

Distributional overlap and potential competition between a threatened habitat specialist and generalist frog species in coastal wallum habitats of South East Queensland, Australia

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Abstract Coastal wallum wetlands inhabited by the vulnerable wallum sedgefrog (*Litoria ongburensis*) are highly susceptible to habitat degradation owing to their unusual hydrology and water chemistry. Anthropogenic impacts on wallum wetland environs pose a significant threat to the wallum sedgefrog by allowing the eastern sedgefrog (*Litoria fallax*), a habitat generalist and closely related competitor species, to colonise and displace the wallum sedgefrog from disturbed wallum habitat. To identify ‘at risk’ areas, overlapping species distribution models were utilised to highlight areas of sympatry between these species in south east Queensland, where competition with the eastern sedgefrog poses a particular threat to the wallum sedgefrog. Significant areas of distributional overlap (including 47% of the wallum sedgefrog’s modelled distribution) were identified, primarily in mainland areas where anthropogenic disturbance is highest. When overlayed with the boundaries of protected areas, 84% of the area exclusively inhabited by the wallum sedgefrog occurs within the bounds of protected lands. In contrast, 74% of overlapping distribution of the two species occurred outside of these parks, highlighting the importance of protected areas in the conservation of the wallum sedgefrog. This study highlights areas where competition with the eastern sedgefrog presents a particular threat to the wallum sedgefrog, helping inform effective conservation initiatives for this species.

Key words: eastern sedgefrog, habitat disturbance, protected areas, wallum, wallum sedgefrog.

INTRODUCTION

The groundwater-dependent wetlands of eastern Australia’s coastal sandy lowlands (a.k.a. the ‘wallum’) are characterised by dilute, oligotrophic waters of low pH (pH 3.4–5.5; Coaldrake 1961; Griffith *et al.* 2008). These naturally acidic wetlands provide habitat for a unique assemblage of ‘acid’ frog species specially adapted to low pH waters (Hines & Meyer 2011; Filer *et al.* 2019). The wallum sedgefrog (*Litoria ongburensis*) is an acid frog species considered vulnerable at the state and national level (Hines *et al.* 2004; Lemckert & Mahony 2018) owing to past and ongoing habitat loss and degradation (Meyer *et al.* 2006). Of particular concern in this regard, is the fragmentation and degradation of wallum environs due to ongoing urban and industrial development in south east Queensland (SEQ; Arthington *et al.* 2019).

Development occurring within and in proximity to wallum environs can result in changes to the hydrology and water chemistry of wallum wetlands that are detrimental to acid frogs, including changes to pond hydroperiod, colonisation of the wetland by predatory fish (including exotic pest species such as the plague minnow [*Gambusia holbrooki*]), habitat eutrophication, and elevated pH (Hines & Meyer 2011; Arthington *et al.* 2019). Increases in the pH of wallum wetlands pose a particular threat to acid frog species like the wallum sedgefrog by facilitating the colonisation of wallum wetlands by more generalist frog species previously excluded by physiological limitations (Meyer *et al.* 2006, 2010).

The eastern sedgefrog (*Litoria fallax*), an ecologically similar congener closely related to the wallum sedgefrog (Meyer *et al.* 2006), is common along the eastern coast of Australia where it occupies a variety of natural and man-made wetlands, including swamps, drainage lines, ponds, dams and detention basins (James & Moritz 2001; Hines & Meyer 2011). In contrast with the wallum sedgefrog, the eastern sedgefrog is rarely found in undisturbed wallum

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habitat, where low pH and elevated tannin-levels inhibit or limit successful breeding and recruitment of this species (Meyer *et al.* 2010; Hines & Meyer 2011). In areas of disturbed wallum habitat, where pH levels are elevated, the eastern sedgefrog is able to breed in, and colonise, habitat previously occupied by the wallum sedgefrog and potentially displace the wallum sedgefrog from areas of disturbed or degraded wallum habitat. Eastern sedgefrog occurrence may, therefore, be an important limiting factor for the wallum sedgefrog in wetlands with higher or elevated pH (Hines & Meyer 2011; Shuker *et al.* 2016).

South east Queensland is currently undergoing rapid population growth (Australian Bureau of Statistics 2021), placing pressure on wallum wetlands occurring outside of protected areas. This in turn threatens the persistence of the wallum sedgefrog in degraded wetlands, particularly as this may facilitate competition with more generalist species like the eastern sedgefrog (see Filer *et al.* 2021). In this study, species distribution models were used to identify areas of potential co-occurrence of the wallum sedgefrog and eastern sedgefrog in SEQ in order to better understand how land use changes may create areas of sympatry and, therefore, competition, between two normally isolated species, thereby enabling more targeted conservation management.

METHODS

Species occurrence data

Analyses were limited to the core region of the wallum sedgefrog's distribution (i.e. SEQ) which encompasses all known Queensland wallum sedgefrog records. State-wide Queensland occurrence records were sourced for the wallum sedgefrog and eastern sedgefrog from the publicly accessible databases: Atlas of Living Australia, New South Wales Office of Environment and Heritage and Queensland WildNet, as well as from unpublished survey records conducted by EM between 1996–2017.

In accordance with, and as described in, Filer *et al.* (2019), vetting was performed to remove wallum sedgefrog records with erroneous locality or identification issues (see DOI: [10.14264/ffe73a3](https://doi.org/10.14264/ffe73a3)). Rigorous vetting was also performed for both species to remove duplicate data, records with inadequate information or an estimated spatial accuracy >500 m, and outdated records collected previous to the January 1990–February 2021 period used in this analysis.

Predictor variables

Thirteen predictor variables (see [Appendix S1](#)) were used to develop the species occurrence models, chosen based on modelling performed on the wallum sedgefrog and

associated species by Filer *et al.* (2019). Where possible these variables were updated to the most contemporary version available and included: dominant vegetation, soil properties (amount of clay, sand and soil pH), wetlands (presence and type), land zone (of remnant regional ecosystem classification scheme), elevation and slope, land use, road density (kernel density) and mean annual rainfall, temperature and rainfall-modified solar radiation. Data for all layers were processed in ArcGIS 10.7.1 (ESRI 2011) and clipped to the SEQ bioregion (Department of the Environment and Energy 2012) at a 50m² resolution.

Modelling procedure

A random forest model was selected due to its proven ability to model acid frog distributions using environmental data with great accuracy (see Filer *et al.* 2019 for detailed information on the modelling procedure). Two measures of model accuracy were reported in this study; an out-of-bag error estimate using samples not used to train the model (calculated by random forest's inherent bootstrapping procedure as a form of model validation), and a mean kappa statistic created using a k-fold cross validation. The use of a random forest model in this study without evaluating alternative frameworks was supported by the sufficiently high kappa scores associated with the produced models (0.93 and 0.76).

The random forest analysis was conducted in R (using raster, sp, rgdal and rgeos packages; R Development Core Team 2020) and used 50 000 random points to sample background locations within the study area. As random forest models are sensitive to large sample size imbalances among classes, the model was implemented using a stratification procedure that resampled 66% of occurrence records and background locations at each step, ensuring that classification accuracies were balanced among classes. The models were run using 1500 trees, with three variables tried at each split.

The predictor variables were used to generate binary predicted distribution maps of occurrence for the wallum sedgefrog and eastern sedgefrog (using a 0.5 probability threshold to categorise the continuous probability model output), which were then overlaid with a map of SEQ protected areas (Department of National Parks, Sport and Racing 2017).

RESULTS

Both species distribution models had high predictive power, with classification accuracies exceeding 86% (model accuracy: wallum sedgefrog = 92%, kappa = 0.93, N = 171; eastern sedgefrog = 86%, kappa = 0.76, N = 2841). Predictor variables contributing most to the wallum sedgefrog distribution model (determined using 'mean decrease in accuracy'), included soil sand and clay content, wetland presence/type, land zone and vegetation type. In comparison, the main contributing variables for the

eastern sedgefrog included land use, mean annual rainfall, vegetation type, road density and land zone.

In Queensland, the wallum sedgefrog's distribution is highly restricted, encompassing sandy lowland areas from Fraser Island south to the Queensland–New South Wales border (Fig. 1, Table 1). In contrast, the predicted distribution and occurrence records of the eastern sedgefrog extends across much of SEQ, with clustering along the south east coast including in densely human populated regions (i.e. Brisbane and Gold Coast regions), where there is a notable lack of wallum sedgefrog occurrences (Fig. 1).

Distributional overlap of the two species primarily occurs in, and south of, the Sunshine Coast, mainly on the mainland, although there are some areas of overlap on North Stradbroke Island and across much of Bribie Island (Fig. 2). The majority of wallum sedgefrog occurrence records (75%) lie within the predicted distribution of the eastern sedgefrog, while the majority of eastern sedgefrog records (72%) lie outside the predicted distribution of the wallum sedgefrog (Table 1).

Notably, while only 56% of the wallum sedgefrog's distribution is predicted to occur within protected areas, this coverage increases to 84% when excluding areas of overlap with the modelled distribution of the eastern sedgefrog (Table 1). In contrast, 74% of

areas of co-occurrence fall outside of any protected areas (Table 1, Appendix S2).

DISCUSSION

In Queensland, the modelled distribution of the wallum sedgefrog closely matches the extent of coastal sandy lowland or 'wallum' habitat characterised by deep siliceous sands or shallower sandy soil overlaying layers of deeper sandstone or clay (Coal-drake 1961). Additionally, the five predictor variables identified to contribute most to the wallum sedgefrog's distribution model (soil sand and clay content, presence/type of wetland, vegetation type and land zone) are indicative of wallum wetland supporting sedgeland, wet heath and *Melaleuca* (paperbark) dominated communities (Griffith *et al.* 2003, 2008).

In contrast, the eastern sedgefrog, a more generalist species, has a broader predicted distribution within SEQ, covering an area double that of the wallum sedgefrog (Fig. 1, Table 1). The key predictor variables for the eastern sedgefrog's distribution are more varied and include two measures of human occupancy: land use and road density. This, combined with their wider and patchier distribution, reflects their greater tolerance to disturbance and ability to utilise a wide variety of freshwater wetlands

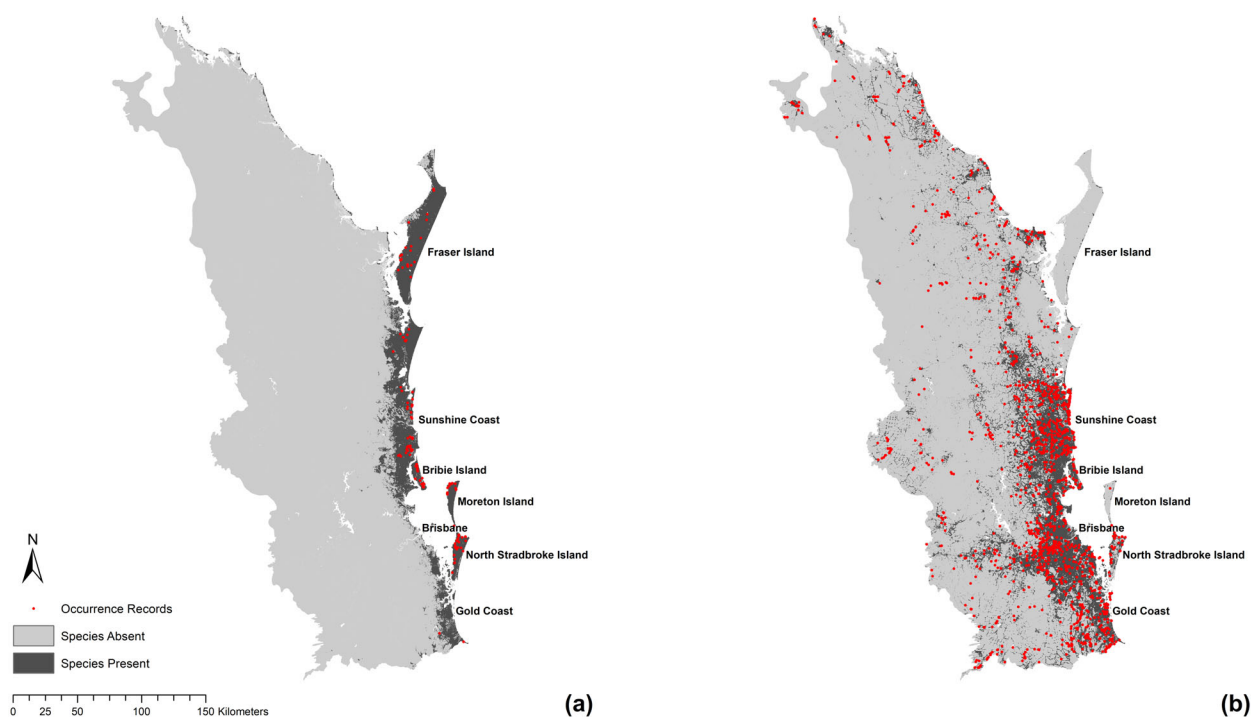
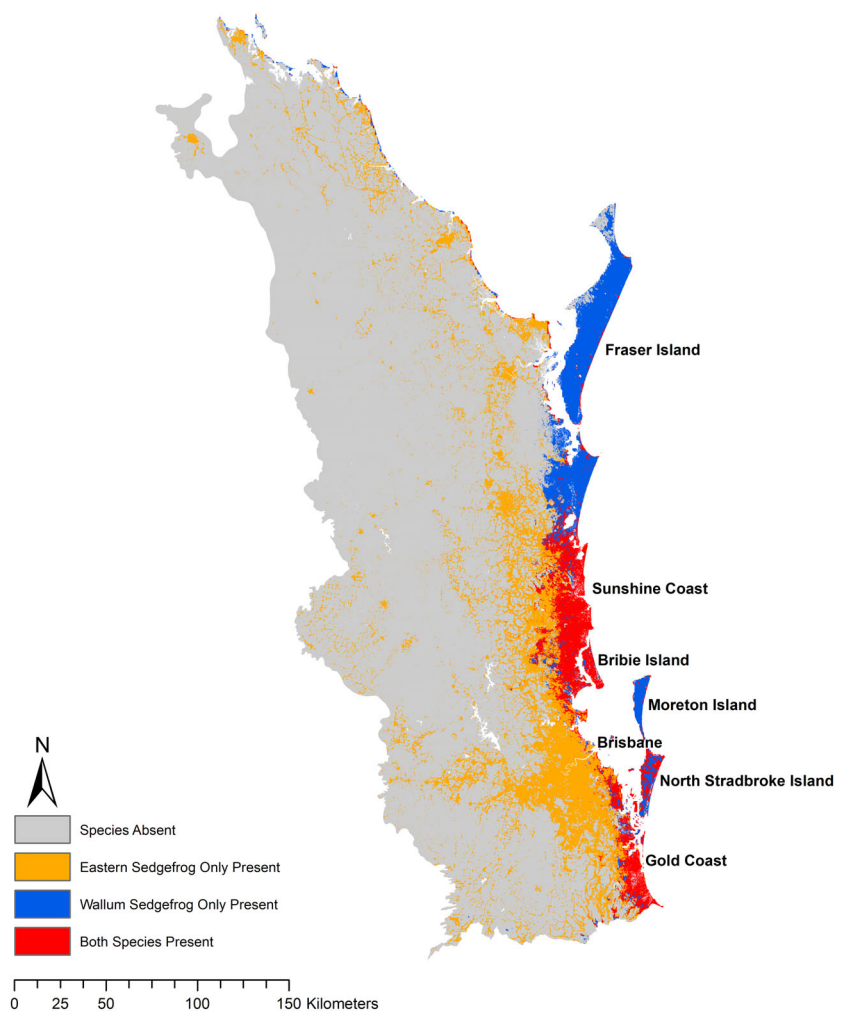


Fig. 1. Predicted distribution of (a) the wallum sedgefrog (*Litoria onlongburensis*) and (b) the eastern sedgefrog (*Litoria fallax*) in the south east Queensland bioregion. Dark grey is indicative of the predicted distribution of each species. Each map is overlaid with the occurrence records of each species (red).

Table 1. Total area, and the proportion, of wallum sedgefrog (*Litoria olongburensis*) and eastern sedgefrog (*Litoria fallax*) predicted distribution (and occurrence records) occurring in single-species (exclusive) versus shared habitats

	Total predicted distribution (km ²)	Proportion (%) of distribution occurring in protected areas	Proportion (%) of distribution (and occurrence records) in exclusive habitat	Proportion (%) of exclusive habitat distribution in protected areas	Proportion (%) of distribution (and occurrence records) in shared habitat	Proportion (%) of shared habitat distribution in protected areas
Wallum sedgefrog	5212	56	53 (25)	84	47 (75)	26
Eastern sedgefrog	10 525	15	77 (72)	12	23 (27)	26

Each species' exclusive and shared distribution occurring within protected areas (national parks, scientific national parks, conservation parks, state forests, resource reserves, forest reserves and timber reserves) has also been calculated. Values have been rounded to the nearest whole integer.

Fig. 2. Colour map showing areas of predicted distribution overlap between the wallum sedgefrog and eastern sedgefrog. Blue cells are representative of the occurrence of only the wallum sedgefrog (*Litoria olongburensis*), orange the occurrence of only the eastern sedgefrog (*Litoria fallax*), and red areas of occurrence of both species, that is an area where competition may potentially occur.

and open forest habitats (James & Moritz 2001), including artificial/man-made wetlands and dams (Hines & Meyer 2011).

While the vast majority of eastern sedgefrog occurrence records (72%) occur in habitat unsuitable for the wallum sedgefrog (Table 1), there was significant overlap between the known and modelled

distributions of these species, particularly in coastal areas of SEQ. The area of distributional overlap for wallum sedgefrog and eastern sedgefrog includes areas where fine scale partitioning of habitat may allow these species to co-exist, as well as areas of marginal wallum sedgefrog habitat (e.g. disturbed wallum) recently colonised by the eastern sedgefrog

due to anthropogenic impacts on wetland hydrology. In regard to the latter, it is noted that areas of known or potential overlap between the two species coincide with densely populated areas such as the Sunshine Coast, Gold Coast and Brisbane. Human land use practices in these areas impact the hydrology and water chemistry of wallum wetlands, facilitating colonisation of wallum sedgefrog habitat by the eastern sedgefrog (Meyer *et al.* 2006), where the eastern sedgefrog may compete with and displace the wallum sedgefrog (Meyer *et al.* 2006; Shuker *et al.* 2016). Managing and monitoring human impacts on water quality in these areas should, therefore, be considered a high priority, especially where development is occurring immediately adjacent or upstream of wallum sedgefrog habitat and shifts in water pH (due to surface runoff and overland flows from developed areas, roads, footpaths and nearby drainage lines) could allow the eastern sedgefrog to colonise areas of wallum sedgefrog habitat.

Important habitat areas where competition with the eastern sedgefrog poses less of a threat include protected areas on Fraser and Moreton Islands (Appendix S2), where anthropogenic activity impacting the hydrology and water chemistry of wallum wetlands is limited, and the eastern sedgefrog is either scarce or entirely absent (Table 1). Protection of refugial wetland habitat in these areas is, therefore, important for the conservation of the wallum sedgefrog, both now and in the future. Indeed, 84% of wallum sedgefrog distribution in the absence of the eastern sedgefrog was found to be contained within protected areas (Table 1), highlighting the potential importance of conservation areas in preventing habitat degradation and subsequent colonisation by the eastern sedgefrog.

In this study, we have used distributional modelling to highlight areas of potential competition between a threatened habitat specialist (wallum sedgefrog) and habitat generalist (eastern sedgefrog), as well as important refugial areas where competition between these species poses little or no threat (e.g. sand islands, such as Fraser and Moreton Island, where the wallum sedgefrog is able to sustain populations in the absence of competition). While habitat in refugial areas is fairly well protected within conservation parks and reserves, habitat within the zone of overlap between the wallum sedgefrog and eastern sedgefrog remains under considerable threat. Managing human impacts on wetland hydrology and water quality within this zone is important for minimising competition and ensuring the long-term persistence of the wallum sedgefrog in these areas. This is especially important in the Sunshine Coast area where development impacts on wetland hydrology and water quality are likely to facilitate colonisation of wallum sedgefrog habitat by the eastern sedgefrog, including habitat within conservation parks or

reserves downstream of and/or adjacent to development areas.

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AUTHOR CONTRIBUTIONS

Alannah Filer: Conceptualization (equal); formal analysis (lead); investigation (lead); methodology (lead); visualization (lead); writing – original draft (lead); writing – review and editing (equal). **Edward A. Meyer:** Conceptualization (equal); writing – review and editing (equal). **Berndt J. Van Rensburg:** Conceptualization (equal); supervision (lead); writing – review and editing (equal).

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The datasets generated and/or analysed during the current study are available in the University of Queensland UQ eSpace data repository: <https://doi.org/10.14264/ffe73a3>.

REFERENCES

- Arthington A. H., Mackay S. J., Ronan M., James C. S. & Kennard M. J. (2019) Freshwater wetlands of Moreton Bay, Quandamooka and catchments: biodiversity, ecology, threats and management. In: *Moreton Bay Quandamooka & Catchment: Past, Present, and Future* (eds I. R. Tibbetts, P. C.

- Rothlisberg, N. D. T., Homburg, B. D. T., Brewer & A. H. Arthington) pp. 319–34. The Moreton Bay Foundation, Brisbane. <https://doi.org/10.6084/m9.figshare.8073851>
- Australian Bureau of Statistics (2021) *Regional Population, 2019–20 Financial Year*. Commonwealth of Australia, Canberra, Australia. Catalogue number 3218.0.
- Coaldrake J. E. (1961) The ecosystem of the coastal lowlands (“wallum”) of southern Queensland. *CSIRO Bulletin*, **283**, 1–119.
- Department of National Parks, Sport and Racing (2017) *Protected Areas of Queensland – Boundaries*. Canberra, Australia: Queensland Spatial Catalogue – Qspatial. [Spatial data]. Available from URL: <http://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={6C180042-2B50-4018-8B29-E245818B1B8A}>
- Department of the Environment and Energy (2012) *Interim Biogeographic Regionalisation for Australia (Regions - States and Territories) (IBRA)*. Canberra, Australia: Australian Government. Version 7. [Spatial data]. Available from URL: <http://www.environment.gov.au/fed/catalog/search/resource/details.page?uuid=%7B4A2321F0-DD57-454E-BE34-6FD4BDE64703%7D>
- ESRI (2011) *ArcGIS Desktop: Release 10.7.1*. Environmental Systems Research Institute, Redlands.
- Filer A., Beyer H. L., Meyer E. & van Rensburg B. J. (2019) Distribution mapping of specialized amphibian species in rare, ephemeral habitats: implications for the conservation of threatened “acid” frogs in south-east Queensland. *Conserv. Sci. Pract.*, **2**, e143.
- Filer A., Burchardt L. S. & van Rensburg B. J. (2021) Assessing acoustic competition between sibling frog species using rhythm analysis. *Ecol. Evol.*, **11**, 8814–30.
- Griffith S. J., Bale C., Adam P. & Wilson R. (2003) Wallum and related vegetation on the NSW north coast: Description and phytosociological analysis. *Cunninghamia*, **8**, 202–52.
- Griffith S. J., Bale C. & Adam P. (2008) Environmental correlates of coastal heathland and allied vegetation. *Aust. J. Bot.*, **56**, 512–26.
- Hines H. & Meyer E. (2011) The frog fauna of Bribie Island: An annotated list and comparison with other Queensland dune islands. *P. Roy. Soc. QLD*, **117**, 261–74.
- Hines H., Newell D., Meyer E., Hero J. M. & Clarke J. (2004) *Litoria ongburensis*. [online] The IUCN Red List of Threatened Species. Available from URL: <https://doi.org/10.2305/IUCN.UK.2004.RLTS.T41037A10392098.en>. [Accessed 15 Jan 2021].
- James C. H. & Moritz C. (2001) Intraspecific phylogeography in the sedge frog *Litoria fallax* (Hylidae) indicates pre-Pleistocene vicariance of an open forest species from eastern Australia. *Mol. Ecol.*, **9**, 349–58.
- Lemckert F. & Mahony M. (2018) The status of decline and conservation of frogs in temperate coastal south-eastern Australia. In: *Status of Conservation and Decline of Amphibians* (eds H. Heatwole & J. J. L. Rowley) pp. 59–73. CSIRO Publishing, Victoria. <https://doi.org/10.1071/9781486308392>
- Meyer E., Hero J. M., Shoo L. & Lewis B. (2006) *National Recovery Plan for the WSF and Other Wallum-dependent Frog Species*. Queensland Parks and Wildlife Service, Brisbane.
- Meyer E. A., Cramp R. L. & Franklin C. E. (2010) Damage to the gills and integument of *Litoria fallax* larvae (Amphibia: Anura) associated with ionoregulatory disturbance at low pH. *Comp. Biochem. Phys. A*, **155**, 164–71.
- R Development Core Team (2020) *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna.
- Shuker J. D., Simpkins C. A. & Hero J. M. (2016) Determining environmental limits of threatened species: The example of the WSF *Litoria ongburensis*. *Ecosphere*, **7**, e01384.

SUPPORTING INFORMATION

Additional supporting information may/can be found online in the supporting information tab for this article.

Appendix S1 The 13 environmental, anthropogenic and climatic variables used to derive species distribution models. Note: resampling using bilinear and nearest neighbour methods were utilised with continuous and categorical data respectively; polygon data were converted using the maximum combined area approach.

Appendix S2 Colour map showing areas of overlap between the modelled distributions of wallum sedgefrog and eastern sedgefrog where areas of wallum sedgefrog only occurrence are blue, eastern sedgefrog only occurrence are orange, and areas of overlap are red. The map is overlaid with the boundaries of protected areas (national parks, scientific national parks, conservation parks, state forests, resource reserves, forest reserves and timber reserves).