http://doi.org/17648/heringeriana.v15i1.917967

Heringeriana 16: e917967. 2021.
http://revistas.jardimbotanico.ibict.br/
Jardim Botânico de Brasília

ISSN 1983-6996 Versão impressa
Heringeriana
ISSN 2359-165X Versão *on-line*

Scientific note

Does habitat suitability affect flight-initiation distance in Burrowing owls?

Eduardo Guimarães Santos [1], Carolyne Oliveira Dias [2] & Helga Correa Wiederhecker [3]

Fleeing from predators might save individual's life, however, being vigilant or fleeing consumes time, energy and decreases chances for feeding, mating, and protecting the nest. Thus, escaping preferentially occurs when the costs of fleeing is higher than remaining (Blumstein 2006, Cooper & Frederick 2007, Bateman & Fleming 2011). Additionally, there is a trade-off between foraging and being vigilant, influencing the decision-making process of staying or fleeing. This trade-off directly influences an animal's decision to remain and/or establish itself in different locations (Bateman & Fleming 2011). For example, in urban environments, the number of pedestrians reduced bird's abundance, and remaining individuals increased vigilance, reducing foraging, being this effect more intense in large animals (Fernández-Juricic *et al.* 2002). However, other factors may favor the individual's decision to flee, such as a menacing predator and the lack of shelter, contributing for the complex interactions leading to the fleeing decision (Price 2008, Dowling & Bonier 2018).

Here we evaluated, within an urban landscape, the influence of environmental suitability in the flight distance relative to possible predators. Environmental suitability is related to the species occurrence likelihood (Johnson 2007, Hirzel & Le Lay 2008, Wang *et al.* 2008). Modeling techniques using environmental suitability have been widely employed in areas such as conservation planning and trajectories studies (Rushton *et al.* 2004, Johnson 2007). Even though this idea was proposed almost 20 years ago (Frid & Dill 2002), as far as we are concerned, no study has ever adopted this approach towards the study of flight-initiation distance. We hypothesize that, in suitable environments, animals are more tolerant to predators' proximity because of the high benefits of permanence. In this context, the predation risk (directly associated with the predator proximity) would be balanced by the benefits of remaining in a suitable environment (Fig. 1A). To test this hypothesis, we used burrowing owls (*Athene cunicularia*) as model organisms. We chose this species because it is well-studied across its broad distribution in the Americas (see Lincer *et al.* 2018) and has a clear preference for open habitats occurring in disturbed environments (Rebolo-Ifrán *et al.* 2015, Baladrón *et al.* 2016, Cavalli *et al.* 2018, Conway 2018, Poulin *et al.* 2020).

We obtained the data during the non-breeding season, from July to September 2019, in the Federal District, Brazil (Figure 1B, 15°52'11.87"S,

[1] Graduate Program in Ecology, Instituto de Ciências Biológicas, Universidade de Brasília, Campus Darcy Ribeiro, 70919-970, Brasília, DF, Brazil. Corresponding author: egsantos1991@gmail.com
[2] Instituto Federal de Goiás: Águas Lindas de Goiás, Goiás, Brazil.
[3] Independent Researcher.

47°55'17.13"W), located in the Cerrado biome (Eiten 1972, Ribeiro & Walter 1998). The study area comprises a mosaic of urbanized areas (103.31 to 1.08 residents per hectare), agriculture, and conserved green areas covered by grassland, woodlands, and forests along streams and rivers (Eiten 1972, Ribeiro & Walter, 1998). The 2,827.4 km^2 studied area was previously characterized by an environmental suitability spatial model, developed to predict flight trajectories for the species, where we used a glm function with binomial family associating species presence data and eight land use and cover variables (for further details, see Figure S1 and Santos *et al.* 2021).

We measured the owl tolerance to a possible predator using the "Flight Initiation Distance" (FID), a widespread and well-established method (Fig. 1C, for more details, see Stankowich & Blumstein 2005, Price 2008, Møller 2010, Tätte *et al.* 2018, Pettit *et al.* 2021). We thoroughly searched for owl nests within the study area (~70 hours) and, at each nest found, one of the authors (C.O.D.) began to walk towards it at a steady pace (starting point of circa 150 m from the nest). Whenever an escaping behavior occurred, C.O.D stopped, and we measured the remaining, distance between the researcher and the nest with a 50 m tape measure, thus obtaining FID for each observation. We sampled 40 nests found in open green areas and, to ensure observation independence, we considered only the reaction of the first animal to fly in each nest sampled (for original data see Table S1). Since burrowing owls are territorial animals (Green & Anthony 1989, Haug & Oliphant 1990, Gervais *et al.* 2003, Moulton *et al.* 2004, Rosenberg & Haley 2004, Valdez-Gómez *et al.* 2018, Poulin *et al.* 2020), we can ensure that each owl was sampled only once.

We tested the influence of habitat suitability on FID considering two spatial scales: burrow adjacency and home range. We used average values of environmental suitability around each burrow (buffer) for a 50m buffer (representing the environmental suitability directly adjacent to the burrow) and a 600m buffer (representing the environmental suitability of the owls' home range – Green & Anthony 1989, Haug & Oliphant 1990, Moulton *et al.* 2004, Rosenberg & Haley 2004, Valdez-Gómez *et al.* 2018, Poulin *et al.* 2020). Each spatial scale buffer was extracted from the suitability raster using the *raster* package (Hijmans 2017). Next, we manually measured nest distance to the nearest pedestrian causeway (walkways, paths, trails) using a google earth satellite image (www.earth.google.com/web/) to control the effect of habituation towards pedestrians (Cavalli *et al.* 2016, Franco & Marçal-Junior 2018). Then, we adjusted a linear model (GLM) relating the suitability at 50m, the suitability at 600m, and the distance to the nearest pedestrian causeway (predictor variables) with the log-transformed FID values (response variable). We rejected the hypothesis of spatial autocorrelation among nests calculating the Moran's I test using model residuals as the input variable (Anselin 1995), using the distance matrix as an associated weight ($I = -0.063 \pm 0.07$, $P = 0.59$) (Gittleman & Kot 1990). We performed the analyses, using the function Moran.I, of package *ape* (Paradis and Schliep 2018). We checked for multicollinearity using the package *car* applying a VIF (variance inflation factor) threshold of 3 (Zuur *et al.* 2010). We used the R software in all analyses and visually evaluated model residuals.

We did not find significant relationship between FID and the environmental suitability (in both scales used) or pedestrian flow (Table 1, FID:

mean = 18.51, SD = 8.65; Suitability: 50m: mean = 25.70, SD = 1.76; 600m: mean = 25.62, SD = 1.46). Thus, we did not corroborate our hypothesis that predator tolerance, measured by the FID, would be inversely related to the environmental suitability (see Fig. 1A).

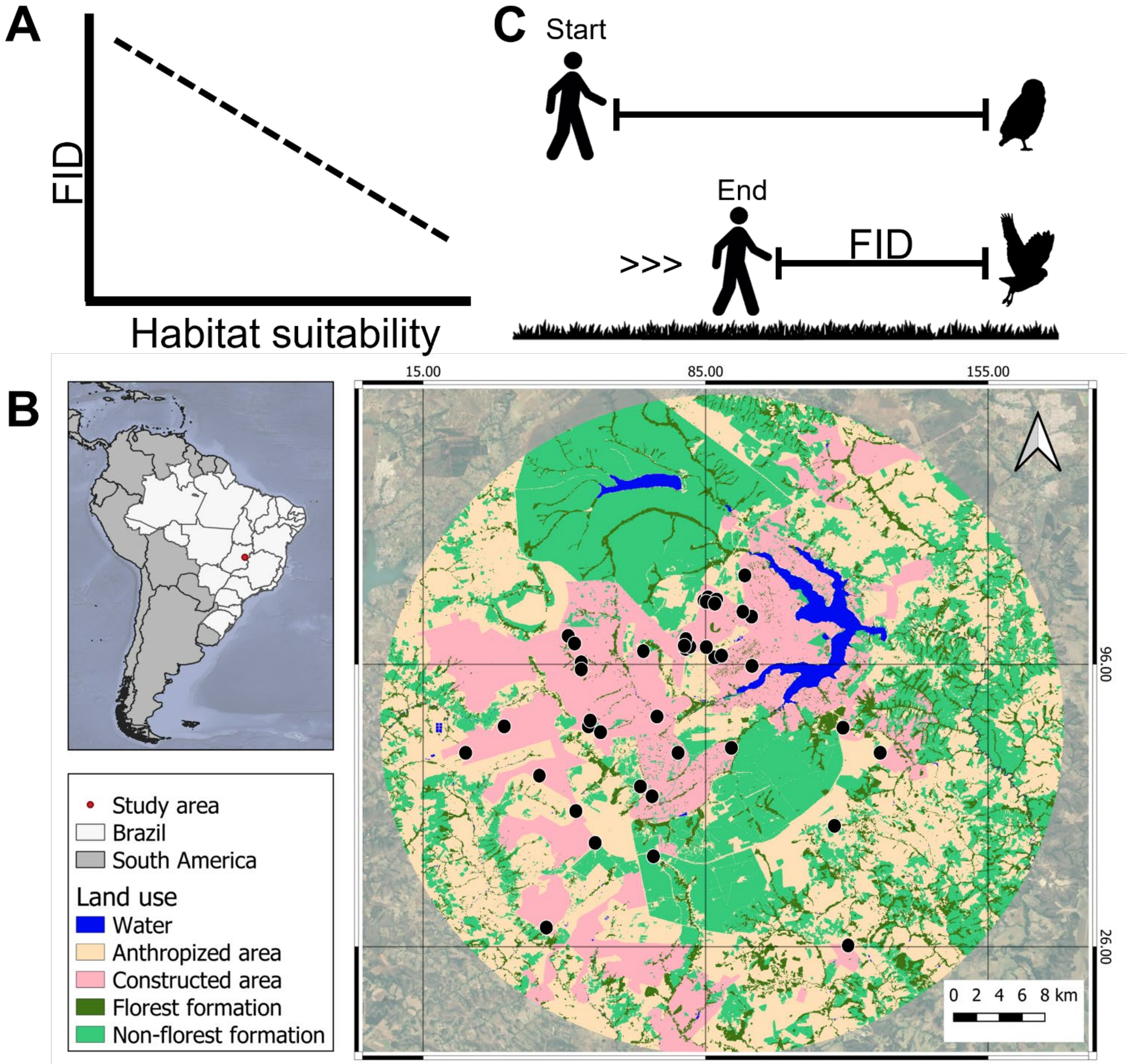

Figure 1. A) Hypothesis addressed in this study relating Flight Initiation Distance (FID) and habitat suitability; B) Study area showing the main land cover classes. Black dots represent our data collection locations. C) Flight-Initiation Distance (FID) used to measure the response of the owls to a potential predator.

Previous study has detected the influence of habitat suitability on burrowing owls' spatial occupation (Uhmann *et al.* 2001). Nevertheless, we did not observe the habitat suitability influence on the FID of burrowing owls in our study area. Indeed, our results showed that neither the suitability of the area directly adjacent to the nest nor the suitability of the individual's home range area influences the tolerance of human approximation.

The absence of the environmental suitability effect suggests that other aspects not investigated here, such as ecological filters, the presence of predators, and spatial scale, might be relevant in future investigations. Initially, urbanization filters can dilute the environmental suitability effect (e. g. Cavalli *et al.* 2016, Franco & Marçal-Junior 2018). Although our study area is not strictly urban, it is an urban-influenced landscape presenting a gradient of human impact composed of noise, fire, agriculture, and human presence even within the green spaces. For burrowing owls, for example, urbanization is a relevant filter towards tolerant/bold animals, directly influencing the occupation of areas under the human influence (Carrete & Tella 2013). However, this does not seem to explain our results since we did not detect a significant response for proximity to pedestrian causeways and therefore there is no evidence that human presence favor bold animals within the explored range.

Table 1. Description to GLM results between FID (response variable) and habitat suitability at 50 m, 600 m, and pedestrian causeways distance (explanatory variables).

Predictors	**Coeficiente**	**Std. Error**	***t*-value**	***P*-value**	**Imp.**	**VIF**
(Intercept)	4.90	2.33				1.87
Habitat suitability 50 m	0.11	0.10	1.13	0.27	1.13	1.87
Habitat suitability 600 m	-0.20	0.12	-1.75	0.09	1.75	1.87
Pedestrian distance	0.00	0.00	-0.43	0.67	0.43	1.15

Notes: **VIF:** variance inflation factor; **Std. Error:** Standard error; **Imp.:** Importance. Residual standard error: 0.34; Adjusted R2: 2%; F-statistic: 1.20; p-value: 0.32.

Alternatively, human presence leads to predator reduction; and it has been detected that species occurring in urban-influenced environments get more abundant and simultaneously habituated to humans (Bateman & Fleming 2011, Stracey & Robinson 2012, Díaz *et al.* 2013, Rodriguez-Martínez *et al*. 2014, Rebolo-Ifrán *et al.* 2017). Future studies using additional predator models, such as dogs and taxidermized predators would be an alternative approach to disentangle human habituation and predator response (e.g. Carrete & Tella 2017).

Lastly, we did not find owls occupying locations with lower habitat suitability values in our extensive searches within the study area (see Table S1). Suitability values ranged from 1 to 32 and all nests were detected in areas with values above 20. Thus, it is possible that within our study area, owls choose places that do not differ sufficiently to influence flight distance. If this is the case, we must consider that future studies may detect different results if they adopt a broader geographic extension.

Moreover, negative scientific results are usually considered unpublishable and deemed "non-important" (Price 2008). Thus, we believe that our results (despite being negative) are relevant and bring light to the impacts on animal behavior that arise from changes in their habitats. In summary, our study provides evidence that, the environmental suitability does not affect the predator-induced flight response of burrowing owls.

ACKNOWLEDGMENTS

We thank the two anonymous reviewers for their valuable comments, which surely improved the manuscript considerably. We are grateful to Chesterton U. O. Eugenio for his criticism of an earlier version of the manuscript.

AUTHORS' CONTRIBUTIONS

EGS**: c**onceptualization, methodology, formal analysis, writing - original draft, visualization, investigation, writing - review & editing. COS: methodology, formal analysis, writing. HCW: supervision, writing - review & editing. All the authors actively participated in the discussion of the results, they reviewed and approved the final version of the paper.

APPENDIX 1. Supplementary material

Supplementary data associated with this correspondence can be found at [10.6084/m9.figshare.18337721](https://doi.org/10.6084/m9.figshare.18337721).

REFERENCES

Anselin, L. (1995) *Local indicators of spatial analysis--LISA*. Geographical Analysis 27: 93–115.

Baladrón, A.V., Isacch, J.P., Cavalli, M., Bó, M.S., Sacch, I., Avalli, M.C., María, S.B.Ó. (2016) Habitat Selection by Burrowing Owls *Athene cunicularia* in the Pampas of Argentina: A Multiple-Scale Assessment Habitat selection by Burrowing Owls *Athene cunicularia* in the Pampas of Argentina: a multiple-scale assessment. *Acta Ornithologica* 51: 137–150.

Bateman, P.W., Fleming, P.A. (2011) Who are you looking at? Hadeda ibises use direction of gaze, head orientation and approach speed in their risk assessment of a potential predator. *Journal of Zoology* 285: 316–323.

Blumstein, D.T. (2006) Developing an evolutionary ecology of fear: How life history and natural history traits affect disturbance tolerance in birds. *Animal Behaviour* 71: 389–399.

Carrete, M., Tella, J.L. (2013) High individual consistency in fear of humans throughout the adult lifespan of rural and urban Burrowing owls. *Scientific Reports* 3: 1–7.

Carrete, M., Tella, J.L. (2017) Behavioral correlations associated with fear of humans differ between rural and urban burrowing owls. *Frontiers in Ecology and Evolution* 5: 1–9.

Cavalli, M., Baladrón, A.V., Isacch, J.P., Biondi, L.M., Bó, M.S. (2016) Differential risk perception of rural and urban Burrowing Owls exposed to humans and dogs. *Behavioural Processes* 124: 60–65.

Cavalli, M., Baladrón, A.V., Isacch, J.P., Bó, M.S. (2018) Burrowing owls eavesdrop on southern lapwings' alarm calls to enhance their antipredatory behaviour. *Behavioural Processes* 157: 199–203. Elsevier.

Conway, C.J. (2018) *Burrowing Owls: Happy Urbanite or Disgruntled Tenant?* Urban Raptors: 166–179.

Cooper, W.E., Frederick, W.G. (2007) Optimal flight initiation distance. Journal of Theoretical Biology 244: 59–67.

Díaz, M., Møller, A.P., Flensted-Jensen, E., Grim, T., Ibáñez-Álamo, J.D., Jokimäki, J., Markó, G., Tryjanowski, P. (2013) The Geography of Fear: A Latitudinal Gradient in Anti-Predator Escape Distances of Birds across Europe. *PLoS ONE* 8.

Dowling, L., Bonier, F. (2018) Should I stay, or should I go: Modeling optimal flight initiation distance in nesting birds. *PLoS ONE* 13: 1–15.

Eiten, G. (1972) The Cerrado Vegetation of Brazil. *Botanical Review* 38: 201–341.

Fernández-Juricic, E., Jimenez, M.D., Lucas, E. (2002) Factors affecting intra- and inter-specific variations in the difference between alert distances and flight distances for birds in forested habitats. *Canadian Journal of Zoology* 80: 1212–1220.

Franco, F.F., Marçal-Junior, O. (2018) Influence of urbanization on the distribution and defense strategies of the burrowing owl *Athene cunicularia* in the city of Uberlândia, southeastern Brazil. *Revista Brasileira de Ornitologia* 26(1): 1–8.

Frid, A., Dill, L. (2002) Human-caused Disturbance Stimuli as a Form of Predation Risk. *Conservation Ecology* 7: 258–261.

Gervais, J.A., Rosenberg, D.K., Anthony, R.G. (2003) Space use and pesticide exposure risk of male burrowing owls in an agricultural landscape. *The Journal of Wildlife Management* 67: 155–164.

Gittleman, J.L., Kot, M. (1990) Adaptation: statistics and a null model for estimating phylogenetic effects. *Systematic Zoology* 39: 227–241.

Green, G.A., Anthony, R.G. (1989) Nesting success and habitat relationships of burrowing owls in the Columbia Basin, Oregon. *The Condor* 91: 347.

Haug, E.A., Oliphant, L.M. (1990) Movements, activity patterns, and habitat use of burrowing owls is Saskatchewan. *The Journal of Wildlife Management* 54: 27–35.

Hijmans, R.J. (2017) raster: Geographic Data Analysis and Modeling. R package version 2.6-7. <https://cran.r-project.org/package=raster>.

Hirzel, A.H., Le Lay, G. (2008) Habitat suitability modelling and niche theory. *Journal of Applied Ecology* 45: 1372–1381.

Johnson, M.D. (2007) Measuring habitat quality: a review. *The Condor* 109: 489–504.

Lincer, J.L. (2018) A Review of Burrowing Owl (*Athene cunicularia*) literature using bibliometric comparisons: Topical Bibliographies and Online Databases. *Journal of Raptor Research* 52: 207–224.

Møller, A.P. (2010) Interspecific variation in fear responses predicts urbanization in birds. *Behavioral Ecology* 21: 365–371.

Moulton, C.E., Brady, R.S., Belthoff, J.R. (2004) Territory defense of nesting Burrowing Owls: responses to simulated conspecific intrusion. *Journal of Field Ornithology* 75: 288–295.

Paradis, E., Schliep, K. (2018) ape 5.0: an environment for modern phylogenetics and evolutionary analyses in R. Bioinformatics.

Pearson, R.G., Thuiller, W., Araújo, M.B., Martinez-Meyer, E., Brotons, L., McClean, C., Miles, L., Segurado, P., Dawson, T.P., Lees, D.C. (2006) Model-based uncertainty in species range prediction. *Journal of Biogeography* 33: 1704–1711.

Pettit, l., Bown, G.P., Ward-Fear, G., Shine, R. (2021) Anthropogenically modified habitats favor bigger and bolder lizards. *Ecology and Evolution*: 1–12.

Poulin, R.G., Todd, L.D., Haug, E.A., Millsap, B.A., Martell, M.S. (2020) Burrowing Owl (*Athene cunicularia*), version 1.0. In Birds of the World (A.F. Poole, ed.), p. Cornell Lab of Ornithology, Ithaca, NY, USA.

Price, M. (2008) The impact of human disturbance on birds: A selective review. *Australian Zoologist* 34: 163–196.

Rebolo-Ifrán, N., Carrete, M., Sanz-Aguilar, A., Rodriguez-Martinez, S., Cabezas, S., Marchant, T.A., Bortolotti, G.R., Tella, J.L. (2015) Links between fear of humans, stress and survival support a non-random distribution of birds among urban and rural habitats. *Scientific Reports* 5: 13723. Nature Publishing Group.

Rebolo-Ifrán, N., Tella, J.L., Carrete, M. (2017) Urban conservation hotspots: predation release allows the grassland-specialist burrowing owl to perform better in the city. *Scientific Reports* 7: 1–9.

Ribeiro, J., Walter, B. (1998) Fitofisionomias do bioma Cerrado. *In Cerrado: ambiente e flora* pp. 89–166. Embrapa Cerrados.

Richard, Y., Armstrong, D.P. (2010) The importance of integrating landscape ecology in habitat models: Isolation-driven occurrence of north island robins in a fragmented landscape. *Landscape Ecology* 25: 1363–1374.

Rodriguez-Martínez, S., Carrete, M., Roques, S., Rebolo-Ifrán, N., Tella, J.L. (2014) High urban breeding densities do not disrupt genetic monogamy in a bird species. *PLoS ONE* 9: e91314.

Rosenberg, D.K., Haley, K.L. (2004) The ecology of burrowing owls in the agroecosystem of the Imperial Valley, California. *Studies in Avian Biology* 27: 120–135.

Rushton, S.P., Ormerod, S.J., Kerby, G. (2004) New paradigms for modelling species distributions? *Journal of Applied Ecology* 41: 193–200.

Santos, E.G., Wiederhecker, H.C. & Machado, R.B. (2021) Predicting burrowing owl flight trajectories in urban environments. *Urban Ecosyst.*

Stankowich, T., Blumstein, D.T. (2005) Fear in animals: A meta-analysis and review of risk assessment. *Proceedings of the Royal Society B: Biological Sciences* 272: 2627–2634.

Stracey, C.M., Robinson, S.K. (2012) Are urban habitats ecological traps for a native songbird? Season-long productivity, apparent survival, and site fidelity in urban and rural habitats. *Journal of Avian Biology* 43: 50–60.

Tätte, K., Møller, A.P., Mänd, R. (2018) Towards an integrated view of escape decisions in birds: relation between flight initiation distance and distance fled. *Animal Behaviour* 136: 75–86.

Uhmann, T.V., Kenkel, N.C., Baydack, R.K. (2001) Development of a habitat suitability index model for

Burrowing Owls in the eastern Canadian prairies. *Journal of Raptor Research* 35: 378–384.

Valdez-Gómez, H.E., Holroyd, G.L., Trefry, H.E., Contreras-Balderas, A.J. (2018) Home ranges, habitats, and roosts of wintering Burrowing owls in agricultural landscapes in Central Mexico. *Journal of Raptor Research* 52: 178–190.

Wang, Y.H., Yang, K.C., Bridgman, C.L., Lin, L.K. (2008) Habitat suitability modelling to correlate gene flow with landscape connectivity. *Landscape Ecology* 23: 989–1000.

Zuur, A. F., Ieno, E. N., & Elphick, C. S. (2010). A protocol for data exploration to avoid common statistical problems. *Methods in Ecology and Evolution* 1(1): 3–14.

Zuur, A.F., Ieno, E.N., Walker, N.J., Saveliev, A.A., Smith, G.M. (2009) Limitations of Linear Regression Applied on Ecological Data. *In Mixed Effects Models and Extensions in Ecology with R* pp. 11–33.

Area Editor: Dr. Renata D. Alquezar
Received in 15/09/2021
Accepted in 30/12/2021
Published in 13/01/2022