Northern Australia Environmental Resources Hub

National Environmental Science Programme

Prioritising threatened species and threatening processes across northern Australia

User guide for data

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This report should be cited as: Pintor A,[1] Kennard M,[2] Álvarez-Romero JG,[1,3] and Hernandez S.[1] 2019. *Prioritising threatened species and threatening processes across northern Australia: User guide for data.* James Cook University, Townsville.

1. James Cook University
2. Griffith University
3. ARC Centre of Excellence for Coral Reef Studies

Cover photographs

Front cover: Butler's Dunnart is a threatened species which is found only on the Tiwi Islands in the Northern Territory, photo Alaric Fisher.

Back cover: One of the spatially explicit maps created during this project.

This report is available for download from the Northern Australia Environmental Resources (NAER) Hub website at nespnorthern.edu.au

The Hub is supported through funding from the Australian Government's National Environmental Science Program (NESP). The NESP NAER Hub is hosted by Charles Darwin University.

ISBN 978-1-925800-44-9

December, 2019

Printed by Uniprint

Contents

List of tables

List of figures

Acronyms

ABARES ....Australian Bureau of Agricultural and Resource Economics and Sciences

ACLUMP ....Australian Collaborative Land Use and Management Program

ALA ....Atlas of Living Australia

ASCII ....ASCII, abbreviated from American Standard Code for Information Interchange, is a character encoding standard for electronic communication

DAWE..................Department of Agriculture, Water and the Environment

DOI ....Digital object identifier

EVNT ....Species or communities listed as Critically Endangered, Endangered, Vulnerable or Near-threatened according to state, territory, federal or IUCN legislation.

FGARA................Flinders and Gilbert Agricultural Resource Assessment

GBIF ....Global Biodiversity Information Facility

GBR.....................Great Barrier Reef

GCM ....Global circulation model

IPCC ....Intergovernmental Panel on Climate Change

IUCN....................International Union for Conservation of Nature

NAER Hub ....Northern Australia Environmental Resources Hub

NAWRA...............Northern Australia Water Resource Assessment

NCCARF ....National Climate Change Adaptation Research Facility

NVIS ....National Vegetation Information System

RDSI ....Research Data Storage Initiative (managed by James Cook University)

SDM.....................Species distribution model

Acknowledgements

We would like to acknowledge the support and input provided by Bob Pressey, Erin Graham and Jeremy VanderWal (James Cook University), and Vanessa Adams (University of Tasmania). We could not have completed such an ambitious project without their invaluable input.

We are also grateful to Michael Douglas, Brendan Edgar, Jane Thomas and Clare Taylor from the Northern Australia Environmental Resources Hub, whose expertise, professionalism, and support have resulted in the success of this project.

This project has been completed in close collaboration with various universities, government departments and non-government organisations. We would, therefore, like to extend our thanks to all of our co-investigators and contributors, especially Ian Cowie, Alaric Fisher, Graeme Gillespie, Damian Milne (Northern Territory Government), Arthur Georges (University of Canberra), Jayden Engert, Mark Hamann, Donald McKnight, Jason Schaffer, Collin Storlie (James Cook University), Ashley Field, Mel Greenfield (Australian Tropical Herbarium, James Cook University), Miles Nicholls, Dave Westcott (CSIRO), David Pannell, Julian Tonti-Filippini (University of Western Australia), Frank Koehler (Australian Museum Research Institute), John Neldner (Qld Herbarium), Stephen Garnett, Peter Kyne, John Zichy-Woinarski (Charles Darwin University), Brad Ellis, Peter Johnson, Lindsey Jones (Qld Department of Environment and Science), Marcus Baseler (Australian Department of Agriculture, Water and the Environment), Mel Hardie (Victorian Biodiversity Atlas), Paul Gioia, Stephen van Leeuwen (WA Department of Biodiversity, Conservation and Attractions), and Terry Reardon (SA Museum), who have contributed to the development of robust methods, ensuring end-user adoption of outputs, contributed data and/or assisted with model vetting. The success of this ambitious project was enabled by your involvement.

The authors acknowledge Aboriginal and Torres Strait Islander Peoples as the traditional custodians of the lands across northern Australia where this research applies. We pay our respects to Elders of the past, present and future, and acknowledge their spiritual connection to Country. In particular, the authors would like to acknowledge the Bindal and Wulgurukaba Peoples of the Townsville region, and the Yugarabul, Yuggera, Jagera and Turrbal Peoples of the Brisbane region where the authors live and work.

Executive summary

Northern Australia's unique and rich biodiversity faces numerous threatening processes. Currently, there is limited knowledge of i) the distribution of species of conservation concern across northern Australia, ii) their level of exposure to various threats and iii) their vulnerability as a result of exposure and differential sensitivity to threats. These knowledge gaps severely limit the efficiency and adequacy of conservation actions and simultaneously create uncertainty for sustainable development in the North. This project aimed to fill these knowledge gaps by creating spatially explicit data that can be used to inform species conservation policy, assessments of species' conservation status and decision-making about threat mitigation and management. The data can also be used to guide where further research may be needed about species of conservation concern, as part of regional planning processes governing land-use and water resources in northern Australia.

This user guide has been prepared to assist stakeholders with the appropriate use of data created for the National Environmental Science Program (NESP) Northern Australia Environmental Resources (NAER) Hub, through Project 3.3 *Prioritising threatened species and threatening processes across northern Australia*. The project has generated the following data sets:

1. **High-resolution maps of the distributions** of >1,400 'species of conservation concern', i.e. rare, range-restricted, threatened or near threatened species or populations of plants and animals that occupy terrestrial or freshwater ecosystems, developed based on habitat suitability models and expert knowledge.
2. **Hotspot maps** that show concentrations, or richness, of species of conservation concern for different taxonomic groups.
3. **Maps of the key threatening processes** that impact northern Australian biodiversity. These include:
    - distribution of current agricultural areas, and capacity of future cropping;
    - predicted changes in climate 'stressors' such as increased or prolonged heat and drought periods;
    - changes in fire frequency and seasonal timing since 1988 and differences to typical conditions for vegetation types;
    - predicted changes in stream flow regimes due to climate change and severity of human modification;
    - risk of overgrazing based on spatial variation of current and estimated future pastoral activity;
    - risk from invasive species based on models of current and future habitat suitability, known current invasion areas, and expert knowledge for ~250 weeds, feral animals and wildlife diseases;
    - risk associated with current and potential mining activities based on information collated from state/territory and federal databases;
    - accessibility of terrestrial and freshwater areas to human activities based on population size and landscape characteristics, as an indicator of risk of overexploitation; and
    - current urbanisation and likely pressure on the environment from expansion of urbanised areas based on land use, population size and accessibility.

4. **Maps of vulnerability**: These combine maps of species of conservation concern distributions with maps of threatening processes and information on how sensitive the species are to those threats. The resulting maps identify areas of high vulnerability – areas, where species of conservation concern coincide with significant threats and thus should be considered for targeted management.

This user guide briefly describes the rationale for, and data files associated with, all four data sets described above. It also provides practical guidance on appropriate interpretation of the data, as well as important methodological caveats and limitations. It does not replace the need for ground-truthing, regional and site-based ecological surveys and/or taxa-specific research, but can help frame where this survey effort might occur and for which species.

1. Introduction

1.1 Background and purpose

The efficacy of conservation prioritisation, threat abatement activities, and environmental impact assessments is often constrained by a lack of spatially explicit information available to the Australian Government, state and territory agencies, Natural Resource Management bodies, industry and non-governmental organisations (Possingham, 2001). Strategic decision making and planning could be enhanced by creating data to fill relevant knowledge gaps (Possingham, 2001), synthesising existing information from disparate sources (including the experience of experts; Fazey, 2006), and using this information in a structured way to support planning for threat management and land and water development decisions (Reyers, 2010; Bottrill, 2008; Soulé, 1985). This project aimed to create a platform for relevant data concerning major threatening processes across northern Australia. More information can be found on the project webpage.[1]

Northern Australia is a key area where these knowledge gaps need to be addressed because of ongoing interest in ‘developing the North’ and to address the paucity of information on species and threat distribution, and their interactions if biodiversity in this region is to be safeguarded. The National Environmental Science Program (NESP) Northern Australia Environmental Resources (NAER) Hub Project 3.3 *Prioritising threatened species and threatening processes across northern Australia* (hereafter ‘the project’) was initiated in 2016 to address some of these knowledge gaps. Federal, state, and territory governments – through various workshop and conservation strategies – have committed to prioritising actions to reduce the risk of species’ decline and extinction. The impact of conservation initiatives in this region are reliant on spatially explicit data. Creating these data involves modelling the exposure and responses of northern biodiversity to threatening processes. The project, therefore, constituted a three-tier initiative that aimed to answer the following three questions:

5. Where is threatened biodiversity distributed across northern Australia?
6. What is the intensity and likelihood of threatening processes across space and time?
7. How and where do species and relevant threatening processes interact?

Each of these questions corresponds to a section of this report and a subset of data now available as a result of this project. In each section, we briefly describe:

1. Background information supporting the need for the collated data;
2. Brief summary of methods; and
3. Limitations of available data and potential data use.

[1] nespnorthern.edu.au/projects/nesp/prioritising-threatened-species

1.2 Study area

Two consultation workshops involving diverse organisations and technical experts were held in Darwin in 2015 for NESP project *Identifying high-priority areas in northern Australia for threat abatement and species recovery*.[2] During these discussions, the study area for this project was defined. Thus, we focused our analysis on northern Australia, which is comprised of the northern tropical savannas and north-eastern tropical rainforests conservation management zones, as well as any overlapping river basins (Figure 1).

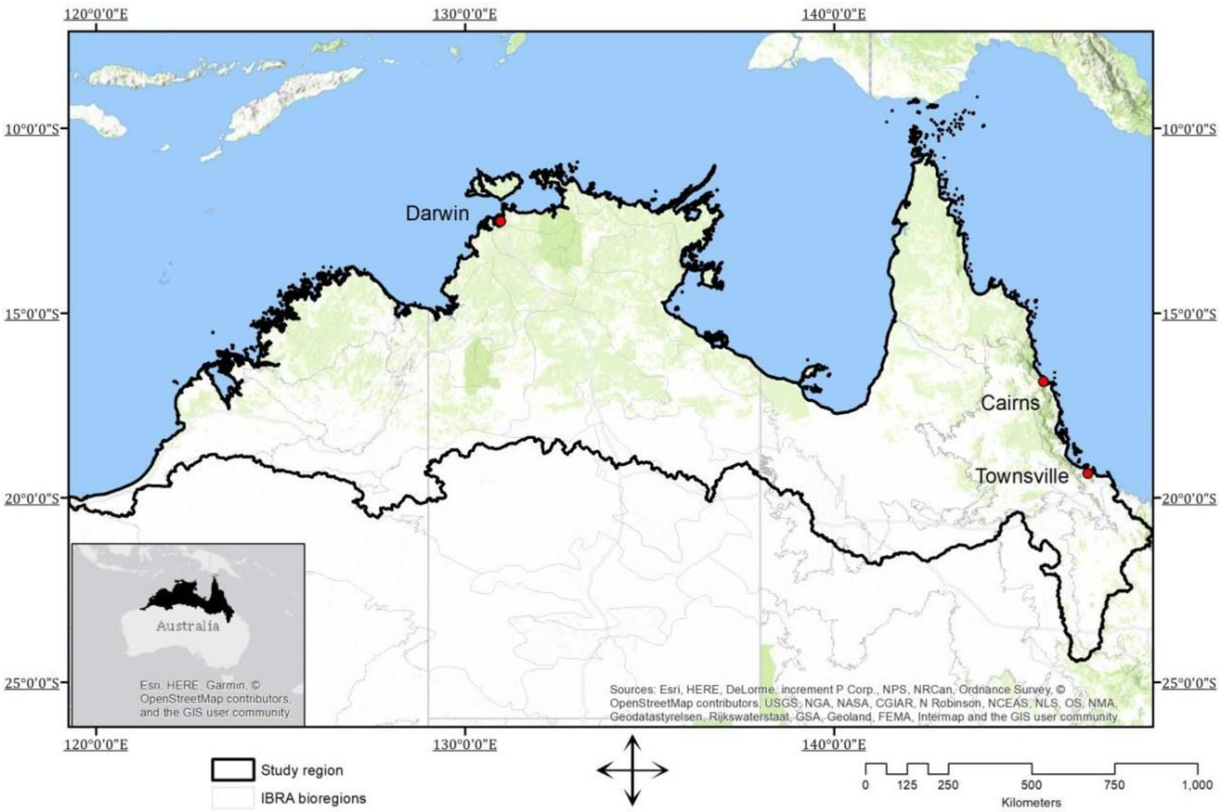

Figure 1. The spatial extent of the study region in northern Australia. Please note that some project outputs are available for all of Australia. Please contact the principal investigator of this study for any additional information regarding Australia-wide data.

1.3 Data access

Data created as part of this project are publicly available, free of charge, under the constraint of approval from a relevant government authority or the principal investigator of the project. The approval process is required to discourage misuse of the data, mainly because of the sensitive information included in some outputs. The outputs can be accessed either via

[2] nespnorthern.edu.au/wp-content/uploads/2017/01/Identifying-high-priority-areas-in-Nth-Aust-Wrap-up-factsheet-28Nov2016-WEB-FINAL.pdf

relevant Australian federal or state/territory government websites in various formats, or as the original spatial grid files from a database managed by James Cook University.

Some of the data relating to the distribution of species or threatening processes is managed and held by the DAWE, mostly as part of the Species Profile and Threats Database (SPRAT).[3] Queensland, Western Australia, and the Northern Territory may incorporate various outputs into their online databases and websites in the near future. We encourage users to seek access to the data through relevant government departments.

The full data collection is also held in a Research Data Storage Initiative (RDSI) collection (identification code Q0634) managed by James Cook University and will be accessible via an online data portal by mid-2020. The link to the data portal will be published on the project website[4] and will follow the same structure as the RDSI collection. Until then, the data is accessible through the principal investigator of this project. For an overview of the directory structure in the RDSI collection Q0634, see Figure 2. A list of references with DOI (digital object identifier) numbers to metadata records and details of the relevant data sets/ directories within the RDSI collection is shown at the beginning of each section of this report and detailed methods documents can be found in the relevant RDSI folder for each data set. The collection consists of three main directories:

1. plots – summary figures of all outputs, including maps of species distributions, images of main threat outputs, and visual summaries of spatial variations in vulnerability for each species and taxonomic groups; this directory is a good place to start for a quick overview over what outputs are available and which ones may be appropriate for a certain purpose;
2. public – outputs that have no restrictions (‘Public’; will also become accessible through the Atlas of Living Australia at ala.org.au); these are mostly maps of species of conservation concern generalised to 10km resolution to obscure detailed location information that could be used for illegal collection; and;
3. restricted – the full set of outputs with content or data resolution; data access requires explicit permission from either DAWE, state or territory government agencies or to the principal investigator of the project. We encourage users to contact government departments first to seek access. Alternatively, access can be given by physical provision of a hard drive or password access can be provided to the project’s data portal (contact Dr. Anna Pintor; annafvp@gmail.com).

[3] environment.gov.au/cgi-bin/sprat/public/sprat.pl
[4] nespnorthern.edu.au/projects/nesp/prioritising-threatened-species/

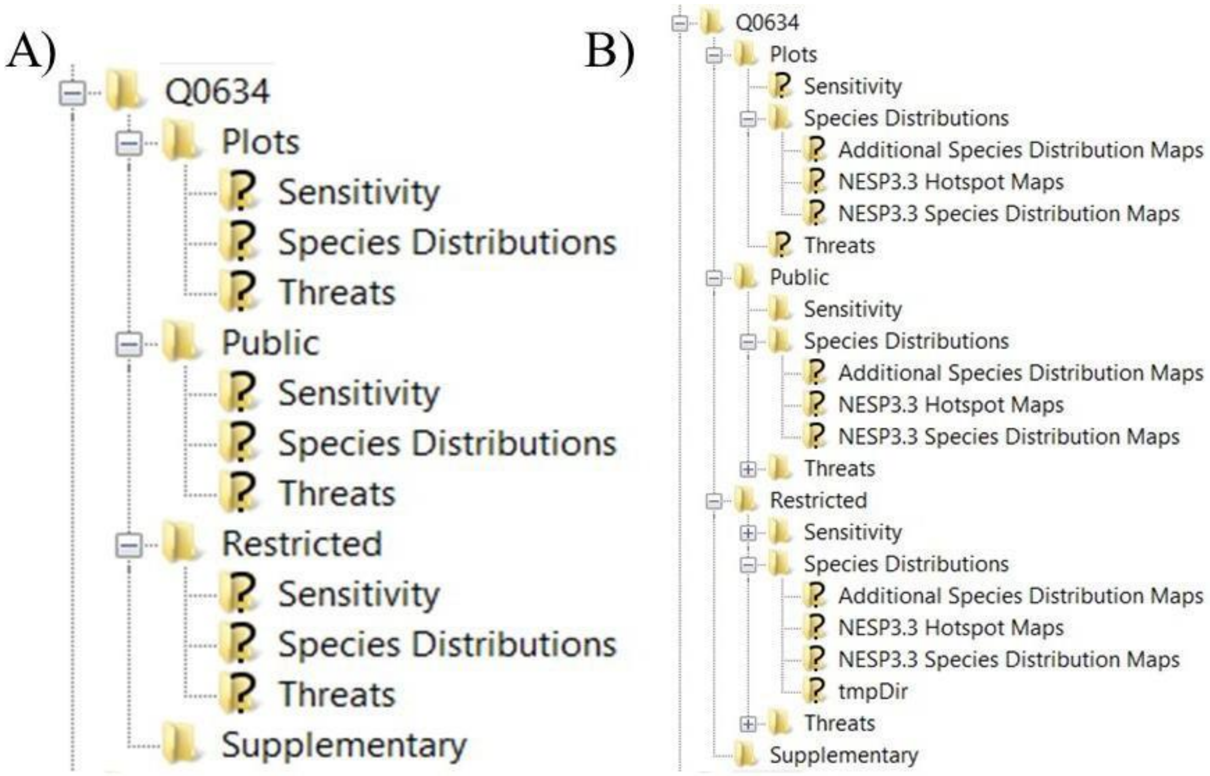

Figure 2. Directory structure of the RDSI collection Q0634 containing the project outputs. Figure 2A refers to the structure within the RDSI collection generally. Figure 2B refers to the refined contents within each of the "Plots", "Public" and "Restricted" subfolders.

The directory structure within "Public", "Plots" and "Restricted" is consistent across the three folders. If outputs are missing from a directory, it means they don't apply to the relating category (i.e. low-resolution species distribution models are located in 'Public' but absent from 'Restricted'). We provide an example of these directories for species distribution models in Figure 2, but please keep in mind this format is identical for the other data categories. The 'Supplementary' directory contains freely available supplementary information.

1.4 Data format, extent and resolution

All data are available for download as ASCII Raster File format. ASCII files are a type of spatial grid. These grids were created using Geographic Coordinate System GCS GDA 94. Some of the data have been created for all of Australia (e.g. distribution models for threatened and invasive species and some threat outputs such as risk of overgrazing). However, for the purposes of this report, we focus on the study region (Figure 1), i.e. northern Australia. Data are available in several resolutions: 250m, 1km, or 10km. Generally, access to 250m resolution data are restricted because it includes sensitive information on threatened species distributions that could be used for illegal collection or lead to destruction of habitat. We also need to ensure users are qualified to interpret outputs correctly, to discourage the potential for data misuse or misinterpretation, and to record who has accessed the data and for what purposes. Threat data mostly have a resolution of 1km except where higher resolution data inputs were available. Publicly available data for threatened species distributions have a resolution of 10km to avoid inappropriate use of sensitive information (e.g. illegal collection). All enquiries about data access should be directed either to the federal DAWE, relevant state and territory government agencies in Western Australia, the Northern Territory, or Queensland, or to the principal investigator of the project (Dr. Anna Pintor, James Cook University, Townsville, Australia; annafvp@gmail.com).

More detailed technical information and descriptions of data lineages can also be found in the RDSI collection. Each subset of data is accompanied with a detailed methods document, located in the same directory as the relating data set. This user guide gives an overview over these methods and contains general information on what outputs are available, but users are strongly encouraged to consult the more detailed methods documents.

2. Expert vetted species distribution models

2.1 Data access

Pintor, A.; Graham, E.; Kennard, M.; VanDerWal, J. (2018). Expert vetted distribution models and biodiversity hotspot maps of terrestrial and freshwater taxa of conservation concern in northern Australia. James Cook University, Griffith University, and Australian Government National Environmental Science Program (NESP), Northern Australia Environmental Resources Hub. dx.doi.org/10.4225/28/5a9f31e23e80b

The data are accessible through DAWE or through the RDSI collection Q0634 at:

/gpfs01/Q0634/Restricted/Species Distributions (high resolution SDMs/hotspot maps)

/gpfs01/Q0634/Public/Species Distributions (low resolution SDMs)

/gpfs01/Q0634/Plots/Species Distributions (summary graphics of SDMs/hotspot maps)

2.2 Background

Northern Australia's rich biodiversity is both nationally and internationally significant (Woinarski, 2007). The North is home to hundreds of thousands of plant and animal species, many of which are found only in the region and some of which are increasingly threatened with extinction (Woinarski, 2011; Ziembicki, 2015). However, there is limited knowledge of the current distributions of taxa, and especially of threatened species across the region, much of which is remote and under surveyed. This knowledge gap is a major impediment to effective conservation and natural resource management. This project, therefore, modelled the present- day distribution of 1,425 plant and animal species of conservation concern (Table 1). 'Of conservation concern' in this context refers to any terrestrial or freshwater, plant or animal species that is:

1. Listed on federal or state/territory (Northern Territory, Queensland, or Western Australia) legislation as critically endangered, endangered, vulnerable or near threatened (EVNT);
2. Indicated to qualify for such listing because of information in the latest action plans for particular taxon groups*
3. Nominated by NT, WA, or QLD governments as relevant to their current conservation management initiatives. Species nominated by governments were typically data deficient, or range restricted species. Detailed information on all species, their conservation status, reason for inclusion and statistical assessment of model fit is provided in the supplementary materials (in the RSDI collection).

2.3 Individual species distribution models

Following the workflow described by Graham and colleagues (Graham, 2019), we provided individual models for 1,425 species. Individual species distribution models in this collection represent the predicted potential present-day distribution for each species based on habitat suitability and expert input. These models are useful tools when used in combination with known locations of occurrence for managers and researchers to better understand where a species might occur and/or where further field surveys may be needed. Naturally, modelled habitat suitability indicates where it is statistically likely for a species to occur, not where it is guaranteed to occur or has been observed.

There are various approaches to species distribution modelling ranging from simple bioclimatic envelopes to machine learning. For the purposes of this project, we used a machine learning approach (Maxent; Elith, 2011; Phillips, 2005). Maxent software uses a set of environmental predictor variables and a set of known occurrence locations to establish habitat suitability per grid cell (Phillips, 2006). Maxent performs well compared to other methods, especially when only presence data (as opposed to presence/absence data) are available (Elith, 2006).

For very rare or under-surveyed species (i.e. those with fewer than 10 occurrence records), instead of using Maxent distributions models, we created buffers around known occurrence records and intersected them with characteristics of suitable habitat (i.e. habitat such as certain vegetation types or landscapes that they are known to occur in based on their occurrence records). This was necessary because statistical distribution models have been proven unreliable with such sparse data (van Proosdij, 2016). Buffer size was adjusted to how wide ranging each species was estimated to be based on the existing data, i.e. more wide-ranging species received a wider buffer zone than highly restricted species. We refer to these species as ‘data deficient’.

Table 1. Number of species modelled within each higher taxonomic group.

Higher taxonomic group	Number of listed taxa
Birds	96
Crustaceans	16
Fish	50
Frogs	36
Insects	48
Mammals	101
Molluscs	80
Plants	894
Reptiles	104
Total	**1,425**

A final distribution model for each species was created following six main steps:

1. collating and cleaning of occurrence records based on expert advice (e.g. where the species has been reliably recorded); where possible only post 1975 data with high location precision (to 250m) was used. However, if this would have excluded large proportions of the data for a species, or if there was a strong spatial bias in the precision of records, older or less precise data was included. For more details, refer to the methods document 'Expert Vetted Distribution Models and Biodiversity Hotspot Maps of Terrestrial and Freshwater Taxa of Conservation Concern in Northern Australia' (Pintor et al. 2019; located in the RDSI directory for this data set)[5].
2. selecting ecologically relevant environmental predictor variables (e.g. landscape or climate characteristics that influence habitat suitability);
3. modelling with Maxent (or by creating buffers intersected with habitat characteristics for data deficient species);
4. model evaluation and re-running (e.g. statistical evaluation of predictors and subsequent removal when predictors were not relevant);
5. expert vetting (e.g. verifying steps 1-4, as well as reliability of final outputs with experts and rerunning models if required);
6. finalising outputs based on the advice obtained from experts (e.g. cutting out areas that are suitable but unoccupied and applying final suitability thresholds selected by experts).

Post-modelling, the outputs were vetted by experts. As noted in some of the steps above, vetting included identification of erroneous records, sourcing additional records where data gaps were noted, general quality control of final outputs, selection of correct model 'threshold', and identification of areas that the models deemed suitable habitat but are likely unoccupied by the target species. Picking a 'threshold' is this context means deciding on how closely habitat has to resemble areas the species has been observed in, i.e. in a suitability map ranging from 0 to 1, the target species might not have viable populations in any habitat with a suitability under 0.15 or 0.21, etc. Areas predicted to be suitable but are known to be unoccupied were 'cut out' of the final versions of distribution maps. Please note that despite extensive vetting, there always remains an element of uncertainty and a species may not be present in every location where habitat is deemed suitable based on the specific predictor variables used here.

For each species, outputs are available as continuous habitat suitability (unsuitable to highly suitable) and binary maps (suitable/unsuitable). For both continuous and binary outputs, there are a number of sub-types of maps available depending on the specific purpose for which users require the maps. Please note that continuous models are available only for taxa that had enough occurrence data to create statistical distribution models – if the files with the naming convention for continuous models (Table 2) are missing, it means that only binary

[5] Note that the expert vetted species distribution models may use different data and methods to that used by DAWE to underpin the Protected Matters Search tool. The user should be aware of the caveats associated with any modelled data before using them. In addition, the time frame of species distribution records used in the SDMs (generally post-1975) and the grain-size of the data (250m) differs to that employed by DAWE for their modelling and will therefore generate different results. The intent and purpose may therefore result in different decisions about the data used and the output generated. Also note that any SDM is generated at a point in time from available data and can be updated and improved with new and better source data as it becomes available.

models were created for those taxa using buffered occurrence records coinciding with *a priori* defined habitat characteristics. Users are encouraged to select maps based on a decision tree (Figure 3).

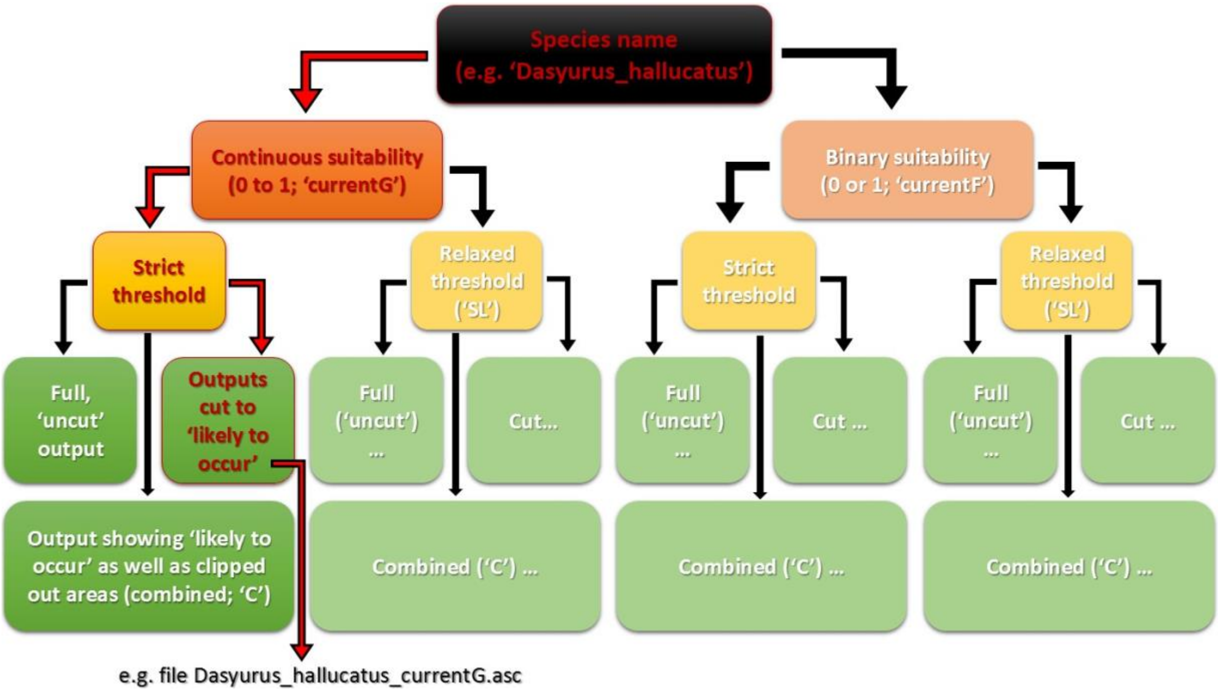

Figure 3. Decision tree for use in selecting maps.

Strict threshold models use the best thresholds selected by experts, while relaxed thresholds are slightly more inclusive. Full, uncut models show all suitable and unsuitable areas, while 'cut' models show suitable areas clipped to areas where the species is likely to occur based on expert input, and combined models show both final 'cut' models, as well as areas that experts recommended to exclude because the species is likely absent there despite apparently suitable habitat. Examples of the different outputs are shown in Figure 4 and Figure 5 for binary and continuous versions, respectively, and a detailed summary of naming conventions for filenames is given in Table 2.

The relaxed and strict thresholds mentioned in the decision tree describe how similar the landscape is to areas where the species has been reliably sighted. Relaxed thresholds simply mean that the habitat is similar, but less closely matched to where the species has been sighted. These two versions can be interpreted as areas where species are likely to occur (strict threshold) as opposed to where they might occur (relaxed threshold). Full models of suitability include all areas likely to contain suitable habitat for a species. Final models are similar but clipped down to areas known to be occupied. For this, experts vetted the full models and identified areas that might be suitable but are known to be unoccupied by that species. Finally, the final models were combined to a single output showing both the extent of known occupation and the extent clipped out based on expert advice.

The files will follow the naming convention: *Gen_sp_namingcode* where "Gen_sp" refers to the genus and species name and "naming code" refers to the map type. See the table below for descriptions of the naming codes (Table 2).

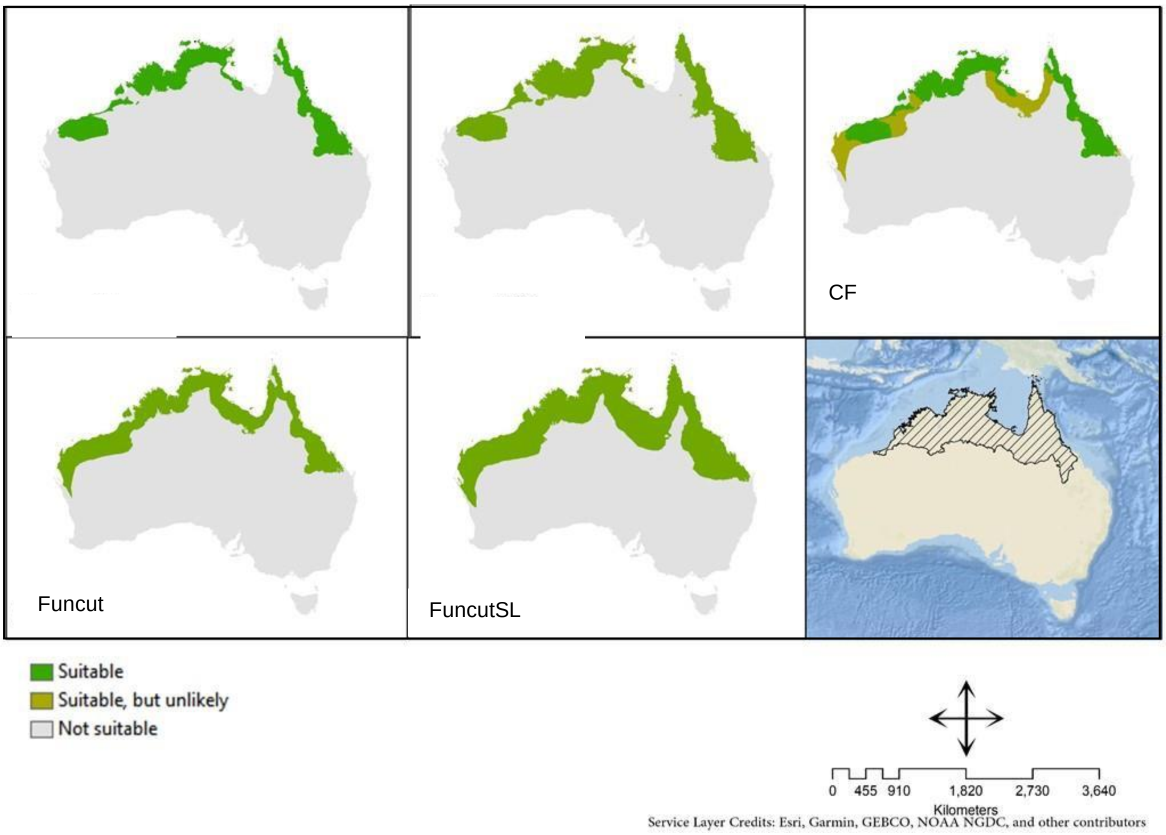

*Figure 4. Example of the binary output types of distribution maps for the Northern Quoll (*Dasyurus hallucatus*). See Table 2 for explanation of file naming conventions.*

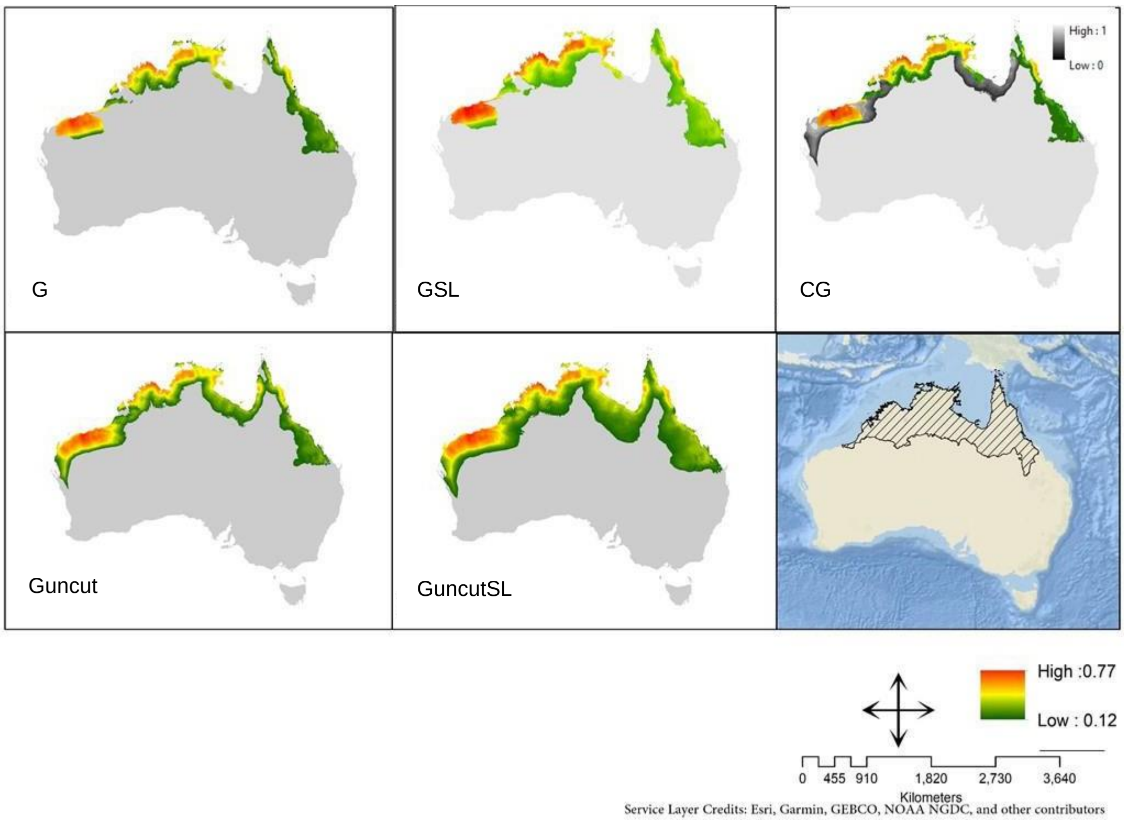

*Figure 5. Example of continuous output types of distribution maps for the Northern Quoll (*Dasyurus hallucatus*). See Table 2 for explanation of model output naming conventions.*

Table 2. Naming convention for species distribution models.

Naming code	Description	Sources	Resolution
Gen_sp_currentF	Final binary model, clipped to a strict threshold of known occupied areas.	This study	250m
Gen_sp_currentF10	Final binary model clipped to a strict threshold of known occupied areas at a low resolution	This study	10km
Gen_sp_currentFSL	Final binary model clipped to a relaxed threshold of known occupied areas	This study	250m
Gen_sp_currentFuncut	Final binary model clipped to a strict threshold, but **not** cut to known occupied areas.	This study	250m
Gen_sp_currentFuncutSL	Final binary model clipped to a relaxed threshold, but **not** cut to known occupied areas.	This study	250m
Gen_sp_currentCF	Final binary clipped to a strict threshold, and cut to occupied areas shown as '2' with unoccupied but suitable areas also shown as '1' and unsuitable areas shown as '0'	This study	250m
Gen_sp_currentG	Final continuous model clipped to a strict threshold of known occupied areas.	This study	250m
Gen_sp_currentG10	Final continuous model clipped to a strict threshold of known occupied areas at a low resolution	This study	10km
Gen_sp_currentGSL	Final continuous model clipped to a relaxed threshold of known occupied areas	This study	250m
Gen_sp_currentGuncut	Final continuous model clipped to a relaxed threshold, but **not** cut to known occupied areas.	This study	250m
Gen_sp_currentGuncutSL	Final continuous model clipped to a relaxed threshold, but **not** cut to known occupied areas.	This study	250m
Gen_sp_currentCG	Final continuous clipped to a strict threshold and cut to occupied areas (1-2) with unoccupied but suitable areas also shown (0-1)	This study	250m

2.4 Hotspot maps

We combined the individual binary species distribution maps by calculating the number of species likely to occur per 250m grid cell (i.e. sum). We created several 'hotspot' maps based on different combinations of species to (e.g. mammal hotspot). Hotspot maps are useful to visualise where many species of conservation concern from a certain group (e.g. from a taxonomic group such as mammals or a certain category such as any species classified as vulnerable) are likely to co-occur (Figure 6).

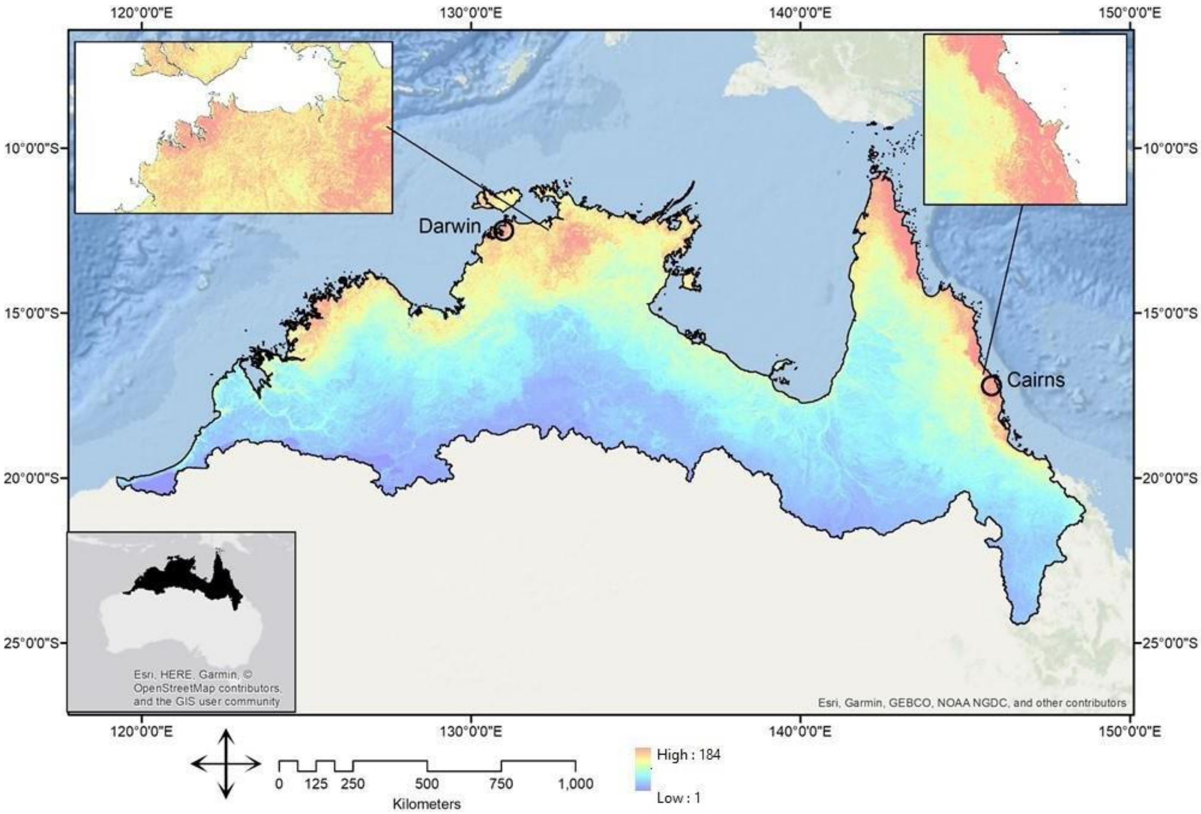

Figure 6. Example hotspot map showing concentration of all species that are currently listed as near threatened, vulnerable, endangered or critically endangered on IUCN, state, territory or federal (EPBC) lists (n=1349). The fewest species per 250m grid cell is one. The maximum number of species per 250m grid cell is 184.

Table 3. Description of available hotspot outputs.

Hotspot map category	Number of categories	Descriptions
Higher taxa	9	Concentrations of species within higher taxonomic group (e.g. birds, molluscs, amphibians)
Family	101	Concentrations of species within family groups
Order	52	Concentrations of species within order groups
Other (miscellaneous)	11	Some functional groups (i.e. granivorous birds), or outputs considered to be potentially useful to other projects (i.e. critically endangered mammals)
EVNT Category*	4	Concentrations of species which: 1. Listed as critically endangered, or endangered, or vulnerable, or near threatened on any listings consulted for this project, i.e. all species of conservation concern 2. Critically endangered and endangered 3. Vulnerable 4. Near threatened

* species listed as near threatened, vulnerable, or endangered/critically endangered on IUCN, state, territory or federal (EPBC) lists. Note that the conservation status of particular species may change over time; for the latest status, refer to the relevant responsible agency.

We produced five categories of hotspot maps, totalling 174 maps (Table 3). We grouped species by broad taxonomic category (e.g. birds, reptiles). We also mapped groups of families, orders, and EVNT categories (i.e. species listed as near threatened, vulnerable, or endangered/critically endangered on IUCN, state, territory or federal/EPBC lists). For ENVT categories, we separately mapped: i) all listed species, ii) critically endangered and endangered species, iii) vulnerable species, and iv) near-threatened species.

2.5 Limitations of the data set of species distributions

The species distribution models developed in this project are statistical models of habitat suitability. Expert vetting is invaluable in ensuring high-quality outputs. In most cases, we recommend the use of our vetted best estimate model versions (i.e. filenames ending in "F.asc" for binary or "G.asc" for continuous prediction). Other versions were supplied to give additional information to users but should be used only after careful consideration. For example, relaxed threshold models show suitable habitat where the species could occur but is not likely to occur, e.g. suitability is close to the lower limit of where populations can be sustained. Uncut models show areas that might be suitable but have been assessed by experts to be unoccupied, i.e. areas that are statistically suitable but have been inaccessible to colonisation, are occupied by a competitor, or cannot be occupied by the species for some other, possibly unknown reason. Statistically suitable, but unoccupied areas might indicate where species' relocation efforts could focus pending further analyses and on-ground assessments. However, this project makes no recommendations for relocation programs because detailed studies and taxon-specific research will need to confirm whether such management action and location(s) would be appropriate and truly suitable.

Please be aware that the data set is not suitable for predicting presence/absence of species on small islands because the underlying spatial data used for predictions often do not cover such islands and because presence on islands can be driven by other factors than habitat suitability. Models cannot assess microhabitat suitability; thus caution needs to be taken when conservation decisions at finer scales than 250m are needed, microclimates vary substantial within a 250m grid cell, or when the quality of baseline mapping of habitat characteristics is suboptimal. For example, if it is known that lithology mapping for an area is suboptimal, model predictions should be used as a general indication of how likely different areas are to be suitable but more finer resolution assessment will have to be made on the ground within these predicted areas.

Please note that hotspot maps represent groups of species that are explicitly listed or otherwise indicated by government departments as being of conservation concern. Our work does not account for any potential listing bias and we acknowledge there could be species that are threatened with extinction but were not yet been listed at the time that the modelling was completed (Dec, 2019).

More detailed technical information and descriptions of data lineages can be found in the methods document *Expert vetted distribution models and biodiversity hotspot maps of terrestrial and freshwater taxa of conservation concern in northern Australia* (Pintor et al. 2019; located in the RDSI directory for this data set). Please also consult the metadata for this data set (dx.doi.org/10.4225/28/5a9f31e23e80b).

3. Mapping threatening processes across northern Australia

3.1 Data access

Pintor, A.; Graham, E.; Engert, J.; Kennard, M. (2018). Threatening processes to taxa of conservation concern in Northern Australia. James Cook University, Griffith University, and Australian Government National Environmental Science Program (NESP), Northern Australia Environmental Resources Hub. dx.doi.org/10.25903/5b72631b2dd70

The data are accessible through DAWE or through the RDSI collection Q0634 at:

/gpfs01/Q0634/Restricted/Threats/

3.2 Background

Spatial representations of the distribution, intensity, frequency or seasonality of threatening processes are often referred to as “threat maps”. Threat maps play a critical role in prioritising decision-making for conservation. That is, they can be used to identify priority areas for threat mitigation or areas suitable for threat exclusion and can be used to infer the degree and area of threat exposure of different species, groups of species, or ecosystems (Tulloch, 2015; Neke, 2004). In this section, we briefly describe the methods and data sets used to create threat maps identified as a priority for this project, namely agricultural suitability, climate change, changes in fire regimes, changes in flow regimes, over-grazing, mining, sea-level rise, overexploitation, and urbanisation. For each threat map, we provide a brief description of the input and output data, a caution statement regarding data set limitations, an example of the output data and a description of the file names.

3.3 Outputs

3.3.1 Land clearing risk associated with intensive agriculture developments

3.3.1.1 Background

Habitat loss by land clearing is a significant threat to Australian biodiversity (Reside, 2017). Clearing for agricultural development is usually targeted towards areas with high cropping capability. Land capability is defined as the capability to support a wide variety of land uses (cropping, grazing, horticulture, forestry and nature conservation) and mapping is based existing mapping for individual states/ territories in combination with reclassification based on a methodology developed and applied in New South Wales (State of NSW and Office of Environment and Heritage 2012). For a more detailed explanation of how land capability was created, please contact Vanessa Adams for a more detailed methods document (publication in preparation). A value of ‘1’ indicates land that is capable of all land uses with no limitations (e.g. highly suitable for cropping or horticulture) and a value of ‘8’ indicates land of extremely low land capability with severe limitations for agricultural production. For our purposes, high land capability (ranked as ‘1’) represents areas with native vegetation that have a higher risk of being cleared, i.e. the land is more likely to be used for agricultural production than land with lower capability and constraints.

Additionally, large areas across Australia are already used for intensive agriculture and have replaced natural vegetation with crops. In our classification, such areas are deemed to pose the highest risk to biodiversity (i.e. compatibility with native plants and animals is lowest). Areas cleared for intensive agriculture can be identified using the existing land use mapping from the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) through the Australian Collaborative Land Use and Management Program[6] (ACLUMP). In this context, our definition of intensive agriculture includes the following land uses: grazing on modified or improved pasture (where the native vegetation has been removed or highly modified to provide pasture for intensive grazing), timber plantations and broad-acre crops. In addition to maps of agriculture, we also created a separate map of areas currently used for forestry according to ACLUMP.

To develop a map of risk for clearing because of agricultural conversion we used the map of land capability (Engert and Adams, 2018, Land Capability of Australia; for distribution contact Vanessa Adams: vm.adams@utas.edu.au), and re-scaled to values of 0 to 0.9, with 0.9 being the highest likelihood of conversion to intensive agriculture; this map was combined with the map derived from ACLUMP to include maximum values of 1 for any land that is already under intensive agricultural uses (Figure 7). Please also refer to the detailed methods document for this data set (located in the corresponding RDSI directory) for more information.

Please note that areas with no current agriculture and no data for land capability were assigned the value 0.1 because they were often represented by small islands, lakes, estuaries, and other areas unlikely to be used for agriculture (see methods document). However, there remain other large areas in Tasmania and some small areas on the mainland that might be suitable for agriculture but for which there is no data available. We suggest gathering additional information when using the product for areas where our categorisation has the value 0.1.

In this collection, there are three data files available (Table 4). Depending on the proposed application of the data, the user should use the most appropriate based on the description provided.

[6] agriculture.gov.au/abares/aclump; version update Dec 2017

Table 4. Agriculture output files.

Name	Description	Sources	Resolution
Agrisk250m*	Risk from agricultural clearing (0-1), including agricultural areas ('finalCurAg') and land capacity for all other areas.	Engert and Adams, 2018 ABARES[6]	250m
finalCurAg	The current extent of agriculture. Here "0" values represent areas with 0 intensive agriculture. Areas with a value of "1" are currently used for agricultural production	ABARES[6]	250m
finalCurfor	The current extent of forestry. Here, values of "0" represent areas with no forestry activities. Values of "1" indicate areas with native forestry, and values of "2" indicate areas with non-native forestry	ABARES[6]	250m

*Embargoed until Dec. 2020. Please contact Vanessa Adams and Anna Pintor for earlier access.

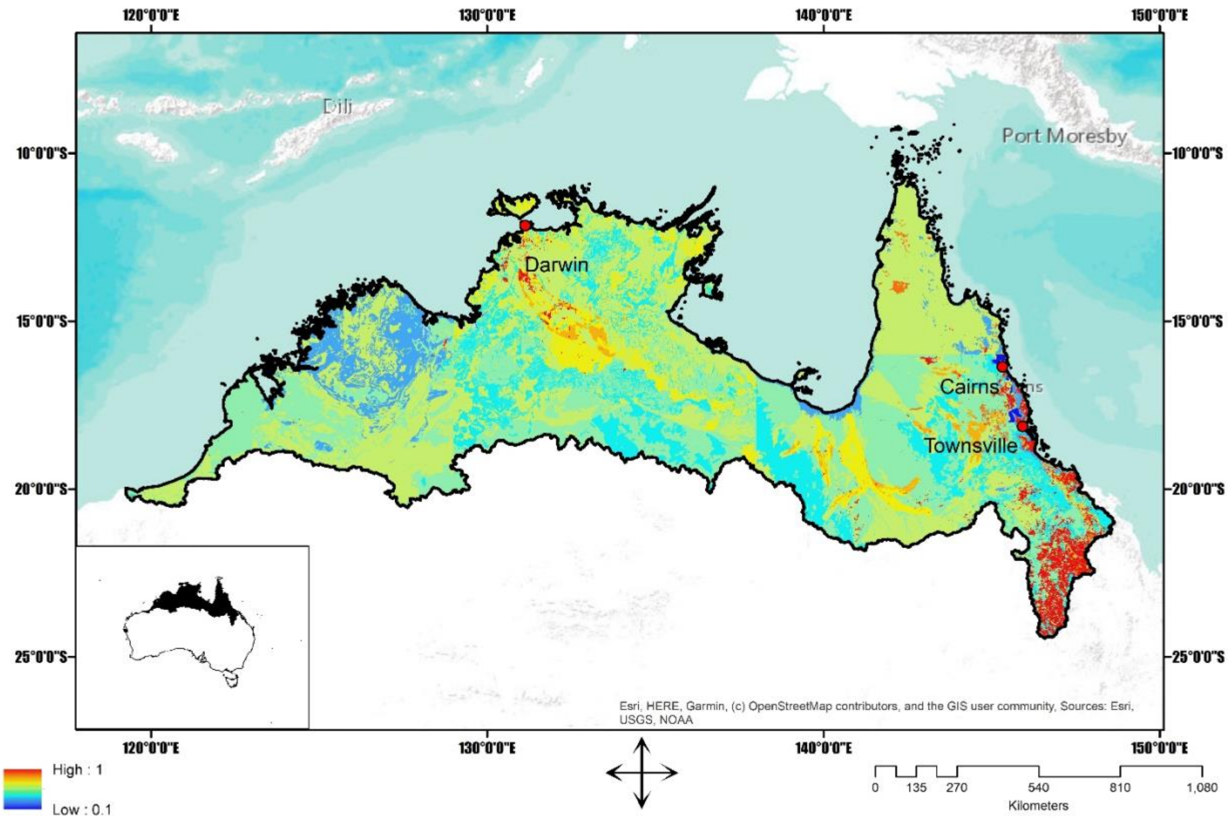

Figure 7. Risk from clearing for agriculture as indicated by agriculture land capability and current areas of intensive agriculture.

3.3.1.2 Limitations of this data set

Likelihood of agricultural development is contingent on several factors, including proximity to current agriculture and infrastructure (e.g. roads, mills, gins), access to reliable and appropriate water sources, tenure, and suitability of soils for a range of different crops. In particular, the accuracy of the latter depends greatly on the quality and resolution of soil data (e.g. permeability, depth, water capacity, texture), which exists only at relatively low resolution for much of Australia. There have been recent advances in the creation of detailed, high-resolution soil information and agricultural suitability layers for some areas (e.g. see Northern Australia Water Resource Assessment, NAWRA,[7] and the Flinders and Gilbert Agricultural Resource Assessment, FGARA[8]). Where possible, such localised information should be used in combination with the relevant factors influencing agricultural development (noted above) to provide a more accurate assessment of the risk of vegetation clearing to biodiversity.

More detailed technical information and descriptions of data lineages can be found in the relevant methods document *Methods for NESP NAER project 3.3 maps of agriculture & forestry* (Pintor et al. 2019; located in the RDSI directory for this data set). Please also consult the metadata for this data set (dx.doi.org/10.25903/5b72631b2dd70).

3.3.2 Risk of increased heat and drought from climate change

3.3.2.1 Background

Climate change can have several negative effects and can influence biodiversity by reducing the range of suitable habitat for species (Araújo, 2006) shifting communities (Prober, 2011) and increasing severe weather conditions (Williams, 2009). Changes in temperature and precipitation will likely result in significant increases in hot and dry conditions across the region (Garcia, 2014), which has significant implications for northern Australia. Our main threat map for climate change combines several variables into an index of predicted heat and drought dissimilarity from current conditions by 2050. The individual metrics, which are also available as separate files for current, future, and change in conditions, include changes in maximum temperature and minimum rainfall, length of hot season and dry season, and in hot season precipitation, based on 17 CMIP5 Global circulation models (GCMs) for 2050. The maps were computed using predictions for a representative concentration pathway (RCP) of 8.5. The RCP 8.5 pathway represents a business-as-usual greenhouse emissions scenario assuming society fails to accommodate emissions-limiting activities (IPCC 2013[9]) and was chosen as a worst-case scenario that we should ideally manage for, i.e. it estimates a maximum potential threat from climate change. Our models assume that increased change in hot and/or dry conditions, will negatively influence biodiversity in terms of continued species persistence. All calculations were based on the most up to date climate data available at the time of analysis from WorldClim Version 1.4[10] (Hijmans et al. 2005). Climate projections for northern Australia may also be periodically updated and made publicly available[11].

[7] nawra-explorer.csiro.au
[8] csiro.au/en/Research/LWF/Areas/Water/Assessing-water-resources/Flinders-Gilbert
[9] ipcc.ch/report/ar5/wg1
[10] worldclim.org
[11] e.g. see nespclimate.com.au and climatechangeinaustralia.gov.au

In this collection, we present data in four categories: current conditions, predicted future conditions, predicted change in relevant variables mentioned above as well as overall climate dissimilarity when combining the changes in all variables (Table 5). The directory, therefore, has four folders with each of these categories.

Directory "current"

Outputs in this dataset show the current conditions for five variables (i.e. dry season length, hot season length, maximum temperature, annual precipitation, hot season precipitation).

Directory "future"

Outputs in these two folders show median ('Median'), minimum (10% quantile; 'Q10'), and maximum (90% quantile; 'Q90') values for conditions in the same five variables as for 'current' conditions. These future conditions are derived from predicted climatic conditions across the 17 GCMs for RCP 8.5 by 2050.

Directory "change"

For each of the same five variables as for 'current' and 'future' conditions we created change layers showing the difference between current and future (Median, Q10, or Q90 for 2050) conditions. The filename for 'current' conditions simply describes the variable name (see Table 5). The file names for 'future' conditions and 'change' in conditions describe which of the metrics (Median, Q10 or Q90) each file pertains to, as well as variable identity. Below we describe further what these 'future' and 'change' outputs for the five variables are.

1. **Hot season length:** the number of months with maximum temperatures above the 75% of current maximum temperature values (i.e. the number of months hotter than the current hottest three months) for 2050 ('future'), as well as how much this time period in 2050 differs from current conditions ('change').
2. **Dry season length:** the number of months with total precipitation below the 25% of current monthly precipitation values in 2050, i.e. the number of months with less rain that the current driest three months ('future'), as well as how much this time period in 2050 differs from current conditions ('change').
3. **Maximum temperature:** maximum temperature in 2050 ('future') and the absolute difference between current and future maximum temperature, i.e. the temperature increase of the highest temperature in the hottest month of the year ('change').
4. **Annual precipitation:** annual precipitation in 2050 ('future') and the proportional change in annual precipitation, i.e. the change in overall rain throughout the year between now and 2050, expressed as a proportion of current annual precipitation ('change'). Change in precipitation was expressed as a proportion because, for example, a 20mm decrease in precipitation in a rainforest with 2000mm annual precipitation is negligible compared to a 20mm decrease in arid regions with only 40mm current annual precipitation.
5. **Hot season precipitation:** hot season precipitation in 2050 ('future') and the proportional change in precipitation during the hottest three months of the year between now and 2050, i.e. the change in availability of water during times of highest heat stress and evaporation ('change').

Directory "dissimilarity"

Additionally, the 'dissimilarity' directory contains an output of the multivariate environmental dissimilarity (standardised Euclidean distance SED) between current and future conditions across the five variables described above (as per the methods described in Williams et al., 2007). It estimates the expected cumulative stress caused by heat and drought due to climate change (Figure 8). This output describes how different heat and drought conditions will be overall in 2050, i.e. what the total threat to biodiversity from heat and drought is if we look at all five variables together.

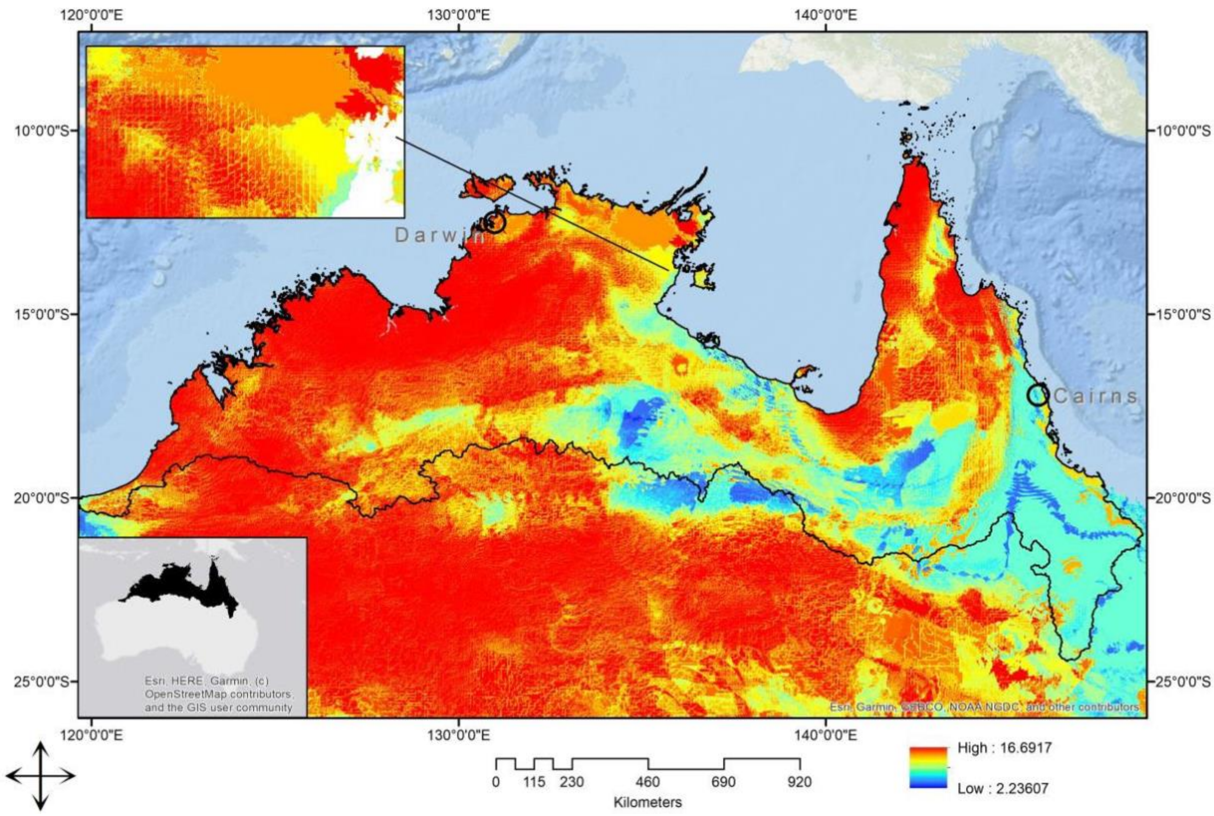

Figure 8. Median dissimilarity in heat and drought conditions for 2050 compared to now based on an RCP 8.5 'business as usual' emission scenario.

3.3.2.2 Limitations of the data set

Future dissimilarity in climate conditions was based on changes in heat and drought conditions because these are most commonly considered to have stronger effects on biodiversity. However, other climate variables can also have notable effects on biodiversity (e.g. increases in minimum temperature may enable some species to expand their ranges into higher latitudes, thus creating changes in species composition in some areas). However, we focused on the main conditions that represent a direct threat to species persistence within their current ranges. Whilst our models are derived from climatic predictions based on 17 different GCMs, there is considerable variation in predictions amongst these GCMs, especially for changes in precipitation. This means that uncertainty needs to be considered when making conservation decisions, which is why it is advised that users consult the provided 10% and 90% quantile outputs to get an idea of the uncertainty of median estimates.

More detailed technical information and descriptions of data lineages can be found in the relevant methods document *Methods for NESP NAER project 3.3 changes in pressures from* *heat and drought due to climate change* (Pintor et al. 2019; located in the RDSI directory for this data set). Please also consult the metadata for this data set (dx.doi.org/10.25903/5b72631b2dd70).

Table 5. Climate change output files.

Name	Description	Sources	Resolution
Current			
annualPrecip_current	Current annual precipitation	WorldClim[10]	1km
Cur_DrySeasLength	Current dry season length	WorldClim[10]	1km
Cur_DrySeasThresh	Current precipitation threshold for dry season	WorldClim[10]	1km
Cur_HotSeasLength	Current hot season length	WorldClim[10]	1km
Cur_HotSeasThres	Current temperature threshold for hot season	WorldClim[10]	1km
HotSeasPrecip_current	Current hot season precipitation	WorldClim[10]	1km
Tmax_current	Current maximum temperature	WorldClim[10]	1km
Future			
Quantile_yearscenario_metric	10% (Q10), 50% (Median), and 90% (Q90) quantile of predicted future conditions in drought/heat metrics under scenario RCP8.5 by the year 2050. Tmax: future maximum temperature anPrecip: future annual precipitation HotSeasPrecip: future hot season precipitation HotSeasLength: future hot season length DrySeasLength: future dry season length	WorldClim[10]	1km
Change			
Quantile_year scenario_metricChange	Predicted change for the 10% (Q10), 50% (Median), and 90% (Q90) quantile of future compared to current drought/heat metrics under scenario RCP8.5 by the year 2050. Tmax: change in maximum temperature PropPrecip: change in total annual precipitation as a proportion of current annual precipitation PropHotPrecip: change in hot season precipitation as a proportion of current hot season precipitation HotSeasLength: change in hot season length DrySeasLength: change in dry season length	WorldClim[10]	1km
Dissimilarity			
C_fm-c_euc	Dissimilarity of future conditions compared to current conditions overall.	WorldClim[10]	1km

3.3.3 Risk of transmission of wildlife diseases

3.3.3.1 Background

The potential distribution of diseases known to have significant detrimental effects on native species of plants or animals according to DAWE[12] and additional expert advice were modelled across the country. The original list included the fungal diseases chytrid fungus (*Batrachochytrium dendrobatidis,* Figure 9), root rot (*Phytophthora cinnamomi),* and myrtle rust (*Puccinia psidii, Uredo rangelii)* as well as some parasitic (Toxoplasmosis; *Toxoplasma gondii*) and viral (Psittacine beak and feather virus; *Circovirus* spp.) diseases. However, we excluded Toxoplasmosis because of lack of occurrence records and because it is mainly spread by feral cats, which are included in our invasive species models. The distribution of feral cats is assumed to be the best available predictor of the risk of infection with Toxoplasmosis. Psittacine beak and feather virus was similarly excluded because of lack of data. Additionally, the distribution of internal diseases such as Toxoplasmosis and viruses depends more of the distribution of their hosts than on external habitat conditions. Most external fungal diseases on the other hand, depend to some degree on external factors such as climate, soil and vegetation and can be modelled using habitat suitability models (Stevens, 2011; La Manna, 2012). Consequently, only the fungal diseases considered to be a significant threat to Australian native species in the North were modelled for this project.

Diseases were modelled using Maxent. For a detailed description of the modelling process please consult Section 3.3.7 (modelling of invasive species) and the relevant methods document Methods for NESP NAER project 3.3 Maxent distribution models of invasive weeds, feral animals, and diseases (Pintor et al. 2019; located in the RDSI directory for this data set). Modelling of potential distributions of fungal diseases followed the same methods and naming convention as invasive species distribution models (Table 6; also see Section 3.3.7).

3.3.3.2 Limitations of this data set

The same limitations as for models of invasive species apply for models of diseases (see Section 3.3.7). Additionally, the distribution of fungal diseases does not only depend on external habitat characteristics but also on the distribution of their hosts. Our models can. Therefore, be seen as an envelope of maximum potential distribution of diseases IF suitable host species occur in those areas.

Please note that there may be other diseases of relevance in northern Australia. Two notable examples that may be of conservation significance are Toxoplasmosis and Psittacine beak and feather disease. However, lack of distribution data and general knowledge on their occurrence and spread meant that these were outside the scope of our study. There are also other wildlife diseases that are not currently considered to be negatively affect wildlife enough to be of conservation concern. However, these should still be kept in mind as potential future problems. Examples are Lyssa virus and Hendra virus in bats, or livestock and human diseases with wildlife reservoirs, such as Ross River Fever or Leptospirosis.

More detailed technical information and descriptions of data lineages can be found in the relevant methods document *Methods for NESP NAER project 3.3 Maxent distribution models*

[12] environment.gov.au/biodiversity/invasive-species/diseases-fungi-and-parasites

of invasive weeds, feral animals, and diseases (Pintor et al. 2019; located in the RDSI directory for this data set). Please also consult the metadata for this data set (dx.doi.org/10.25903/5b72631b2dd70).

Table 6. Wildlife disease output files.

Name	Description	Sources	Resolution
Gen_sp_cat_AUS1km	Continuous habitat suitability (0-1) for the species for each of the following categories: current, future median, future 10% quantile (Q10) and future 90% quantile (Q90) of projected suitabilities (across the 17 future circulation models)	This study	1km
Gen_sp_cat_AUSbin1km	Binary habitat suitability (0 or 1) for the species for each of the above categories	This study	1km
Gen_sp_OccupancyR_cat_AUS 1km	Likelihood of occupancy, measured as cost distance from occurrence points and using habitat suitability as a cost surface, i.e. the lower the habitat suitability of a pixel, the higher the cost for the species to travel across it.	This study	1km
Gen_sp_Occ_cat_AUS1km	Binary raster showing all areas as 1 that are within >=90% likelihood of occupancy (i.e. close to occurrences).	This study	1km
Gen_sp _cat_Threat	Continuous habitat suitability weighted by cost distance to occurrence points (i.e. suitable habitat far away from known occurrences is down weighted correspondingly) for each of the above categories	This study	1km
Gen_sp_cat_Threat_1-3	Continuous habitat suitability weighted by cost distance to occurrence points (i.e. suitable habitat far away from known occurrences is down weighted correspondingly) for each of the above categories – rescaled to 0-3 to represent low (1), medium (2) and high (3) threat levels corresponding to threat levels used in vulnerability analysis (see Section 4)	This study	1km

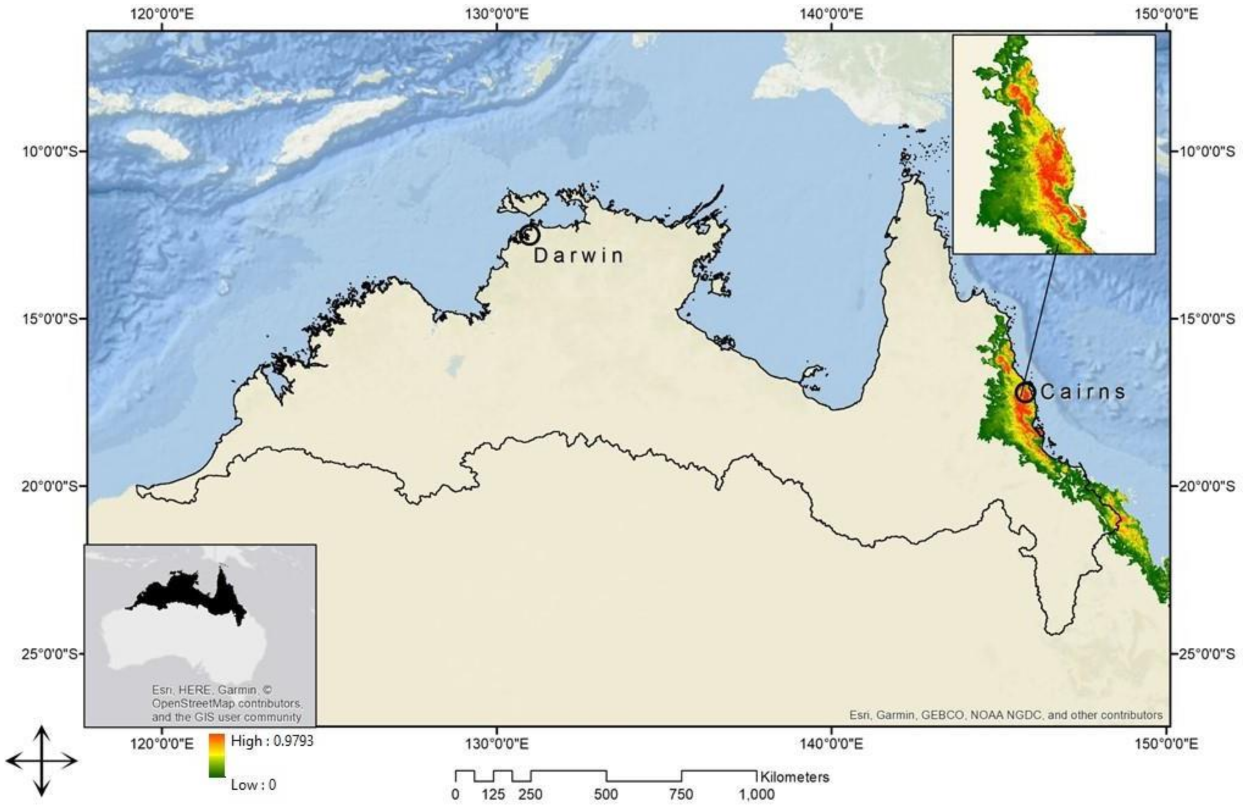

*Figure 9. Potential distribution (continuous habitat suitability) of chytrid fungus (*Batrachochytrium dendrobatidis*).*

3.3.4 Risk associated with changes in fire regimes

3.3.4.1 Background

The occurrence, frequency and intensity of fire is crucial to the health of many ecosystems in northern Australia (Cremer, 2004). Fire is a necessary part of the life cycle of many organisms, such as those that require fire to enable seed germination (Benson, 1985), species that require burnt patches for foraging (Woinarski, 1990), or vegetation types that require regular burning to maintain a certain structure or complexity of strata (Nieuwenhuis, 1987). However, fires that occur at the wrong time in the life cycle of a species (e.g. during time of germination) and 'overburning' through inappropriately high fire frequencies or extremely hot or large (less 'patchy') fires has negative effects on many taxa (Williams, 2009; Woinarski, 1990; Garnett et al., 2001; Lawes et al., 2015). Unusually hot or large fires are more likely if the fuel load of a vegetation type is allowed to build up for too long, i.e. if fires occur at a relatively late point in the dry season (Bradstock, 2002). As a result, while fire is necessary for the functioning of many tropical ecosystems in northern Australia, deviations of fire frequency and seasonal timing of fire from appropriate regimes can pose a risk, whether through 'underburning' (earlier, less frequent, smaller fires) or 'overburning' (later, more frequent, large, and very hot fires; Gill, 1975). Changes in the characteristics of fire regimes (compared to 'typical' conditions) can thus have significant detrimental impacts on ecosystems in northern Australia (Oliveira et al. 2015; Perry et al., 2016). In this context, the threat linked to changes in fire regimes is thus defined as the departure from the frequency and seasonal timing that is considered adequate for the persistence of a given vegetation community. However, the 'typical' or 'adequate' fire frequency and timing for each vegetation type is a topic of ongoing debate and research (Kelley, 2019; Russell-Smith, 2013).

We aimed to create baseline layers that can inform stakeholders on how fire frequency and timing has changed in the last decade compared to long term averages over the time period for which data is available (~ last 30 years; since 1988) as well as how fire regimes are different from what was typical for a vegetation type (i.e. eucalyptus woodlands, grasslands, etc). Our fire threat maps are based on fire scar data from Landgate[13] and describe recent (last decade) deviations in fire frequency and timing from long term averages in each 250m grid cell across northern Australia as well as how these regimes in each grid cell are different from 'typical' conditions for each vegetation type present in northern Australia (NVIS vegetation subgroups[14]) split across three climate type (based on annual rainfall layers created using ANUCLIM:[15] monsoonal, transition zone, or arid). In other words, to look to what conditions are typical for a vegetation type, following expert advice, we split each vegetation type that occurs over all three precipitation zones further into sub-types (e.g. type A in monsoonal areas, type A in arid areas, and type A in the transition zone).

The data set contains 12 layers, The first ten layers describe, for each grid cell, the average conditions (fire frequency and timing) over the maximum available time period (1988-–2015; two layers), the average conditions over the last available decade (2006–2015; two layers), the 'typical' conditions for the vegetation type and precipitation regime associated with each grid cell (two layers), the difference between recent to long term conditions in each grid cell (two layers), as well as the difference between recent conditions and 'typical' conditions for the vegetation type and precipitation regime in each grid cell (two layers; total: 10 layers).

The final two layers are indices of the risk of fire regimes varying from 'appropriate' conditions and describe the extent to which areas are over burnt (fire more frequent and later in the season than typical for the grid cell and vegetation subgroup) or underburnt (fire less frequent or earlier in the season than typical for the grid cell and vegetation subgroup; Figure 10). The difference between the two indices is that one describes both, the changes in each grid cell as well as how the conditions are different from the vegetation type baseline, while the other only described the deviation of conditions from the vegetation type baseline but not how conditions have changed in the grid cell over the last 30 years. The first index, therefore, includes an estimate of how 'unstable' conditions have been since 1988, while the latter only assesses how close conditions are to what we would expect for the vegetation type and precipitation regime. Depending on the research question, users are encouraged to review the methods document for this data and consult with the description of the data files below to select the appropriate layer for their purposes (Table 7).

[13] landgate.wa.gov.au
[14] environment.gov.au/land/native-vegetation/national-vegetation-information-system
[15] fennerschool.anu.edu.au/research/products/anuclim

Table 7. Fire regime output files.

Name	Description	Sources	Resolution
Final indices			
FireDistIndex_V2	Fire disturbance index, describing how much the fire frequency and timing of each grid cell differs from what is typical for the relevant vegetation type x precipitation regime (based on "DiftoMedFFforVeg_V2" and "DiftoMedFTforVeg_V2")	Landgate[13]; NVIS[14]; ANUCLIM[15]	250m
FireInconsIndez_V2	Index of fire inconsistencies, describing how much fire frequency and timing of each grid cell differs from what is typical for the relevant vegetation type x precipitation regime as well as how much both have changed within that grid cell in the last decade compared to the median across the last 30 years (based on "DiftoMedFFforVeg_V2", "DiftoMedFTforVeg_V2", "ChangeFFaloc_V2", and "ChangeFTatloc_V2")	Landgate[13]; NVIS[14]; ANUCLIM[15]	250m
Fire frequency			
MedianFFatloc_V2	Median fire frequency (burns per decade) in each grid cell across the last 30 years	Landgate[13]	250m
RecentFFatloc_V2	Recent fire frequency of each grid cell (burns last decade)	Landgate[13]	250m
ChangeFFaloc_V2	Difference in fire frequency in each grid cell across last decade compared to average across last 30 years (positive: higher frequency, negative: lower frequency)	Landgate[13]	250m
MedianFFforVeg_V2	Median fire frequency across northern Australia for the vegetation type x precipitation regime of each grid cell (burns per decade)	Landgate[13]; NVIS[14]; ANUCLIM[15]	250m
DiftoMedFFforVeg_V2	Difference between the fire frequency of each grid cell and the typical fire frequency for the relevant vegetation type x precipitation regime (positive: higher frequency, negative: lower frequency)	Landgate[13]; NVIS[14]; ANUCLIM[15]	250m
Seasonal fire timing			
MedianFTatloc_V2	Median seasonal fire timing (month of the year) in each grid cell across the last 30 years	Landgate[13]	250m
RecentFTatloc_V2	Recent seasonal fire timing of each grid cell (median month of burn across last decade)	Landgate[13]	250m
ChangeFTatloc_V2	Difference in seasonal fire timing in each grid cell across last decade compared to average across last 30 years (positive: later burns, negative: earlier burns)	Landgate[13]	250m
MedianFTforVegV2	Median seasonal fire timing (month of the year) across northern Australia for the vegetation type x precipitation regime of each grid cell (number of burns per decade)	Landgate[13]; NVIS[14]; ANUCLIM[15]	250m
DiftoMedFtforVeg_V2	Difference between the seasonal fire timing of each grid cell and the typical fire frequency for the vegetation type x precipitation regime (positive: later burns, negative: earlier burns)	Landgate[13]; NVIS[14]; ANUCLIM[15]	250m

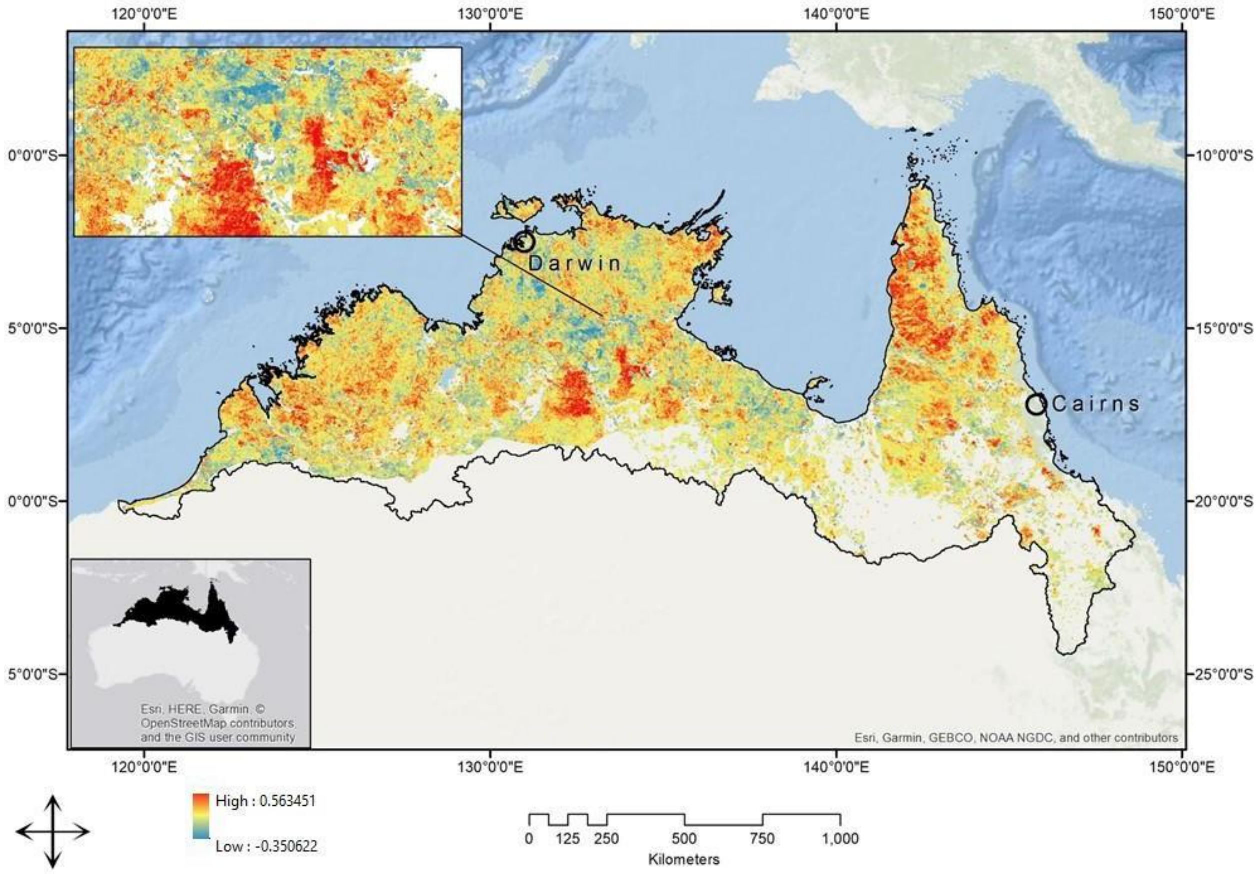

Figure 10. Index of fire inconsistencies, describing how much fire frequency and timing of each grid cell differs from what is typical for the relevant vegetation type/precipitation regime as well as how much both have changed within that grid cell in the last decade compared to the median across the last 30 years.

3.3.4.2 Limitations of this data set

The ‘appropriate’ fire regimes for different locations and vegetation types, and especially the ideal date for managed burns, are poorly understood and a topic of ongoing debate (Altangerel, 2013; Woinarski, 1990): this is because fire regimes have varied substantially over the centuries, first with different Indigenous burning practices, and later with the introduction of post-European- settlement burning practices as well as with the various changes in management strategies and government policies. Remote sensing data on these changes across northern Australia only date back to 1988, with previous changes being less well documented. Knowledge of pre-European fire management history is especially sparse (Fensham, 1997). Any estimates we provide of how far fire regimes deviate from what we define as ‘typical’ for our purposes are, therefore, only a starting point and hopefully a basis for more detailed studies on the actual measurable effects of these deviations on ecosystems.

Additionally, our indices aim to highlight areas that burn more or less frequently, and earlier or later than what we defined as ‘typical’, i.e. the median for the relevant vegetation type and/or the median for each grid cell over the last 30 years. However, we observed that fire frequency has been increasing for many vegetation types over this period (see detailed methods document in the RDSI collection). The ‘median’ conditions across time could, therefore, overestimate the ‘adequate’ fire frequency.

Furthermore, changes in any one location can represent a deviation from an appropriate regime or, alternatively, a return from inappropriate conditions to a well-managed regime. Therefore, an area that has changed a lot over the last 30 years does not necessarily have an inappropriate fire regime at present. However, we assume that an area where fire regime has been changing greatly over the last ~30 years has experienced a high level of disturbance.

More detailed technical information and descriptions of data lineages can be found in the relevant methods document *Methods for NESP NAER project 3.3 fire disturbance indices* (Pintor et al. 2019; located in the RDSI directory for this data set). Please also consult the metadata for this data set (dx.doi.org/10.25903/5b72631b2dd70).

3.3.5 Risk associated with changes in stream flow regimes

3.3.5.1 Background

Flow regimes define the intensity, seasonality, and connectivity of water flow through freshwater ecosystems. These characteristics are impacted directly by human disturbances, such as dams and water extraction, and by climate change, because of changes in water moving through the system as a result of changes in precipitation. We created datasets in relation to two both of these aspects of major flow regime changes: anthropogenic disturbances and changes associated with climate change.

Anthropogenic disturbances incorporate change in flow regimes associated with impoundment, fragmentation, and general river disturbance. Such disturbances often affect the ability of organisms to move through the system, such as when barriers to fish migrations are created, or change the structure of freshwater ecosystems, such as creating a lake through damming of a river (Rolls, 2017; Harris, 2017). We mapped these disturbances by creating grid files from existing vector file products from the National Environmental Stream Attributes v1.1.5 dataset (Stein, 2014; Stein, 2012; Geoscience Australia[16]). Rasters were created at 250m resolutions. The original vector products were based on a 250m digital elevation model and modification of the original data were, therefore, minimal. The rasters of current anthropogenic disturbance metrics are provided in the RDSI directory “FreshwaterDisturbance”.

Climate change-related flow disturbances predicted for the year 2045 (Figure 11) were based on an existing data set created for the National Climate Change Adaptation Research Facility (James, 2013; NCCARF[17]). This dataset includes monthly runoff estimates predicted for several future time steps (2025 to 2085 in 10-year intervals) across 18 GCMs for RCP 8.5 (business as usual).

We selected outputs for the year 2045 for our project because it came closest to the 2050 future time step we aimed for in our other outputs. Based on the monthly layers we calculated the 10% quantile (Q10), 90% quantile (Q90) and median (‘Median’) across the 18 GCMS for the following variables, which were suggested by experts to be of the greatest relevance to stream connectivity and freshwater habitat structure:

[16] ecat.ga.gov.au/geonetwork/srv/eng/catalog.search?node=srv#/metadata/75066
[17] nccarf.edu.au

1. **Accumulated annual runoff:** the total runoff crossing through each grid cell across the whole year based on rainfall upstream;
2. **Perenniality:** the percentage contribution to annual runoff from the dry season months (the lowest 6 months of the year), i.e. how low runoff gets in the dry season compared to when the stream is 'in season';
3. **Runoff seasonality**, measured as the coefficient of variation of monthly runoff values;
4. **Minimum monthly runoff**, i.e. the runoff at the driest time of year; and
5. **Maximum monthly runoff**, i.e. the runoff at the wettest time of year.

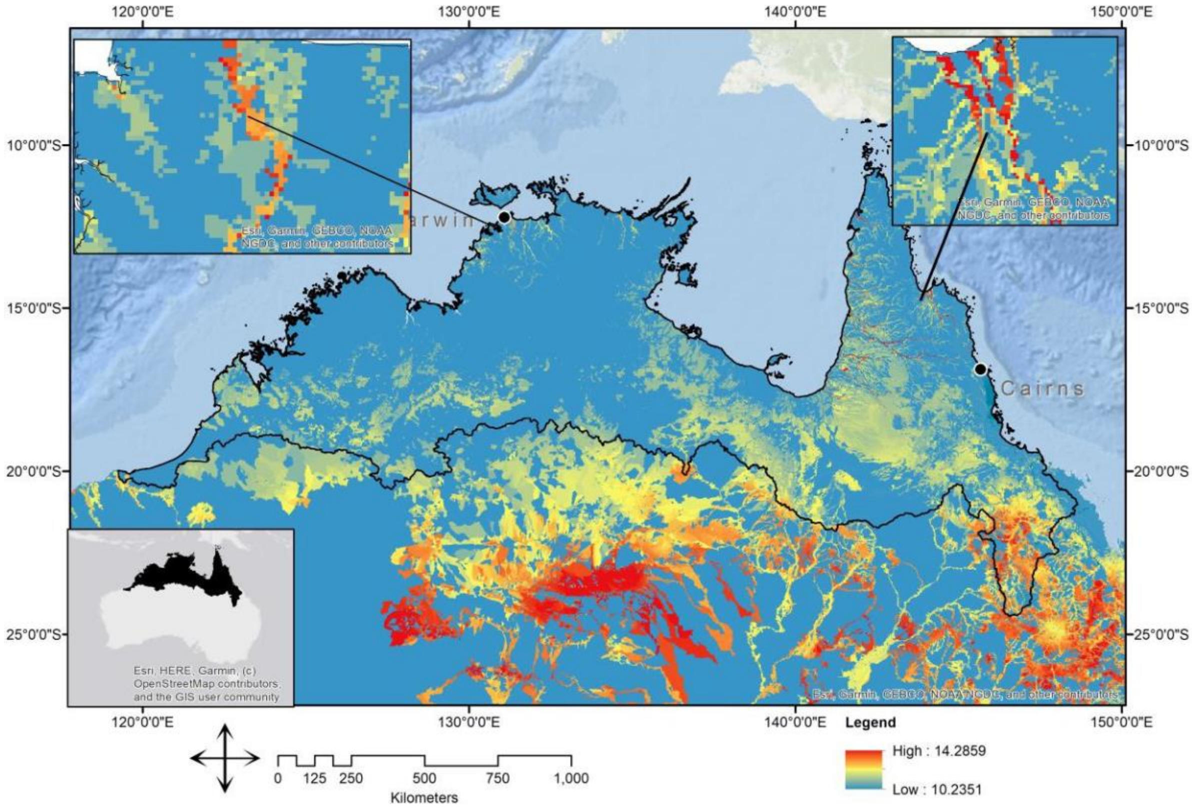

Figure 11. Median dissimilarity between current and future freshwater flow regimes. The dissimilarity output shows how different runoff regimes are predicted to be in 2045 compared to now when looking at all relevant variables combined.

The above variables were summarised using the Euclidean distance of future conditions from current conditions to describe overall 'dissimilarity' predicted for 2045 compared to now across all of these parameters. The final data set is contained in the directory "FreshwaterRunoff". In the same way as for outputs for risk from changes in heat and drought conditions as a result of climate change (see Section 3.3.2), we present outputs in separate sub-directories for "current", and 'future', ('Median', 'Q10' and 'Q90') conditions as well as for 'change' in each variable between now and 2045 ('Median', 'Q10' and 'Q90'). However, we additionally provide proportional change in runoff variables in addition to the absolute changes. This may be more useful for describing changes in stream structure because a small absolute change in runoff is of greater importance in arid areas than in high rainfall areas. Finally, there is a separate sub-directory for overall 'dissimilarity' expected for 2045 (Table 8).

3.3.5.2 Limitations of this data set

We summarised data from an earlier NCCARF project for this analysis, which was based on earlier CMIP3 GCMs. The original report (James, 2013) outlines any limitations associated with the original data.

Similar to our assessment of climate change dissimilarity, flow regime dissimilarity was calculated based on several variables that are likely to impact threatened species the most, in this case variables affection typical runoff conditions and runoff variability or seasonality. Many of these variables depend on changes in precipitation and predictions of such changes these have a high degree of uncertainty associated with them and vary greatly among GCMs. Please consult the provided 10% and 90% quantile outputs to get an idea of the uncertainty of median estimates.

More detailed technical information and descriptions of data lineages can be found in the relevant methods document *Methods for NESP NAER project 3.3 changes in natural flow regimes* (Pintor et al. 2019; located in the RDSI directory for this data set). Please also consult the metadata for this data set (dx.doi.org/10.25903/5b72631b2dd70).

Table 8. Flow regime output files.

Name	Description	Sources	Resolution
Freshwater disturbance			
Artbar_250	Presence/absence of artificial barriers to stream flow	Stein, 2012	250m
Frdi250	Flow regime disturbance index	Stein, 2012	250m
Imp250	Impoundment index	Stein, 2012	250m
Current runoff parameters			
geoscaus_runperen_1km	Current runoff perenniality	Stein, 2012	1km
geoscaus_runmthcov_1km	Current runoff seasonality (coefficient of variation of monthly cumulated runoff)	Stein, 2012	1km
geoscaus_runminmth_1km	Minimum monthly runoff	Stein, 2012	1km
geoscaus_runmaxmth_1km	Maximum monthly runoff	Stein, 2012	1km
geoscaus_runanmean_1km	Mean cumulated annual runoff	Stein, 2012	1km
Future runoff parameters			
Quantile_metric_yearscenario_ 1km	10% (Q10), 50% (median), and 90% (Q90) quantile of predicted future conditions in runoff metrics under scenario RCP8.5 (RCP85, business as usual) by the year 2045. Peren: perenniality of flow MonthCV: seasonality of flow as described by the coefficient of variation between monthly amounts of runoff AnRO: cumulated annual runoff minRO: minimum monthly runoff maxRO: maximum monthly runoff	Stein, 2012; James, 2013	1km
Change in runoff parameters			
Quantile_metric_yearscenario_ CHANGE	10% (Q10), 50% (median), and 90% (Q90) quantile of predicted absolute change in flow regime metrics due to climate change under scenario RCP8.5 (RCP85, business as usual) by the year 2045. See “future” directory description (above) for variable abbreviations.	James, 2013	1km
Quantile_metric_yearscenario_ CHANGEprop	As above but change is expressed as a proportion of current conditions rather than absolute.	James, 2013	1km
Dissimilarity in runoff parameters			
r_fm-c_euc	Median predicted dissimilarity between current and future (2045) runoff conditions across all runoff variables combined.	Stein, 2012; James, 2013	1km

3.3.6 Risks associated with intensity of grazing practices

3.3.6.1 Background

Overgrazing by domestic livestock can affect biodiversity in several ways, including by modifying the structure, composition and function of vegetation communities (Hassani, 2008; Crowley, 1998; Landsberg, 2003; Eldridge, 2016). The effects of overgrazing depend on the intensity and level of modification of native vegetation. The highest level of degradation is associated with intensive grazing on cleared land or highly modified (e.g. introduced pastures) areas, resulting in habitat loss for most native species. On the other hand, overgrazing can also occur without modifying or clearing native vegetation, which is the most common form of pastoral activity across northern Australia (i.e. extensive grazing of native vegetation; Eldridge, 2016). The extent of degradation can be determined by combining information about the grazing type (intensive vs. extensive), grazing intensity and grazing pressure compared to carrying capacity of the vegetation community. We created an overgrazing risk index based on these different aspects of actual and potential land use. The final data set contains the index as well as the layers used to create the final index. The extra layers are provided to give users the option to look at different aspects of grazing separately and provide the widest range of possible uses of the data depending on users' preferences and individual purposes.

The overgrazing risk index aims to estimate overgrazing risk based on the combination of four elements: (a) a land use map identifying areas currently known to be grazed intensively or extensively; (b) estimates of grazing intensity or likelihood of grazing across native vegetation based on pasture productivity; (c) estimates of inappropriate stocking rates compared to carrying capacity (variability in pasture growth, i.e. difficulty in 'getting stocking rates right' across years); and (d) proximity to water sources, where cattle is likely to concentrate.

Current land use (a) was based on ABARES ACLUMP data,[18] the same data set used in previous sections to describe land use. The density of livestock (b), including what is likely to be today (within currently grazed areas) or how likely areas are to be used for grazing in the future (within currently not grazed areas) was estimated based on average pasture production as described by AussieGRASS[19] products. How likely stocking rates are to be inadequate (c), i.e. the likelihood that cattle density will exceed carrying capacity at least from time to time, was estimated based on the degree of interannual variability in pasture production (also obtained from AussieGRASS). The rationale behind this was that high variability in pasture production leads to limited ability to accurately predict how much pasture will be available from year to year, which can result in damage of ecosystems due to misjudgement of carrying capacity each year and because of difficulty destocking to appropriate levels in low-productivity years (O'Reagain, 2009). Lastly, livestock tend to use areas around natural and human-made water sources more heavily and frequently. Thus vegetation near rivers, dams and other water bodies is more prone to damage (Landsberg, 2003), so these areas were upweighted (by a factor of 2 near water source, declining to a factor of 1 at 2km from water source; d). The final data set contains index for risk of overgrazing (Figure 12) as well as several of the data sets used to create the index, namely a

[18] agriculture.gov.au/abares/aclump
[19] longpaddock.qld.gov.au/aussiegrass

raster showing areas that ae currently grazed intensively or extensively, median pasture production across the time period of 2000-2017 (the time period for which data was available from AussieGRASS online), and the interannual variability in pasture production for the years 2000–2017.

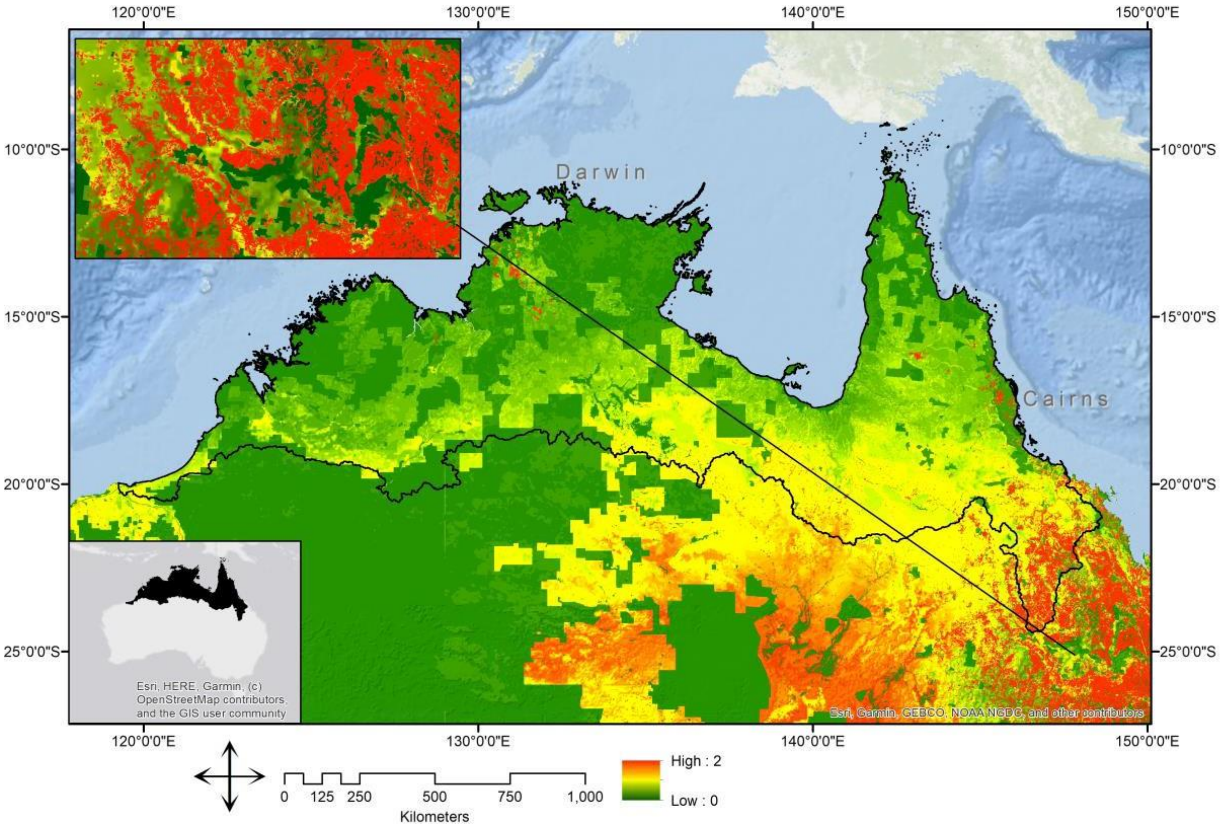

Figure 12. Index of risk of overgrazing, describing the likelihood of changes to native biodiversity based on known grazed areas, potential grazing intensity, and variability in pasture production.

Table 9. Overgrazing risk output files.

Name	Description	Sources	Resolution
GrazingImpactRiskWat	Grazing impact risk index, describing the likelihood of impacts from grazing on native biodiversity based on known grazed areas, likelihood of grazing (pasture production), unpredictability of pasture conditions (inter-annual variability), and proximity to water sources (areas used more intensively by livestock).	ABARES[18]; AussieGRASS[19]	250m
finalCurGraze	Areas used for extensive rangeland grazing and intensive grazing on non- native vegetation.	ABARES[18]	250m
pastureMedRel2000-2017	Median annual pasture production from 2000 to 2017 as a fraction of maximum pasture production observed.	AussieGRASS[19]	250m
pastureCV2000-2017	Coefficient of variation of annual pasture production from 2000 to 2017, indicating inter-annual variability in pasture growth.	AussieGRASS[19]	250m

3.3.6.2 *Limitations of this data set*

In addition to intentionally grazed areas, many grazing properties in Australia's rangelands are not fenced. Because of this and, additionally, because of feral cattle populations, many areas that are not officially grazed still experience grazing pressure. Our index identifies such areas to some degree by using pasture production and pasture variability of ungrazed areas to estimate grazing potential – areas with higher values are likely to be used by feral cattle even if not officially used for grazing. However, the exact pressure from feral cattle populations as well as the additional pressure from other feral graziers, such as horses and goats, and native species, such as kangaroos and wallabies (Eldridge, 2016), is difficult to estimate and should be kept in mind when assessing damage from overgrazing. Additionally, pressure from grazing depends a lot on the quality of land management and there is evidence of degradation of northern Australia's rangelands from poor land management practices (Office of the Auditor General Western Australia 2017). The impacts of local variations in land management practices is difficult to predict. Actual stocking numbers within specific study areas should, therefore, be assessed and compared to our risk estimates by users to improve conservation decisions.

More detailed technical information and descriptions of data lineages can be found in the relevant methods document *Methods for NESP NAER project 3.3 potential grazing impact indices* (Pintor et al. 2019; located in the RDSI directory for this data set). Please also consult the metadata for this data set (dx.doi.org/10.25903/5b72631b2dd70).

3.3.7 Risks from invasive species

3.3.7.1 *Background*

Numerous invasive animals and weeds threaten Australia's native biodiversity through a multitude of mechanisms such as predation (e.g. feral cats, foxes; Graham, 2013), physical destruction of habitat (e.g. feral pigs, rabbits; Massei, 2004; Jernelöv, 2017), alteration of soil and vegetation by trampling and overgrazing (e.g. feral horses, goats; Bomford, 2002), changing vegetation structure (e.g. Lantana, Chinee Apple; Sundaram, 2012), or increases in fuel load for fires (e.g. Gamba grass; Head, 2015). Owing to their recent introduction (within the last 200 years), many of these invasive species, especially weeds, have not yet realised their maximum potential distribution within Australia. To understand the current and potential future impact invasives may have on native biodiversity, and to support planning of control or eradication programs, a detailed understanding of realised current distributions and other potentially suitable habitat is required.

There are various approaches to assessing the risk posed by invasive species. For this project, we modelled the potential distributions of 38 invasive animal species (6 birds, 17 mammals, 3 fishes, 1 amphibian, 1 reptile, and 10 insects) and 224 weeds (10 annual grasses, 37 perennial grasses, 83 shrubs/trees, 29 annual forbs, 14 aquatic weeds, 33 vines, and 18 'other' weeds) using a machine learning approach (Maxent). Maxent software uses a set of environmental predictor variables and a set of known occurrence locations to establish habitat suitability per grid cell. Maxent performs well compared to other methods, especially when only presence data (as opposed to presence/absence data) is available (Elith et al. 2006) and has been widely used to model the potential distribution of invasive species (Wilson, 2009; Elith, 2013; Cunningham, 2016).

Species were selected based on federal and state/territory listings, such as inclusion in 'Weeds of National Significance', class A-C weeds and feral animals (Northern Territory), prohibited, restricted and other invasives (QLD), and declared pests (WA). We also added invasives that were mentioned explicitly as being a current or potential future problem in northern Australia by experts involved in the project. We included only invasives that either had known occurrences in northern Australia or have known tropical distributions elsewhere, as indicated by their global occurrence records, and hence may possess unrealised invasion potential in northern Australia. Global and Australian records for invasive species occurrences were obtained from the Global Biodiversity Information Facility (GBIF[20]), the Atlas of Living Australia (ALA[21]), and Feralscan.[22] Records were cleaned to exclude any pre-1975 records and any records with a location precision below 1km (i.e. the modelling resolution). Predictor layers all had a resolution of 1km because global data is often only available at this resolution (compared to Australian data used for native threatened species models, which were done at 250m). They included information on climate (bio1,4,5,6,12,15, minimum humidity and maximum radiation based on WorlClim[23] data), soil (percent clay and soil type from the Harmonized World Soil Database[24] and dominant lithology from the Commission for the Geological Map of the World[25]), geography (topographic ruggedness based on the digital elevation model from the Harmonized World Soil Database and distance from water courses based on watercourses mapped by HydroSHEDS[26]) and vegetation (land cover from the European Space Agency[27]), to provide as much detail as possible. Inclusion of a large number of starting variables was possible because a variable selection process was applied to reduce predictor variables and avoid overfitting of models. Please refer to the detailed methods document located in the RDSI folder for this data set for further information on sources of predictor variables and detailed modelling methods.

Maps of invasive species' distributions can be used for different purposes in conservation and natural resource management (e.g. weed management in agriculture, eradication of predators from vulnerable areas, selection of areas for targeted eradication or control, etc.). Thus, we produced several outputs that can be adequate for different applications. Users are encouraged to select from a range of model outputs based on the description below. All outputs are available for current climatic conditions, as well as for median, 10% quantile (Q10) and 90% (Q90) quantile of habitat suitability across 17 GCMs under an RCP8.5 climate change scenario for 2050. See Table 10 for more details and file naming conventions. The range of outputs produced are:

1. Full habitat suitability maps (current, future median, future Q10 and future Q90) with a continuous 0 (unsuitable) to 1 (highly suitable) scale as well as ones with binary 1 (suitable) vs. 0 (unsuitable) scale. These were created using Maxent models based on global occurrence records and global predictor variables at 1 km resolution (Figure 13).

[20] gbif.org
[21] ala.org.au
[22] feralscan.org.au
[23] worldclim.org
[24] webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML
[25] ccgm.org/en/home/168-lithological-map-of-the-world-9782917310250.html
[26] hydrosheds.org
[27] esa-landcover-cci.org

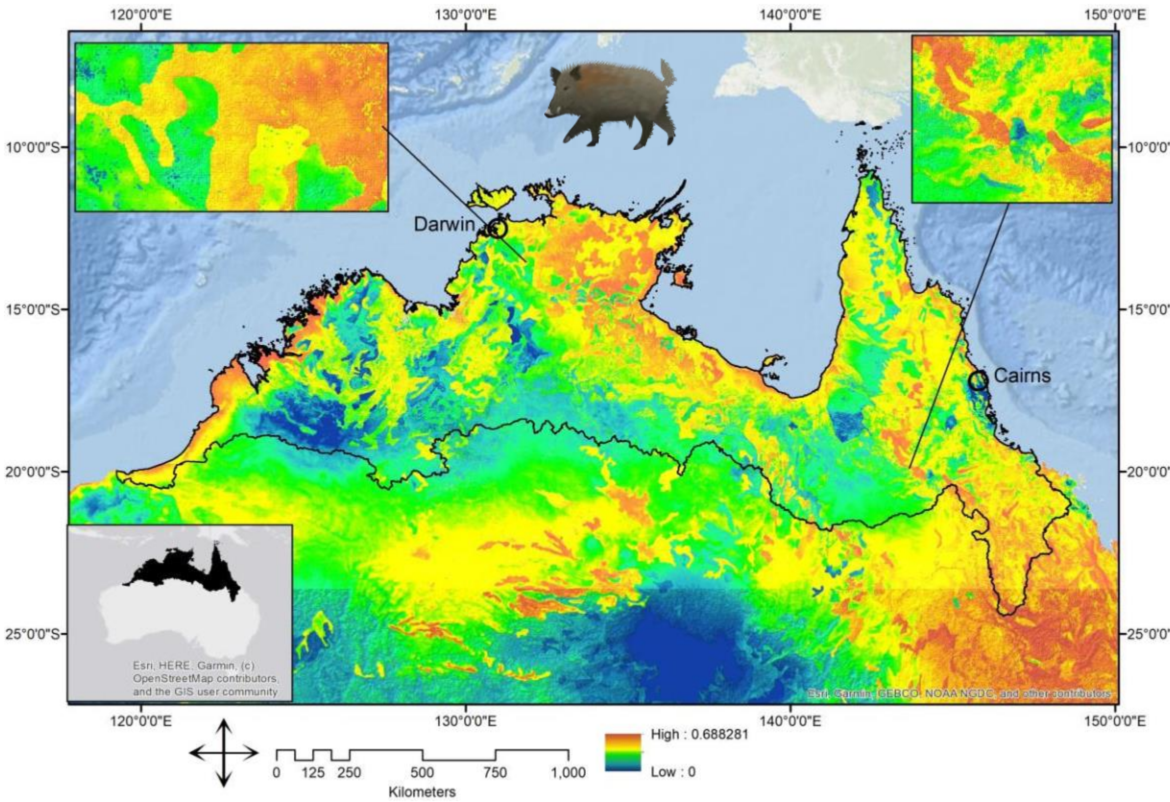

*Figure 13. Median predicted species habitat suitability for feral pig (*Sus scrofa*) under future climatic conditions (2050).*

2. Likelihood of occupancy maps (current, future median, future Q10 and future Q90), showing the 'cost distance' from known occurrence records of each species within Australia. Cost distance describes how easy it is for a species to spread from known occurrences through a habitat depending on the habitat's suitability for the same species (output 1). The cost distance was inverted so any areas with a high value could be accessed more easily by the invasive species and areas with values close to 0 would be harder to access or are far away from occurrences and are, therefore, unlikely to be occupied.
3. Likely current distributions of each species were estimated based on likelihood of occupancy (output 2). These are binary rasters showing any areas with a likelihood of occupancy >90% as 1 (likely occupied) and other areas as 0 (unlikely to be occupied at the moment.
4. 'Threat' layers showing the habitat suitability (output 1, weighted by multiplying it with the likelihood of occupancy (output 2). These maps provide adjusted habitat suitability maps based on the assumption that risks to biodiversity decrease with cost-distance to known occurrences of an invasive species even if habitat suitability for the invasive species causing the threat is high. They represent the potential threat the invasive species poses to any given area in terms of potential interaction with native species, i.e. if the invasive species is already present and the area has a high suitability, the potential to interact and affect native biodiversity is higher. In contrast, if the invasive species is far from a given area and suitability is low, the risk to native biodiversity is much lower. These maps are available as 0-1 maps (where 1 = high suitability and close proximity to known occurrences of the invasive species, and 0 = low suitability far away from known occurrences) and as maps rescaled to a 0-3 scale. The latter were used in our vulnerability analyses (Section 4).

Lastly, we produced summary maps describing the number of invasive species present in each grid cell for a few different groups (grasses, weeds or feral animals) to give an idea of where invasive species are concentrated in northern Australia. This output was produced for binary current distributions for species in each group (outputs 3) as well as for the maximum potential distributions of all species if they were allowed to spread (for current conditions, future median, Q10, and Q90 conditions; outputs 1). As an example, for weeds there is an output of current 'weediness' (number of weeds present), current potential 'weediness' (number of weeds present if allowed to spread to their full potential), and future potential weediness (median, Q10, and Q90).

3.3.7.2 Limitations of this dataset

Please note that our outputs are based on **KNOWN** current occurrences. Ranges of invasive species are highly dynamic and might occur in other areas that have not been sampled sufficiently or might have been eradicated from some of the 'known' occurrences. Populations could be in the process of invading new areas or might be targeted under control or eradication programs. Habitat suitability models thus aim to describe where an invasive species could occur if there were no major constraints to its spread. As such, not all suitable areas are currently occupied.

Similarly, likelihood of occupancy estimates accessibility of invasive species from areas where they have been recorded (assuming they have established populations and thus can act as source populations for further invasions, yet this is not always the case) to other currently unoccupied areas. Some of these new areas might have already been invaded, but not been sampled and some existing populations might have been locally eradicated (i.e. no longer acting as source populations). Consequently, our models are not a substitute for detailed, ongoing, finer-resolution assessments of local invasion risk and field sampling for invasive species.

More detailed technical information and descriptions of data lineages can be found in the relevant methods document *Methods for NESP NAER project 3.3 Maxent distribution models of invasive weeds, feral animals, and diseases* (Pintor et al. 2019; located in the RDSI directory for this data set). Please also consult the metadata for this data set (dx.doi.org/10.25903/5b72631b2dd70).

Table 10. Invasive species output files.

Name	Description	Sources	Resolution
Gen_sp_cat_AUS1km	Continuous habitat suitability (0-1) for the species for each of the following categories: current, future median, future 10% quantile (Q10) and future 90% quantile (Q90) of projected suitabilities (across the 17 future circulation models)	This study	1km
Gen_sp_cat_AUSbin1km	Binary habitat suitability (0 or 1) for the species for current, future median, future Q10 and future Q90.	This study	1km
Gen_sp_OccupancyR_cat_AUS1km	Likelihood of occupancy, measured as cost distance from occurrence points using habitat suitability as a cost surface (i.e. the lower the habitat suitability of a pixel, the higher the cost for the species to travel across it). Available for current, future median, future Q10 and future Q90.	This study	1km
Gen_sp_Occ_cat_AUS1km	Binary raster showing all areas as 1 that are within >=90% likelihood of occupancy (i.e. close to occurrences) for current, future median, future Q10 and future Q90.	This study	1km
Gen_sp_cat_Threat	Continuous habitat suitability weighted by cost distance to occurrence points (i.e. suitable habitat far away from known occurrences is down weighted correspondingly) for current, future median, future Q10 and future Q90.	This study	1km
Gen_sp_cat_Threat_1-3	Continuous habitat suitability weighted by cost distance to occurrence points (i.e. suitable habitat far away from known occurrences is down weighted correspondingly) for current, future median, future Q10 and future Q90 – rescaled to 0-3 to represent low (1), medium (2) and high (3) threat levels corresponding to threat levels used in vulnerability analysis (see Section 4)	This study	1km
group_Invhotspot_Current	Hotspot of current species richness within the group (invasive animals, all invasive weeds, or invasive grasses), i.e. sum of all “Gen_sp_Occ_cat_AUS1km” rasters for species within that group	This study	1km
group_Suithotspot_cat	Current (Current), future median (FutMed), future 10% quantile (FutMin), and future 90% quantile (FutMax) of species richness if all species within each group spread across their whole suitable habitat, i.e. sum of all ‘Gen_sp_cat_AUSbin1km’ rasters for species within that group	This study	1km

3.3.8 Risk from current or potential mining activities

3.3.8.1 Background

Mining activities can have negative effects on native species through habitat loss or habitat degradation (e.g. increased human activities and vehicle access around the mine, impacts of ground water extraction, or pollution; Karanovic, 2013; Mudd, 2010; Vanderduys, 2016). Our map of risk associated with current and potential mining (Figure 14, Table 11) represents an aggregation and reclassification of spatial data representing mining lease status across multiple jurisdictions.[28] It includes information about current and potential mining for minerals, petroleum, or coal, and is based on the highest permit status for properties extending over each pixel. Pixel status was ranked in the following order from highest to lowest risk: Currently active mine sites, proposed mines and applications for mining leases, current exploration permits, known resource presences according to existing drill holes, applications for exploration permits and areas advertised for exploration, and absence of known mining activities.

3.3.8.2 Limitations of this data set

We present the current lease status as a broad and coarse-scale estimate of risk according to permits recorded for land parcels. Parcel based permits do not account for the fine-scale effects within the parcel or localised concentrations of effects within a lease (i.e. where small areas have been converted to pits or tailings dams), the type of effect (e.g. based on mining or exploration activity, native species can be affected differently through different mechanisms, including noise, dust, toxic pollutants, etc.), or off-site effects (e.g. via pollution of rivers or aquifers, dispersal of fine dust, propagation of noise, etc.). Such fine-resolution and off-site variation of threat type and intensity should be assessed in separate, detailed studies when deciding on specific conservation or mitigation activities. This information is not suitable to guide environmental impact assessments of mining developments.

Additionally, new applications for mining activities are continuously submitted and our data only represents a snapshot in time. Some mines may become inactive, new resources may be found and exploited, or new exploration permits may be granted. Lastly, the occurrence of exploitable resources is not well-known and new discoveries of resources can quickly lead to large changes in ecosystems' exposure to mining activities. The spatial distribution of risks from mining activities is, therefore, highly dynamic, and users are encouraged to seek out additional recent information for their study area.

More detailed technical information and descriptions of data lineages can be found in the relevant methods document *Methods for NESP NAER project 3.3 risk of mining impacts* (Pintor et al. 2019; located in the RDSI directory for this data set). Please also consult the metadata for this data set (dx.doi.org/10.25903/5b72631b2dd70).

[28] nt.gov.au/industry/mining-and-petroleum
catalogue.data.wa.gov.au/dataset?tags=mining
data.qld.gov.au/dataset/queensland-mining-and-exploration-tenure-series
ga.gov.au/cedda/maps/1085
ecat.ga.gov.au/geonetwork/srv/eng/catalog.search?node=srv#/metadata/104762

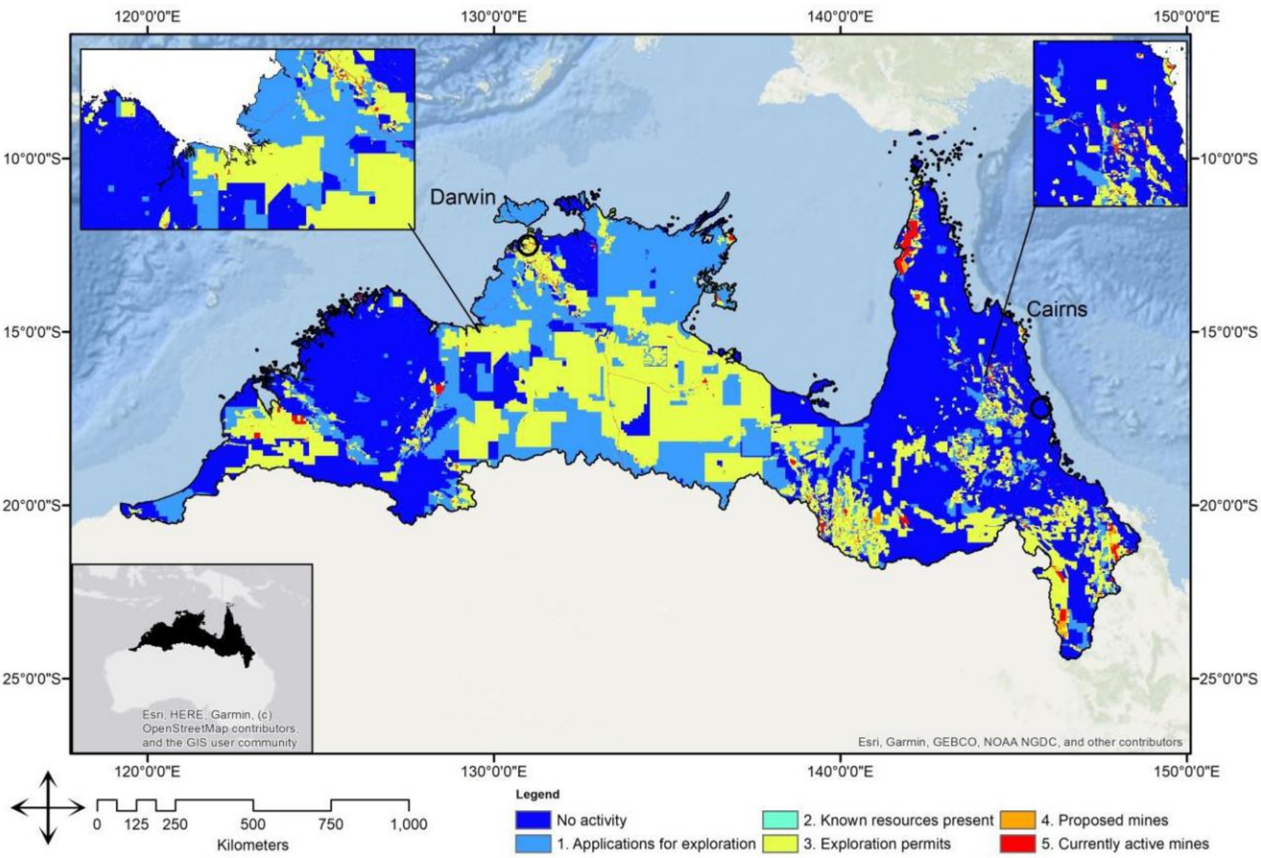

Figure 14. Risk of exposure to mining activities in northern Australia, based on lease status and mineral occurrences.

Table 11. Mining output files.

Name	Description	Sources	Resolution
Mining	Likelihood of mining activities based on legal status (current mining leases, exploration leases, etc) and known mineral occurrences	Federal and state/territory governments[28]	250m

3.3.9 Risk from inundation and associated effects from sea-level rise

3.3.9.1 Background

Sea level rise poses a notable threat to some areas in northern Australia, in particular areas that are sensitive to exposure to increased salinity, inundation, or wave action, such as coastal wetlands, intertidal ecosystems, or littoral rainforests and by encroaching on critical freshwater resources and causing damage to coastal infrastructure (Werner, 2010; Abel, 2011). Our map of risk associated with sea level rise was created by classifying a map depicting climate change-induced inundation potential into three 'risk categories'. These categories correspond to the following conditions: i) the area is currently already under the high-tide mark based on known high tide levels (Sagar, 2017[29]) and the current 9 sec digital elevation model (Geoscience Australia[30]), meaning that sea level rise will increase the inundation period and salinity of ecosystems in this intertidal zone; ii) likely to be inundated at high tide by 2100 (according to RCP8.5; IPCC 2013[31]), meaning that ecosystems in this zone are not currently adjusted to saltwater inundation but will likely be exposed to permanent or occasional inundation and increased salinity by 2100; and iii) unlikely to be inundated at high tide under RCP 8.5 but at risk from flow on affects from nearby sea level rise, meaning that near-by inundation may increase soil salinity or that these ecosystems are likely to experience exposure to waves during storms, or to intertidal organisms that move up with sea level rise (Figure 15).

As for climate change, we used the average predictions for a worst-case scenario 'business as usual' (RCP 8.5) for our assessment of risk of exposure to rising sea levels, which is a commonly used benchmark (see e.g. fine scale coastal risk assessments for Australian cities[32]). However, there is a high level of uncertainty associated with predictions of sea level rise. The IPCC estimates that, for RCP 8.5, by 2100 sea level rise will be between 0.52 to 0.98 m with 5%-95% of projections being between 0.45 to 0.82 m and an average expected value of 0.74 m, which was the value we used for our mapping. Even a very enthusiastically low RCP 2.6, which assumes substantial anthropogenic emission reduction including extraction of greenhouse gases from the atmosphere, estimates sea level rises of 0.44 m (range 0.28–0.61; IPCC, 2013). Further research could subdivide our risk categories further according to these estimates based on different RCPs or uncertainty of predictions within RCPs.

There are two data files associated sea-level rise. Users may choose a data file that is clipped to the coast or includes a value for non-coastal areas (Table 12).

3.3.9.2 Limitations of this data set

Sea level rise was modelled using a business as usual (RCP8.5) scenario for the year 2100, while most other outputs from this project are projected only to 2050. We used 2100 as an endpoint to maintain consistency with international and national policy directives and other prediction analysis (IPCC 2013). Please note that predictions of sea level rise vary greatly depending on RCP and even for productions by different models within each RCP. However, even the low RCP 2.6 expects a sea level rise of up to 0.61 m, which is not far from the average prediction of 0.74 m for RCP 8.5 used in this study. Depending on the purpose, users may want to modify our output by further subdividing our categories according to these estimates of uncertainty.

Additionally, our map essentially shows risk associated with rises from the current high tide mark. However, these sea levels may be exceeded during storm tides and changes in wave action with climate change will likely add to the negative effects of higher sea levels (Morim, 2019), including through coastal erosion.

[29] nationalmap.gov.au
[30] ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/66006
[31] ipcc.ch/report/ar5/wg1
[32] coastalrisk.com.au

Users should also consult other, fine scale models of sea level change that exists for limited areas such as some coastal Australian cities (see e.g. Coastal Risk Australia[33]).

More detailed technical information and descriptions of data lineages can be found in the relevant methods document *Methods for NESP NAER project 3.3 sea level rise* (Pintor et al. 2019; located in the RDSI directory for this data set). Please also consult the metadata for this data set (dx.doi.org/10.25903/5b72631b2dd70).

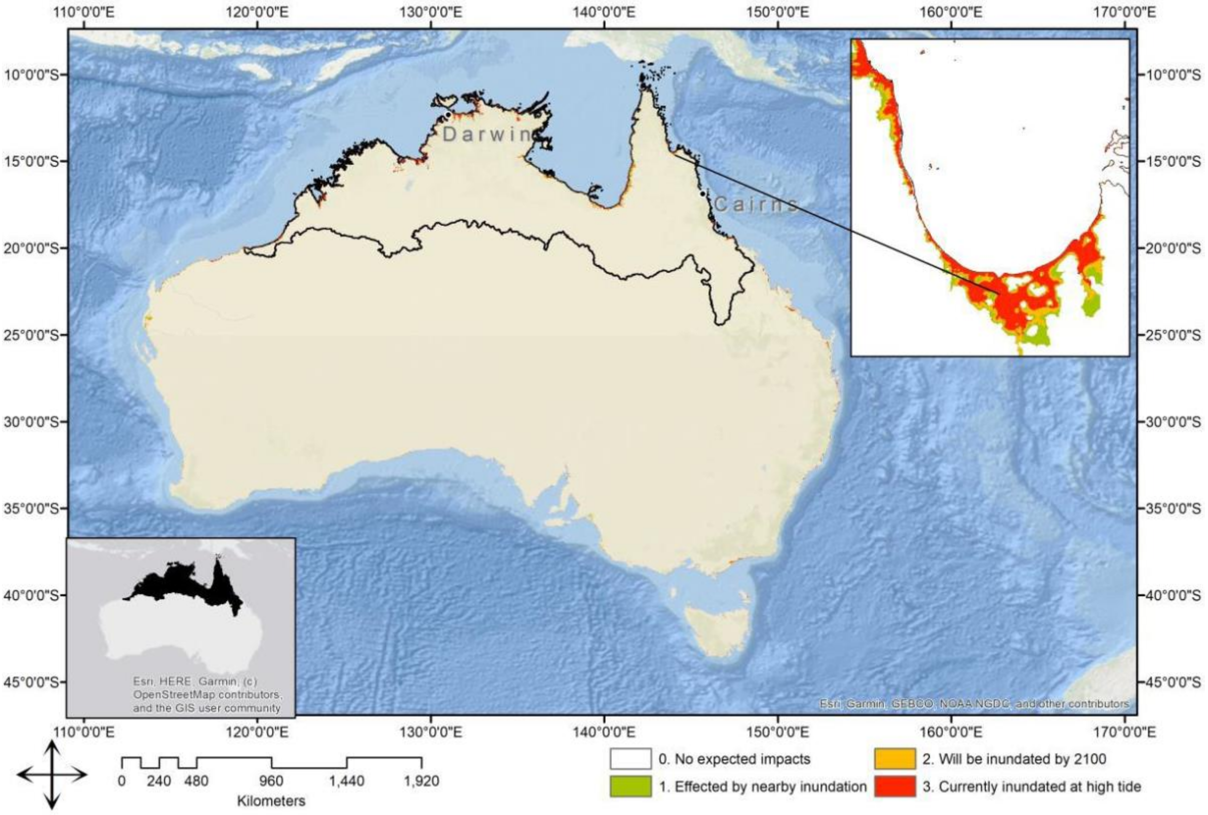

Figure 15. Expected risk associated with predicted sea level rise by 2100.

Table 12. Sea-level rise output files.

Name	Description	Sources	Resolution
Sealevel1-3	Expected risk from sea level rise by 2100 according to RCP 8.5 (0-3)	Sagar, 2017; Geoscience Australia[30]	250m
Slr85_2100	Expected risk from sea level rise by 2100 according to RCP 8.5 (0-3) restricted to coast (inland areas are NA)	Sagar, 2017; Geoscience Australia[30]	250m

[33] coastalrisk.com.au

3.3.10 Risks associated with accessibility of natural areas

3.3.10.1 Background

The degree of accessibility of natural areas is an important factor mediating interactions of humans with natural ecosystems, and – in some cases – higher access could result in higher risk to biodiversity, particularly for threatened species or vulnerable ecosystems (Kaufman, 2009; Goosem, 2001; Laurance, 2006; Laurance, 2008). The effects vary notably depending on how access is regulated (including compliance with regulations) and the type of interactions with the environment (e.g. tourism, hunting, transit), and can be mediated by different mechanisms, including direct extraction of plants and animals through hunting, fishing or collection activities (these are particularly problematic if they are unsustainable or target highly-threatened species), disturbance through noise, light and littering, and direct physical damage of native species (e.g. accidental road kill) or ecosystems (e.g. trampling of vegetation, erosion). Our map of accessibility to natural environments provides a broad representation of risk related to potential interactions of humans with natural ecosystems. We estimated accessibility based on cost distance to, and size of population centres. The 'cost' or effort of travelling across the landscape is usually higher the steeper the terrain (i.e. higher slopes) and the denser the vegetation, while travelling along paths such as roads or rivers (in the case of fishing) incurs a very low cost. Similarly, interactions are more likely if an area is accessible to a larger number of people (Figure 16). Depending on the application, users may choose between modelled accessibility when waterways act as barriers (prevent access) or act as roads (create access; Table 13). The intermediary spatial files used to create the final layers are also available as a part of this collection.

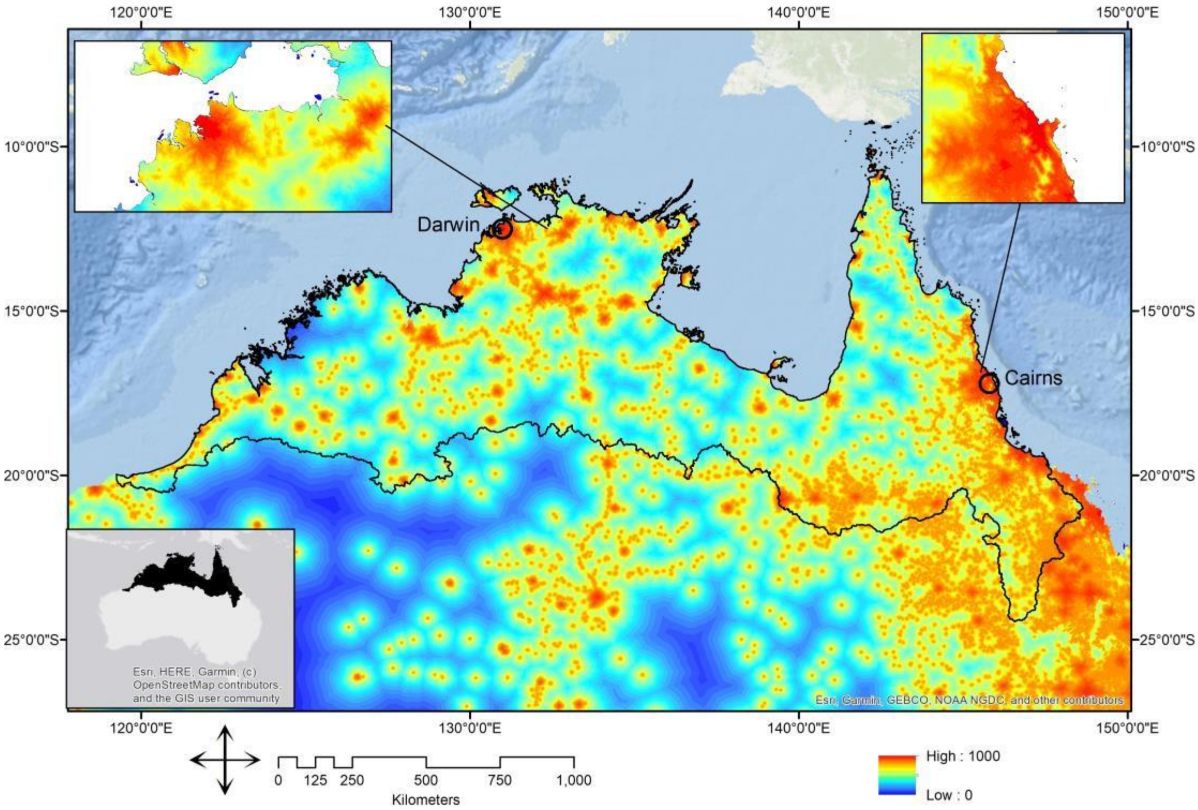

Figure 16. Accessibility of terrestrial flora and fauna for exploitation/negative interactions through humans, i.e. cost distance output when waterways act as roads, after normalisation and inversion.

3.3.10.2 Limitations of this data set

Our model is a proxy for accessibility of the landscape to humans and does not represent actual interactions of impact (or whether these can have positive or negative effects one ecosystems), which depends on the multiple factors described above, including motivations and restrictions to access specific areas. Accessibility could be used a broad proxy to identify how easily an area could be used (e.g. for recreational, subsistence or commercial purposes) and, combined with information about areas or taxa of interest, it can help to identify higher-risk areas for sensitive or highly threatened ecosystems or species. Consequently, this output should be used in conjunction with additional information on factors such as potential user groups, specific activities/possible interactions, and species distribution maps of specific target species (or ecosystems) because such knowledge on occurrences can act as a motivating force for human activity. On the other hand, many 'unintentional' impacts of human activity on the environment, such as damage to vegetation by off-road vehicles or hikers, or death of animals from vehicle traffic, may relate more directly to raw accessibility estimates.

Please also consult the metadata for this data set (dx.doi.org/10.25903/5b72631b2dd70). More detailed technical information and descriptions of data lineages can be found in the relevant methods document *Methods for NESP NAER project 3.3 accessibility to overexploitation* (Engert et al. 2019; located in the RDSI directory for this data set).

Table 13. Accessibility to potential overexploitation output files.

Name	Description	Sources	Resolution
p25s100r200g	Accessibility of terrestrial flora and fauna for exploitation/negative interactions through humans, i.e. cost distance output when waterways act as barriers, after normalisation and inversion (value range 0–1000).	Engert et al. 2019; Geoscience Australia[30]; NVIS[14]; Stein et al. 2012; Geodata Topo 250k[34]; ABS[35]	250m
p25s100r5g	Accessibility of freshwater flora and fauna for exploitation/negative interactions through humans, i.e. cost distance output when waterways act as roads, after normalisation and inversion (value range 0–1000).	Engert et al. 2019; Geoscience Australia[30]; NVIS[14]; Stein et al. 2012; Geodata Topo 250k[34]; ABS[35]	250m
other_layers.zip	Other layers used in the production of the main outputs as well as summaries of cost distances for different areas – a naming convention file is included in the zipped folder		250m

[34] data.gov.au/data/dataset/a0650f18-518a-4b99-a553-44f82f28bb5f
[35] abs.gov.au/ausstats/abs@.nsf/mf/1270.0.55.007

3.3.11 Risks associated with urbanising landscapes

3.3.11.1 Background

Urbanisation directly affect biodiversity through loss of habitat, but also most native plants and animals are not suited to survival in heavily urbanised environments (McKinney, 2006). Our urbanisation threat map (Figure 17) shows currently populated areas (based on land use data from ABARES[36]) and estimates likelihood of urban expansion based on the accessibility cost distance (see 3.3.10 above; Engert et al. unpublished). The cost distance was cut to areas with close proximity to current urban centres with values >90% accessibility. Because accessibility was weighted by population density 2011 Australian Population Grid[37] from the Australian Bureau of Statistics, this output assumes greater urban expansion around larger population centres (Table 14).

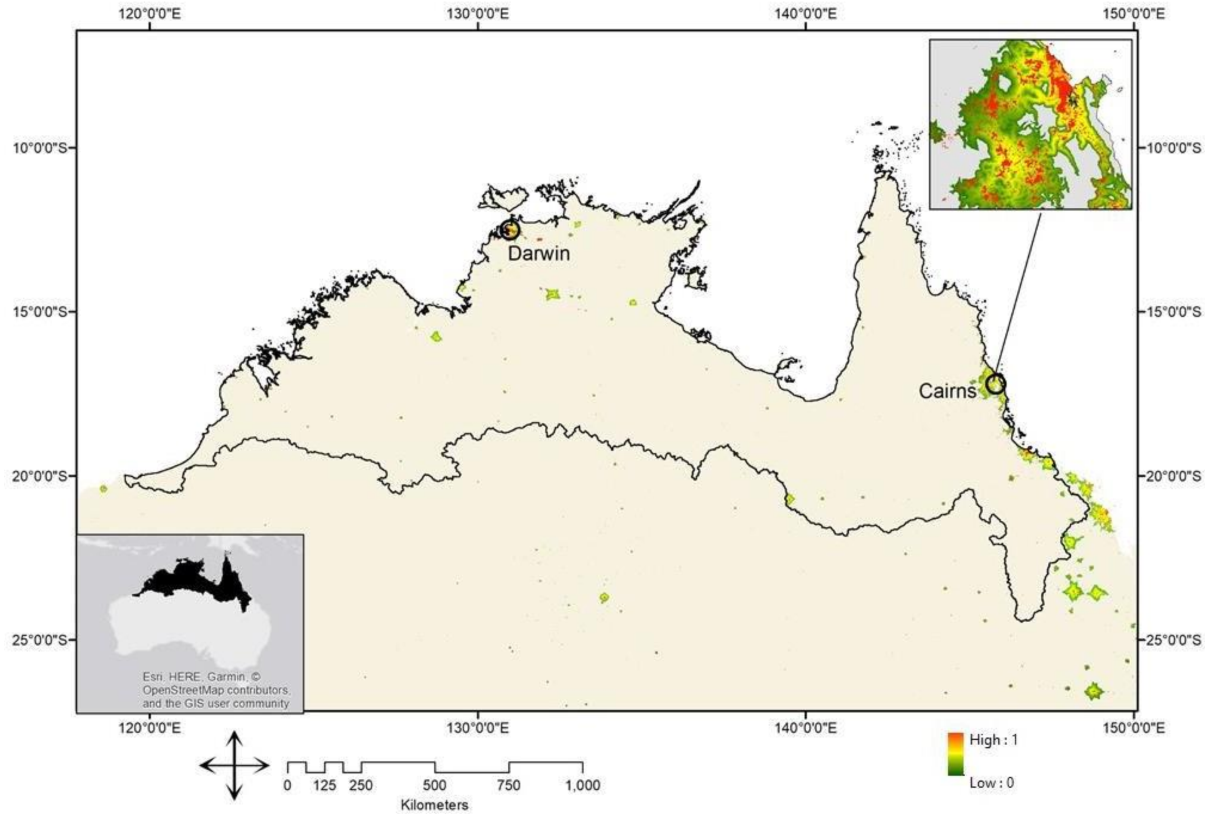

Figure 17. Risk of urbanisation based on current urbanisation and cost distance to currently urbanised areas.

[36] agriculture.gov.au/abares/aclump
[37] abs.gov.au/ausstats/abs@.nsf/mf/1270.0.55.007

Table 14. Urbanisation output files.

Name	Description	Sources	Resolution
finalCurUrb	Areas currently urbanised, i.e. built up and inhabited.	Engert et al. 2019; Geoscience Australia[30]; NVIS[14]; Stein et al. 2012; Geodata Topo 250k[34]; ABS[35]; ABARES[36]	250m
urbriskfin	Risk of urbanisation based on current urbanisation and cost distance to currently urbanised areas	Engert et al. 2019; Geoscience Australia[30]; NVIS[14]; Stein et al. 2012; Geodata Topo 250k[34]; ABS[35]; ABARES[36]	250m

3.3.11.2 Limitations of this data set

The output estimates the likelihood that a pixel will be converted to an urban land-use based on geographic features, accessibility and proximity to existing urban centre of different population sizes. Many other aesthetic, legal, and political factors may influence how urban planners allocate areas for further development and such motivators are difficult to predict. Local development policies and protocols should be consulted when working at a fine resolution close to current urban centres as these can severely limit where urbanisation may occur.

Please also consult the metadata for this data set (dx.doi.org/10.25903/5b72631b2dd70). More detailed technical information and descriptions of data lineages can be found in the relevant methods document *Methods for NESP NAER project 3.3 degree of urbanisation* (Pintor et al. 2019; located in the RDSI directory for this data set).

4. Species vulnerability mapping

4.1 Data access

Pintor, A.; Graham, E.; Kennard, M. (2019). Vulnerability maps identifying the response of threatened species in northern Australia to specific threatening processes. James Cook University, Griffith University, and Australian Government National Environmental Science Program (NESP), Northern Australia Environmental Resources Hub.
dx.doi.org/10.25903/5d2d3d79a6837

The data are accessible through DAWE or through the RDSI collection Q0634 at

/gpfs01/Q0634/Restricted/Vulnerability

4.2 Background

To prevent species' decline and extinction, it is critical for managers and researchers to have an intimate understanding of where a species is located and the effect of threatening processes on species viability (i.e. likelihood of extinction). The combination of presence and effect is defined as the species' vulnerability. Vulnerability to extinction (hereafter, vulnerability) is determined by the species' exposure (present/absent) to a threat and how sensitive the species is to different levels of that threat (Weis, 2016). If exposure, sensitivity and vulnerability are known, targeted threat mitigation and management can be effective in achieving the outcome for the species.

For example, if the northern quoll is sensitive to grazing at medium or high levels because the species is dependent on intact ground cover, then, to prevent species extinction, managers need to know where the species distribution overlaps with grazing activities which are at medium and high intensity. In those overlapping locations, managers might choose to encourage grazing at low intensity to encourage the species' recovery and future viability. If grazing intensities continue at high or medium levels, and the quoll is subject to other threatening processes in the area, its likelihood of persistence could decline (Figure 18). In this study, we combined the outputs from Section 2 (species distributions), and Section 3 (threats distributions) with a sensitivity matrix of species and threat interactions to create maps of species' vulnerability to extinction across their ranges. Finally, we mapped the cumulative vulnerability to extinction of each species included in this project. Critically, these maps can inform managers about prioritisation. For example, if a species is exposed to multiple significant threatening processes that are likely to significantly affect the viability of the species, that species is likely to be a higher management priority than a species that is exposed to fewer threatening processes.

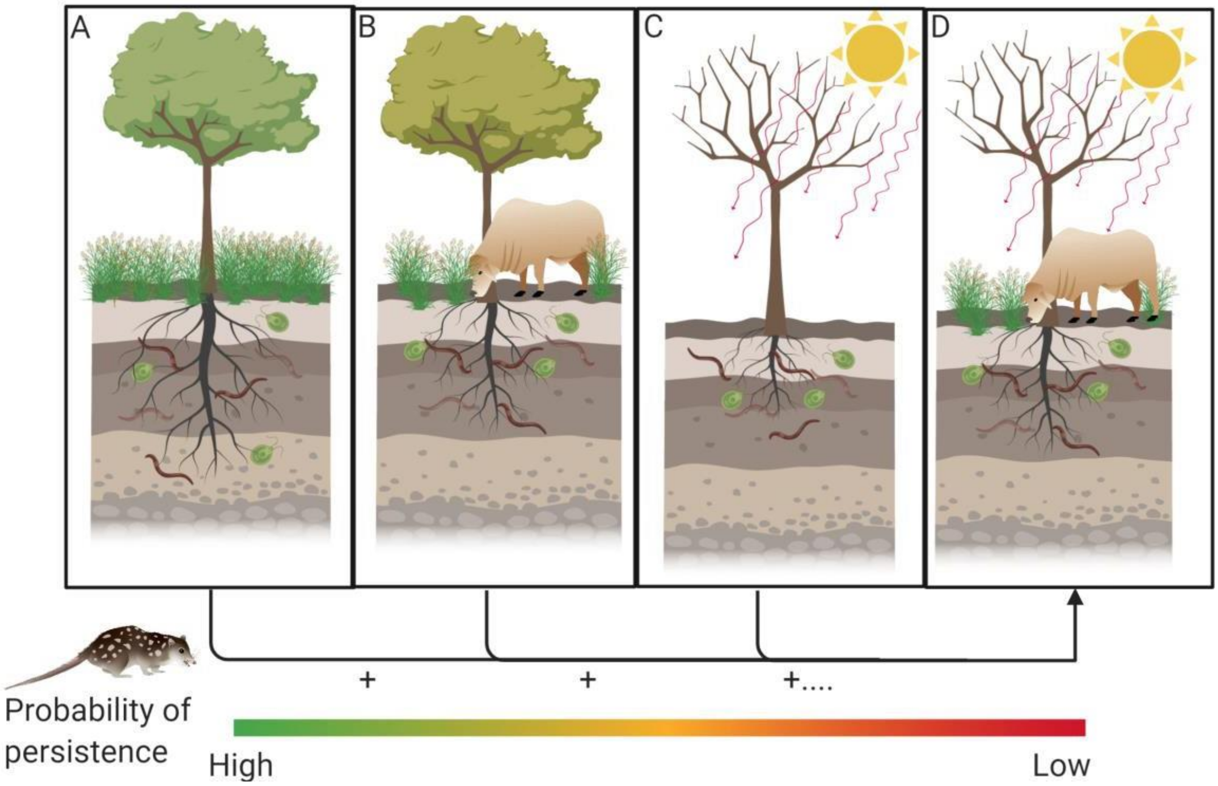

Figure 18. Schematic representation of cumulative vulnerability. A) An area of suitable habitat for a threatened species, in this case, the Northern Quoll, combined with B) a certain degree of vulnerability from grazing pressure in that area based on the level of grazing and the species' sensitivity to the threat plus C) a certain degree of vulnerability from temperature dissimilarity in that area based on the level of temperature dissimilarity and the species' sensitivity to the threat leads to D) a cumulative vulnerability from these two example threats. In our analysis, the vulnerabilities of each species to all threats that it is sensitive to were combined rather than just the two threats shown here.

4.3 Outputs

4.3.1 Threats transformed for vulnerability analysis

All threat outputs (Section 3) were transformed to an appropriate semi-linear scale and rescaled before assessing vulnerability (for details on methods see *Methods for NESP NAER project 3.3 spatial estimates of threatened species vulnerability*; Pintor et al. 2019; located in the RDSI directory for this data set). This was a necessary step to create consistency among the threat levels of low (1), medium (2), and high (3) from an expert elicitation process. These rescaled threat layers can be accessed as part of the vulnerability data collection.

4.3.2 Species x threat interactions

Vulnerability was defined as the product of exposure and sensitivity, i.e. the likelihood of persistence of a population of a species when exposed to the threat. The sensitivity of a species to a threat was derived from previous studies using a robust expert elicitation process (Cattarino et al. 2018; Alvarez-Romero et al., in prep.). The vulnerability of a species was defined as the interaction of the species' distribution, its sensitivity to a threat and the extent to which it overlaps with a threatening process (i.e. if a species is highly sensitive to a threat, and it is exposed to high levels of that threat, it will have a high overall vulnerability to extinction or population decline. In the context of this study, exposure was defined as any areas of suitable habitat that overlap with the presence of a particular threat. Within this area of overlap, different threat intensities or probabilities can occur. To estimate the vulnerability of a species across its exposed range, one therefore needs to have an idea of what its response to these different levels of threat is likely to be. We estimated this based on a previous study using an extensive expert elicitation process to determine the responses of different functional groups to low, medium, or high threat levels. For each threat x species interaction, an exposure map was created (areas of overlap between species range and threat presence). The different threat levels within the exposed areas were then transformed into the corresponding risk of extinction at that threat level for that species in each pixel (Figure 19). Two different outputs are available for any species x threat interaction (if the species was actually sensitive to the threat): exposure (overlap of species and threat) and vulnerability (the species estimated response to different threat levels across its exposure range; Table 15).

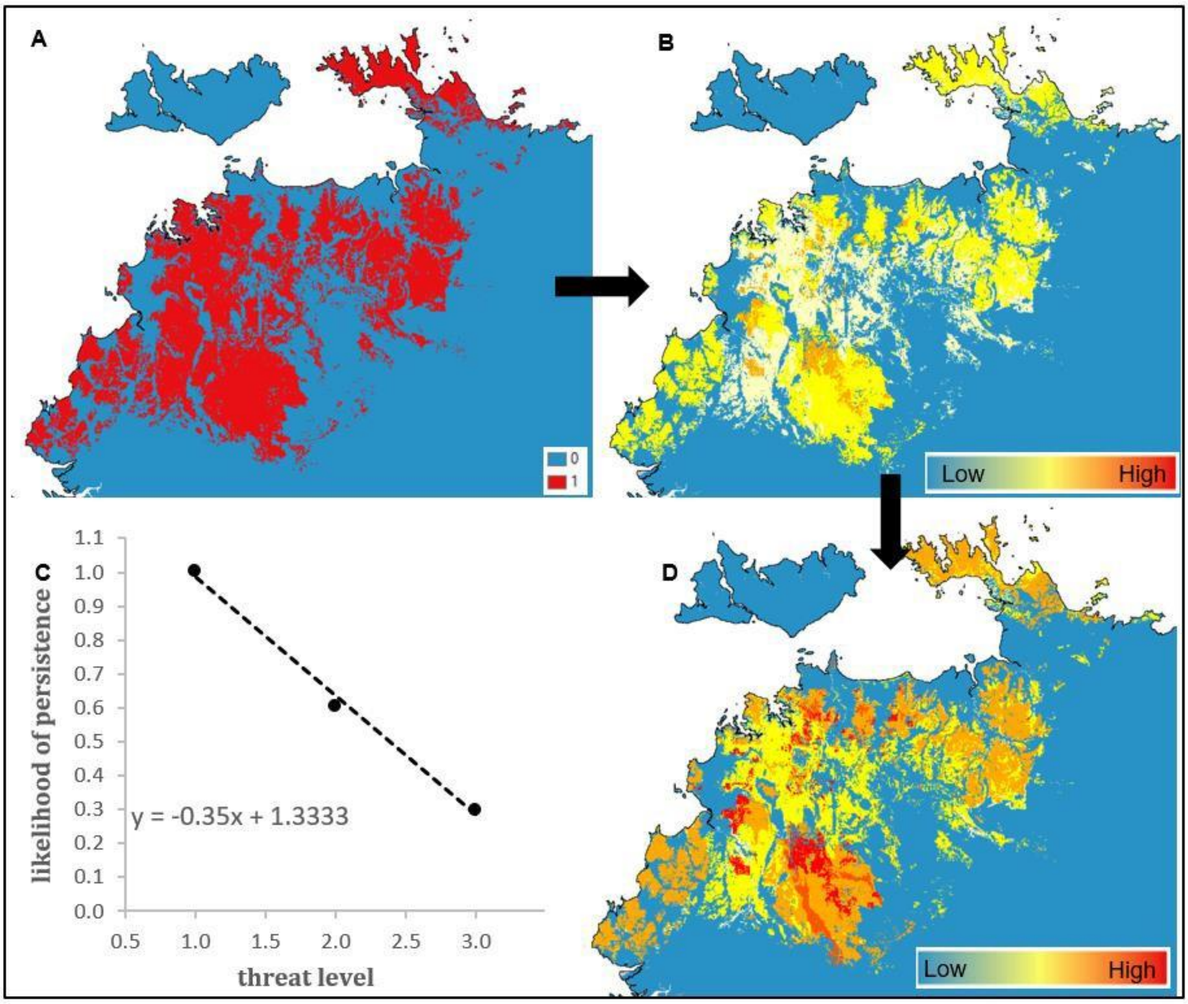

*Figure 19. Explanation of how the presence of suitable species habitat (A) was used to extract exposure to a certain threat within that area (B; here agriculture) and combined with its sensitivity to that threat (C) to establish vulnerability to this threat across its range (D) for the endangered (EPBC) mainland Northern Territory population of the Black-footed Tree-rat (*Mesembriomys gouldii gouldii*)[38]. Note that areas of high threat intensity in B were up-weighted in D in accordance to the species' high sensitivity, or low probability of persistence, to those threat levels (at threat level 3 in C).*

[38] Note that the conservation status of particular species may change over time; for the latest status, refer to the relevant responsible agency.

Table 15. Data files for species-specific exposure and vulnerability to individual threats.

Name	Description	Resolution
Gen_sp_Threat_Exp	Species x threat exposure	250m
Gen_sp_Threat_Vul	Species x threat vulnerability	250m

4.3.3 Cumulative vulnerability

In addition to individual species vulnerability maps per threat, we also provide summary maps of cumulative vulnerability for each species, cumulative vulnerability maps across all species within a taxon, and cumulative vulnerability maps for all species affected by each threat. For example, the endangered (EPBC) population of the Black-footed Tree-rat in mainland Northern Territory (*Mesembriomys gouldii gouldii*) has several outputs describing how vulnerable it is to each threat across its range within northern Australia. The sum of these maps demonstrates how vulnerable the species is overall across its range (Figure 20). If we then add this total vulnerability of this species and all other mammal species together, we get a cumulative vulnerability map for mammals across northern Australia (Table 16).

Table 16. Data files for summaries of cumulative vulnerabilities for each species and across different groups and threats

Name	Description	Resolution
Gen_sp_CumVul	Species total cumulative vulnerability	250m
Gen_sp_CumVulSC	Species total cumulative vulnerability rescaled 0-1	250m
Group_Vulnerability	Taxonomic or functional group total vulnerability	250m
Group_Vulnerability_Scaled	Taxonomic group total vulnerability based on rescaled 0-1 single species vulnerabilities	250m
Northern_Vulnerability	Threatened species total vulnerability	250m
Northern_Vulnerability_Scaled	Threatened species total vulnerability based on rescaled 0-1 single species vulnerabilities	250m
Threat_totVul	Threat cumulative vulnerability across all sensitive species	250m
Threat_totVulSc	Threat cumulative vulnerability across all sensitive species based on rescaled 0-1 single species vulnerabilities	250m

4.3.4 Limitations of the vulnerability data set

Cumulative vulnerability maps were created in an additive way. In reality, vulnerability to different threats may depend on the interactions of the threats or vulnerability to one major threat may render effects of other threats negligible. Similarly, not all threats can practically co- occur in one grid cell. Additionally, many threats incorporate probability or potential intensity rather than just currently realised threat intensity. Our vulnerability estimates, therefore, are a measure of maximum potential impact risk rather than realised impact.

Please also consult the metadata for this data set (dx.doi.org/10.25903/5d2d3d79a6837). More detailed technical information and descriptions of data lineages can be found in the relevant methods document *Methods for NESP NAER project 3.3 spatial estimates of threatened species vulnerability* (Pintor et al. 2019; located in the RDSI directory for this data set).

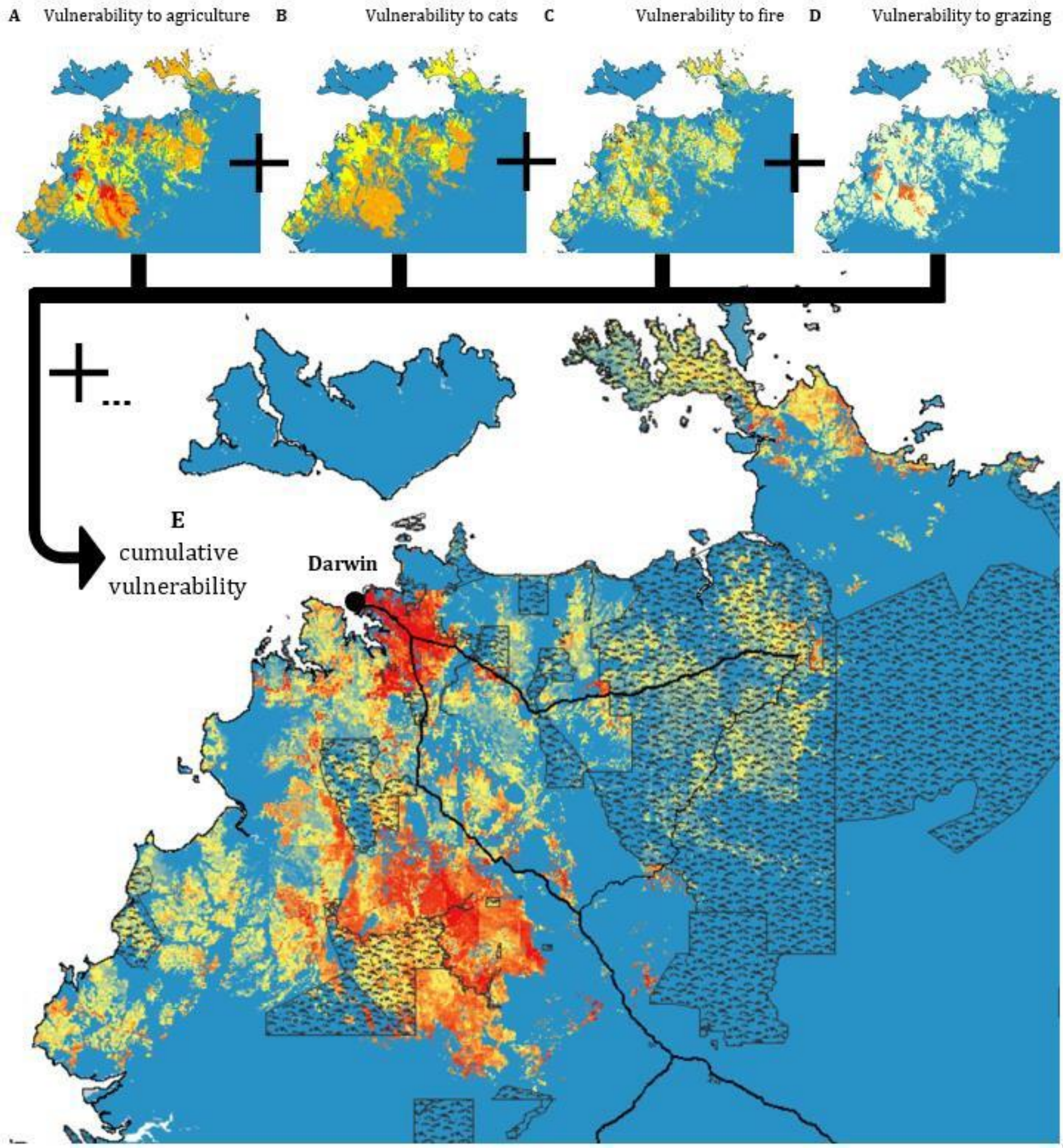

*Figure 20. Explanation of how individual vulnerabilities to e.g. agriculture, feral cats, fire regime alterations, grazing, and other threats, were combined into cumulative vulnerabilities for an endangered (EPBC) population of the Black-footed Tree-rat (*Mesembriomys gouldii gouldii*). Major roads are shown as black lines and protected areas as black-patterned areas.*

5. Key research findings and applications

The project filled three critically important knowledge gaps concerning: i) the distribution of species of conservation concern across northern Australia, ii) their level of exposure to various threats and iii) their vulnerability as a result of exposure and differential sensitivity to threats. The data created in this project provide a key portal for conservation and ecological research projects and there are several research directions that have arisen out of this work. Notably, most data created and collated in this study represent the best currently available knowledge on threatened species and threatening process across northern Australia and achieves two essential objectives: i) fill current knowledge gaps with the best available data and ii) identify further knowledge gaps that need to be filled to further improve this 'baseline' data. These knowledge gaps and data limitations include, but are not limited to, the following:

First, northern Australia spans very remote and often under surveyed landscapes. Models are representations of reality and are utterly dependent on the quality of the supporting information. Ideally, estimates of habitat suitability should be backed up by ground truthing efforts and surveys, which, in turn, can be guided by models of habitat suitability.

Second, the extent to which certain threats have deviated from ecological baselines is poorly understood. Recent literature has improved our understanding of some modern patterns. However, we do not have reliable ecological baseline data for some threats, such as for example ideal fire regime scenarios across northern Australia. Lack of data on fire regimes from time-steps that include pre and post traditional burning practices could skew the impact of fire regime change on certain species. Future research on historical patterns of burning as well as fire regime implications on priority species is much needed.

For some threats, more fine-resolution source data need to be collected/created. For example, agricultural suitability greatly depends on soil parameters that are not well measured at a fine resolution across Australia, with the exception of some recent data sets created for certain areas by NAWRA (Northern Australia Water Resource Assessment; CSIRO) and similar projects.

Lastly, most of our information on species' sensitivity to different threats is based on expert opinion and generalised across functional groups. More empirical research is needed on the responses of individual species or species with certain traits to different levels of threats, as well as on the mechanisms facilitating such responses.

Nevertheless, our outputs represent a huge advance in our understanding of how threats are affecting northern Australian biodiversity and are already being use by a variety of end users, including CSIRO, researchers and many government agencies. The fine-resolution (~250–1km) of our maps facilitates effective conservation management at relevant scales and provides novel options for decision making processes. Another upcoming NESP project is aiming to expand the research conducted here to all of Australia and use it for detailed management recommendations.

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Appendix 1: Summary table of data locations, formats and descriptions

No.	Data set description	Accessibility	doi	HPC storage location
1	Low resolution species distribution models of threatened species in northern Australia	Public	dx.doi.org/10.4225/28/5a9f31e23e80b	HPC: sftp://zodiac.hpc.jcu.edu.au Directory: /gpfs01/Q0634/Public
2	High resolution species distribution models of threatened species in northern Australia	Restricted	dx.doi.org/10.4225/28/5a9f31e23e80b	HPC: sftp://zodiac.hpc.jcu.edu.au Directory: /gpfs01/Q0634/Restricted
3	Hotspot maps of threatened species in northern Australia	Restricted	dx.doi.org/10.4225/28/5a9f31e23e80b	HPC: sftp://zodiac.hpc.jcu.edu.au Directory: /gpfs01/Q0634/Restricted
4	Changes in catchment runoff regime & disturbance	Restricted	dx.doi.org/10.25903/5b72631b2dd70	HPC: sftp://zodiac.hpc.jcu.edu.au Directory: /gpfs01/Q0634/Restricted
5	Probability of mining	Restricted	dx.doi.org/10.25903/5b72631b2dd70	HPC: sftp://zodiac.hpc.jcu.edu.au Directory: /gpfs01/Q0634/Restricted
6	Grazing impact risk	Restricted	dx.doi.org/10.25903/5b72631b2dd70	HPC: sftp://zodiac.hpc.jcu.edu.au Directory: /gpfs01/Q0634/Restricted
7	Land use for agriculture and forestry	Restricted	dx.doi.org/10.25903/5b72631b2dd70	HPC: sftp://zodiac.hpc.jcu.edu.au Directory: /gpfs01/Q0634/Restricted
8	Urbanisation Intensity	Restricted	dx.doi.org/10.25903/5b72631b2dd70	HPC: sftp://zodiac.hpc.jcu.edu.au Directory: /gpfs01/Q0634/Restricted
9	Predicted change in climate stressors & future climate dissimilarity	Restricted	dx.doi.org/10.25903/5b72631b2dd70	HPC: sftp://zodiac.hpc.jcu.edu.au Directory: /gpfs01/Q0634/Restricted
10	Invasive weeds and animal distribution models & risk of spread from current invasion areas	Restricted	dx.doi.org/10.25903/5b72631b2dd70	HPC: sftp://zodiac.hpc.jcu.edu.au Directory: /gpfs01/Q0634/Restricted

No.	Data set description	Accessibility	doi	HPC storage location
11	Invasive animals distribution models & risk of spread from current invasion areas	Restricted	dx.doi.org/10.25903/5b72631b2dd70	HPC: sftp://zodiac.hpc.jcu.edu.au Directory: /gpfs01/Q0634/Restricted
12	Potential overexploitation	Restricted	dx.doi.org/10.25903/5b72631b2dd70	HPC: sftp://zodiac.hpc.jcu.edu.au Directory: /gpfs01/Q0634/Restricted
13	Wildlife diseases distribution models & risk of spread from currently affected areas	Restricted	dx.doi.org/10.25903/5b72631b2dd70	HPC: sftp://zodiac.hpc.jcu.edu.au Directory: /gpfs01/Q0634/Restricted
14	Sensitivity matrix identifying sensitivity of threatened species in northern Australia to specific threatening processes	Restricted	Tba	HPC: sftp://zodiac.hpc.jcu.edu.au Directory: /gpfs01/Q0634/Restricted
15	Species x threat vulnerability maps and vulnerability hotspot maps.	Restricted	dx.doi.org/10.25903/5b72631b2dd70	HPC: sftp://zodiac.hpc.jcu.edu.au Directory: /gpfs01/Q0634/Restricted

Appendix 2: Summary table of species modelled in this project

Birds			
Family	**Order**	**Scientific name**	**Common name**
Accipitriformes	Accipitridae	*Elanus scriptus*	Letter-winged Kite
Accipitriformes	Accipitridae	*Erythrotriorchis radiatus*	Red Goshawk
Accipitriformes	Accipitridae	*Lophoictinia isura*	Square-tailed Kite
Casuariiformes	Casuariidae	*Casuarius casuarius*	Southern Cassowary
Casuariiformes	Dromaiidae	*Dromaius novaehollandiae*	Emu
Charadriiformes	Burhinidae	*Burhinus grallarius*	Bush Stone-curlew
Charadriiformes	Burhinidae	*Esacus magnirostris*	Beach Stone-curlew
Charadriiformes	Charadriidae	*Charadrius leschenaultii*	Greater Sand Plover
Charadriiformes	Charadriidae	*Charadrius mongolus*	Lesser Sand Plover
Charadriiformes	Charadriidae	*Pluvialis squatarola*	Grey Plover
Charadriiformes	Rostratulidae	*Rostratula australis*	Australian Painted Snipe
Charadriiformes	Scolopacidae	*Arenaria interpres*	Ruddy Turnstone
Charadriiformes	Scolopacidae	*Calidris acuminata*	Sharp-tailed Sandpiper
Charadriiformes	Scolopacidae	*Calidris canutus*	Red Knot
Charadriiformes	Scolopacidae	*Calidris canutus piersmai*	Red Knot
Charadriiformes	Scolopacidae	*Calidris canutus rogersi*	Red Knot

Birds			
Family	**Order**	**Scientific name**	**Common name**
Charadriiformes	Scolopacidae	*Calidris ferruginea*	Curlew Sandpiper
Charadriiformes	Scolopacidae	*Calidris ruficollis*	Red-necked Stint
Charadriiformes	Scolopacidae	*Calidris tenuirostris*	Great Knot
Charadriiformes	Scolopacidae	*Limnodromus semipalmatus*	Asian Dowitcher
Charadriiformes	Scolopacidae	*Limosa lapponica*	Bar-tailed Godwit
Charadriiformes	Scolopacidae	*Limosa lapponica baueri*	Bar-tailed Godwit
Charadriiformes	Scolopacidae	*Limosa lapponica menzbieri*	Bar-tailed Godwit
Charadriiformes	Scolopacidae	*Limosa limosa*	Black-tailed Godwit
Charadriiformes	Scolopacidae	*Numenius madagascariensis*	Eastern Curlew
Charadriiformes	Scolopacidae	*Numenius phaeopus*	Whimbrel
Charadriiformes	Scolopacidae	*Tringa brevipes*	Grey-tailed Tattler
Charadriiformes	Turnicidae	*Turnix olivii*	Buff-breasted Button-quail
Ciconiiformes	Ciconiidae	*Ephippiorhynchus asiaticus*	Black-necked Stork
Columbiformes	Columbidae	*Geophaps smithii*	Partridge Pigeon
Columbiformes	Columbidae	*Geophaps smithii blaauwi*	Partridge Pigeon
Columbiformes	Columbidae	*Geophaps smithii smithii*	Partridge Pigeon
Columbiformes	Columbidae	*Petrophassa albipennis*	White-quilled Rock-pigeon

Birds			
Family	**Order**	**Scientific name**	**Common name**
Columbiformes	Columbidae	*Petrophassa albipennis boothi*	White-quilled Rock-pigeon
Columbiformes	Columbidae	*Petrophassa rufipennis*	Chestnut-quilled Rock-pigeon
Columbiformes	Columbidae	*Phaps histrionica*	Flock Bronzewing
Columbiformes	Columbidae	*Ptilinopus cinctus*	Banded Fruit-dove
Falconiformes	Falconidae	*Falco hypoleucos*	Grey Falcon
Falconiformes	Falconidae	*Falco peregrinus*	Peregrine Falcon
Gruiformes	Rallidae	*Amaurornis moluccana*	Pale-vented Bush-hen
Gruiformes	Rallidae	*Eulabeornis castaneoventris*	Chestnut Rail
Gruiformes	Gruidae	*Grus antigone*	Sarus Crane
Otidiformes	Otididae	*Ardeotis australis*	Australian Bustard
Passeriformes	Acrocephalidae	*Acrocephalus australis*	Australian Reed-warbler
Passeriformes	Alaudidae	*Mirafra javanica*	Horsfields Bushlark
Passeriformes	Alaudidae	*Mirafra javanica melvillensis*	Horsfields Bushlark
Passeriformes	Estrildidae	*Erythrura gouldiae*	Gouldian Finch
Passeriformes	Estrildidae	*Erythrura trichroa*	Blue-faced Parrot-finch
Passeriformes	Estrildidae	*Heteromunia pectoralis*	Pictorella Mannikin
Passeriformes	Estrildidae	*Lonchura flaviprymna*	Yellow-rumped Mannikin

Birds			
Family	**Order**	**Scientific name**	**Common name**
Passeriformes	Estrildidae	*Neochmia phaeton*	Crimson Finch
Passeriformes	Estrildidae	*Neochmia phaeton evangelinae*	Crimson Finch
Passeriformes	Estrildidae	*Neochmia ruficauda*	Star Finch
Passeriformes	Estrildidae	*Neochmia ruficauda clarescens*	Star Finch
Passeriformes	Estrildidae	*Neochmia ruficauda ruficauda*	Star Finch
Passeriformes	Estrildidae	*Neochmia ruficauda subclarescens*	Star Finch
Passeriformes	Estrildidae	*Poephila cincta*	Black-throated Finch
Passeriformes	Estrildidae	*Poephila cincta cincta*	Black-throated Finch
Passeriformes	Maluridae	*Amytornis dorotheae*	Carpentarian Grasswren
Passeriformes	Maluridae	*Amytornis housei*	Black Grasswren
Passeriformes	Maluridae	*Amytornis woodwardi*	White-throated Grasswren
Passeriformes	Maluridae	*Malurus coronatus*	Purple-crowned Fairy-wren
Passeriformes	Maluridae	*Malurus coronatus coronatus*	Purple-crowned Fairy-wren
Passeriformes	Maluridae	*Malurus coronatus macgillivrayi*	Purple-crowned Fairy-wren
Passeriformes	Meliphagidae	*Epthianura crocea*	Yellow Chat
Passeriformes	Meliphagidae	*Epthianura crocea crocea*	Yellow Chat
Passeriformes	Meliphagidae	*Epthianura crocea tunneyi*	Yellow Chat

Birds			
Family	**Order**	**Scientific name**	**Common name**
Passeriformes	Meliphagidae	*Meliphaga albilineata*	White-lined Honeyeater
Passeriformes	Meliphagidae	*Grantiella picta*	Painted Honeyeater
Passeriformes	Meliphagidae	*Lichenostomus flavescens*	Yellow-tinted Honeyeater
Passeriformes	Meliphagidae	*Lichenostomus flavescens melvillensis*	Yellow-tinted Honeyeater
Passeriformes	Meliphagidae	*Trichodere cockerelli*	White-streaked Honeyeater
Passeriformes	Monarchidae	*Arses lorealis*	Frilled-necked Monarch
Passeriformes	Pachycephalidae	*Falcunculus frontatus*	Crested Shrike-tit
Passeriformes	Pachycephalidae	*Falcunculus frontatus whitei*	Crested Shrike-tit
Passeriformes	Petroicidae	*Melanodryas cucullata*	Hooded Robin
Passeriformes	Petroicidae	*Melanodryas cucullata melvillensis*	Hooded Robin
Passeriformes	Petroicidae	*Poecilodryas cerviniventris*	Buff-sided Robin
Passeriformes	Ptilonorhynchidae	*Ptilonorhynchus cerviniventris*	Fawn-breasted Bowerbird
Psittaciformes	Cacatuidae	*Calyptorhynchus lathami*	Glossy Black Cockatoo
Psittaciformes	Cacatuidae	*Lophochroa leadbeateri*	Major Mitchells Cockatoo
Psittaciformes	Cacatuidae	*Probosciger aterrimus*	Palm Cockatoo
Psittaciformes	Psittaculidae	*Cyclopsitta diophthalma*	Double-eyed Fig-parrot
Psittaciformes	Psittaculidae	*Cyclopsitta diophthalma coxeni*	Double-eyed Fig-parrot

Birds			
Family	**Order**	**Scientific name**	**Common name**
Psittaciformes	Psittaculidae	*Cyclopsitta diophthalma macleayana*	Double-eyed Fig-parrot
Psittaciformes	Psittaculidae	*Cyclopsitta diophthalma marshalli*	Double-eyed Fig-parrot
Psittaciformes	Psittaculidae	*Eclectus roratus*	Eclectus Parrot
Psittaciformes	Psittaculidae	*Polytelis alexandrae*	Princess Parrot
Psittaciformes	Psittaculidae	*Psephotus chrysopterygius*	Golden-shouldered Parrot
Psittaciformes	Psittaculidae	*Psephotus dissimilis*	Hooded Parrot
Strigiformes	Strigidae	*Ninox rufa*	Rufous Owl
Strigiformes	Strigidae	*Ninox rufa meesi*	Rufous Owl
Strigiformes	Tytonidae	*Tyto longimembris*	Eastern Grass Owl
Strigiformes	Tytonidae	*Tyto novaehollandiae*	Masked Owl
Strigiformes	Tytonidae	*Tyto novaehollandiae kimberli*	Masked Owl
Strigiformes	Tytonidae	*Tyto novaehollandiae melvillensis*	Masked Owl

Crustaceans			
Family	**Order**	**Scientific name**	**Common name**
Decapoda	Atyidae	*Caridina spelunca*	Rock Freshwater Prawn
Decapoda	Gecarcinucidae	*Austrothelphusa tigrina*	Freshwater Crab
Decapoda	Gecarcinucidae	*Austrothelphusa valentula*	Freshwater Crab
Decapoda	Gecarcinucidae	*Austrothelphusa wasselli*	Freshwater Crab
Decapoda	Palaemonidae	*Leptopalaemon gibbosus*	Rock Freshwater Prawn
Decapoda	Palaemonidae	*Leptopalaemon glabrus*	Rock Freshwater Prawn
Decapoda	Palaemonidae	*Leptopalaemon gudjangah*	Rock Freshwater Prawn
Decapoda	Palaemonidae	*Leptopalaemon magelensis*	Rock Freshwater Prawn
Decapoda	Palaemonidae	*Macrobrachium rosenbergii*	Freshwater Crayfish
Decapoda	Parastacidae	*Cherax cartalacoolah*	Freshwater Crayfish
Decapoda	Parastacidae	*Cherax parvus*	Freshwater Crayfish
Decapoda	Parastacidae	*Euastacus balanensis*	Freshwater Crayfish
Decapoda	Parastacidae	*Euastacus fleckeri*	Freshwater Crayfish
Decapoda	Parastacidae	*Euastacus robertsi*	Freshwater Crayfish
Decapoda	Parastacidae	*Euastacus yigara*	Freshwater Crayfish
Decapoda	Atyidae	*Pycnisia raptor*	Rock Freshwater Prawn

Fishes			
Family	**Order**	**Scientific name**	**Common name**
Anguilliformes	Anguillidae	*Anguilla bicolor*	Indian short-finned eel
Atheriniformes	Atherinidae	*Craterocephalus helenae*	Drysdale hardyhead
Atheriniformes	Atherinidae	*Craterocephalus lentiginosus*	Freckled hardyhead
Atheriniformes	Atherinidae	*Craterocephalus marianae*	Mariana's hardyhead
Atheriniformes	Melanotaeniidae	*Cairnsichthys rhombosomoides*	Cairns rainbowfish
Atheriniformes	Melanotaeniidae	*Melanotaenia eachamensis*	Lake Eacham rainbowfish
Atheriniformes	Melanotaeniidae	*Melanotaenia exquisita*	Exquisite rainbowfish
Atheriniformes	Melanotaeniidae	*Melanotaenia gracilis*	Slender rainbowfish
Atheriniformes	Melanotaeniidae	*Melanotaenia maccullochi*	McCulloch's rainbowfish
Atheriniformes	Melanotaeniidae	*Melanotaenia pygmaea*	Pygmy rainbowfish
Beloniformes	Hemiramphidae	*Zenarchopterus caudovittatus*	Long-jawed river garfish
Carcharhiniformes	Carcharhinidae	*Carcharhinus leucas*	Bull shark
Carcharhiniformes	Carcharhinidae	*Glyphis garricki*	Northern river shark
Carcharhiniformes	Carcharhinidae	*Glyphis glyphis*	Speartooth shark
Clupeiformes	Engraulidae	*Thryssa scratchleyi*	Freshwater anchovy
Dasyuromorphia	Dasyatidae	*Himantura (Urogymnus) dalyensis*	Freshwater whipray
Dasyuromorphia	Dasyatidae	*Himantura hortlei*	Hortle's whipray

Fishes			
Family	**Order**	**Scientific name**	**Common name**
Elopiformes	Megalopidae	*Megalops cyprinoides*	Tarpon
Perciformes	Eleotridae	*Bostrichthys zonatus*	Barred gudgeon
Perciformes	Eleotridae	*Hypseleotris barrawayi*	Barraway’s carp gudgeon
Perciformes	Eleotridae	*Hypseleotris ejuncida*	Slender gudgeon
Perciformes	Eleotridae	*Hypseleotris kimberleyensis*	Barnett River gudgeon
Perciformes	Eleotridae	*Hypseleotris regalis*	Prince Regent gundgeon
Perciformes	Eleotridae	*Kimberleyeleotris hutchinsi*	Mitchell gudgeon
Perciformes	Eleotridae	*Kimberleyeleotris notata*	Drysdale gudgeon
Perciformes	Eleotridae	*Mogurnda mogurnda*	Northern purple-spotted gudgeon
Perciformes	Eleotridae	*Mogurnda oligolepis*	False-spotted gudgeon
Perciformes	Gobiidae	*Glossogobius bellendenensis*	Mulgrave goby
Perciformes	Gobiidae	*Stenogobius psilosinionus*	Teardrop goby
Perciformes	Gobiidae	*Stiphodon atratus*	Daintree cling goby
Perciformes	Gobiidae	*Stiphodon birdsong*	Emerald cling goby
Perciformes	Gobiidae	*Stiphodon rutilaureus*	Orange cling goby
Perciformes	Gobiidae	*Stiphodon semoni*	Opal cling goby
Perciformes	Kurtidae	*Kurtus gulliveri*	Nurseryfish

Fishes			
Family	**Order**	**Scientific name**	**Common name**
Perciformes	Percichthyidae	*Guyu wujalwujalensis*	Bloomfield River cod
Perciformes	Terapontidae	*Hannia greenwayi*	Greenway's grunter
Perciformes	Terapontidae	*Hephaestus epirrhinos*	Long-nose sooty grunter
Perciformes	Terapontidae	*Leiopotherapon macrolepis*	Large-scaled grunter
Perciformes	Terapontidae	*Pingalla gilberti*	Gilbert's grunter
Perciformes	Terapontidae	*Pingalla lorentzi*	Lorentz's grunter
Perciformes	Terapontidae	*Pingalla midgleyi*	Midgley's grunter
Perciformes	Terapontidae	*Scortum neili*	Angalarri grunter
Perciformes	Terapontidae	*Scortum parviceps*	Small-headed grunter
Perciformes	Terapontidae	*Syncomistes kimberleyensis*	Kimberley grunter
Perciformes	Terapontidae	*Syncomistes rastellus*	Drysdale grunter
Pristiformes	Pristidae	*Pristis clavata*	Dwarf sawfish
Pristiformes	Pristidae	*Pristis pristis*	Largetooth sawfish
Siluriformes	Ariidae	*Cinetodus froggatti*	Smallmouth catfish
Siluriformes	Plotosidae	*Porochilus obbesi*	Obbes' catfish
Siluriformes	Plotosidae	*Neosilurus spA*	Flinders catfish

Frogs			
Family	**Order**	**Scientific name**	**Common name**
Anura	Hylidae	*Litoria andiirrmalin*	Cape Melville Tree Frog
Anura	Hylidae	*Litoria cryptotis*	Hidden-Ear Frog
Anura	Hylidae	*Litoria dayi*	Australian Lace Lid
Anura	Hylidae	*Litoria jungguy*	Stoney CreekFrog
Anura	Hylidae	*Litoria longirostris*	Long Snouted Tree Frog
Anura	Hylidae	*Litoria lorica*	Armoured Frog
Anura	Hylidae	*Litoria myola*	Kuranda Tree Frog
Anura	Hylidae	*Litoria nannotis*	Waterfall Frog
Anura	Hylidae	*Litoria nyakalensis*	Mountain Mistfrog
Anura	Hylidae	*Litoria platycephala*	Water-holding Frog
Anura	Hylidae	*Litoria rheocola*	Common Mistfrog
Anura	Hylidae	*Litoria serrata*	Green-Eyed Tree Frog
Anura	Limnodynastidae	*Notaden nichollsi*	Desert Shovelfoot
Anura	Limnodynastidae	*Notaden weigeli*	Weigels Toad
Anura	Microhylidae	*Cophixalus aenigma*	Tapping Nurseryfrog
Anura	Microhylidae	*Cophixalus bombiens*	Buzzing Frog
Anura	Microhylidae	*Cophixalus concinnus*	Elegant Frog

Frogs			
Family	**Order**	**Scientific name**	**Common name**
Anura	Microhylidae	*Cophixalus crepitans*	Rattling Frog
Anura	Microhylidae	*Cophixalus exiguus*	Scanty Frog
Anura	Microhylidae	*Cophixalus hosmeri*	Hosmers Frog
Anura	Microhylidae	*Cophixalus kulakula*	Kutini Boulder-Frog
Anura	Microhylidae	*Cophixalus monticola*	Mountain-Top Nursery Frog
Anura	Microhylidae	*Cophixalus neglectus*	Neglected Frog
Anura	Microhylidae	*Cophixalus pakayakulangun*	Golden-Capped Boulder-Frog
Anura	Microhylidae	*Cophixalus peninsularis*	Cape York Nursery Frog
Anura	Microhylidae	*Cophixalus saxatilis*	Black Mountain Boulder Frog
Anura	Microhylidae	*Cophixalus zweifeli*	Cape Melville Frog
Anura	Myobatrachidae	*Pseudophryne covacevichae*	Magnificent Broodfrog
Anura	Myobatrachidae	*Taudactylus acutirostris*	Sharp Snouted Day Frog
Anura	Myobatrachidae	*Taudactylus rheophilus*	Tinkling Frog
Anura	Myobatrachidae	*Uperoleia arenicola*	Jabiru Toadlet
Anura	Myobatrachidae	*Uperoleia daviesae*	Daviess Toadlet
Anura	Myobatrachidae	*Uperoleia marmorata*	Marbled Toadlet
Anura	Myobatrachidae	*Uperoleia minima*	Small Toadlet

Frogs			
Family	**Order**	**Scientific name**	**Common name**
Anura	Myobatrachidae	*Uperoleia orientalis*	Alexandria Toadlet
Anura	Ranidae	*Hylarana daemeli*	Water Frog

Insects			
Family	**Order**	**Scientific name**	**Common name**
Coleoptera	Scarabaeidae	*Aulacopris matthewsi*	a scarab beetle
Coleoptera	Scarabaeidae	*Coproecus hemisphaericus*	a scarab beetle
Coleoptera	Scarabaeidae	*Demarziella eungella*	a scarab beetle
Coleoptera	Scarabaeidae	*Demarziella planitarsis*	a scarab beetle
Coleoptera	Scarabaeidae	*Demarziella storeyi*	a scarab beetle
Coleoptera	Scarabaeidae	*Demarziella tropicalis*	a scarab beetle
Coleoptera	Scarabaeidae	*Lepanus pisoniae*	a scarab beetle
Coleoptera	Scarabaeidae	*Onthophagus bindaree*	a scarab beetle
Coleoptera	Scarabaeidae	*Onthophagus ferrari*	a Scarab Beetle
Coleoptera	Scarabaeidae	*Onthophagus lamgalio*	a scarab beetle
Coleoptera	Scarabaeidae	*Onthophagus rugosicollis*	a scarab beetle
Coleoptera	Scarabaeidae	*Onthophagus vilis*	a scarab beetle
Coleoptera	Scarabaeidae	*Onthophagus yiryoront*	a scarab beetle
Coleoptera	Scarabaeidae	*Tesserodon feehani*	a Scarab Beetle
Lepidoptera	Lycaenidae	*Acrodipsas hirtipes*	Black Ant-blue
Lepidoptera	Lycaenidae	*Acrodipsas melania*	Grey Ant-Blue
Lepidoptera	Lycaenidae	*Hypochrysops apollo*	Apollo Jewel

Insects			
Family	**Order**	**Scientific name**	**Common name**
Lepidoptera	Lycaenidae	*Hypochrysops apollo apollo*	Apollo Jewel
Lepidoptera	Lycaenidae	*Jalmenus eichhorni*	Northern Hairstreak
Lepidoptera	Lycaenidae	*Ogyris iphis*	Dodds Azure Butterfly
Lepidoptera	Lycaenidae	*Ogyris iphis doddi*	Dodds Azure Butterfly
Lepidoptera	Nymphalidae	*Euploea alcathoe*	Striped Black Crow
Lepidoptera	Nymphalidae	*Euploea alcathoe enastri*	Striped Black Crow
Lepidoptera	Oecophoridae	*Trisyntopa scatophaga*	Antbed Parrot Moth
Lepidoptera	Pieridae	*Elodina claudia*	Cape York Pearl-White
Lepidoptera	Saturniidae	*Attacus wardi*	Atlas Moth
Odonata	Aeshnidae	*Dromaeschna forcipata*	Green-Striped Darner
Odonata	Aeshnidae	*Spinaeschna watsoni*	Tropical Cascade Darner
Odonata	Coenagrionidae	*Agriocnemis dobsoni*	Tropical Wisp
Odonata	Corduliidae	*Cordulephya bidens*	Tropical Shutwing
Odonata	Corduliidae	*Lathrocordulia garrisoni*	Queensland Swiftwing
Odonata	Gomphidae	*Antipodogomphus dentosus*	Top End Dragon
Odonata	Gomphidae	*Austrogomphus atratus*	Black Vicetail
Odonata	Gomphidae	*Austrogomphus doddi*	Northern River Hunter

Insects			
Family	**Order**	**Scientific name**	**Common name**
Odonata	Gomphidae	*Austrogomphus pusillus*	Tiny Hunter
Odonata	Gomphidae	*Hemigomphus magela*	Kakadu Vicetail
Odonata	Isostictidae	*Eurysticta coomalie*	Coomalie Pin
Odonata	Isostictidae	*Eurysticta reevesi*	Queensland Pin
Odonata	Isostictidae	*Lithosticta macra*	Rock Narrow-Wing
Odonata	Lestidae	*Indolestes alleni*	Small Reedling
Odonata	Libellulidae	*Huonia melvillensis*	Forestwatcher
Odonata	Macromiidae	*Macromia viridescens*	Rainforest Cruiser
Odonata	Petaluridae	*Petalura pulcherrima*	Beautiful Petaltail
Odonata	Platycnemididae	*Nososticta kalumburu*	Spot-Winged Threadtail
Odonata	Platycnemididae	*Nososticta koolpinyah*	Koolpinyah Threadtail
Odonata	Synthemistidae	*Eusynthemis netta*	Pretty Tigertail
Orthoptera	Pyrgomorphidae	*Petasida ephippigera*	Leichhardts Grasshopper
Orthoptera	Tettigoniidae	*Hemisaga elongata*	A Katydid

Mammals			
Family	**Order**	**Scientific name**	**Common name**
Carnivora	Canidae	*Canis lupus dingo*	Dingo
Chiroptera	Emballonuridae	*Saccolaimus mixtus*	Papuan Sheath-Tailed Bat
Chiroptera	Emballonuridae	*Saccolaimus saccolaimus*	Bare-Rumped Sheathtail Bat
Chiroptera	Emballonuridae	*Taphozous australis*	Coastal Sheathtail Bat
Chiroptera	Emballonuridae	*Taphozous kapalgensis*	Arnhem Sheath-Tailed Bat
Chiroptera	Hipposideridae	*Hipposideros ater*	Dusky Leaf-Nosed Bat
Chiroptera	Hipposideridae	*Hipposideros ater aruensis*	Dusky Leaf-Nosed Bat
Chiroptera	Hipposideridae	*Hipposideros cervinus*	Fawn Leaf-Nosed Bat
Chiroptera	Hipposideridae	*Hipposideros diadema*	Diadem Leaf-Nosed Bat
Chiroptera	Hipposideridae	*Hipposideros inornata*	Arnhem Leaf-Nosed Bat
Chiroptera	Hipposideridae	*Hipposideros semoni*	Semons Leaf-Nosed Bat
Chiroptera	Hipposideridae	*Hipposideros stenotis*	Northern Leaf-Nosed Bat
Chiroptera	Megadermatidae	*Macroderma gigas*	Ghost Bat
Chiroptera	Molossidae	*Mormopterus cobourgianus*	Mangrove Free-Tailed Bat

Mammals			
Family	**Order**	**Scientific name**	**Common name**
Chiroptera	Molossidae	*Mormopterus halli*	Cape York Free-Tailed Bat
Chiroptera	Pteropodidae	*Pteropus conspicillatus*	Spectacled Flying Fox
Chiroptera	Pteropodidae	*Pteropus conspicillatus camps*	Spectacled Flying Fox WT camps
Chiroptera	Rhinolophidae	*Rhinolophus robertsi*	Large-Eared Horseshoe Bat
Chiroptera	Rhinolophidae	*Rhinolophus spA*	Greater Horseshoe-Bat
Chiroptera	Rhinolophidae	*Rhinonicteris aurantia*	Orange Horseshoe Bat
Chiroptera	Vespertilionidae	*Murina florium*	Tube-Nosed Bat
Chiroptera	Vespertilionidae	*Phoniscus papuensis*	Golden-Tipped Bat
Dasyuromorphia	Dasyuridae	*Antechinomys laniger*	Kultarr
Dasyuromorphia	Dasyuridae	*Antechinus bellus*	Fawn Antechinus
Dasyuromorphia	Dasyuridae	*Antechinus godmani*	Atherton Antechinus
Dasyuromorphia	Dasyuridae	*Dasyurus hallucatus*	Northern Quoll
Dasyuromorphia	Dasyuridae	*Dasyurus maculatus*	Spotted-Tail Quoll
Dasyuromorphia	Dasyuridae	*Dasyurus maculatus gracilis*	Spotted-Tail Quoll

Mammals			
Family	**Order**	**Scientific name**	**Common name**
Dasyuromorphia	Dasyuridae	*Phascogale pirata*	Northern Brush-Tailed Phascogale
Dasyuromorphia	Dasyuridae	*Phascogale tapoatafa*	Brush-Tailed Phascogale
Dasyuromorphia	Dasyuridae	*Phascogale tapoatafa kimberleyensis*	Kimberley Brush-Tailed Phascogale
Dasyuromorphia	Dasyuridae	*Phascogale tapoatafa tapoatafa*	Eastern Brush-Tailed Phascogale
Dasyuromorphia	Dasyuridae	*Pseudantechinus bilarni*	Sandstone Antechinus
Dasyuromorphia	Dasyuridae	*Pseudantechinus mimulus*	Carpentarian Pseudantechinus
Dasyuromorphia	Dasyuridae	*Pseudantechinus ningbing*	Ningbing Antechinus
Dasyuromorphia	Dasyuridae	*Sminthopsis archeri*	Chestnut Dunnart
Dasyuromorphia	Dasyuridae	*Sminthopsis bindi*	Kakadu Dunnart
Dasyuromorphia	Dasyuridae	*Sminthopsis butleri*	Butlers Dunnart
Dasyuromorphia	Dasyuridae	*Sminthopsis douglasi*	Julia Creek Dunnart
Dasyuromorphia	Dasyuridae	*Sminthopsis leucopus*	White-Footed Dunnart
Dasyuromorphia	Dasyuridae	*Sminthopsis leucopus QLD*	White-Footed Dunnart
Diprotodontia	Macropodidae	*Dendrolagus bennettianus*	Bennetts Tree-Kangaroo

Mammals			
Family	**Order**	**Scientific name**	**Common name**
Diprotodontia	Macropodidae	*Dendrolagus lumholtzi*	Lumholtzs Tree Kangaroo
Diprotodontia	Macropodidae	*Lagorchestes conspicillatus*	Spectacled Hare-Wallaby
Diprotodontia	Macropodidae	*Macropus antilopinus*	Antilopine Wallaroo
Diprotodontia	Macropodidae	*Macropus bernardus*	Black Wallaroo
Diprotodontia	Macropodidae	*Onychogalea unguifera*	Northern Nailtail Wallaby
Diprotodontia	Macropodidae	*Petrogale brachyotis*	Short-Eared Rock Wallaby
Diprotodontia	Macropodidae	*Petrogale brachyotis victoriae*	Victoria River Short-Eared Rock Wallaby
Diprotodontia	Macropodidae	*Petrogale burbidgei*	Monjon
Diprotodontia	Macropodidae	*Petrogale coenensis*	Cape York Rock-Wallaby
Diprotodontia	Macropodidae	*Petrogale concinna*	Nabarlek
Diprotodontia	Macropodidae	*Petrogale concinna canescens*	Nabarlek
Diprotodontia	Macropodidae	*Petrogale concinna concinna*	Nabarlek
Diprotodontia	Macropodidae	*Petrogale concinna monastria*	Nabarlek
Diprotodontia	Macropodidae	*Petrogale godmani*	Godmans Rock-Wallaby

Mammals			
Family	**Order**	**Scientific name**	**Common name**
Diprotodontia	Macropodidae	*Petrogale lateralis*	Black-Footed Rock-Wallaby
Diprotodontia	Macropodidae	*Petrogale lateralis WK*	Black-Footed Rock-Wallaby
Diprotodontia	Macropodidae	*Petrogale mareeba*	Mareeba Rock Wallaby
Diprotodontia	Macropodidae	*Petrogale purpureicollis*	Purple-Necked Rock Wallaby
Diprotodontia	Macropodidae	*Petrogale sharmani*	Sharmans Rock-Wallaby
Diprotodontia	Petauridae	*Petaurus australis*	Yellow-Bellied Glider
Diprotodontia	Petauridae	*Petaurus australis WT*	Wet Tropics Yellow-Bellied Glider
Diprotodontia	Petauridae	*Petaurus gracilis*	Mahogany Glider
Diprotodontia	Phalangeridae	*Trichosurus vulpecula*	Common Brushtail Possum
Diprotodontia	Phalangeridae	*Trichosurus vulpecula arnhemensis*	Common Brushtail Possum
Diprotodontia	Phalangeridae	*Trichosurus vulpecula vulpecula*	Common Brushtail Possum
Diprotodontia	Phalangeridae	*Wyulda squamicaudata*	Scaly-Tailed Possum
Diprotodontia	Potoroidae	*Bettongia tropica*	Northern Bettong
Diprotodontia	Pseudocheiridae	*Hemibelideus lemuroides*	Lemuroid Ringtail Possum

Mammals			
Family	**Order**	**Scientific name**	**Common name**
Diprotodontia	Pseudocheiridae	*Petauroides volans*	Greater Glider
Diprotodontia	Pseudocheiridae	*Petropseudes dahli*	Rock Ringtail Possum
Diprotodontia	Pseudocheiridae	*Phascolarctos cinereus*	Koala
Diprotodontia	Pseudocheiridae	*Pseudochirops archeri*	Green Ringtail Possum
Diprotodontia	Pseudocheiridae	*Pseudochirulus cinereus*	Daintree Ringtail Possum
Monotremata	Ornithorhynchidae	*Ornithorhynchus anatinus*	Platypus
Notoryctemorphia	Notoryctidae	*Notoryctes caurinus*	Northern Marsupial Mole
Peramelemorphia	Peramelidae	*Isoodon auratus*	Golden Bandicoot
Peramelemorphia	Peramelidae	*Isoodon macrourus*	Northern Brown Bandicoot
Peramelemorphia	Thylacomyidae	*Macrotis lagotis*	Bilby
Rodentia	Muridae	*Conilurus penicillatus*	Brush-Tailed Rabbit-Rat
Rodentia	Muridae	*Hydromys chrysogaster*	Water Rat
Rodentia	Muridae	*Leggadina lakedownensis*	Tropical Short-Tailed Mouse
Rodentia	Muridae	*Melomys capensis*	Cape York Melomys

Mammals			
Family	**Order**	**Scientific name**	**Common name**
Rodentia	Muridae	*Mesembriomys gouldii*	Black-Footed Tree-Rat
Rodentia	Muridae	*Mesembriomys gouldii gouldii*	Black-Footed Tree-Rat
Rodentia	Muridae	*Mesembriomys gouldii melvillensis*	Black-Footed Tree-Rat
Rodentia	Muridae	*Mesembriomys gouldii rattoides*	Black-Footed Tree-Rat
Rodentia	Muridae	*Mesembriomys macrurus*	Golden-Backed Tree-Rat
Rodentia	Muridae	*Notomys aquilo*	Northern Hopping Mouse
Rodentia	Muridae	*Pseudomys calabyi*	Kakadu Pebble-Mound Mouse
Rodentia	Muridae	*Pseudomys johnsoni*	Central Pebble-Mouse
Rodentia	Muridae	*Pseudomys nanus*	Western Chestnut Mouse
Rodentia	Muridae	*Rattus sordidus*	Dusky Field Rat
Rodentia	Muridae	*Rattus sordidus NT*	Dusky Field Rat
Rodentia	Muridae	*Rattus tunneyi*	Pale Field Rat
Rodentia	Muridae	*Rattus villosissimus*	Long-Haired Rat
Rodentia	Muridae	*Uromys hadrourus*	Masked White-Tailed Rat

Mammals			
Family	**Order**	**Scientific name**	**Common name**
Rodentia	Muridae	*Xeromys myoides*	False Water Rat
Rodentia	Muridae	*Zyzomys maini*	Arnhem Land Rock Rat
Rodentia	Muridae	*Zyzomys palatalis*	Carpentarian Rock Rat

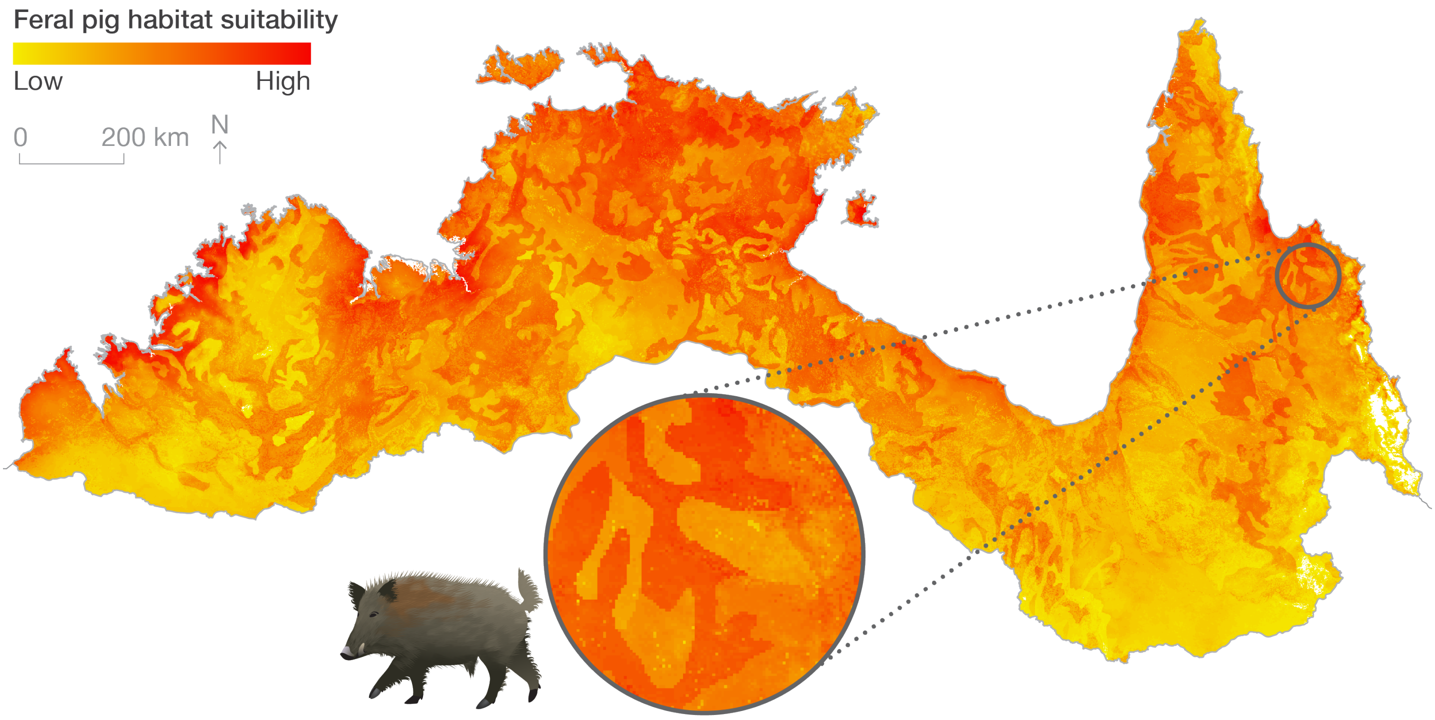
Molluscs			
Family	**Order**	**Scientific name**	**Common name**
Cyclophoroidea	Pupinidae	Amphidromus cognatus	a camaenid land snail
Cyclophoroidea	Pupinidae	Amplirhagada astuta	a camaenid land snail
Gastrodontoidea	Trochomorphidae	Amplirhagada montalivetensis	a camaenid land snail
Helicarionoidea	Helicarionidae	Amplirhagada questroana	a camaenid land snail
Helicarionoidea	Helicarionidae	Baudinella baudinensis	a camaenid land snail
Helicoidea	Camaenidae	Carinotrachia carsoniana	a camaenid land snail
Helicoidea	Camaenidae	Corbicula australis	a freshwater mussel
Helicoidea	Camaenidae	Craterodiscus pricei	a corillid landsnail
Helicoidea	Camaenidae	Cristigibba wesselensis	a camaenidland snail
Helicoidea	Camaenidae	Cristilabrum bubulum	a camaenid land snail
Helicoidea	Camaenidae	Cristilabrum buryillum	a camaenid land snail
Helicoidea	Camaenidae	Cristilabrum grossum	a camaenid land snail
Helicoidea	Camaenidae	Cristilabrum isolatum	a camaenid land snail
Helicoidea	Camaenidae	Cristilabrum monodon	a camaenid land snail
Helicoidea	Camaenidae	Cristilabrum primum	a camaenid land snail
Helicoidea	Camaenidae	Cristilabrum rectum	a camaenid land snail
Helicoidea	Camaenidae	Cristilabrum simplex	a camaenid land snail

Molluscs			
Family	**Order**	**Scientific name**	**Common name**
Helicoidea	Camaenidae	Cristilabrum solitudum	a camaenid land snail
Helicoidea	Camaenidae	Cristilabrum spectaculum	a camaenid land snail
Helicoidea	Camaenidae	Damochlora millepunctata	a camaenid land snail
Helicoidea	Camaenidae	Forrestena delicata	Mount Lewis Keeled Snail
Helicoidea	Camaenidae	Gabbia carinata	a freshwater snail
Helicoidea	Camaenidae	Gabbia lutaria	a freshwater snail
Helicoidea	Camaenidae	Gabbia napierensis	a freshwater snail
Helicoidea	Camaenidae	Gabbia tumida	a freshwater snail
Helicoidea	Camaenidae	Georissa palmerensis	Palmer River Microturban
Helicoidea	Camaenidae	Hedleya macleayi	a pupinid landsnail
Helicoidea	Camaenidae	Hedleyoconcha ailaketoae	a charopid land-snail
Helicoidea	Camaenidae	Jacksonena rudis	Atherton Tableland Keeled Snail
Helicoidea	Camaenidae	Jardinella thaanumi	a freshwater snail
Helicoidea	Camaenidae	Kimboraga exanima	a camaenid land snail
Helicoidea	Camaenidae	Kimboraga micromphala	a camaenid land snail
Helicoidea	Camaenidae	Kimboraga yammerana	a camaenidland snail
Helicoidea	Camaenidae	Meliobba shafferyi	Mossman Gorge Treesnail

Molluscs			
Family	**Order**	**Scientific name**	**Common name**
Helicoidea	Camaenidae	Mesodontrachia desmonda	a camaenid land snail
Helicoidea	Camaenidae	Mesodontrachia fitzroyana	a camaenid land snail
Helicoidea	Camaenidae	Mouldingia occidentalis	a camaenid land snail
Helicoidea	Camaenidae	Mouldingia orientalis	a camaenid land snail
Helicoidea	Camaenidae	Ningbingia australis	a camaenid land snail
Helicoidea	Camaenidae	Ningbingia bulla	a camaenid land snail
Helicoidea	Camaenidae	Ningbingia dentiens	a camaenid land snail
Helicoidea	Camaenidae	Ningbingia laurina	a camaenid land snail
Helicoidea	Camaenidae	Ningbingia octava	a camaenid land snail
Helicoidea	Camaenidae	Ningbingia res	a camaenid land snail
Helicoidea	Camaenidae	Noctepuna muensis	Mua Treesnail
Helicoidea	Camaenidae	Ordtrachia australis	a camaenid land snail
Helicoidea	Camaenidae	Ordtrachia elegans	a camaenid land snail
Helicoidea	Camaenidae	Ordtrachia septentrionalis	a camaenid land snail
Helicoidea	Camaenidae	Oreokera cumulus	a land snail
Helicoidea	Camaenidae	Oreokera nimbus	a land snail
Helicoidea	Camaenidae	Palmervillea elevata	Red Dome Glass-Snail

Molluscs			
Family	**Order**	**Scientific name**	**Common name**
Helicoidea	Camaenidae	Pilsbrycharopa tumida	a charopid land-snail
Helicoidea	Camaenidae	Pisidium australiense	a freshwater mussel
Helicoidea	Camaenidae	Protolinitis pusilla	Tinaroo Red-Striped Snail
Helicoidea	Camaenidae	Prototrachia sedula	a camaenid land snail
Helicoidea	Camaenidae	Rhagada gibbensis	a camaenid land snail
Helicoidea	Camaenidae	Rhagada harti	a camaenid land snail
Helicoidea	Camaenidae	Setobaudinia spina	a camaenid land snail
Helicoidea	Camaenidae	Setobaudinia victoriana	a camaenid land snail
Helicoidea	Camaenidae	Suavocallia splendens	a pupinid landsnail
Helicoidea	Camaenidae	Theskelomensor creon	a helicarionid landsnail
Helicoidea	Camaenidae	Tolgachloritis campbelli	a camaenid land snail
Helicoidea	Camaenidae	Torresitrachia thedana	a camaenid land snail
Helicoidea	Camaenidae	Trochomorpha melvillensis	a tropchomorphid land snail
Helicoidea	Camaenidae	Turgenitubulus aslini	a camaenid land snail
Helicoidea	Camaenidae	Turgenitubulus christenseni	a camaenid land snail
Helicoidea	Camaenidae	Turgenitubulus costus	a camaenid land snail
Hydrocenoidea	Hydrocenidae	Turgenitubulus depressus	a camaenid land snail

Molluscs			
Family	**Order**	**Scientific name**	**Common name**
Plectopyloidea	Corillidae	Turgenitubulus foramenus	a camaenid land snail
Punctoidea	Charopidae	Turgenitubulus opiranus	a camaenid land snail
Punctoidea	Charopidae	Turgenitubulus pagodula	a camaenid land snail
Punctoidea	Charopidae	Turgenitubulus tanmurrana	a camaenid land snail
Punctoidea	Charopidae	Westraltrachia alterna	a camaenid land snail
Truncatelloidea	Bithyniidae	Westraltrachia inopinata	a camaenid land snail
Truncatelloidea	Bithyniidae	Westraltrachia lievreana	a camaenid land snail
Truncatelloidea	Bithyniidae	Westraltrachia porcata	a camaenid land snail
Truncatelloidea	Bithyniidae	Westraltrachia recta	a camaenid land snail
Truncatelloidea	Hydrobiidae	Westraltrachia subtila	a camaenid land snail
Veneroida	Cyrenidae	Westraltrachia turbinata	a camaenid land snail
Veneroida	Sphaeriidae	Youwanjela wilsoni	a camaenid land snail



Northern Australia Environmental Resources Hub

National Environmental Science Programme

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This project is supported through funding from the Australian Government's National Environmental Science Program.

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