

Supplementary Information: text, tables and figures

High habitat invasibility unveils the invasiveness potential of water frogs

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Supplementary Text S1 Methodological details on measures of habitat features at local and landscape scales

A. Local scale (pond). (1) *Water depth* was measured (in cm) either with a 3-m long stick placed at the maximum depth of the pond (substrate level) or by collecting data from a water-depth logger (Hobo; Onset) placed on the deepest bottom of some ponds. (2) *Water area* (m²) was obtained by measuring the longest and largest dimensions of the ponds using a laser-meter (GLM 250 VF, Bosch). (3) *Aquatic vegetation cover* (%) was quantified as the percentage of the surface of water occupied by submersed plants and *Characae* algae. (4) Pond substrate (binary variable) can be artificial or "natural" (i.e. no artificial cover). (5) *Fish* were considered present if seen during the corresponding year of survey (no change in fish distribution occurred during the two years of surveys). Observation processed similarly as for water frogs, i.e. at distance by binoculars and afterward at close proximity. Observed fish were mainly Goldfish (*Carassius auratus*), but also mosquitofish (*Gambusia holbrooki*) and common roaches (*Rutilus rutilus*). All could be considered as potential predators of *Pelophylax* embryos or tadpoles. Crayfish were not considered because not present in the studied ponds. (6) *Sun exposure* was quantified by measuring the percentage of tree cover in the 5 m buffer around the center of each pond. This was measured on orthophotos (Institut Géographique National 2018; resolution 0.2m) and mapped in QGIS 3.18. (7) Drying risk (binary variable) referred to ponds that did not retain water during the whole survey period (May-July) versus remained permanent.

B. Landscape scale. (8) The number of ponds around the core ponds was based on all aquatic bodies (minimum 1 m²) from our personal database resulting particularly from analyses of orthophotos and topographical maps (Institut Géographique National, infra-red at 0.5m resolution and color at 0.2 m resolution, 2018), municipality maps and information gathered locally. (9) Forest cover was quantified on the basis of the BD Topo V3, vegetation layer, considering only dense forests (i.e. removing open fields and shrubs) (Institut Géographique National 2019). (10) building cover was quantified on the basis of BD Topo V3 (Institut Géographique National 2019). The four landscape variables were quantified within the 1 km buffer radius around each pond to highlight the global environmental terrestrial land use with respect to movements of water frogs and local configuration of sites. Analyses were run in QGIS 3.18.

Supplementary Table S1 Pairwise correlation matrix for environmental predictors used in models of the year 2019 (above the diagonal) and the year 2020 (under the diagonal).

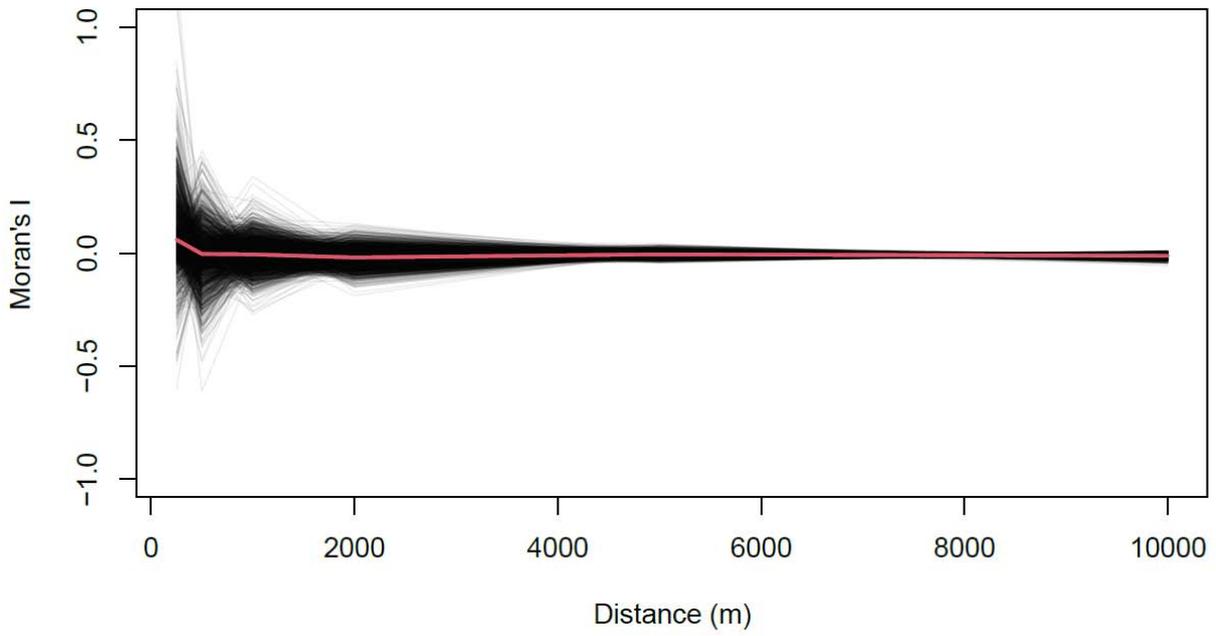
| | Area | Building | Substrate | Depth | Drying | Fish | Forest | Ponds | Sun | Vegetation |
|------------|-------|----------|-----------|-------|--------|-------|--------|-------|-------|------------|
| Area | | 0.16 | -0.03 | 0.66 | -0.31 | 0.22 | -0.23 | -0.20 | 0.39 | 0.32 |
| Building | 0.15 | | 0.09 | 0.21 | 0.00 | 0.26 | -0.36 | 0.43 | 0.10 | -0.03 |
| Substrate | 0.13 | 0.17 | | 0.11 | -0.27 | 0.22 | -0.08 | -0.04 | 0.33 | -0.12 |
| Depth | 0.55 | 0.30 | 0.23 | | -0.42 | 0.36 | -0.09 | -0.05 | 0.28 | 0.15 |
| Drying | -0.15 | 0.00 | -0.25 | -0.38 | | -0.20 | 0.00 | 0.07 | -0.13 | -0.05 |
| Fish | 0.11 | 0.17 | 0.24 | 0.29 | -0.17 | | -0.22 | 0.17 | 0.18 | -0.18 |
| Forest | -0.20 | -0.30 | -0.13 | -0.10 | -0.09 | -0.13 | | 0.13 | -0.27 | -0.10 |
| Ponds | -0.24 | 0.33 | -0.04 | -0.11 | 0.04 | 0.09 | 0.18 | | -0.13 | -0.06 |
| Sun | 0.57 | 0.11 | 0.34 | 0.41 | -0.19 | 0.15 | -0.25 | -0.30 | | 0.15 |
| Vegetation | 0.17 | -0.09 | -0.23 | -0.07 | 0.03 | -0.24 | 0.07 | -0.05 | 0.09 | |

Area: surface area of the pond, Building: building cover around ponds, Substrate: artificial cover of the pond, Depth: water depth, Drying: temporary versus permanent pond, Fish: fish presence, Forest: forest cover around ponds, Ponds: number of surrounding ponds, Sun: sun exposure, Vegetation: Proportion of aquatic vegetation. For details on variables see Supplementary Text 1.

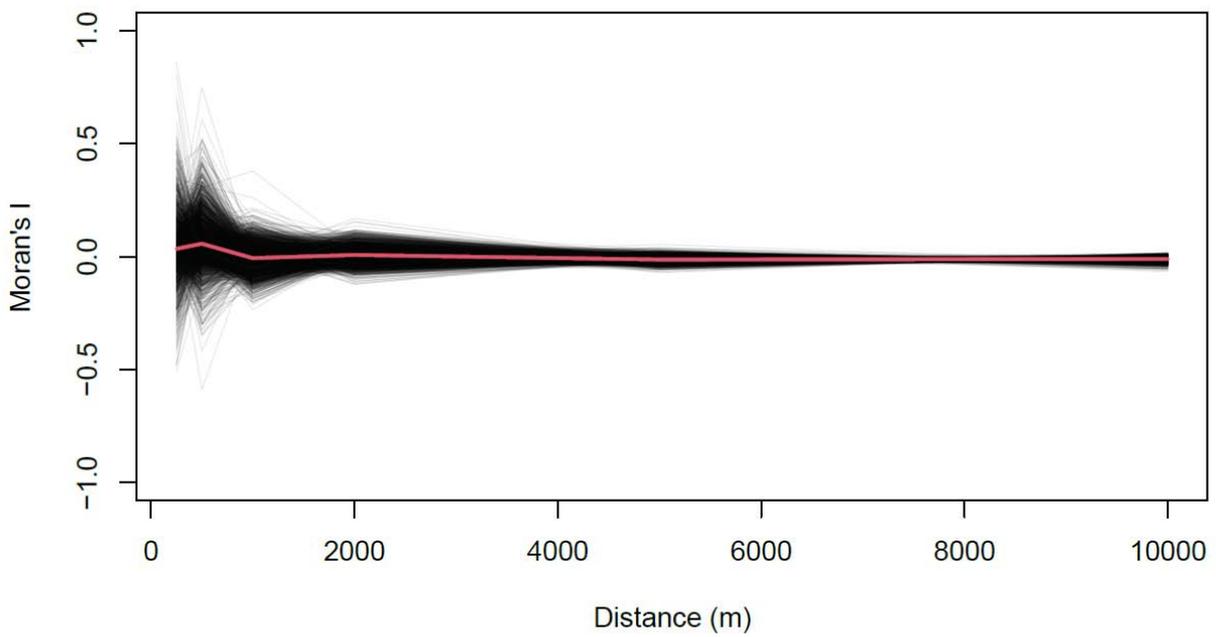
Supplementary Table S2 Coefficients estimated by the occupancy model relating environmental factors to invasive *Pelophylax ridibundus*. The coefficients refer to the model with site random effect.

| Variable | Mean | SD | Lower 95% CI | Upper 95% CI | Rhat | Average odds ratio | Lower 95% CI odds ratio | Upper 95% CI odds ratio | |
|-------------------------------|-------|------|--------------|--------------|------|--------------------|-------------------------|-------------------------|--|
| Variables of occupancy | | | | | | | | | |
| Depth | 3.12 | 1.39 | 0.77 | 6.22 | 1.00 | ↑ 22.58 | ↑ 2.16 | ↑ 502.62 | |
| Drying | -1.68 | 1.03 | -3.96 | 0.19 | 1.00 | ↓ 5.35 | ↓ 52.54 | ↑ 1.21 | |
| Area | 1.07 | 1.25 | -1.17 | 3.68 | 1.00 | ↑ 2.90 | ↓ 3.23 | ↑ 39.54 | |
| Vegetation cover | 1.99 | 0.94 | 0.35 | 4.05 | 1.00 | ↑ 7.31 | ↑ 1.42 | ↑ 57.46 | |
| Artificial substrate | 0.40 | 1.01 | -1.54 | 2.47 | 1.00 | ↑ 1.49 | ↓ 4.67 | ↑ 11.79 | |
| Sun exposure | 2.17 | 1.14 | 0.23 | 4.67 | 1.01 | ↑ 8.75 | ↑ 1.26 | ↑ 106.60 | |
| Fish | -1.05 | 1.02 | -3.11 | 0.94 | 1.00 | ↓ 2.86 | ↓ 22.38 | ↑ 2.56 | |
| Number of ponds | 0.55 | 1.01 | -1.40 | 2.64 | 1.00 | ↑ 1.74 | ↓ 4.05 | ↑ 13.95 | |
| Forest cover | -0.62 | 1.05 | -2.76 | 1.38 | 1.00 | ↓ 1.87 | ↓ 15.86 | ↑ 3.99 | |
| Building cover | 0.40 | 1.07 | -1.68 | 2.60 | 1.00 | ↑ 1.50 | ↓ 5.35 | ↑ 13.44 | |
| Variables of detection | | | | | | | | | |
| Date | 0.26 | 0.18 | -0.09 | 0.62 | 1.01 | ↑ 1.30 | ↓ 1.10 | ↑ 1.87 | |
| Hour | -0.38 | 0.19 | -0.76 | -0.01 | 1.00 | ↓ 1.46 | ↓ 2.13 | ↓ 1.01 | |

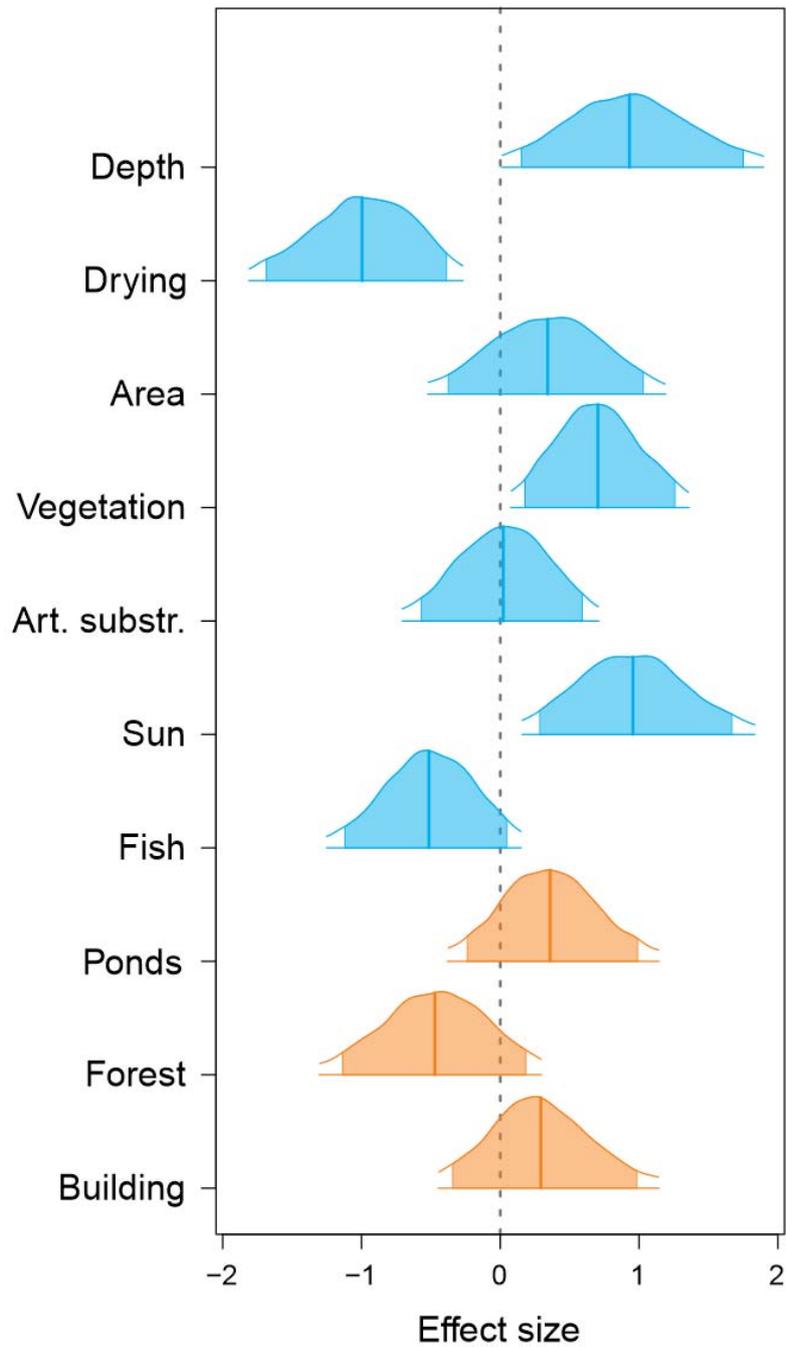
2019



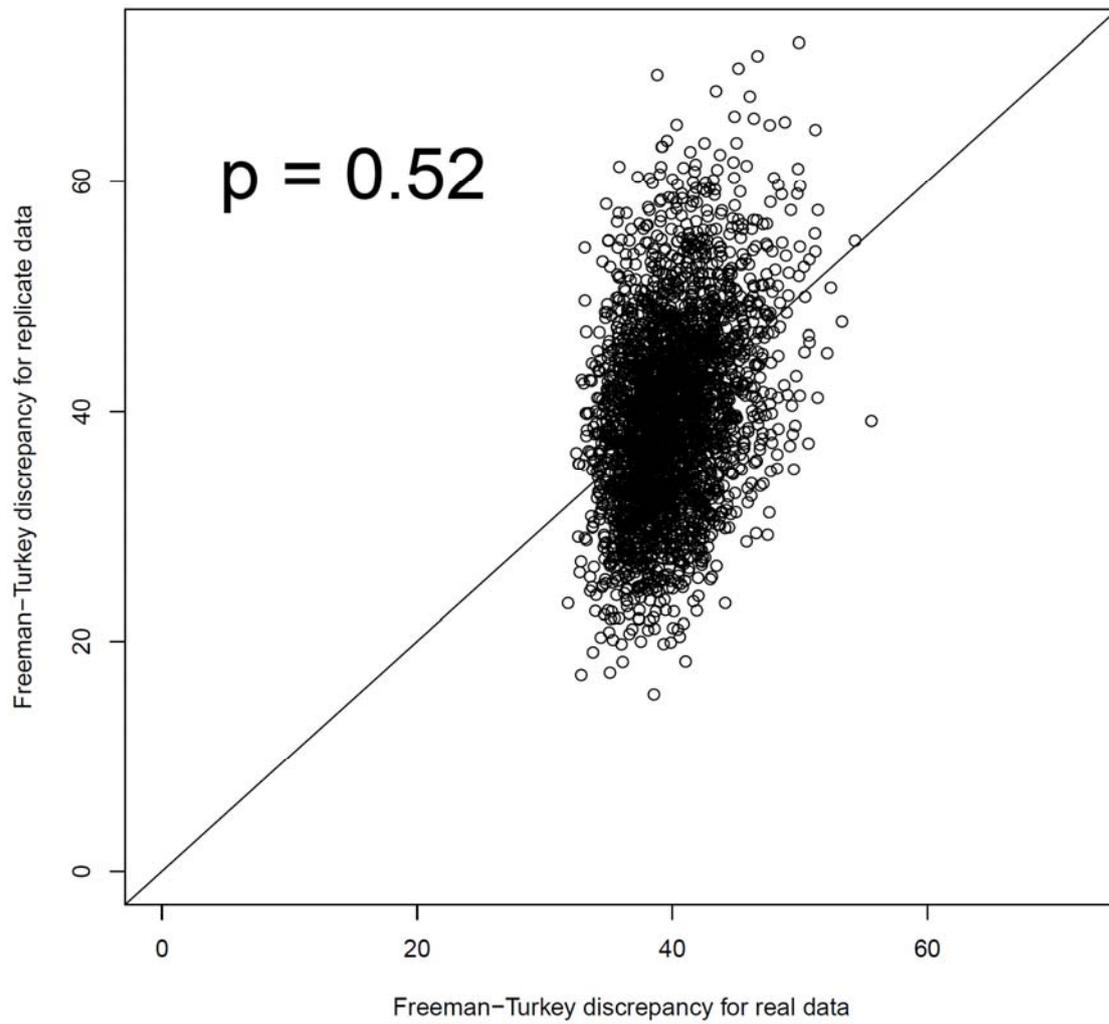
2020



Supplementary Figure S1. Moran's I values for the residuals of the non-spatial model with the site random effect.



Supplementary Figure S2 Posterior distributions of parameters related to *Pelophylax ridibundus* occupancy for both local (blue) and landscape (orange) features, as estimated by Bayesian generalized linear models without accounting for detection probabilities. The outlines represent the 95% Credible Intervals (CIs), the shaded areas represent 90% CIs, and the vertical lines denote the mean estimate. The variables are explained in Supplementary Text 1. Art. subs.: artificial substrate.



Supplementary Figure S3 Goodness of fit of the non-spatial model with the site random effect: Freeman-Turkey discrepancy for real data and data simulated from the posterior distribution.