A Preliminary Map of the Likelihood of Koala Occurrence in NSW

Comparison of preliminary baseline likelihood of occurrence mapping with koala habitat mapping on the NSW north coast

© Copyright State of NSW and Office of Environment and Heritage

The Office of Environment and Heritage (OEH) has compiled this document in good faith, exercising all due care and attention. No representation is made about the accuracy, completeness or suitability of the information in this publication for any particular purpose. OEH shall not be liable for any damage which may occur to any person or organisation taking action or not on the basis of this publication. Readers should seek appropriate advice when applying the information to their specific needs. This document may be subject to revision without notice and readers should ensure they are using the latest version.

Published by:
Office of Environment and Heritage NSW
59 Goulburn Street, Sydney NSW 2000
PO Box A290, Sydney South NSW 1232
Phone: (02) 9995 5000 (switchboard)
Phone: 131 555 (environment information and publications requests)
Phone: 1300 361 967 (national parks, climate change and energy efficiency information, and publications requests)
Fax: (02) 9995 5999
TTY: (02) 9211 4723
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

Report pollution and environmental incidents
Environment Line: 131 555 (NSW only) or info@environment.nsw.gov.au
See also www.environment.nsw.gov.au

ISBN 9781 74359 857 3
OEH 2014/0868
December 2014

Contents

Sub-project team

Project management, data analysis, report writing – David Scotts (Wildlife Matters, 40 Oceanview Crescent, Emerald Beach NSW 2456).

GIS oversight, data collation and mapping – Jill Smith, Office of Environment and Heritage (OEH) NSW.

Project planning and management, report editing – John Turbill, OEH.

Project planning and technical input – Martin Predavec and Dan Lunney, OEH; Bill Faulkner, Environment Protection Authority, NSW.

List of figures

Appendices

1. Summary

Preliminary baseline koala occurrence mapping has been undertaken to assist with forestry regulation in NSW (Predavec *et al.* 2014). This report covers the evaluation of 5 km grid cell baseline koala occurrence mapping, against koala habitat mapping undertaken to prepare the Comprehensive Koala Plans of Management (CKPOMs) on the NSW north coast.

The baseline likelihood of occurrence mapping was compared to spatially referenced habitat mapping collated for all or part of eight Local Government Areas (LGAs): Tweed, Byron, Coffs Harbour, Bellingen (east), Kempsey (east), Port Macquarie-Hastings, Greater Taree and Port Stephens.

Overall, the comparisons demonstrated broad agreement between koala likelihood of occurrence and the locally derived koala habitat mapping. Given the inherent differences between the two mapping methods it would be unrealistic to expect anything approaching perfect agreement.

Anomalies are suspected to relate to aspects such as different mapping scales, variable vegetation mapping accuracy (with flow on effects to extrapolated habitat mapping), different timescales of the maps, possible issues of koala proportion dilution or concentration that may result from disproportionate mammal survey effort in coastal growth centres; and possible issues relating to data filtering. It is anticipated that some of these issues can be dealt with in further iterations of the baseline likelihood mapping. This in turn may help improve the quality of future habitat-based mapping.

As with all mobile fauna species, the mapping of koala habitat or likelihood of occupancy is fraught with difficulties that cannot all be accounted for by any single method. Integration of the best elements of different approaches will always yield the best result. For example, preferred koala habitat mapping at local scales can incorporate and cater for locally identified patterns and vagaries in koala habitat preferences and occurrence patterns. But overall mapping classes are necessarily broad in spatial extent and often incorporate extensive areas of unoccupied habitat. In contrast, the preliminary baseline koala likelihood of occurrence mapping does not relate to habitat as such but provides a direct reflection of collated koala records relative to other mammal records. With a 1994 cut-off for historical koala records this mapping provides a '20 year view' of likely koala occurrence and non-occurrence. A mapping confidence estimate gives added value to the baseline mapping informing the user of the extent to which the allocated likelihood can be trusted.

Where the two mapping methods are integrated to inform regulation of logging activities the predictive power of each is likely to be enhanced. In areas where preferred koala habitat mapping has not been undertaken, the results of this sub-project suggest that the baseline koala likelihood of occurrence mapping provides a sound basis for regulation of forestry as it pertains to koala conservation.

2. Background and introduction

As outlined by Lunney *et al*. (2009a), determining where a species of conservation significance occurs – or is likely to occur – is essential for its management and conservation. The fundamental first step in systematic conservation planning is zoning or classification of important locations or habitats. The importance of identifying, mapping and managing important koala habitats is central to the review of logging prescriptions on state forests and freehold lands.

Preliminary baseline koala occurrence mapping has been undertaken to assist with forestry regulation in NSW (Predavec *et al.* 2014). This report concerns the evaluation of this mapping against koala habitat mapping undertaken on the NSW north coast and specifically within Koala Management Area (KMA) 1 (see DECC 2008). This area was chosen since it represents the area where there is likely to be the most conflict between koalas and their habitat and forestry operations.

Koalas in NSW are listed as a vulnerable species under both State and Federal legislation and native forest logging is identified as a potential threat to the species (DECC 2008).

2.1 Koalas and forestry regulation

Existing measures to protect koala habitat and populations under the current coastal Forestry Operations Agreements (IFOAs) (applying to state forests) and the Private Native Forestry (PNF) Code are inconsistent, impractical to apply and enforce, and of questionable benefit (e.g. EPA 2014). New approaches are needed to regulate forestry activities alongside koala conservation.

The koala is an iconic species and an example of a threatened species that, due to its habitat preferences and its widespread but patchy occurrence, is unlikely to be greatly advantaged by surrogate approaches. While floodplains and coastal plains, largely held within private tenure, have historically supported the best koala populations (e.g. Lunney *et al*. 2009a), coastal and foothill forests, both private and public, also support significant koala habitats and populations (e.g. Lunney *et al.* 2009b, Biolink 2013, OEH 2013, Scotts 2013). As ongoing threats such as disease, road strike, habitat loss and fragmentation, and dogs continue to affect koala populations within human-dominated coastal areas, hinterland forest populations may assume greater overall conservation significance placing a correspondingly greater emphasis on regulation of forest logging.

Koalas are negatively affected by logging regimes that simplify forest stand structure (Smith 2004) and the loss of preferred food and shelter trees (DECC 2008) – particularly the larger tree size classes generally targeted for removal (Smith 2004, Biolink 2013). Cumulative impacts over time are apparent with significantly lower size classes of preferred food tree species leading to lower koala carrying capacity (e.g. Biolink 2013). The current revision of forestry regulation procedures on public forest lands (the IFOA remake) and private forest lands (PNF) is an opportunity to enhance koala conservation within NSW's forests.

2.2 A baseline koala occurrence map to help guide forestry regulation

The generation of baseline maps of koala occurrence intends to provide a new, systematically derived, tool to regulate forestry activities and their impacts on koala populations and habitats. Baseline mapping of the likelihood of koala occurrence will be developed to provide a tenure blind framework to apply PNF and State forest koala habitat protection measures across the seven KMAs identified in the NSW Koala Recovery Plan (DECC 2008). The baseline mapping provides full coverage of the seven KMAs and has been consistently and systematically derived to represent the likelihood of koala occurrence. In this way it differs from existing koala habitat mapping which provides a variably derived representation of potential koala habitat, consistent within a certain study area, e.g. LGAs, but varies in accuracy and method of derivation between study areas. Existing mapping is also quite piecemeal in its coverage of KMAs across the state.

Where koala habitat mapping is available, it is expected to be accredited and incorporated with the baseline mapping for koala-based forest regulation purposes. The baseline mapping is tenure blind and provides important context for the accreditation and application of habitat mapping for forestry regulation and subsequent conservation planning.

Map integration will allow for the classification of relevant parts of NSW based on the likely occurrence of koala populations and the distribution of mapped habitat classes. Protection measures will be developed accordingly.

The study area for this sub-project is Koala Management Area 1 (KMA1): The NSW North Coast (Figure 1).

The baseline koala likelihood of occurrence mapping has been undertaken at the 10 km and 5 km grid cell scales within KMA1. The 5 km output is the subject of evaluation (see Figures 2 and 3).

2.2.1 Evaluating the baseline koala map in north-east NSW

This sub-project aims to evaluate the baseline koala occurrence mapping through comparison with available koala mapping within the North Coast KMA. This will consider the differences between habitat mapping and occurrence likelihood modelling (see section 4).

The focus for mapping comparison will be the potential koala habitat mapping prepared for CKPOMs under State Environmental Planning Policy (SEPP) 44 – Koala Habitat Protection. The aim is to check for inconsistencies recognising the inherent difference between koala habitat mapping and koala likelihood of occurrence mapping and potential errors that may occur in both mapping processes.

The koala likelihood of occurrence mapping will also be compared, in a qualitative way, to other koala mapping:

- generational persistence mapping and area of occupancy estimations (undertaken as part of some LGA-based koala habitat mapping projects)
- known or predicted important habitats on public and private lands.

Baseline mapping is intended to inform regulation of private (and potentially public land) forestry activities. Accordingly, another aim is to evaluate the mapping against approved PNF Property Vegetation Plans (PNF PVPs) to ensure that application of the mapping will not result in a weakening of koala protection measures. Current PNF approvals prohibit logging in areas of ‘core koala habitat’ for the purpose of State Environmental Planning Policy 44 (SEPP 44) and require a koala record (within the *NSW Wildlife Atlas*) within 500 m of a PNF application to trigger koala prescriptions.

Application excludes logging in areas where ‘core koala habitat’ has been identified under a Koala Plan of Management but typically has little or no requirement to protect koala habitat in other areas. A key intention of koala likelihood mapping is to provide the basis for a more strategic, systematic and spatially consistent PNF assessment process for managing koalas.

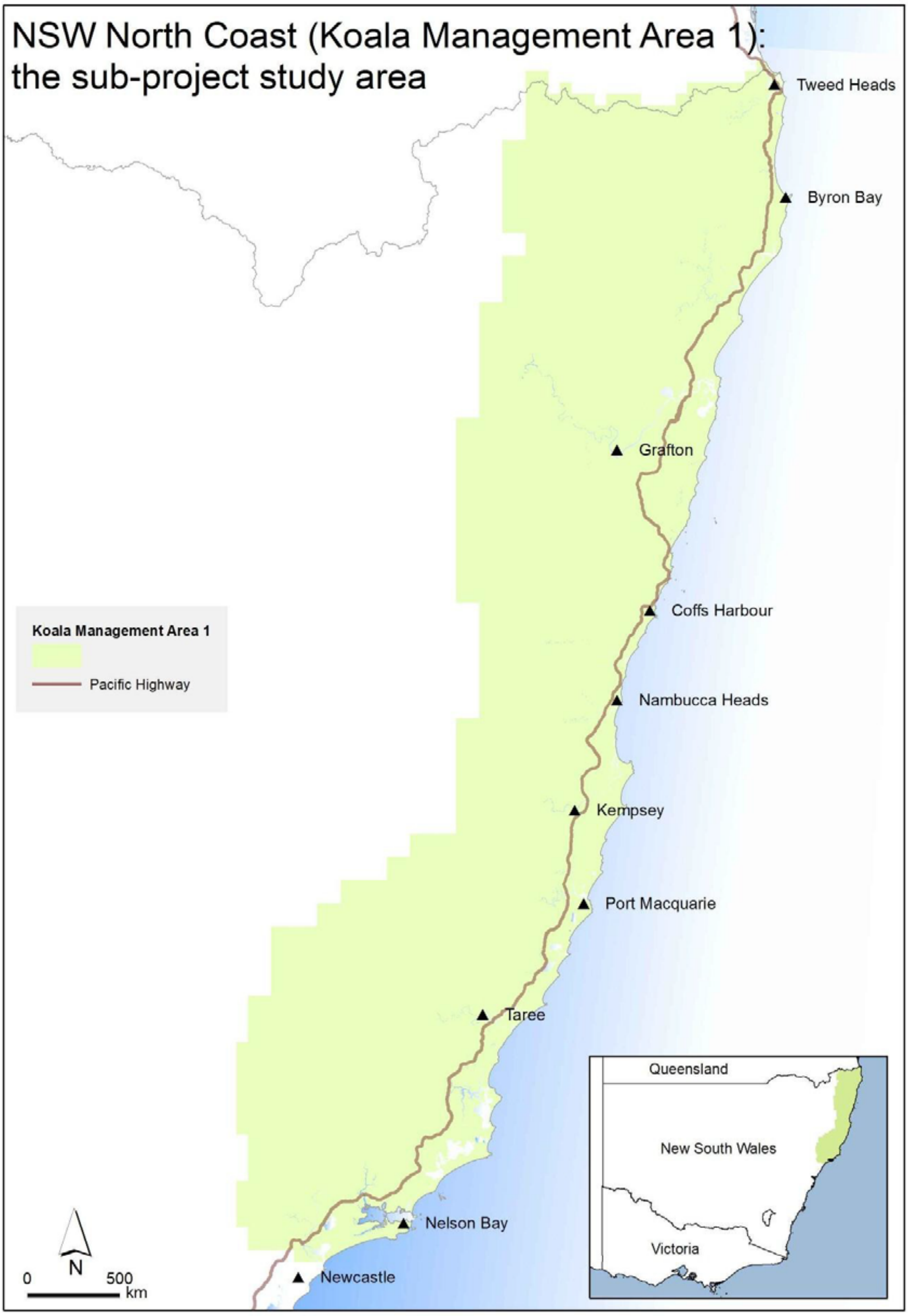


Figure 1. The sub-project study area. The boundary of KMA1 is derived from the 10 km grid used in the baseline koala likelihood of occurrence mapping project.

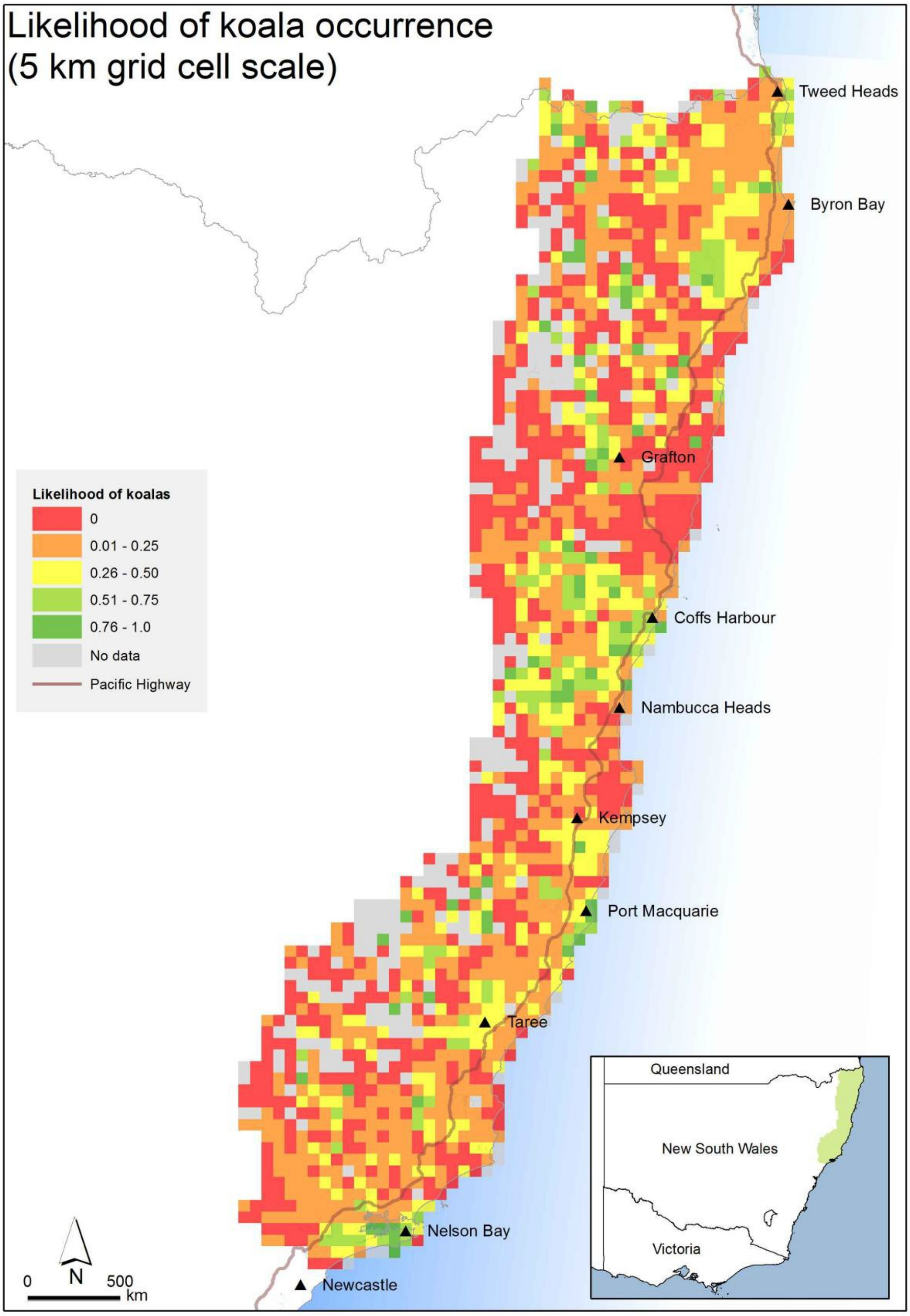


Figure 2. Baseline koala likelihood of occurrence mapping for 5 km grid cells of the NSW North Coast (KMA 1) (see Predavec *et al.* (2014) for details).

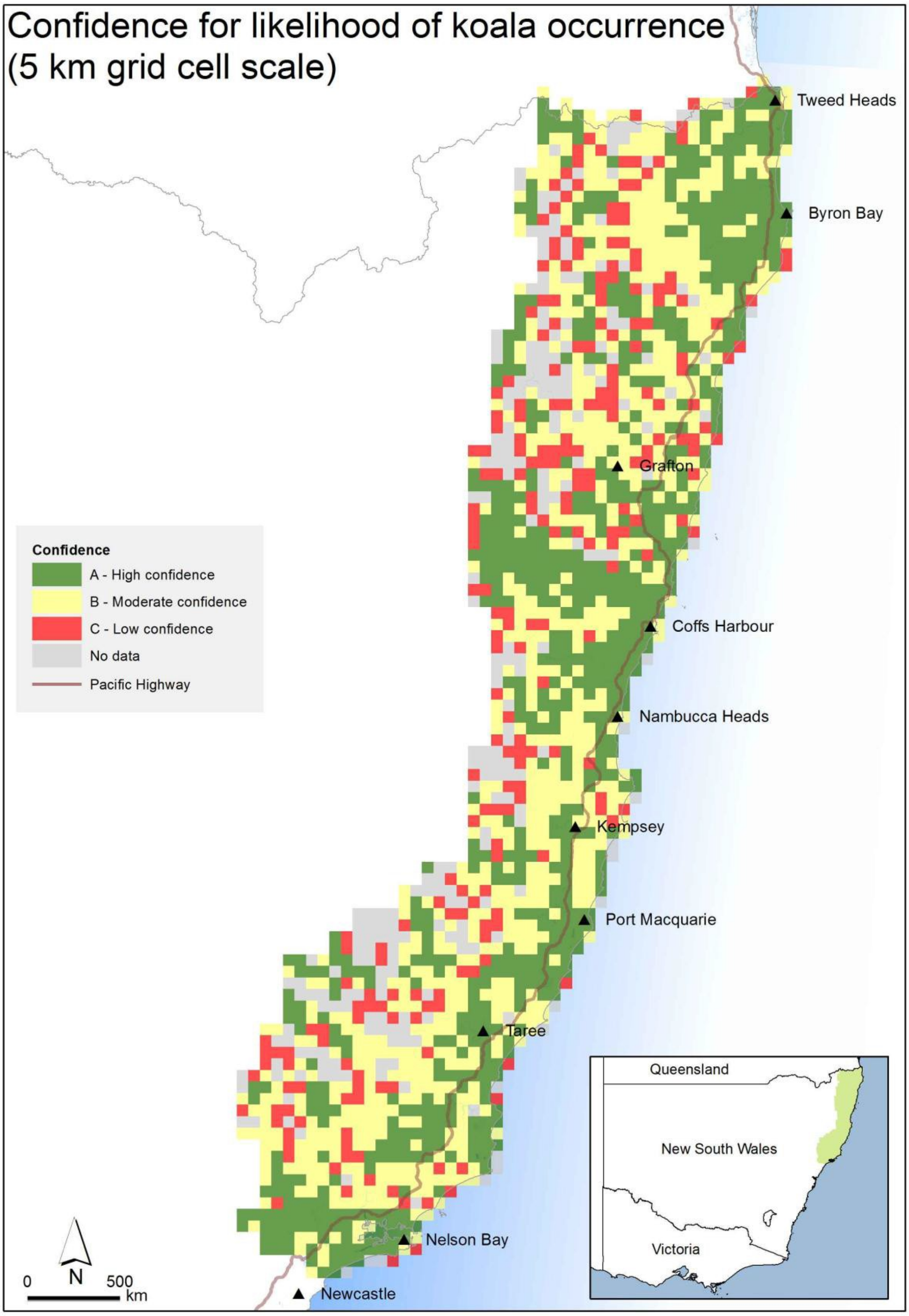


Figure 3. Confidence for the baseline koala likelihood of occurrence mapping for 5 km grid cells of the NSW North Coast (KMA 1) (see Predavec *et al.* (2014) for details).

3. Koala habitat mapping on the NSW North Coast

Koala habitat mapping has been attempted by various projects, using various methods and at a number of spatial scales on the NSW North Coast. Two types of mapping will form the basis and context to compare with baseline koala occurrence mapping:

a) koala habitat mapping for the development of CKPOMs under SEPP 44 (various LGAs)
b) koala habitat modelling for north-east NSW (CRAFTI Koala Habitat Model)[1].

3.1 Koala habitat mapping to develop Comprehensive Koala Plans of Management under SEPP 44

Mapping at the LGA scale has been adopted to meet the requirements of SEPP 44: Koala Habitat Protection and to develop CKPOMs.

SEPP 44 provides direction for the identification and mapping of important koala habitats on freehold lands. It encourages a coordinated and strategic approach to koala habitat management within LGAs through the preparation of CKPOMs, which can be for the whole of the LGA, or any section where important koala populations and/or koala habitat are under threat. Under CKPOMs, koala habitat is identified and ranked in terms of quality, e.g. primary, secondary and tertiary habitat (DECC 2008).

Koala habitat studies form the basis for CKPOMs in north-east NSW, have been generally undertaken using a similar methodology which includes collation of koala records (e.g. from the *Atlas of NSW Wildlife*), and community-based and systematic field surveys. The results are used to derive feed tree preferences by vegetation association. Koala habitat is then ranked across available vegetation mapping within a Geographic Information System (GIS). The LGA scale has proven to be convenient and appropriate to establish locally relevant associations between koalas and their preferred feed tree species, and for the identification of koala population patterns and trends. This koala habitat mapping is considered to be the highest quality and spatial accuracy for each of the relevant LGAs. Other mapped outputs may include areas of mapped koala occupancy or generational persistence (i.e. consistency of koala records within a grid cell over three or more koala generations), used to confirm or refine preferred koala habitats. These mapping products are the basis to evaluate baseline koala occurrence mapping.

As with all spatial map layers, it is recognised that applying koala habitat mapping undertaken to prepare a CKPOM may require validation at the property or site scale to confirm the accuracy of vegetation boundaries, vegetation community types and associated habitat rankings. Although this may be necessary, LGA habitat mapping is the best available representation of potential koala habitat to compare with the baseline occurrence mapping. It is further recognised that koala habitat maps prepared under SEPP 44 relate to private lands only, whereas the baseline likelihood of occurrence mapping is tenure blind. To account for this difference, the broad-scale CRAFTI Koala Habitat model was also used in the comparison (see Section 3.2).

[1] Areas modelled as habitat significance under the Comprehensive Regional Assessment of Northern NSW undertaken as part of the Regional Forestry Agreements in 1999.

3.2 The CRAFTI Koala Habitat Model

This is a modelled GIS layer developed from the CRAFTI vegetation data generated for the upper and lower north-east Regional Forestry Assessments. It was derived by an expert modelling process facilitated by the (then) Department of Environment and Climate Change in the early 2000s, to help Regional Vegetation Management Plans to predict areas of likely koala habitat. In the absence of any other more localised and detailed habitat mapping or site surveys, the model provides an indicative layer of the likely presence of koala habitat at any site based on the predicted presence of primary or secondary feed trees. As with all regional modelling processes the accuracy of the layer is limited by the quality of data layers used in the modelling and it is a broad prediction only.

The broad and indicative character of the CRAFTI Koala Habitat Model mapping is acknowledged. Its use in this project was restricted to providing spatial context for the private land-based koala habitat mapping that formed the basis for comparisons with the baseline koala occurrence mapping. The available CKPOM koala habitat mapping is restricted to private lands but most of the 5 km grid cells within KMA1 incorporate some public lands and many grid cells are largely or entirely covered by public lands. Given that the koala likelihood mapping has been generated for entire 5 km grid cells it was necessary to also include characterisation of koala habitat mapping for public lands within the relevant grid cells of the three LGA test cases. This gave more detailed quantitative comparisons with the baseline koala occurrence mapping (see section 5).

4. Differences between koala habitat mapping and baseline likelihood of occurrence mapping

Koalas are naturally patchy in their occurrence across a landscape (e.g. Lunney *et al*. 2009a). This patchiness reflects preferences for certain tree species for foraging and sheltering (e.g. Phillips and Callaghan 2011). In addition, koalas appear to further distinguish their preferred habitats, and their numbers, based on even more subtle environmental and physical variations. These include soil fertility and moisture, topography and landform, tree size and health, leaf chemistry as it relates to palatability and digestibility, prevailing threats (e.g. dogs, disease, roads and car strike), presence or absence of other koalas, prior disturbance intensity (e.g. logging, fires, droughts) and landscape configuration (e.g. patch size and shape, level of habitat connectivity) (See various references in DECC 2008). The complexity of these associations and habitat selection cues makes the mapping of koala habitat and occurrence particularly difficult and has confounded previous attempts to map and model potential koala distribution at regional scales (e.g. NSW NPWS 1994, Wintle *et al*. 2004).

Preferred koala habitat mapping has been generated at relatively local scales (whole or parts of LGAs) where at least some of the environmental variation and inherent patchiness of occurrence has been accounted for by various means, including locally-held knowledge. Applied methods have included collation of historical records and community-held records, systematic field survey (generally faecal pellet surveys) and extrapolation of locally established koala feed tree preferences with available vegetation mapping and assigned habitat quality classes to establish polygons of preferred habitat that reflect the scale of vegetation mapping available. Many local koala habitat studies have further informed and refined habitat mapping. This has comprised analyses of generational persistence and estimates of koala occupancy rates and areas. The resulting maps of koala habitat provide an inclusive, classified representation of potential habitat. Local koala occurrence nuances are incorporated to the maximum extent possible for a static mapped product.

The baseline koala likelihood of occurrence mapping is not a habitat map. In its current preliminary form it is based on the proportion of koalas recorded within a grid cell relative to the records of other mammals in the same grid cell (see Predavec *et al*. 2014). Being based on koala records, this method considers the koalas' inherent patchy occurrence. All grid cells with an occurrence likelihood above zero have had at least one koala recorded within them in the cut-off period, in this case over the last 20 years (1994–2014). This mapping provides a '20 year view' of likely koala occurrence and non-occurrence.

The mapped outputs reflect surveys to determine the likelihood score and give a confidence level. Where survey effort has not been expended, i.e. where no mammals have been recorded, the user is made aware of that through allocation of a No Data label. The likelihood mapping therefore depicts potential koala occurrence and non-occurrence directly driven by the available data. The likelihood mapping cannot account for local and recent koala population declines nor can it account for increases within the timeframes of the applied data; these are better detected by the more localised LGA habitat mapping. It is recognised however that koala habitat mapping may eventually be out of date. For example, the koala habitat mapping included in the CKPOM for Coffs Harbour (Lunney *et al.* 2009) is based largely on data collected in 1990 (community surveys) and on 1996 field-based surveys. It therefore does not take account of more recent declines in distribution in the Coffs Harbour area. The likelihood mapping also directly depends on the quality of records and record locations applicable to each grid cell. Data filtering to avoid potential biases caused by data vagaries (e.g. nests of associated records, duplicated records) needs to be judiciously applied (see Predavec *et al.* 2014).

Given the inherent differences between the two mapping methods it would be unrealistic to expect anything approaching perfect agreement between the two mapped outputs. What can be expected is that the two mapping methods (within their relative scales of application) broadly agree, that potentially important areas for koalas are mapped, that areas of likely non-importance to koalas are also shown and that each mapping method provides a positive input to the regulation of forestry activities.

5. Methods applied to compare baseline koala likelihood of occurrence mapping with habitat mapping

The baseline koala likelihood of occurrence mapping will be referred to from here on as koala likelihood mapping. A number of mapped outputs were used to evaluate the koala likelihood mapping:

a) The focus for comparison with the koala likelihood mapping in this sub-project is the koala habitat mapping prepared for CKPOM under SEPP 44. The aim is to check for inconsistencies, recognising the differences between koala habitat mapping and koala likelihood mapping (see Section 4).

b) The CKPOM-mediated koala habitat mapping is restricted to private lands. Most of the 5 km grid cells of KMA1 incorporate some public lands and many grid cells are mostly or entirely covered by public lands. Given that the koala likelihood mapping has been generated for entire 5 km grid cells regardless of tenure it was considered necessary to include characterisation of koala habitat mapping for these public lands. As explained above, CRAFTI was used to allow for generation of relative proportions of koala habitat classes (mapped and modelled) for each relevant 5 km grid cell.

c) The koala likelihood mapping will also be compared, in a qualitative way, to other koala mapping including intergeneration persistence mapping and area of occupancy estimates (undertaken as part of some LGA-based koala habitat mapping projects) and known or predicted important habitats on public and private lands.

d) The koala likelihood mapping is also compared to mapping of approved PNF PVPs (as of June 2014) to assess its potential application in this approval process.

Mapping of koala habitat to develop CKPOMs has varied slightly between LGAs. This includes variation in the terminology of koala habitat mapped outputs and in some instances delineation thresholds for habitat classes. This is discussed further below but it is relevant here to note that LGA-based koala habitat mapping outputs may also vary in the number of habitat categories mapped and thresholds used. In seeking to apply consistency to the evaluation of baseline koala occurrence mapping, the habitat mapping for each relevant LGA was converted to three classes (1, 2 and 3).

It should be noted that the 1, 2 and 3 classes in this sub-project are not related to the potential, core or important koala habitats as outlined in state or federal legislation. They are merely a convenient unit to compare koala habitat mapping and baseline koala occurrence likelihood mapping.

Koala habitat mapping for the development of CKPOMs has to date been undertaken for 11 NSW North Coast LGAs. Digital mapping was available for eight of these, allowing direct comparison of mapped koala habitat and baseline koala occurrence likelihood based on GIS overlay within ArcMap 10.1 (Figures 4, 5, 6).

Two levels of analysis were employed to compare the baseline koala occurrence mapping with the habitat mapping of the eight LGAs with digital habitat mapping available:

5.1 Methods

Method 1

Three LGAs were chosen for relatively more detailed habitat mapping characterisation.

Coffs Harbour LGA: This LGA was the first in the state to have an approved CKPOM and has available koala habitat mapping. The south-eastern part of this LGA includes the northern portion of Bongil Bongil National Park and Pine Creek State Forest, a regionally significant koala population. This LGA also has many PVP approvals.

Bellingen (east) LGA: The coastal part of the Bellingen LGA has been the subject of recent koala habitat mapping (OEH 2014). The north-eastern part of this LGA includes part of the southern portion of the regionally significant Bongil Bongil National Park and Pine Creek State Forest koala population.

Port Macquarie-Hastings LGA: This is a large LGA with recent koala habitat mapping (Biolink 2013). The coastal populations between Port Macquarie and Dunbogan are recognised as regionally significant. This LGA is also a focus for existing PNF approvals.

Each grid cell (5km) within each of these LGAs was characterised to calculate and add together the areas of mapped koala habitat classes (preferred koala habitat) on private lands (KM1, 2, 3) and modelled habitat on public lands (national parks and state forests) (KM1, 2, 3 from CRAFTI koala model). Variations include:

- grid cells for which the test LGA occupied less than 10% of the cell area were excluded from characterisation and analysis
- a multiplier was applied to mapped and modelled habitat classes within grid cells adjoining the Pacific Ocean and only partly (but >10%) within the LGA to generate figures relative to the full grid cells
- grid cells adjoining neighbouring LGAs to the north, west and south and only partly within the test LGAs are treated as full grid cells. The available mapped (from other LGA mapping) or modelled (from CRAFTI koala model) habitat was used to inform the collated figures in those instances.

Collated figures for mapped and modelled koala habitat within each grid cell of the test LGAs were combined in excel tables, with relevant grid cell identifiers and corresponding koala likelihood of occurrence values. Graphs were generated within excel to provide relevant visual comparisons between the mapped likelihood values and the mapped habitat values.

Method 2

Five additional LGAs, for which digital data was also available, are subject of a relatively lower level of quantitative analysis (see section 5 (d) above).

These LGAs were (north to south): Tweed, Byron, Kempsey (east), Greater Taree and Port Stephens (Figure 4).

5.2 Qualitative evaluation

For each of the eight LGAs assessed in this sub-project the koala likelihood of occurrence mapping is also compared, in a qualitative way, to other koala mapping information:

- generational persistence mapping and area of occupancy estimates (undertaken as part of some LGA-based koala habitat mapping projects)
- known or predicted important habitats on public and private lands.

A qualitative assessment is also undertaken of the distribution and occurrence of current PNF approvals as they relate to the koala likelihood mapping within each of the eight test LGAs.

5.3 Mapping variation – potential to confound comparisons

As discussed above, the mapping of koala habitat for the development of CKPOMs has varied between LGAs. This may confound application of the standard set of evaluation methods listed above. Some of the different approaches relevant to each LGA are discussed in the results below.

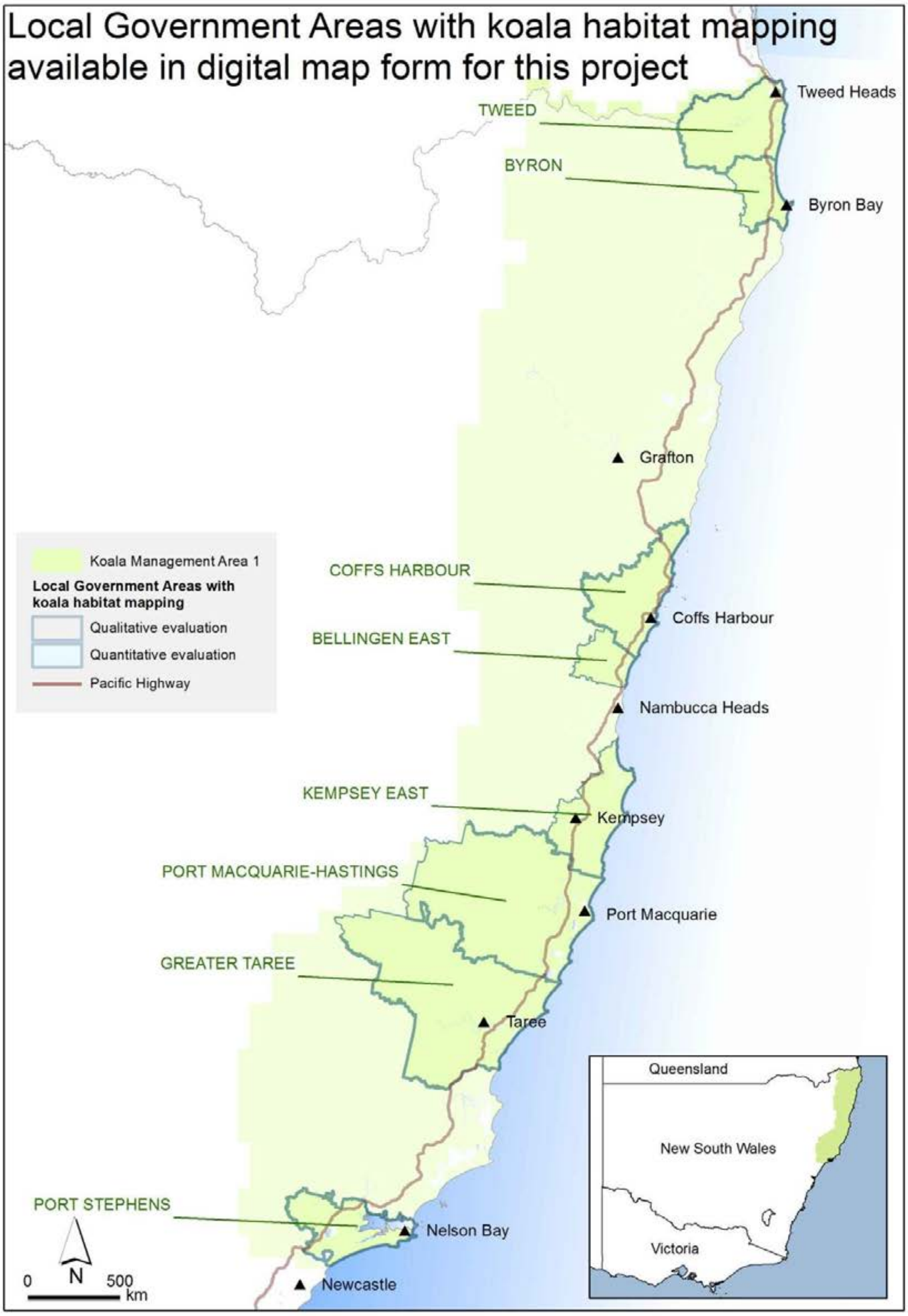


Figure 4. KMA1 showing the eight LGAs for which digital koala habitat mapping was available for evaluation against koala likelihood mapping in this sub-project.

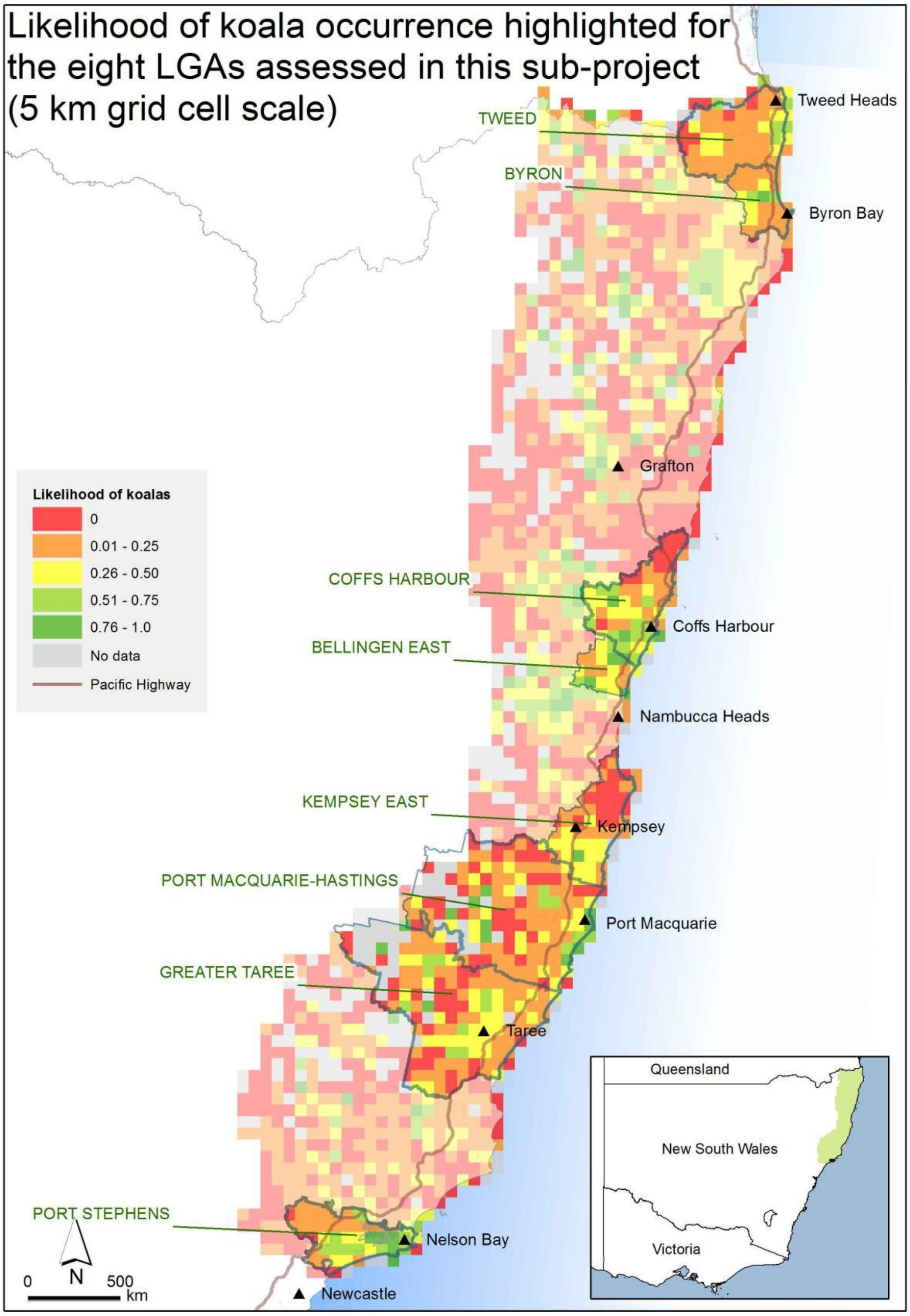


Figure 5. KMA1: 5 km grid cell koala likelihood mapping within the eight LGAs assessed in this sub-project.

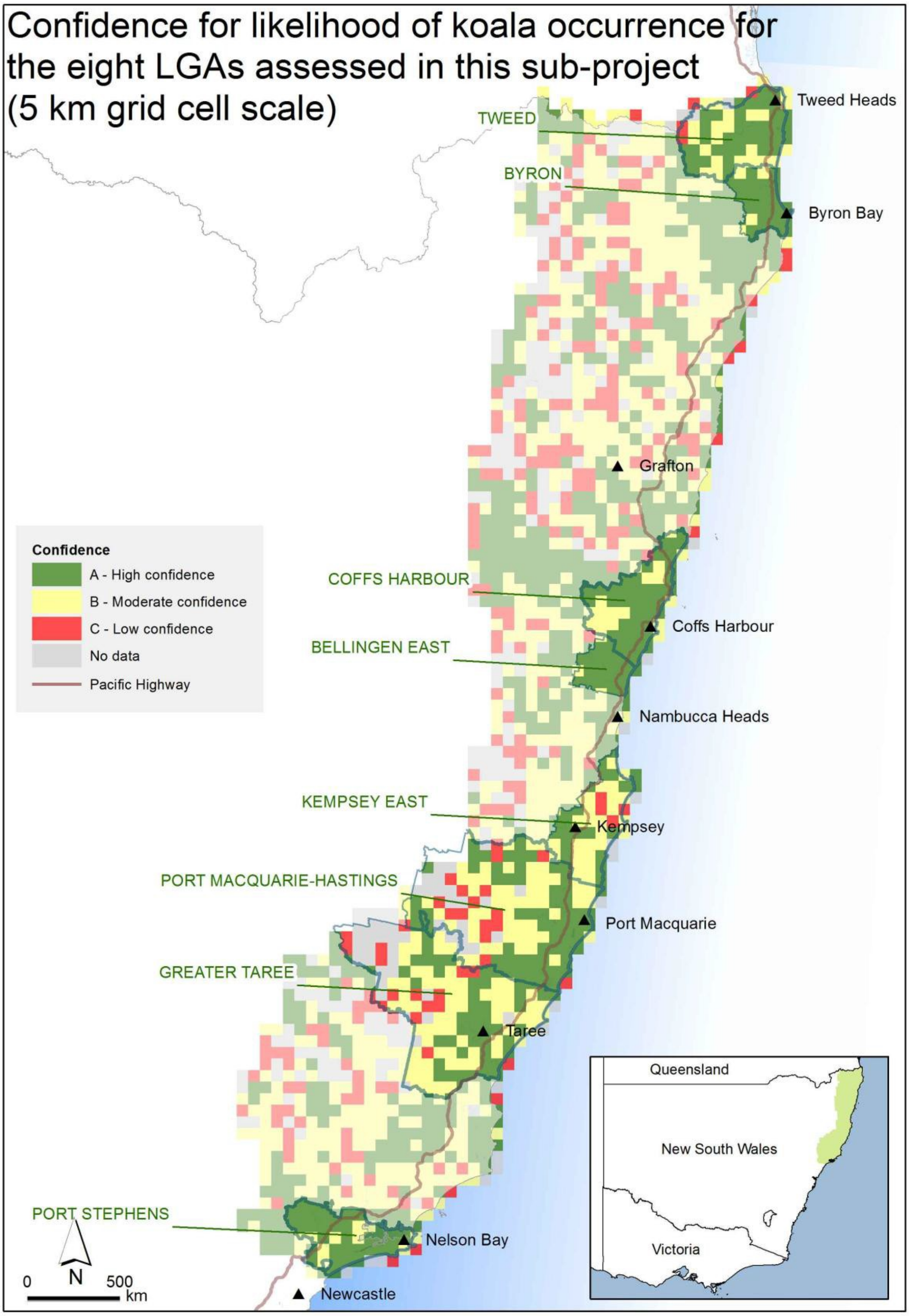


Figure 6. KMA1: 5 km grid cell koala confidence for the koala likelihood mapping within the eight LGAs assessed in this sub-project.

6. Results for eight test LGAs

As explained above, a more detailed evaluation was undertaken for three LGAs: Coffs Harbour, Bellingen (east) and Port Macquarie-Hastings. These are considered first, then the five additional test LGAs are considered north to south: Tweed, Byron, Kempsey (east), Greater Taree and Port Stephens.

Five standard outputs, one map composite, one table of raw data and three graphs of collated data, are provided for each of the first three LGAs:

1. A map composite including the best three classes of mapped preferred koala habitat, baseline koala occurrence mapping, broad confidence for the baseline mapping (as an inset) and the broad spatial occurrence of approved PNF locations. The map composite provides for a visual comparison of these mapped outputs.

2. A raw table of collated mapped and modelled koala habitat relative to the likelihood of occurrence levels applied to 5 km grid cells of the LGA. Cells are sorted from highest to lowest likelihood. These tables are provided as appendices.

3. A graphed representation of the raw data tables (point 2) depicting the spread of likelihood of occurrence across the LGA (sorted highest to lowest) and the corresponding proportions of mapped and modelled koala habitat. This gives a broad visual depiction of the variation between grid cells in the amount of public land (national park, nature reserve, state forest combined) and private forested lands mapped as koala habitat relative to the allocated likelihood of occurrence.

4. A graphed representation of the relationship between the proportion of the best mapped habitat (class 1 habitat) in each grid cell and the baseline koala likelihood. A linear trend-line indicates the broad level of correlation between the two mapping methods. A positive trend of higher likelihood for grid cells containing more mapped class 1 habitat would reflect overall congruence between the mapping methods.

5. A graphed representation of the relationship between baseline koala likelihood and habitat class for each grid cell that includes class 1, 2 or 3 habitat. A trend-line is provided to indicate the broad level of correlation between the two mapping methods. In this case a negative trend of overall higher likelihood for grid cells containing mapped class 1 habitat as opposed to grid cells containing class 2 or 3 habitat would reflect overall agreement between the mapping methods.

Only outputs 1 and 5 are provided for the latter five LGAs.

6.1 Coffs Harbour LGA

Koala Habitat mapping: Lunney *et al.* (2009b): Coffs Harbour City Koala Plan of Management; Revised Edition.

The original Coffs Harbour Koala Plan of Management used 1996 vegetation mapping combined with results of a 1990–91 community survey, and targeted field surveys in 1996. The 2009 review incorporated some revision of mapped classes to reflect better soils mapping and changes to vegetation extent (clearing and revegetation), and northern additions to the LGA. (Lunney *et al*. 2009b). The review documented anecdotal evidence of recent koala population declines in the coastal north of the LGA (e.g. Korora Basin and coastal forests north to the northern boundary of the LGA) and also around Coffs Harbour City.

The best koala habitats occur between Coffs Harbour itself and the southern boundary of the LGA including private lands, state forests (e.g. Pine Creek, Boambee and Tuckers Nob state forests) and Bongil Bongil National Park. These are koala habitats of national significance. Higher elevation habitats of the eastern Dorrigo Plateau and Bagawa and Wild Cattle Creek state forests also support important populations. Koala occurrence drops dramatically north of Sherwood Nature Reserve where lower fertility soils, including parts of the Glenreagh sandstone belt, predominate. Forestry activity is concentrated in the coastal and foothill state forests and private forestry is also relatively extensive in these areas.

Figures 7, 8, 9, 10 and Appendix 1 provide the basis for mapping comparisons.

Broad mapping comparisons for known koala areas (Figure 7): Coffs Harbour – Pine Creek State Forest – Bongil Bongil National Park

Agreement between the mapping methods in this south-west section of the LGA is high with grid cells of class 1 preferred habitat matched by relatively high occurrence likelihood.

Eastern Dorrigo Plateau to Bagawa State Forest

Grid cells in the Lowanna – Brooklana district are allocated a relatively high likelihood of occurrence in general agreement with the LGA koala habitat mapping.

Summary

The baseline mapping generally agrees with the koala habitat mapping in this LGA. Known significant koala habitats are mapped at a correspondingly higher likelihood level (Figures 7, 8, 9). An over-prediction of koala habitat in the sandstone derived areas in the north of the LGA is better represented by low likelihood in the baseline mapping.

A positive correlation is recorded between mapped class 1 habitat and likelihood of occurrence (Figure 9). Agreement between the two mapping methods is also confirmed by a trend of decreasing koala likelihood from cells containing class 1 then 2 then 3 habitats (Figure 10).

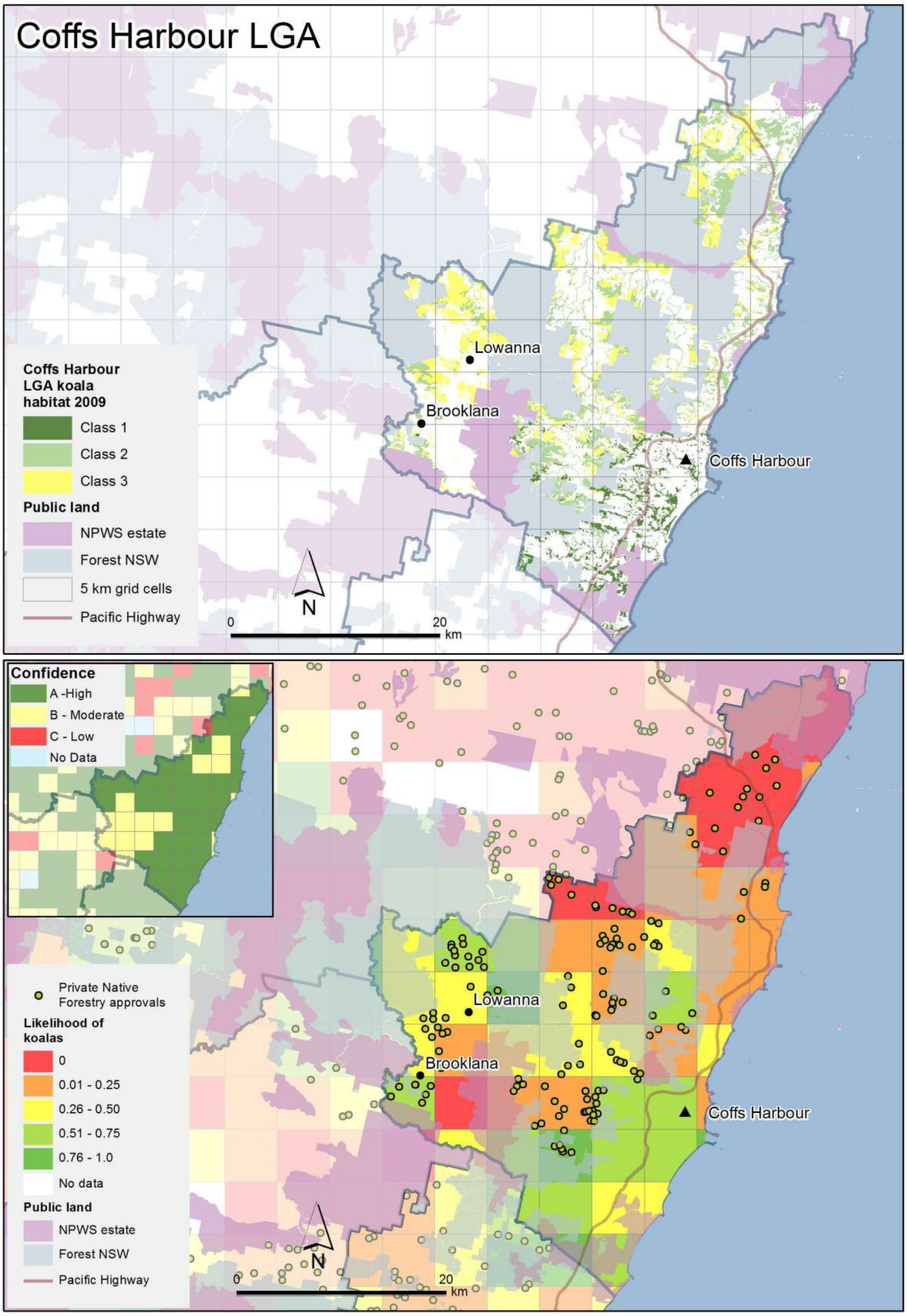


Figure 7. Coffs Harbour LGA: Mapped koala habitat (Lunney *et al*. 2009b), koala likelihood (and confidence) and PNF approvals (as of June 2014).

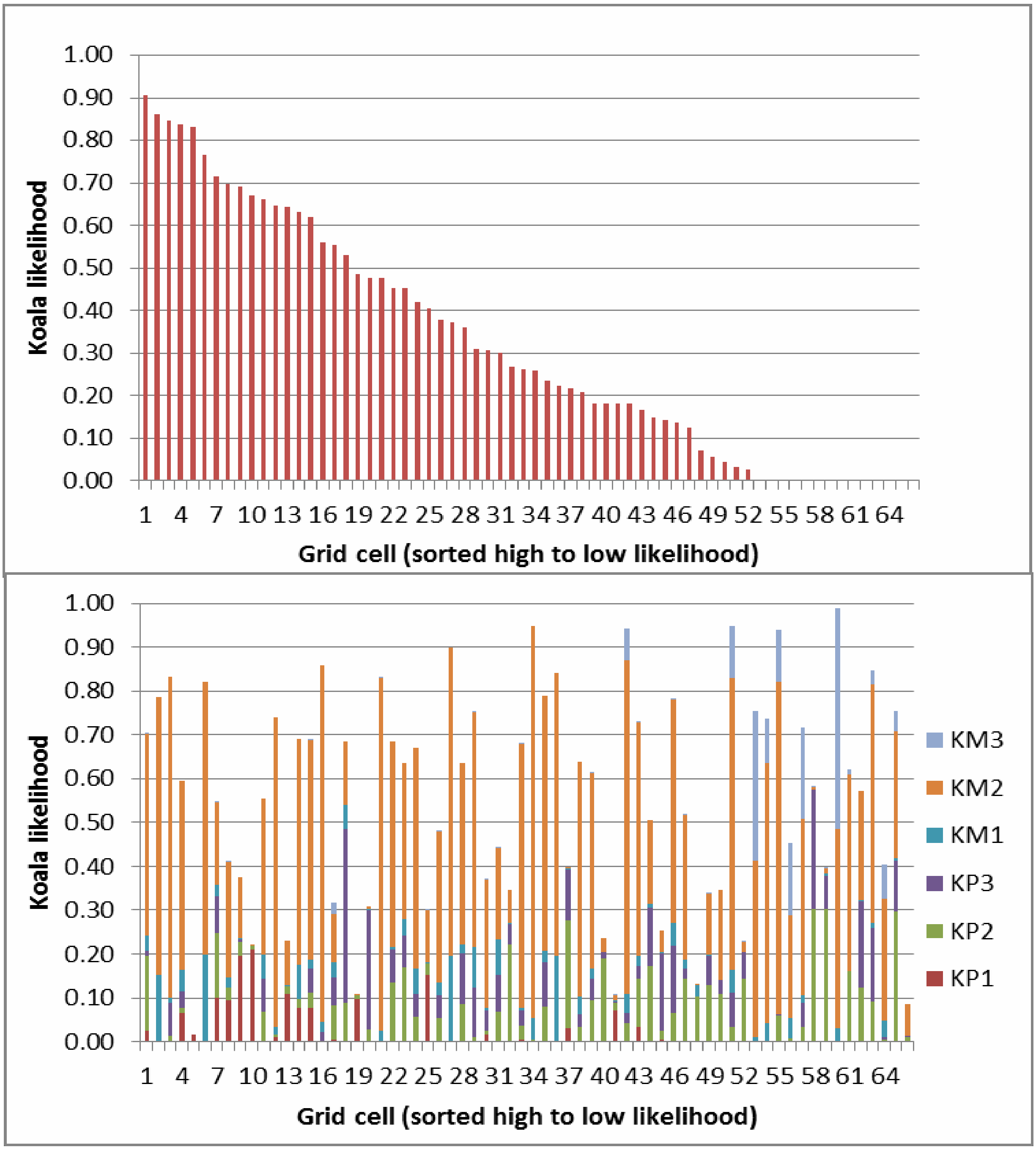


Figure 8. Coffs Harbour LGA: Likelihood of koala occurrence (sorted most to least) and corresponding relative proportions of mapped (Lunney *et al*. 2009b) and modelled (CRAFTI Koala Model) koala habitat within 67, 5 km grid cells with more than 10% of their area within the LGA.

KP: mapped preferred koala habitat classes. KM: modelled habitat classes

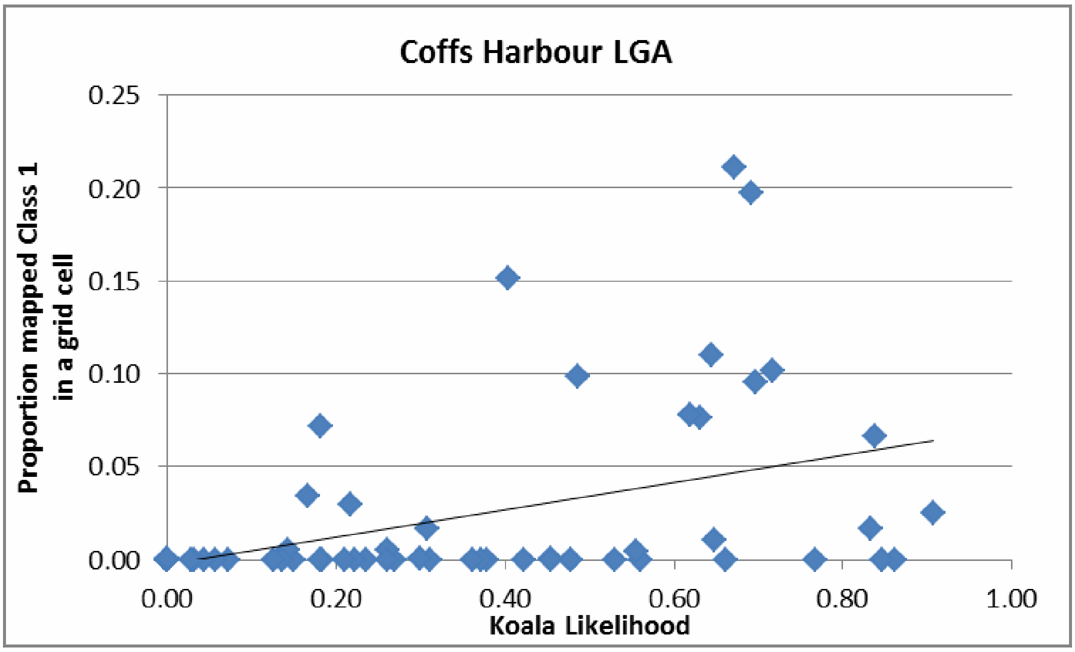


Figure 9. Coffs Harbour LGA: The proportion of the best mapped koala habitat (class 1) relative to mapped koala likelihood of occurrence within 67, 5 km grid cells with more than 10% of their area within the LGA.

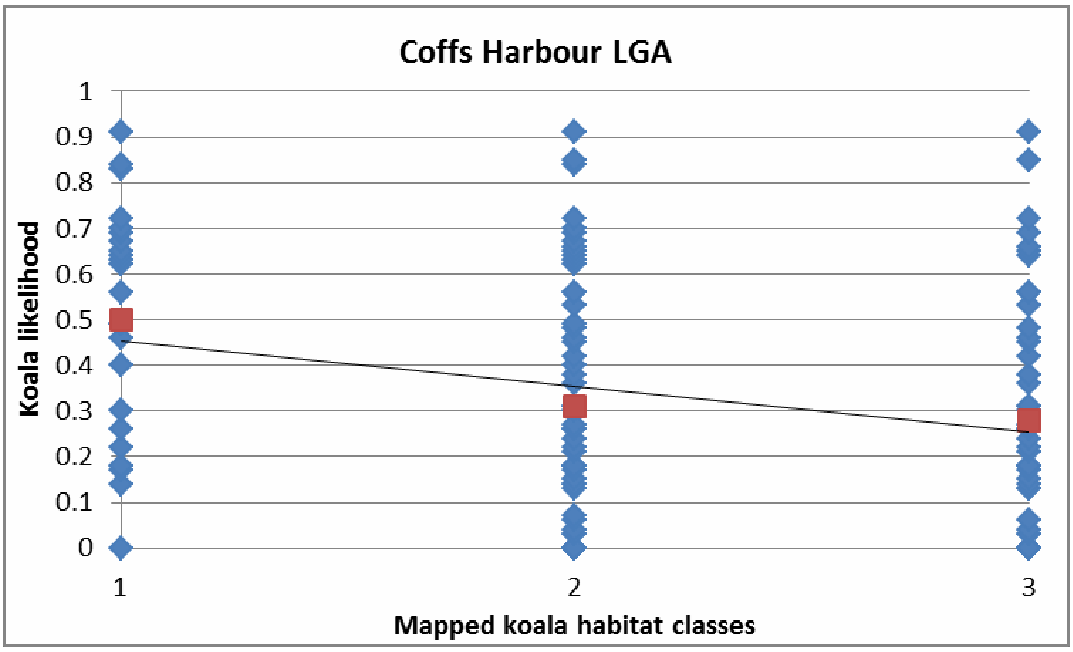


Figure 10. Coffs Harbour LGA likelihood of occurrence for grid cells containing mapped habitat of either class 1, 2 or 3 across 67, 5 km grid cells with more than 10% of their area within the LGA.

6.2 Bellingen (east) LGA

Koala habitat mapping: OEH 2014 (Koala habitat study) and OEH 2014 (Draft CKPOM)

Koala habitat mapping, based on collation of historical records, analysis of population persistence, targeted field survey (faecal pellet surveys) and extrapolation of fine-scale vegetation mapping, was undertaken within two precincts: north and south of the Bellinger River. These areas vary between higher density koala populations to the north and lower to the south. The koala habitat mapping confirms the high importance of koala habitats in the vicinity of Bongil Bongil National Park as well as Pine Creek and Tuckers Nob state forests. It also maps high quality habitats backing on to Dorrigo National Park in the west of the Bellingen (east) study area. The report identifies an overall decline in the area of occupancy and trends of decline in certain areas (e.g. south-west of Bellingen township, south and west of Urunga and in the far south-east of the LGA.

Figures 11, 12, 13, 14 and Appendix 2 give the basis for mapping comparisons.

Broad mapping comparisons for known important koala areas (Figure 11):

North Bellingen – Tuckers Nob, Pine Creek state forests – Bongil Bongil National Park

High agreement between mapping methods in this significant north-east section of the LGA shows grid cells of extensive class 1 preferred habitat matched by relatively high occurrence likelihood.

Summary

Comparison between the koala habitat mapping and baseline occurrence mapping in the Bellingen (east) LGA agrees in some areas but is at apparent odds in other areas (Figure 10). This reflects the inherent differences between the two mapping methods. For some locations and grid cells there is a disparity between the mapped habitat classes and the corresponding grid cell likelihoods of occurrence (Figures 11, 12, 13, 14). The reverse and neutral trend-lines in Figures 13 and 14 show this disparity. The difference in koala habitat quality to the north and south of the Bellinger River as reflected in the LGA koala habitat mapping is not borne out in the likelihood mapping. It appears to show an over-prediction for the area south of the river. This potentially reveals a data issue for the baseline mapping. The inclusion of numerous koala faecal pellet records without spatial filtering to account for those in proximity collected on the same day may have led to an over-prediction in certain grid cells containing a high proportion of state forest (where scat based survey technique are required under existing forestry approvals. This tendency to over-prediction is preferable to under-prediction but may require addressing in the future.

Three areas within the Bellingen (east) LGA indicate a level of difference between the likelihood mapping compared to the available habitat mapping (Figure 11):

- in the north-west of the LGA, backing on to Dorrigo National Park, high quality habitats are mapped but there are relatively few koala records
- the far south-east coastal area is mapped at a high likelihood level but is identified as an area of recent local decline (last three koala generations) by OEH (2014). The baseline mapping uses all records post-1994 to determine likelihoods of occurrence. While recent local decline has been identified, koala habitat still remains and could potentially be reoccupied

- west of Brierfield in the Gladstone State Forest area a high likelihood level appears to have resulted from number of koala faecal pellet records within the state forest. Although these records indicate a koala population it is not otherwise known as a particularly significant location. The mapping disparity suggests the need for further assessment to ascertain actual koala occupancy levels.

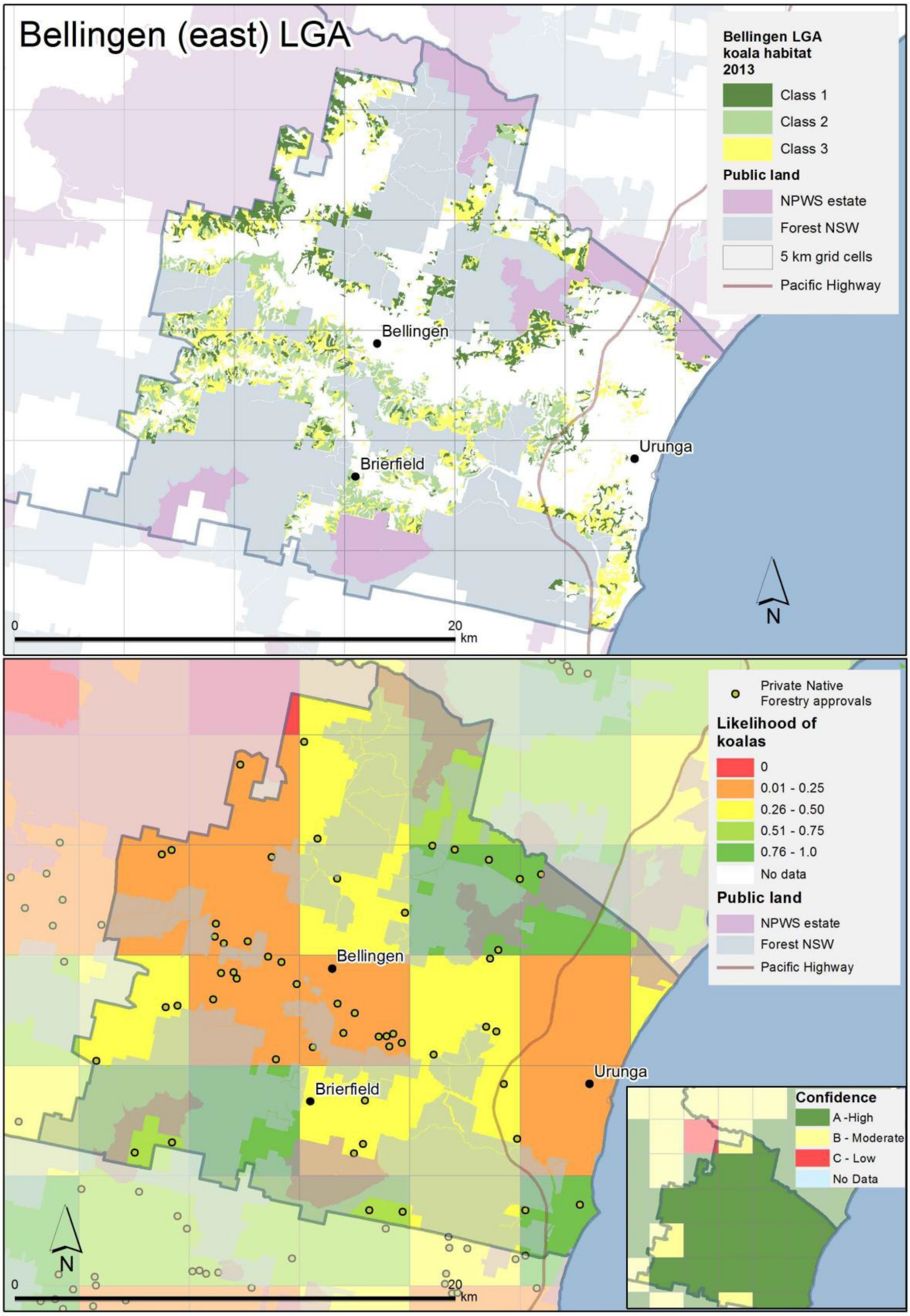


Figure 11. Bellingen (east) LGA: Mapped koala habitat (OEH 2013, 2014), koala likelihood (and confidence) and PNF approvals (as of June 2014).

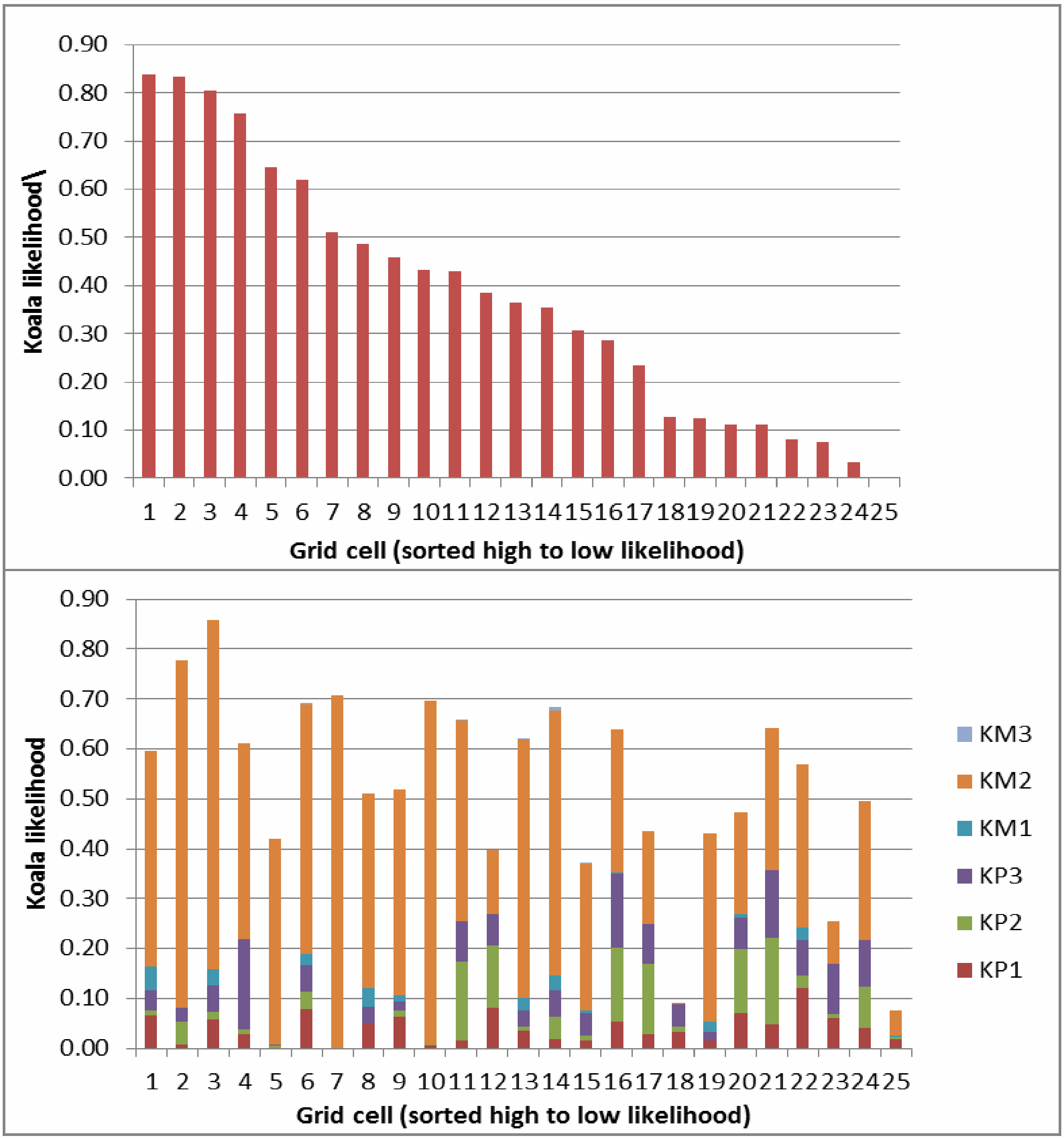


Figure 12. Bellingen (east) LGA: Likelihood of koala occurrence (sorted most to least) and corresponding relative proportions of mapped (OEH 2013) and modelled (CRAFTI Koala Model) koala habitat within 25, 5 km grid cells with more than 10% of their area within the LGA.

KP: mapped preferred koala habitat classes; KM: modelled habitat classes

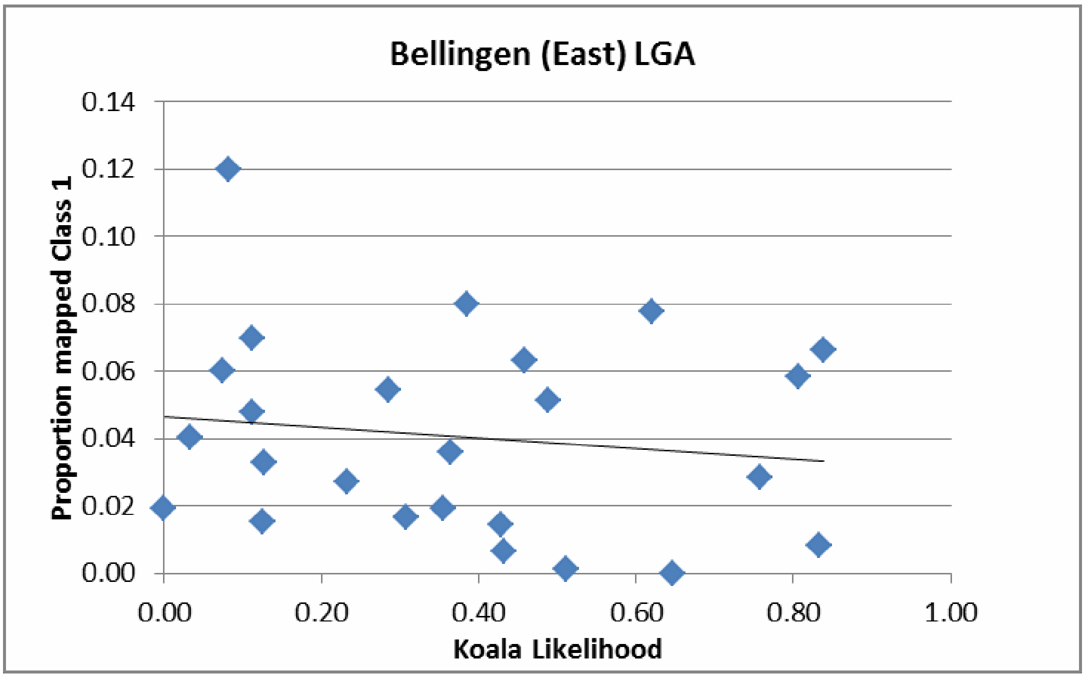


Figure 13. Bellingen (east) LGA: The proportion of the best mapped koala habitat (class 1) relative to mapped koala likelihood of occurrence within 25, 5 km grid cells with more than 10% of their area within the LGA.

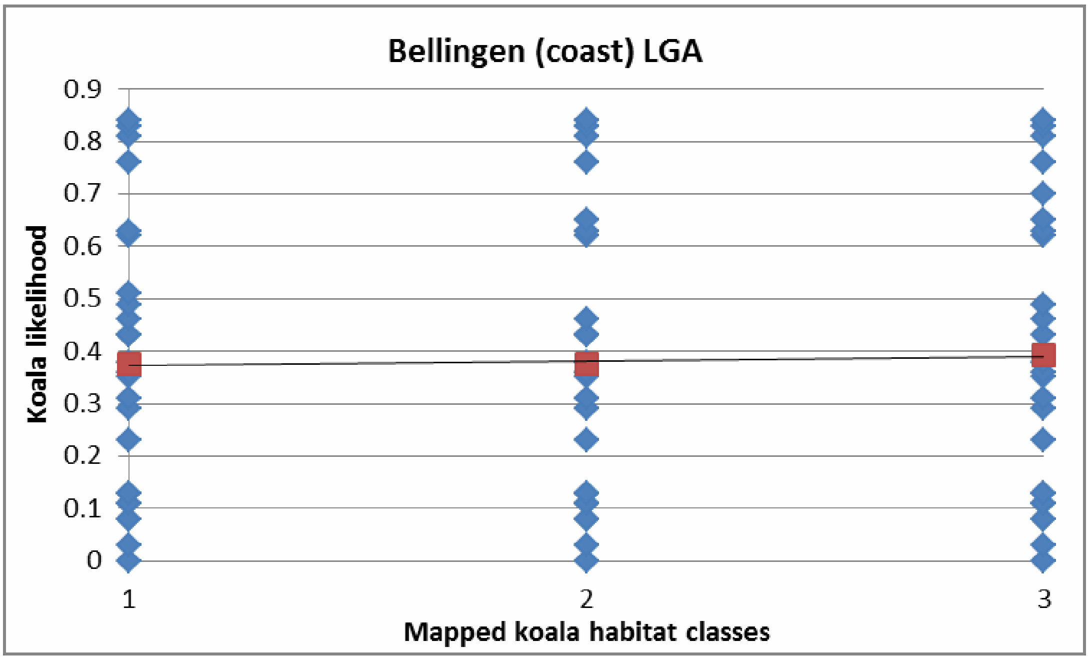


Figure 14. Bellingen (east) LGA: Koala likelihood of occurrence for grid cells containing mapped habitat of either class 1, 2 or 3 across 25, 5 km grid cells with more than 10% of their area within the LGA.

6.3 Port Macquarie-Hastings LGA

Koala habitat mapping: Biolink 2013 (Koala habitat and population assessment).

Koala habitat mapping, based on collation of historical records, analysis of population persistence, targeted field survey (faecal pellet surveys) and extrapolation of fine-scale vegetation mapping, was undertaken over the entire LGA but field survey was more intensive within the eastern portion. Biolink (2013) estimates that approximately 2,000 koalas occur in the LGA, more than 1,000 of these east of the Pacific Highway between the Hastings and Camden Haven rivers. The LGA includes a significant source population (comprising more than 500 individuals) located on public and freehold lands from Port Macquarie to Lake Innes.

Koala activity remains relatively widespread across the LGA (Biolink 2013) but most records from targeted surveys came from private lands and national parks. A possible decline on state forests reflects a documented loss of larger preferred tree species through logging. This has possible ramifications for the high numbers of PNF approvals in this LGA.

Overall koala generational persistence has been high but Biolink (2013) reports local declines in populations in the Laurieton, Bago and Wauchope districts. A less than optimal occupancy rate (about 24%) of habitat is also reported by Biolink (2013) indicating that substantial areas of mapped potential habitat are currently unoccupied. A large proportion of the koala population is centred within two relatively localised areas of habitat: the Lake Innes district and the Yarras-Debenham district, west of Ellenborough (Figure 15).

Figures 15, 16, 17, 18 and Appendix 3 provide the basis for mapping comparisons. Overall there is relatively little class 1 habitat mapped in this LGA (Figures 16, 17; Appendix 3) and it all falls east of the Pacific Highway. Class 1 habitat is difficult to discern at the scale of mapping provided in this report (Figure 15). Extensive areas of class 2 and 3 habitat are mapped throughout the LGA but the relatively low occupancy rate suggests that large tracts may be unoccupied or support low density koala populations. Quite a few of the 5 km grid cells, particularly in the western portion of the LGA, have a No Data label indicating a complete lack of mammal records and a need for survey (Figure 15). Further, much of the western third of the LGA is allocated a low confidence level (or No Data). This reiterates the need for targeted koala survey in these districts to allow regulation and assessment of logging activities and proposals.

Broad mapping comparisons for known important koala areas (Figure 15): Lake Innes district (all lands within 5 km of the water body centre) and smaller outliers at Lake Cathie and Bonny Hills

There is high agreement between the mapping methods in this significant coastal koala centre with grid cells of Class 1 and 2 preferred habitat matched by relatively high occurrence and likelihood of occurrence between Port Macquarie and Bonny Hills (Figure 15).

Dunbogan Peninsula and district between Camden Haven River and the northern boundary of Crowdy Bay National Park

This shows an area of localised population persistence and class 1 habitat mapping. This area is also allocated a relatively high likelihood of occurrence (Figure 15).

Red Hill – Telegraph Point (links into Kempsey LGA)

This is an area of population persistence west of the Pacific Highway and also shows relatively high likelihood of occurrence (Figure 15).

Hinterland population west of Ellenborough-Mt Seaview, Upper Pappinbarra-Mt Boss, Yarras-Debenham district

This is identified as an important hinterland habitat and koala population and also as an area of population persistence (Biolink 2013). The area contains some grid cells of moderate to high likelihood along with others containing no data and no koala records. Unsurprisingly these grid cells have confidence of No Data, “C” or “B”.

Summary

The baseline likelihood mapping generally agrees with the preferred koala habitat mapping for this LGA (Figure 15). The overall low area of occupancy reported this LGA is reflected in the rather patchy depiction of cells of high occurrence likelihood.

Grid cells demonstrating anomalous comparisons between the two mapping methods are generally also allocated a low confidence level or have been identified as No Data (Figure 15).

A positive correlation is recorded between mapped class 1 habitat and likelihood of occurrence (Figure 17); the many zero values in this graph illustrates the restricted extent of class 1 habitat mapping in this LGA. Agreement between the two mapping methods is also confirmed by a trend of decreasing koala likelihood from cells containing class 1 then 2 then 3 habitats (Figure 18).

This LGA is a focus for PNF and many PNF approvals have been given. Current approvals fall across all classes of preferred koala habitat and koala likelihood levels but primary clusters are mostly outside areas of moderate to high koala likelihood (Figure 15). Approvals in the Bonny Hills area and also in the Red Hill-Telegraph Point area are within cells of high koala likelihood. The lack of koala (and other mammal) records in the western third of the LGA highlights the lack of survey data in this area and further assessment would be required to properly assess logging proposals.

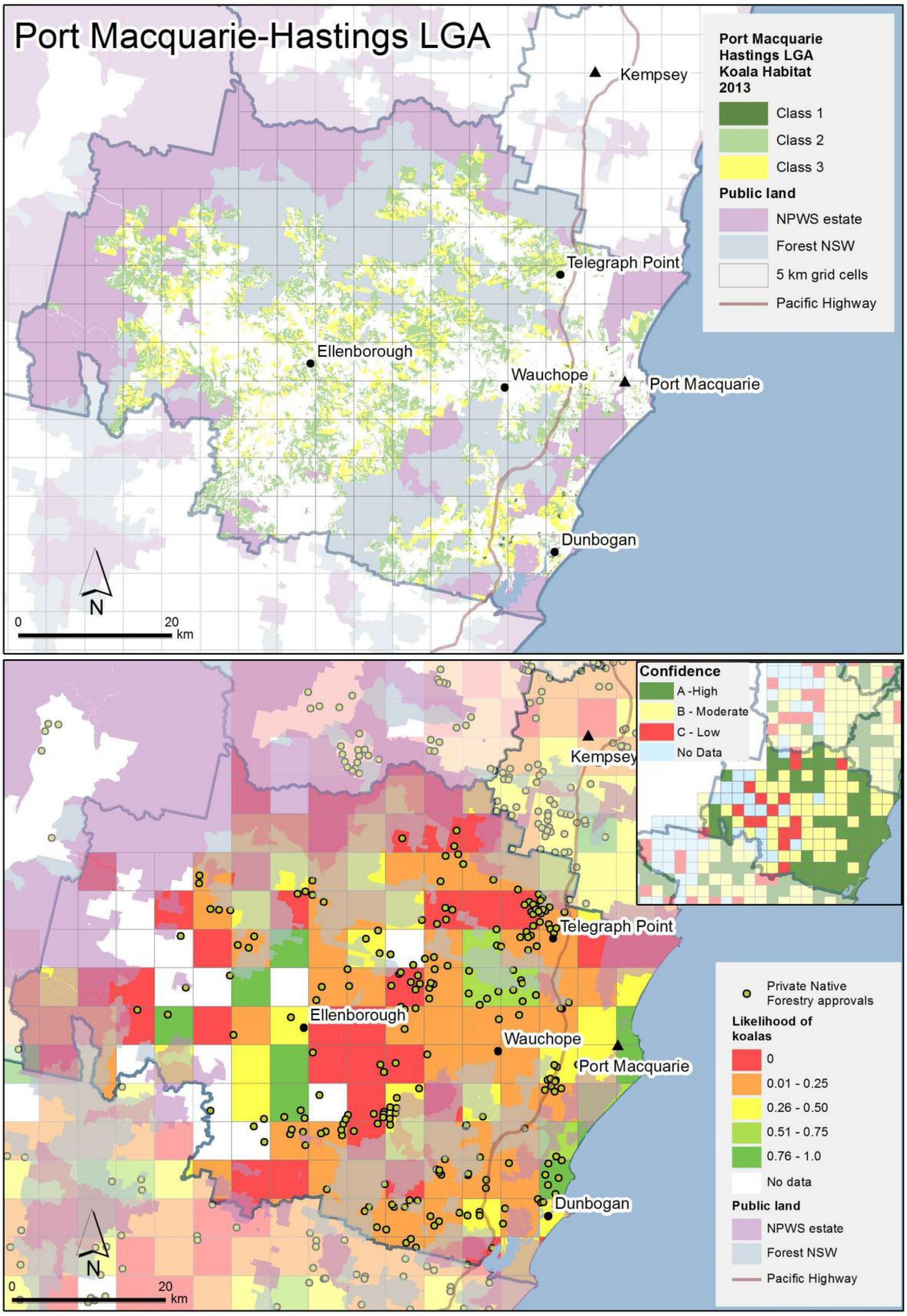


Figure 15. Port Macquarie-Hastings LGA: Mapped koala habitat (OEH 2013, 2014), koala likelihood (and confidence) and PNF approvals (as of June 2014).

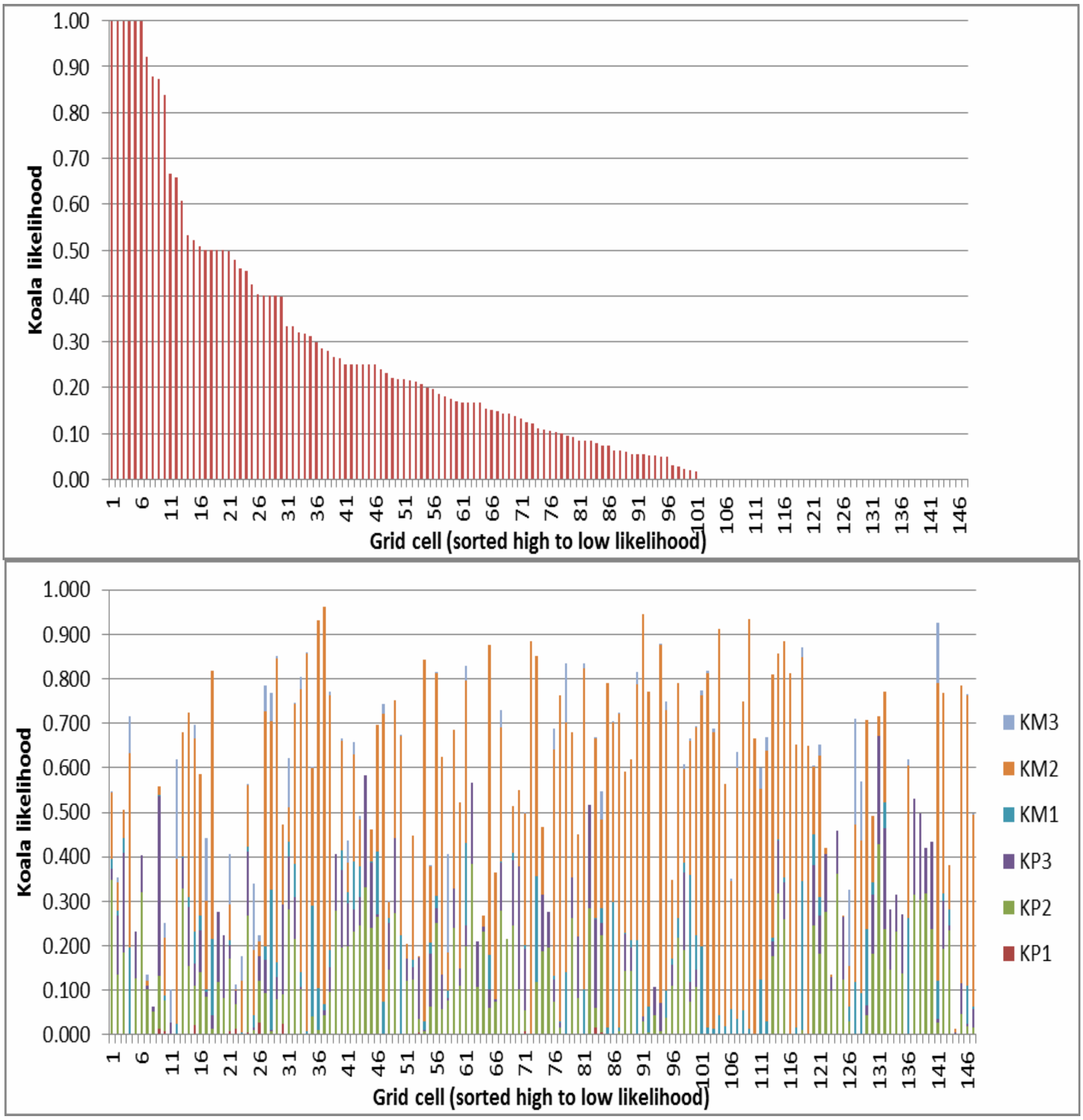


Figure 16. Port Macquarie-Hastings LGA: Likelihood of koala occurrence (sorted most to least) and corresponding relative proportions of mapped (Biolink 2013) and modelled (CRAFTI Koala Model) koala habitat within 147, 5 km grid cells with more than 10% of their area within the LGA.

KP: mapped preferred koala habitat classes. KM: modelled habitat classes

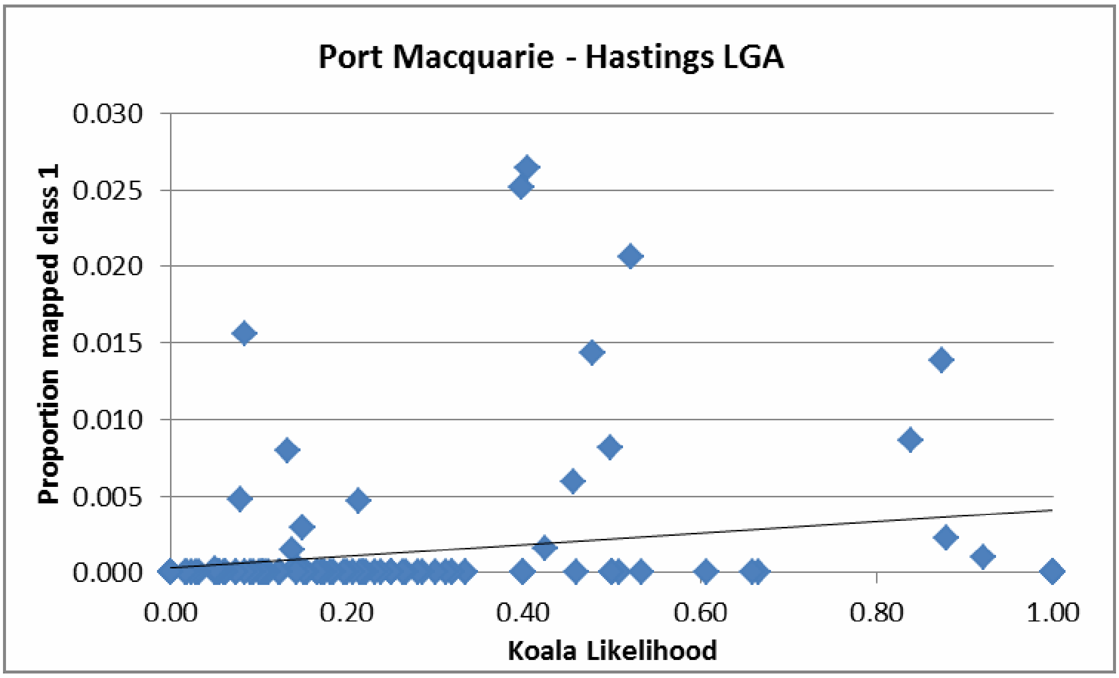


Figure 17. Port Macquarie-Hastings LGA: The proportion of the best mapped koala habitat (class 1) relative to mapped koala likelihood of occurrence within 147, 5 km grid cells with more than 10% of their area within the LGA.

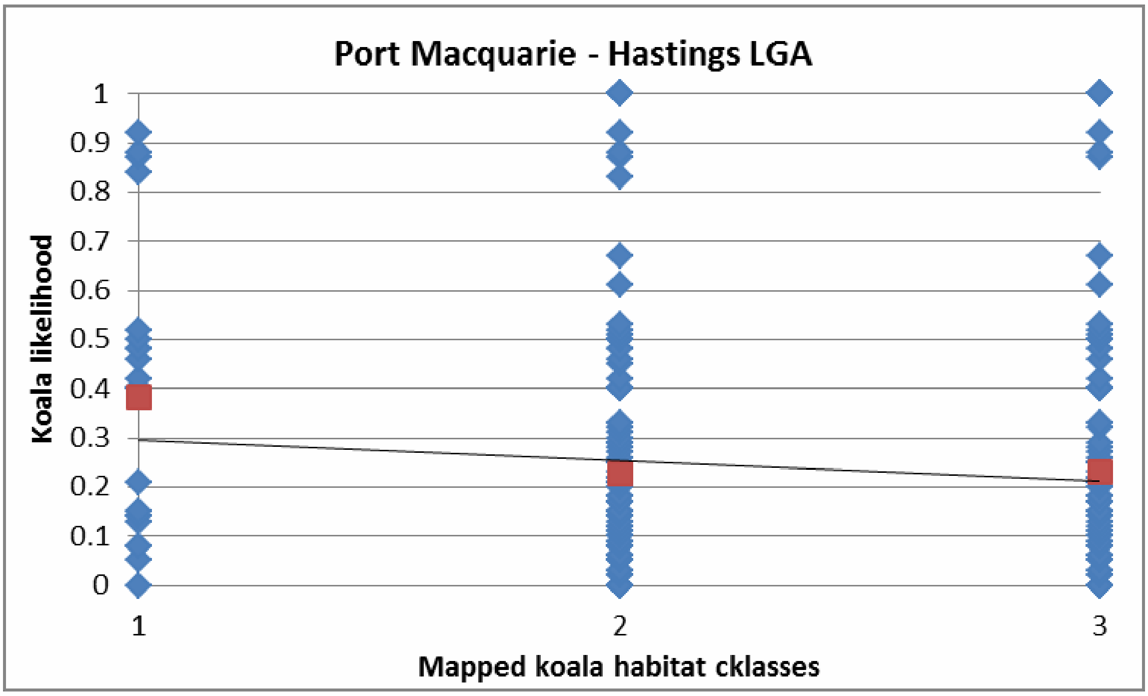


Figure 18. Port Macquarie-Hastings LGA: Koala likelihood of occurrence for grid cells containing mapped habitat of either class 1, 2 or 3 across 147, 5 km grid cells with more than 10% of their area within the LGA.

6.4 Tweed LGA

Koala Habitat mapping: Biolink (2011). Tweed Coast Koala Habitat Study

Koala habitat mapping was based on 2004 vegetation mapping in this LGA. Biolink (2011) reported that koalas have declined with a population estimate of just 144 (range 25–267) in the coastal part of the LGA. Vegetation and koala habitat mapping is considered better in east Tweed than west Tweed.

The best habitats are compartmentalised patches east of the Pacific Highway in a narrow band running the length of the LGA (Figure 19). These habitats are embedded within an urban and peri-urban landscape subject to high level threats.

Areas of koala generational persistence are scattered throughout the LGA and are particularly widespread within the coastal area. This indicates that koala breeding continues, even in low density hinterland populations allocated a low koala likelihood overall in the baseline likelihood mapping. A less than optimal area of occupancy (about 20%) is also reported by Biolink (2011) indicating substantial areas of mapped preferred habitat to be currently unoccupied.

Figures 19 and 20 provide the basis for mapping comparisons. The higher quality preferred habitats (classes 1 and 2) are concentrated along the coastal fringe, mostly east of the Pacific Highway. Lower quality koala habitats, supporting low density populations are mapped west of the Highway.

Broad mapping comparisons for known important koala areas (Figure 20): North of the Tweed River: Terranora–Bilambil Heights; Tweed Heads South

These are small relic populations facing low viability and high threats. These areas are not discerned by baseline mapping; the relevant grid cells are mapped as low likelihood.

South of the Tweed River: three distinct sub-populations occupying discrete areas between Bogangar and Pottsville

These areas of class 1 and class 2 koala habitats are picked up by the baseline mapping with the grid cells allocated low/moderate or moderate/high likelihood.

Wollumbin National Park and associated foothills

Koalas are well known in this location. The area is mapped as class 3 koala habitat by Biolink (2011) and as such is not distinguished from the rest of the western Tweed LGA. The baseline likelihood mapping allocates a moderate to high likelihood of occurrence.

Summary

The baseline likelihood mapping broadly agrees with the koala habitat mapping but cannot discern the fine-scaled patchiness illustrated by habitat mapping in this LGA. Known good koala habitats are mostly picked by the baseline mapping. This confirms its use to highlight areas of concern for forestry regulation. The overall low area of occupancy is reflected in the restricted and patchy depiction of cells of high occurrence likelihood. The broad allocation of class 3 habitat mapping in the western section LGA appears to be improved upon by identifying areas of elevated likelihood in the baseline mapping.

The trend shown in Figure 19 confirms broad correlation between the two mapping methods with grid cells containing class 1 habitat tending to higher koala likelihoods than cells containing class 3 habitats.

The baseline likelihood mapping allocates a moderate to high likelihood to four locations that are not discerned by the habitat mapping at any greater quality than class 3. These areas reflect numbers of koala records locally: west of Uki (near Wollumbin National Park), north of

Chillingham (around Numinbah Nature Reserve), south of Limpinwood Nature Reserve and between Murwillumbah and Bogangar. Confidence levels are moderate to high for these grid cells, further assessment may be needed to clarify local koala population status.

There is little or no forestry activity within the two highest koala habitat classes of the LGA. Fifteen PNF PVPs are mapped within the west Tweed LGA, all occur on class 3 koala habitat. The 12 grid cells with PNF PVPs are allocated zero (1), low (10) or moderate (1) koala likelihood. This indicates that a similar assessment outcome would have been expected. The latter approval is located west of Wollumbin National Park in an area of noted generational persistence. This elevates the importance of this area.

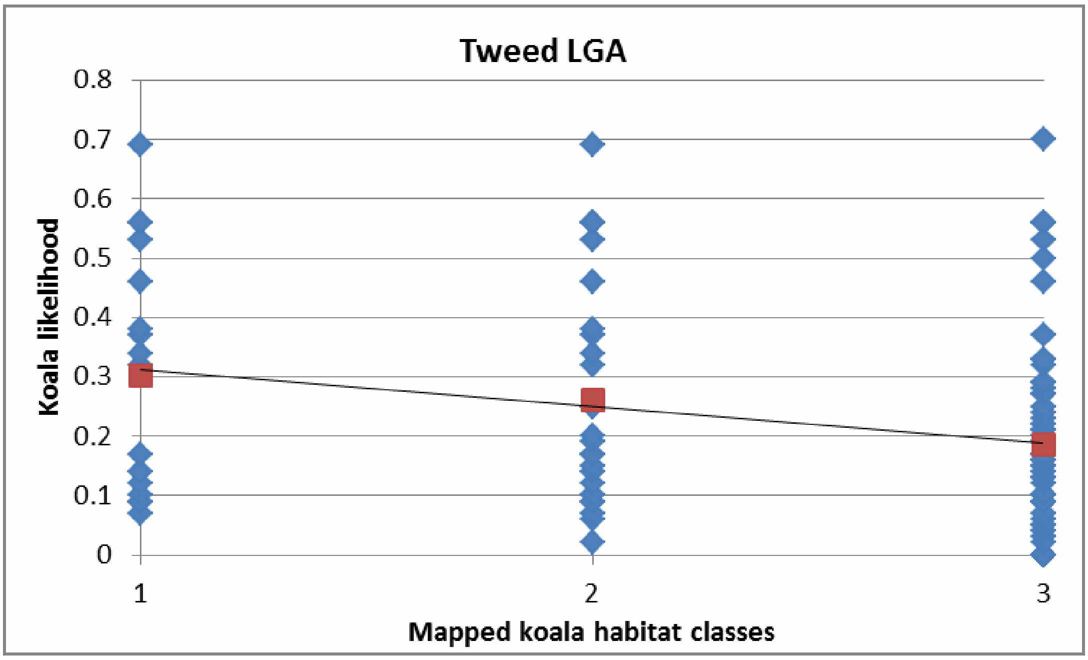


Figure 19. Tweed LGA: Koala likelihood of occurrence for grid cells containing mapped habitat of either class 1, 2 or 3.

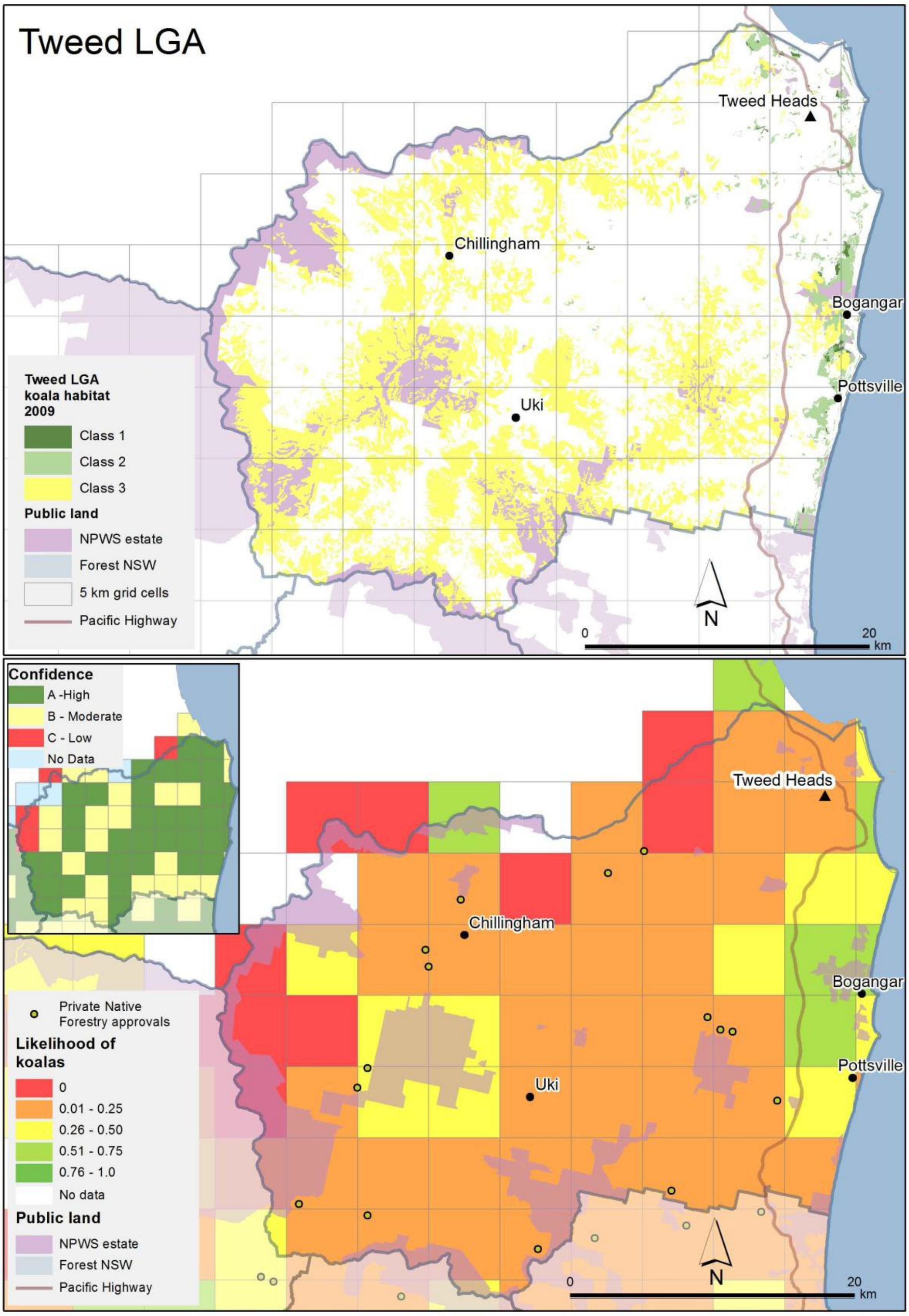


Figure 20. Tweed LGA: Mapped koala habitat (Biolink 2011), koala likelihood (and confidence) and PNF approvals (as of June 2014).

6.5 Byron LGA

Koala habitat mapping: Biolink (2012) ***Byron Coast Koala Habitat Study***

Vegetation and koala habitat mapping is more refined for the coastal Byron study area than for the rest of the LGA. Koala habitat mapping exists for areas of west Byron LGA, courtesy of an earlier study, but is very general.

The best koala habitats are within a highly fragmented coastal urban and peri-urban habitat matrix mostly east of the Pacific Highway (Figure 22). It is suggested by Biolink (2012) that the overall distribution of the coastal koala population may be expanding. However Biolink (2012) also consider that viability in the face of high level threats remains questionable.

Approximately 70% of the coastal Byron study area is substantially cleared of native vegetation and was not mapped during the vegetation mapping study that underlies the koala habitat mapping. That study (Landmark 1999) worked to a 0.5 ha threshold patch size. Some of these smaller patches are expected to support koalas and potential koala habitat.

Figures 21 and 22 provide the basis for mapping comparisons. The higher quality preferred habitats (classes 1 and 2) are concentrated along the coastal fringe, mostly east of the Pacific Highway.

Broad mapping comparisons for known important koala areas (Figure 22):

Biolink (2012) identifies two areas of generational persistence within two identified KMAs:

North Byron Coast KMA

This KMA, which includes Billinudgel Nature Reserve and some surrounding lands extends into the Tweed LGA (Tweed-Brunswick Coast Population). The koala population here appears to have been devastated by 2004 and 2009 bushfires and it has an uncertain status and future. It is considered to be near endangered by Biolink (2012). A very recent record from this location confirms an extant population (J. Turbill personal communication). This area is not discerned by the baseline mapping and is mapped at a low likelihood. The reason for this is unclear as there are a number of post 1994 koala records within this grid cell. The existence of other mammals records in this location, the subject of numerous surveys, may have influenced the map output in this grid cell.

South Byron Coast KMA

The bulk of the coastal Byron koala population occurs here in an area bisected by the Pacific Highway. It extends from Brunswick Heads to Mullumbimby to Tyagarah to West Byron to Broken Head (Figure 22). This area is only partially picked up by the baseline mapping with relevant cells mapped from low to moderate – and one at high likelihood near the well-known Tyagarah population. Areas of mapped class 1 habitat in west Byron and Broken Head are only low likelihood under the baseline mapping. This may again reflect the relative abundance of other mammal records and a consequent down grading of koala proportion in this area of concentrated human activity, observers and targeted mammal surveys.

Another district of koala importance lies between Goonengerry National Park and the area to the north of Coorabell.

This is an area of known historical importance to koalas but there is also a number of recent records as well. The preferred koala habitat mapping does not distinguish the area from the general allocation of class 3 mapping applied to much of the western portion of Byron LGA. The baseline mapping highlights this area at moderate to high likelihood levels (Figure 22). The reason for this discrepancy is unclear but may highlight issues with vegetation mapping in that area.

Summary

The baseline mapping broadly agrees with koala habitat mapping but cannot discern the fine-scaled patchiness illustrated by the LGA mapping. In some areas it has not delineated high quality habitats mapped in certain parts of the LGA. As explained above a likely explanation may relate to the abundance of mammal surveys in this area of focused human presence. Koala proportions may be diluted by an overall abundance of other mammal records in such areas. The neutral trend-line in Figure 21 illustrates disparity between the two mapping methods. Although LGA mapping has mapped habitat at a finer scale in the coastal section of the LGA, the likelihood mapping may provide a better representation of known koala habitats near of Goonengerry and Goonengerry National Park (Figure 22).

Only five PNF PVPs are mapped within the west Byron LGA. One is on non-koala habitat, three are on class 3 habitat and one is on class 2 habitat. Three fall within low likelihood baseline cells and two within moderate likelihood cells within the vicinity of Goonengerry.

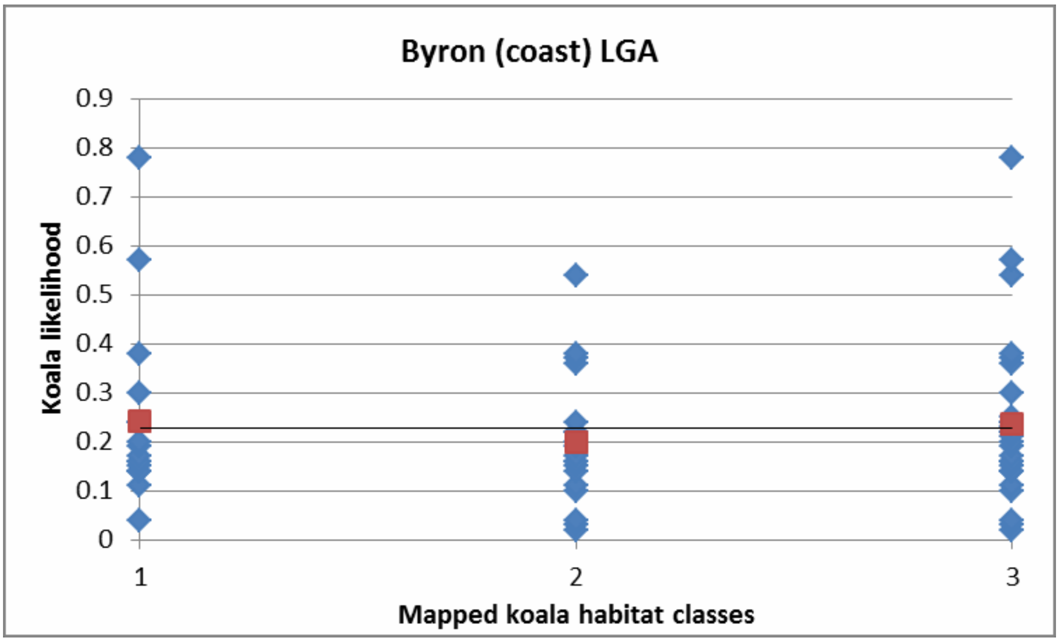


Figure 21. Byron LGA: Koala likelihood of occurrence for grid cells containing mapped habitat of either class 1, 2 or 3.

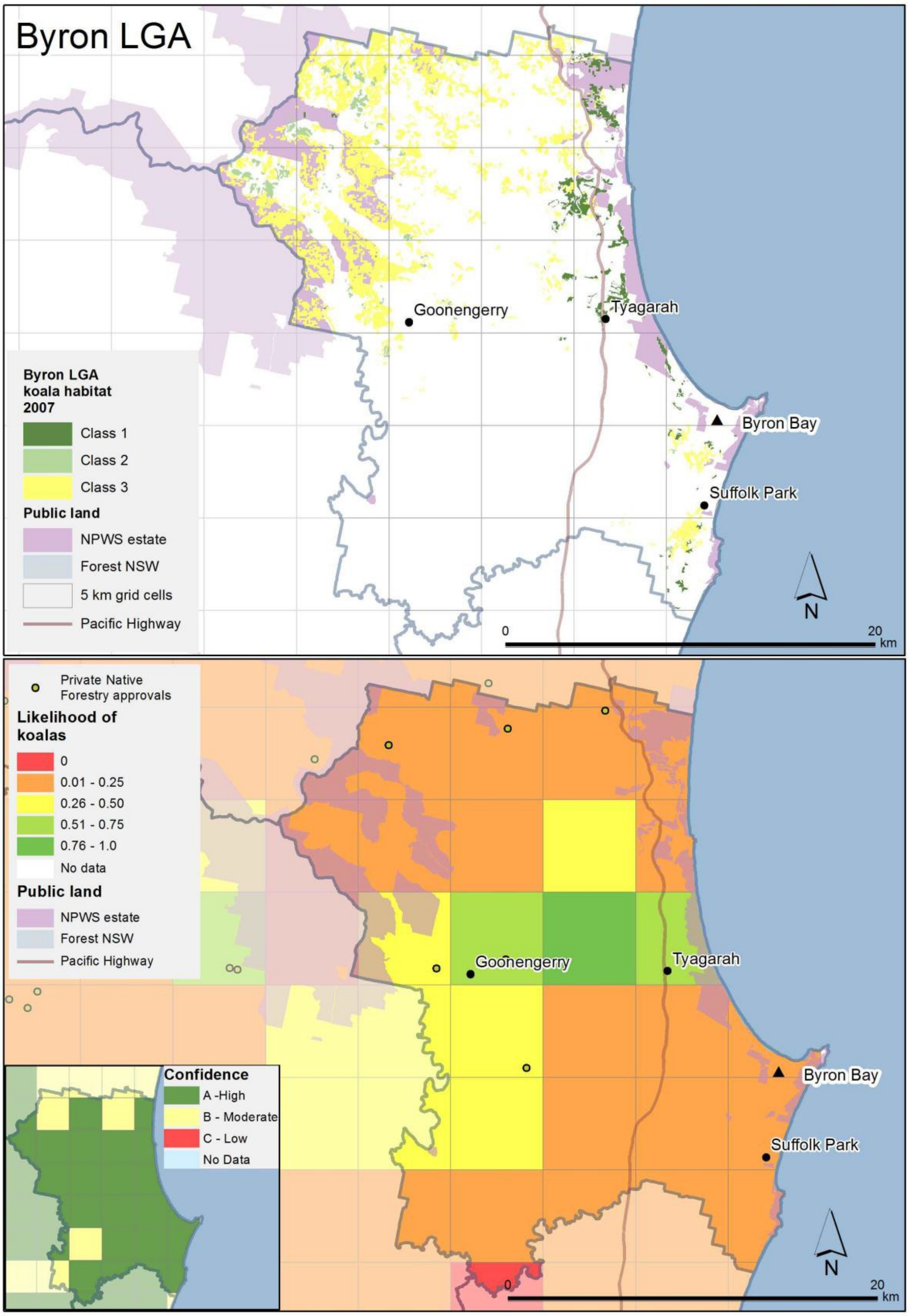


Figure 22. Byron LGA: Mapped koala habitat (Biolink 2012), koala likelihood (and confidence) and PNF approvals (as of June 2014).

6.6 Kempsey (east) LGA

Koala habitat study: Biolink 2009: Comprehensive Koala Plan of Management for Eastern Portion of Kempsey Shire LGA; Volume II – Resource Study.

Approximately 250 to 400 koalas may inhabit the Kempsey east study area (Biolink 2009), mostly occurring at low densities over a fairly broad area. The larger and more contiguous areas of forest, including national parks and state forests in the southern half of the study area are considered source areas.

Koala records in this LGA are concentrated south of the Macleay River with apparent relatively recent declines in the north and far south-east of the LGA. There are areas of generational persistence north of the river as well but they are small and relatively isolated with relatively large areas of apparently suitable habitats north of the river largely unoccupied.

Figures 23 and 24 provide the basis for mapping comparisons.

Broad mapping comparisons for known important koala areas (Figure 24):

Three KMAs are identified by Biolink (2009):

Dondingalong – Kundabung – Crescent Head KMA

This is a significant area of koala habitat which extends south into the adjoining Port Macquarie-Hastings LGA. This KMA includes the bulk of the koala population in this LGA as well as the best generational persistence (Biolink 2009). The relatively broad areas of class 1, 2, and 3 mapped in this area are supported by at least moderate to high koala likelihood mapping (Figure 24).

Eungai Rail – Stuarts Point – Grassy Head KMA

This is another area of generational persistence in the far north of the LGA but lack of recent records indicates a possible recent decline (Biolink 2009). Agreement between the two mapping methods is less strong here with low to zero likelihood levels applied, reflecting the relatively few records in the area.

South West Rocks KMA

Although a small number of relatively recent records and the mapping of class 1 and 2 habitats occur in this KMA the population is considered low. Koala habitat is known in this area, but based on the records the corresponding baseline mapping indicates a low likelihood level.

Summary

The baseline mapping and the likelihood mapping provide broadly agreeable outputs for a large portion of the LGA – in particular the important Dondingalong-Kundabung-Crescent Head KMA where most historic koala records are and where relatively broader areas of class 1 and 2 habitats are mapped (Figure 24). Some disparity is apparent in the northern section where identified KMAs are given relatively low likelihood levels. These areas of disparity are reflected in Figure 23 which shows a neutral trend-line rather than the negative correlation expected for conforming data sets. In this case grid cells containing class 2 habitat were typically mapped at a higher likely level than cells containing class 1 habitat. The LGA mapping, which reflects more recent analyses of generational persistence, should take precedence in areas of mapping disagreement.

There are many PNF approvals in the Kempsey East section of the LGA. All are away from the coast and most are in areas of residual, less fertile soils supporting low density koala populations in mapped class 2 and 3 preferred habitats.

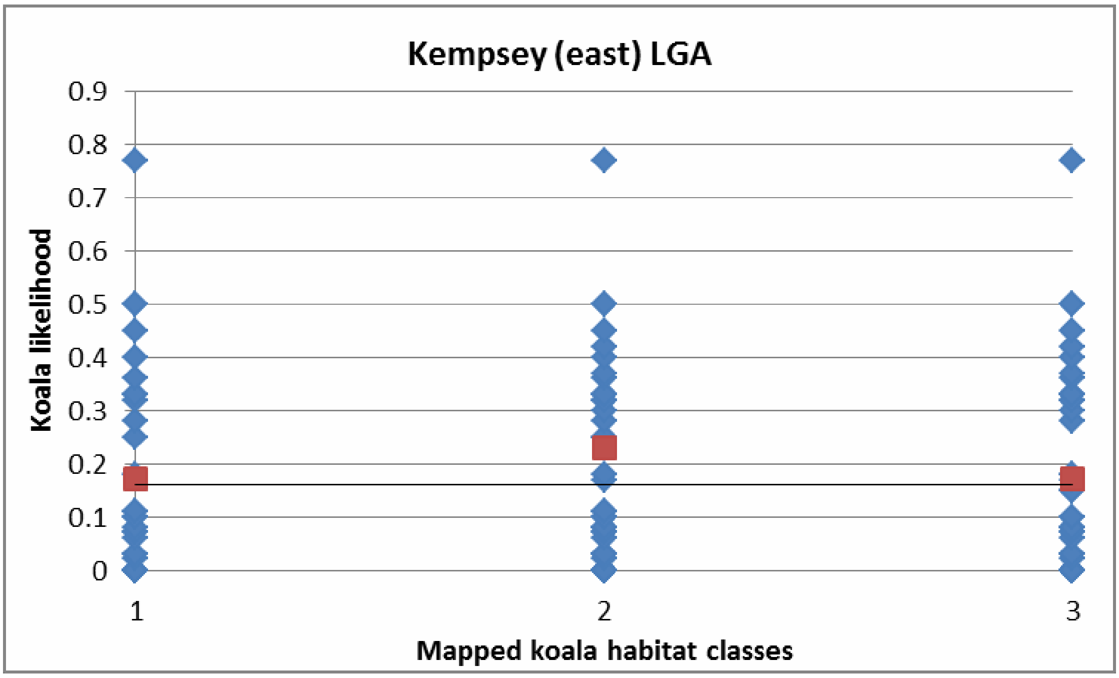


Figure 23. Kempsey (east) LGA: Koala likelihood of occurrence for grid cells containing mapped habitat of either class 1, 2 or 3.

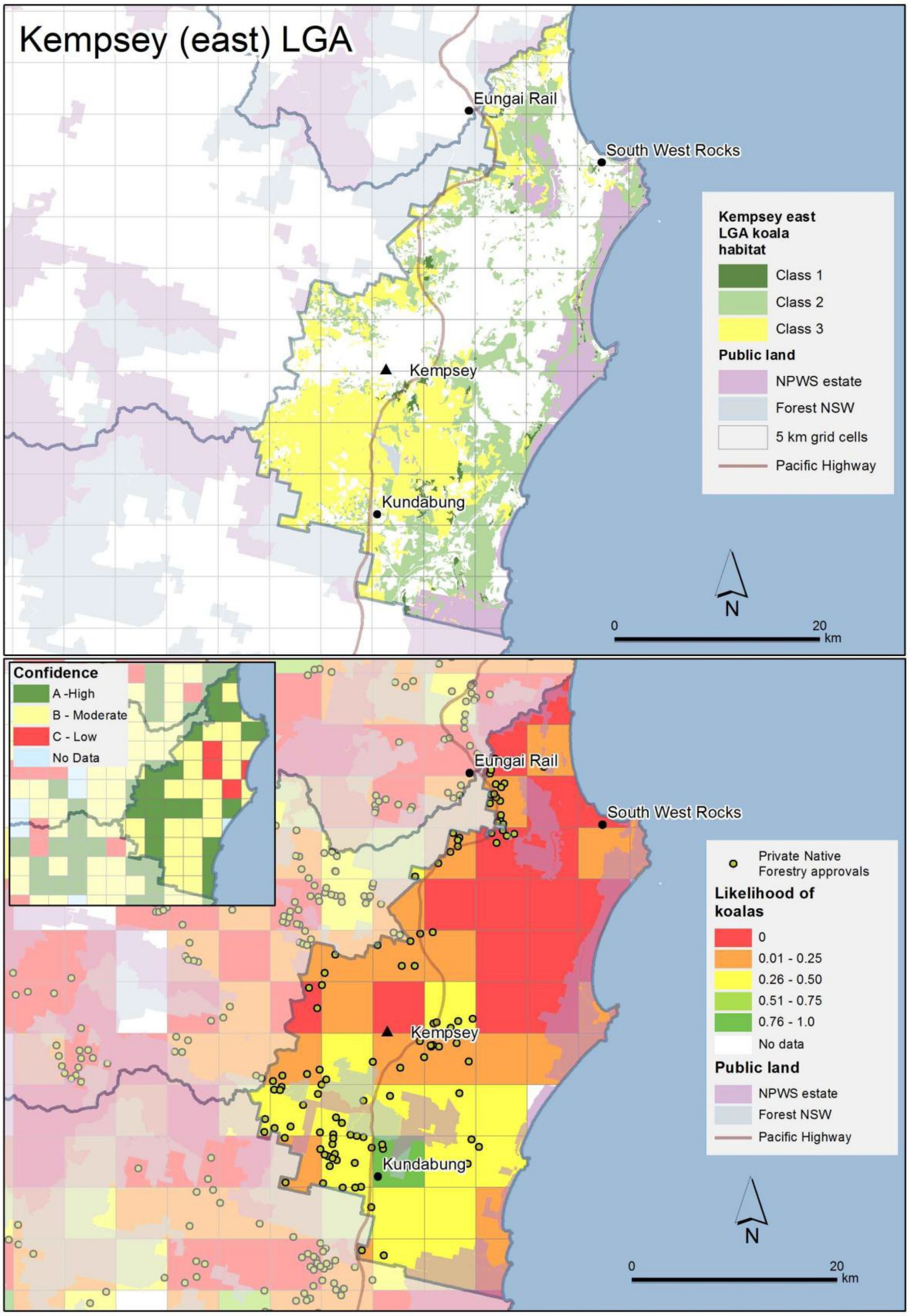


Figure 24. Kempsey (east) LGA: Mapped koala habitat (Biolink 2009), koala likelihood (and confidence) and PNF approvals (as of June 2014).

6.7 Greater Taree

Broad mapping of koala habitat was undertaken by the Australian Koala Foundation (AKF 2002). Only a draft CKPOM has been produced.

The majority of koala records in the LGA fall within three broad areas – between Taree and Killabakh, west of Taree along the Manning River floodplain and in the north of the LGA in the vicinity of Tapin Tops National Park and Bulga State Forest.

Figures 25 and 26 are the basis for mapping comparisons. Broad swathes of preferred koala habitat are mapped across the LGA with class 1 habitat mapped in three restricted locations (Figure 26). Two of these locations are largely devoid of koala or mammal records and require targeted survey to ascertain the likelihood of koala occurrence; No Data labels for likelihood and confidence are allocated in these areas (Figure 26).

Broad mapping comparisons for known important koala areas (Figure 26):

The draft CKPOM identifies a Priority Koala Conservation Zone for the LGA:

The areas north and south of the Manning River centred on Taree itself and then extending north to the Killabakh district

This area includes Yarratt State Forest and private forests to its east that are mapped as class 1 and 2 preferred koala habitats. The baseline likelihood mapping is in direct agreement with the preferred koala habitat mapping here with grid cells allocated moderate to high levels of likelihood.

Summary

The baseline likelihood mapping generally agrees with the preferred koala habitat mapping for this LGA (Figure 26). The overall low koala reporting rate, outside of a handful of core areas, is reflected in the patchy depiction of cells of higher occurrence likelihood. This patchiness is somewhat at odds with the rather broad mapping of preferred habitat classes in the LGA (Figure 26). Large parts of these broadly mapped habitats are devoid of koala records and may be unoccupied. Relatively broad areas of moderate occurrence likelihood extending west from Taree along the Manning floodplain are not reflected in the preferred habitat mapping. This may be due to the broad nature of available vegetation mapping and extrapolation of the koala habitat mapping across vegetation types. Habitat patches in this area may fall below the vegetation mapping patch size threshold.

Overall agreement between the two mapping methods is indicated by a slight trend of decreasing koala likelihood from cells containing class 1 then 2 then 3 habitats (Figure 25) but the correlation appears tenuous given the anomalies above and may be influenced by the large number of cells assigned a low confidence level.

A number of PNF approvals within this LGA have been granted. Current approvals fall across all classes of preferred koala habitat and koala likelihood levels including cells with no survey data (Figure 26). Approvals in the Killabakh district and also near Bulga State Forest and some other more isolated areas are within cells of high koala likelihood. The lack of koala (and other mammal) records in the western third of the LGA highlights the need for further assessment to inform logging proposals.

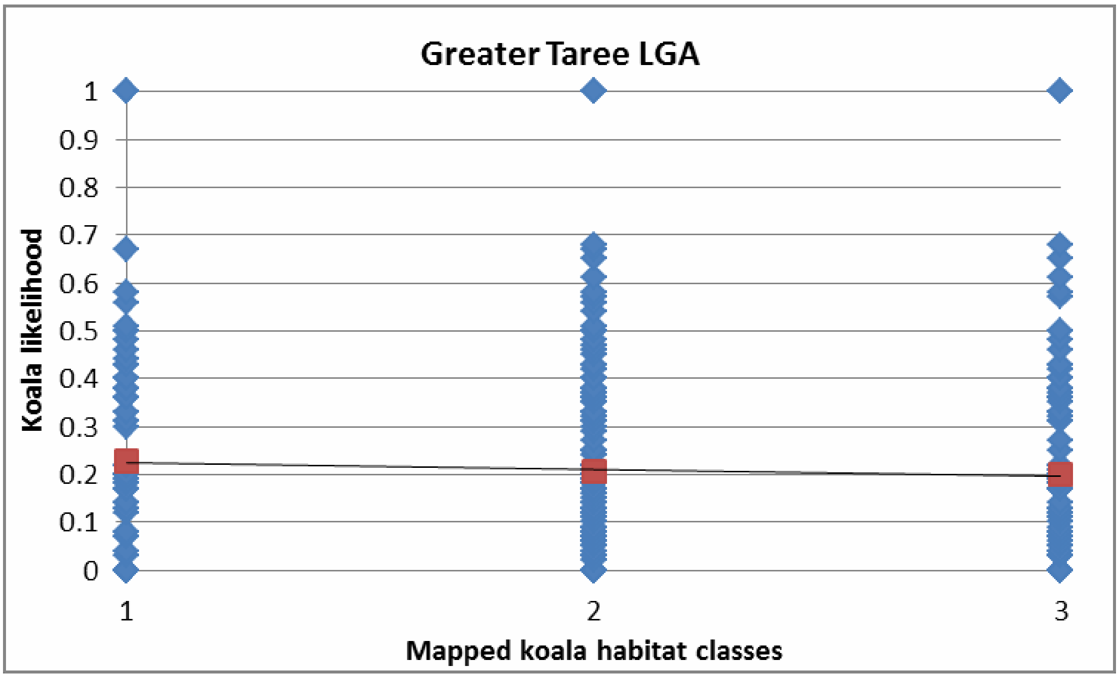


Figure 25. Greater Taree LGA: Koala likelihood of occurrence for grid cells containing mapped habitat of either class 1, 2 or 3.

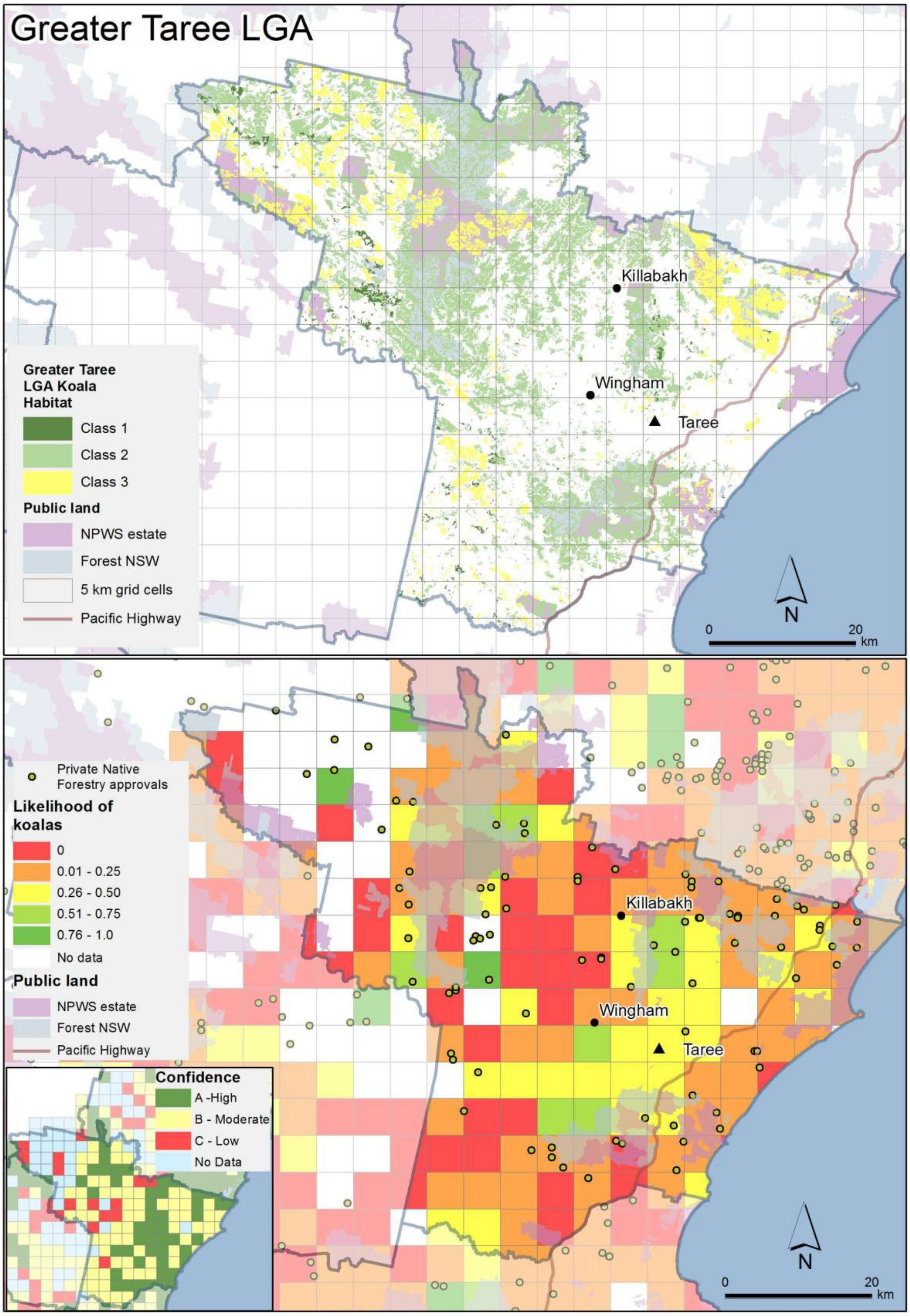


Figure 26. Greater Taree LGA: Mapped koala habitat (AKF 2002), koala likelihood (and confidence) and PNF approvals (as of June 2014).

6.8 Port Stephens LGA

Koala habitat mapping: Lunney *et al*. 1998, Port Stephens Council (2001)

Koala records are concentrated between Nelson Bay and Raymond Terrace. The identification of koala habitat in this LGA involved combining field-based survey and community-based survey data, interpreted in the context of available vegetation mapping to derive preferred koala habitat classes (Port Stephens Council 2001).

Figures 27 and 28 provide the basis for mapping comparisons.

6.8.1 Broad mapping comparisons for known important koala areas (Figure 27):

Nelson Bay – Bobs farm – Soldiers Point district

This area supports a well-known important koala population within mosaics of urban and peri-urban habitat remnants. Agreement between the mapping methods in this portion of the LGA is high. Grid cells supporting the highest quality habitats (class 1) are matched by relatively high occurrence likelihood (Figure 27).

Medowie – Raymond Terrace district

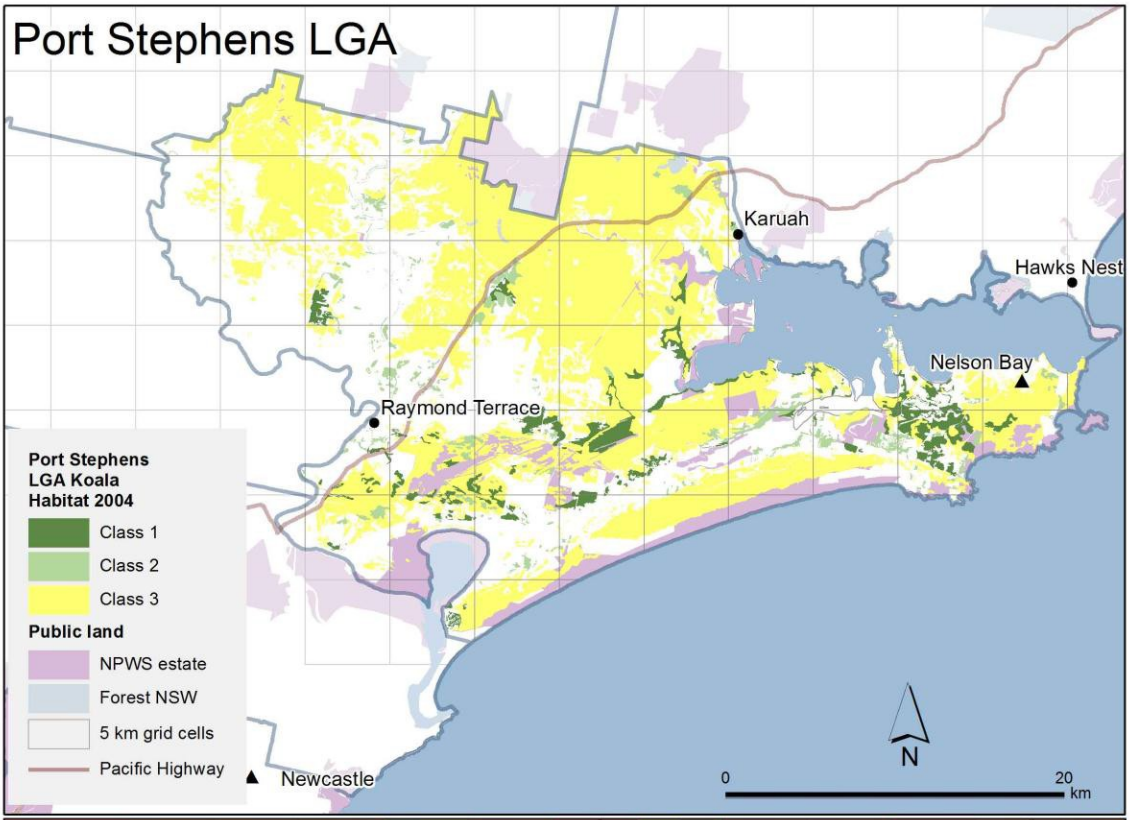
This is also an area of important koala habitats and the two mapping methods again align well. Grid cells supporting class 1 habitats are also allocated a relatively high likelihood of occurrence.

Summary

The baseline mapping broadly agrees with the koala habitat mapping in this LGA. One area of disagreement concerns a grid cell west of Karuah (Figure 27) where a number of koala records have yielded a high likelihood of occurrence, and a high confidence level, but the mapped habitat class is not distinguished beyond the broad allocation of class 3 habitat characterising the northern part of the LGA. It is unclear as to why this anomaly has arisen, but vegetation mapping in this part of the LGA may be inaccurate.

The broad agreement between the two mapping methods is confirmed by a trend of decreasing koala likelihood from cells containing class 1 then 2 then 3 habitats (Figure 28).

There are no PNF approvals within this LGA but any that do arise should be adequately assessed by the application of habitat mapping and baseline occurrence mapping.



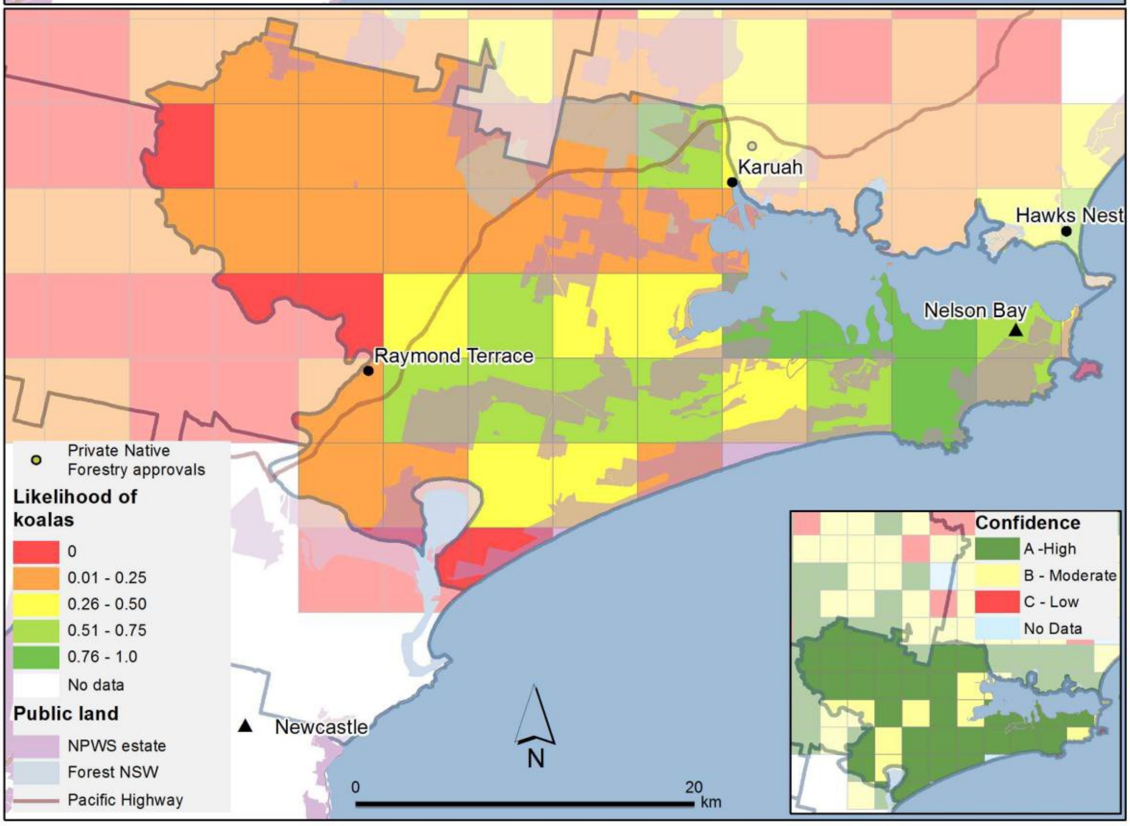


Figure 27. Port Stephens LGA Area: Mapped koala habitat (Lunney *et al. 1998,* Port Stephens Council 2001), koala likelihood (and confidence) and Private Native Forestry approvals (as of June 2014).

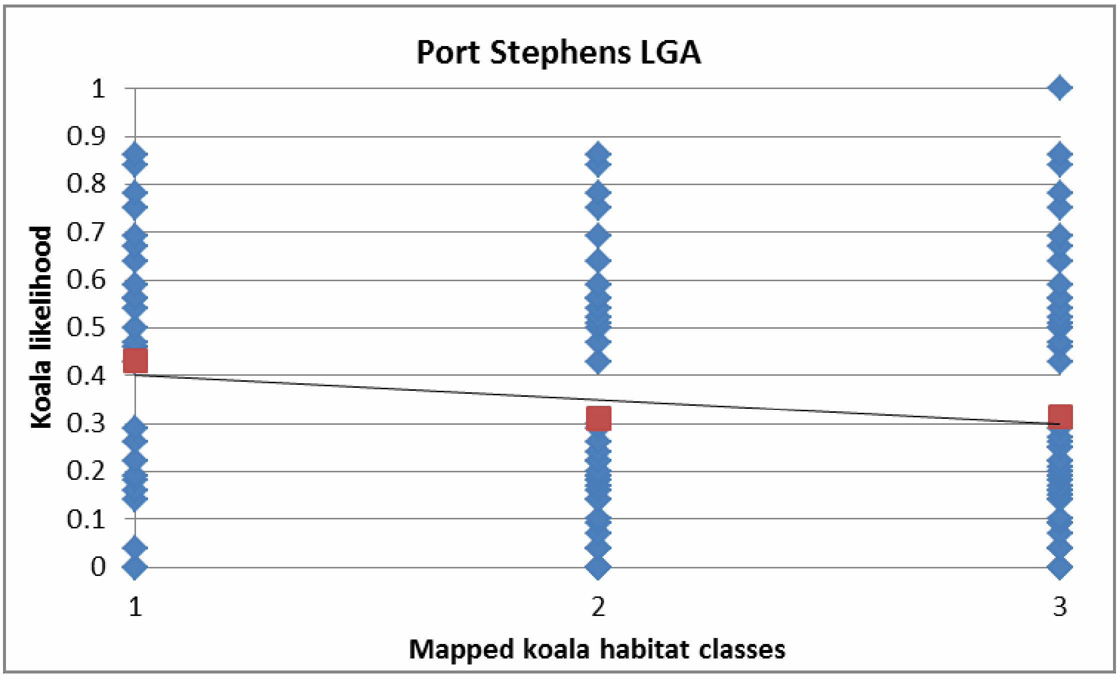


Figure 28. Port Stephens LGA: Koala likelihood of occurrence for grid cells containing mapped habitat of either class 1, 2 or 3.

7. Conclusion

Overall this sub-project has shown broad agreement between local mapping of koala habitat and 5 km grid cell outputs of koala likelihood of occurrence. It would be unrealistic to expect anything approaching perfect agreement between local habitat mapping and broader scale likelihood of occurrence.

Observed anomalies between the two mapping methods may relate to:

- Differences in the scale of mapping with fine-scale variation detected in preferred habitat mapping being indistinguishable in the baseline mapping ; preferred koala habitat mapping is extrapolated directly from associated vegetation mapping polygons (generally less than 0.5 hectares) while the baseline likelihood mapping assessed in this sub-project is at the scale of 5 kilometre grid cells (2500 hectares).
- Local variation in vegetation mapping accuracy with flow on effects to extrapolated koala habitat mapping.
- The inability of the baseline koala likelihood mapping, derived from a 20 year span of koala records, to detect relatively recent koala declines or increases at local scales. It should also be noted that some of the koala habitat maps are based on older spatial data and hence may not directly overlap with the baseline mapping.
- Possible dilution and concentration of koala proportions in the baseline likelihood mapping by inconsistent reporting levels of particular mammal records in some locations. This could have a particular effect in those areas of high human habitation (e.g. development centres of the NSW north coast). Additionally, many koala records are based on scats rather than actual animals sighted. This may result in multiple reporting of the one koala.
- The possible need to apply data filters for certain types of data used in the determination of baseline koala likelihood mapping. This may relate particularly to the use of koala faecal pellet records whereby spatially related records may need to be filtered to avoid implications of data duplication. It is recognised however that this will increase the likelihood of koalas in these cells and therefore may provide a higher level of protection.

By its very nature, koala habitat mapping provides a generalised and quite broad depiction of potential habitat. Estimates of area of occupancy carried out in various koala habitat mapping projects highlight an overall low percentage of available habitat being occupied at any one time. This illustrates the koalas' naturally patchy occurrence and the influence of various threats. Koala habitat preferences are informed by the locations of koala records but the mapping itself reflects the occurrence and extent of preferred habitats based on associated polygons of vegetation classes.

In contrast, the preliminary baseline koala likelihood of occurrence mapping does not relate to habitat as such but provides a direct reflection of collated koala records relative to other mammal records. With a 1994 cut-off for historical koala records this mapping provides a '20 year view' of likely koala occurrence and non-occurrence. The provision of a mapping confidence estimate provides added value to the baseline mapping informing the user of the extent to which the allocated likelihood can be trusted and the extent to which the assigned likelihood value can aid the assessment and regulation of forestry activities.

Where differences between the mapping methods cannot be accounted for, the LGA mapping should take first preference. Where LGA mapping is not available then the baseline mapping is a reasonable representation of koala occurrence likelihood.

As with all mobile fauna species the mapping of koala habitat or likelihood of occupancy is fraught with difficulties that cannot all be accounted for by any single method. Integration of the best elements of different approaches will always yield the best result. Where the two mapping methods can be combined to inform koala habitat locations then the predictive powers of each is likely to be enhanced. In areas where koala habitat mapping has not been undertaken the results of this sub-project suggest that the baseline koala likelihood of occurrence mapping is a sound basis for regulation of forestry activities as they pertain to koala conservation.

8. References

Australian Koala Foundation (2002) Greater Taree City Council. Draft Comprehensive Koala Plan of management A report for the Greater Taree City Council

Biolink (2009) Comprehensive Koala Plan of Management for Eastern Portion of Kempsey Shire LGA; Volume II – Resource Study Biolink Ecological Consultants Uki NSW

Biolink (2011) *Aspects of the ecology, distribution and abundance of koalas in the Lismore LGA*. Unpublished report to Lismore City Council. Biolink Ecological Consultants Uki NSW

Biolink (2012) *Byron Coast Koala Habitat Study* Report to Byron Shire Council Biolink Ecological Consultants Uki NSW

Biolink (2013. *Port Macquarie – Hastings Koala Habitat & Population Assessment*. Final Report to Port Macquarie-Hastings Council Biolink Ecological Consultants Uki NSW

DECC (2008) *Recovery Plan for the Koala (*Phascolarctos cinereus) Department of Environment and Climate Change Sydney South NSW

Department of Planning (1995) *State Environmental Planning Policy No. 44 – Koala Habitat Protection* Department of Planning Sydney NSW

EPA (2014) *Remake of the Coastal Integrated Forestry Operations Approvals; Discussion paper February 2014* Environment Protection Authority Sydney NSW

Lunney D Phillips S Callaghan J and Coburn D. (1998) Determining the distribution of koala habitat across a shire as a basis for conservation: a case study from Port Stephens NSW *Pacific Conservation Biology* 4: pp 186–196

Lunney D Gresser S O'Neill LE, Matthews A and Rhodes J (2007) The impact of fire and dogs on koalas at Port Stephens New South Wales using population viability analysis *Pacific Conservation Biology* 13: pp 189–201

Lunney D Crowther MS Shannon I and Bryant JV (2009a) Combining a map- based public survey with an estimation of site occupancy to determine the recent and changing distribution of the koala in New South Wales *Wildlife Research* 36: pp 262–73

Lunney D Moon C Matthews A Turbill J and Ecological Australia (2009b) Coffs Harbour City Koala Plan of Management Part A Revised edition Coffs Harbour City Council, Coffs Harbour NSW

Minister for Sustainability Environment Water Population and Communities (April 2012). *Approved Conservation Advice for* Phascolarctos cinereus *(combined populations of Queensland, New South Wales and the Australian Capital Territory) (koala Northern Designatable Unit)* Canberra ACT

OEH (2014) *Koala Habitat Study Bellingen Shire Council Coastal Area* Report to Bellingen Shire Council OEH Coffs Harbour NSW

OEH (2014) *Draft Comprehensive Koala Plan of Management Bellingen Shire Council Coastal Area* Report to Bellingen Shire Council OEH Coffs Harbour NSW

Phillips S and Callaghan J (2011) The Spot Assessment Technique: a tool for determining levels of localized habitat use by koalas *Phascolarctos cinereus. Australian Zoologist* 35(3): pp 774–780

Phillips S Hopkins M and Shelton M (2011) Tweed Coast Koala Habitat Study Unpublished report to Tweed Shire Council. Biolink Pty Ltd

Port Stephens Council (2001) *Port Stephens Council Comprehensive Koala Plan of Management (CKPOM): CKPOM Resource Document – June 2001* Prepared by Port Stephens Council Australian Koala Foundation and NSW National Parks and Wildlife Service

Predavec M Scotts D Lunney D Turbill J and Shannon . (2014) A preliminary map of the likelihood of koala within NSW; For use in Private Native Forestry applications Unpublished report for the NSW Environment Protection Authority

Smith AP (2004. Koala conservation and habitat requirements in a timber production forest in north-east New South Wales pp. 591-611 in *Conservation of Australia's Forest Fauna* (second edition) Lunney D. (ed) Royal Zoological Society of NSW Mosman NSW

Wintle BA Elith R J Yamada K Burgman M A 2004 *Modelling priority species habitat requirements* Lower Hunter & Central Coast Biodiversity Strategy Hunter Region Councils NSW

Appendices

Appendix 1: Coffs Harbour LGA: Koala likelihood of occurrence, proportion mapped koala habitat classes (KP) (Lunney *et al*. (2009) and proportion modelled habitat classes (KM) (CRAFTI Koala Model) within 67, 5 km grid cells with more than 10% of their area within the LGA.

	RELATIVE PROPORTION OF GRID CELL											
Koala Likelihood of Occurrence	**KP1**	**KP2**	**KP3**	**KP1,2,3**	**KM1**	**KM2**	**KM3**	**KM1,2,3**	**KP1,KM1**	**KP2,KM2**	**KP3,KM3**	**Ktotal**
0.91	0.02	0.17	0.01	0.21	0.03	0.46	0.00	0.49	0.06	0.63	0.01	0.70
0.86	0.00	0.00	0.00	0.00	0.15	0.63	0.00	0.79	0.15	0.63	0.00	0.79
0.85	0.00	0.01	0.07	0.09	0.01	0.73	0.00	0.74	0.01	0.75	0.07	0.83
0.84	0.07	0.01	0.04	0.12	0.05	0.43	0.00	0.48	0.11	0.44	0.04	0.59
0.83	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.02
0.77	0.00	0.00	0.00	0.00	0.20	0.62	0.00	0.82	0.20	0.62	0.00	0.82
0.72	0.10	0.15	0.08	0.33	0.03	0.19	0.00	0.21	0.13	0.33	0.08	0.55
0.70	0.10	0.03	0.00	0.12	0.02	0.26	0.00	0.29	0.12	0.29	0.00	0.41
0.69	0.20	0.03	0.01	0.23	0.00	0.14	0.00	0.14	0.20	0.17	0.01	0.38
0.67	0.21	0.01	0.00	0.22	0.00	0.00	0.00	0.00	0.21	0.01	0.00	0.22
0.66	0.00	0.07	0.08	0.14	0.05	0.35	0.00	0.41	0.05	0.42	0.08	0.55
0.65	0.01	0.01	0.00	0.02	0.02	0.71	0.00	0.72	0.03	0.71	0.00	0.74
0.64	0.11	0.02	0.00	0.13	0.00	0.10	0.00	0.10	0.11	0.12	0.00	0.23
0.63	0.08	0.02	0.00	0.10	0.08	0.51	0.00	0.59	0.15	0.53	0.00	0.69
0.62	0.08	0.03	0.05	0.17	0.02	0.50	0.00	0.52	0.10	0.53	0.06	0.69
0.56	0.00	0.00	0.02	0.02	0.02	0.81	0.00	0.84	0.02	0.81	0.02	0.86
0.56	0.00	0.08	0.06	0.15	0.04	0.11	0.03	0.17	0.04	0.19	0.09	0.32
0.53	0.00	0.09	0.40	0.49	0.06	0.14	0.00	0.20	0.06	0.23	0.40	0.68
0.49	0.10	0.01	0.00	0.11	0.00	0.00	0.00	0.00	0.10	0.01	0.00	0.11
0.48	0.00	0.03	0.27	0.30	0.00	0.01	0.00	0.01	0.00	0.04	0.27	0.31
0.48	0.00	0.00	0.00	0.00	0.02	0.81	0.00	0.83	0.02	0.81	0.00	0.83
0.45	0.00	0.14	0.08	0.21	0.00	0.47	0.00	0.47	0.01	0.60	0.08	0.68
0.45	0.00	0.17	0.07	0.24	0.04	0.35	0.00	0.39	0.04	0.52	0.07	0.64
0.42	0.00	0.06	0.05	0.11	0.06	0.51	0.00	0.56	0.06	0.56	0.05	0.67
0.40	0.15	0.03	0.00	0.18	0.00	0.12	0.00	0.12	0.15	0.15	0.00	0.30
0.38	0.00	0.06	0.05	0.11	0.03	0.34	0.00	0.37	0.03	0.40	0.05	0.48
0.37	0.00	0.00	0.00	0.00	0.20	0.70	0.00	0.90	0.20	0.70	0.00	0.90
0.36	0.00	0.09	0.12	0.20	0.02	0.42	0.00	0.44	0.02	0.50	0.12	0.64
0.31	0.00	0.01	0.11	0.12	0.09	0.53	0.00	0.63	0.09	0.55	0.11	0.75
0.31	0.02	0.01	0.05	0.07	0.01	0.29	0.00	0.30	0.02	0.30	0.05	0.37
0.30	0.00	0.07	0.09	0.15	0.08	0.21	0.00	0.29	0.08	0.28	0.09	0.44
0.27	0.00	0.22	0.05	0.27	0.00	0.08	0.00	0.08	0.00	0.30	0.05	0.35
0.26	0.01	0.03	0.03	0.07	0.01	0.60	0.00	0.61	0.01	0.63	0.03	0.68
0.26	0.00	0.00	0.00	0.01	0.05	0.89	0.00	0.94	0.05	0.90	0.00	0.95

0.24	0.00	0.08	0.10	0.18	0.03	0.58	0.00	0.61	0.03	0.66	0.10	0.79
0.22	0.00	0.00	0.00	0.00	0.20	0.65	0.00	0.84	0.20	0.65	0.00	0.84
0.22	0.03	0.25	0.12	0.39	0.00	0.00	0.00	0.00	0.03	0.25	0.12	0.40
0.21	0.00	0.03	0.03	0.06	0.04	0.54	0.00	0.58	0.04	0.57	0.03	0.64

	RELATIVE PROPORTION OF GRID CELL											
Koala Likelihood of Occurrence	**KP1**	**KP2**	**KP3**	**KP1,2,3**	**KM1**	**KM2**	**KM3**	**KM1,2,3**	**KP1,KM1**	**KP2,KM2**	**KP3,KM3**	**Ktotal**
0.18	0.00	0.09	0.05	0.14	0.03	0.44	0.00	0.47	0.03	0.54	0.05	0.61
0.18	0.00	0.19	0.02	0.21	0.00	0.03	0.00	0.03	0.00	0.22	0.02	0.24
0.18	0.07	0.02	0.00	0.09	0.00	0.01	0.00	0.01	0.07	0.03	0.00	0.10
0.18	0.00	0.04	0.02	0.07	0.04	0.76	0.07	0.88	0.04	0.80	0.09	0.94
0.17	0.03	0.11	0.03	0.17	0.03	0.53	0.00	0.56	0.06	0.64	0.03	0.73
0.15	0.00	0.17	0.14	0.31	0.01	0.19	0.00	0.20	0.01	0.36	0.14	0.51
0.14	0.00	0.02	0.18	0.20	0.00	0.05	0.00	0.05	0.01	0.07	0.18	0.25
0.14	0.00	0.07	0.15	0.22	0.05	0.51	0.00	0.56	0.05	0.57	0.15	0.78
0.13	0.00	0.14	0.02	0.17	0.02	0.33	0.00	0.35	0.02	0.47	0.03	0.52
0.07	0.00	0.10	0.00	0.10	0.02	0.00	0.00	0.02	0.02	0.10	0.00	0.13
0.06	0.00	0.13	0.07	0.20	0.00	0.14	0.00	0.14	0.00	0.27	0.07	0.34
0.04	0.00	0.11	0.03	0.14	0.00	0.20	0.00	0.21	0.00	0.31	0.03	0.34
0.03	0.00	0.03	0.08	0.11	0.05	0.67	0.12	0.84	0.05	0.70	0.20	0.95
0.03	0.00	0.14	0.06	0.20	0.00	0.02	0.00	0.02	0.00	0.17	0.06	0.23
0.00	0.00	0.00	0.00	0.00	0.01	0.40	0.34	0.76	0.01	0.40	0.34	0.76
0.00	0.00	0.00	0.00	0.00	0.04	0.59	0.10	0.74	0.04	0.59	0.10	0.74
0.00	0.00	0.06	0.00	0.06	0.00	0.76	0.12	0.88	0.00	0.82	0.12	0.94
0.00	0.00	0.01	0.00	0.01	0.05	0.23	0.17	0.45	0.05	0.24	0.17	0.45
0.00	0.00	0.03	0.05	0.09	0.02	0.40	0.21	0.63	0.02	0.44	0.26	0.72
0.00	0.00	0.30	0.27	0.57	0.00	0.01	0.00	0.01	0.00	0.31	0.27	0.58
0.00	0.00	0.30	0.07	0.38	0.01	0.01	0.00	0.02	0.01	0.32	0.07	0.40
0.00	0.00	0.00	0.00	0.00	0.03	0.46	0.50	0.99	0.03	0.46	0.50	0.99
0.00	0.00	0.16	0.00	0.16	0.00	0.45	0.01	0.46	0.00	0.61	0.01	0.62
0.00	0.00	0.12	0.20	0.32	0.00	0.25	0.00	0.25	0.00	0.37	0.20	0.57
0.00	0.00	0.09	0.17	0.26	0.01	0.54	0.03	0.59	0.01	0.63	0.20	0.85
0.00	0.00	0.00	0.00	0.01	0.04	0.28	0.08	0.40	0.04	0.28	0.09	0.41
0.00	0.00	0.30	0.12	0.41	0.01	0.29	0.05	0.34	0.01	0.59	0.16	0.76
0.00	0.00	0.01	0.00	0.01	0.00	0.07	0.00	0.07	0.00	0.08	0.00	0.09

Appendix 2: Bellingen (east) LGA: Koala likelihood of occurrence, proportion of mapped koala habitat classes (KP) (OEH 2013) and proportion modelled habitat classes (KM) (CRAFTI Koala Model) within 25, 5 km grid cells with more than 10% of their area within the LGA.

	RELATIVE PROPORTION OF GRID CELL											
Koala Likelihood of Occurrence	**KP1**	**KP2**	**KP3**	**KP1,2,3**	**KM1**	**KM2**	**KM3**	**KM1,2,3**	**KP1,KM1**	**KP2,KM2**	**KP3,KM3**	**Ktotal**
0.84	0.07	0.01	0.04	0.12	0.05	0.43	0.00	0.48	0.11	0.44	0.04	0.59
0.83	0.01	0.04	0.03	0.08	0.00	0.70	0.00	0.70	0.01	0.74	0.03	0.78
0.81	0.06	0.01	0.05	0.13	0.03	0.70	0.00	0.73	0.09	0.71	0.05	0.86
0.76	0.03	0.01	0.18	0.22	0.00	0.39	0.00	0.39	0.03	0.40	0.18	0.61
0.65	0.00	0.01	0.00	0.01	0.00	0.41	0.00	0.41	0.00	0.42	0.00	0.42
0.62	0.08	0.03	0.05	0.17	0.02	0.50	0.00	0.52	0.10	0.53	0.06	0.69
0.51	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.71	0.00	0.71	0.00	0.71
0.49	0.05	0.00	0.03	0.08	0.04	0.39	0.00	0.43	0.09	0.39	0.03	0.51
0.46	0.06	0.01	0.02	0.09	0.01	0.41	0.00	0.42	0.08	0.42	0.02	0.52
0.43	0.01	0.00	0.00	0.01	0.00	0.69	0.00	0.69	0.01	0.69	0.00	0.70
0.43	0.01	0.16	0.08	0.25	0.00	0.40	0.00	0.40	0.01	0.56	0.08	0.66
0.39	0.08	0.13	0.06	0.27	0.00	0.13	0.00	0.13	0.08	0.25	0.06	0.40
0.36	0.04	0.01	0.03	0.08	0.02	0.52	0.00	0.54	0.06	0.52	0.04	0.62
0.35	0.02	0.04	0.05	0.12	0.03	0.53	0.01	0.57	0.05	0.58	0.06	0.69
0.31	0.02	0.01	0.05	0.07	0.01	0.29	0.00	0.30	0.02	0.30	0.05	0.37
0.29	0.05	0.15	0.15	0.35	0.00	0.29	0.00	0.29	0.06	0.43	0.15	0.64
0.23	0.03	0.14	0.08	0.25	0.00	0.18	0.00	0.18	0.03	0.32	0.08	0.43
0.13	0.03	0.01	0.04	0.09	0.00	0.00	0.00	0.00	0.03	0.01	0.04	0.09
0.13	0.02	0.00	0.02	0.03	0.02	0.38	0.00	0.40	0.03	0.38	0.02	0.43
0.11	0.07	0.13	0.06	0.26	0.01	0.20	0.00	0.21	0.08	0.33	0.06	0.47
0.11	0.05	0.17	0.14	0.36	0.00	0.28	0.00	0.28	0.05	0.46	0.14	0.64
0.08	0.12	0.03	0.07	0.22	0.03	0.33	0.00	0.35	0.15	0.35	0.07	0.57
0.08	0.06	0.01	0.10	0.17	0.00	0.09	0.00	0.09	0.06	0.09	0.10	0.26
0.03	0.04	0.08	0.09	0.22	0.00	0.28	0.00	0.28	0.04	0.36	0.09	0.50
0.00	0.02	0.00	0.00	0.02	0.00	0.05	0.00	0.05	0.02	0.05	0.00	0.08

Appendix 3: Port Macquarie-Hastings LGA: Koala likelihood of occurrence, proportion mapped koala habitat classes (KP) (OEH 2013) and proportion modelled habitat classes (KM) (CRAFTI Koala Model) within 147, 5 km grid cells with more than 10% of their area within the LGA.

	RELATIVE PROPORTION OF GRID CELL											
Koala Likelihood of Occurrence	KP1	KP2	KP3	KP1,2,3	KM1	KM2	KM3	KM1,2,3	KP1,KM1	KP2,KM2	KP3,KM3	Ktotal
1.00	0.00	0.35	0.02	0.37	0.02	0.15	0.00	0.17	0.02	0.50	0.02	0.55
1.00	0.00	0.14	0.13	0.27	0.01	0.06	0.01	0.09	0.01	0.20	0.14	0.35
1.00	0.00	0.18	0.23	0.41	0.03	0.06	0.00	0.10	0.03	0.25	0.23	0.51
1.00	0.00	0.00	0.00	0.00	0.20	0.43	0.08	0.71	0.20	0.43	0.08	0.71
1.00	0.00	0.13	0.11	0.23	0.00	0.00	0.00	0.00	0.00	0.13	0.11	0.23
1.00	0.00	0.32	0.08	0.40	0.00	0.00	0.00	0.00	0.00	0.32	0.08	0.40
0.92	0.00	0.10	0.01	0.11	0.00	0.01	0.01	0.02	0.00	0.11	0.02	0.13
0.88	0.00	0.05	0.01	0.06	0.00	0.00	0.00	0.00	0.00	0.05	0.01	0.06
0.87	0.01	0.12	0.40	0.54	0.00	0.02	0.00	0.02	0.02	0.14	0.40	0.56
0.84	0.01	0.07	0.00	0.08	0.01	0.13	0.03	0.17	0.02	0.20	0.03	0.25
0.67	0.00	0.00	0.03	0.03	0.00	0.00	0.07	0.07	0.00	0.00	0.10	0.10
0.66	0.00	0.00	0.00	0.00	0.02	0.37	0.23	0.62	0.02	0.37	0.23	0.62
0.61	0.00	0.33	0.07	0.40	0.00	0.28	0.00	0.28	0.00	0.61	0.07	0.68
0.53	0.00	0.15	0.13	0.29	0.02	0.41	0.00	0.44	0.02	0.57	0.13	0.72
0.52	0.02	0.09	0.05	0.16	0.07	0.43	0.03	0.54	0.09	0.52	0.08	0.70
0.51	0.00	0.14	0.09	0.23	0.03	0.32	0.00	0.35	0.03	0.46	0.09	0.59
0.50	0.00	0.09	0.01	0.10	0.01	0.20	0.14	0.35	0.01	0.28	0.15	0.44
0.50	0.00	0.01	0.03	0.04	0.17	0.60	0.00	0.77	0.17	0.61	0.03	0.82
0.50	0.00	0.12	0.16	0.28	0.00	0.00	0.00	0.00	0.00	0.12	0.16	0.28
0.50	0.00	0.08	0.14	0.22	0.00	0.00	0.00	0.00	0.00	0.08	0.14	0.22
0.50	0.01	0.16	0.03	0.20	0.01	0.08	0.11	0.20	0.02	0.24	0.15	0.41
0.48	0.01	0.06	0.03	0.10	0.00	0.00	0.01	0.01	0.01	0.06	0.04	0.11
0.46	0.00	0.00	0.00	0.00	0.00	0.12	0.06	0.18	0.00	0.12	0.06	0.18
0.46	0.01	0.26	0.14	0.41	0.01	0.14	0.00	0.15	0.02	0.40	0.14	0.56
0.42	0.00	0.01	0.01	0.01	0.03	0.15	0.15	0.32	0.03	0.16	0.15	0.34
0.40	0.03	0.09	0.06	0.18	0.00	0.03	0.01	0.05	0.03	0.13	0.07	0.22
0.40	0.00	0.09	0.07	0.17	0.03	0.53	0.06	0.62	0.03	0.62	0.13	0.78
0.40	0.00	0.01	0.00	0.01	0.31	0.38	0.06	0.76	0.31	0.39	0.07	0.77
0.40	0.00	0.08	0.05	0.13	0.03	0.68	0.01	0.72	0.03	0.76	0.06	0.85
0.40	0.03	0.06	0.20	0.29	0.00	0.18	0.00	0.18	0.03	0.24	0.20	0.47
0.33	0.00	0.28	0.12	0.40	0.04	0.08	0.11	0.22	0.04	0.36	0.23	0.62
0.33	0.00	0.22	0.09	0.31	0.08	0.36	0.00	0.44	0.08	0.58	0.09	0.75
0.32	0.00	0.10	0.01	0.11	0.03	0.64	0.03	0.70	0.03	0.74	0.03	0.80
0.32	0.00	0.00	0.00	0.00	0.01	0.85	0.00	0.86	0.01	0.85	0.00	0.86
0.31	0.00	0.04	0.00	0.04	0.25	0.31	0.00	0.56	0.25	0.35	0.00	0.60
0.30	0.00	0.01	0.00	0.01	0.10	0.83	0.00	0.92	0.10	0.84	0.00	0.93

0.29	0.00	0.04	0.01	0.05	0.01	0.89	0.00	0.91	0.01	0.94	0.01	0.96
0.28	0.00	0.10	0.05	0.15	0.04	0.57	0.01	0.62	0.04	0.67	0.06	0.77

	RELATIVE PROPORTION OF GRID CELL											
Koala Likelihood of Occurrence	KP1	KP2	KP3	KP1,2,3	KM1	KM2	KM3	KM1,2,3	KP1,KM1	KP2,KM2	KP3,KM3	Ktotal
0.27	0.00	0.28	0.13	0.41	0.00	0.00	0.00	0.00	0.00	0.28	0.13	0.41
0.26	0.00	0.20	0.18	0.37	0.04	0.25	0.00	0.29	0.04	0.44	0.18	0.66
0.25	0.00	0.20	0.10	0.29	0.02	0.07	0.05	0.14	0.02	0.27	0.15	0.44
0.25	0.00	0.23	0.05	0.28	0.11	0.24	0.03	0.37	0.11	0.47	0.08	0.66
0.25	0.00	0.25	0.06	0.31	0.07	0.10	0.01	0.18	0.07	0.35	0.08	0.49
0.25	0.00	0.33	0.25	0.58	0.00	0.00	0.00	0.00	0.00	0.33	0.25	0.58
0.25	0.00	0.24	0.14	0.39	0.00	0.07	0.00	0.08	0.00	0.31	0.14	0.46
0.25	0.00	0.26	0.01	0.27	0.14	0.29	0.00	0.43	0.14	0.55	0.01	0.70
0.24	0.00	0.00	0.00	0.00	0.07	0.65	0.02	0.74	0.07	0.65	0.02	0.74
0.23	0.00	0.15	0.10	0.25	0.01	0.04	0.00	0.05	0.01	0.18	0.11	0.30
0.22	0.00	0.27	0.17	0.44	0.00	0.31	0.00	0.31	0.00	0.58	0.17	0.75
0.22	0.00	0.00	0.00	0.00	0.22	0.45	0.00	0.67	0.22	0.45	0.00	0.67
0.22	0.00	0.12	0.05	0.17	0.00	0.03	0.00	0.03	0.00	0.15	0.05	0.20
0.21	0.00	0.12	0.03	0.15	0.02	0.28	0.00	0.29	0.02	0.40	0.03	0.45
0.21	0.00	0.03	0.14	0.17	0.00	0.00	0.00	0.00	0.00	0.03	0.14	0.17
0.21	0.00	0.01	0.00	0.01	0.02	0.81	0.00	0.83	0.02	0.82	0.00	0.84
0.20	0.00	0.06	0.12	0.18	0.03	0.17	0.00	0.20	0.03	0.23	0.12	0.38
0.20	0.00	0.25	0.03	0.28	0.03	0.50	0.00	0.53	0.03	0.75	0.03	0.82
0.19	0.00	0.06	0.08	0.14	0.00	0.49	0.00	0.49	0.00	0.55	0.08	0.62
0.18	0.00	0.08	0.00	0.08	0.02	0.09	0.22	0.32	0.02	0.16	0.22	0.41
0.18	0.00	0.24	0.09	0.33	0.00	0.36	0.00	0.36	0.00	0.60	0.09	0.68
0.17	0.00	0.11	0.04	0.15	0.00	0.37	0.00	0.37	0.00	0.48	0.04	0.52
0.17	0.00	0.20	0.05	0.25	0.19	0.36	0.03	0.58	0.19	0.56	0.08	0.83
0.17	0.00	0.38	0.18	0.57	0.00	0.00	0.00	0.00	0.00	0.38	0.18	0.57
0.17	0.00	0.11	0.10	0.21	0.00	0.00	0.00	0.00	0.00	0.11	0.10	0.21
0.17	0.00	0.23	0.01	0.24	0.00	0.02	0.00	0.02	0.00	0.26	0.01	0.27
0.15	0.00	0.06	0.04	0.10	0.08	0.70	0.00	0.77	0.08	0.76	0.04	0.88
0.15	0.00	0.08	0.00	0.08	0.00	0.29	0.00	0.29	0.00	0.36	0.00	0.37
0.15	0.00	0.28	0.11	0.39	0.00	0.30	0.04	0.34	0.01	0.58	0.14	0.73
0.14	0.00	0.22	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.22
0.14	0.00	0.24	0.15	0.39	0.02	0.11	0.00	0.12	0.02	0.35	0.15	0.51
0.14	0.00	0.10	0.28	0.38	0.00	0.17	0.00	0.17	0.00	0.27	0.28	0.55
0.13	0.01	0.05	0.14	0.19	0.01	0.29	0.00	0.30	0.02	0.34	0.14	0.50
0.13	0.00	0.00	0.00	0.00	0.00	0.88	0.00	0.88	0.00	0.88	0.00	0.88
0.12	0.00	0.12	0.00	0.12	0.24	0.50	0.00	0.73	0.24	0.61	0.00	0.85
0.11	0.00	0.19	0.13	0.31	0.00	0.15	0.00	0.15	0.00	0.34	0.13	0.47
0.11	0.00	0.20	0.08	0.28	0.00	0.00	0.00	0.00	0.00	0.20	0.08	0.28
0.10	0.00	0.07	0.05	0.12	0.01	0.51	0.05	0.56	0.01	0.58	0.10	0.69
0.10	0.00	0.02	0.01	0.03	0.00	0.73	0.00	0.74	0.00	0.75	0.01	0.76
0.10	0.00	0.00	0.00	0.00	0.14	0.56	0.13	0.83	0.14	0.56	0.13	0.83

	RELATIVE PROPORTION OF GRID											
Koala Likelihood of Occurrenc	**KP1**	**KP2**	**KP3**	**KP1,2,3**	**KM1**	**KM2**	**KM3**	**KM1,2,3**	**KP1,KM1**	**KP2,KM2**	**KP3,KM3**	**Ktotal**
0.09	0.00	0.26	0.09	0.35	0.00	0.33	0.00	0.33	0.00	0.59	0.09	0.68
0.09	0.00	0.08	0.14	0.22	0.00	0.23	0.00	0.23	0.00	0.31	0.14	0.45
0.08	0.00	0.00	0.00	0.00	0.10	0.72	0.01	0.83	0.10	0.72	0.01	0.83
0.08	0.00	0.28	0.23	0.52	0.00	0.00	0.00	0.00	0.00	0.28	0.23	0.52
0.08	0.02	0.04	0.20	0.26	0.00	0.41	0.00	0.41	0.02	0.45	0.20	0.67
0.08	0.00	0.22	0.03	0.25	0.03	0.20	0.06	0.30	0.04	0.42	0.09	0.55
0.07	0.00	0.00	0.00	0.00	0.02	0.77	0.00	0.79	0.02	0.77	0.00	0.79
0.07	0.00	0.00	0.00	0.00	0.30	0.40	0.00	0.70	0.30	0.40	0.00	0.70
0.06	0.00	0.01	0.00	0.01	0.01	0.71	0.00	0.71	0.01	0.71	0.00	0.72
0.06	0.00	0.14	0.08	0.23	0.00	0.36	0.00	0.36	0.00	0.50	0.08	0.59
0.06	0.00	0.14	0.05	0.19	0.02	0.41	0.00	0.42	0.02	0.55	0.05	0.62
0.06	0.00	0.00	0.00	0.00	0.21	0.58	0.03	0.82	0.21	0.58	0.03	0.82
0.06	0.00	0.03	0.01	0.04	0.00	0.90	0.00	0.90	0.00	0.93	0.01	0.94
0.05	0.00	0.00	0.00	0.00	0.06	0.71	0.00	0.77	0.06	0.71	0.00	0.77
0.05	0.00	0.04	0.06	0.11	0.00	0.00	0.00	0.00	0.00	0.04	0.06	0.11
0.05	0.00	0.01	0.06	0.07	0.00	0.80	0.00	0.81	0.00	0.81	0.07	0.88
0.05	0.00	0.04	0.00	0.04	0.06	0.63	0.02	0.71	0.06	0.67	0.02	0.75
0.05	0.00	0.11	0.05	0.16	0.01	0.18	0.00	0.19	0.02	0.29	0.05	0.35
0.03	0.00	0.22	0.00	0.22	0.04	0.53	0.00	0.57	0.04	0.75	0.00	0.79
0.03	0.00	0.19	0.18	0.37	0.02	0.21	0.01	0.24	0.02	0.40	0.19	0.61
0.02	0.00	0.07	0.04	0.12	0.24	0.30	0.00	0.55	0.24	0.38	0.05	0.67
0.02	0.00	0.11	0.04	0.15	0.08	0.46	0.00	0.55	0.08	0.57	0.04	0.69
0.02	0.00	0.00	0.00	0.00	0.20	0.56	0.01	0.77	0.20	0.56	0.01	0.77
0.00	0.00	0.00	0.00	0.00	0.02	0.80	0.00	0.82	0.02	0.80	0.00	0.82
0.00	0.00	0.00	0.00	0.00	0.01	0.67	0.01	0.69	0.01	0.67	0.01	0.69
0.00	0.00	0.00	0.00	0.00	0.04	0.87	0.00	0.91	0.04	0.87	0.00	0.91
0.00	0.00	0.00	0.00	0.00	0.02	0.54	0.00	0.56	0.02	0.54	0.00	0.56
0.00	0.00	0.00	0.00	0.00	0.06	0.29	0.00	0.35	0.06	0.29	0.00	0.35
0.00	0.00	0.00	0.00	0.00	0.04	0.56	0.04	0.63	0.04	0.56	0.04	0.63
0.00	0.00	0.00	0.00	0.00	0.05	0.69	0.00	0.75	0.05	0.69	0.00	0.75
0.00	0.00	0.00	0.00	0.00	0.01	0.92	0.00	0.93	0.01	0.92	0.00	0.93
0.00	0.00	0.00	0.00	0.00	0.00	0.66	0.00	0.66	0.00	0.66	0.00	0.66
0.00	0.00	0.00	0.00	0.00	0.13	0.43	0.05	0.60	0.13	0.43	0.05	0.60
0.00	0.00	0.00	0.00	0.00	0.03	0.61	0.03	0.67	0.03	0.61	0.03	0.67
0.00	0.00	0.18	0.03	0.21	0.01	0.59	0.00	0.60	0.01	0.77	0.03	0.81
0.00	0.00	0.32	0.12	0.44	0.00	0.42	0.00	0.42	0.00	0.73	0.12	0.86
0.00	0.00	0.26	0.08	0.34	0.01	0.53	0.00	0.54	0.01	0.79	0.08	0.88
0.00	0.00	0.00	0.00	0.00	0.00	0.81	0.00	0.81	0.00	0.81	0.00	0.81
0.00	0.00	0.00	0.00	0.00	0.01	0.64	0.00	0.65	0.01	0.64	0.00	0.65
0.00	0.00	0.01	0.00	0.01	0.33	0.50	0.02	0.86	0.33	0.52	0.02	0.87

RELATIVE PROPORTION OF GRID CELL												
Koala Likelihood of Occurrence	KP1	KP2	KP3	KP1,2,3	KM1	KM2	KM3	KM1,2,3	KP1,KM1	KP2,KM2	KP3,KM3	Ktotal
0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00	0.65	0.00	0.65	0.00	0.65
0.00	0.00	0.25	0.13	0.38	0.07	0.15	0.00	0.22	0.07	0.40	0.13	0.60
0.00	0.00	0.18	0.08	0.27	0.04	0.32	0.03	0.38	0.04	0.50	0.11	0.65
0.00	0.00	0.28	0.13	0.41	0.00	0.01	0.00	0.01	0.00	0.29	0.13	0.42
0.00	0.00	0.10	0.03	0.13	0.00	0.01	0.00	0.01	0.00	0.10	0.03	0.14
0.00	0.00	0.36	0.10	0.46	0.00	0.00	0.00	0.00	0.00	0.36	0.10	0.46
0.00	0.00	0.13	0.14	0.26	0.00	0.00	0.00	0.00	0.00	0.13	0.14	0.27
0.00	0.00	0.03	0.00	0.03	0.03	0.09	0.17	0.30	0.03	0.12	0.17	0.32
0.00	0.00	0.00	0.00	0.00	0.12	0.36	0.24	0.71	0.12	0.36	0.24	0.71
0.00	0.00	0.00	0.00	0.00	0.09	0.34	0.13	0.57	0.09	0.34	0.13	0.57
0.00	0.00	0.04	0.02	0.07	0.17	0.47	0.00	0.64	0.17	0.51	0.02	0.71
0.00	0.00	0.18	0.13	0.32	0.03	0.15	0.00	0.18	0.03	0.33	0.13	0.49
0.00	0.00	0.43	0.24	0.67	0.00	0.04	0.00	0.05	0.00	0.47	0.24	0.72
0.00	0.00	0.24	0.23	0.46	0.06	0.25	0.00	0.31	0.06	0.49	0.23	0.77
0.00	0.00	0.15	0.14	0.28	0.00	0.00	0.00	0.00	0.00	0.15	0.14	0.28
0.00	0.00	0.23	0.08	0.32	0.00	0.00	0.00	0.00	0.00	0.23	0.08	0.32
0.00	0.00	0.14	0.13	0.27	0.00	0.00	0.00	0.00	0.00	0.14	0.13	0.27
0.00	0.00	0.00	0.00	0.00	0.26	0.34	0.01	0.62	0.26	0.34	0.01	0.62
0.00	0.00	0.32	0.22	0.53	0.00	0.00	0.00	0.00	0.00	0.32	0.22	0.53
0.00	0.00	0.30	0.20	0.50	0.00	0.00	0.00	0.00	0.00	0.30	0.20	0.50
0.00	0.00	0.32	0.10	0.42	0.00	0.00	0.00	0.00	0.00	0.32	0.10	0.42
0.00	0.00	0.24	0.19	0.43	0.00	0.00	0.00	0.00	0.00	0.24	0.19	0.43
0.00	0.00	0.03	0.01	0.04	0.08	0.67	0.14	0.89	0.08	0.70	0.15	0.93
0.00	0.00	0.19	0.11	0.30	0.02	0.45	0.00	0.47	0.02	0.64	0.11	0.77
0.00	0.00	0.23	0.01	0.25	0.04	0.10	0.00	0.13	0.04	0.33	0.01	0.38
0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01
0.00	0.00	0.05	0.07	0.12	0.00	0.67	0.00	0.67	0.00	0.71	0.07	0.79
0.00	0.00	0.02	0.01	0.03	0.08	0.65	0.00	0.74	0.08	0.67	0.01	0.76
0.00	0.00	0.02	0.04	0.06	0.00	0.43	0.00	0.44	0.00	0.45	0.04	0.50