KEY HABITATS AND CORRIDORS FOR FAUNA: A LANDSCAPE FRAMEWORK FOR REGIONAL CONSERVATION PLANNING IN NORTH-EAST NEW SOUTH WALES.

II. METHODS, DECISION RULES, ASSUMPTIONS AND MAPPED OUTPUTS.

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SUMMARY

This document forms part of a larger report detailing the approach and outputs of the Key Habitats and Corridors (KHC) Project undertaken in north-east New South Wales. Briefly, the KHC Project summarises and integrates available priority fauna modelled distributions, accumulated over the last decade under the NSW Government's forest reform program, to produce a landscape framework for regional conservation planning and assessment. In order to inform current government vegetation, water and forest reforms, this integrated data is required in a manageable, but ecologically relevant format; that requirement has been the foundation for the KHC Project. A more detailed account of the planning context surrounding the KHC Project is provided in part one of this report (I. Background, Principles and Framework)

The purpose of this, part two, document is to outline the process, methods, rules and assumptions incorporated in the derivation of fauna key habitats and corridors for four study areas in north-east NSW (see figure 1).

The process employed in deriving fauna key habitats and corridors is repeatable in as much as:

- The fauna species models, which are the basic biodiversity entities that the project seeks to summarise and integrate are stored and held by NPWS;
- All relevant data layers, developed at each stage of the project, are stored and held by NPWS;
- The Geographic Information System (GIS) tools developed for the analyses are available as extensions to the ARCVIEW GIS.

At numerous stages of the analyses, informed interpretation of outputs and assignment of thresholds has been required to move the process along or to finalise an output. Any qualitative decisions taken have been based on the project manager's ecological expertise and knowledge of the data sets being considered. When possible, 'decision rules' have been explicitly documented below, along with the rest of the project process, to provide for assessment and review of the methods employed and assumptions made.

REGIONAL FAUNA KEY HABITATS

Provision of suitable habitats is the fundamental basis for wildlife conservation. For most species this means protection of areas of natural habitat of suitable quality, size and location, because few native animals or plants are able to live in cleared farmland environments.

The Key Habitats and Corridors Project (KHC Project) has mapped key habitats for forest fauna of north-east NSW within four study areas (Figure 1). The types of key habitats reflect the recommendations and directions found within the landscape ecology literature (e.g. see Myers 1999, Noss *et al.* 1997); they are focus areas for regional conservation planning. The categories of fauna key habitat derived are:

I. <u>Fauna assemblage core habitats</u>; areas where the highest proportion of species comprising each priority fauna assemblage are predicted to occur (an index of priority species diversity).

II. <u>Fauna assemblage hot spots</u>; areas where the highest quality habitats for at least one third of species comprising each priority fauna assemblage are predicted to occur (an index of priority species relative abundance).

III. <u>Centres of endemism for vertebrates and invertebrates</u>; areas where the highest proportion of endemic vertebrates and invertebrates are predicted to occur.

It is important to note that the KHC Project has focused on the delineation of regional key habitats, to be linked by regional and sub-regional corridors (see below). Clearly, there are more localised key habitats, reflecting more localised species considerations, which also require delineation in order to complete any conservation plan (Noss *et al.* 1997). These will either be known, or remain to be identified, at more localised scales, i.e. by local planners and managers, landowners and community groups. The types of local key habitats to be delineated and mapped include:

I. Known, and modelled, distributions of priority species with special significance at more localised scales;

II. Known, and modelled, distributions of species for which private lands comprise the highest quality habitats.

DERIVING FAUNA KEY HABITATS- THE PROCESS

The process of deriving and mapping regional key habitats for fauna has revolved around the summary and integration of priority species' modelled distributions into a manageable but ecologically relevant format. This process is detailed here:

STEP 1. COLLATE BEST "ALL-TENURE" DISTRIBUTIONAL MODELS FOR NORTH-EAST NSW PRIORITY FAUNA.

The species of forest fauna (and flora) requiring most attention in regional conservation planning are those that are restricted in distribution or most vulnerable to processes that threaten their long term viability. Lists of priority fauna inhabiting forests of north-east NSW have been derived under criteria that emphasise level of endemism[1] (Gilmore and Parnaby 1994, Environment Australia 1998) and vulnerability to threatening processes (Gilmore and Parnaby 1994, NPWS 1994c, 1995b, Environment Australia 1998). The most contemporary

[1] Consideration of endemic species here follows the rationale of the RFAs for LNE and UNE which defined an endemic species as "a species for which more than 75% of its range or more than 75% of its total population falls within north-east NSW (UNE and LNE combined).

of these are two overlapping lists, one of 75 endemic priority species (see Appendix 1), the other of 146 Regional Forestry Agreement (RFA) priority species[2] (see Appendix 2).

The KHC Project takes a landscape approach and addresses all land tenures in the process. Consequently only those priority species for which a sound (see decision rule 1), all-tenure distributional model was available (see NPWS 1994c for endemic priority species models, NPWS 1999b for RFA priority species models) were included in the project analyses. The modelled distributions for these species (48 endemic species and 122 RFA priority species; see Appendices 1 & 2) comprise the basic analytical entities for deriving key habitats for vertebrate fauna in the KHC Project.

> *<u>BOX 1. Decisions concerning use of modelled distributions</u>.*
> *Distributional models for priority or endemic species were considered to be suitable for inclusion in the KHC Project analyses if they had been assessed and approved by the expert fauna panels assembled for the predictive modelling projects undertaken for the Upper and Lower North East (UNE and LNE) Regional Forestry*

STEP 2. COLLATE INTEGRATED KEY HABITAT DATA LAYERS DERIVED FOR PREVIOUS REGIONAL CONSERVATION PLANNING AND ASSESSMENT PROJECTS: VERTEBRATE AND INVERTEBRATE CENTRES OF ENDEMISM

Two important data layers had been developed during the UNE & LNE Regional Forestry Asessments to summarise and integrate the 48 endemic species distributional models to a form suitable for consideration in that project; these were available for immediate inclusion as subsets of regional fauna key habitats in the KHC Project:

Centres of Endemism were highlighted as a key conservation planning feature by the scientific committee convened to determine conservation criteria for the conduct of Comprehensive Regional Assessments of forests (see JANIS 1997). Centres of endemism for vertebrates, invertebrates and vascular plants were identified and delineated across all land tenures of the UNE and LNE RFA areas for inclusion and consideration in the development of reservation options. Reservation targets were developed for these features, all of which remain under-achieved.

The process of summary and integration of the 48 available endemic species modelled distributions (NPWS 1999b) was exactly the same process used for priority fauna species assemblages in the KHC Project; this process is detailed below. Six vertebrate centres of endemism (COEs) were identified and mapped, for the UNE and LNE RFA study areas. These individual COE data layers are stored and held by NPWS. For the purposes of the KHC Project these six were amalgamated to a single <u>vertebrate fauna COE</u> map layer, one subset of regional fauna key habitat (Figure 2). This map layer does not extend into the Northern Sydney Basin KHC Project study area as the species distributional models used to derive it were constrained to the North East Forests Biodiversity Study (NEFBS) area (NSW NPWS 1994c).

Invertebrate centres of endemism were also identified and mapped for the UNE and LNE RFA study areas (NPWS 1999b) using a different analytical strategy undertaken by the Australian Museum. Briefly, actual species location records of invertebrates, from the five families: worms, snails, crustaceans, insects and spiders, were used to determine "narrow range endemics". These were species with a total range within the UNE and LNE combined RFA regions of 50 km x 50 km. The rest of the species records were allocated to background data, a measure of sampling effort. An index of records and sampling effort per hectare was

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[2] Consideration of priority fauna species here follows the rationale and listing originally documented by Gilmore and Parnaby (1994) and refined for the RFAs for LNE and UNE.

then calculated and used to identify spatial areas with high levels of endemism and comprehensive sampling effort. These were then classified, via the PATNMAP software (see priority species fauna assemblages below) into groups based on the species compositions. Twelve invertebrate centres of endemism resulted for UNE and LNE RFA study areas. These individual COE data layers are stored and held by NPWS. For the purposes of the KHC Project these twelve were amalgamated to a single invertebrate fauna COE map layer, one subset of regional fauna key habitat (Figure 3). This map layer does not extend into the New England Tablelands or Northern Sydney Basin KHC Project study areas as the museum's work was constrained to the eastern portion of the North East Forests Biodiversity Study (NEFBS) area (Gray and Cassis 1994).

STEP 3. TAILOR PRIORITY SPECIES DISTRIBUTIONAL MODELS TO THE FOUR KHC PROJECT STUDY AREAS.

The four KHC Project areas (Figure 1) were chosen for two reasons:

A. To reflect the Interim Biogeographic Regionalisation for Australia (IBRA) classification which describes a framework for setting national reserve priorities (Thackway and Cresswell 1995). The IBRA divides the UNE and LNE RFA study areas, source of the current fauna distributional models, into three bioregions, NSW North Coast, New England Tablelands (hereafter referred to as TAB) and Sydney Basin (SYD);

B. The NSW North Coast Bioregion was split into two, the Upper North Coast(UNC) and Lower North Coast (LNC) to prevent a "swamping" effect noticed in a trial of the KHC Project whereby the relative abundance of priority species models in the upper north part of the North Coast tended to bias the delineation of assemblage and key habitats to the north and away from known important habitats in the south, often the southern limits or disjunct occurences of priority species which were better delineated by a more focused consideration. The UNC – LNC splitalso reflects the UNE – LNE RFA study area split.

The 122 fauna distributional models available for summary and integration were tailored to the four study areas in a two-staged process:

A. Initially available across the two RFA study areas, the models were cut to fit each KHC area;

B. Models within each KHC study area were then assessed in order to exclude those predicting habitat for a particular species within a KHC study area but that species is not known to occur , and is unlikely to occur, in that area.

This process left a subset of the 122 available distributional models for summary and integration within each KHC study area:

UNC – 104 models; **TAB – 54 models;**
LNC – 84 models; **SYD – 51 models.**

BOX 2. Decisions concerning species models within study areas
Priority fauna distributional models predicting habitat within a particular KHC study area but not known to occur, and considered, by the KHC Project ecologist, unlikely to occur there were excluded from further analysis for that area.

STEP 4. DERIVE PRIORITY FAUNA ASSEMBLAGES

Two techniques, developed and refined by the Research and Development Unit of the NPWS GIS Division, were implemented to aid the derivation of fauna assemblages and key habitats for fauna: PATNMAP and CONTEXT; both are extensions to the ARCVIEW GIS program.

1. PATNMAP

PATNMAP utilises pattern analysis to derive a greatly reduced set of mapped species assemblages from a pool of individual species distributions by grouping those with similar distribution patterns, a reflection of their ecological association, at least at the regional scale. The outputs are assessed at this stage to reveal any anomalies, based on an ecologist's expert knowledge of species associations. The system-derived groupings can be altered at this stage to adjust for ecological reality; minimal adjustments were required to the KHC assemblage outputs. PATNMAP then provides a means to produce spatial surfaces representing the likely distribution of the assemblages by averaging the component species models, transformed to eliminate bias due to the effects of varying abundance between species. Higher values within the spatial surface generated for each assemblage indicate areas that are likely to support a larger proportion of the species comprising the assemblage. Species assemblages represent ecologically relevant entities for the identification of regional key habitats for species and a level that is manageable at the regional planning level (see Myers 1999, Noss *et al.* 1997). An illustration of the process of assemblage formation by PATNMAP is provided in Figure 1. The outputs are continuous probability surface models (map layers) depicting the predicted distributions of each assemblage These can be used as planning entities in their own right or, as in this project, can be further worked to derive key habitats and corridors.

BOX 3. Decisions concerning the PATNMAP analyses.

The PATNMAP process provides for expert ecological interpretation to adjust the system-derived species groupings prior to final assemblage designation. Minimal adjustment was required to the KHC Project

2. COST-BENEFIT SPATIAL CONTEXT

COST-BENEFIT SPATIAL CONTEXT (C-BSC) is used to refine modelled probability surfaces by considering spatial context in terms of species-habitat interaction and by recognising the patchy nature of natural landscape. Habitat for any particular species occurs as a heterogeneous mosaic of favourable and unfavourable areas, in terms of resources and impediments to movement. Impedance weightings are applied to different classes of predicted habitat and non-habitat and considered relative to a defined ecological neighbourhood that reflects connectivity, in a landscape sense, and incorporates the concept of non-linear connectivity that characterises many important ecological functions (e.g. foraging, predation, dispersal). For the purposes of this project the CONTEXT analysis was used to refine the predicted fauna assemblage distributions, accentuating areas of highest probability of occurrence, and larger area of predicted habitat, and lowering the relative value of lower probability and smaller, more fragmented areas.

The C-BSC analysis involved a number of stages:

A. Expert classification of the continuous probability surface assemblage layers, based on the assessment of predicted habitat quality, to generate four habitat classes and a "habitat grid" for each assemblage. The four classes are: 0 – non-habitat; 1 – marginal habitat; 2 – intermediate habitat; 3 – high quality habitat;

B. Expert application of "thresholds of impedance" to the habitat grids reflecting perceived habitat quality for the assemblage and relative impedance of the four habitat classes. The resultant “impedance grid” reflects predicted habitat patchiness and variation in resource and movement potential.

C. C-BSC produces a “cost-benefit” grid for each assemblage; this is a continuous probability surface model (map layer) depicting the predicted distribution of each assemblage. As before, these can be used as planning entities in their own right or, as in this project, can be further worked to derive key habitats and corridors.

> *BOX 4. Decisions concerning the COST-BENEFIT SPATIAL CONTEXT analyses.*
> *The COST-BENEFIT SPATIAL CONTEXT analysis requires the input of ecological interpretation to re-classify continuous assemblage surfaces to categories of habitat quality and then to apply thresholds of impedance to each derived category. Expert-based decisions such as these are not quantifiable but, as in all regional conservation planning and assessment projects (see NPWS 1994c,d; NPWS 1999b) are necessary to direct the process.*

The PATNMAP and C-BSC analyses undertaken for the four KHC study areas yielded final priority fauna assemblages for the four KHC areas:

Upper North Coast (UNC) – Eight priority fauna assemblages (see Appendix 3);

Lower North Coast (LNC) – Eight priority fauna assemblages (see Appendix 4);

Tablelands (TAB) – Six priority fauna assemblages (see Appendix 5);

Northern Sydney Basin (SYD) – Five priority fauna assemblages (see Appendix 6).

STEP 5. KEY HABITATS: FAUNA ASSEMBLAGE CORE HABITATS

The process of deriving fauna assemblage core habitats from each assemblage distribution model was to apply a threshold to the cost-benefit grid for each assemblage that resulted from the CONTEXT analyses. Initially it was planned to assign a set cut point with the highest 25% of the predicted assemblage habitat included in the core category but this proved enormously varied between assemblages and lead to small fragmented fragments being included for some. Other cut-points yielded similar problems. It was decided to determine the core habitat threshold individually for each assemblage by assessing the proportion of predicted assemblage habitat included or excluded by varying the cut-off points.

> *BOX 5. Decisions concerning fauna core habitats.*
> *Core habitat thresholds were applied individually to each predicted assemblage distribution. Rules guiding the application of thresholds:*
> *- Incorporate the largest contiguous patches of predicted high quality habitat in order to promote the retention of landscape connectivity as far as possible;*
> *- Accentuate the importance of larger contiguous patches by excluding smaller fragmented patches of predicted high quality habitat; these generally occupy areas of marginally lower predicted probability of occurrence, courtesy of the COST-BENEFIT SPATIAL CONTEXT*.analyses.

The core habitats for each assemblage were then combined to produce overall fauna assemblages core habitat map layers for each KHC study area and for north-east NSW (Figure 5).

STEP 6. KEY HABITATS: FAUNA ASSEMBLAGE HOT SPOT HABITATS

Fauna assemblage hot spots were derived from the seven identified assemblage distributions. This was done by returning to the original priority fauna modelled distributions for each identified assemblage, delineating the highest probability class for each species and overlaying these to identify hot spots for each assemblage. The hot spots represent the subset of regional key habitats for priority fauna where highest quality habitat for at least one third of the species in each assemblage overlap.

The hot spot habitats for each assemblage were then combined to produce overall fauna assemblage hot spot habitat map layers for each study area and for north-east NSW (Figure 6).

BOX 6. Decisions concerning fauna hot spots.   *High quality habitat overlap for at least one third of the species comprising each fauna assemblage was deemed a suitable benchmark threshold for delineating hot spots. For each assemblage, the threshold was applied, assessed and varied in line with the decision rules applied for Core Habitat delineation (See BOX 5).*

REGIONAL AND SUB-REGIONAL CORRIDORS

Having derived fauna key habitats as focal areas for habitat protection the next step for the KHC Project was to address landscape connectivity, which, as stressed in the landscape ecology literature, should be maximized to maintain ecological processes (Bennett 1999, Noss *et al.*1997, Mackey *et al.* 1998*).*

As outlined by Bennett (1999) in his comprehensive review of the role of landscape linkages, “It is generally accepted that landscape patterns that promote connectivity for species, assemblages and ecological processes are a key element in nature conservation, particularly in environments modified by human impacts”.

Three pertinent points:

- Maintaining ecological processes (e.g. migration, dispersal, predation, pollination) requires long term functioning and interaction of ecosystem components;
- A true landscape approach, where the mosaics of preferred habitat are linked as one functional system through the overall maintenance or enhancement of connectivity can be achieved via habitat corridors;

Bennett (1990) has reviewed the role of habitat corridors in wildlife management and conservation; the ecological functions of habitat corridors can be summarised as:

I. to provide habitat for resident populations of flora and fauna in their own right and as stock for re-colonisation of refuge areas that suffer catastrophe (e.g. wildfire, disease);

II. to create a continuous gene pool between larger refuge areas, allowing gradual gene flow and reducing or preventing the isolation of species populations or ecosystems'

III. to provide increased foraging area and dispersal routes for wide-ranging faunal species;

IV. to provide alternative refuge from large disturbances (e.g. wildfire).

Consistent with their ecological functions there are different types of corridors; for the purposes of the KHC Project the following corridors will be referred to:

- Regional Habitat Corridors- corridors wide enough (or planned to be wide enough) to have their own ecological integrity, including sufficient habitat for resident populations of focal species and interior habitat for species detrimentally impacted by edge effects. While local conditions may limit the final width of regional corridors they should be planned to be of the order of kilometres wide. A minimum of 500 metres would be acceptable in certain instances but typically at least 1000 metres width is envisaged. Planned regional corridor widths should reflect the known demographics of focal species selected to represent the species assemblages. Regional corridors will often link formal reserves to other public lands, key habitats or to other corridors. Regional corridors will often run along major gradients such as altitudinal and latitudinal gradients. Regional corridors linking the escarpment to the coast, as well as a near-continuous north-south regional coastal corridor will be emphasised in the KHC Project. Where ever possible, regional corridors should occupy all available landforms (ridge, mid-slope, flat, gully) to ensure representation of habitat variation and resources.

The identification and protection of regional habitat corridors along altitudinal and other geographical gradients is particularly important in regional conservation planning. This relates importantly to the maintenance of ecological processes acting along these gradients (e.g. east-west and north-south gradients utilised by dispersing and migrating fauna). Aside from the intrinsic requirement to protect these natural ecological gradients, the realisation of global warming impacts will reinforce the requirement for the protection, and enhancement, of all regional corridors. The National Greenhouse Response Strategy identifies a number of adaptive response actions to global warming including "In developing conservation reserve systems and management approaches, governments will seek to provide corridor systems that link reserves and refuges with a relatively large altitudinal and other geographical variation to take into account climate change impacts." (Commonwealth of Australia 1992).

- Sub-regional Corridors- corridors wide enough to support resident populations of at least a subset of priority species or wide enough to provide a substantial link between key habitats and other key habitats, reserves, public lands or other corridors. A benchmark minimum width of 300 metres is envisaged but, where possible, they should be wider (e.g. 400 – 1000 metres). Sub-regional corridors should be positioned to maximise the protection and linkage of available landforms (ridge, mid-slope, flat, gully).

- Local Corridors- The regional and sub-regional corridors identified by the KHC Project are intended to provide a framework for conservation planning at the landscape scale. Clearly, other corridors, identified at more localised scales and designed to link more localised key habitats into a protected area network are also required. Their delineation falls to local planners and communities. Local corridors may be narrower than regional and sub-regional corridors (e.g. less than 500 metres width). Local corridors may include riparian and roadside as well as remnants. Whenever possible local corridors should link into the wider regional and sub-regional network..

- Stepping-stone Patches- While less-mobile species require continuous corridors to facilitate movement between larger protected key habitats some more mobile species, such as some birds and bats, can move via stepping-stone patches of habitat across otherwise unsuitable matrices. Documented examples include the fruit-doves which are known to utilise remnant or regrowth rainforest habitats within rural landscapes as stepping-stones during their annual move from higher elevation spring-summer habitats to lowland autumn-winter habitats and vice versa (Date *et al.* 1996) and flying-foxes which aid the dispersal and pollination of native forest trees during their day to day movement patterns (Eby 1991, Eby *et al.* 1999). For the purposes of the KHC Project stepping-stone patches include any key habitats that have not been linked into the proposed protected area network by regional or sub-regional corridors. Some of these may be linked in to the network by local corridors, derived at a later stage, and any consequent improvement in overall connectivity is considered a plus. Others will remain more isolated but their protection and enhancement is also promoted.

STEP 7. DERIVE LEAST COST PATHWAYS AS POTENTIAL REGIONAL AND SUB-REGIONAL CORRIDORS:

A technique has been developed and refined by the Research and Development Unit of the NPWS GIS Division to aid with the delineation of habitat corridors; LEAST COST PATHWAYS is used as an extension to the ARCVIEW GIS program.

LEAST COST PATHWAYS

LEAST COST PATHWAYS (LCP) is used to identify the pathways that most efficiently link identified significant landscape elements or habitats. The program operates under the principle that species, and their constituent genes, are most likely to move (while foraging, dispersing, breeding, migrating) along gradients of preferred habitat; non-preferred habitats representing varying levels of impedance or even barriers.

For any particular biodiversity entity, the most efficient landscape links are those that exact the "least cost", in terms of energy expenditure, for their use. It can be reasonably expected that the biodiversity entity, in the case of the KHC Project, the species comprising an assemblage, will preferentially utilise habitats that are more favourable to that use, be it for foraging, roosting, nesting or as transitory movement habitat. These more favourable habitats exact less cost for their use than less favourable marginal or non-habitats. Non-habitats may include areas of native vegetation that are simply not suitable for use by the entity concerned. They also include areas that have been cleared of native vegetation and developed for human uses such as agriculture and urban expansion.

The basic requirement of the LCP program is a "cost grid". This is a continuous probability surface covering the entire study area and describing the relative costs, to a particular biodiversity entity (e.g. a species or species assemblage), of utilising each grid cell within the area as habitat, or as a potential linking pathway. Cost grids for LCP analyses can be as simple as a map of vegetation cover, provided that relative costs, of relevance to the biodiversity entities concerned, can be applied to reflect variation in habitat quality (e.g. key habitats, land systems, vegetation communities) or to weight different land tenures.

Cost grids were derived for the KHC Project through a combination of the assemblage habitat map layer and existing maps of extant vegetation and land tenure. The derived cost grids reflect levels of habitat suitability and tenure class for every grid cell available as a potential linking pathway. Predicted habitats for the assemblage are deemed the least costly pathways, while non-habitat extant vegetation represents a less costly path than cleared land. Within each habitat suitability class, tenure is weighted to place greater cost on private lands as opposed to public lands and, within public lands, a greater cost on state forests as opposed to NPWS estate and Crown Reserves managed by NPWS. The effect of tenure weightings is to favour reserved lands over state forests over private lands as corridor links, all else being equal. Additional costs were applied to mapped estuaries making it more “costly”, but not impossible, for the program to link across these features, relative to alternative links, all else being equal.

The LCP program utilises paired reference points, assigned in an iterative manner and apportioned within focal habitat types (e.g. assemblage habitats and key habitats), which it works to via the most efficient pathways available according to the cost grid. The reference points are directed into identified strategic areas, making them focal areas for landscape links. For the purposes of the KHC Project analyses 10,000 reference points were used and assigned to the predicted assemblage habitats with a minimum proportion directed into fauna core habitats.

In seeking to establish the most ecologically valid corridor network for the KHC Project study areas, that is one linking the identified fauna assemblages and key habitats, it was decided to run the LCP analysis at two levels:

Level 1: a LCP analysis for each of the each identified fauna assemblage independently (7 for UNC, 7 for LNC, 6 for TAB and 5 for SYD);
Level 2: a LCP analysis for the combined assemblages within each study area.

These two levels were selected in order to pursue the goal of enhancing overall landscape connectivity. The first level will establish potential corridor links for species within each assemblage, a clear goal of landscape ecology. The second level will consolidate the landscape approach, whereby the mosaics of habitats and species assemblages across a landscape are treated as one functional system, another ecological requirement enhancing overall landscape connectivity. These between assemblage corridors are also intended to provide for larger scale dispersal and movement (e.g. migration) between assemblages.

Figure 7 provides an illustration of the process carried out by the LCP program, as implemented for the KHC Project.

The LCP outputs are continuous probability surface models (map layers) depicting the pathways of least cost linking habitats, and particularly core habitats, of each fauna assemblage individually, plus a combined assemblages run for each KHC study area. These map layers can be used as planning entities in their own right or, as in this project, can be combined and weighted to derive regional and sub-regional corridors.

BOX 7. Decisions concerning the LEAST COST PATHWAYS analyses.

In seeking to enhance the potential for landscape connectivity the KHC Project LEAST COST PATHWAYS analyses were undertaken at two levels, within and between assemblages. The former will identify potential corridors specifically linking habitats of the same assemblage, the latter will link between assemblages and consolidate the mosaics of habitats and species assemblages across a landscape as one functional system.

Assemblage core habitats were chosen as the focus areas for directing the assignment of paired reference points for the LEAST COST PATHWAYS analyses. They were chosen over assemblage hot spots due to their inherent landscape perspective; they are derived directly from the continuous probability surfaces of the actual assemblage distribution whereas hot spots are derived by the overlap of modelled high quality habitat for the constituent species of each assemblage.

STEP 8. DERIVING REGIONAL AND SUB-REGIONAL CORRIDOR GRIDS FROM LEAST COST PATHWAYS OUTPUTS

The LEAST COST PATHWAYS outputs represent potential corridors; assessing them and moving them from potential corridors to Regional and Sub-regional corridors followed another set process for each KHC study area:

A. Reclassify the continuous probability surface layers depicting the potential corridors for each assemblage to five classes; 0,1,2,3,4, based on perceived thresholds of significance, with class 4 being those potential corridors at the highest probability end of the scale, and of the highest priority for that assemblage;

B. Do the same for the between assemblage potential corridors for each KHC study area;

C. For each KHC study area, combine the classified assemblage, and between assemblage corridor grids and sum the combined classes;

D. Apply thresholds to delineate Regional and Sub-regional corridors (see BOX 8);

E. For interim display purposes (prior to final conversion of the grid map layers to polygon map layers) use existing vegetation mapping (from NPWS 1999_) to intersect the derived corridors map layers and display vegetated and non-vegetated portions of the regional and sub-regional corridors.

Figure 8 is a regional depiction of the potential regional and sub-regional corridor map layers. As illustrated, regional and sub-regional corridors extend across all tenures with certain private lands being crucial links in the network. In many instances, the least costly pathway to link some assemblage habitats crossed cleared lands. Figure 8 highlights these currently cleared corridors which are important planning focus areas for re-habilitation and re-establishment of corridor links.

The potential regional and sub-regional corridor grid map layers depicting potential corridors linking predicted fauna assemblage habitats are available for each KHC study area and as a combined potential corridors map layer for the entire KHC area. These map layers can be used as planning entities in their own right but the final stage of the KHC Project (mapping phase) is to undertake final assessment and refinement of the potential regional and sub-regional corridors and to convert them to final polygon layers for implementation on planning and management programs.

BOX 8. Decisions concerning the designation of potential corridor hierarchy labels:

For the KHC Project three potential corridor categories are recognised, regional, sub-regional and local, but only regional and sub-regional corridors are delineated and mapped at this, the regional landscape scale. Local corridors remain to be identified by local planners and communities

The interpretation of LEAST COST PATHWAYS outputs requires ecological interpretation to re-classify continuous potential corridor surfaces to four classes of corridor status and then to set thresholds for corridor potential regional and sub-regional status. Expert-based decisions such as these are not quantifiable but, as in all regional conservation planning and assessment projects (see NPWS 1994c,d; NPWS 1999b) are necessary to direct the process.

The thresholds applied to determine potential corridor status were based on summed class categories (0,1,2,3,4) for the combined assemblage and between assemblage map layers for each study area:

- *Summed values of ≥3 were designated potential regional corridors. A value of ≥3 indicates that the potential corridor is either of high value for a particular fauna assemblage or of high value as a between assemblages corridor or has been identified for more than one assemblage (and at least one at >2 level) or has been identified for at least one assemblage and as a between assemblages corridor (and at least one of these at >2 level)*
- *Summed values of 1 or 2 were designated as potential sub-regional corridors. Potential regional and sub-regional corridors require further assessment as part of the final stage of the KHC Project (mapping phase), conversion and refinement of potential corridors to final polygon corridors.*

STEP 9. REFINING THE POTENTIAL CORRIDOR GRID MAP LAYERS TO FINAL CORRIDOR POLYGON LAYERS

The potential corridor map layers are useful as planning entities in their own right, providing an index of the importance of the respective corridors identified within the parameters of the analytical programs employed. However, not all of the potential corridors identified by the LEAST COST PATHWAYS (LCP) process are sensible, from either ecological or practical planning perspectives. In addition, the potential corridor grid layers are not easily adaptable to direct field implementation seeking to place the corridors on the ground and determine boundaries.

A process of assessment and refinement of the potential corridors is the final stage of the KHC Project (mapping phase) whereby the potential corridor grid map layers are converted to final polygons with defined boundaries. In this process certain potential corridors are accentuated and extraneous potential corridors are ignored. It is anticipated that this polygon output will be the most appropriate for provision to planners, managers and community groups.

A technique has been developed and refined by the Research and Development Unit of the NPWS GIS Division as a means of refining grid data layers, such as the potential corridors data, to clearer polygon planning units; POLYEDIT is used as an extension to the ARCVIEW GIS program.

POLYEDIT

POLYEDIT allows the user to select portions of continuous or classified grid map layers for refinement and categorisation. For example, a portion of the potential corridor grid layer can be selected which corresponds to a particular, locally identifiable, part of the landscape. By refining and naming the selected corridor portion the refined corridor can take on a “life of its own” and be recognisable by local planners, managers and community groups. The program allows the progressive and cumulative refinement of the entire grid layer in this manner. After selecting the portion of the grid layer to be refined POLYEDIT requires the user to apply a threshold to the grid, parts of the grid below the threshold will be retained within the derived polygon, the excess will be ignored. The polygon can then be edited to reflect aspects such as pre-determined corridor widths, tenure boundaries and local topography, as indicated by 1:25,000 topographic map layers. By combining the functions provided in the POLYEDIT program, coupled with the shape editing capabilities of ARCVIEW, virtually any configuration of shapes can be readily derived to refine the polygon outputs in line with the mapped features available to the user.

An additional feature of the POLYEDIT program allows the user to identify known corridors that the LEAST COST PATHWAYS (LCP) analyses have not delineated (non-LCP corridors) (see BOX 9). This POLYEDIT feature requires the user to outline the non-LCP corridor, by on-screen digitising.

For the KHC Project, POLYEDIT was incorporated into the process of assessment and refinement of potential corridors in the following manner:

A. Visual assessment of the potential corridor layers, within Arcview, against available vegetation mapping, LANDSAT imagery, 1:25,000 topographic maps and tenure maps;

B. Acceptance or rejection of the potential corridors, and identification of any non-LCP corridors based on decision rules; (see BOX 9);

C. Refinement of accepted corridor boundaries, utilising POLYEDIT in combination with vegetation mapping, LANDSAT imagery and topographic maps;

D. Delineation of public land and private land corridors separately;

E. Editing of the polygon attributes table, within ARCVIEW, to summarise decisions made in the refinement process (table sample provided as Appendix ? ????????); this included a scoring procedure to assess the overall status of each corridor according to six criteria (modified from Bennett 1999) (see BOX 10);

F. Final designation of corridors to the categories, Regional or Sub-regional according to the overall score thresholds (see BOX 10).

At of the time of writing, the final corridors are still being refined from the potential corridor grid layers. This is happening under a staged process and its completion is dependent upon the procurement of additional funds. Certain Regional Vegetation Planning Areas (RVPAs) have been targeted for initial refinement. The Richmond RVPA has been finalised, along with the Tweed and Byron Local Government Area-based RVPAs. The Clarence, Tenterfield and Manning areas will be addressed next.

An illustration of the results of the corridor refinement process is provided for the Richmond RVPA and Tweed and Byron local government areas in figures 9 and 10.

BOX 9. Decisions concerning the acceptance or rejection of the potential corridors, and identification of any non-LCP corridors

Criteria for accepting and rejecting potential regional and sub-regional corridors

Potential corridors were accepted if they:

- *Made ecological sense in terms of perceived landscape flows, perceived fauna movement patterns, extant vegetation patterns;* ***AND***
- *Required little or no boundary modification in order to maximise the area occupied by extant native vegetation compared to area currently cleared of native vegetation;*

Potential corridors were rejected if they:

- *Did not make ecological sense; for example, potential corridors identified by the 'between assemblages' analyses but proposing linkage of inappropriate assemblage habitats, such as dry foothills habitat and rainforest habitat, or potential corridors clearly linking across rather than along major landscape gradients and so unlikely to form natural linkages;* ***OR***
- *Did not make planning sense; for example, potential sub-regional corridors mapped across very wide expanses of land currently cleared of native vegetation;* ***OR***
- *Were fragmented or disconnected and did not enhance overall landscape connectivity;*

Non-LCP Corridors

In certain instances additional corridors, or parts of corridors, not identified by the LEAST COST PATHWAYS (LCP) analysis were included as final regional or sub-regional corridors. These "non-LCP" corridors, as opposed to those derived from the LCP analysis, were included under three scenarios:

I) Where known information relating to a corridor recognised by other planning and assessment programs could be applied;

II) Within the NSW Coastal Zone (NSW Coastal Policy 1997) where a near-continuous north-south regional coastal corridor is targeted;

III) To enhance overall landscape connectivity.

BOX 10. Six criteria, modified from Bennett (1999), used to assess accepted LCP and Non-LCP corridors and determine the final regional and sub-regional corridor hierarchy.

I) Spatial scale of the corridor

Corridors operating at the biogeographic or regional scales have a more significant role than those operating at sub-regional or more localised scale. Corridors are scored accordingly:
3 = biogeographic scale (Major ecological gradients such as potential migratory gradients; eg. major altitudinal corridors, the coastal corridor, some major forested river valleys and ranges);
2 = regional scale (Other natural gradients including alternative links for migrating, nomadic and dispersing fauna);
1 = Other potential corridors operating at sub-regional or more localised scales.

II) Landscape context

Certain private lands support important, even irreplaceable conservation assets but public lands will always form the basis and backbone of protected area networks. Therefore, corridors contributing demonstrably to landscape connectivity by linking and supplementing public lands directly and succinctly are scored higher than more indirect or disparate corridors with high length to area ratios or without a public land focus:
3 = Major links between formal reserves and other formal reserves, other significant public lands, or regional corridors;
2 = alternative links between formal reserves and other formal reserves, other significant public lands, or regional corridors and alternative links between key habitats on private lands and the public land estate;
1 = Other potential corridors.

III) Level of redundancy

Are there alternative linking corridors? Is the corridor link replaceable?
3 = Irreplaceable corridor, no alternatives; 2 = One of two alternatives;
1 = More than two alternatives.

IV) Degree of threat

Some of the priority fauna species assemblages derived in the KHC project are more threatened and less well protected by formal reserves than others. (See Appendices 3,4,5,6 for full assemblage names). Corridors derived for more threatened assemblages receive a higher score.
3 = Corridors derived for CC, DCF, MEF, TAB, DGT, DWT, DCR, DWC, DV assemblages;
2 = Corridors derived for WEF, DET, SNET assemblages;
1 = Corridors derived for WE, NE, WET, WEET, WCR assemblages.

V) Condition

Corridors currently supporting natural vegetation are scored higher than those requiring partial or major restoration, recognising that restoration is a highly desirable possibility but is subject to many unresolved factors.
3 = 100-66% native vegetation;2 = 66-33% native vegetation;1 = 0-33% native vegetation.

VI) Assemblage score

The potential corridors within the KHC project study areas each have a quantitative value assigned to them indicating the summed value of the constituent assemblage and between assemblage corridor analyses (see Box 8). These are re-used here as an index of the range of priority species, and assemblages, that the corridor under consideration will benefit. The assemblage score is derived by interrogating the relevant potential corridor grid at 10 interior points along the corridor's length and averaging the scores revealed. Non-LCP corridors (see Box 9) are designated a default score of 2.
3 = a score ≥ 4; 2 = a score of $\geq 3 < 4$; 1 = a score < 3.

SUMMED CORRIDOR SCORE THRESHOLDS

11 – 18 = Regional corridors & 6 – 10 = Sub-regional corridors.

Box 11. Decisions regarding final corridor dimensions- Focal Species.

In planning the most appropriate spatial dimensions for any particular habitat corridor the ecological requirements of the species for which it is a planned linkage are of the utmost importance. On the whole, the regional and sub-regional corridors delineated in the KHC Project are intended to maintain connectivity for priority fauna species assemblages but in determining final dimensions, and planning for their longer term management, the ecological requirements of "focal species" (after Lambeck 1997, Noss et al.1997) will be emphasised. This is in line with Bennett (1999) who recommends that corridor linkages should encompass the requirements of the most "extinction-prone" species, and in so doing are likely be effective for the majority of more common species. Within the landscape context being addressed by the KHC Project focal species will generally be those most sensitive to the impacts of habitat fragmentation. By designing landscape corridor dimensions to address the requirements for these sensitive species a spatial benchmark will be set allowing subsequent management of the corridor to address the maintenance, enhancement, or restoration of the best possible quality habitats for the focal species and other priority species.

Information pertaining to the known, or estimated, life history characteristics of the focal species is used in finalising the spatial dimensions of derived corridors. Home range diameter is used to set minimum corridor widths in a manner simply reflecting the different roles of regional and sub-regional corridors (see Table X). Having identified a minimum benchmark corridor width for each focal species and refined the potential corridor boundaries in line with that benchmark and other mappable variables (see text), corridor management can ultimately be focused towards the provision of habitats of suitable quality for the focal species and the wider assemblage.

Corridor width

- *As primary landscape linkages regional corridors will ideally provide both residential and dispersal habitats. It is proposed that corridor widths of at least twice the width of average focal species home ranges will be required for that purpose.*
- *As alternative landscape linkages, serving more as dispersal routes than habitats in their own right, sub-regional corridors will be at least as wide as one home range diameter for focal species.*

Table X provides a summary of the focal species used to set benchmark corridor dimensions for each priority fauna assemblage in the KHC Project, their average known, or estimated, home range and the derived minimum benchmark regional corridor width (minimum benchmark sub-regional corridor width is half the regional value).

NB. Minimum benchmark corridor widths are not always attained in the final refined corridor polygons. This may be due to a variety of factors including amount, configuration and type of extant vegetation available, nature of the local topography, presence of other features such as towns, roads, etc.

NB2. Minimum benchmark corridor widths may be exceeded for relatively small home range focal species in order to maintain overall consistency for regional corridors (minimum of 500 metres) and sub-regional corridors (minimum of 300 metres).

NB3. More than one focal species is chosen for certain assemblages (see Table 1) because some focal species are restricted to a subset of a KHC Project study area, even though representative of the assemblage within the area occupied.

Table 1. Focal species for KHC Project fauna assemblages, corresponding known, or estimated, home ranges and minimum benchmark regional corridor width.

Focal species	**Assemblage***	**Average Home Range (ha)**	**Reference**	**Minimum benchmark regional corridor width (metres)**
Alpine Copperhead Snake	DET (U) TAB (L) SNET (T)	3	Estimate in Scotts 1996#	400
Stephen's Banded Snake	WET (U, L)	5	Estimate in Scotts 1996#	500
Marbled Frogmouth	WEF (U)	20	Corben and Roberts 1993	1000
Albert's Lyrebird	WEF (U)	20	A. Gilmore, pers. comm.	1000
Rufous Scrub-bird	NE (U) WET (L) DET (T)	15	Ferrier 1985	875
Brush-tailed Phascogale	DCF (U, L) DET (T) CC (S)	20	Soderquist 1995	1000
Yellow-bellied Glider	MEF (U, L) WET (T) DCR (S)	50	Goldingay and Kavanagh 1993, 1995	1600
Rufous Bettong	MEF (U) DCF (L) DET (T)	20	Schlager 1981	1000
Long-nosed Potoroo	WE (U) WET (L, T) WCR (S)	5	Schlager 1981	500
Parma Wallaby	WET (U, L, T) WCR (S)	22	Maynes 1979	1060
Brush-tailed Rock Wallaby	DET (U, T) DVA (L) DCR (S)	15	Short 1980	875
Golden-tipped Bat	NE (U) WE (L)	2	M. Schultz pers. comm.	320
Northern Long-eared Bat	CC (U)	5	Estimate in Scotts 1996#	500
New Holland Mouse	DV (L)	1	Estimate in Scotts 1996#	225
Eastern Chestnut Mouse	CC (L)	1	Fox (1995)	225

* For full assemblage names see appendices 3 ,4 ,5 ,6.

Estimates by Interim Forestry Assessment Northern Fauna Expert Panel

STEP 10. THE CONSOLIDATED KEY HABITATS AND CORRIDORS MAP LAYERS

Figure 11 provides an example of the consolidated key habitats and corridors map layers, including the final corridor polygons, for the Richmond RVPA and Tweed and Byron local government areas. For simplification purposes, and to accentuate private lands, the largest categories of public land, NPWS lands, State Forests and Crown Reserves have been masked.

The consolidated key habitats and corridors map layers are now available for regional conservation planning and assessment work. These layers are stored by the NPWS.

The layers can be used at many different levels of data summary and integration from the individual species models themselves through the different levels of key habitat and corridor layer formulation to the final fauna key habitats layers and the potential corridors grid layers for the KHC Project area. For part of the KHC area the final corridor polygon layers are also available for use. The refinement process is continuing.

A CD is available which includes the ………………A directory of the various layers used and developed by the KHC Project, along with a summary of the layers applicability and structure is provided as Appendix 6.

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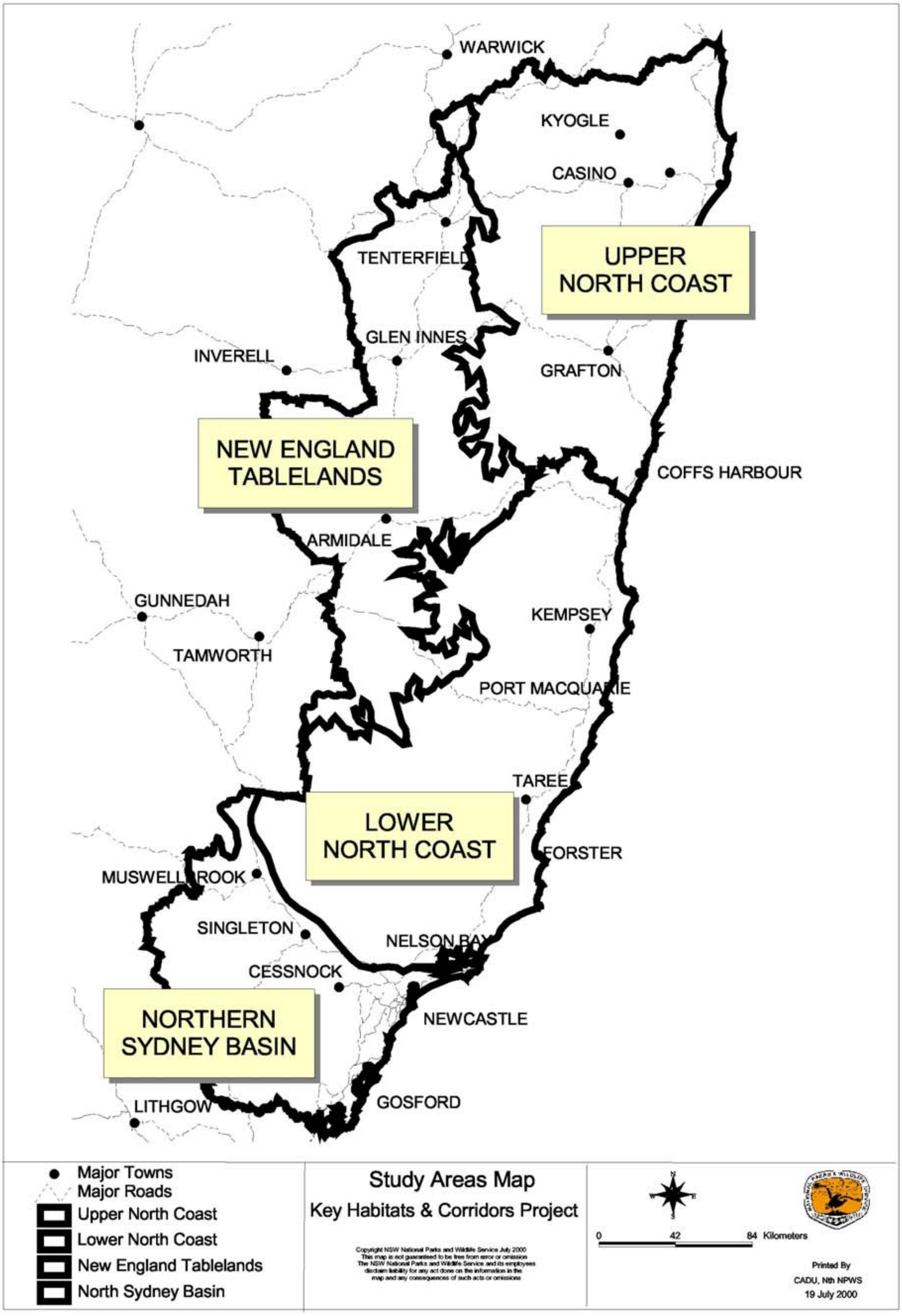

Figure 1. The four north-east New South Wales study areas; Key Habitats and Corridors Project, 2000.

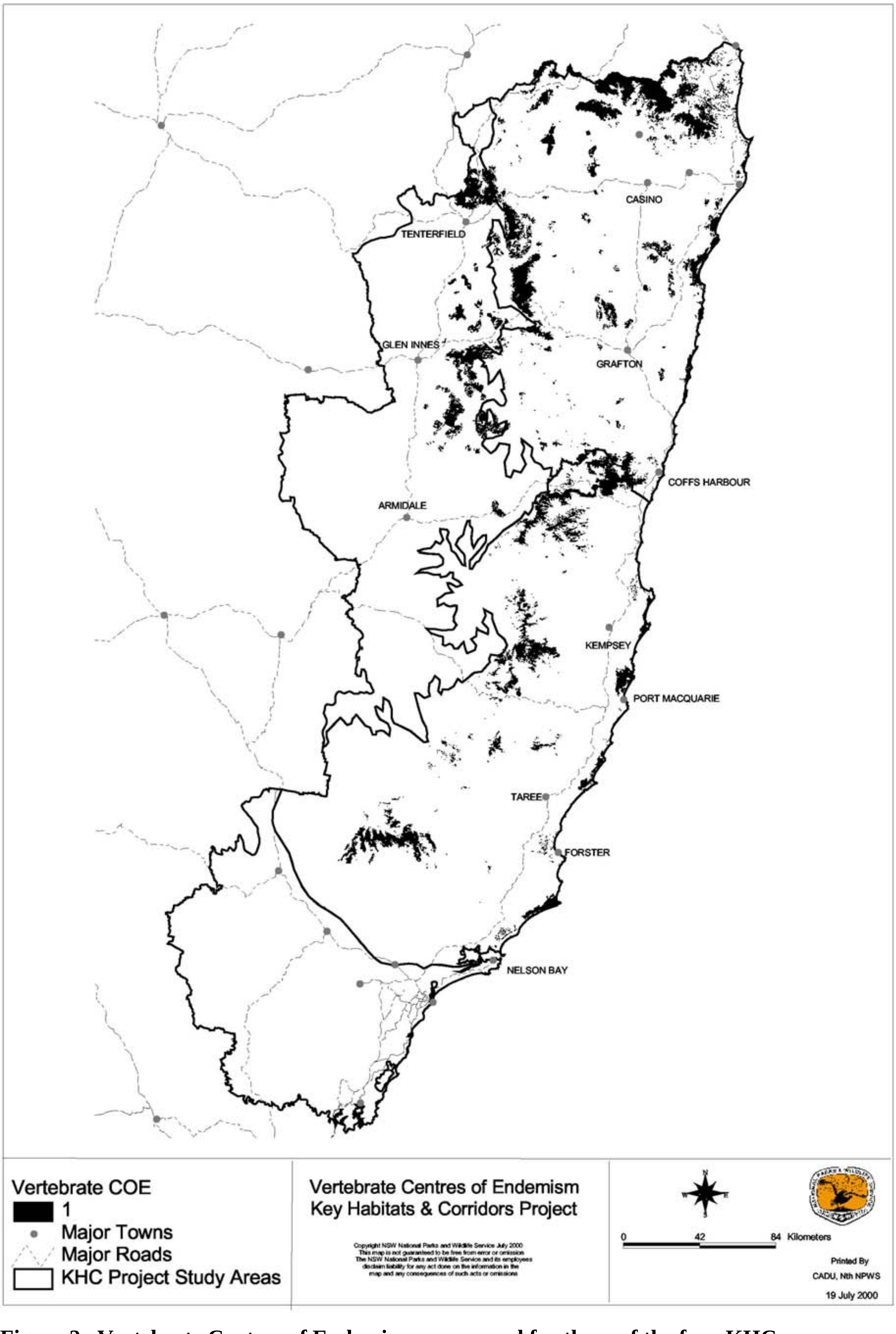

Figure 2. Vertebrate Centres of Endemism as mapped for three of the four KHC Project study areas (NPWS 1999b); Key Habitats and Corridors Project, 2000.

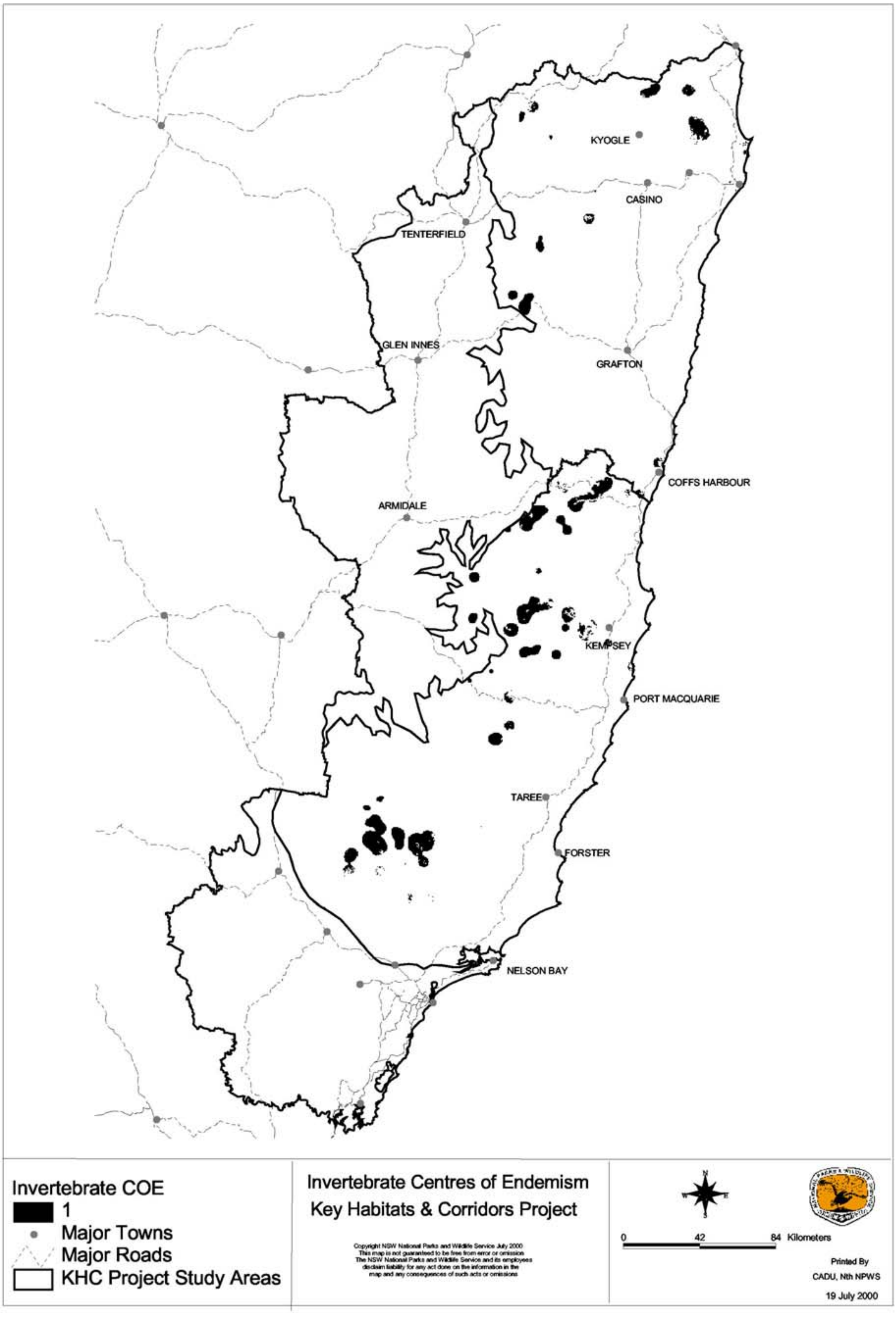

Figure 3. Invertebrate Centres of Endemism as mapped for two of the four KHC Project study areas (NPWS 1999b);
Key Habitats and Corridors Project, 2000.

Deriving fauna species assemblages:
PATNMAP: grouping ecological associates to derive species assemblages (and key habitats)

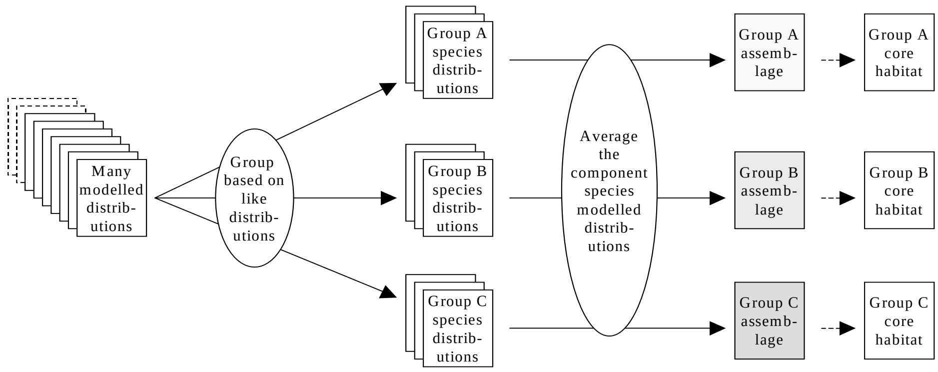

Figure 4. An illustration of the PATNMAP process used to derive priority fauna assemblages for north-east NSW;
Key Habitats and Corridors Project, 2000.

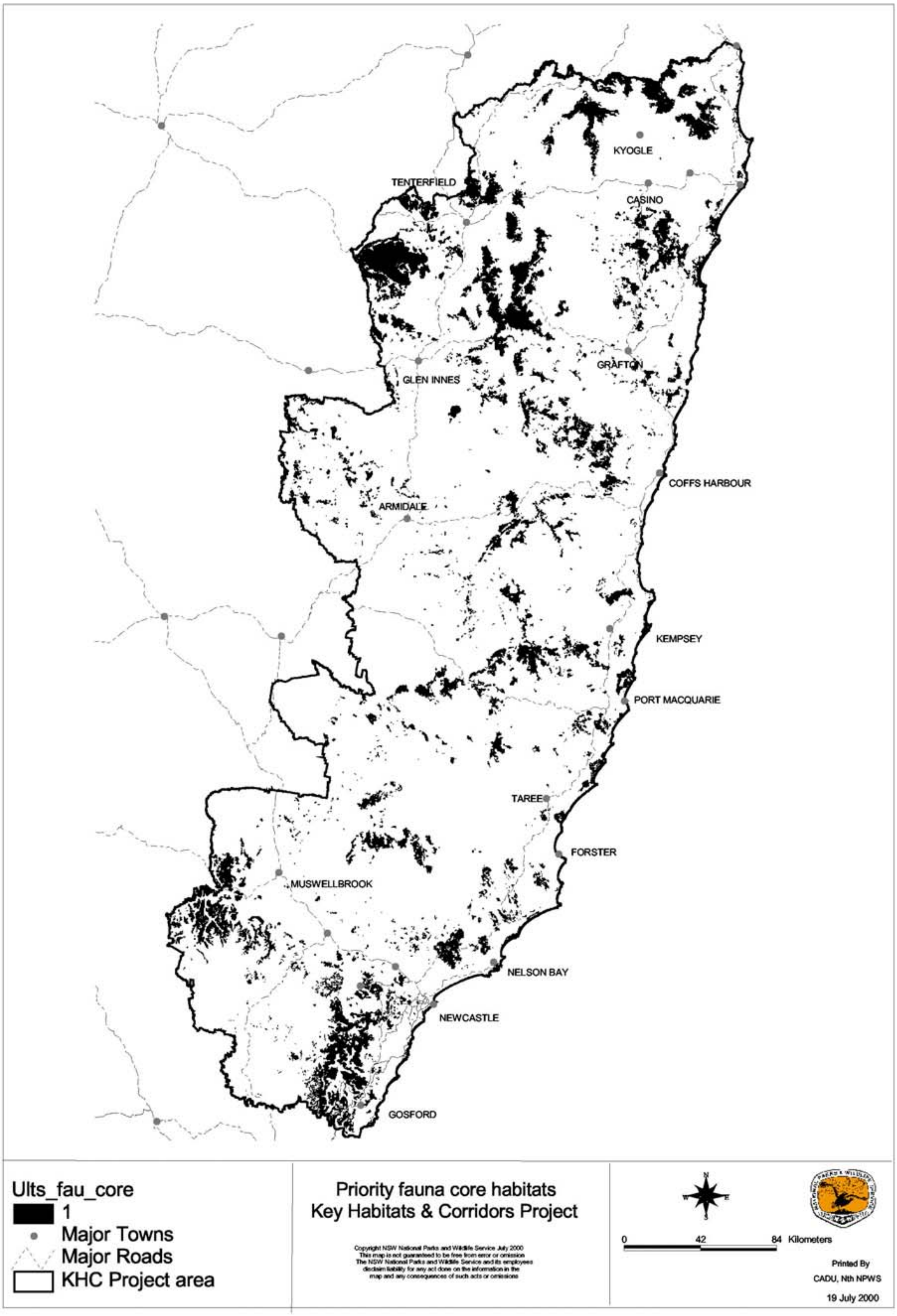

Figure 5. Priority fauna core habitats as mapped for the KHC Project study areas; Key Habitats and Corridors Project, 2000.

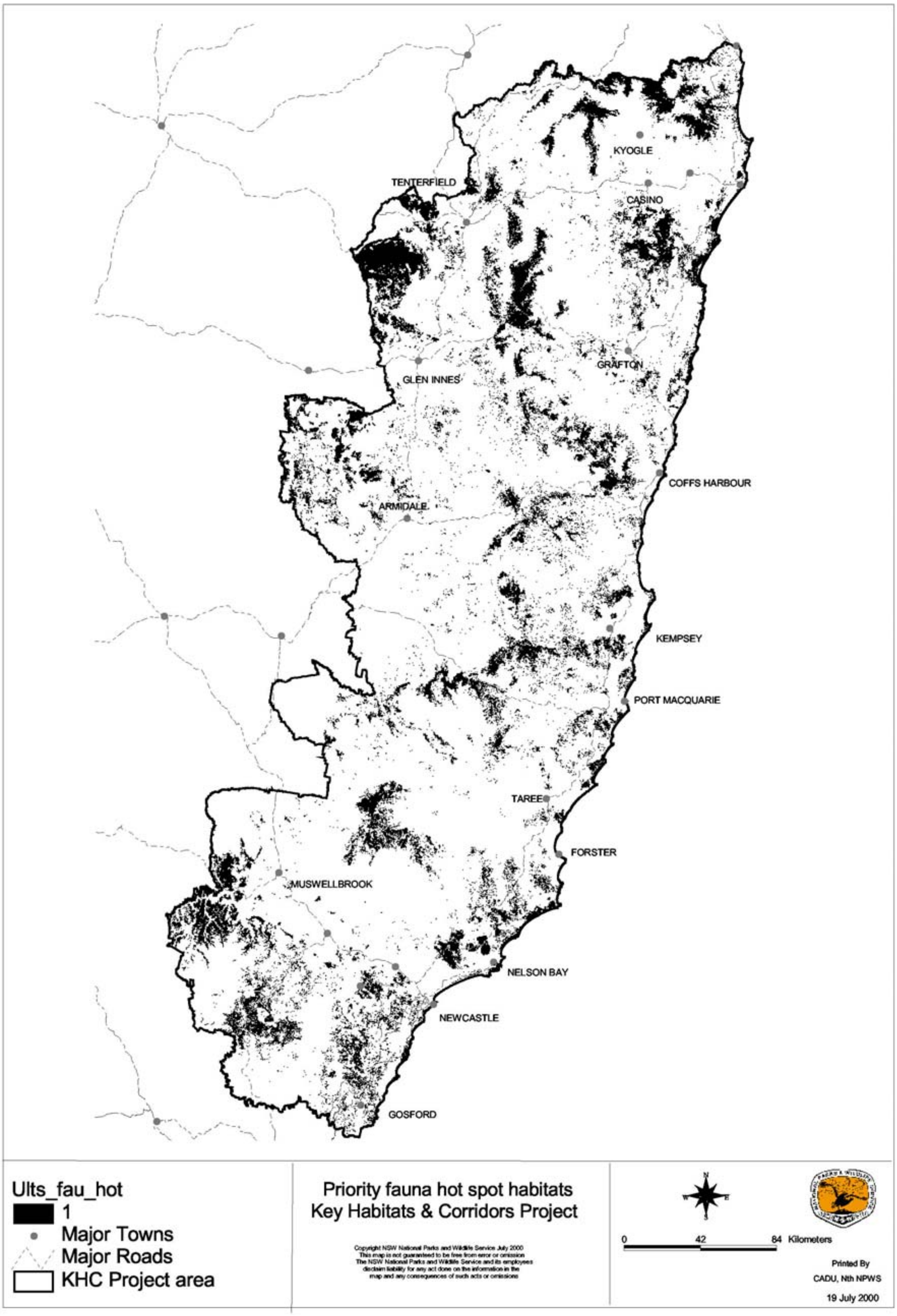

Figure 6. Priority fauna hot spot habitats as mapped for the KHC Project study areas; Key Habitats and Corridors Project, 2000.

Identifying potential corridor links
LEAST COST PATHWAYS- linking within and between species assemblages;

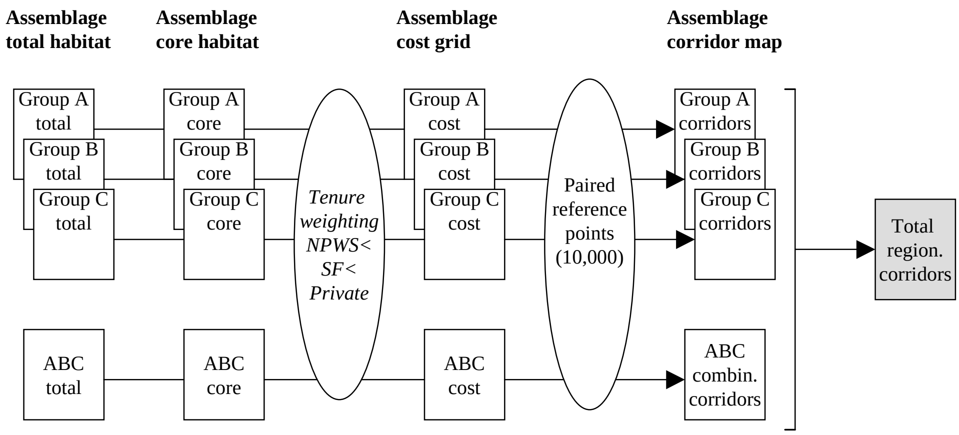

Figure 7. An illustration of the LEAST COST PATHWAYS process used to derive potential habitat corridors for north-east NSW;
Key Habitats and Corridors Project, 2000.

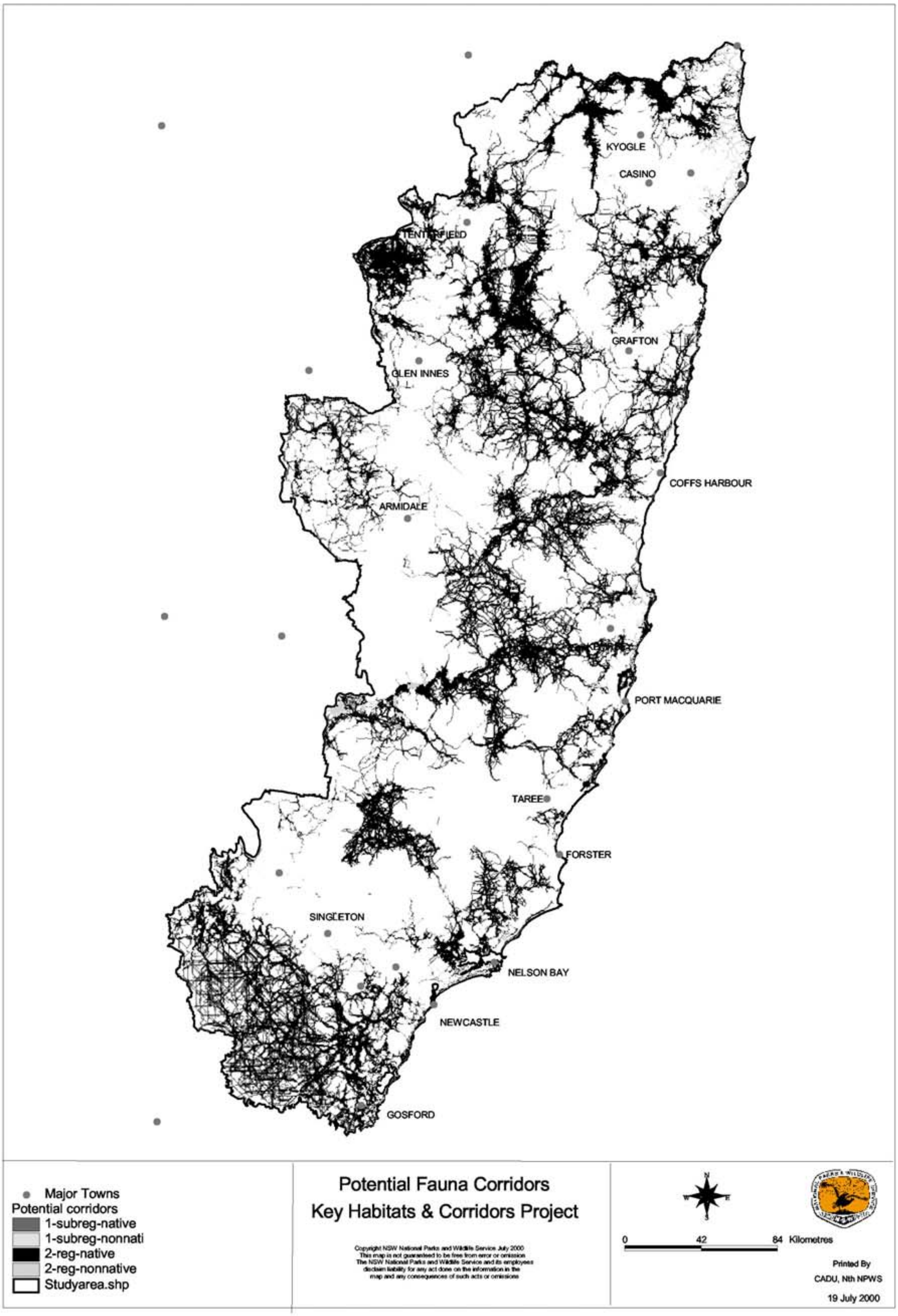

Figure 8. Potential regional and sub-regional corridors for fauna as mapped for the KHC Project study areas;
Key Habitats and Corridors Project, 2000.

Figure 9. Potential regional and sub-regional corridors for fauna as mapped for the Far North-east of NSW;
Key Habitats and Corridors Project, 2000.

Figure 10. Refined regional and sub-regional corridors for fauna as mapped for the Far North-east of NSW;
Key Habitats and Corridors Project, 2000.

Figure 11. The consolidated Fauna Key Habitats and Corridors map for the Far North-east of NSW;
Key Habitats and Corridors Project, 2000.

Appendix 1. Endemic forest vertebrate species of north-east NSW
*** indicates species with all-tenure predictive models assessed and approved by the expert fauna panels assembled for the predictive modelling projects undertaken for the Upper and Lower North East (UNE and LNE) Regional Forestry Assessments (NPWS 1999b).**

Taxonomy as per the time of derivation of Centres of Endemism data layers for the UNE & LNE Regional Forestry Assessment programs (1998).

DIURNAL BIRDS

*Yellow-throated Scrubwren

*Green Catbird

*Regent Bowerbird

*Albert's Lyrebird

*Superb Lyrebird (edwardsii)

*Logrunner

*Rufous Scrub-bird

*Russet-tailed Thrush

*Glossy Black-Cockatoo

*Forest Raven

*Northern Olive Whistler

*Pale-yellow Robin

*Paradise Riflebird

Double-eyed Fig-Parrot

*Eastern Bristlebird (northern sp.)

NOCTURNAL BIRDS

*Marbled Frogmouth

GROUND MAMMALS

*Parma Wallaby

*Brush-tailed Rock-wallaby

*Hastings River Mouse

Eastern Chestnut Mouse (southern ssp)

New Holland Mouse

MICROBATS

Mormopterus norfolkensis

Vespadelus pumilus

FROGS

**Assa darlingtoni*

Crinia tinnula

**Lechriodus fletcheri*

**Mixophyes balbus*

Mixophyes fleayi

**Mixophyes iteratus*

**Philoria loveridgei*

**Philora sp. 1*

**Philoria sp. 2 (pughi)*

**Philoria sp. 3 (richmondensis)*

**Philoria sphagniclous*

**Pseudophryne coriacea*

Litoria barringtonensis

Litoria booroolongensis

Litoria brevipalmata

Litoria castanea

**Litoria dentata*

Litoria freycineti

**Litoria olongburensis*

**Litoria pearsoniana*

**Litoria phyllochroa*

Litoria piperata

Liroia revelata

**Litoria subglandulosa*

**Litoria tyleri*

SNAKES

**Cacophis krefftii*

Hoplocephalus stephensii

Tropedechis carinatus

LIZARDS

Oedura leseurii

Saltuarius swaini

**Amphibolurus nobbi nobbi*

Anomalopus swansoni

**Calyptotis ruficauda*

**Cautula zia*

**Coeranoscincus reticulatus*

Ctenotus eurydice

Egernia major

**Egernia mcpheei*

**Eulamprus martini*

**Eulamprus murrayi*

**Hypsilurus spinipes*

**Lampropholis caligula*

Lampropholis elongata

**Ophioscincus truncatus*

**Saiphos equalis*

**Saproscincus challengeri*

Saproscincus galli

**Saproscincus rosei*

Saproscincus oriarus

TURTLES

Elseya georgesi

Elseya purvisi

Emydura sp (Bellinger River)

Emydura sp 1

<u>Appendix 2</u>. Priority forest inhabiting fauna species of north-east NSW
*** indicates species with all-tenure predictive models assessed and approved by the expert fauna panels assembled for the predictive modelling projects undertaken for the Upper and Lower North East (UNE and LNE) Regional Forestry Assessments (NPWS 1999b).**

Taxonomy as per the time of the UNE & LNE Regional Forestry Assessment programs (1998).

DIURNAL BIRDS
Black-breasted Button-quail
Rose-crowned Fruit-Dove*
Superb Fruit-Dove*
Wompoo Fruit-Dove*
Black-necked Stork*
Black Bittern*
Double-eyed Fig-Parrot
Superb Lyrebird (edwards*)
Albert's Lyrebird*
Rufous Scrub-bird*
Yellow-eyed Cuckoo-shrike*
Grey-crowned Babbler*
Eastern Bristlebird*
Brush Bronzewing*
Red Goshawk
Square-tailed Kite*
Pacific Baza
Osprey*
Musk Lorikeet*
Red-tailed Black-Cockatoo
Glossy Black-Cockatoo*
Gang-gang Cockatoo*
Turquoise Parrot*
Swift Parrot*
Painted Honeyeater*
Regent Honeyeater*
Mangrove Honeyeater*
Yellow-tufted Honeyeater*
Forest Kingfisher*
Little Bronze-Cuckoo*
White-eared Monarch*
Hooded Robin*
Pale-yellow Robin*
Olive Whistler
Little Shrike-thrush*
Chestnut-rumped Hylacola*
Paradise Riflebird*
Forest Raven*

NOCTURNAL BIRDS
Bush Stone-curlew*
Barking Owl
Powerful Owl*
Masked Owl*
Sooty Owl*
Marbled Frogmouth*

ARBOREAL MAMMALS
Greater Glider*
Yellow-bellied Glider*
Squirrel Glider*
Eastern Pygmy-possum*
Koala*

GROUND MAMMALS
Dingo
Tiger Quoll*
Brush-tailed Phascogale*
Dusky Antechinus*
Common Planigale*
Common Wombat*
Long-nosed Potoroo*
Rufous Bettong*
Brush-tailed Rock-wallaby*
Red-legged Pademelon*
Parma Wallaby*
Whiptail Wallaby*
Black-striped Wallaby
Pale Field-rat*
Broad-toothed Rat
New Holland Mouse*
Hastings River Mouse*
Eastern Chestnut Mouse*
Grassland Melomys*

MEGABATS
*Pteropus alecto**
*Pteropus poliocephalus**
*Nyctimene robinsoni**
*Syconycteris australis**

MICROBATS
*Rhinolophus megaphyllus**
*Nyctinomus australis**
*Nyctophilus bifax**
*Miniopterus schreibersii**
*Miniopterus australis**
*Chalinolobus dwyeri**
*Chalinolobus nigrogriseus**
*Myotis adversus**
*Scoteanax rueppellii**
*Scotorepens greyii**
*Kerivoula papuensis**
*Falsistrellus tasmaniensis**
*Vespadelus pumilus**
*Scotorepens sp 1**
*Vespadelus troughtoni**
*Mormopterus norfolkensis**
Mormopterus sp 1
*Scotorepens balstoni**

FROGS
*Assa darlingtoni**
*Crinia tinnula**
*Heleioporus australiacus**
Mixophyes fleayi
*Mixophyes balbus**
*Mixophyes iteratus**
*Philoria kundagungan**
*Philoria loveridgei**
*Philoria richmondensis**
*Philoria sphagnicolus**
*Philoria sthn sphagnicolus**
*Philoria sp 2 (pughi)**
*Pseudophryne bibronii**
*Litoria aurea**
Litoria booroolongensis
*Litoria brevipalmata**
Litoria freycineti
Litoria jervisiensis
*Litoria littlejohni**
*Litoria olongburensis**
*Litoria piperata**
Litoria revelata
*Litoria subglandulosa**

SNAKES
*Austrelaps ramsayi**
Acanthophis antarcticus
*Cacophis harriettae**
*Drysdalia coronoides**
*Hoplocephalus bungaroides**
*Hoplocephalus bitorquatus**
*Hoplocephalus stephensii**
*Tropidechis carinatus**

LIZARDS
*Underwoodisaurus sphyrurus**
*Saltuarius swaini**
*Saltuaris wyberba**
*Varanus rosenbergi**
*Hypsilurus spinipes**
*Tympanocryptis diemensis**
*Cautula zia**
*Coeranoscincus reticulatus**
*Ctenotus eurydice**
*Eulamprus kosciuskoi**
Eulamprus martini
*Eulamprus murrayi**
*Eulamprus tenuis**
Eulamprus tryoni
*Lampropholis caligula**
*Lampropholis elongata**
*Ophioscincus truncatus**
*Saproscincus challengeri**
*Saproscincus galli**
*Saproscincus oriarus "North coast"**
*Saproscincus rosei**

TURTLES
Emydura sp 1
Elseya georgesi
Elseya sp 2 (Gwydir & Namoi)
Elseya purvisi

<u>Appendix 3.</u> Eight fauna species assemblages for the Upper North Coast Study area: based on models covering all tenures for 104 priority species; Key habitats and Corridors project, 2000

Coastal complex assemblage (CC) 11 species

Crinia tinnula	Wallum Froglet
Litoria olongburensis	Wallum Tree Frog
Saproscincus oriarus	-
Dupetor flavicollis	Black Bittern
Pandion haliaetus	Osprey
Phaps elegans	Brush Bronzewing
Lichenostomus fasciogularis	Mangrove Honeyeater
Syconycteris australis	Eastern Blossom Bat
Pteropus alecto	Black Flying-fox
Nyctophilus bifax	Northern Long-eared Bat
Melomys burtoni	Grassland Melomys

Dry coastal foothills assemblage (DCF) 22 species

Litoria brevipalmata	Green-thighed Frog
Caccophis harriettae	White-crowned Snake
Hoplocephalus bitorquatus	Pale-headed Snake
Ephippiorynchus asiaticus	Black-necked Stork
Erythrotriorchis radiatus	Red Goshawk
Burrhinus grallarius	Bush Stone-curlew
Glossopsitta concinna	Musk Lorikeet
Neophema pulchella	Turquoise Parrot
Chrysococcyx malayanus	Little Bronze-cuckoo
Todiramphus macleayii	Forest Kingfisher
Melanodryas cuculatta	Hooded Robin
Pomatostomus temporalis	Grey-crowned Babbler
Lichenostomus melanops	Yellow-tufted Honeyeater
Phascogale tapoatafa	Brush-tailed Phascogale
Planigale maculata	Common Planigale
Petaurus norfolcensis	Squirrel Glider
Chalinolobus nigrogriseus	Hoary Bat
Scotorepens greyi	Little Broad-nosed Bat
Scotorepens sp.1	Broad-nosed Bat
Pseudomys gracilicaudatus	Eastern Chestnut Mouse
P. novaehollandiae	New Holland Mouse
Rattus tunneyi	Pale Field Rat

Wet escarpment – foothills assemblage (WEF) 19 species

Assa darlingtoni	Pouched Frog
Mixophyes fleayi	-
Saltuarius swaini	Leaf-tailed Gecko
Hypsilurus spinipes	Southern Angle-headed Dragon
Ophioscincus truncatus	-
Saproscincus challengeri	-
Hoplocephalus stephensii	Stephens Banded Snake
Ptilinopus regina	Rose-crowned Fruit-dove
P.superbus	Superb Fruit-dove
P.magnificus	Wompoo Fruit-dove
Podargus ocellatus	Marbled Frogmouth
Menura alberti	Albert's Lyrebird
Tregallasio capito	Pale-yellow Robin
Colluricincla megarhyncha	Little Shrike Thrush
Monarcha leucotis	White-eared Monarch
Coracina lineata	Barred Cuckoo-shrike
Antechinus swainsonii	Dusky Antechinus
Thylogale stigmatica	Red-legged Pademelon
Nyctimene robinsoni	Queensland Tube-nosed Bat

Moist escarpment – foothills assemblage (MEF) 13 species

Calyptorynchus lathami	Glossy Black-cockatoo
Ninox strenua	Powerful Owl
Tyto novaehollandiae	Masked Owl
Dasyurus maculatus	Spotted-tail Quoll
Phascolarctos cinereus	Koala
Petauroides volans	Greater Glider
Petaurus australis	Yellow-bellied Glider
Aepyprymnus rufescens	Rufous Bettong
Pteropus poliocephalus	Grey-headed Flying Fox
Nyctinomus australis	White-striped Mastiff Bat
Miniopterus australis	Little Bent-wing Bat
Miniopterus schreibersii	Common Bent-wing Bat
Vespadelus pumilus	Little Vespadelus

Wet eastern tablelands assemblage (WET) 5 species

Mixophyes balbus	Stuttering Frog
Saproscincus rosei	-
Macropus parma	Parma Wallaby
Falsistrellus tasmaniensis	Great Pipistrelle
Pseudomys oralis	Hastings River Mouse

Wet escarpment assemblage (WE) 11 species

Mixophyes iteratus	Giant Barred Frog
Eulamprus murrayi	Murray's Skink
E.tenuis	Barred-sided Skink
Tyto tenebricosa	Sooty Owl
Ptiloris paradiseus	Paradise Riflebird
Cercartetus nanus	Eastern Pygmy Possum
Potorous tridactylus	Long-nosed Potoroo
Rhinolophus megaphyllus	Eastern Horseshoe Bat
Mormopterus norfolkensis	Eastern Little-mastiff Bat
Chalinolobus dwyeri	Large Pied bat
Scoteanax ruepellii	Greater Broad-nosed Bat

Dry eastern tablelands assemblage (DET) 12 species

Litoria subglandulosa	New England Tree Frog
Austrelaps ramsayi	Alpine Copperhead
Saltuarius wyberba	Leaf-tailed Gecko
Eulamprus kosciuskoi	Alpine Water Skink
Drysdalia coronoides	White-lipped Snake
Grantiella picta	Painted Honeyeater
Hylacola pyrrhopygio	Chestnut-rumped Hylacola
Corvus tasmanicus	Forest Raven
Vombatus ursinus	Common Wombat
Macropus parryi	Whiptail Wallaby
Petrogale penicillata	Brush-tailed Rock-wallaby
Scotorepens balstoni	Western Broad-nosed Bat

Northern escarpment assemblage (NE) 11 species

Philoria kundagungan	Kundagungan Frog
P.loveridgei	Loveridge's Frog
P.pughi	-
P.richmondensis	-
P. sphagnicolus	Sphagnum Frog
Cautula zia	Beech Skink
Coeranoscincus reticulatus	-
Saproscincus galli	-
Atrichornis rufescens	Rufous Scrub-bird
Dasyornis brachypterus	Eastern Bristlebird
Kerivoula papuensis	Golden-tipped Bat

Appendix 4. Eight fauna species assemblages for the Lower North Coast Study area: based on models covering all tenures for 84 priority species; Key habitats and Corridors project, 2000

Coastal complex assemblage (CC) 7 species	
Crinia tinnula	Wallum Froglet
Saproscincus oriarus	-
Dupetor flavicollis	Black Bittern
Chrysococcyx minutellus	Little Bronze-cuckoo
Pandion haliaetus	Osprey
Pseudomys gracilicaudatus	Eastern Chestnut Mouse
Syconycteris australis	Eastern Blossom Bat

Dry coastal foothills assemblage (DCF) 8 species	
Pseudophryne bibroni	*Bibron's Toadlet*
Litoria brevipalmata	Green-thighed Frog
Phaps elegans	Brush Bronzewing
Phascogale tapoatafa	Brush-tailed Phascogale
Planigale maculata	Common Planigale
Petaurus norfolcensis	Squirrel Glider
Aepyprymnus rufescens	Rufous Bettong
Scotorepens sp.1	Broad-nosed Bat

Dry eastern assemblage tablelands (DET) 6 species	
Litoria subglandulosa	New England Tree Frog
Eulamprus kosciuskoi	Alpine Water Skink
Drysdalia coronoides	White-lipped Snake
Corvus tasmanicus	Forest Raven
Vombatus ursinus	Common Wombat
Falsistrellus tasmaniensis	Great Pipistrelle

Moist escarpment – foothills assemblage (MEF) 10 species	
Calyptorynchus lathami	Glossy Black-cockatoo
Ninox strenua	Powerful Owl
Tyto novaehollandiae	Masked Owl
Phascolarctos cinereus	Koala
Petaurus australis	Yellow-bellied Glider
Mormopterus norfolkensis	Eastern Little-mastiff Bat
Pteropus poliocephalus	Grey-headed Flying Fox
Miniopterus australis	Little Bent-wing Bat
Miniopterus schreibersii	Common Bent-wing Bat
Vespadelus pumilus	Little Vespadelus

Dry valleys assemblage (DV) 15 species	
Hoplocephalus bitorquatus	Pale-headed Snake
Ephippiorynchus asiaticus	Black-necked Stork
Burrhinus grallarius	Bush Stone-curlew
Callocephalon fimbriatum	Gang Gang Cockatoo
Glossopsitta concinna	Musk Lorikeet
Neophema pulchella	Turquoise Parrot
Todiramphus macleayii	Forest Kingfisher
Lichenostomus melanops	Yellow-tufted Honeyeater
Grantiella picta	Painted Honeyeater
Hylacola pyrrhopygio	Chestnut-rumped Hylacola
Melanodryas cuculatta	Hooded Robin
Pomatostomus temporalis	Grey-crowned Babbler
P. novaehollandiae	New Holland Mouse
Petrogale penicillata	Brush-tailed Rock-wallaby
Scotorepens balstoni	Western Broad-nosed Bat

Wet escarpment assemblage (WE) 13 species	
Assa darlingtoni	Pouched Frog
Mixophyes iteratus	Giant Barred Frog
Saltuarius swaini	Leaf-tailed Gecko
Cautula zia	Beech Skink
Ophioscincus truncatus	-
Saproscincus galli	-
Ptilinopus magnificus	Wompoo Fruit-dove
P. regina	Rose-crowned Fruit-dove
P. superbus	Superb Fruit-dove
Tregallasio capito	Pale-yellow Robin
Colluricincla megarhyncha	Little Shrike Thrush
Coracina lineata	Barred Cuckoo-shrike
Kerivoula papuensis	Golden-tipped Bat

Wet eastern tablelands assemblage (WET) 21 species	
Mixophyes balbus	Stuttering Frog
P. sphagnicolus	Sphagnum Frog
Hypsilurus spinipes	Southern Angle-headed Dragon
Eulamprus murrayi	Murray's Skink
Hoplocephalus stephensii	Stephens Banded Snake
Saproscincus rosei	-
Tyto tenebricosa	Sooty Owl
Atrichornis rufescens	Rufous Scrub-bird
Ptiloris paradiseus	Paradise Riflebird
Dasyurus maculatus	Spotted-tail Quoll
Antechinus swainsonii	Dusky Antechinus
Cercartetus nanus	Eastern Pygmy Possum
Potorous tridactylus	Long-nosed Potoroo
Thylogale stigmatica	Red-legged Pademelon
Macropus parma	Parma Wallaby
Petauroides volans	Greater Glider
Pseudomys oralis	Hastings River Mouse
Rhinolophus megaphyllus	Eastern Horseshoe Bat
Chalinolobus dwyeri	Large Pied bat
Nyctinomus australis	White-striped Mastiff Bat
Scoteanax ruepellii	Greater Broad-nosed Bat

Tablelands assemblage (TAB) 4 species	
Saltuarius wyberba	Leaf-tailed Gecko
Tympanocryptis diemensis	Mountain Dragon
Lampropholis caligula	-
Austrelaps ramsayi	Alpine Copperhead

<u>Appendix 5.</u> Six fauna species assemblages for the Tablelands (CRA component) Study area: based on models covering all tenures for 54 priority species; Key habitats and Corridors project, 2000

Dry eastern tablelands (granite-based) assemblage (DET) species	
Saltuarius wyberba	Leaf-tailed Gecko
Phaps elegans	Brush Bronzewing
Calyptorynchus lathami	Glossy Black-cockatoo
Ninox strenua	Powerful Owl
Tyto novaehollandiae	Masked Owl
Atrichornis rufescens	Rufous Scrub-bird
Phascogale tapoatafa	Brush-tailed Phascogale
Aepyprymnus rufescens	Rufous Bettong
Macropus parryi	Whiptail Wallaby
Petrogale penicillata	Brush-tailed Rock-wallaby
P. novaehollandiae	New Holland Mouse
Pseudomys gracilicaudatus	Eastern Chestnut Mouse
Nyctinomus australis	White-striped Mastiff Bat
Falsistrellus tasmaniensis	Great Pipistrelle
Dry granite tablelands assemblage (DGT) 7 species	
Underwoodisaurus sphyrurus	-
Ctenotus eurydice	-
Neophema pulchella	Turquoise Parrot
Menura novaehollandiae	Superb Lyrebird (edwards race)
Hylacola pyrrhopygio	Chestnut-rumped Hylacola
Scotorepens balstoni	Western Broad-nosed Bat
Scoteanax ruepellii	Greater Broad-nosed Bat
Dry western tablelands assemblage (DWT) 6 species	
Burrhinus grallarius	Bush Stone-curlew
Glossopsitta concinna	Musk Lorikeet
Melanodryas cuculatta	Hooded Robin
Pomatostomus temporalis	Grey-crowned Babbler
Lichenostomus melanops	Yellow-tufted Honeyeater
Grantiella picta	Painted Honeyeater
Southern New England Tablelands assemblage (SNEET) 5 species	
Pseudophryne bibroni	Bibron's Toadlet
Tympanocryptis diemensis	Mountain Dragon
Lampropholis caligula	-
Austrelaps ramsayi	Alpine Copperhead
Drysdalia coronoides	White-lipped Snake
Wet eastern tablelands assemblage (WET) 15 species	
Philoria pughi	-
Mixophyes balbus	Stuttering Frog
Litoria subglandulosa	New England Tree Frog
L. piperata	Peppered Tree Frog
Eulamprus kosciuskoi	Alpine Water Skink
Dasyurus maculatus	Spotted-tail Quoll
Phascolarctos cinereus	Koala
Vombatus ursinus	Common Wombat
Petaurus australis	Yellow-bellied Glider
Cercartetus nanus	Eastern Pygmy Possum
Potorous tridactylus	Long-nosed Potoroo
Macropus parma	Parma Wallaby
Rhinolophus megaphyllus	Eastern Horseshoe Bat
Chalinolobus dwyeri	Large Pied bat
Scotorepens greyi	Little Broad-nosed Bat
Wet escarpment – eastern tablelands assemblage (WEET) 7 species	
Philoria sphagnicolus	Sphagnum Frog
Tyto tenebricosa	Sooty Owl
Ptiloris paradiseus	Paradise Riflebird
Corvus tasmanicus	Forest Raven
Antechinus swainsonii	Dusky Antechinus
Mormopterus norfolkensis	Eastern Little-mastiff Bat
Pteropus poliocephalus	Grey-headed Flying Fox

Appendix 6. Five fauna species assemblages for the Sydney Basin (Lower North East CRA component) Study area: based on models covering all tenures for 51 priority species; Key habitats and Corridors project, 2000

Coastal complex assemblage (CC) 8 species	
Litoria aurea	Green and Golden Bell Frog
Saproscincus oriarus	-
Dupetor flavicollis	Black Bittern
Ephippiorynchus asiaticus	Black-necked Stork
Pandion haliaetus	Osprey
Phaps elegans	Brush Bronzewing
Phascogale tapoatafa	Brush-tailed Phascogale
Pseudomys gracilicaudatus	Eastern Chestnut Mouse
Dry coast and ranges assemblage (DCR) 14 species	
Helioporous australiacus	Giant Burrowing Frog
Varanus rosenbergi	Heath Monitor
Calyptorynchus lathami	Glossy Black-cockatoo
Ninox strenua	Powerful Owl
Hylacola pyrrhopygio	Chestnut-rumped Hylacola
Dasyurus maculatus	Spotted-tailed Quoll
Phascolarctos cinereus	Koala
Vombatus ursinus	Common Wombat
Cercartetus nanus	Eastern Pygmy Possum
Petaurus australis	Yellow-bellied Glider
Petrogale penicillata	Brush-tailed Rock-wallaby
Rhinolophus megaphyllus	Eastern Horseshoe Bat
Nyctinomus australis	White-striped Mastiff Bat
Chalinolobus dwyeri	Large Pied Bat
Dry west – central assemblage (DWC) 5 species	
Hoplocephalus bungaroides	Broad-headed Snake
Lichenostomus melanops	Yellow-tufted Honeyeater
Grantiella picta	Painted Honeyeater
Mormopterus norfolkensis	Eastern Little-mastiff Bat
Scotorepens balstoni	Western Broad-nosed Bat
Dry valleys assemblage (DV) 7 species	
Hoplocephalus bitorquatus	Pale-headed Snake
Pseudophryne bibroni	Bibron's Toadlet
Tyto novaehollandiae	Masked Owl
Neophema pulchella	Turquoise Parrot
Melanodryas cuculatta	Hooded Robin
Pomatostomus temporalis	Grey-crowned Babbler
Scoteanax ruepellii	Greater Broad-nosed Bat
Wet coastal ranges assemblage (WCR) 17 species	
Litoria brevipalmata	Green-thighed Frog
L. littlejohni	-
Mixophyes balbus	Stuttering Frog
M. iteratus	Giant Barred Frog
Hypsilurus spinipes	Southern Angle-headed Dragon
P. regina	Rose-crowned Fruit-dove
P. superbus	Superb Fruit-dove
Callocephalon fimbriatum	Gang Gang Cockatoo
Tyto tenebricosa	Sooty Owl
Antechinus swainsonii	Dusky Antechinus
Aepyprymnus rufescens	Rufous Bettong
Potorous tridactylus	Long-nosed Potoroo
Macropus parma	Parma Wallaby
Falsistrellus tasmaniensis	Great Pipistrelle
Kerivoula papuensis	Golden-tipped Bat
Vespadelus pumilus	Little Vespadelus
P. novaehollandiae	New Holland Mouse

<u>Appendix ?.</u> Example from the final corridors attribute table depicting fields relevant to corridor derivation process; Key Habitats and Corridors Project, 2000

Appendix 7. A directory of relevant data layers used, developed and stored by the KHC Project; Key Habitats and Corridors Project, 2000