

Methods for mapping of Carnaby's cockatoo habitat

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DOCUMENT REVISION HISTORY

Revision	Description	Originator	Reviewed	Date
A				
B				

TITLE

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August 2011

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Acknowledgements

This document has been produced from funding received from the Western Australian Natural Resource Management (NRM) Program in 2008/09 and 2009/10 for the project *High Priority Recovery Actions for Matters of National Environmental Significance in WA*. This joint project of the Department of Environment and Conservation (DEC) and the Department of Planning (DoP), included the collation and preparation of mapping of habitat for Carnaby's cockatoo.

The Department of Environment and Conservation would like to thank all those who contributed to this publication. We would particularly like to thank the many volunteers and institutions who contributed to the Great Cocky Counts and the WA Museum, who provided some of the breeding and night roost data.

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1. Aim

To use available data to map likely habitat of the endangered Carnaby's cockatoo (*Calyptrorhynchus latirostris*) used for feeding, night roosts and breeding in the Swan Coastal Plain and Jarrah Forest IBRA regions, at the regional scale. We also aimed to update and where possible improve on the detail of current mapping used by the Department of Environment and Conservation (DEC) and the Department of Planning (DoP) by utilizing more detailed vegetation mapping.

2. Deliverables

The deliverables of this project are a set of GIS data layers and this methodology document. The set of GIS data layers generated were:

1. Areas requiring investigation as Carnaby's cockatoo feeding habitat – Swan Coastal Plain IBRA region.
2. Areas requiring investigation as Carnaby's cockatoo feeding habitat – Jarrah Forest IBRA region.
3. Known Carnaby's cockatoo night roost areas.
4. Known and possible Carnaby's cockatoo breeding areas.

Potential Carnaby's cockatoo feeding habitat in the Swan Coastal Plain IBRA is provided as a separate layer from that in the Jarrah Forest IBRA as it is essential to ensure that the food resource provided by the two vegetation types, eucalyptus forest in the Jarrah Forest IBRA and banksia woodland in the Swan Coastal Plain IBRA are not considered as equivalent. The amount and type of food, as well as the time of year it is available differs between these two areas.

Note that pine plantations are also important Carnaby's cockatoo feeding areas. Pine plantations are not considered in this report as they are not native and their area will change significantly in the next few years with the removal without replacement of 22,000 hectares of pines in the Gnangara, Pinjar and Yanchep plantations. GIS layers or maps of current extent of pine plantations are available from the Forest Product Commission.

These GIS data layers allow the preparation of statistics of feeding, night roosting, and breeding areas (including break-down by sub-categories such as tenure and land use planning zones).

3. Methodology and Discussion

3.1. Overall Approach

This desktop analysis was performed on the Swan Coastal Plain and Jarrah Forest IBRA regions. This covers a region greater than that of the DEC Swan Region (as well as the regional planning schemes of metropolitan Perth and Peel) as the IBRA regions have a biological basis for their boundaries and hence greater relevance to assessing an animal's potential habitat. Notwithstanding this, the coverage of this analysis is less than the entire distribution of Carnaby's cockatoo that includes the Geraldton Sandplains, Swan Coastal Plain, Jarrah Forest, Warren, Avon Wheatbelt, Mallee and Esperance Plains IBRA regions.

Mapping of night roosts and of breeding sites is based on point records of roosting and breeding behavior which have a buffer applied that aims to reflect the flexible use of these areas by cockatoos and to indicate the important zone for access to potential feeding habitat around each roost or breeding site.

This buffered point approach differs from a mapping project carried out by DEC in 2009 (DEC 2009), which produced two GIS layers titled *Potential Carnaby's Cockatoo Breeding Locations*, and *Potential Carnaby's Cockatoo Roosting Locations*, which collated vegetation types that are typical to breeding and roosting of Carnaby's cockatoo. The polygons produced by that mapping are not of actual or observed breeding or roosting sites, rather they are vegetation types that Carnaby's cockatoo show preference for when choosing breeding or roosting locations.

In this project the mapping of feeding habitat on the Swan Coastal Plain and Jarrah Forest IBRA regions has been carried out in the similar manner to that in DEC 2009, in that the potential feeding habitat is based on mapping vegetation that Carnaby's cockatoo show a preference for when feeding, and so (unlike the mapping of night roosts and breeding sites in this study) is not based on observations or point records of feeding.

The majority of the GIS calculations, re-projections and intersections were performed in FME® Workbench 2010 software by Safe. A minority of the calculations were performed in ESRI ArcMap® 9.2. All steps and options chosen were saved in FME® Workbench project files and these would be valuable in replicating the work.

3.2. Intended Use

This work is intended to be used to provide spatial assistance for planning conservation and recovery activities for the species, and to be used for strategic land use planning as a first

step in assisting statutory planners or consultants in deciding whether Carnaby's cockatoo needs to be considered in a given planning area. Due to the resolution of the current mapping, when a subject area is identified as potential Carnaby's cockatoo habitat using these GIS products, it will then require additional detailed site mapping and field examination for actual Carnaby's cockatoo resources or use by Carnaby's cockatoo. For example, some areas mapped as potential feeding habitat in these products are likely to contain a mosaic of vegetation units of which some will not contain Carnaby's cockatoo forage species. Hence there is a need for further investigation or mapping at a more detailed scale.

3.3. Night Roosts

In this 2010 analysis, the mapping of night roosts is developed from point data of known night roosts (differing from the vegetation selection approach used in the DEC 2009 analysis discussed above in 3.1).

The point data is derived from that held by DEC and is primarily from the 2006 and 2010 Great Cocky Count project (Burnham *et al.* 2010) and some observations brought to the attention of DEC during this period. The night roost sites in this mapping layer includes categories of "Confirmed Roost" and "Unconfirmed Roost". A "Confirmed Roost" is a site where Carnaby's cockatoo were recorded roosting as part of a formal roost survey (using the Great Cocky Count method in which birds are recorded as they fly into the roost site, 30 minutes either side of sunset), as described by Berry (2008). An "Unconfirmed Roost" is a site where roosting Carnaby's cockatoo have been reported to Birds Australia or DEC and only an informal count of cockatoo numbers has been provided. These unconfirmed roost sites have either: not had any roosting birds recorded during any formal surveys (using the Great Cocky Count methods); or have not had any formal surveys (using the Great Cocky Count methods) carried out. Details of the reporting source and unofficial count have been recorded for each of the unconfirmed roost sites.

A night roost can include tall trees (>8m) within 1km of the central roosting area of larger roost sites (>150 birds recorded at any given time) and within 500m of smaller roost sites (<150 birds recorded). Therefore the night roost points were buffered to 1000 m at sites where at least 150 birds had been recorded, and buffered to 500m at roost sites where fewer than 150 birds had been recorded. This produced a GIS data layer of areas or polygons that will accommodate the use by Carnaby's cockatoo of multiple trees in close proximity to the roost site, rather than any single tree indicated by a point record. Carnaby's cockatoos at a large Bentley roost site (R4) are known to shift the roost location within a 2km x 2km area (Geoff Barrett pers. comm. 2010). Within this roosting area, a clump of trees used on any individual night for roosting may be as small as one tenth of a hectare (a few large trees) but usually a patch of trees with roosting birds is at least 2-3 hectares in

area. Typically, night roost sites have a standing water source nearby for drinking which may be a natural waterway or lake but constructed lakes, farm dams and stock water troughs are also used.

Modelling data indicates that night roost occupancy is associated with the amount of potential feeding habitat within a 6km radius of night roosts sites (DEC 2011 report Kabat *et al.* in prep.). As a consequence, separate GIS data layers have been produced of the night roost data points (confirmed and unconfirmed) buffered to 6 km and the buffered areas combined. The resulting areas shown in this GIS data layer indicate areas where the relationship between a night roost and associated potential Carnaby's cockatoo feeding habitat is considered to be important. Flock follows by DEC Swan Coastal District and Shah (published in Shah (2006)) and Hugh Finn (Murdoch University) suggest that roost flocks will travel up to 13km in the two hours prior to roosting (evening) and in the two hours after roosting (early morning). Mapped movements of flocks that were followed suggest that they regularly forage to around 6km from the central roost area, however foraging areas outside of this 6km from a night roost are also used by Carnaby's cockatoo.

The factors determining the use of night roosts by Carnaby's cockatoo are currently being researched, and these maps will be updated based on most current understanding.

3.4. Currently Recorded Breeding Areas

Data records of breeding site points were obtained from a variety of sources and projects and amalgamated (see Appendix 3). Each record was assigned to one of two categories indicating a level of confidence.

- "Confirmed" category was assigned to records when eggs or chicks were recorded.
- "Possible" category was assigned for observations relating to Carnaby's cockatoo breeding that did not include actual records of eggs or chicks. For example evidence of hollow use (chewing) or records of breeding or nesting behaviour by an expert observer.

Duplication of observations between the various datasets used to identify areas were suspected but ignored as it would have no consequence on the digital layers produced in this project, which show the full extent of breeding observations, not the density or numbers of breeding records.

There is evidence to support social factors encouraging new breeding attempts to areas where breeding is already occurring, resulting in grouping of nesting behavior and relatively high density of nests (Groom 2010a). Studies have demonstrated that (in the wheatbelt at least) banksia woodland and heathland feeding areas within 12 km of the nest site are important for successfully raising chicks (Saunders 1977, 1986; Saunders and Ingram 1987).

For these reasons the dataset point records in both confidence categories were then buffered to 12 km and the buffered areas combined. The resulting areas shown in this GIS data layer indicate that confirmed or possible Carnaby's cockatoo breeding has been observed somewhere within these polygons and further, that breeding and feeding habitat within these polygons is important for continued success of any breeding occurring within these polygons.

The breeding area polygons (of confirmed and possible confidence categories) have been clipped to the Swan Coastal Plain and Jarrah Forest IBRA regions. The breeding area polygons outside of these two IBRA regions have been placed in a separate GIS layer so breeding may also be considered in the context of the distribution of the whole of the species.

It should also be noted that these data are obtained from projects developed for a variety of purposes and there will be breeding outside of the areas indicated in this report. Many nesting sites are not known, particularly in areas distant from human habitation and roads.

In areas outside of the known recorded breeding areas presented in this report, the presence of individuals and stands of those species that can support breeding should be considered on a case-by-case basis. Tree species that are known to be utilized for breeding are given in Appendix 6. Large mature trees of those species listed in Appendix 6 that have hollows may attract Carnaby's cockatoo and would need further assessment.

Further practical use of these breeding GIS layers can be obtained by intersection with the other deliverable, areas requiring investigation for Carnaby's cockatoo feeding habitat, to obtain probable areas of remnant vegetation that could be particularly important in providing food during the breeding and chick rearing season.

3.5. Feeding Areas

In this project the mapping of feeding habitat on the Swan Coastal Plain and Jarrah Forest IBRA regions has been carried out in a similar manner to that in DEC (2009), in that it is based on mapping vegetation that contains plant species which Carnaby's cockatoo show a preference for when feeding. It is not based on observations or point records of feeding.

Of the available vegetation mapping products, we found that the Draft Pre-European SCP Vegetation (Strelein *et al.* 2009), Vegetation Complexes (RFA) mapping prepared for the Regional Forest Agreement (RFA) (Havel and Mattiske 2000), Vegetation Complexes (System 6) (Heddle *et al.* 1980) and Pre-European State Vegetation (DEC 2007) were likely to be suitable for determining likely Carnaby's cockatoo feeding areas. They have good spatial coverage, are available as digital datasets and are mapped in scales appropriate to this mapping project (see Appendix 1 for further details of the datasets). Most had a suitable vegetation description already within the dataset or descriptions that could be linked to the dataset. All of these datasets, except Draft Pre-European SCP Vegetation, were used in the previous mapping of Carnaby's cockatoo feeding habitat (DEC 2009).

We have applied the vegetation mapping products in a distinct priority order. The most appropriate dataset for an area is used first. This order reflects a combination of decreasing detail due to map scale, map coverage and level of detail in the vegetation descriptions. The datasets used will influence the accuracy of selection of areas of habitat. In the Swan Coastal Plain IBRA region the order utilized was: Draft Pre-European SCP Vegetation first where available, then Vegetation Complexes (System 6) and then Pre-European State Vegetation. In the Jarrah Forest IBRA region the order was: Vegetation Complex (RFA) first where available, then Pre-European State Vegetation (see Figure 1).

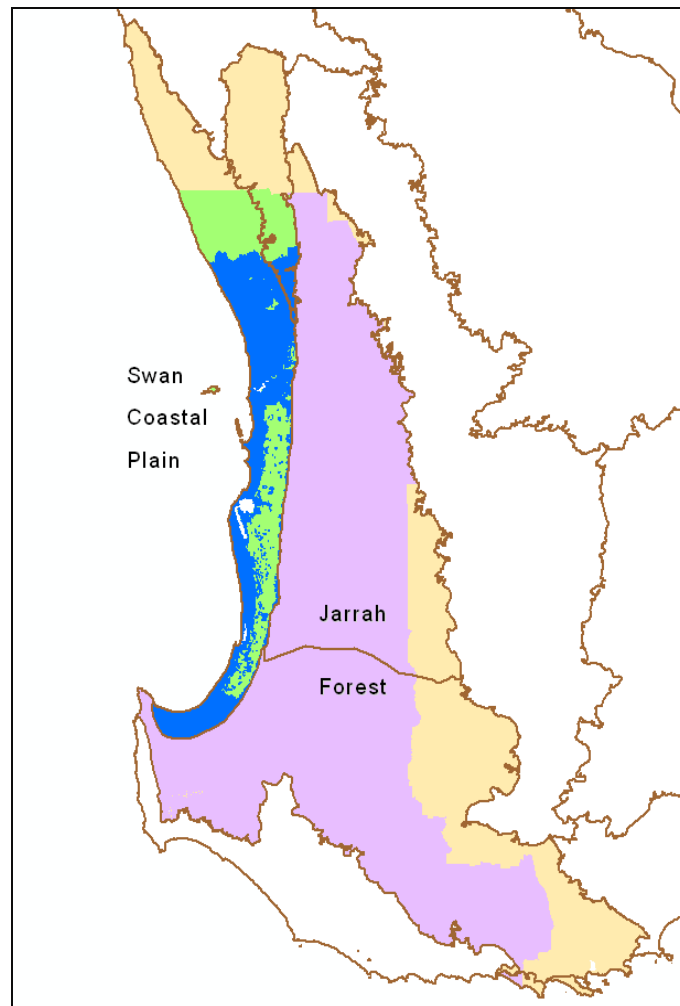


Figure 1. Vegetation mapping products used for selecting Carnaby’s cockatoo feed areas. Draft Pre-European SCP Vegetation Mapping shown in blue, Vegetation Complexes (System 6) in green, Vegetation Complexes (RFA) in mauve, Pre-European State Vegetation in tan, brown lines delineate the IBRA regions/subregions.

A list of names of native plant species that are considered high priority food sources for Carnaby’s cockatoo in each of the Swan Coastal Plain IBRA and the Jarrah Forest IBRA regions was created for use in searches of the vegetation description fields. These plant species came mainly from the “Plants for Carnaby’s Search Tool” (Groom 2010b) with the attribute ‘high priority food species’ selected and the appropriate ‘area covered’ chosen (e.g. “SCP coastal”). This list was reviewed by David Mitchell, Geoff Barrett and Karen Clarke, who added a few more species and gave suggestions to search terms (see Appendices 4 and 5 for the species and terms searched).

We chose to analyze the Jarrah Forest IBRA region separately to accommodate the known difference in food availability and feeding behaviour in these vegetation types. This in turn allowed us to use a different set of plant species (Appendix 5) to produce a map for the

Jarrah Forest IBRA region. The Jarrah Forest and Swan Coastal Plain IBRA regions need to be considered separately for conservation planning due to the manner in which, and season, that Carnaby's cockatoo utilizes them and it is important to ensure that these two IBRA regions are not considered as providing equivalent feeding resources.

The vegetation description of each polygon of the vegetation mapping products were searched with a FME program code script and if it contained a high priority feeding plant species the polygon was selected and saved for further processing. On occasions the known plant species were not in the description and vegetation names were selected instead. These exceptions are noted in the text below.

The selected vegetation polygons were intersected with the most current remnant vegetation (2009) available to give "Areas requiring investigation for Carnaby's cockatoo feeding habitat".

3.5.1. Draft Pre-European Swan Coastal Plain (SCP) Vegetation Mapping

For the feeding areas the names of native plant species that were considered to be high priority food sources to Carnaby's cockatoo were searched for in the vegetation description fields as described above.

When a decision was close we erred on the side of being inclusive rather than exclusive due to the expectation that the areas selected will subsequently be assessed or mapped in more detail. For example, for a mosaic of five vegetation units with only one unit containing high priority Carnaby's cockatoo food species we included the whole mosaic polygon in the feeding areas map.

3.5.2. Vegetation Complexes (System 6)

Due to the Vegetation Complexes (System 6) dataset having a structure field but no vegetation description field that could be automatically searched by the FME program code script we used an expert advice method for this dataset. Each Vegetation Complex within the area of the analysis was given a Yes/No value (containing Carnaby's cockatoo priority food species using the same list of high priority food sources) after evaluation and consideration by our vegetation expert (Karen Clarke) of the vegetation description in the published companion document to this vegetation complex mapping (Heddlé *et al.* 1980). The Yes values were then selected by the FME program code script.

3.5.3. Vegetation Complex mapping prepared for the Regional Forest Agreement (RFA)

The Vegetation Complexes (RFA) mapping (Havel and Mattiske 2000) covers only that part of the Jarrah Forest IBRA region within the RFA study area boundary. Available in the supporting files for the Vegetation Complexes (RFA) mapping there is a list (in MS Excel format) describing each vegetation complex in more detail, including vegetation storeys and their species composition. However, there is a many to one relationship – several descriptions for each vegetation complex code are possible. Some, but not all, of these variations describe a climatic or regional variation of the same vegetation complex. This climatic or regional geographic position is not interpretable via automatic means. Hence we amalgamated all descriptions for each vegetation complex and then searched for the Carnaby's cockatoo food species. This is likely to overestimate the area of possible Carnaby's cockatoo feeding habitat; however, it was the only approach feasible within the available time of the project to include all likely Carnaby's cockatoo feeding areas.

Note also that some truncation of the amalgamated vegetation descriptions (VEG_DESC) occurred on occasions when the total number of characters exceeded 256 (an ArcGIS® Shapefile limit). The authors consider this issue to be inconsequential as the dominant vegetation storey and dominant species come early in the description and most high priority Carnaby's cockatoo food species will be dominant or co-dominant in the dominant storeys. As a check of this, several of those descriptions exceeding 256 characters were manually examined in full and all were found to have been assigned the correct selection by the automatic process.

3.5.4. Pre-European State Vegetation Mapping

We investigated searching for plant species in the Pre-European State Vegetation dataset, in the same manner done for the Draft Pre-European SCP Vegetation dataset, but found several Pre-European State Vegetation descriptions lacking detail. For example, GUILDERTON_1026 has only five species in the brief VEG_DESC field (the field searched) even though it covers several hundred hectares and is a mosaic. In the Level 5 description (in the supporting metadata files) there are only two species listed and hence even this field is not suitable for our plant species name search. Our vegetation expert (Karen Clarke) advised that this Vegetation Association would have many more dominant and co-dominant species and also contain pockets of limestone which are prime soils for *Banksia sessilis*. At the northern end of the Swan Coastal Plain IBRA we found three vegetation associations (GUILDERTON_1026, KOOJAN_952 and WARRO_1031) that would have been excluded if the plant species method alone was used but again expert opinion advised that they would contain significant numbers of high priority Carnaby's cockatoo food species.

We thus decided to use the expert opinion method for the Pre-European State Vegetation dataset in the Swan Coastal Plain IBRA region. Using the vegetation description within the dataset and where this was lacking (as noted above) each vegetation association was given a Yes/No value for containing Carnaby's cockatoo high priority food sources by our vegetation expert (Karen Clarke).

The vegetation description fields of this dataset in the Jarrah Forest IBRA region were not thought to have these limitations and so an automated plant name search (using the same list of high priority food sources) of the vegetation description fields was conducted using the FME program code script for the Jarrah Forest IBRA region part of this dataset.

3.5.5. Remnant Vegetation Mapping (2009)

The selected vegetation polygons from each feeding mapping product was intersected with the most current remnant vegetation mapping available to give "Areas requiring investigation for Carnaby's cockatoo feeding habitat".

The Remnant Vegetation (2009) mapping used was sourced from the Department of Agriculture and Food and is current as of 2009.

It should be noted that the remnant vegetation dataset is intended to map native vegetation only and includes human interpretation of aerial photography.

3.6. Testing of the Feeding Areas Deliverables

3.6.1. Desktop Testing

Several areas of Draft Pre-European SCP Vegetation mapping were examined and compared to more detailed vegetation mapping for Mandurah (Trudgen 1991), Alkimos and northern Eglinton (RPS 2008). We found that the analysis carried out in this study can overestimate the area with Carnaby's cockatoo food species by anything up to 25% compared to detailed site-based vegetation mapping, primarily due to the scale of mapping. In other words more detailed mapping could exclude a portion (but not the whole) of an area, or vegetation unit, selected in this analysis.

The opposite type of error was also found in this analysis – where areas not selected in this analysis contained some Carnaby's cockatoo food when compared to the more detailed vegetation mapping. This type of error was only detected at one of the three areas examined; Mandurah (Trudgen 1991), and was of the order of about 5% in one vegetation unit.

3.6.2. Ground-truthing

As time available for ground-truthing was limited (4 - 5 days), we focused on the areas of the Swan Coastal Plain (SCP) where the regional vegetation mapping was either:

- very broad and covered a mosaic of vegetation types,
- vegetation descriptions were brief and/or
- where regional datasets overlapped and lead to different conclusions.

For the jarrah forest, the RFA vegetation complex mapping was of a scale and the detail of vegetation description considered more reliable for the purposes of this project, so no ground-truthing was undertaken.

3.6.2.1. Comparison of the Draft Pre-European SCP Vegetation Mapping to the Vegetation Mapping of the Gngangara Mound - North Metropolitan Region

To test the validity of the Draft Pre-European SCP Vegetation mapping (Strelein *et al.* 2009) it was compared to a regional vegetation survey referred to in this report as “Vegetation Gngangara Mound”, undertaken by Matiske Consulting (2003). This revealed a number of locations where the Draft Pre-European SCP Vegetation mapping included polygons of remnant vegetation containing high priority Carnaby’s cockatoo food species but the vegetation unit description field of Matiske Consulting (2003) did not. To determine which mapping was more accurate in predicting potential Carnaby’s cockatoo food habitat several field trips were made.

Twelve locations mapped as Carnaby’s cockatoo feeding habitat using the vegetation mapping by Strelein *et al.* (2009) but not using Matiske Consulting (2003) mapping were examined in the suburbs of Gngangara, Jandabup, Mariginiup, Nowergup and Neerabup (see Figure 2). The number of locations (12) was chosen due to time constraints and the need to give a good spatial coverage of inconclusive areas that appeared to be accessible. The field examinations were undertaken by Karen Clarke and Brett Glossop to determine whether Carnaby’s cockatoo food species were present as well as describe plant community units and vegetation condition using the standardized scales of Keighery (1994). The examinations varied from 15 to 30 minutes using a combination of roadside observations (private land) and on-foot transects (public land).

Eight out of the twelve locations confirmed that the Draft Pre-European SCP Vegetation mapping was a more accurate predictor of the presence of Carnaby’s cockatoo food species than the Vegetation Gngangara Mound mapping. The Carnaby’s cockatoo high priority food

species seen were one or more of *Banksia attenuata*, *B. ilicifolia*, *B. littoralis*, *B. menziesii*, *B. sessilis*, *Eucalyptus todtiana* and *Hakea trifurcata*.

The remaining four locations were wetland vegetation units with two locations containing either none or very low numbers of Carnaby's cockatoo food species. The other two locations, both around Mariginiup Lake, were inconclusive, as the fringing vegetation of the wetland could not be observed adequately to confirm whether the Carnaby's cockatoo food species Marri (*Corymbia calophylla*) was present as indicated by the mapping of Strelein *et al.* (2009).

The work by Mattiske Consulting (2003) appeared to map vegetation of certain land use categories (e.g. rural subdivision) as "disturbed", but ground-truthing revealed that many of these areas actually contained banksia woodland in very good condition. Hence the discrepancies between the Draft Pre-European SCP Vegetation (Strelein *et al.* 2009) and the Vegetation Gnangara Mound (Mattiske Consulting 2003) are likely due to their differing objectives and methodologies. Also in other areas Mattiske Consulting (2003) didn't add any more accuracy than obtained from Strelein *et al.* (2009). In conclusion, the Draft Pre-European SCP Vegetation mapping (Strelein *et al.* 2009) proved a more accurate predictor than the mapping of Mattiske Consulting (2003) for determining "Areas requiring investigation as Carnaby's cockatoo feeding habitat" in the north metropolitan region.

However, it should be noted that the Draft Pre-European SCP Vegetation mapping of Strelein *et al.* (2009) is incomplete in coverage (see Figure 1); it covers about half of the Swan Coastal Plain at present and is under peer review. One issue is the misinterpretation of the description of vegetation units from one of the key references used, *Bush Forever* (Government of Western Australia 2000). This has resulted in technically incorrect vegetation descriptions for many of the polygons in Strelein *et al.* (2009). While this draft mapping still proved useful for the specific purpose of this Carnaby's cockatoo habitat mapping project, it is not yet a final product that accurately maps the pre-European vegetation of the Swan Coastal Plain.

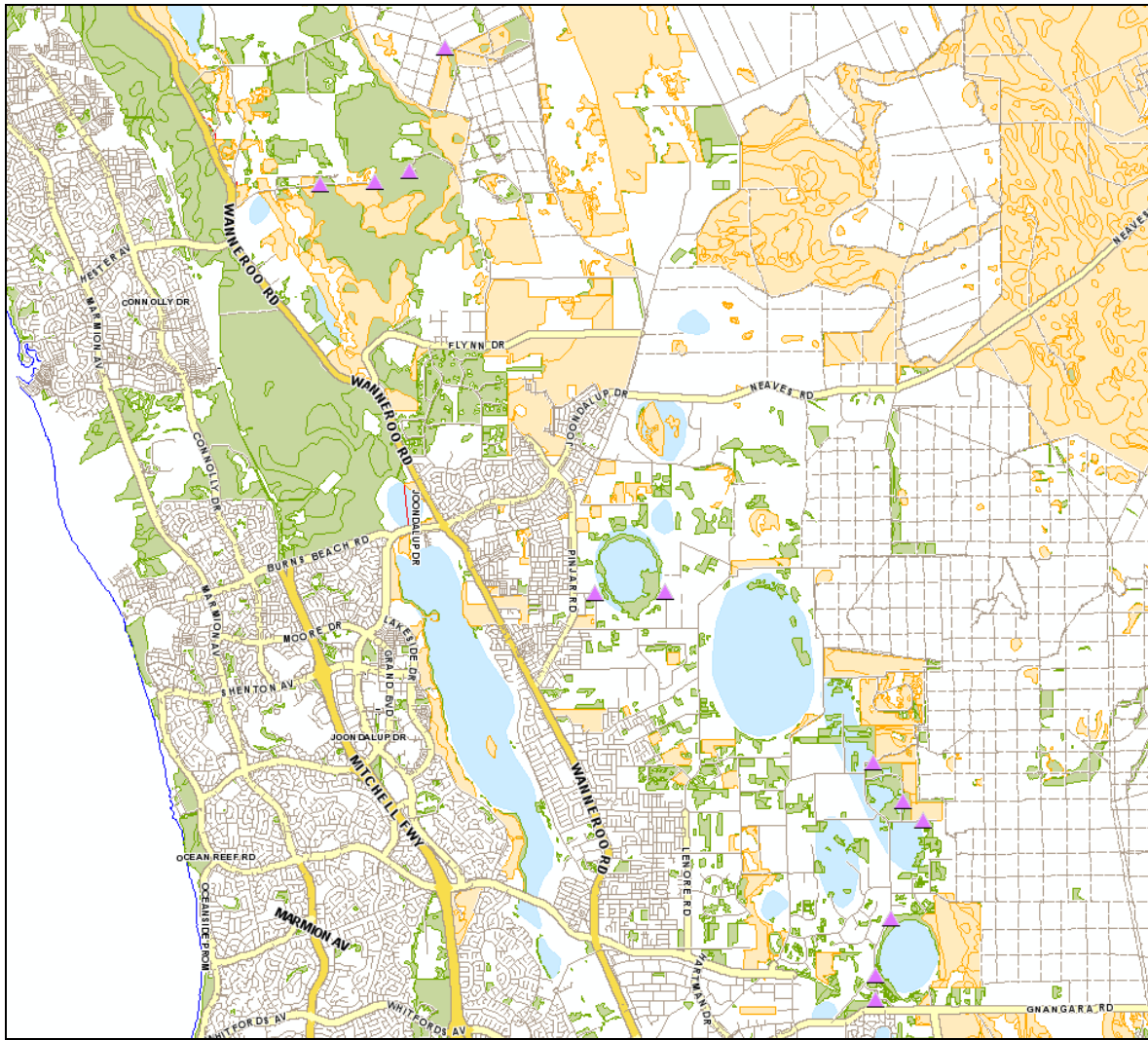


Figure 2. Locations examined in the north metropolitan area (triangles) to compare the Draft Pre-European SCP Vegetation mapping (Strelein *et al.* 2009) selected as containing Carnaby's cockatoo high priority food species, coloured in green, and the similarly selected Vegetation Gnaragura Mound mapping (Mattiske Consulting 2003), coloured in tan (layer is on top).

3.6.2.2. Vegetation Complexes (System 6) - South Metropolitan Region on the Swan Coastal Plain

Twelve locations in the southern part of the Perth Metropolitan Region were examined covering the localities of Jandakot, Forrestdale and Mandogalup (see Figure 3). This area included four Hedde *et al.* (1980) vegetation complexes. Before ground-truthing three of these were considered, from experience and vegetation description, to contain significant numbers of Carnaby's cockatoo food species by vegetation expert Karen Clarke (namely the Bassendean Central and South, Southern River and Guildford vegetation complexes). The fourth, the Serpentine River vegetation complex, primarily consists of wetland vegetation with few or no high priority Carnaby's cockatoo food species (see Appendix 4 for species

names). Small areas of upland of either marri-jarrah-banksia or jarrah-banksia woodland do occur in this complex (Hedde *et al.* 1980), but intersection with the remnant vegetation mapping and aerial photo interpretation by Karen Clarke revealed that very few of these uplands remain.

The field examinations undertaken by Brett Glossop were brief but sufficient to identify Carnaby's cockatoo food species. The examinations varied from five minutes (obvious presence of Carnaby's cockatoo food species) to 60 minutes on foot (when there appeared to be a mosaic of plant communities or no obvious presence of Carnaby's cockatoo food species from road side viewing).

Significant numbers of Carnaby's cockatoo high priority food species were found in each of the three complexes regarded as "Areas requiring investigation as Carnaby's cockatoo feeding habitat" for eleven out of the 12 locations examined. The food species seen were one or more of *Banksia attenuata*, *B. menziesii*, *B. ilicifolia*, *B. littoralis* and *Corymbia calophylla*. "Significant numbers" here is defined as sufficient numbers of one or more of the species for it to be included as a dominant or co-dominant in a vegetation storey description.

No Carnaby's cockatoo food species were identified for the one location within the Serpentine River complex examined. Although B. Glossop concluded that this complex should be excluded from "Areas requiring investigation as Carnaby's cockatoo feeding habitat" it is be noted that the area or number of remnants available in this region to examine the complex was limited due to clearing and grazing.

The use of the Hedde *et al.* (1980) Vegetation Complexes (System 6) mapping was validated as suitable for determining "Areas requiring investigation as Carnaby's cockatoo feeding habitat" for this south metropolitan region and these vegetation complexes.

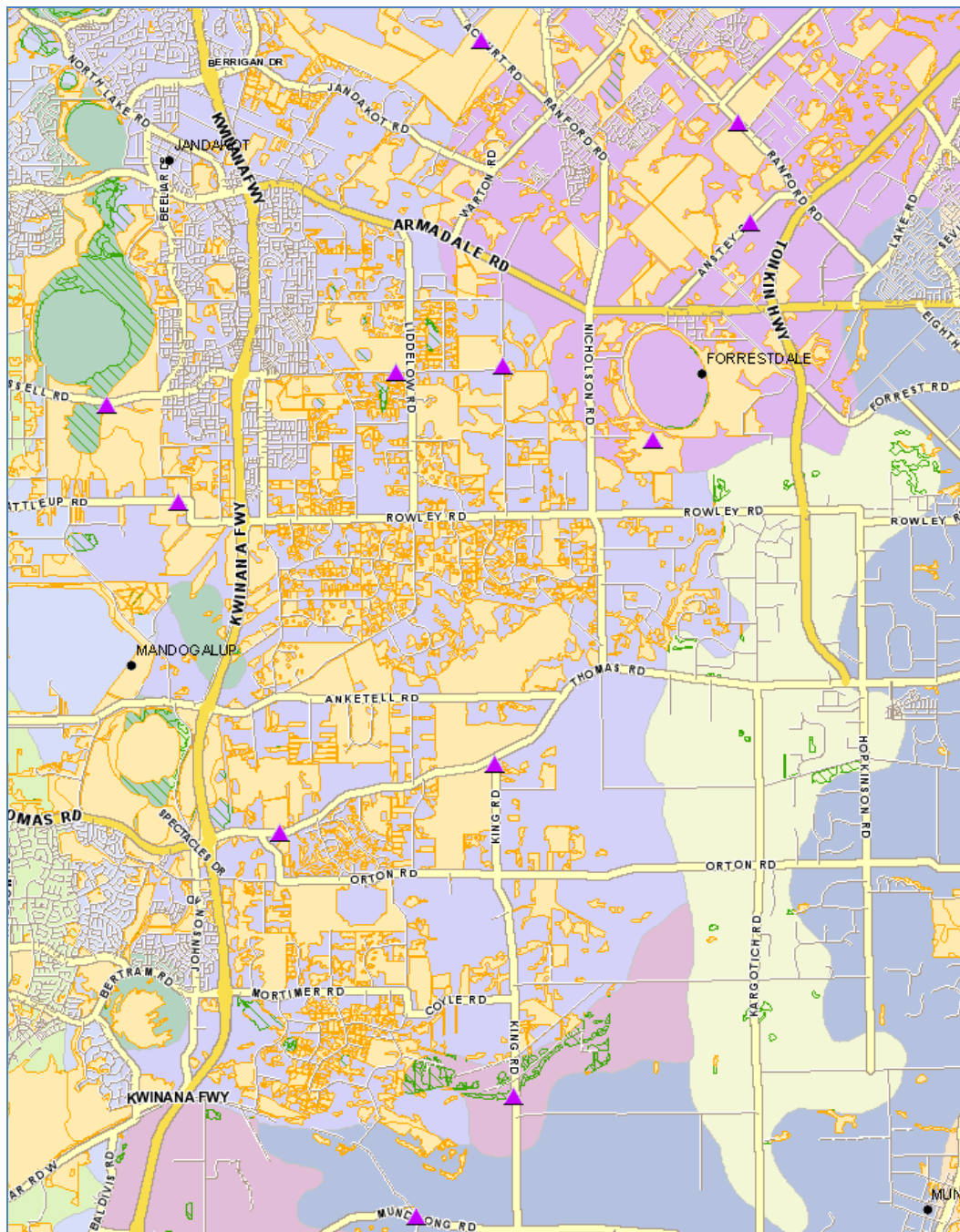


Figure 3. Locations examined to ground truth Vegetation Complexes (System 6) (Hedde *et al.* 1980) mapping in the south metropolitan area. Locations (triangles) shown over selected “Areas requiring investigation as Carnaby’s cockatoo feeding habitat” (tan with orange outline) over remnant vegetation (hashed green) over Vegetation Complexes (System 6) in pastel colours.

3.6.2.3. Vegetation Complexes (System 6) – North of the Perth Metropolitan Region on the Swan Coastal Plain

Thirteen locations were examined covering areas between the townships of Guilderton, Gingin and Ledge Point (Figure 4). This covered nine Hedde *et al.* (1980) vegetation

complexes. Before ground-truthing all but two of these were considered, from species within the vegetation description or vegetation interpretation by botanist Karen Clarke, to contain significant numbers of Carnaby's cockatoo high priority food species. The two complexes excluded were Moore River Complex and Quindalup Complex.

The field examinations undertaken over one day by Brett Glossop and Karen Clarke were brief but sufficient to identify the species and evaluate the vegetation. The examinations varied from 15 minutes (obvious presence of Carnaby's cockatoo food species) to 60 minutes on foot (when there appeared to be a mosaic or dominants to clarify).

The Carnaby's cockatoo high priority food species seen were one or more of *Banksia attenuata*, *B. menziesii*, *B. ilicifolia*, *B. littoralis*, *B. prionotes*, *Hakea trifurcata* and *Corymbia calophylla*.

Significant numbers (as defined in Section 3.6.2.2) of Carnaby's cockatoo food species were found in each of the following complexes: Moore River, Karrakatta North, Gingin, Coonambidgee, Bootine, Yanga, Mungala and Caladenia. These complexes were already regarded as "Areas requiring investigation as Carnaby's cockatoo feeding habitat" via desktop analysis and expert examination except for the Moore River Complex. In the Moore River Complex significant numbers of *Corymbia calophylla* were observed and as a result the Moore River Complex was subsequently included in "Areas requiring investigation as Carnaby's cockatoo feeding habitat" in the deliverables.

No Carnaby's cockatoo food species were observed in the areas mapped as Quindalup complex and hence it was excluded from "Areas requiring investigation as Carnaby's cockatoo feeding habitat". The possible occurrence of *B. sessilis* in the Quindalup complex was suggested by botanist Karen Clarke, but subsequent review of the literature documenting the habitat preferences of this Carnaby's cockatoo food species revealed a strong link to the presence of limestone in coastal soils for this shrub (for example, Cavanagh and Pieroni 2006) and so it was concluded that the distribution of *B. sessilis* is not a dominant component of the Quindalup vegetation complex.

The use of the Heddle *et al.* (1980) Vegetation Complexes (System 6) mapping was validated as suitable for determining "Areas requiring investigation as Carnaby's cockatoo feeding habitat" in this region and these vegetation complexes.

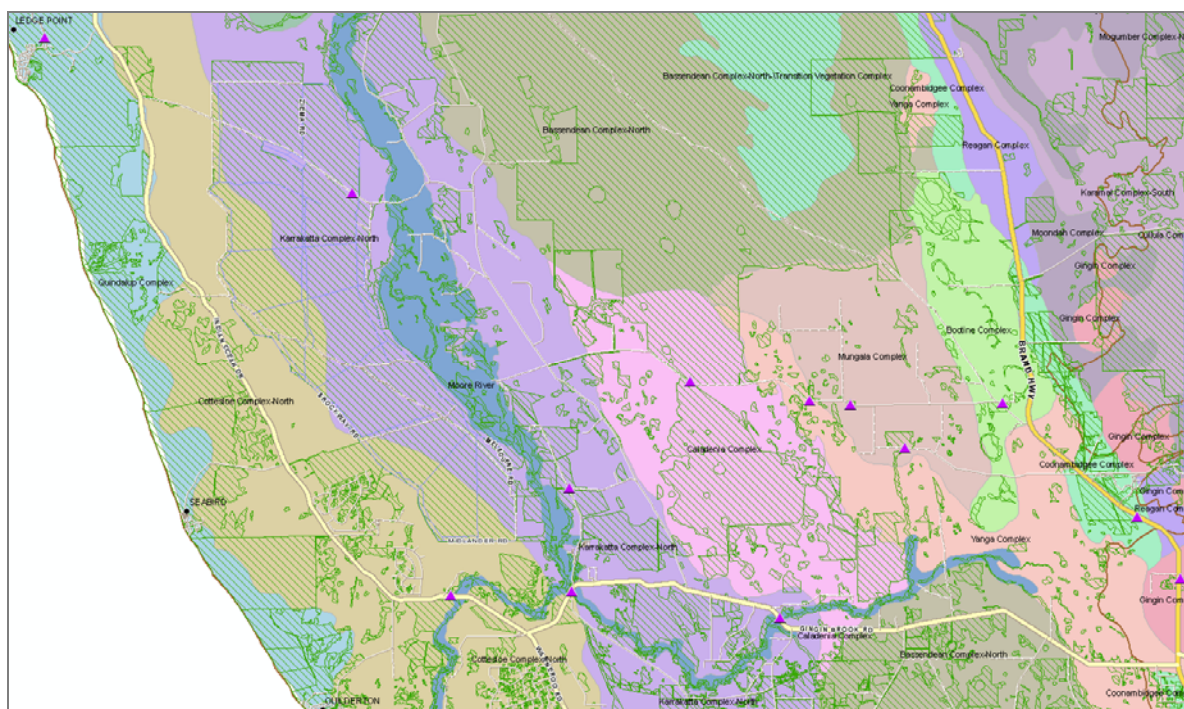


Figure 4. Locations examined to ground truth Vegetation Complexes (System 6) (Hedde et al. 1980) mapping north of the metropolitan area. Locations (triangles) shown over remnant vegetation (hashed green) over Vegetation Complexes (System 6) in pastel colours.

3.6.2.4. Pre-European State Vegetation Mapping - North of Moore River on the Swan Coastal Plain

Five locations in eight system associations were examined over one day in the area approximately between the townships of Cervantes, Dandaragan, Moora, Regan's Ford and Lancelin (see Figure 5). Coverage of possible system associations was less in this ground-truthing due to the larger distances involved and predominance of cleared land in the east. The authors focused on system associations that had changed selection status due to expert opinion, or whose selection status was indeterminate, during the desktop analysis. Before ground-truthing the Carnaby's cockatoo selection status (degree to which they contained high priority food species for Carnaby's cockatoo) of the coastal strip of Guilderton_1026, the inland Bassendean_1031 and Gingin_1015 was indeterminate from the vegetation descriptions included in the mapping dataset. Ground examination was required to check if these vegetation associations contained high priority Carnaby's cockatoo food species.

The field roadside examinations undertaken by Brett Glossop and Karen Clarke were sufficient to identify the species and describe the vegetation. The examinations varied from 15 minutes to 60 minutes on foot.

Carnaby's cockatoo high priority food species were seen and recorded for the following system associations: Guilderton_1026, Bassendean_1031, Gingin_1015, as well as

Dandaragan_999, Warro_1031, Gingin_1030, and Gingin_4. Species seen were one or more of *Banksia attenuata*, *B. menziesii*, *B. ilicifolia*, *B. prionotes*, *B. sessilis* and *Corymbia calophylla*.

Two system associations in the west and centre had been excluded by desktop analysis from “Areas requiring investigation as Carnaby’s cockatoo feeding habitat” in this part of the SCP IBRA region – namely Guilderton_129 and Bassendean_125, described as “bare areas of shifting sands”, and “bare areas; salt lakes” respectively. Distant visual confirmation was obtained for these during ground-truthing. In the north east of the IBRA region several Warro system associations of York gum (*Eucalyptus loxophleba*) and samphire (excluded by the analysis) were not ground-truthed due to their small extent and the lengthy travel times required to examine these associations.

Following the ground-truthing, the vegetation associations Guilderton_1026, Bassendean_1031 and Gingin_1015, which had been excluded as indeterminate by desktop analysis, were subsequently included in “Areas requiring investigation as Carnaby’s cockatoo feeding habitat” due to the presence of *Banksia* tree species.

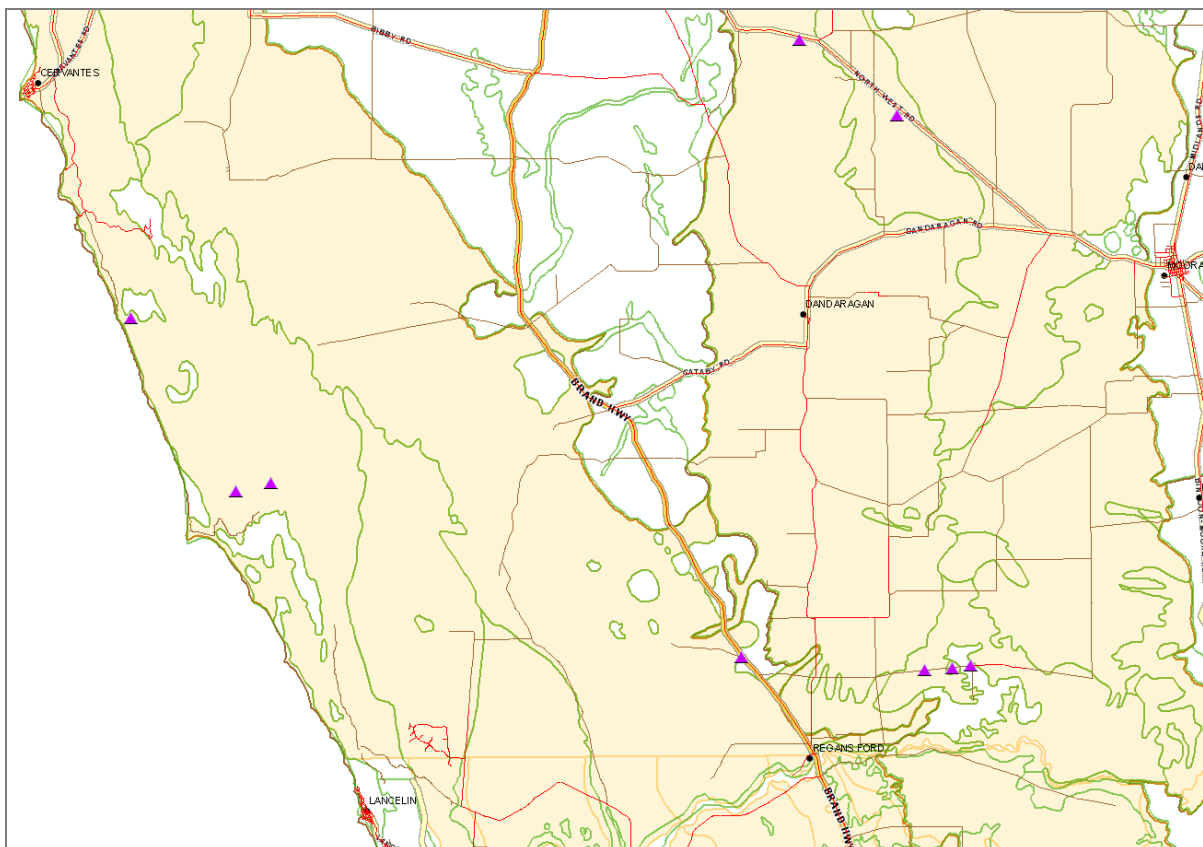


Figure 5. Locations examined (triangles) to ground truth the Pre-European State Vegetation mapping north of the Moore River. System associations (green outlines) selected prior to ground-truthing are shown over the “Areas requiring investigation as Carnaby’s cockatoo

feeding habitat” (coloured tan) with the IBRA sub-region boundaries shown in deep brown. Note that the locations near the coast were near the new Indian Ocean Drive which is not shown in Figure 5 as a road.

3.6.3. Some Conclusions from the Ground-truthing

Ground-truthing revealed that the datasets in order of usefulness and accuracy for Carnaby’s cockatoo feeding habitat mapping on the Swan Coastal Plain were:

- 1) Draft Pre-European SCP Vegetation (Strelein *et al.* 2009)
- 2) Vegetation Complexes (System 6) (Heddle *et al.* 1980) and then,
- 3) Pre-European State Vegetation (DEC 2007).

This is not surprising due to the scale associated with each dataset (see Appendix 1). As the area of coverage of each of these vegetation mapping products differs it is still necessary to use all three to map Carnaby’s cockatoo feeding habitat over the whole of the Swan Coastal Plain (see Figure 1).

Ground-truthing found the Pre-European State Vegetation (DEC 2007) descriptions incomplete near the coast and for two inland system associations, and two more were difficult to assess on ground but were clearly mosaic in nature. Hence we recommend that these Pre-European State Vegetation areas be re-mapped in more detail at a regional scale. In this project, where unsure, we have erred on the side of inclusiveness, and so in particular where the Pre-European State Vegetation mapping is used for Carnaby’s cockatoo evaluations then it needs to be done with great care. As for all the selected “Areas requiring investigation as Carnaby’s cockatoo feeding habitat” we recommend field assessment of individual sites be completed before any environmental assessment or planning decisions are made.

3.6.4. Improvements That Can Help the Mapping Accuracy of Feed Areas

Some actions that can be taken to improve the accuracy and resolution of this analysis and the methodology used are listed below; this would also assist in the use of similar methods for mapping requirements for other species or communities:

- Vegetation mapping of the entire SCP IBRA region at a scale of 1:20,000 using a consistent methodology
- Including the longer vegetation descriptions available for the Pre-European State Vegetation mapping (DEC 2007) and Vegetation Complexes (System 6) (Heddle *et al.*

- Automated searches of the Vegetation Complexes (RFA) can be assisted by resolving (i.e. to tease apart) the location ambiguities in this dataset where one vegetation code in different locations may have different vegetation descriptions reflecting geographical or climatic changes. The data seem to be available in the dataset (see geographic region field) but need manual interpretation. The work around used in this project, to amalgamate all vegetation descriptions to the one vegetation code, is less than ideal.
- Within the Vegetation Complexes (RFA) dataset the Veg_class field is case-sensitive, with different vegetation complexes having similar codes that make automated searches in some software difficult. For example, Coate and Cooke Vegetation Complexes (RFA) are named Ce and CE respectively. Automatic searches under some software, such as MS Access®, will group Ce and CE into one group though they are different vegetation complexes. Automated searches of the Vegetation Complexes (RFA) can be assisted by ensuring fields have unique, discernable (non-case sensitive) codes.
- Improve the vegetation descriptions for the Pre-European State Vegetation (DEC 2007) dataset. We discovered several vegetation associations that were lacking detail in the description (e.g. only two plant species mentioned for one association).
- Completion and release of Draft Pre-European SCP Vegetation mapping (Strelein *et al.* 2009) as a corporate dataset. This will require completion of the full coverage of mapping, completion of the peer review process, more field-checking of mapping and then adjustment of its attributes.

It is evident from recent studies (Geoff Barrett pers. comm. 2010) that the location of watering sources is also important to the use of the landscape by Carnaby's cockatoo, in particular locations of night roosts. Therefore future projects could include mapping of watering points (natural and anthropogenic in origin), and site based investigations of habitat use should also consider location of water sources.

4. Conclusions and Cautions

Based on the largely desktop assessment used in this project, much of the remnant vegetation of the Swan Coastal Plain and Jarrah Forest IBRA regions have been identified as potential feeding areas for Carnaby's cockatoo. This is supported by the fact that Carnaby's cockatoo feed upon a large number of plant species, many of which have large natural distributions. Carnaby's cockatoo have been observed to feed on almost any remnant that contains suitable feed plants, even targeting what are now individual isolated trees. The vegetation identified as not potential feeding areas primarily included wetland and young Quindalup dune vegetation.

Areas requiring investigation as Carnaby's cockatoo feeding habitat, as determined by this report, are indicative due to the regional scale of the underlying mapping used and to the limited ground-truthing able to be carried out during this project. In this project, where unsure, we have taken a precautionary approach and in some cases will have erred on the side of inclusiveness.

The maps of potential feeding areas are useful for strategic purposes although statistics generated using the GIS products accompanying this report will provide both over and under estimates of the feeding resource available. Planning and environmental approval decisions on specific sites will need understanding of the limits of this mapping and should be based on more detailed vegetation mapping or on-ground investigation of vegetation and habitat.

Many areas have indeed had vegetation mapped more intensively, such as for planning and environmental approvals of district structure plans, but such mapping has not been included in this project due to their relatively small spatial extent and non-public ownership of these data layers.

For the breeding habitat deliverable the areas shown indicate that breeding sites do or may occur somewhere within these polygons and that in addition to breeding habitat, the feeding habitat (and possibly roosting habitat) within these polygons is important for continued success of any breeding that does occur within these polygons.

It should be noted that the breeding habitat deliverable was derived from projects developed for a variety of purposes (see Appendix 3) and there will be breeding outside of the areas indicated in this report. The location of many nesting sites is likely to be unknown, particularly in areas distant from human habitation and roads.

In areas outside of the known recorded breeding areas presented in this report, the presence of individual trees and stands of those tree species that can support breeding should be considered on a case-by-case basis. Tree species that are known to be utilized for breeding by Carnaby's cockatoo are given in Appendix 6. Large mature trees of those

species listed in Appendix 6 that have hollows may attract Carnaby's cockatoo and their possible use by Carnaby's cockatoo would need further investigation.

This project has demonstrated that the data sets and the processing techniques used in this project can make useful strategic maps of feeding, breeding and night roost areas for Carnaby's cockatoo. Although there are deficiencies, the datasets have been shown to be the best available for this mapping project's intent and large spatial extent.

Finally the project has shown that there are large areas of potential feeding habitat, a significant number of confirmed breeding areas and many night roosts in the Perth and Peel regions, indicating the significance of the intensively developed part of the metropolitan region to the survival of Carnaby's cockatoo.

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Appendix 1: Data used for processing of feeding areas

DEC Corporate Dataset Name	Reference	Comments	Spatial Coverage	Source	Custodian	Currency
Remnant Vegetation (2009)	Shepherd <i>et al.</i> 2001	Native Vegetation Extent with updates by DAFWA (2001-2009)	The entire state of Western Australia	DEC	DAFWA	2009
Vegetation Complexes (RFA)	Havel & Mattiske 2000	Vegetation Complex mapping prepared for the Regional Forest Agreement (RFA)	The Regional Forest Agreement boundary as defined in The Regional Forest Agreement for the South -West Forest Region of Western Australia at http://www.daff.gov.au/rfa/regions/wa/rfa (That is, most of the forested areas on the Darling Plateau plus the southern part of the Swan Coastal Plain near Busselton.)	DEC	DEC	2000
Vegetation Complexes (System 6)	Heddlie <i>et al.</i> 1980		The System 6 boundary as defined in Conservation Through Reserves Committee (1974)	DEC	DEC	1978
Vegetation Gnaragala Mound	Mattiske Consulting 2003	Undertaken for the Gnaragala Sustainability Strategy (GSS)	North Metropolitan Perth with some exclusions, especially the Quindalup dune areas. (is not pre-European mapping but is remnant vegetation as mapped by Mattiske Consulting 2003)	DEC	DEC/GSS	2003
Draft Pre-European SCP Vegetation	Strelein <i>et al.</i> 2009	Draft vegetation mapping by Forest Management Branch (FMB) of DEC. Under peer review.	The Swan Coastal Plain south of the Moore River. However, this is incomplete with about 50% of area not assigned a vegetation description.	DEC	DEC	2009
Pre-European State Vegetation	DEC 2007	Digitised vegetation mapping based on Beard (1981), Hopkins (undated) and Hopkins <i>et al.</i> (2000), as updated periodically by DEC.	Statewide for WA	DEC	DAFWA	2007

1. Note that pine plantations are also important feed species for Carnaby's cockatoo as discussed in section 2 ("Deliverables"). The GIS layer or maps are available from the Forest Product Commission.

Appendix 2: Data used for processing of roost areas

Dataset Name	Reference	Spatial Coverage	Source	Custodian	Currency	Record Selection
CBC Roost Counts	Burnham <i>et al.</i> 2010, and Berry 2008 for method in official surveys	Approximately the urban areas of Perth.	Great Cocky Count 2006 and 2010, WA Museum, Murdoch University, Edith Cowan University, Birds Australia WA, and DEC	DEC	2010	Only sites with counts have been included. This covers categories of “Confirmed Roost” and “Unconfirmed Roost”

Appendix 3: Data used in the processing of currently recorded breeding areas

A) Allocated to the “Confirmed Breeding Site” category:

Dataset or Project Name	Spatial Coverage	Source	Currency/years	Record Selection
WA Threatened and Priority Fauna Database	WA state	DEC	Extracted October 2010	Records of Carnaby’s cockatoo with the breeding field containing either: “Eggs/young in nest”, “Hollow/nest”, “Nest hollow”, or “Nest” 239 records
CBC Breeding Locations	Ledge Point to Yalgorup and to Muchea	P Mawson, DEC, Pers. Comm. Oct 2010	-	All 26 records
CBC Twins Paper	WA state	P Mawson, DEC, Pers. Comm. Oct 2010	-	All 280 records
CBC Veg Nest Chick Banding	WA state	P Mawson, DEC, Pers. Comm. Oct 2010	Covers the years 2003 – 2010.	All 140 records

B) Allocated to the “Possible Breeding Site” category:

Dataset Name	Spatial Coverage of project	Source	Currency/years	Record Selection
Carnaby Cockatoo Hollows	Large areas within the SCP and JF IBRA regions	DoP / Storr Johnstone	Received June 2010 dataset, known to be a	All of those records received. Thirty three records.

			partial dataset.	
Carnaby Cockatoo Mating Behaviour	Large areas within the SCP and JF IBRA regions	DoP / Storr Johnstone	Received June 2010 dataset, known to be a partial dataset.	All of those records received. Four records.
NSCP Cockatoo Data	Northern parts of Swan Coastal Plain	DEWHA / Storr Johnstone	Received 2009	Where "possible nest" or "mating call" or "breeding behaviour" found in Comments field. Two records
NSCP Cockatoo Data Lancelin to Perth	Lancelin to Perth	DEWHA / Storr Johnstone	Received 2009	Where "possible nest" in Comments2 (was Location1) or any comment in Breeding Behaviour field. Five records.
SCP Cockatoo ground-truthing 2007	Various areas Bunbury to Dunsborough	DEWHA / Storr Johnstone	Received 2009	Where "nesting" in Comments2 field. Three records.
SCP Whicher cockatoo data	Greater Whicher Range area implied by name and point coverage.	DEWHA / Storr Johnstone	Received 2009	Where "male feeding female Indicating breeding". One record.

Appendix 4: Search terms used to find the high priority plant species for determining potential feeding areas in the Swan Coastal Plain IBRA region.

Plant Scientific Name	Common Name	Terms used in vegetation description search
<i>Banksia attenuata</i>	Slender Banksia	<i>Banksia</i> ¹
<i>Banksia ilicifolia</i>	Holly Banksia	<i>Banksia</i> ¹
<i>Banksia littoralis</i>	Swamp Banksia	<i>Banksia</i> ¹
<i>Banksia menziesii</i>	Menzies's Banksia	<i>Banksia</i> ¹
<i>Banksia dallanneyi</i> ²	Honeypot Dryandra	<i>Dryandra lindleyana</i> ; <i>Dryandra nivea</i>
<i>Banksia prionotes</i>	Acorn Banksia	<i>Banksia</i> ¹
<i>Banksia</i> woodlands unspecified sp ¹		<i>Banksia</i> ¹
<i>Banksia sessilis</i>	Parrot Bush	<i>D. sessilis</i> ; <i>Dryandra sessilis</i>
<i>Banksia squarrosa</i>	Pingle	<i>Banksia</i> ¹
<i>Corymbia calophylla</i>	Marri	<i>Corymbia calophylla</i> ; <i>C. calophylla</i> ; <i>Eucalyptus calophylla</i> ; <i>E. Calophylla</i> ; <i>marri</i>
<i>Eucalyptus tottiana</i>	Coastal Blackbutt	<i>Eucalyptus tottiana</i> ; <i>E. tottiana</i>
<i>Eucalyptus wandoo</i>	Wandoo	<i>Eucalyptus wandoo</i> ; <i>E. wandoo</i>
<i>Eucalyptus accedens</i>	Powderbark wandoo	powderbark; <i>E. accedens</i>
<i>Eucalyptus gomphocephala</i> ³	Tuart	woodland AND <i>Eucalyptus gomphocephala</i> ; woodland AND <i>E. gomphocephala</i> ; forest AND <i>Eucalyptus gomphocephala</i> ; forest AND <i>E. gomphocephala</i> ; mallee AND <i>Eucalyptus gomphocephala</i> ; mallee AND <i>E. gomphocephala</i>
<i>Hakea prostrata</i>	Harsh Hakea	<i>Hakea prostrata</i> ; <i>H. prostrata</i>
<i>Hakea trifurcata</i>	Two-leaved Hakea	<i>Hakea trifurcata</i> ; <i>H. trifurcata</i>
<i>Hakea undulata</i>	Wavy-leaved Hakea	<i>Hakea undulata</i> ; <i>H. undulata</i>

1. The term “*Banksia*” was chosen to cover all the variations of the many high priority food species of *Banksia* (listed above), and as importantly, phrases like “*Banksia* woodlands”, “*Banksia* uplands” and “*Banksia* spp.”.
2. *Banksia nivea* can be misidentified as *Banksia dallanneyi* and both were previously known as *Dryandra nivea* and *Dryandra lindleyana* respectively (Karen Clarke, personal comm.)
3. *Eucalyptus gomphocephala* had a form adjective, “AND”, added to prevent selection of emergents.
4. On occasions the older scientific name was used as that is what was found in a preliminary perusal of the datasets e.g. *Dryandra sessilis*

Appendix 5: Search terms used to find the high priority plant species for determining potential feeding areas in the Jarrah Forest IBRA region.

Plant Scientific Name	Common Name	Terms used in vegetation description search
<i>Banksia attenuata</i>	Slender Banksia	<i>Banksia</i> ¹
<i>Banksia ilicifolia</i>	Holly Banksia	<i>Banksia</i> ¹
<i>Banksia littoralis</i>	Swamp Banksia	<i>Banksia</i> ¹
<i>Banksia menziesii</i>	Menzies's Banksia	<i>Banksia</i> ¹
<i>Banksia dallanneyi</i> ²	Honeypot Dryandra	<i>Dryandra lindleyana</i> ; <i>Dryandra nivea</i>
<i>Banksia prionotes</i>	Acorn Banksia	<i>Banksia</i> ¹
Banksia woodlands unspecified sp		<i>Banksia</i> ¹
<i>Banksia sessilis</i>	Parrot Bush	<i>D. sessilis</i> ; <i>Dryandra sessilis</i>
<i>Banksia squarrosa</i>	Pingle	<i>Banksia</i> ¹
<i>Corymbia calophylla</i>	Marri	<i>Corymbia calophylla</i> ; <i>C. calophylla</i> ; <i>Eucalyptus calophylla</i> ; <i>E. Calophylla</i> ; marri
<i>Eucalyptus tottiana</i>	Coastal Blackbutt	<i>Eucalyptus tottiana</i> ; <i>E. tottiana</i>
<i>Eucalyptus wandoo</i>	Wandoo	<i>Eucalyptus wandoo</i> ; <i>E. wandoo</i>
<i>Eucalyptus accedens</i>	Powderbark wandoo	powderbark; <i>E. accedens</i>
<i>Eucalyptus marginata</i>	Jarrah	<i>Eucalyptus marginata</i> ; <i>E. marginata</i> ; jarrah
<i>Hakea prostrata</i>	Harsh Hakea	<i>Hakea prostrata</i> ; <i>H. prostrata</i>
<i>Hakea trifurcata</i>	Two-leaved Hakea	<i>Hakea trifurcata</i> ; <i>H. trifurcata</i>
<i>Hakea undulata</i>	Wavy-leaved Hakea	<i>Hakea undulata</i> ; <i>H. undulata</i>

1. The term “*Banksia*” was chosen to cover all the variations: the many high priority food species of *Banksia* (listed above), and as importantly, phrases like “*Banksia* woodlands”, “*Banksia* uplands” and “*Banksia* spp.”.
2. *Banksia nivea* can be misidentified as *Banksia dallanneyi* and both were previously known as *Dryandra nivea* and *Dryandra lindleyana* respectively (Karen Clarke, personal comm.)
3. Jarrah is regarded as a high priority food species *only* in the Jarrah forest (Tony Kirkby, personal comm. 2010)

Appendix 6: Plant species potentially used by Carnaby's cockatoo for breeding purposes on the Swan Coastal Plain and Jarrah Forest IBRA regions, from "Plants for Carnaby's Search Tool" Groom (2010b).

Swan Coastal Plain:

Plant Scientific Name	Common Name
<i>Corymbia calophylla</i>	Marri
<i>Eucalyptus gomphocephala</i>	Tuart
<i>Eucalyptus wandoo</i>	Wandoo

Jarrah Forest:

Plant Scientific Name	Common Name
<i>Corymbia calophylla</i>	Marri
<i>Eucalyptus diversicolor</i>	Karri
<i>Eucalyptus occidentalis</i>	Swamp Yate
<i>Eucalyptus salmonophloia</i>	Salmon Gum
<i>Eucalyptus wandoo</i>	Wandoo