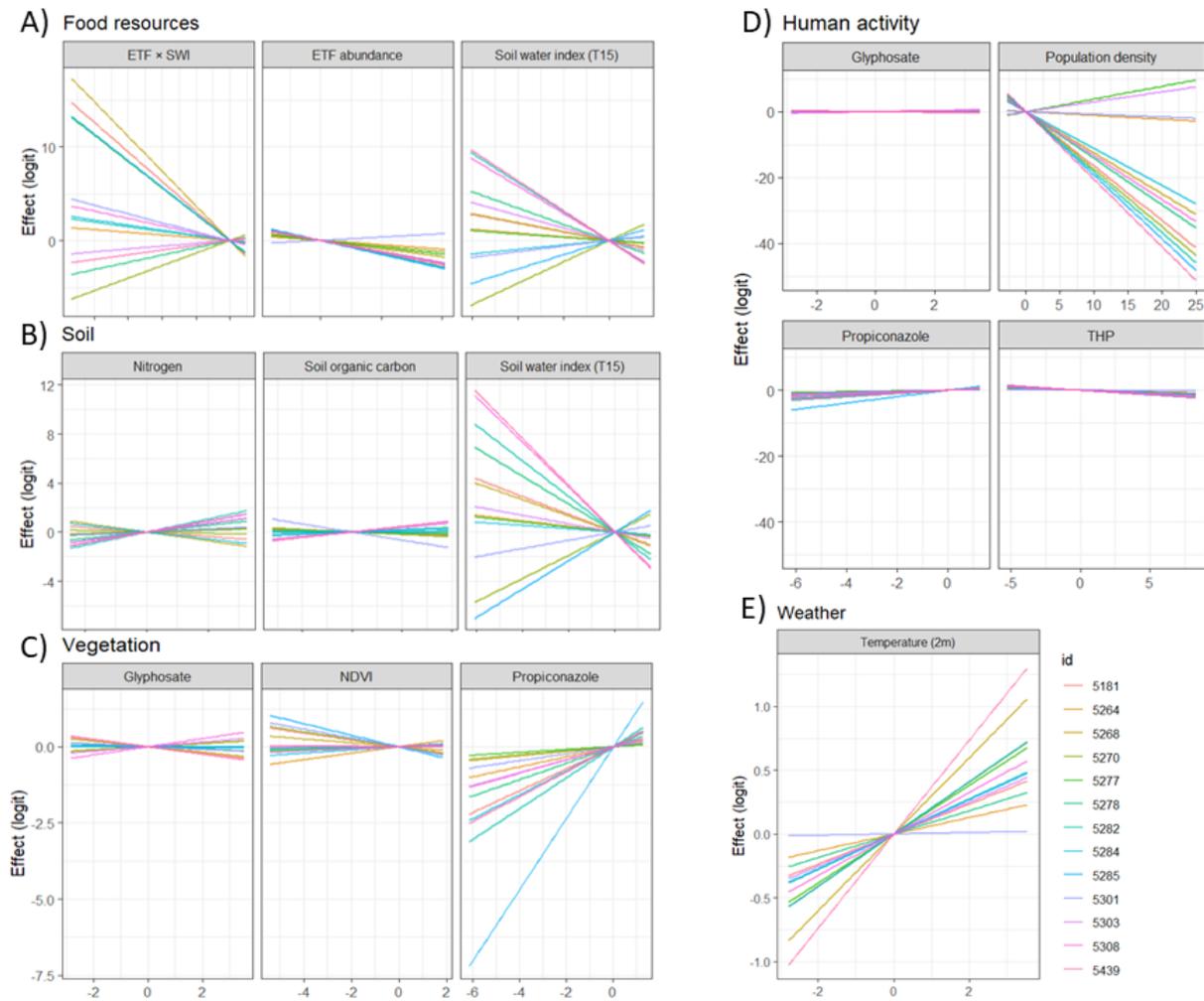


265

266 **Figure 2.** Resource selection function coefficients for each resource type based on the
 267 movement of northern lapwings (n=13). The coefficients represent the population-level
 268 averages that describe the strength of selection based on the mixed-effects resource selection
 269 functions. The results are based on the whole dataset, before filtering.

270

271 The resource selection function coefficients (Table S1) just confirm what is already known
 272 about the ecology of the species. To explore individual niche variation in resource selection, it
 273 is necessary to incorporate random slopes, also known as reaction norms (Dingemanse et al.,
 274 2010), to allow each individual have a different response to each environmental variable (Fig.
 275 3).



276

277 **Figure 3.** Random slopes (reaction norms) of each northern lapwing (n=13) and model
 278 predictor (facets). The random slopes were calculated with mixed-effects resource selection
 279 functions. The results are based on the whole dataset, before filtering.

280

281

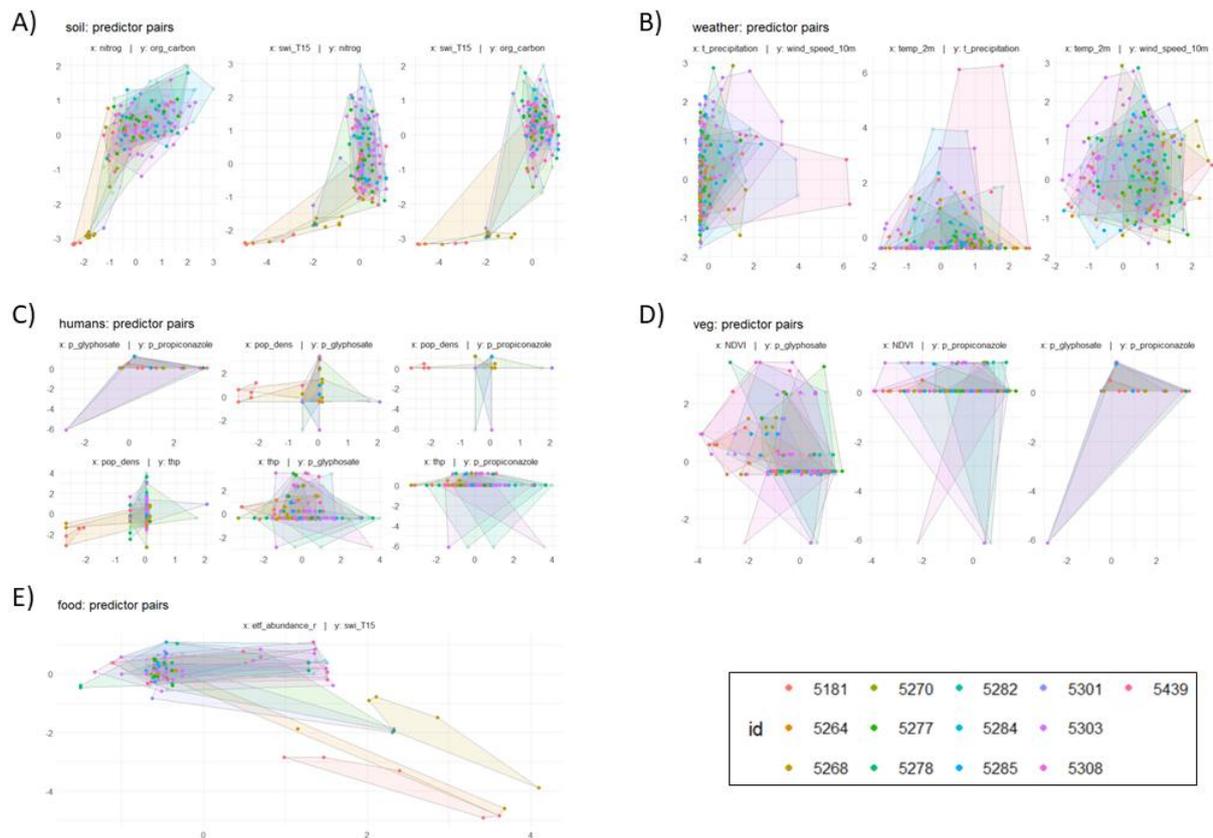
282 *Step 2: Relative selection probabilities (RSPs)*

283 The relative selection probability is a metric that allows for inter-individual comparison because
284 it is standardized. Each individual has a certain RSP per model (food, soil, weather etc.), which
285 was calculated based on the model's coefficients and the individual strength of selection. In
286 this study, I use $RSP > 0.65$ as an arbitrary threshold for an expected lifetime reproductive
287 success of at least 1 surviving offspring. This filtering results in the removal of most available
288 points, due to low selectability by the lapwings.

289 *Step 3: Visual diagnostics of individualised niches in the environmental space*

290 The niche space filtered by high expected fitness outcome ($RSP > 0.65$) is the individualised
291 niche space (Fig. 1C). These niches can be visualized as convex hull polygons, similarly to
292 multidimensional hypervolumes. Here, I visualize them in two dimensions, to facilitate
293 interpretability. A visual inspection of these polygons can provide information on individual
294 niche overlap and niche breadth of each individual. Originally, the niche hypervolume is an
295 ellipsoid, but this is not necessarily the case with individualised niches. In addition, the
296 individualised niche is not necessarily a continuous space, but this depends on the
297 environmental variables that comprise it and how they are linked to individuals' fitness.

298 In Fig. 4, many points of the potential individualised niche have been excluded due to the
299 filtering of $RSP > 0.65$. However, the plots are still informative and present the increased overlap
300 among the northern lapwing individuals of the analysed dataset.



301

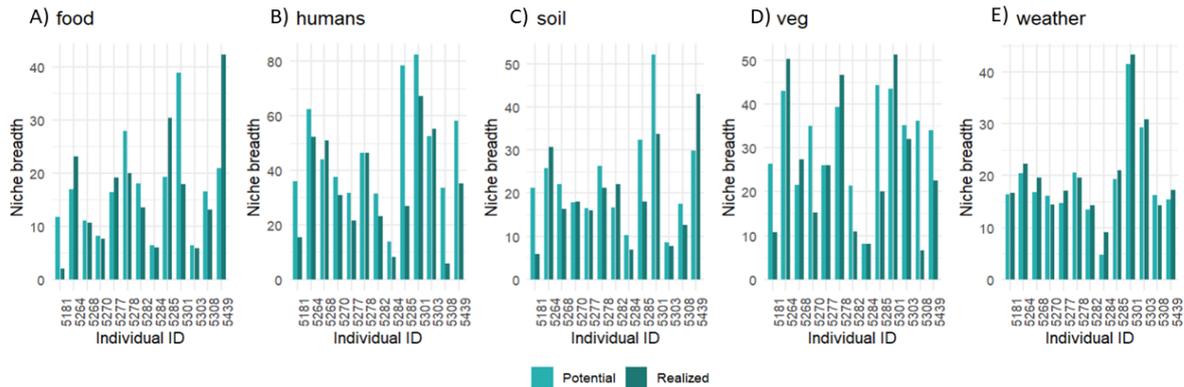
302 **Figure 4.** Convex hull polygon representations of individualised niche hypervolumes
 303 (RSP>0.65) of northern lapwings (n=13) in the PCA space. Each colour corresponds to one
 304 individual. The results are based on the dataset after filtering with RSP>0.65.

305

306 *Step 4: Quantifying individualised niches: overlap, and breadth*

307 The niche breadth was quantified as the area of the convex hull of Figure 4 in Step 3 (Table
 308 S2). Here, niche breadth can be considered the equivalent of within-individual variance of
 309 individualised niche. In many cases, for example the selection of soil variables and human
 310 presence variables, the realised niche breadth is smaller than the potential niche breadth,
 311 providing evidence for stronger individual specialization (Fig. 5).

Niche Breadth by Domain (polygon area in PCA space)



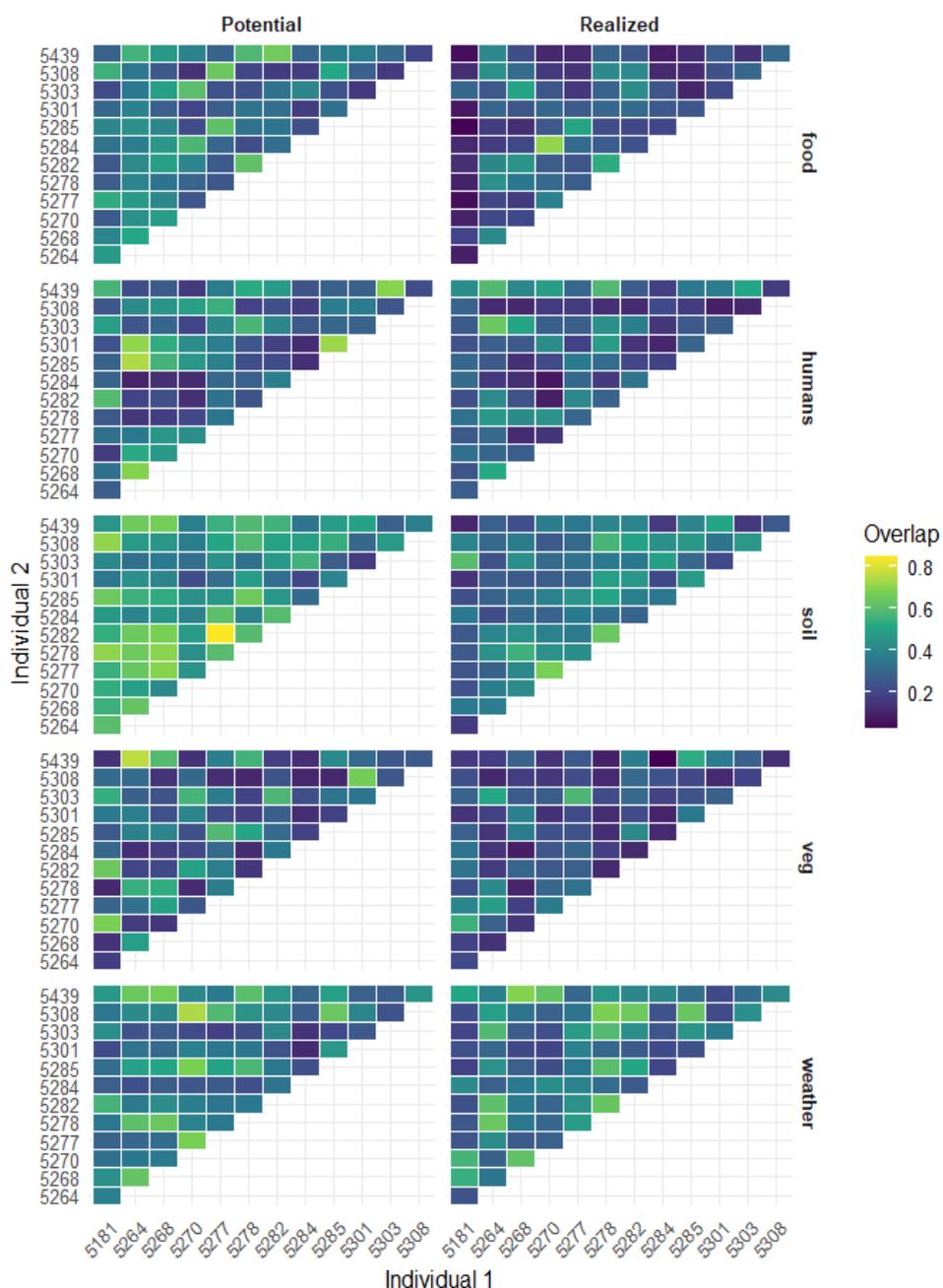
312

313 **Figure 5.** Niche breadth of the potential and realised individualised niche of northern
314 lapwings (n=13). Each individual has one bar for the breadth of potential and one bar for the
315 breadth of the realised niche.

316

317 Regarding pair-wise overlap among individuals (Fig. 6), high overlap among potential
318 individualised niches is observed in the soil variables, which can be interpreted as limited
319 potential for individual differentiation and likely a highly suitable environment. High overlap
320 between individualised realised niche is observed in food resources (soil water index,
321 earthworm abundance and their interaction), which in practice means that individuals tend to
322 use the same resources.

Pairwise Niche Overlap by Domain (Jaccard, PCA hulls)



323

324 **Figure 6.** Pairwise overlap among 13 individual northern lapwings calculated with the
 325 Jaccard index in a two-dimensional PCA space.

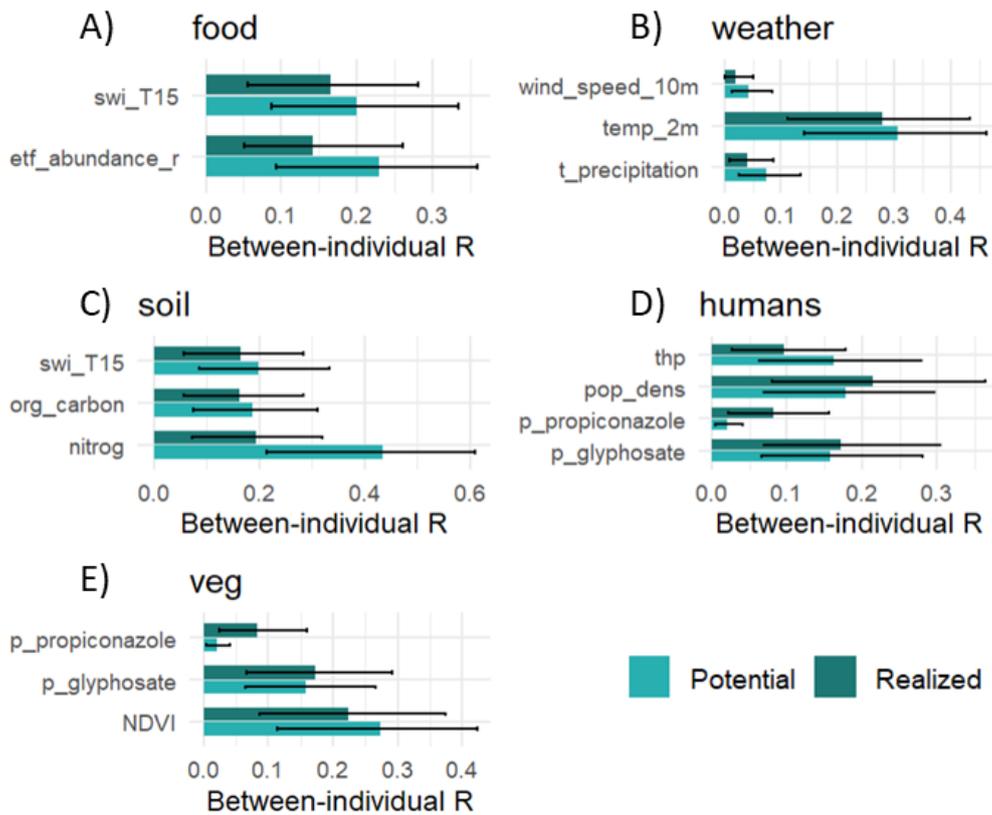
326

327 *Step 5: Repeatability of individual resource use*

328 This step is essentially an attempt to account for resource availability. Individual niche variation
 329 in resource use is strongly affected by the available resources in the area. The repeatability of

330 behaviour is an important metric to quantify intraspecific variation. High repeatability of the
331 realised niche means individuals consistently use different parts of that environmental axis. If
332 repeatability is high for the potential individualised niche, individuals differ in what is accessible
333 to them because of spatial segregation, different home ranges, different study sites, or
334 sampling design. Consequently, high repeatability in both the realised and potential niche
335 mean that individual differences can be explained by different opportunity sets rather than by
336 different choices or behavioural syndromes. In this step I propose the calculation of
337 repeatability of realised and potential niches, because the comparison of the repeatability
338 values can unveil how dependent individual variation in resource use is on available resources.
339 If realised repeatability exceeds potential repeatability, individuals differ more in what they use
340 than expected given what they could have used, which supports the interpretation of
341 individualised selection or specialisation. If realised and potential repeatability are similar,
342 individual differences in use largely mirror differences in availability, which points to
343 constrained opportunity sets rather than strong individualised choice. If potential repeatability
344 is higher than realised repeatability, individuals experience different environments or exhibit
345 home range segregation.

346 Northern lapwing repeatability of potential and realised individualised niches did not differ
347 significantly and their relationship differed across all predictors (Table S3), with repeatability
348 value ranging from 0 to 0.55 for potential and from 0 to 0.83 for realised niches (Fig. 7). In most
349 cases, the repeatability of the realised niche was larger than the potential, which is consistent
350 with the hypothesis that northern lapwings exhibit 'spatial personalities' (Stuber et al., 2022).



351

352 **Figure 7.** Repeatability of potential and realised niches across all predictors for the northern
 353 lapwings (n=13).

354

355 Discussion

356 This study proposes a workflow to quantify the inter-individual differences of resource use and
 357 produce metrics and indices that can be used for further analyses. It is a synthesis of already
 358 existing tools and concepts, commonly used in Movement Ecology, Behavioural Ecology and
 359 Remote Sensing. Furthermore, it is a response to recent calls during the last decade for the
 360 incorporation of individual-level variation in Ecology and Conservation (Jeltsch et al., 2025;
 361 Matthiopoulos, 2022; Merrick and Koprowski, 2017; Panzacchi et al., 2015; Réale et al., 2007).

362 The repeatability of the potential and realised individualised niches is my suggestion to tackle
 363 the problem of availability. In many cases, habitat selection studies compare individual patterns
 364 without accounting for availability. Based on the workflow of the present study, resource

365 availability is taken into consideration through the comparison of the repeatability values of the
366 potential and realised niches.

367 Individualised niche is a useful conceptual tool with multiple implications for conservation. The
368 development of individual-based models, which incorporate energy costs, demographic trends,
369 habitat selection patterns and life-history traits is a promise for a more accurate and
370 mechanistic representation of wild population dynamics (Bluhm et al., 2025; Van Benthem and
371 Wittmann, 2020; Zurell et al., 2024) and their future (Braschler et al., 2020).

372 An important distinction between the potential and the fundamental individualised niche is that
373 the former takes into consideration the conspecific context, while the latter does not. The
374 fundamental niche and its individualised expression (Takola and Schielzeth, 2022) are two
375 theoretical concepts that were introduced as thought experiments, to present the counter-
376 factual of the realised niches. In practice, the fundamental niche of species has shown a
377 mismatch with the realised (observed) niche, which has revived the debate about the
378 usefulness of the niche concept (Angilletta et al., 2019; Matthiopoulos, 2022; McInerney and
379 Etienne, 2012; Musters and De Snoo, 2025). Overall, the observed mismatch between the
380 fundamental and realised niche (Jiménez et al., 2019; Rosado et al., 2016), in combination
381 with behavioural syndromes, stress tolerance (Lian et al., 2022) and phenotypic plasticity
382 (Angilletta et al., 2019), might explain the smaller breadth of potential individualised niche
383 (compared to realised individualised niche breadth) in some cases.

384 Future research can focus on finding the link between individualised niches and population
385 growth rates. Previous studies have established a link between intraspecific variation and both
386 intra- and inter-specific competition (Enne et al., 2026; Moran et al., 2022). Furthermore, there
387 have been multiple attempts across decades to establish conceptual links between habitat
388 selection and population dynamics (Boyce et al., 2016; Holt, 1987; Kristan, Iii, 2003;
389 Matthiopoulos et al., 2015; Morris, 1996; Pulliam and Danielson, 1991; Rosenzweig, 1991) but
390 also to find empirical evidence of the mechanism behind this link (Smith et al., 2023;
391 Weimerskirch, 2018). However, none of these attempts has taken place within the

392 individualised niche framework. The difficulty of finding this link can lie either in the perspective
393 (top-down instead of bottom-up) or in the strong methodological traditions in habitat selection
394 studies, focusing on correlational models (Boyce and McDonald, 1999; Fieberg et al., 2010;
395 Gehring and Swihart, 2003).

396 Nevertheless, the intersection of behavioural and landscape ecology is one of those areas of
397 Ecology where methods have evolved faster than concepts. As a result, we are now (especially
398 during the last decade) at a stage where we have stronger analytical pathways but relatively
399 weak inference and limited cross-pollination with the field of Philosophy (Heger et al., 2025).
400 The concept of individualised niches can function as the conceptual “epoxy” that fills the
401 inference gaps and supports the structural robustness of this scientific niche.

402 Environmental niche modelling has been useful for predicting invasions (De Andrade et al.,
403 2019) and the incorporation of fitness can further strengthen these predictions. In addition, the
404 metric of individualised niche breadth can facilitate the incorporation of intraspecific trait
405 variation in global change studies (Carscadden et al., 2020).

406

407 Outlook

408 This framework provides a practical step towards scaling up individual-level movement
409 behaviour and facilitating population-level inference. It achieves this by quantifying individual
410 niche variation, filtering for highly selectable areas, and aggregating resource-use data into
411 meaningful indices of intraspecific variation. The workflow requires compiling a dataset
412 containing recorded locations and the corresponding environmental variables. It is designed
413 to be transparent, reproducible, and compatible with common movement ecology data
414 structures and tools. Future work can further examine links between movement patterns,
415 resource use, and fitness outcomes. As the individualised niche concept becomes established
416 in ecology, there is an increasing need to draw population-level inference from individual-level
417 data. Quantifying individualised niches is therefore an essential tool in a behavioural
418 ecologist’s toolbox.

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719 **Table S1.** Model coefficients for the mixed-effects resource selection functions.

MODEL	TERM	ESTIM	STD.ER	CONF.	CONF.	STATI	P.VA
		ATE	ROR	LOW	HIGH	STIC	LUE
FOOD RESOUR CES	cos(turn angle)	-0.73	0.03	-0.79	-0.66	-22.37	0.00
FOOD RESOUR CES	log(step length)	0.19	0.01	0.18	0.21	26.93	0.00
FOOD RESOUR CES	ETF abundance	-0.50	0.12	-0.73	-0.27	-4.29	0.00
FOOD RESOUR CES	Soil water index (T15)	-0.42	0.31	-1.03	0.19	-1.34	0.18
FOOD RESOUR CES	ETF \bar{A} — SWI	-0.21	0.19	-0.58	0.16	-1.13	0.26
WEATHE R	cos(turn angle)	-0.72	0.03	-0.78	-0.66	-22.36	0.00
WEATHE R	log(step length)	0.18	0.01	0.16	0.19	25.90	0.00
WEATHE R	Temperature (2m)	0.16	0.06	0.05	0.28	2.83	0.00
WEATHE R	Precipitation	-0.01	0.02	-0.05	0.04	-0.30	0.76

WEATHER	Wind speed (10m)	0.03	0.02	-0.02	0.08	1.33	0.18
SOIL	cos(turn angle)	-0.72	0.03	-0.79	-0.66	-22.22	0.00
SOIL	log(step length)	0.19	0.01	0.18	0.20	26.33	0.00
SOIL	Soil water index (T15)	-0.51	0.34	-1.17	0.16	-1.50	0.13
SOIL	Nitrogen	0.14	0.11	-0.09	0.36	1.20	0.23
SOIL	Soil organic carbon	0.01	0.09	-0.17	0.18	0.07	0.94
HUMAN ACTIVITY	cos(turn angle)	-0.71	0.03	-0.78	-0.65	-21.91	0.00
HUMAN ACTIVITY	log(step length)	0.19	0.01	0.18	0.21	27.06	0.00
HUMAN ACTIVITY	Population density	-1.16	0.73	-2.60	0.27	-1.59	0.11
HUMAN ACTIVITY	THP	-0.18	0.05	-0.28	-0.08	-3.47	0.00
HUMAN ACTIVITY	Single-season cropping	0.33	0.07	0.20	0.47	5.02	0.00
HUMAN ACTIVITY	Double-season cropping	0.34	0.07	0.20	0.47	4.95	0.00
HUMAN ACTIVITY	Multi-season cropping	-0.69	0.77	-2.19	0.82	-0.89	0.37
HUMAN ACTIVITY	Glyphosate	0.03	0.05	-0.07	0.13	0.53	0.60
HUMAN ACTIVITY	Propiconazole	0.35	0.10	0.15	0.56	3.44	0.00

VEGETAT ION	cos(turn angle)	-0.71	0.03	-0.77	-0.64	-21.53	0.00
VEGETAT ION	log(step length)	0.21	0.01	0.20	0.22	28.38	0.00
VEGETAT ION	NDVI	-0.03	0.06	-0.15	0.09	-0.51	0.61
VEGETAT ION	Common wheat crops	2.82	0.31	2.20	3.43	9.01	0.00
VEGETAT ION	Barley crops	1.33	0.43	0.48	2.17	3.08	0.00
VEGETAT ION	Maize crops	2.82	0.30	2.24	3.40	9.47	0.00
VEGETAT ION	Potato crops	2.48	0.31	1.88	3.08	8.10	0.00
VEGETAT ION	Sugar beet crops	3.15	0.31	2.55	3.76	10.15	0.00
VEGETAT ION	Sunflower crops	2.82	0.41	2.01	3.63	6.81	0.00
VEGETAT ION	Pulses/Vegetable s/Flowers	3.38	0.35	2.68	4.07	9.55	0.00
VEGETAT ION	Other fodder crops	1.79	0.46	0.88	2.70	3.86	0.00
VEGETAT ION	Woody shrublands	0.05	0.48	-0.89	1.00	0.11	0.91
VEGETAT ION	Grasslands	2.52	0.29	1.95	3.08	8.77	0.00
VEGETAT ION	Water	2.33	0.38	1.58	3.08	6.09	0.00

VEGETAT ION	Glyphosate	-0.01	0.05	-0.11	0.10	-0.16	0.87
VEGETAT ION	Propiconazole	0.33	0.12	0.09	0.57	2.67	0.01

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722 **Table S2.** Realised and potential individualised niche breadth per individual.

ID	REALISED_BREADTH	POTENTIAL_BREADTH	DOMAIN
5181	2.02	11.79	food
5264	23.1	16.9	food
5268	10.64	11.07	food
5270	7.64	8.16	food
5277	19.13	16.46	food
5278	19.98	27.89	food
5282	13.47	18.1	food
5284	6.06	6.36	food
5285	30.37	19.24	food
5301	17.97	38.94	food
5303	5.8	6.41	food
5308	13.06	16.48	food
5439	42.24	20.87	food
5181	16.68	16.37	weather
5264	22.23	20.45	weather
5268	19.63	16.82	weather
5270	14.37	16.13	weather
5277	17.15	14.75	weather
5278	19.68	20.56	weather
5282	14.23	13.42	weather
5284	9.07	4.68	weather
5285	20.99	19.34	weather
5301	43.3	41.5	weather
5303	30.88	29.28	weather
5308	14.28	16.32	weather
5439	17.21	15.36	weather
5181	5.87	21.17	soil
5264	30.69	25.74	soil
5268	16.3	22.1	soil
5270	18.06	17.8	soil
5277	16.02	16.59	soil
5278	21.2	26.24	soil
5282	22.08	16.68	soil
5284	6.84	10.23	soil
5285	18.06	32.38	soil
5301	33.81	52.1	soil
5303	7.77	8.56	soil
5308	12.63	17.45	soil
5439	43.09	29.93	soil
5181	15.29	36.12	humans
5264	52.23	62.41	humans
5268	50.87	43.91	humans
5270	30.8	37.54	humans
5277	21.5	31.6	humans
5278	46.4	46.53	humans
5282	23.08	31.41	humans

5284	8.3	13.77	humans
5285	27.02	78.49	humans
5301	67.18	82.35	humans
5303	55.22	52.46	humans
5308	5.85	33.65	humans
5439	35.23	58.19	humans
5181	10.68	26.33	veg
5264	50.3	42.96	veg
5268	27.32	21.61	veg
5270	15.19	35.01	veg
5277	25.99	26	veg
5278	46.66	39.42	veg
5282	10.96	21.43	veg
5284	8.17	8.18	veg
5285	20.12	44.41	veg
5301	51.23	43.47	veg
5303	31.97	35.21	veg
5308	6.56	36.14	veg
5439	22.55	34.09	veg

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726 **Table S3.** Variance decomposition of repeatability of realised and potential niches per model
 727 and predictor.

predictor	betweenIndR	CI_low	CI_high	withinIndR	model
etf_abundance_r	0.72	0.45	0.84	0.28	food
swi_T15	0.83	0.63	0.91	0.17	food
etf_abundance_r	0.13	0	0.42	0.87	food
swi_T15	0	0	0.23	1	food
temp_2m	0.37	0.12	0.57	0.63	weather
t_precipitation	0.02	0	0.12	0.97	weather
wind_speed_10m	0.03	0	0.13	0.97	weather
temp_2m	0.55	0.06	0.80	0.45	weather
t_precipitation	0.01	0	0.24	0.98	weather
wind_speed_10m	0.01	0	0.26	0.99	weather
swi_T15	0.83	0.62	0.91	0.17	soil
nitrog	0.65	0.38	0.80	0.35	soil
org_carbon	0.80	0.58	0.88	0.20	soil
swi_T15	0	0	0.23	1	soil
nitrog	0.21	0	0.53	0.79	soil
org_carbon	0.13	0	0.43	0.87	soil
pop_dens	0.78	0.55	0.87	0.22	humans
thp	0.28	0.08	0.47	0.72	humans
p_glyphosate	0.03	0	0.14	0.97	humans
p_propiconazole	0	0	0.09	1	humans
pop_dens	0	0	0.23	1	humans
thp	0	0	0.24	1	humans
p_glyphosate	4.25E-20	4.25E-20	4.25E-20	1	humans
p_propiconazole	0.01	0	0.27	0.99	humans

NDVI	0.41	0.17	0.60	0.58	veg
p_glyphosate	0.03	0	0.14	0.97	veg
p_propiconazole	0	0	0.08	1	veg
NDVI	0	0	0.25	1	veg
p_glyphosate	4.25E-20	4.25E-20	4.25E-20	1	veg
p_propiconazole	0.01	0	0.23	0.99	veg