Characterization of habitat requirements of European fishing spiders

Lisa Dickel^{1,2*}, Jérémy Monsimet^{1*}, Denis Lafage^{3,4}, Olivier Devineau¹

¹*Department of Forestry and Wildlife management, Inland Norway University of Applied Sciences, Campus Evenstad, Koppang, Norway*

²*Centre for Biodiversity Dynamics, Department of Biology, Norwegian University of Sciences and Technology (NTNU)*

³*UMR CNRS 6553 ECOBIO, Université de Rennes, Rennes, France*

⁴*Department of Environmental and Life Sciences/Biology, Karlstad University, Karlstad, Sweden*

*Corresponding authors: Lisa Dickel and Jérémy Monsimet

Abstract

Wetlands are among the most threatened habitats in the world, and so are their species, which suffer habitat loss due to climate and land use changes. Freshwater species and arthropods receive little attention in research and conservation, and the goals to stop and reverse the destruction of wetlands published 25 years ago in a manifesto by the Union of Concerned Scientists have not been reached. In this study, we investigated the occurrence and habitat requirements at two spatial scales of two species of European fishing spiders *Dolomedes*, which rely heavily on declining wetland habitats in Sweden and southern Norway.

We collected occurrence data for *Dolomedes plantarius* and *Dolomedes fimbriatus*, using a live-determination-method. We modelled the placement of nursery webs to describe fine scaled habitat requirements related to vegetation and microclimate. Using a machine learning approach, we described the habitat features for each species, and for co-occurrence sites, to provide insight into variables relevant for the detectability of *Dolomedes*.

We found that habitat requirements were narrower for *D. plantarius* compared to *D. fimbriatus*; that the detection of nursery webs can be affected by weather conditions and that nursery placement is mostly dependent on the proximity to water, the presence of *Carex sp.* (Sedges) and of crossing vegetation structures, and on humidity. Furthermore, co-occurring sites were more similar to *D. plantarius* sites than to *D. fimbriatus* sites, whereby surrounding forest, water type and velocity, elevation and latitude were of importance for explaining which species of *Dolomedes* was present.

32 We provide a detailed field protocol for *Dolomedes* studies, including a novel live-determination
33 method, and recommendations for future field protocols.

34

35 **Keywords:** *Dolomedes*, Pisauridae, detectability, red listed species, conservation

Introduction

Biodiversity is threatened by anthropogenic land use and climate changes (Sala 2000). Wetlands are among the most threatened habitats, yet they are particularly important ecosystems in terms of climate change mitigation, biodiversity by providing breeding and feeding grounds for many species, and hydrology through flood regulation, water holding bodies, and nutrient retention. Thereby, wetlands are crucial to human existence (De Groot et al. 2006). 87% of wetlands have been lost since the beginning of the 18th century, mainly because of expansion of agriculture and urbanization (Davidson 2014). De Groot et al. (2006), and Hu et al. (2017) estimated that 33% of wetlands were lost due to human activities. The Ramsar Convention (Ramsar Convention Secretariat 2013) and the first world's scientists warning to humanity (Kendall 1992) formulated wetland conservation as a global goal. However, in a recently published second warning to humanity, the authors stated that not only wetland protection and restoration goals were reached, but that wetlands destruction and loss have proceeded (Finlayson et al. 2019). Conservation priorities are mostly determined through variable and dynamic human value (Lindenmayer and Hunter 2010), which has led to unequal conservation efforts across habitats and taxa, with groups like invertebrates (Clark and May 2002, Finlayson et al. 2019) and freshwater/wetland species being particularly neglected (Darwall et al. 2011). Other issues interact with and add on this: the difficult accessibility of wetlands and the low detection of invertebrates (Noreika et al. 2015) cause bias across habitats and taxa. Yet, according to a review by Kellner and Swihart (2014),

few studies accounted for imperfect detection, and even less often in invertebrate studies than in studies of other taxa (Kellner and Swihart 2014)..

Although Clark and May (2002) recognized the taxonomic imbalance of research, basic knowledge is still missing to inform conservation of wetlands' invertebrates. This knowledge is lacking for the two European fishing spiders of the *Dolomedes* genus, namely the raft spider *Dolomedes fimbriatus* and the great raft spider *Dolomedes plantarius*. Both species are semi-aquatic, forage on land as well as on water, and build their nursery webs close to or even above the water surface (Gorb and Barth 1994, Duffey 2012). The detection of both species is difficult due to their lifestyle, which includes fleeing behavior on and under the water surface when disturbed (Gorb and Barth 1994). *Dolomedes* do not build prey-webs, which makes it even more difficult to detect. Like other members of the family Pisauridae (Stratton et al. 2004), *Dolomedes* build nursery webs, which are a convenient sign of presence during the reproductive season, thus facilitating their detection. Females are found close to their nursery webs, which is useful for identification, mainly because only adults can be identified with certainty by inspecting their genitals. Further, the placement of nursery webs functions as an important indicator for *Dolomedes* habitat determining reproductive success and survival. habitat determining reproductive success and survival.

Habitats of both species are declining because of anthropic transformation and draining of wetlands (van Helsdingen 1993, Hu et al. 2017, Finlayson et al. 2019). While *D. fimbriatus* is relatively common (Duffey 2012), *D. plantarius* is much rarer, and is one of the few red-listed

75 spiders in Europe, despite its fairly broad distribution range (Leroy et al. 2013). Naturalist
76 observations suggest that *D. plantarius* has more specific habitat requirements than *D. fimbriatus*
77 (Duffey 2012). Habitat loss for might have more severe consequences for *D. plantarius*, which
78 has less potential to adapt, thus making it a species of conservation interest (Smith 2000).
79 Investigating the population decline is difficult, as historical distribution data of *Dolomedes* are
80 scarce (Duffey 2012). Some authors suggest that there may be denser populations of *D.*
81 *plantarius* than known, especially in the less monitored areas in eastern Europe (Ivanov et al.
82 2017). Additionally, misidentifications of the two species were common in the first half of the
83 20th century, when body color was used for determination, although it is not a reliable indicator
84 for the discrimination of both species (Bonnet 1930, van Helsdingen 1993). Little monitoring
85 combined with potential misidentifications and difficult detection of *Dolomedes* caused an
86 overall lack of knowledge about the distribution and status of the species. Recent observations
87 indicate that co-occurrence, which was considered rare or even impossible, might be more
88 frequent than previously thought (Ivanov et al. 2017).
89 In this study, we contribute to further characterizing the habitat requirements of the two
90 European *Dolomedes* species. Based on naturalist observations by van Helsdingen (1993) and
91 (1995, 2012), we expect *D. fimbriatus* to be more flexible than *D. plantarius* in its habitat
92 requirements regarding the presence of water, and the specific characteristics of the aquatic
93 habitat. We also expect *D. fimbriatus* to occur at higher altitudes and latitudes due to less
94 restricted temperature requirements, and to tolerate more acidic terrestrial habitats, which would
95 facilitate its presence in mires, bogs, and near coniferous forest. coniferous forest.

Materials and Methods

Study Area and Site Choice

In order to find potential *Dolomedes* habitats, we chose our study sites based on prior observations extracted from the Global Biodiversity Information Facility (GBIF: The Global Biodiversity Information Facility 2019) using the R package rgbif (Chamberlain and Boettiger 2017) and based on the habitat suitability map of *D. plantarius* from Leroy et al. (2014). Because the resolution of the suitability map and the accuracy of the GBIF positions were too low for our purpose, we selected sampling areas within the highly suitable habitat and close to the GBIF positions based on information from the literature.

We chose water bodies with riparian vegetation and other types of wetlands (bogs, fens, meadows) for data collection (van Helsdingen 1993, Duffey 1995, 2012). Because the model by Leroy et al. (2014) is only valid for *D. plantarius*, we assessed the potential suitability for *D. fimbriatus* based on the visual impression we had of the wetland, during a visit. The selected locations and the detected species are shown in Figure 1.

Data Collection

We collected and geo-referenced all data using the data collection software KoBoToolbox (KoBoToolbox 2020). We collected habitat data at site and microhabitat scales. We determined and recorded species of *Dolomedes* at the site scale. We delimited each study site by its natural borders, or, if too big, after five transects; i.e. 40 m along the water body, see transect description below. after five transects; i.e. 40 m along the water body, see transect description below.

Site Scale Data

Since the detectability of free-ranging spiders varies with weather conditions (Noreika et al. 2015), we recorded temperature and wind speed, and visually classified rain and clouds at the beginning of each field work session. In case of wind (Beaufort scale > 3, equivalent to 12- 19 km/h wind speed) or rain, we did not attempt to detect the spiders, to keep detection conditions equal.

We searched for nursery webs and spiders for 20 min on each site. If possible, we searched the edge of the vegetation both visually and by sweep-netting, while wading through the water. If entering the water was not possible (e.g., due to quality of the substrate, the strength of stream or water depth), we moved carefully across the riparian vegetation to the contact zone of marginal vegetation and water and applied the same search strategy. We found most adult females in nursery webs or in the nearby vegetation, or on the water. We captured the spiders in a glass container. If the spider dived, we caught it with a fishing net (mesh size approximately 0.9*0.3 mm) from the water and transferred it into a glass container.

Once inside the container, we determined the species by pressing the individual gently with a soft sponge against the glass, to inspect the epigyne or pedipalps (A picture of the identification process is available in Appendix A). We released all spiders after identification. If we detected only nursery webs but no spider on a site, we discarded the data, as the nursery web of *Pisaurida mirabilis* cannot safely be distinguished from the web of *Dolomedes*.

We collected variables regarding vegetation type, land use and surroundings at site level (Table 2). As *Dolomedes* are semi-aquatic species, measurements on plot level were concentrated around the water body or in the ‘wet center’ of study sites without open water, from where we drew transects for further data collection plots.

Microhabitat Data

Within each site, we placed up to five transects to systematically arrange sampling plots (Fig. 2) to collect microhabitat data. If open water was present, we placed the transects perpendicular to the water body and 10 m apart. If no open water was present, we placed transects along a wet to dry ground gradient. If no gradient was detectable, the transects started (at random) from a habitat edge, to represent the site of interest. We recorded the applied sampling type for each site.

Along each transect, we collected plot-scale data for one aquatic plot (if water was present) at the beginning of each transect and terrestrial circular plots (radius = 1.5 m). Terrestrial plots were located at two, seven and twelve meters from the water edge based on test sites to represent the gradient from aquatic to terrestrial habitat. The focus on the shore-area (or the wettest area in the site) is reflected by the higher density of plots close to the water (Figure 2). We collected data in one to three terrestrial plots, depending on the width of the site. When the riparian vegetation was limited to a few centimeters by the water edge, we included a fourth half-circle ($r = 0.5\text{m}$) terrestrial plot with its center at the water edge to represent the vegetation (see tw plot in Figure 2). The shape of the additional plot differed from the others to avoid plots overlapping. We

collected percent cover data for the five most relevant plant species according to literature (*Carex spp.*, *Juncus spp.*, *Typha spp.*, *Phragmites spp.* and *Sphagnum spp.*) on the Braun-Blanquet scale (Westhoff and Van Der Maarel 1978), which we later reduced for modeling purposes (Table 3). Furthermore, we collected structural and microclimate variables (Table 2). We collected the same measurements around the nursery webs, which we searched for in the entire site. We extracted site elevation after data collection from a digital elevation model (EEA 2018).

Statistical Analysis

We prepared and analysed all data in R (R Core Team 2020), and R Studio (RStudio Team 2012). We followed the protocol for data exploration by Zuur et al. (2010) and used the tidyverse framework for data exploration and preparation (Wickham et al. 2019). We standardized all continuous variables to facilitate model convergence and interpretation.

Site Scale Analysis

In order to investigate differences among habitats occupied by the two the occupied habitats of both species, we compared sites in which only *D. fimbriatus*, only *D. plantarius*, both species or no *Dolomedes* and none of both species were detected by using flexible discriminant analysis (FDA) (Hastie et al. 1994) using the R package ‘mda’ (Hastie et al. 2013) We used the *Dolomedes* species detection; i.e. *D. fimbriatus*, *D. plantarius*, both species, or no *Dolomedes* detected, as the response variable in this supervised machine-learning-model. We considered

surrounding landscape and forest type, latitude, elevation, water type, water speed, water clearness, and vegetation type as predictors (Table 1).

In addition, we used a single-season occupancy model (MacKenzie et al. 2002) within the unmarked package (Fiske and Chandler 2011) to predict the nursery detection probability pooled for both species. We used the nursery and plot-scale data as spatial replicates, as an alternative to the usual temporal replicates/detection attempts. We considered weather, microclimatic variables (wind, cloudiness, rain, shade), vegetation structure and sampling related variables as potentially influencing detectability.

Microhabitat Characteristics Around Nursery

We modeled nursery presence/absence for sites in which *Dolomedes* presence was verified and in which we found at least one nursery web. Thereby we ensured that the sampling was not temporally unsuitable or the site generally unsuitable, which allowed us to model nursery placement within generally suitable sites.

For variable selection and parameter estimation, we fitted a binomial Generalized Additive Model (GAM) by component-wise boosting, using package mboost (function gamboost, Hothorn et al. 2020). Prior to model fitting, we checked variables correlation and we dropped highly correlated variables accordingly (threshold 0.7, Dormann et al. 2012). We did not consider interactions due to the low sample size. From variables humidity at ground level and humidity at 20 cm above ground level, we kept humidity at ground level. We kept average vegetation height, but we discarded the highly correlated maximum vegetation height. We then fitted a regularized

model, following the recommendation in Hofner et al. (2018) using all other predictor variables to identify the most relevant predictors and estimate the model parameters. We validated the model using cross validation and present the final model estimates.

To validate the model, we tested the stability of the selected variables via resampling using the package ‘stabs’ (Hofner and Hothorn 2017). Stability selection provides a reliable way to find an appropriate level of regularization, to keep variables with high selection probabilities. In our model, we used standard choices of tuning parameters, with a cut-off of 0.75 and the number of falsely selected base learners tolerated of 1 (Meinshausen and Bühlmann 2010). A conceptual overview of the analyses performed and the data used is presented in Figure 3 and in Appendix C.

Results

Site Scale Habitat Characteristics – Species Specific – Flexible Discriminant Analysis

We detected *D. fimbriatus* alone in 12 sites, *D. plantarius* alone in 6 sites, both species together in 4 sites and none of the two species in 9 of the visited sites (total sites: n= 31, Fig. 1).

The first axis of the FDA explained 82.58%, the second axis 10.34% (Fig. 4). The main variables loading onto the FDA axes, i.e., discriminating best between sites with none/ both / each species, were water type and surrounding forest on the first axis, and water speed on the second axis.

Sites holding either of the two species were well discriminated by the combination of variables loading on the first axis. *D. plantarius* sites were more restricted with respect to the associated

habitat variables, and sites with both species overlapped mostly with *D. plantarius* sites (Figure 4).

Microhabitat Characteristics Around Nursery

In the field, we found a nursery in 35 plots out of 184. The main variables selected in the boosted GAM model (Figure 5) were distance to water (selection frequency = 0.66), *Carex spp.* cover (selection frequency 0.13), crossing structures (selection frequency 0.09), the random effect site ID (0.08), humidity at ground level (selection frequency 0.02) and the intercept (selection frequency 0.01). We found that high abundances of *Carex spp.*, crossing structures, high values of humidity and low distances to water increased the probability of presence of a *Dolomedes* nursery (Figure 6). If water was present, the probability of encountering nursery webs beyond 70 cm away from the water edge was low. There was variation in the probability of finding nursery webs across sites (Figure 6). However, when testing the stability of the selected variables via resampling, only distance to water, the intercept and the random site ID were found to be stable enough, which was most likely caused by the small sample size (Appendix C).

The detection probability of nursery webs was higher for plots with a high abundance of crossing structures, higher air temperatures, fewer clouds (at the time of data collection), as well as for sites with open water compared to sites without a water body (Figure 4). Model details can be found in Appendix D.

Discussion

In this study, we found that the two *Dolomedes* present different habitat requirements. We found that *D. fimbriatus* is more generalist than to *D. plantarius*. Forested habitats, and habitats with low pH (as indicated by the presence of species such as *Carex* and *Sphagnum* and the proximity to coniferous forest, Blacklocke (2016)) or without open water appear to still be suitable for *D. fimbriatus*. At the microhabitat scale, nurseries were more likely to be located close to water, and where sedge and crossing structures were present.

The habitat requirements of the two fishing spiders were discriminated mainly by water, represented by the water type and speed, and by the site's surroundings, both in terms of landscape and forest. We found that *D. fimbriatus* was more tolerant to forested areas, and especially of coniferous forest. Duffey (1995) hypothesized that *D. fimbriatus* can occupy habitat with lower pH values compared to *D. plantarius*. Surrounding coniferous forest, which are dominant in Fennoscandia, may acidify water streams (Blacklocke 2016), thus impacting the pH and potentially restricting *D. plantarius*. We found *D. plantarius* most often at sites with slow-flowing rivers, and we found *D. fimbriatus* most often in bogs. *D. plantarius* was also highly associated with open and slow water, whereas *D. fimbriatus* was less restricted by water conditions. *Dolomedes* can use water as a hunting area and benefit from the use of vibrations at the water surface to detect prey (Bleckmann and Lotz 1987). This close relationship to water, together with the observation of juveniles of *D. fimbriatus* far from the shore, while juveniles of *D. plantarius* are found on the water (Duffey 2012), might result from different hunting abilities between the two fishing spider species.

We found some overlap in , which reflected a spatio-temporal overlap at the site scale. Holec (2000) hypothesized that co-occurrence of both species might only be observed in transitional habitats between sites suitable for *D. plantarius* (ie ponds) and sites suitable for *D. fimbriatus* (ie bogs). This observation is validated for one of the sympatric sites sampled (Figure 1), a fen in the forest. Nonetheless, we hypothesize that the conditions for co-occurrence are less restrictive because similar to (Lecigne 2016), we found two sympatric populations on the vegetation at the shore of a lake (Finjasjön lake, Figure 1). As already hypothesized by van Helsdingen (1993) or Duffey (1995, 2012), our data confirmed the higher degree of association of *D. plantarius* with water compared to *D. fimbriatus*, and in general more substantial restrictions in potential habitats for the former. This suggests that *D. plantarius* is more strictly specialist than *D. fimbriatus*. Even though the separation between generalist and specialist is not clear-cut, species which are ‘rather’ specialist seem to face extinction more often than generalists, especially when facing environmental changes (Colles et al. 2009). The co-occurrence of the two species might be explained by a broader ecological niche of *D. fimbriatus*, which partly overlaps with the niche of *D. plantarius*. The co-occurrence observed hide a possible segregation of both fishing spider species at the microhabitat scale.

At the microhabitat scale, *D. plantarius* might be more dependent on water for its reproductive behavior and nursery placement, which will require further species-specific investigation. Moreover, distance to water and humidity of the ground influenced nursery web placement. This dependency of *D. plantarius* on the water could facilitate cohabitation with *D. plantarius* being spatially segregated towards the shore. Indeed, DeVito et al. (2004) found that spider

273 assemblages of Lycosidae in a microhabitat was influenced by the physiology of the species. We
 274 also observed, in two sympatric populations, *D. plantarius* females carrying egg-sac while
 275 females of *D. fimbriatus* were already guarding their nursery webs with spiderlings. This might
 276 indicate temporal segregation as well, which would also facilitate the co-occurrence of otherwise
 277 ecologically close spiders species (Uetz 1977, Fasola and Mogavero 1995). Lastly, the
 278 coexistence of wandering spiders at the site scale is usually possible by segregation in micro-
 279 habitat use, which is mainly triggered by competition for food (Uetz 1977). An equivalent
 280 segregation could occur based on the different diet of the two species, with juveniles of *D.*
 281 *plantarius* being more restricted to water (Duffey 2012).

282 Within habitats occupied by *Dolomedes*, we found at the microhabitat scale that abundance of
 283 sedges (*Carex sp.*) and crossing structures, together with distance to water and humidity, were
 284 the most relevant variables for predicting the presence of nursery webs. Indeed, the architecture
 285 complexity of the vegetation is important for wandering spiders (Vasconcellos-Neto et al. 2017),
 286 and is illustrated here by the positive influence of the presence of crossing structures. We can
 287 also hypothesize that spiders benefit from the stiff stems of the sedge more than being
 288 taxonomically exclusive to them for placing nurseries. De Omena and Romero (2008) showed
 289 that some species which are associated with specific host plants are sometimes mostly dependent
 290 on the plant's architectural structure for hunting and as dwelling. The relation between plant
 291 community and plant architecture might then be crucial for fishing spiders, as for predatory
 292 arthropods in general (Woodcock et al. 2007). The structural aspect should be for conservation of
 293 fishing spiders, e.g. by managing the mowing season.

In this study, our sample was small due to the rarity of the two species, especially in Scandinavia, and due to a narrow temporal window of data collection. At the landscape scale, this small sample, and especially the lack of co-occurrence sites limits the scope of our conclusions about the characteristics of sympatric populations. At the microhabitat scale, repeated visits of the same sites would provide opportunities to refine the occupancy model and to clarify detection issues for these two species. With a better knowledge of nursery timing, other microhabitat studies would also be facilitated. Further data collection at the landscape level would increase knowledge about potential habitat, and investigating water and soil acidity could be helpful to clarify habitat restrictions for *D. plantarius*. Finally, species-specific occupancy modeling could be helpful, as especially *D. plantarius* is likely to dive when disturbed and might be more difficult to detect than *D. fimbriatus*, which might prevent identification of double-species sites.

While the distribution of both *Dolomedes* species might shift towards the North (Leroy et al. 2013, 2014, Monsimet et al. 2020), this shift might be limited by low dispersal abilities and unconnected habitats in Fennoscandia (Monsimet et al. 2020). It is therefore essential to protect both current and future habitats. Conserving both *Dolomedes* species emphasizes the special importance to protect wetlands, in Fennoscandia and elsewhere (Sala 2000, Davidson 2014, Carson et al. 2019). The conservation of the red-listed *D. plantarius* might be prioritized as it seems to have narrower habitat requirements than *D. fimbriatus*, which makes it more vulnerable to climate change (Cardoso et al. 2020). Moreover, a reassessment of the outdated IUCN status (World Conservation Monitoring Centre 1996) of the red-listed *D. plantarius* is needed.

315 Management and conservation could here serve and inform each other, as more monitoring of
 316 *Dolomedes* could contribute to more protection of wetlands.

317 To counteract various threats, which spiders currently face, land protection and the management
 318 of both land and species, is important (Branco and Cardoso 2020). For efficient management,
 319 estimating the local probability of presence of the species is important. Occupancy modeling can
 320 help to decide which areas could be necessary to protect and where to apply conservation efforts
 321 (McFarland et al. 2012). In this study, the detection probability of nursery webs was higher
 322 where abundance of crossing vegetation structures was high and with good weather condition,
 323 i.e., optimal temperature and sunny weather. Nonetheless, the use of nursery webs as detection
 324 units could be improved by specifying the timing and duration of nursery webs with repeated
 325 visits (e.g. weekly) to the same sites and nursery webs (Smith 2000). Monitoring nursery webs
 326 also makes it possible to encounter the female spiders, which is especially valuable with the non-
 327 invasive sponge-technique we used for identifying the species. Additionally, to estimating the
 328 population's abundance dynamic, the management of population by preserving wet habitat and
 329 with abundant crossing structures is essential.

330 Nature conservation is driven and motivated by a normative component, which is dependent on
 331 flexible human values (Lindenmayer and Hunter 2010), causing direct effects on the protection
 332 of invertebrates which are traditionally considered less in conservation (Clark and May 2002,
 333 Troudet et al. 2017) and might be one of largest obstacles in spider conservation (Branco and
 334 Cardoso 2020). For this reason, raising awareness for the conservation of arthropods like fishing

spiders is fundamental, e.g. with citizen science projects (Troudet et al. 2017), like SpiderSpotter (“SpiderSpotter” 2020).

Acknowledgment

We thank Lars Jonsson (Kristianstad University) for his advice and help during the data collection, Andres Ordiz for comments on a previous manuscript version, and Boris Leroy for sharing with us his prediction maps to select sites.

341 References

- Blacklocke, S. 2016. Progressing understanding of episodic stream acidification in upland plantation conifer forested subcatchments in Ireland. University College Dublin. School of Civil Engineering, Ireland.
- Bleckmann, H., and T. Lotz. 1987. The vertebrate-catching behaviour of the fishing spider *Dolomedes triton* (Araneae, Pisauridae). *Animal Behaviour* 35:641–651.
- Bonnet, P. 1930. La mue, l'autotomie et la régénération chez les Araignées, avec une étude des Dolomèdes d'Europe. *Bulletin de la société d'histoire naturelle de Toulouse* 59:237–700.
- Branco, V. V., and P. Cardoso. 2020. An expert-based assessment of global threats and conservation measures for spiders. *Global Ecology and Conservation* 24:e01290.
- Cardoso, P., P. S. Barton, K. Birkhofer, F. Chichorro, C. Deacon, T. Fartmann, C. S. Fukushima, R. Gaigher, J. C. Habel, C. A. Hallmann, M. J. Hill, A. Hochkirch, M. L. Kwak, S. Mammola, J. Ari Noriega, A. B. Orfinger, F. Pedraza, J. S. Pryke, F. O. Roque, J. Settele, J. P. Simaika, N. E. Stork, F. Suhling, C. Vorster, and M. J. Samways. 2020. Scientists' warning to humanity on insect extinctions. *Biological Conservation* 242:108426.
- Carson, M., G. Kibria, M. Löfroth, B. Macura, D. S. Alm, and Z. Kalantari. 2019. Arctic wetlands: time bomb or saving grace? *SEI Project Brief*:1–4.
- Chamberlain, S., and C. Boettiger. 2017. R Python, and Ruby clients for GBIF species occurrence data. *PeerJ PrePrints* e3304v1.

- Clark, J. A., and R. M. May. 2002. Taxonomic Bias in Conservation Research. *Science* 297:191–192.
- Colles, A., L. H. Liow, and A. Prinzing. 2009. Are specialists at risk under environmental change? Neoecological, paleoecological and phylogenetic approaches. *Ecology Letters* 12:849–863.
- Darwall, W. R. T., R. A. Holland, K. G. Smith, D. Allen, E. G. E. Brooks, V. Katarya, and others. 2011. Implications of bias in conservation research and investment for freshwater species. *Conservation Letters* 4:474–482.
- Davidson, N. C. 2014. How much wetland has the world lost? Long-term and recent trends in global wetland area. *Marine and Freshwater Research* 65:934–941.
- De Groot, R., M. Stuij, M. Finlayson, and N. C. Davidson. 2006. Valuing wetlands. Guidance for valuing the benefits derived from wetland ecosystem services. Ramsar Convention Secretariat, Gland, Switzerland.
- De Omena, P. M., and G. Q. Romero. 2008. Fine-scale microhabitat selection in a bromeliad-dwelling jumping spider (Salticidae). *Biological Journal of the Linnean Society* 94:653–662.
- DeVito, J., J. M. Meik, M. M. Gerson, and D. R. Formanowicz, Jr. 2004. Physiological tolerances of three sympatric riparian wolf spiders (Araneae: Lycosidae) correspond with microhabitat distributions. *Canadian journal of zoology* 82:1119–1125.
- Dorman, C., J. Elith, S. Bacher, C. Buchmann, G. Carl, G. Carré, J. Marquéz, B. Gruber, B. Lafourcade, P. Leitao, T. Münkemüller, C. McClean, P. Osborne, B. Reineking, and

- others. 2012. Collinearity: a review of methods to deal with it and a simulation study evaluating their performance. *Ecography* 36:27–46.
- Duffey, E. 1995. The distribution, status and habitat of *Dolomedes fimbriatus* (Clerck) and *D. plantarius* (Clerck) in Europe. Proceedings of the 15th European Colloquium of Arachnology:54–65.
- Duffey, E. 2012. *Dolomedes plantarius* (Clerck, 1757) (Araneae: Pisauridae): a reassessment of its ecology and distribution in Europe, with comments on its history at Redgrave and Lopham Fen, England. *Bulletin of the British Arachnological Society* 15:285–292.
- EEA. 2018. European Union, Copernicus Land Monitoring Service 2018, European Environment Agency (EEA).
- Fasola, M., and F. Mogavero. 1995. Structure and habitat use in a web-building spider community in northern Italy. *Bollettino di zoologia* 62:159–166.
- Finlayson, C. M., G. T. Davies, W. R. Moomaw, G. L. Chmura, S. M. Natali, J. E. Perry, N. Roulet, and A. E. Sutton-Grier. 2019. The Second Warning to Humanity – Providing a context for wetland management and policy. *Wetlands* 39:1–5.
- Fiske, I. J., and R. B. Chandler. 2011. unmarked: an R package for fitting hierarchical models of wildlife occurrence and abundance. *Journal of Statistical Software* 43:1–23.
- GBIF: The Global Biodiversity Information Facility. 2019, October 10. What is GBIF? <https://www.gbif.org/what-is-gbif>.

- Gorb, S. N., and F. G. Barth. 1994. Locomotor behavior during prey-capture of a Fishing Spider, *Dolomedes plantarius* (Araneae: Araneidae): galloping and stopping. *Journal of Arachnology* 22:89–93.
- Hastie, T., R. Tibshirani, and A. Buja. 1994. Flexible discriminant analysis by optimal scoring. *Journal of the American Statistical Association* 89:1255–1270.
- Hastie, T., R. Tibshirani, F. Leisch, K. Hornik, and B. Ripley. 2013. mda: Mixture and flexible discriminant analysis. R package version 0.4-4, URL <http://cran.r-project.org/package=mda>.
- van Helsdingen, P. J. 1993. Ecology and distribution of *Dolomedes* in Europe (Araneida: Dolomedidae). *Boll. Acc. Gioenia Sci. Nat.* 26:181–187.
- Hofner, B., and T. Hothorn. 2017. stabs: stability selection with error control (2017). URL <https://CRAN.R-project.org/package=stabs>. R package version 0.6-3.
- Hofner, B., A. Mayr, N. Fenske, J. Thomas, and M. Schmid. 2018. gamboostLSS: boosting methods for GAMLSS models. URL <http://CRAN.R-project.org/package=gamboostLSS>. R package version:2.0–1.1.
- Holec, M. 2000. Spiders (Araneae) of the fishpond eulittoral zone. *Ekológia (Bratislava)* 19:51–54.
- Hothorn, T., P. Buehlmann, T. Kneib, M. Schmid, and B. Hofner. 2020. mboost: Model-based boosting. R package version 2.9-3.
- Hu, S., Z. Niu, Y. Chen, L. Li, and H. Zhang. 2017. Global wetlands: potential distribution, wetland loss, and status. *Science of the Total Environment* 586:319–327.

- Ivanov, V., O. Prishchepchik, and E. Setrakova. 2017. *Dolomedes plantarius* (Araneae, Pisauridae) in Belarus: records, distribution and implications for conservation. *Arachnologische Mitteilungen* 54:33–37.
- Kellner, K. F., and R. K. Swihart. 2014. Accounting for imperfect detection in ecology: a quantitative review. *PloS ONE* 9.
- Kendall, H. W. 1992. World Scientists' Warning to Humanity.
<https://www.ucsusa.org/resources/1992-world-scientists-warning-humanity>.
- KoBoToolbox. 2020. <http://www.kobotoolbox.org>.
- Lecigne, S. 2016. Redécouverte de *Dolomedes plantarius* (Clerck, 1758)(Araneae, Pisauridae) en région Nord-Pas-de-Calais (France), actualisation de sa distribution en France et aperçu de la situation en Europe. *Revue arachnologique* 2.
- Leroy, B., C. Bellard, N. Dubos, A. Colliot, M. Vasseur, C. Courtial, M. Bakkenes, A. Canard, and F. Ysnel. 2014. Forecasted climate and land use changes, and protected areas: the contrasting case of spiders. *Diversity and Distributions* 20:686–697.
- Leroy, B., M. Paschetta, A. Canard, M. Bakkenes, M. Isaia, and F. Ysnel. 2013. First assessment of effects of global change on threatened spiders: potential impacts on *Dolomedes plantarius* (Clerck) and its conservation plans. *Biological Conservation* 161:155–163.
- Lindenmayer, D., and M. Hunter. 2010. Some guiding concepts for conservation biology. *Conservation Biology* 24:1459–1468.

- MacKenzie, D. I., J. D. Nichols, G. B. Lachman, S. Droege, J. A. Royle, and C. A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. *Ecology* 83:2248–2255.
- McFarland, T. M., H. A. Mathewson, J. E. Groce, M. L. Morrison, J. C. Newnam, R. T. Snelgrove, K. L. Skow, B. A. Collier, and R. N. Wilkins. 2012. Utilization of a species occupancy model for management and conservation. *Wildlife Society Bulletin* 36:432–439.
- Meinshausen, N., and P. Bühlmann. 2010. Stability selection. *Journal of the Royal Statistical Society: Series B (Statistical Methodology)* 72:417–473.
- Monsimet, J., O. Devineau, J. Pétillon, and D. Lafage. 2020. Explicit integration of dispersal-related metrics improves predictions of SDM in predatory arthropods. *Scientific Reports* 10:1–12.
- Noreika, N., J. S. Kotiaho, J. Penttinen, P. Punttila, A. Vuori, T. Pajunen, O. Autio, O. J. Joukola, and D. J. Kotze. 2015. Rapid recovery of invertebrate communities after ecological restoration of boreal mires. *Restoration Ecology* 23:566–579.
- R Core Team. 2020. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
- Ramsar Convention Secretariat. 2013. The Ramsar convention manual: A guide to the convention on wetlands (Ramsar, iran, 1971). Sixth edition. Ramsar Convention Secretariat, Gland, Switzerland.
- RStudio Team. 2012. RStudio: integrated development environment for R.

- Sala, O. E. 2000. Global biodiversity scenarios for the year 2100. *Science* 287:1770–1774.
- Smith, H. 2000. The status and conservation of the fen raft spider (*Dolomedes plantarius*) at Redgrave and Lopham fen national nature reserve, England. *Biological Conservation* 95:153–164.
- SpiderSpotter. 2020. . www.spiderspotter.com.
- Stratton, G. E., R. B. Suter, and P. R. Miller. 2004. Evolution of water surface locomotion by spiders: a comparative approach. *Biological Journal of the Linnean Society* 81:63–78.
- Troutet, J., P. Grandcolas, A. Blin, R. Vignes-Lebbe, and F. Legendre. 2017. Taxonomic bias in biodiversity data and societal preferences. *Scientific Reports* 7:9132.
- Uetz, G. W. 1977. Coexistence in a guild of wandering spiders. *Journal of Animal Ecology* 46:531–541.
- Vasconcellos-Neto, J., Y. F. Messas, H. da Silva Souza, G. A. Villanueva-Bonila, and G. Q. Romero. 2017. Spider–plant interactions: an ecological approach. Pages 165–214 *Behaviour and ecology of spiders*. Springer.
- Westhoff, V., and E. Van Der Maarel. 1978. The braun-blauquet approach. Pages 287–399 *Classification of plant communities*. Springer.
- Wickham, H., M. Averick, J. Bryan, W. Chang, L. D. McGowan, R. François, G. Grolemund, A. Hayes, L. Henry, J. Hester, M. Kuhn, T. L. Pedersen, E. Miller, S. M. Bache, K. Müller, J. Ooms, D. Robinson, D. P. Seidel, V. Spinu, K. Takahashi, D. Vaughan, C. Wilke, K. Woo, and H. Yutani. 2019. Welcome to the tidyverse. *Journal of Open Source Software* 4:1686.

- Woodcock, B. A., S. G. Potts, D. B. Westbury, A. J. Ramsay, M. Lambert, S. J. Harris, and V. K. Brown. 2007. The importance of sward architectural complexity in structuring predatory and phytophagous invertebrate assemblages. *Ecological Entomology* 32:302–311.
- World Conservation Monitoring Centre. 1996. The IUCN red list of threatened species 1996.
- Zuur, A. F., E. N. Ieno, and C. S. Elphick. 2010. A protocol for data exploration to avoid common statistical problems. *Methods in Ecology and Evolution* 1:3–14.

342 **Data availability**

343 We added new records to Gbif (indirectly, they are on artsobservasjoner and artportalen).

344 **Tables**

345 Table 1: Braun Blanquet scale and simplification used in this study.

Percentage	Number of occurrences	Original Braun-Blanquet category	Simplified category
0	0	no	0
<1	1	r	0
<1	43953	+	0
<5	6-50	1	1
<5	>50	2m	1
5-15		2a	1
26-25		2b	1
26-50		3	2
51-75		4	3
76-100		5	4

346 Table 2: Levels and explanations of variables on landscape/ site scale

Variable name	Levels
Surrounding	Infrastructure/forest/other
Surrounding forest	Deciduous/coniferous/mixed
Water type	River/bog/lake/creek
Water speed	Standing/slow/fast
Water clearness	Clear/brown/murky
Vegetation type (at site)	Open wet/open dry/deciduous forest/coniferous forest
Latitude	Latitude (continuous), DEM
Elevation	Elevation (continuous), DEM
Clouds (detectability)	Yes/no/partly
Wind (detectability)	Measured with anemometer on Beaufort scale
Reason visit	Suitable habitat/GBIF/other

347

348 Table 3: Levels and explanations of variables on microhabitat/ nursery scale

Variable	Description/Levels
<i>Dolomedes</i> detection	Spider/nursery web/no
Aquatic vegetation	Braun-Blanquet scale
Distance to water	No water; 0m; 0.7m; 2m; 7m
Humidity	Measured at ground level and 20cm above ground
Dominant plant group	Dominant group of plants in plot
Horizontal cover	Measured at 10cm; 30cm; 50 cm above ground
Maximum height	Maximal height of vegetation in plot, measured with 10cm accuracy
Average height	Measured 5 times in random location within plot with 10cm accuracy
Tussocks	Tuft of grasses or sedges, measured on Braun-Blanquet scale
Large leaves	Yes/no
Litter	Yes/no
Shade	Yes/no/partly
Crossing structures	Abundance of crossing vegetation structures, measured on Braun-Blanquet scale
<i>Carex</i> spp.	Abundance measured on Braun-Blanquet scale
<i>Juncus</i> spp.	Abundance measured on Braun-Blanquet scale
<i>Typha</i> spp.	Abundance measured on Braun-Blanquet scale
<i>Phragmites</i> spp.	Abundance measured on Braun-Blanquet scale

<i>Sphagnum</i> spp.	Abundance measured on Braun-Blanquet scale
Deciduous plants	Abundance measured on Braun-Blanquet scale
Aquatic vegetation	Yes/no
Nursery web detected	Yes/no
Nursery height	Height of web above ground or water
Nursery plant	Host plant of nursery web
Number of Nurseries in plot	Number of nursery webs detected in one plot

Figures

Fig. 1: Overview map of the study area in Sweden and Norway (left) with detail maps of the three study areas (right). Dots represents the study sites (Purple: both species; red: *D. plantarius*; Light blue: *D. fimbriatus*; blue: absence sites; beige: *Dolomedes sp.*) The background map is obtained from OpenStreetMap.

358 Fig. 3: Objective (left), data (middle), and analysis (right) performed in this study and described
 359 in the text.

Fig. 4: Results of the flexible discriminant analysis (FDA) to separate sites with both species (red), with *D. fimbriatus* only (green), with *D. plantarius* only (purple), or with no *Dolomedes* (blue). Ellipses size indicates uncertainty (95% confidence intervals).

366 Fig. 5: Variables importance for the nursery placement model (boosted GAM). distanceWater:
367 distance to water, rCarex: abundance of *Carex* on simplified Brown-Blanquet scale,
368 rCrossingStr: crossing vegetation structures on simplified Brown-Blanquet-scale, siteID: varying
369 intercept per site ID, humidityGround.sc: humidity at ground level (standardized).

370

371 Fig. 6: Marginal effects for variables selected in the nursery placement model (boosted GAM).