

1 **Supplementary Information**

2

3

4 *Sequeira et al.*

5 **Transferring Biodiversity Models for Conservation: Opportunities and**

6 **Challenges**

7

8

9 **Contents**

10		Page no
11	Search details for Figure 2_____	2
12	Appendix S1_____	3

13 ***Search details for Figure 2***

14 Cumulative number of peer-reviewed journal articles listed on the ISI Web of Science
15 (webofknowledge.com) were calculated after searching within the subjects *Ecology*,
16 *Biodiversity Conservation*, *Environmental Sciences*, *Zoology*, *Marine Freshwater Biology*
17 and *Fisheries* as of 7th August 2016. Only papers written in English were considered.
18 Biodiversity models were defined as per (Tulloch et al. 2016), with the addition of the
19 following the keywords: “SDM*”, “environmental niche mod*”, “climat* envelope”,
20 “resource selection function”, “climat* matching mod*” and “potential habitat distribution
21 model*”, where * denote wildcard characters. Publications addressing transferability were
22 identified by refining the search query using the terms “transferab*”, “extrapol*”,
23 “hindcast*”, “forecast*”, “generalit*”, “transference”, “project*”, “backcast*”,
24 “generalizability” and “generalizability”.

Appendix S1: Complete list of references included in Table 1 and Table 2

1. Barbosa, A.M. et al. (2009) Transferability of environmental favourability models in geographic space: The case of the Iberian desman (*Galemys pyrenaicus*) in Portugal and Spain. *Ecol Model* 220 (5), 747-754.
2. Thuiller, W. et al. (2004) Effects of restricting environmental range of data to project current and future species distributions. *Ecography* 27, 165-172.
3. Randin, C.F. et al. (2006) Are niche-based species distribution models transferable in space? *J Biogeogr* 33 (10), 1689-1703.
4. Williams-Tripp, M. et al. (2012) Modeling rare species distribution at the edge: The case for the vulnerable endemic Pyrenean desman in France. *The Scientific World Journal* 2012, art612965.
5. Pearson, R.G. et al. (2007) Predicting species distributions from small numbers of occurrence records: A test case using cryptic geckos in Madagascar. *J Biogeogr* 34 (1), 102-117.
6. Wisz, M.S. et al. (2008) Effects of sample size on the performance of species distribution models. *Divers Distrib* 14 (5), 763-773.
7. Zharikov, Y. et al. (2009) Interplay between physical and predator landscapes affects transferability of shorebird distribution models. *Landsc Ecol* 24 (1), 129-144.
8. Edwards, T.C. et al. (2006) Effects of sample survey design on the accuracy of classification tree models in species distribution models. *Ecol Model* 199 (2), 132-141.
9. Hirzel, A. and Guisan, A. (2002) Which is the optimal sampling strategy for habitat suitability modelling? *Ecol Model* 157 (2-3), 331-341.
10. Barnes, M.A. et al. (2014) Geographic selection bias of occurrence data influences transferability of invasive *Hydrilla verticillata* distribution models. *Ecol Evol* 4 (12), 2584-2593.

11. Lobo, J.M. et al. (2007) How does the knowledge about the spatial distribution of Iberian dung beetle species accumulate over time? *Divers Distrib* 13 (6), 772-780.
12. Varela, S. et al. (2014) Environmental filters reduce the effects of sampling bias and improve predictions of ecological niche models. *Ecography* 37 (11), 1084-1091.
13. Dextrase, A.J. et al. (2014) Modelling occupancy of an imperilled stream fish at multiple scales while accounting for imperfect detection: implications for conservation. *Freshw Biol* 59 (9), 1799-1815.
14. Zipkin, E.F. et al. (2012) Evaluating the predictive abilities of community occupancy models using AUC while accounting for imperfect detection. *Ecol Appl* 22 (7), 1962-1972.
15. Bamford, A.J. et al. (2009) Trade-offs between specificity and regional generality in habitat association models: A case study of two species of African vulture. *J Appl Ecol* 46 (4), 852-860.
16. Graf, R. et al. (2006) On the generality of habitat distribution models: A case study of capercaillie in three Swiss regions. *Ecography* 29 (3), 319-328.
17. Vanreusel, W. et al. (2007) Transferability of species distribution models: A functional habitat approach for two regionally threatened butterflies. *Conserv Biol* 21 (1), 201-212.
18. Domisch, S. et al. (2013) Choice of study area and predictors affect habitat suitability projections, but not the performance of species distribution models of stream biota. *Ecol Model* 257, 1-10.
19. Dobrowski, S.Z. et al. (2011) Modeling plant ranges over 75 years of climate change in California, USA: Temporal transferability and species traits. *Ecol Monogr* 81 (2), 241-257.

20. Fielding, A.H. and Bell, J.F. (1997) A review of methods for the assessment of prediction errors in conservation presence/absence models. *Environ Conserv* 24 (01), 38-49.
21. Vaughan, I. and Ormerod, S. (2005) The continuing challenges of testing species distribution models. *Ecology* 42, 720-730.
22. Jiménez-Valverde, A. and Lobo, J. (2006) The ghost of unbalanced species distribution data in geographical model predictions. *Divers Distrib* 12 (5), 521-524.
23. Duque-Lazo, J. et al. (2016) Transferability of species distribution models: The case of *Phytophthora cinnamomi* in Southwest Spain and Southwest Australia. *Ecol Model* 320, 62-70.
24. García-Callejas, D. and Araújo, M.B. (2016) The effects of model and data complexity on predictions from species distributions models. *Ecol Model* 326, 4-12.
25. Hijmans, R.J. and Graham, C.H. (2006) The ability of climate envelope models to predict the effect of climate change on species distributions. *Glob Chang Biol* 12 (12), 2272-2281.
26. Lauria, V. et al. (2015) Spatial transferability of habitat suitability models of *Nephrops norvegicus* among fished areas in the Northeast Atlantic: Sufficiently stable for marine resource conservation? *PloS one* 10 (2), e0117006.
27. McAlpine, C. et al. (2008) Can multiscale models of species' distribution be generalized from region to region? A case study of the koala. *J Appl Ecol* 45 (2), 558-567.
28. Merow, C. et al. (2014) What do we gain from simplicity versus complexity in species distribution models? *Ecography* 37 (12), 1267-1281.
29. Moreno-Amat, E. et al. (2015) Impact of model complexity on cross-temporal transferability in Maxent species distribution models: An assessment using paleobotanical data. *Ecol Model* 312, 308-317.

30. Verbruggen, H. et al. (2013) Improving transferability of introduced species' distribution models: New tools to forecast the spread of a highly invasive seaweed. *PLoS ONE* 8 (6), e68337.
31. Huang, J. et al. (2016) Temporal transferability of stream fish distribution models: Can uncalibrated SDMs predict distribution shifts over time? *Divers Distrib* 22 (6), 651-662.
32. Sundblad, G. et al. (2009) Transferability of predictive fish distribution models in two coastal systems. *Estuarine, Coastal and Shelf Science* 83 (1), 90-96.
33. Barrientos, R. and de Dios Miranda, J. (2012) Can we explain regional abundance and road-kill patterns with variables derived from local-scale road-kill models? Evaluating transferability with the European polecat. *Divers Distrib* 18 (7), 635-647.
34. Martin, J. et al. (2012) Brown bear habitat suitability in the Pyrenees: Transferability across sites and linking scales to make the most of scarce data. *J Appl Ecol* 49 (3), 621-631.
35. Murray, J. et al. (2011) Evaluating model transferability for a threatened species to adjacent areas: Implications for rock-wallaby conservation. *Austral Ecol* 36 (1), 76-89.
36. Sequeira, A.M. et al. (2016) Transferability of predictive models of coral reef fish species richness. *J Appl Ecol* 53 (1), 64-72.
37. Torres, L.G. et al. (2015) Poor transferability of species distribution models for a pelagic predator, the grey petrel, indicates contrasting habitat preferences across ocean basins. *PLoS ONE* 10 (3), e0120014.
38. Crase, B. et al. (2014) Incorporating spatial autocorrelation into species distribution models alters forecasts of climate-mediated range shifts. *Glob Chang Biol* 20 (8), 2566-2579.
39. Guisan, A. and Thuiller, W. (2005) Predicting species distribution: Offering more than simple habitat models. *Ecol Lett* 8 (9), 993-1009.

40. Schadt, S. et al. (2002) Assessing the suitability of central European landscapes for the reintroduction of Eurasian lynx. *J Appl Ecol* 39 (2), 189-203.
41. Swanson, A.K. et al. (2013) Spatial regression methods capture prediction uncertainty in species distribution model projections through time. *Glob Ecol Biogeogr* 22 (2), 242-251.
42. Breiner, F.T. et al. (2015) Overcoming limitations of modelling rare species by using ensembles of small models. *Methods Ecol Evol* 6 (10), 1210-1218.
43. Crimmins, S.M. et al. (2013) Evaluating ensemble forecasts of plant species distributions under climate change. *Ecol Model* 266, 126-130.
44. Scales, K.L. et al. (2016) Identifying predictable foraging habitats for a wide-ranging marine predator using ensemble ecological niche models. *Divers Distrib* 22 (2), 212-224.
45. Wenger, S.J. and Olden, J.D. (2012) Assessing transferability of ecological models: An underappreciated aspect of statistical validation. *Methods Ecol Evol* 3 (2), 260-267.
46. Dambach, J. and Rödder, D. (2011) Applications and future challenges in marine species distribution modeling. *Aquat Conservat Mar Freshwat Ecosyst* 21 (1), 92-100.
47. Strauss, B. and Biedermann, R. (2007) Evaluating temporal and spatial generality: How valid are species–habitat relationship models? *Ecol Model* 204 (1-2), 104-114.
48. Wang, L. and Jackson, D.A. (2014) Shaping up model transferability and generality of species distribution modeling for predicting invasions: Implications from a study on *Bythotrephes longimanus*. *Biol Invasions* 16 (10), 2079-2103.
49. Araújo, M.B. and Luoto, M. (2007) The importance of biotic interactions for modelling species distributions under climate change. *Glob Ecol Biogeogr* 16 (6), 743-753.
50. Bateman, B.L. et al. (2012) Biotic interactions influence the projected distribution of a specialist mammal under climate change. *Divers Distrib* 18 (9), 861-872.

51. Godsoe, W. et al. (2015) Information on biotic interactions improves transferability of distribution models. *Am Nat* 185 (2), 281-290.
52. Heikkinen, R.K. et al. (2007) Biotic interactions improve prediction of boreal bird distributions at macro-scales. *Glob Ecol Biogeogr* 16 (6), 754-763.
53. Hof, A.R. et al. (2012) How biotic interactions may alter future predictions of species distributions: Future threats to the persistence of the arctic fox in Fennoscandia. *Divers Distrib* 18 (6), 554-562.
54. Pellissier, L. et al. (2013) Combining food web and species distribution models for improved community projections. *Ecol Evol* 3 (13), 4572-4583.
55. Tylianakis, J.M. et al. (2008) Global change and species interactions in terrestrial ecosystems. *Ecol Lett* 11 (12), 1351-1363.
56. Wisz, M.S. et al. (2013) The role of biotic interactions in shaping distributions and realised assemblages of species: Implications for species distribution modelling. *Biological Reviews* 88 (1), 15-30.
57. Austin, M.P. and Van Niel, K.P. (2011) Improving species distribution models for climate change studies: Variable selection and scale. *J Biogeogr* 38 (1), 1-8.
58. Heinänen, S. et al. (2012) High resolution species distribution models of two nesting water bird species: A study of transferability and predictive performance. *Landsc Ecol* 27 (4), 545-555.
59. Budic, L. et al. (2016) Squares of different sizes: effect of geographical projection on model parameter estimates in species distribution modeling. *Ecol Evol* 6 (1), 202-211.
60. Cord, A.F. et al. (2014) Remote sensing data can improve predictions of species richness by stacked species distribution models: A case study for Mexican pines. *J Biogeogr* 41 (4), 736-748.

61. Deblauwe, V. et al. (2016) Remotely sensed temperature and precipitation data improve species distribution modelling in the tropics. *Glob Ecol Biogeogr.*
62. Zimmermann, N.E. et al. (2010) Climatic extremes improve predictions of spatial patterns of tree species. *Proc Natl Acad Sci Unit States Am* 106 (Supplement 2), 19723-19728.
63. Graham, M.H. (2003) Confronting multicollinearity in ecological multiple regression. *Ecology* 84 (11), 2809-2815.
64. Kamino, L.H. et al. (2012) Challenges and perspectives for species distribution modelling in the neotropics. *Biology letters* 8 (3), 324-326.
65. Tuanmu, M.N. et al. (2011) Temporal transferability of wildlife habitat models: Implications for habitat monitoring. *J Biogeogr* 38 (8), 1510-1523.
66. Fernández, M. et al. (2012) Does adding multi-scale climatic variability improve our capacity to explain niche transferability in invasive species? *Ecol Model* 246, 60-67.
67. Porfirio, L.L. et al. (2014) Improving the use of species distribution models in conservation planning and management under climate change. *PloS one* 9 (11), e113749.
68. Pearman, P.B. et al. (2008) Niche dynamics in space and time. *Trends Ecol Evol* 23 (3), 149-158.
69. Howard, C. et al. (2014) Improving species distribution models: The value of data on abundance. *Methods Ecol Evol* 5 (6), 506-513.
70. Kharouba, H.M. et al. (2009) Historically calibrated predictions of butterfly species' range shift using global change as a pseudo-experiment. *Ecology* 90 (8), 2213-2222.
71. Phillips, S.J. (2008) Transferability, sample selection bias and background data in presence-only modelling: A response to Peterson et al.(2007). *Ecography* 31 (2), 272-278.

72. Acevedo, P. et al. (2014) Generalizing and transferring spatial models: a case study to predict Eurasian badger abundance in Atlantic Spain. *Ecol Model* 275, 1-8.
73. Fernández, M. and Hamilton, H. (2015) Ecological niche transferability using invasive species as a case study. *PloS one* 10 (3), e0119891.
74. Heikkinen, R.K. et al. (2012) Does the interpolation accuracy of species distribution models come at the expense of transferability? *Ecography* 35 (3), 276-288.
75. McPherson, J.M. and Jetz, W. (2007) Effects of species' ecology on the accuracy of distribution models. *Ecography* 30 (1), 135-151.
76. Syphard, A.D. and Franklin, J. (2010) Species traits affect the performance of species distribution models for plants in southern California. *J Veg Sci* 21 (1), 177-189.
77. Zhang, L. et al. (2015) Consensus forecasting of species distributions: The effects of niche model performance and niche properties. *PloS one* 10 (3), e0120056.
78. Grenouillet, G. et al. (2011) Ensemble modelling of species distribution: The effects of geographical and environmental ranges. *Ecography* 34 (1), 9-17.
79. Manel, S. et al. (2001) Evaluating presence-absence models in ecology: The need to account for prevalence. *J Appl Ecol* 38 (5), 921-931.
80. Santika, T. (2011) Assessing the effect of prevalence on the predictive performance of species distribution models using simulated data. *Glob Ecol Biogeogr* 20 (1), 181-192.
81. Evangelista, P.H. et al. (2008) Modelling invasion for a habitat generalist and a specialist plant species. *Divers Distrib* 14 (5), 808-817.
82. Segurado, P. and Araujo, M. (2004) An evaluation of methods for modelling species distributions. *J Biogeogr* 31, 1555-1568.
83. Wogan, G.O. (2016) Life history traits and niche instability impact accuracy and temporal transferability for historically calibrated distribution models of North American birds. *PloS one* 11 (3), e0151024.

220 84. Muñoz, A.R. et al. (2015) An approach to consider behavioral plasticity as a source of
 221 uncertainty when forecasting species' response to climate change. *Ecol Evol* 5 (12),
 222 2359-2373.

223 85. Bell, D.M. and Schlaepfer, D.R. (2016) On the dangers of model complexity without
 224 ecological justification in species distribution modeling. *Ecol Model* 330, 50-59.

225 86. Elith, J. and Graham, C.H. (2009) Do they? How do they? Why do they differ? On
 226 finding reasons for differing performances of species distribution models. *Ecography* 32
 227 (1), 66-77.

228 87. Fitzpatrick, M.C. and Hargrove, W.W. (2009) The projection of species distribution
 229 models and the problem of non-analog climate. *Biodivers Conserv* 18 (8), 2255-2261.

230 88. Mannocci, L. et al. (2015) Extrapolating cetacean densities beyond surveyed regions:
 231 habitat-based predictions in the circumtropical belt. *J Biogeogr* 42 (7), 1267-1280.

232 89. Mesgaran, M.B. et al. (2014) Here be dragons: A tool for quantifying novelty due to
 233 covariate range and correlation change when projecting species distribution models.
 234 *Divers Distrib* 20 (10), 1147-1159.

235 90. Rödder, D. and Engler, J.O. (2012) Disentangling interpolation and extrapolation
 236 uncertainties in species distribution models: A novel visualization technique for the
 237 spatial variation of predictor variable collinearity. *Biodiversity Informatics* 8 (1).

238 91. Zanini, F. et al. (2009) The transferability of distribution models across regions: An
 239 amphibian case study. *Divers Distrib* 15 (3), 469-480.

240 92. Zurell, D. et al. (2012) Predicting to new environments: Tools for visualizing model
 241 behaviour and impacts on mapped distributions. *Divers Distrib* 18 (6), 628-634.

242 93. Whittingham, M.J. et al. (2007) Should conservation strategies consider spatial
 243 generality? Farmland birds show regional not national patterns of habitat association.
 244 *Ecol Lett* 10 (1), 25-35.

94. Bridges, M.E., Nonindigenous plant species distributions: Modeling the role of human disturbances and predicting management responses, Montana State University, 2012, p. 179.
95. Dirnböck, T. et al. (2003) A regional impact assessment of climate and land-use change on alpine vegetation. *J Biogeogr* 30 (3), 401-417.
96. Marshall, L. et al. (2015) Testing projected wild bee distributions in agricultural habitats: predictive power depends on species traits and habitat type. *Ecol Evol* 5 (19), 4426-4436.
97. Warren, D.L. et al. (2008) Environmental niche equivalency versus conservatism: quantitative approaches to niche evolution. *Evolution* 62 (11), 2868-2883.
98. Rödder, D. and Lötters, S. (2010) Explanative power of variables used in species distribution modelling: an issue of general model transferability or niche shift in the invasive Greenhouse frog (*Eleutherodactylus planirostris*). *Naturwissenschaften* 97 (9), 781-796.
99. Whittingham, M.J. et al. (2003) Do habitat association models have any generality? Predicting skylark *Alauda arvensis* abundance in different regions of southern England. *Ecography* 26 (4), 521-531.
100. Thomas, J.A. and Bovee, K.D. (1993) Application and testing of a procedure to evaluate transferability of habitat suitability criteria. *River Res Appl* 8 (3), 285-294.
101. Mäki-Petäys, A. et al. (2002) Transferability of habitat suitability criteria of juvenile Atlantic salmon (*Salmo salar*). *Can J Fish Aquat Sci* 59 (2), 218-228.
102. Gray, T.N. et al. (2009) Generality of models that predict the distribution of species: Conservation activity and reduction of model transferability for a threatened bustard. *Conserv Biol* 23 (2), 433-439.