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Bird survey and reports for selected Corangamite estuaries

B. Hansen

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Bird survey and reports for selected Corangamite estuaries

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Summary

During the winter months of 2010, whole estuary bird surveys were conducted of 11 important estuaries within the Corangamite Catchment Management Authority (CMA) region (see Figure 1). These were (east to west) Hovells Creek, Thompson Creek, Spring Creek, Anglesea River, Painkalac Creek, Erskine River, Kennett River, Barham River, Aire River, Gellibrand River and Curdies River. The purpose of these surveys was to obtain information on the distribution and abundance of birds, focussing on waterbirds and other estuarine specialists, in order to make an assessment of bird use in the context of estuary entrance openings. Species were classified according to their listing in the Estuary Entrance Management Support System (EEMSS). This was done to provide information necessary to parameterise the EEMSS tool, which will be undertaken after this project by the Corangamite CMA.

A total of 10,118 birds representing 124 species were recorded across all estuaries over the period of surveys. This represents 55**%** of all species reported from these estuaries during the most recent Atlas of Australian Birds period, 1998-2002. The largest number of birds counted was in Curdies estuary (3953 individuals of 69 species), followed by Aire estuary (2146 individuals of 61 species), Gellibrand estuary (1406 individuals of 48 species) and Hovells Creek (1159 individuals of 34 species).

The majority of species recorded represented “margin dwellers – vegetated” (EEMSS functional group 2b) and riparian passerines (EEMSS functional group 6). Fifty-five of a possible 99 species that are listed in EEMSS as estuarine specialists were recorded during surveys. The majority of the absences of Appendix G listed species were migratory species like shorebirds (waders), and seasonally-transient species like Hardhead (*Aythya australis*), Pink-eared duck (*Malacorhynchus membranaceus*), Whiskered Tern (*Chlidonias hybrida*) and Australian Reed-Warbler (*Acrocephalus australis*). No species listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999 were recorded during surveys.

Ten species listed under the Flora and Fauna Guarantee Act 1988 (see below) and three species of regional interest (Azure Kingfisher *Ceyx azureus*, Beautiful Firetail *Stagonopleura bella*, and Southern Emu-wren *Stipiturus malachurus*) were recorded during surveys:

- Australasian Bittern (*Botaurus poiciloptilus*)
- Brolga (*Grus rubicunda*)
- Caspian Tern (*Hydroprogne caspia*)
- Fairy Tern (*Sternula nereis*)
- Grey Goshawk (*Accipiter novaehollandiae*)
- Hooded Plover (*Thinornis rubricollis*)
- Lewin’s Rail (*Lewinia pectoralis*)
- Little Egret (*Egretta garzetta*)
- Rufous Bristlebird (*Dasyornis broadbenti*)
- White-bellied Sea Eagle (*Haliaeetus leucogaster*)

Mapping was done in ArcView GIS (version 3.2) to produce high resolution imagery illustrating the distribution of birds in each of eight EEMSS functional groups in each estuary (where sufficient survey information was obtained to make that assessment). These maps are presented

separately to the report due to their size, and are available on request from Corangamite CMA. They will be used to guide the EEMSS process.

Bird surveys were conducted during the period May-July. This coincides with a period of absence of a number of species, most notably, trans-equatorial migratory waders. Migratory waders are a specialist group of waterbirds that rely heavily on the intertidal areas of south-eastern Australia during their non-breeding season, which coincides with the late spring through to early autumn period. As late autumn is also the time of northward migration of a number of estuarine passerines and waterbirds, for example, Australian Reed-Warblers and Whiskered Tern, these species were also absent. The 2010 temperate Australian winter was also a time of abundant inland water, meaning that many transient waterfowl species (for example, Grey Teal *Anas gracilis*, Hardhead and Pink-eared Duck) were largely absent from coastal habitats. The absence of quantitative survey data for these migratory and transient estuarine species means that the impacts on these species of changes in estuary water levels (as well as indirect effects like changes in water quality and salinity) in these estuaries cannot be fully assessed.

The presence of a number of threatened species in addition to the considerable numbers of birds recorded supports previous assertions that estuaries are important habitat for birds. Birds were found to use the whole suite of available estuarine habitats, most notably open waterbodies. This broad pattern of usage did not appear to change markedly with changes in hydrological regime or salinity, suggesting that the presence of inlets, wetlands and lakes is critical to determining the distribution and abundance of estuarine avifauna.

Surveys in the late spring–early autumn period are critical to gain an understanding of how migratory species use estuaries, and how birds respond to changes in water level though dry months. Without this information the EEMSS cannot be fully paramaterised, which will hinder its use for assessing the impact of artificial entrance openings. Further survey work for late summer will be necessary to fill this knowledge gap.

1 Introduction

Estuaries contain a variety of habitats that are simultaneously influenced by exports from catchments (e.g. fresh water, nutrients and sediment, terrestrial carbon) and imports from the marine environment (e.g. saline water, marine carbon). Birds are an important and conspicuous part of estuarine biota and their presence or absence may indicate significant changes to nutrient and sediment dynamics and trophic interactions, especially those involving important estuarine resources such as marine invertebrates and fish (Trayler et al 1989, Yates et al 1993, Dann et al 2003, Desgranges and Jobin 2003, Heithaus 2005). Their use of a wide range of estuarine habitat exposes birds to the full inventory of stressors associated with human impacts, thus making them suitable as environmental indicators (Ludwig et al 2010).

The distribution and abundance of bird populations in estuaries is primarily influenced by bathymetry (Rosa et al 2003), presence of open water (Craig and Beal 1992), salinity regime and freshwater inflows (Ravenscroft and Beardall 2003), prey densities (Rosa et al 2003, West et al 2005), and estuarine riparian vegetation (Craig and Beal 1992). Estuarine birds are represented by a variety of different functional groups (usually relating to dominant foraging mode or habitat use). Not all groups of birds will respond in the same way to variations within the estuarine environment. For example, exposed mudflats are used by migratory shorebirds (waders) for foraging during their (austral summer) non-breeding season (Geering et al 2007). Channels and open water are used by fish-eating birds like cormorants for foraging at all times of the year (Heithaus 2005). Saltmarsh containing freshwater pools may be used by swans for breeding during the late winter / early spring months (Loyn 1978, Hansen, *pers. obs.*).

1.1 The Estuary Entrance Management Support System (EEMSS)

Victorian coastal systems are unusual in having numerous estuaries with entrances that regularly open and close, a characteristic which is rare elsewhere in the world (D. Rogers, *pers.comm.*). However, this natural phenomenon has been exacerbated as a result of anthropogenic changes to flow regimes in source catchments. The Estuarine Entrance Management Support System (EEMSS) has been developed to provide coastal managers with a more rigorous and consistent method for assessing the hazards of artificially opening estuary entrances. Reductions in flow regimes from a catchment may result in upstream progression of the salt-wedge into the estuary and a build-up of sand at the freshwater-saltwater interface (Roy et al. 2001, Arundel 2006, Barton et al 2008a). Where that sand build-up is significant, the waterway mouth may close causing retention of freshwater inflows, creating a wetland behind the blocked estuary mouth that inundates surrounding low-lying land. Such wetlands are characterised by stratification of water layers and depletion of dissolved oxygen in the bottom layers (Arundel 2006). Inundated adjacent land may provide important habitat to estuarine biota, but may also lie in private ownership and provide important economic benefits to the community (e.g. agriculture). The decision to open an estuary entrance ought to rely on an assessment of the threats to the biota of the estuary, in addition to socio-economic considerations.

An important component of the EEMSS is to assess current use of estuaries by birds and the extent to which important habitat for these species might be impacted by opening an estuary entrance. EEMSS is operated by categorising a sub-sample of bird species (that are thought to be estuarine specialists) according to a suite of “functional groups”. These functional groups are intended to represent the dominant habitat that estuarine bird species use and the thus allow an assessment of the likely impact of artificial entrance openings on these species. There are eight EEMSS functional groups of birds:

1. waterbirds – (a) diving birds, (b) dabbling birds, and (c) surface feeders

2. margin dwellers – (a) non-vegetated habitat, and (b) vegetated habitat
3. aerial feeders
4. raptors and other predators
5. sandy shorebirds

Ultimately, the decision to open a closed entrance will need to consider the ramifications for birds which breed in, visit or make use of estuaries for different parts of their life cycles.

1.2 The Corangamite coastal region

Coastal land under the jurisdiction of the Corangamite Catchment Management Authority (CCMA) contains 11 important estuaries (among others). These are (east to west) Hovells Creek, Thompson Creek, Spring Creek, Anglesea River, Painkalac Creek, Erskine River, Kennett River, Barham River, Aire River, Gellibrand River and Curdies River (Figure 1). The majority of these are located within coastal communities with high human population densities and in close proximity to important recreational and environmental assets like the Otway Ranges National Park. These estuaries are likely to contain a variety of species that are affected by entrance closure. The presence of a number of estuaries with closed entrances heightens the need to acquire information about their biota.

Figure 1. The location of the 11 Corangamite estuaries (highlighted in pale yellow) along the western-central Victorian coast. The green boundary indicates the geographic extent of Corangamite CMA.

1.3 Project objective

The aim of this project was to investigate the avifauna of Corangamite CMA estuaries in order to make an assessment of their bird distribution and abundance in the context of entrance closures and openings. This required a detailed field assessment of each Corangamite estuary supplemented, where possible, by data from the Atlas of Australian Birds (Birds Australia) and any other local records.

2 Methods

2.1 Field surveys

Whole estuary bird surveys were conducted at three West Otway sites (Aire, Gellibrand and Curdies), seven Surf Coast sites (Thompson, Spring, Anglesea, Painkalac, Erskine, Kennett and Barham) and a single Port Phillip site (Hovells) (see Figure 1). Estuary extent was defined on the basis of the most recent mapping done by Deakin University (Barton et al 2008b). Each estuary was divided into three sections, lower, middle and upper. Sections were defined on the basis of changes in one or more features of the estuary: geomorphology, channel form (which includes width), dominant vegetation community (defined using Ecological Vegetation Classes: see Table 1), and riparian vegetation cover. This was done for three purposes, (1) to reflect broad changes in estuarine habitats from the mouth to the upstream limit of the estuary that may influence bird distribution and abundance, (2) to simplify data recording, and (3) to maintain consistency with other bird estuarine projects operating elsewhere in the state.

In each section at each estuary, bird counts of the channel and riparian zone were conducted by two observers, either from a vessel or on foot, by traversing the estuary from the lower reaches to the upper reaches. Each section was divided into sequential 200 m transects (recorded using a hand held GPS unit) and birds were counted separately in each transect. All bird species were recorded – this includes waterbirds, riparian passerines, raptors, parrots and introduced species. The only species not recorded during surveys were seabirds (e.g. Australasian Gannet, shearwaters and albatross). When a bird was observed, the broad habitat type it was observed in was recorded (e.g. in the channel, in reed beds, on exposed mud: see Table 2). Thus, every section was divided into multiple transects of 200m, spanning the riparian zone, the channel and in some cases, adjacent paddocks and off-stream waterbodies, each transect having a separate count of birds categorised into their use of a variety of habitat types.

Where the estuary also contained separate waterbodies (lakes or distinct swamps), these were counted separately as single units. These surveys were conducted from a canoe and supplemented, where possible, with foot-based counts from the shore. In the case of off-stream swamps and lakes in Gellibrand and Curdies estuaries, counts were done either by traversing a section of the swamp on foot, or by disembarking from the vessel at the closest access point and conducting a count from the river bank. In the case of Curdies River, extensive (and sometimes continuous) off-stream swamps along most of the estuary length were not counted by foot due to time restrictions. In these cases, birds visible on/in open water or on the swamp edge were counted from the river bank.

Some “target” surveys were also undertaken. These involved traversing a section of habitat (usually swamp vegetation) on foot. These counts were pooled with transect counts for the appropriate section for the purpose of analysis and reporting.

Several notable species were separately recorded by marking their location with the GPS and recording the time and habitat. Species recorded in this manner were Australasian Bittern (*Botaurus poiciloptilus*), Lewins Rail (*Lewinia pectoralis*) and in some cases, Southern Emu-Wren (*Stipiturus malachurus*). (Nomenclature and taxonomy follows Christidis and Boles 2008).

Table 1. Ecological Vegetation Classes occurring streamside / lakeside for all CCMA estuaries.
These EVCs were sourced from the Biodiversity Interactive Mapping (BIM) website (http://www.dse.vic.gov.au/dse/index.htm) and do not correspond to revised EVC mapping that has recently been completed but not yet incorporated into BIM (S. Sinclair *pers.comm.*).

Number	Description
992	Water body - fresh
684	Permanent saline
1	Coastal dune scrub / grassland mosaic
161	Coastal headland scrub
53	Swamp scrub
10	Estuarine wetland
863	Floodplain reedbed
165	Damp heath scrub
45	Shrubby foothill forest
23	Herb-rich foothill forest
3	Damp sands herb-rich woodland
16	Lowland forest
18	Riparian forest
300	Reed swamp
9	Coastal saltmarsh
302	Coastal saltmarsh / mangrove shrubland mosaic
140	Mangrove Shrubland

Table 2. Definitions of habitat categories used in bird surveys.
(Table split over 2 pages)

Summarised categories	Description of "sub-categories"	Corresponding Ecological Vegetation Classes (refer to table 1)
channel /		992 684
open water	open water	
	channel	992
	channel & snags	992
	poles, fences, piers, bridges	992 684
exposed mud	bare mud	992 684 10
sandy banks	sand & beach & dunes	1 10
coastal scrub	coastal scrub	1 161 165
rocky banks	rocky banks	161
reeds	reeds (incl. patches)	53 10 863 300
	juncus /reeds (incl.transistion zones)	53 10 863 300
	teatree & reeds	53 10 863 300
tussocks +/- scattered		53 10 165 300
shrubs	juncus &/or sedge (incl. gahnia) &/or poa	
	grazed juncus &/or sedge (incl. gahnia) &/or poa	53 10 863 300
	grazed juncus weed scattered shrubs	53 10 3
off-stream swamps	grazed OS swamp (incl. on-stream & off-stream w or without juncus / sedge)	300
	off-stream swamp (incl. on-stream & off-stream w or without juncus / sedge)	53 10
scrub &		53 10 3
shrubs	teatree & juncus grazed	

Summarised categories	Description of "sub-categories"	Corresponding Ecological Vegetation Classes (refer to table 1)
	teatree scrub &/or other shrubs	53 23 3 18
	riparian scrub & shrubs (incl. willows)	45 16 18
riparian forest	riparian forest /woodland	45 18
grazing / paddocks	paddocks with trees & shrubs (incl. scattered trees)	45 23 3 18
	paddocks (banks usually bare)	53 10 863 300
	paddocks with riparian sedge &/or juncus	53 10 300
mangrove	cover dominated by mangrove	9 140
saltmarsh	cover dominated by saltmarsh communities	9 302

2.2 Data analysis

Data from all transects were pooled to produce a section total for every species in every habitat type. Section totals (all bird species recorded) were used to calculate a total abundance for that section and the total number of species (species diversity). Counts of the number of species in each transect were averaged across all survey transects to provide a measure of the mean number of species per transect for each estuary. Lakes, swamps, backwaters and other waterbodies that were counted independently of the main stem were not included in estimates of species richness as their counts could not be divided into transects of repeatable length. As counts were pooled across whole sections in each estuary, where a section contained counts of these waterbodies, it was excluded from a computation of mean number of species per transect for that estuary. Totals (abundance and species diversity) from each section (including waterbodies) were combined to give whole estuary totals.

In addition to the computation of standard metrics (abundance and diversity), species were categorised according to their EEMSS functional bird groups and totals for each functional group calculated by pooling all species that constitute that group. Totals of each functional group for each habitat type in every section of the estuary were used to guide mapping of bird distribution (see below).

In addition to the mapping, the total abundance of birds in each EEMSS functional group in every estuary was plotted against the dominant habitat type each bird was recorded in. The dominant habitat types are those that would be expected to correspond to a given EEMSS group, that is:

- channel and open water (intended to represent habitats used by diving, dabbling and surface feeding waterbirds),
- non-vegetated margins (mud, sand and rocky banks), and
- vegetated margins (all other riparian habitats referred to in Table 2).

This was done to provide an indication of the actual habitats that birds were using to contrast against their EEMSS classification and assumed preferred habitats according to that classification.

2.3 EEMSS functional group distribution mapping

The distribution of birds in each EEMSS functional group was mapped for each estuary using the following as a guide:

- high resolution aerial photography
- presence of a representative EEMSS species in each 200m transect

- broad habitat type each bird was recorded in
- spatial distribution of relevant vegetation communities

Only species that represent each EEMSS functional groups were mapped. Riparian passerines, parrots and cockatoos, invasive species, and non-estuarine generalist taxa were not included in the mapping.

Polygon shapefiles were created to represent the spatial distribution of each EEMSS functional group in Arcview GIS 3.2 (Environmental Systems Research Institute, California). Where there was only a single record (either a single bird or one species recorded at a single location) in a functional group, that group was not mapped. This is because it was not deemed spatially representative of potential habitat use by a given group, given the available habitat, for that part of the estuary. For example, a single record of two Pacific Black Duck in Spring Creek is not representative of the potential habitat requirements of dabbling waterbirds (functional group 1b) in that estuary. Therefore, for some estuaries, maps of some functional groups are not provided.

In some cases (e.g. the middle section of Curdies estuary), the precise delineation of the area of “use” by a given functional group was hindered by spatially insufficient data. In these cases, those boundaries were estimated on the basis of the dominant habitat types that birds were recorded in elsewhere in the estuary. In the case of Spring Creek, a number of species were recorded using the golf course, but the precise area over which they were distributed was difficult to visually estimate. In this case, polygons were created to represent the approximate area that could be viewed from the east bank.

Threatened species were marked on maps as a single point (illustrated using a star). Species that are marked in this manner are EPBC and FFG-listed species, that is:

- Australasian Bittern (*Botaurus poiciloptilus*)
- Brolga (*Grus rubicunda*)
- Caspian Tern (*Hydroprogne caspia*)
- Fairy Tern (*Sternula nereis*)
- Grey Goshawk (*Accipiter novaehollandiae*)
- Hooded Plover (*Thinornis rubricollis*)
- Lewin’s Rail (*Lewinia pectoralis*)
- Little Egret (*Egretta garzetta*)
- Rufous Bristlebird (*Dasyornis broadbenti*)
- White-bellied Sea-Eagle (*Haliaeetus leucogaster*)

Maps were produced to represent two different levels of spatial information: (1) the distribution of each functional group in each estuary using different colour-shaded polygons accompanied by basic topographic information (up to eight figures per estuary) and (2) estuary extent, total area surveyed, updated EVCs (where available; S. Sinclair *unpub data*) and point records of threatened species overlaid on aerial photography.

3 Results

3.1 Field survey details

Surveys were conducted between 25 and 30 May 2010 (West Otway estuaries: Aire, Gellibrand and Curdies) and between 18 and 22 July 2010 (Surf Coast & Port Phillip estuaries: Spring, Hovells, Thompson, Anglesea, Painkalac, Erskine, Kennett and Barham).

Each West Otway estuary was surveyed over a two day period beginning at dawn and finishing at dusk. Water was slightly brackish in the lower sections of Aire and Gellibrand estuaries but fresh further upstream. Curdies Inlet was salty and the river was brackish all the way to the upper mapped limit of the estuary. Aire and Gellibrand estuary entrances were both open (Aire having been artificially opened by Parks Victoria just prior to commencement of surveys) but water exchange across each was minimal, and salt water was observed extending only a few hundred metres into each estuary. Curdies estuary entrance was closed. There was no tidal influence in any estuary and water levels did not fluctuate during the day. As no strictly intertidal-foraging species (i.e. migratory waders) were present during the study, there was no need to survey during specific periods of the tidal cycle. The only exception to this was Australia Pied Oystercatcher (*Haematopus longirostris*), which was recorded once at Hovells estuary on the incoming tide. Surveys of each estuary commenced in the lower estuary and proceeded upstream until complete. Lakes, swamps and other target surveys were surveyed last (usually on the second day).

Thompson estuary was surveyed over a whole day. Spring, Hovells, Anglesea and Painkalac estuaries were surveyed over a half day each and Erskine, Kennett and Barham estuaries were collectively surveyed in one day. Hovells, Anglesea and Painkalac estuaries were surveyed from a vessel, and the other five were surveyed from foot. The estuary entrance was open at Spring, Thompson and Hovells Creeks. Anglesea, Erskine, Kennett and Barham were all “perched” estuaries, meaning that there was freshwater outflow at the mouth but no marine-freshwater exchange except at high tide. Painkalac estuary entrance was closed. Thompson and Hovells were the only estuaries with a strong tidal influence. Thompson was surveyed on an outgoing tide, beginning just after high tide. Hovells was surveyed on an incoming tide, beginning mid-tide and finishing on high tide.

3.2 Field survey results

A total of 10,118 birds representing 124 species were recorded across all estuaries over the two week period of surveys. This represents 55.1**%** of all species reported from these estuaries during the most recent Atlas of Australian Birds period, 1998-2002 (source: Birds Australia).

A total of 7505 birds were counted across the three West Otway estuaries, representing 85 species. The largest number of birds counted was in Curdies estuary (3953), followed by Aire estuary (2146) and then Gellibrand (1406) (see Table 3). Curdies estuary also had the highest number of species (n=69, *c.f.* n=61 at Aire and n=48 at Gellibrand), which is a reflection of its greater length compared to the other two estuaries. The mean number of species per transect was higher at Curdies (6.3) than both Aire and Gellibrand (5.4 and 5.2, respectively). The highest mean number of species per transect occurred at Kennett (8.0) and Spring (7.7) estuaries, and the lowest at Hovells (3.5).

A total of 2802 birds were counted across the seven Surf Coast and one Port Phillip estuary, representing 102 species. The largest number of birds was recorded in Hovells Creek (1159), representing 34 species. This contrasts with a relatively small total estuary length of 3.6 km (Barton et al 2008). This count is somewhat remarkable as the weather conditions on the day of the survey were very poor and fringe-dwelling non-waterbirds were rarely observed. This is despite the high likelihood of them being present but undetected, on the basis of available habitat and records in similar suitable habitat made in other estuaries. The next highest total count was 457 birds at Thompson Creek, representing 49 species (Table 3).

Table 3. Summary statistics for whole estuary bird surveys of 11 Corangamite estuaries

Estuary	Total abundance	No. species	Mean no. spp. per transect	Length (km) *	No. transects lower [3]	No. transects middle [3]	No. transects upper [3]
Hovells [1]	1159	34	3.5	3.6	(inlet)	6	7
Thompson	457	49	6.3	6.0	10	7	5
Anglesea	220	39	6.2	3.5	4	4	5 (plus BW)
Painkalac	285	32	5.4	3.6	5	6	5
Barham	242	37	5.4	3.1	4	11	3
Aire [2]	2146	61	5.4	8.8	8	22 (plus lakes)	13
Gellibrand	1406	48	5.2	7.8	6	20	20
Curdies [1]	3953	69	6.3	16.8	(inlet)	42	21
Spring	256	43	7.7	4.1	5	6	NA
Erskine	90	17	6.5	1.0	4	NA	NA
Kennett	93	16	8.0	1.2	3	NA	NA

* source: Barton et al (2008)

[1] only transects from middle and upper sections included in calculations of mean number of species per transect

[2] only transects from lower and upper sections included in calculations of mean number of species per transect

[3] waterbodies for which 200m transects were not feasible were in-channel lakes, inlets and the Anglesea backwater (BW), which was comprised of a network of small channels

NA = section not distinct from previous (Spring: lower and middle/upper sections only; Erskine and Kennett: no distinction between lower, middle and upper)

3.3 Estuarine habitats used by birds

Birds were recorded in a large number of different habitat categories (see Table 2 for details of categories). These categories span multiple Ecological Vegetation Classes (EVCs) for the region (Table 1). Many EVCs were found to be inaccurate or incorrectly mapped at the scale of the estuary (S. Sinclair *pers. comm.*, B.H. *pers. obs.*). Furthermore, they are largely meaningless for use as avian habitat categories as they do not represent discrete structural elements for birds (e.g. channel form, vegetation form). Therefore, they were not used for classification of dominant avian habitats. Instead, they were incorporated into 15 broad habitat types that encompass dominant vegetative and estuarine physical forms (Table 2). An additional category was added to account for birds recorded in flight but not in association with any particular habitat type ("flying over": used only for the three West Otway estuaries but discarded for the other eight estuaries).

Across all estuaries, birds were most consistently recorded on or in open water (channels, lakes, inlets and swamps) (Table 4). In Aire estuary, large numbers of birds were recorded using open water (due to the presence of three large waterbodies) and in Curdies estuary equally large numbers were recorded on off-stream swamps. In addition, Curdies estuary had relatively large numbers of birds recorded "flying over" and in association with grazed areas (paddocks). Curdies estuary is the longest of the three and has off-stream waterbodies along its entire length, adding to its complexity in terms of available habitat types. Birds were constantly observed flying up- and down-stream, presumably between different habitat types used at different stages of their feeding/roosting cycle. In addition, the length and area of Curdies estuary means that there are more paddocks adjacent to the waterway. These provide additional feeding and roosting habitat for species that prefer open areas where their field-of-view is not obscured (i.e. by tall vegetation and embankments).

Table 4. Total abundance and species diversity of birds recorded in each habitat type across all 11 Corangamite estuaries

Habitat category	Total bird abundance	Number of species	Number of estuaries habitat present in
Coastal scrub	184	8	8
Channels and open water	2615	11	All
Snags, poles, piers, etc.	1115	10	10
Exposed mud	414	6	6
Sand and sandy shores	306	9	8
Rocky banks	31	5	2
Reeds and reed complexes	821	9	9
Tussock grassland	805	9	All
Off-stream swamps	1579	8	6
Scrub & shrubs	389	10	10
Riparian trees and woodlands	369	10	10
Paddocks (grazed areas)	1362	9	All
Mangroves	30	2	1
Saltmarsh	212	4	3

Across all Surf Coast and Port Phillip estuaries, birds were most consistently recorded in association with grazed areas (paddocks) and grassy parks or reserves. The exceptions were Hovells (open water), Thompon (saltmarsh), Anglesea (riparian shrubs and trees) and Spring (scrub and shrubs). In each case, these differences appear to reflect the dominant habitat occurring at these sites. In all of these estuaries, birds were observed flying upstream or downstream, usually over the channel but sometimes over riparian zones.

3.4 EEMSS bird functional groups

Bird species were placed into EEMSS functional groups according to Appendix G in the Estuary Entrance Management Support System Background Report and User Manual (Arundel 2006). There were numerous species recorded during surveys that were not listed in the EEMSS, presumably because they are not considered “estuarine specialists”. These were either placed in one of the existing functional groups on the basis of dominant estuarine habitat use, or in a new group distinct from the EEMSS categories. Three new groups were defined to account for other species recorded and were called “riparian passerines”, “invasive species” and “other” (the last containing generalist species like Australian Magpie and cockatoos, and non-riparian passerines). Species recorded are listed at the end of this document with their corresponding functional group as used in the analysis here (Appendix 1). Raw data supplied from the project will list species newly assigned to an EEMSS category distinctly, so that they are not erroneously incorporated into the software data analysis.

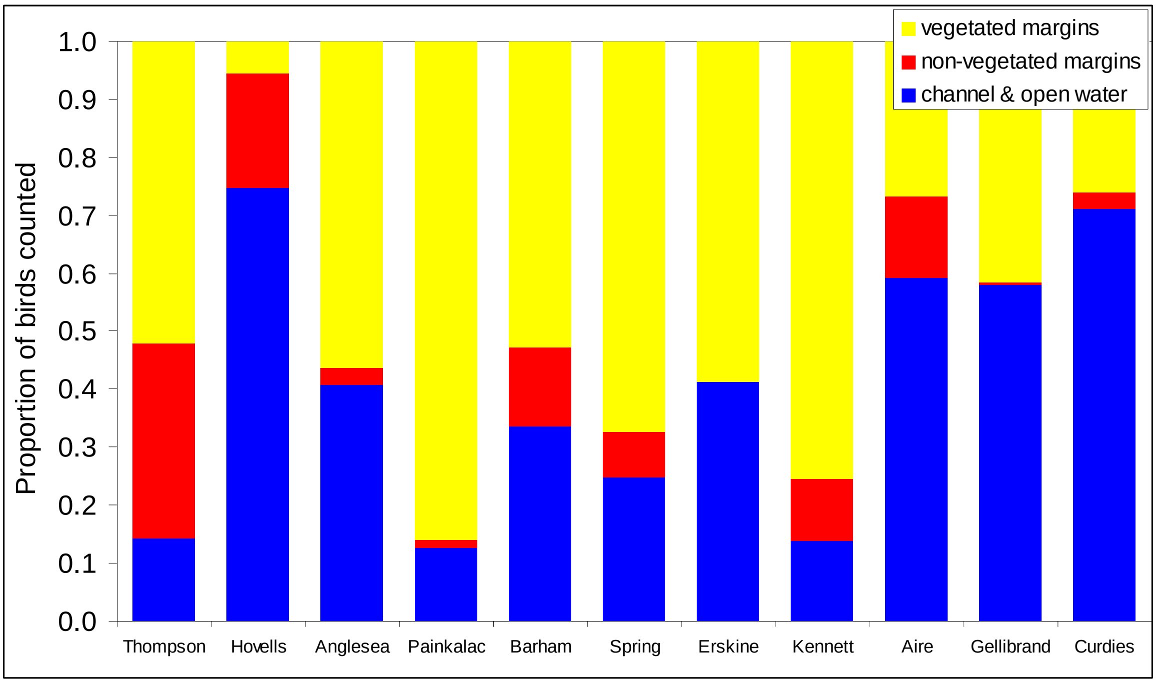
The majority of species recorded represented “margin dwellers – vegetated” (group 2b) and riparian passerines (group 6) (see Table 5). The absence of migratory species would account for the lower-than-expected numbers of species recorded belonging to group 2a “margin dwellers – non-vegetated”. Fifty-five species were recorded that are listed in Appendix G of the EEMSS document (which has 99 species listed). The majority of the absences of Appendix G-listed species were migratory species like waders, and seasonally-transient species like Hardhead, Pink-eared duck, Whiskered Tern and Australian Reed-Warbler. No EPBC-listed species were recorded during surveys.

Table 5. Total abundance and species diversity of birds recorded in each functional group (EEMSS functional groups plus others created in this study)

Functional group	Hovells	Thompson	Anglesea	Painkalac	Barham	Aire	Gellibrand	Curdies	Spring	Erskine	Kennett
Total abundance											
1a diving	80	16	7	4	23	153	20	407	21	1	2
1b dabbling	33	11	17	28	8	795	404	837	4	8	4
1c surface feeders	0	0	0	0	0	5	0	0	0	0	0
2a non-veg margin	371	19	8	14	9	164	38	844	10	1	1
2b veg margin dwellers	24	130	61	77	103	539	578	562	66	41	47
3 aerial feeders	8	10	9	12	20	8	144	395	0	5	11
4 raptors	32	7	15	0	4	10	18	55	9	0	0
5 sandy shorebirds	576	122	18	0	2	77	0	180	2	2	0
6 riparian passerine	17	75	69	59	18	76	82	45	64	25	2
7 invasive	8	44	6	80	48	97	47	605	11	0	17
8 other	10	23	10	11	7	33	75	23	69	7	9
Total number of species											
1a diving	4	3	2	1	2	7	4	9	2	1	1
1b dabbling	4	2	3	3	1	3	4	4	1	1	1
1c surface feeders	0	0	0	0	0	1	0	0	0	0	0
2a non-veg margin	5	5	2	4	3	7	3	10	4	1	1
2b veg margin dwellers	5	12	9	5	11	18	17	19	7	3	5
3 aerial feeders	1	1	1	1	1	1	1	1	0	1	2
4 raptors	4	3	3	0	2	4	6	7	1	0	0
5 sandy shorebirds	4	5	1	0	1	2	0	1	1	1	0
6 riparian passerine	3	11	12	15	7	11	8	8	17	8	2
7 invasive	2	4	4	1	6	4	3	5	3	0	2
8 other	2	3	2	2	3	3	2	5	7	1	2
Total number of transects											
	13 (plus inlet)	22	13 (plus backwater)	16	18	43 (plus lakes)	46	63 (plus inlet)	10	4	3

Each of the fourteen habitat categories listed in Table 4 could be summarised into three broad habitat types, corresponding to the EEMSS functional groups that would be most affected by changes in water levels, salinity and flow regimes. These were channels and open water, non-vegetated margins and vegetated margins. Figure 2 shows data for bird counts summarised by each of these broad groupings for each estuary. Estuaries varied substantially in terms of the relative representation of each habitat type, for example, Hovells and Curdies estuaries had greater than 60% of birds in channels and open water, whereas at Painkalac and Kennett estuaries more than 75% of birds were recorded in vegetated margins.

Figure 2. Relative representation of birds in each of three broad habitat types (channels and open water, non-vegetated margins and vegetation margins) summarised for each estuary.



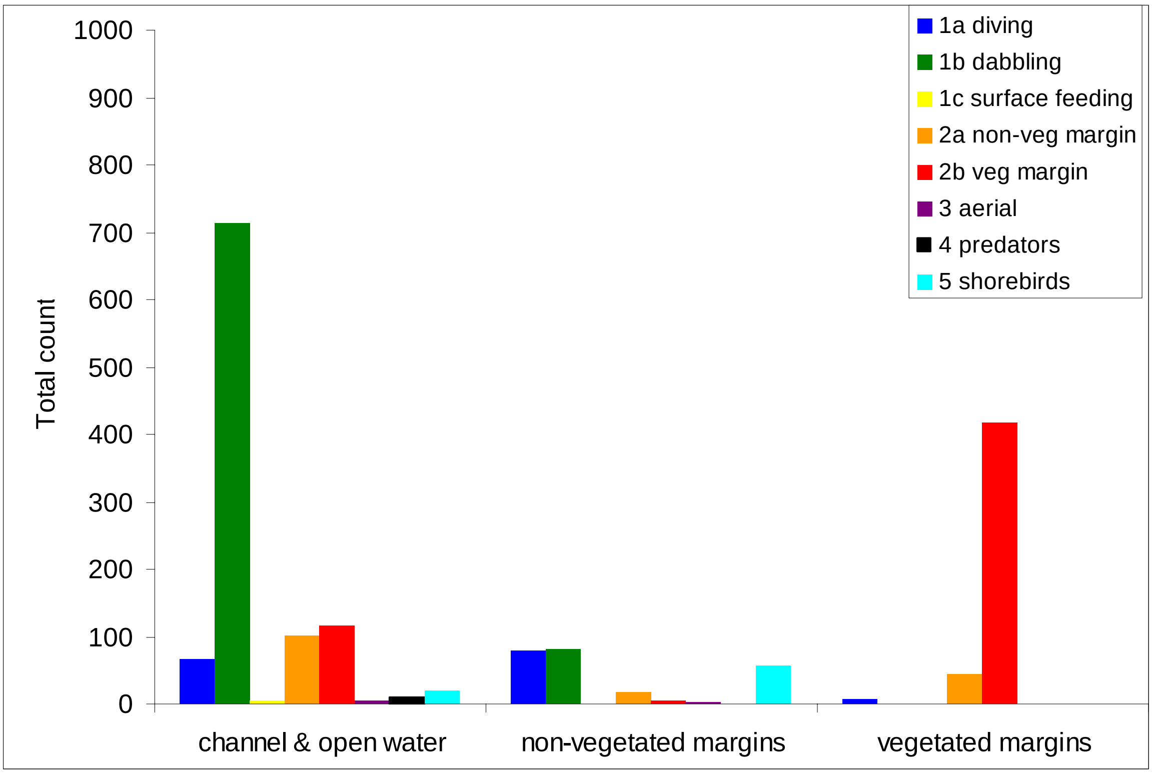
Across all estuaries there was a pattern of birds being recorded in a wider range of habitats than would be expected on the basis of their EEMSS functional groupings. The most notable of these were:

- **Hovells**: functional group 2a (margin dwellers, non-vegetated habitat) was most often recorded on or in open water
- **Painkalac**: functional group 1b (dabbling waterbirds) was recorded in both open water habitats and vegetated margins
- **Barham**: functional group 2b (margin dwellers, vegetated habitat) was most often recorded on or in open water, and group 1a more so in non-vegetated margin habitat than open water
- **Erskine**: functional group 2b was most often recorded on or in open water
- **Gellibrand**: functional group 2b was most often recorded on or in open water
- **Curdies**: functional group 2a was most often recorded on or in open water, and functional group 2b was most often recorded in vegetated margins

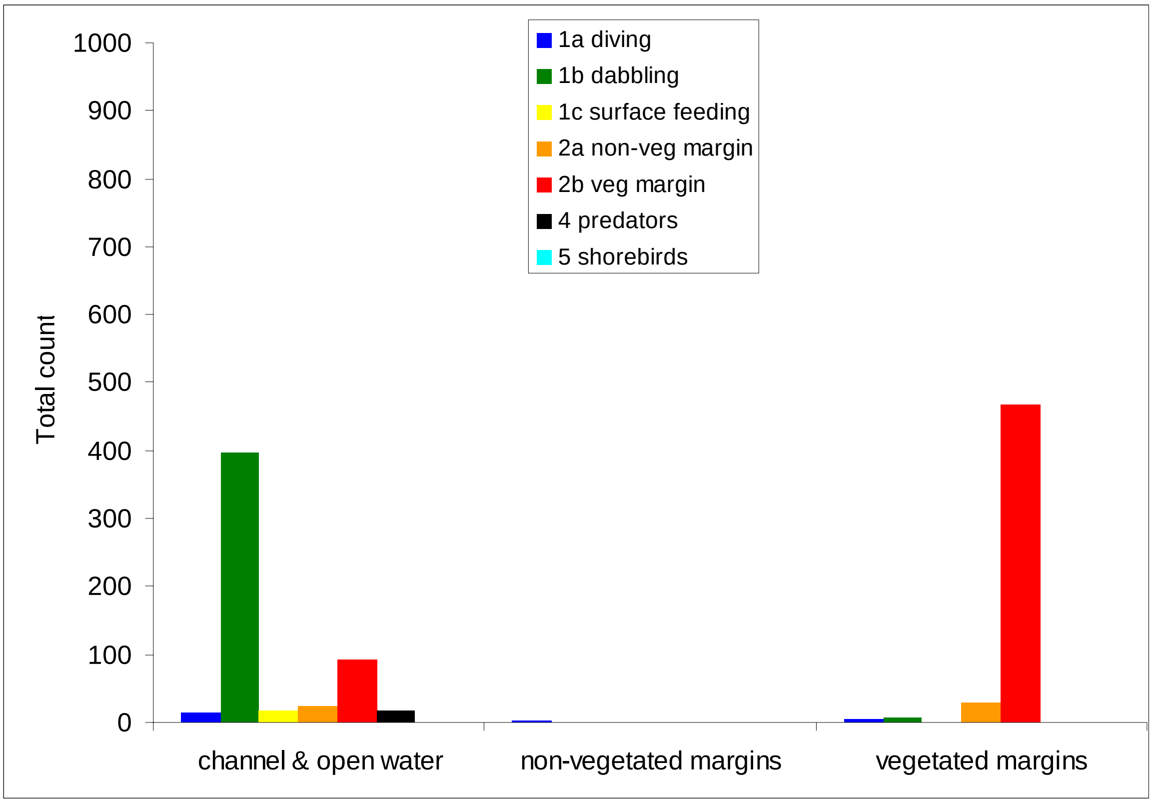
Figure 3 shows the total counts of birds in each functional group, in each of the three key representative EEMSS habitats (channels and open water, non-vegetated margins and vegetated margins).

Figure 3. Total count of birds for each EEMSS functional group in three key habitats.

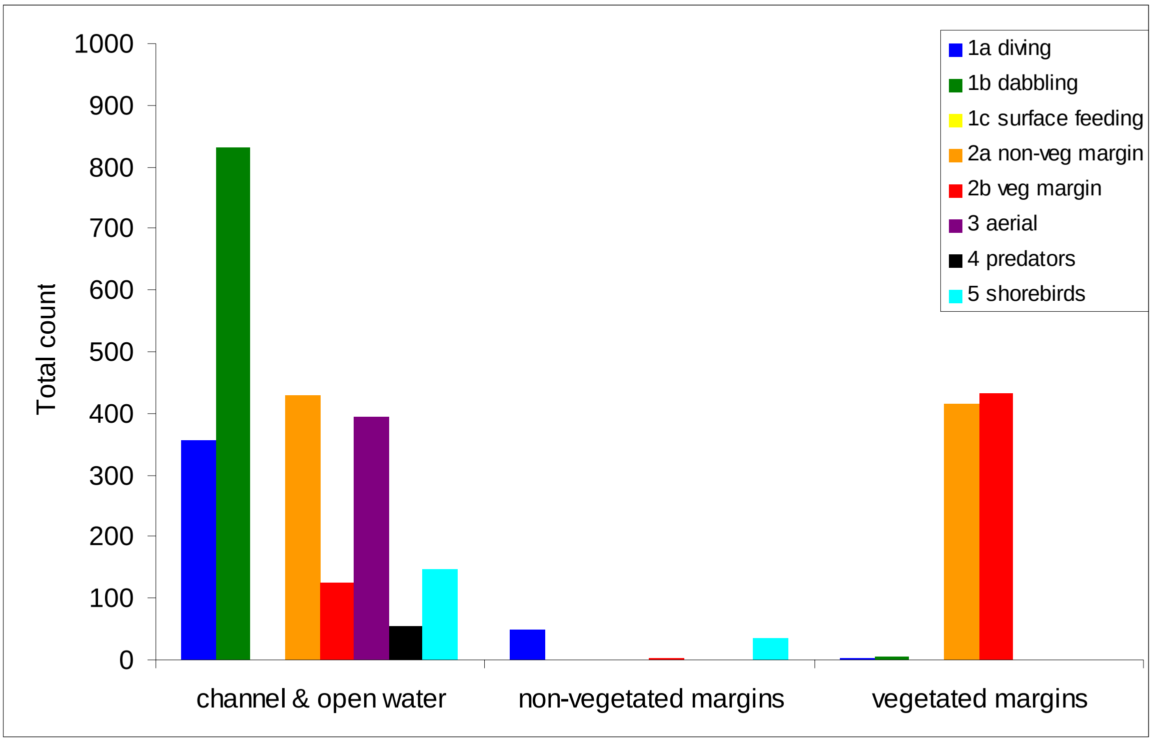
a) Aire



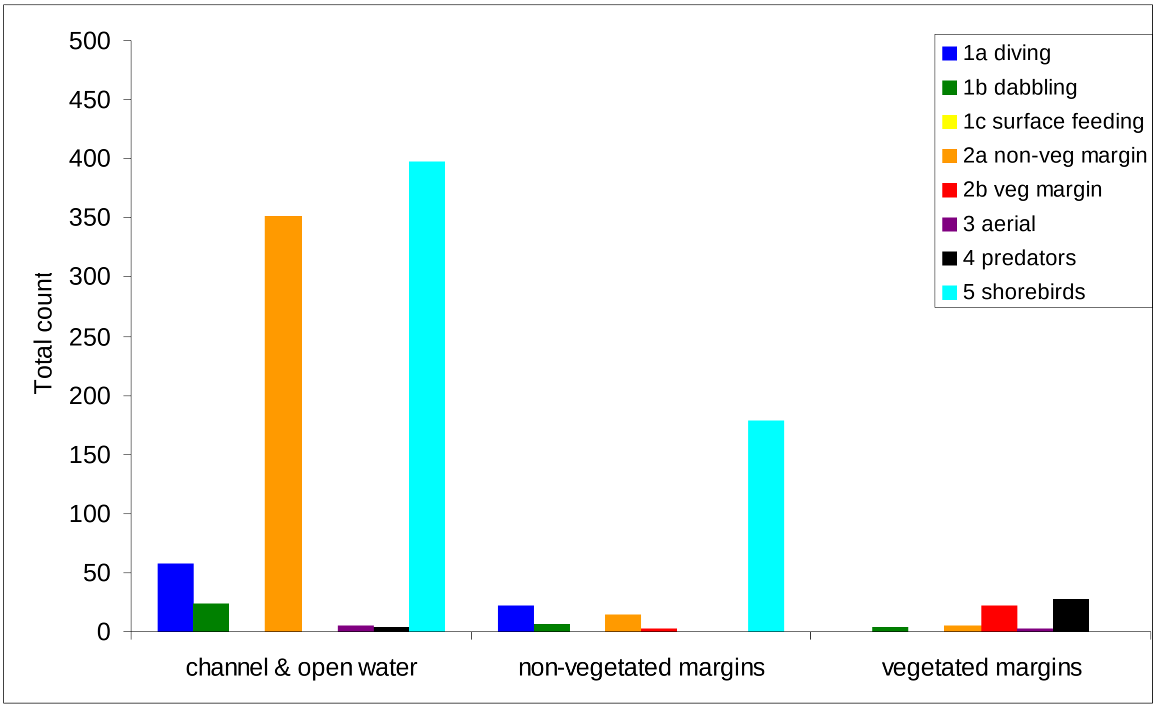
b) Gellibrand



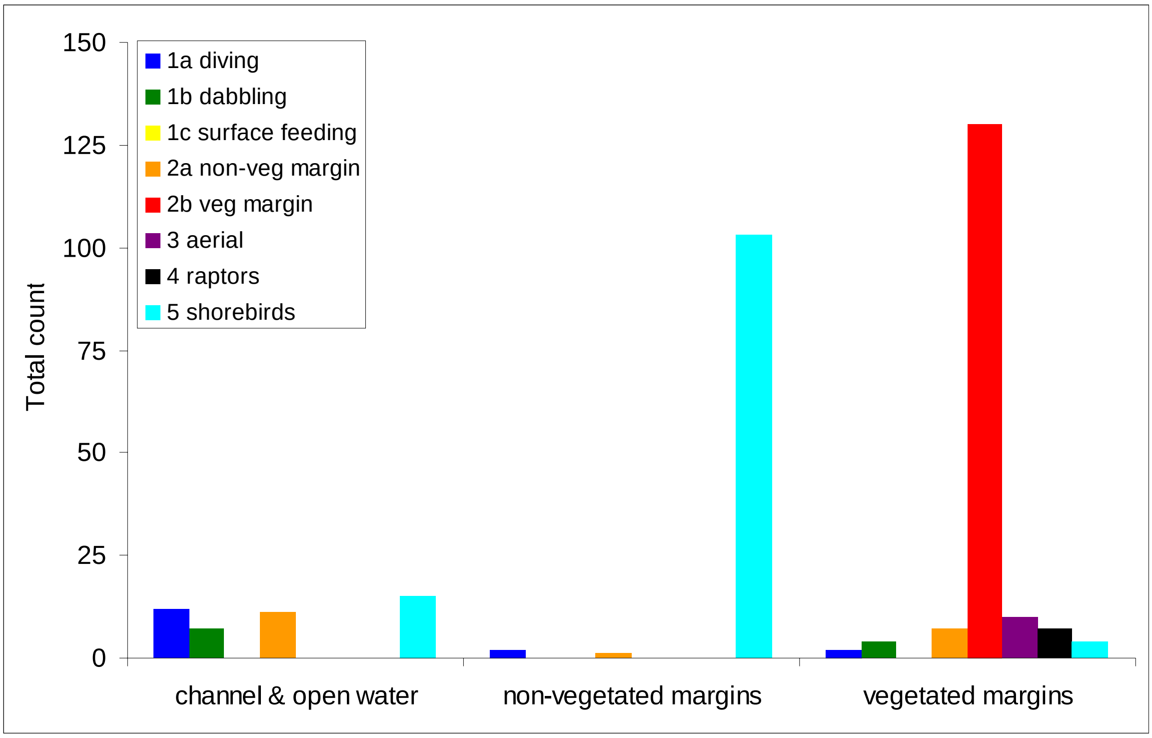
c) Curdies



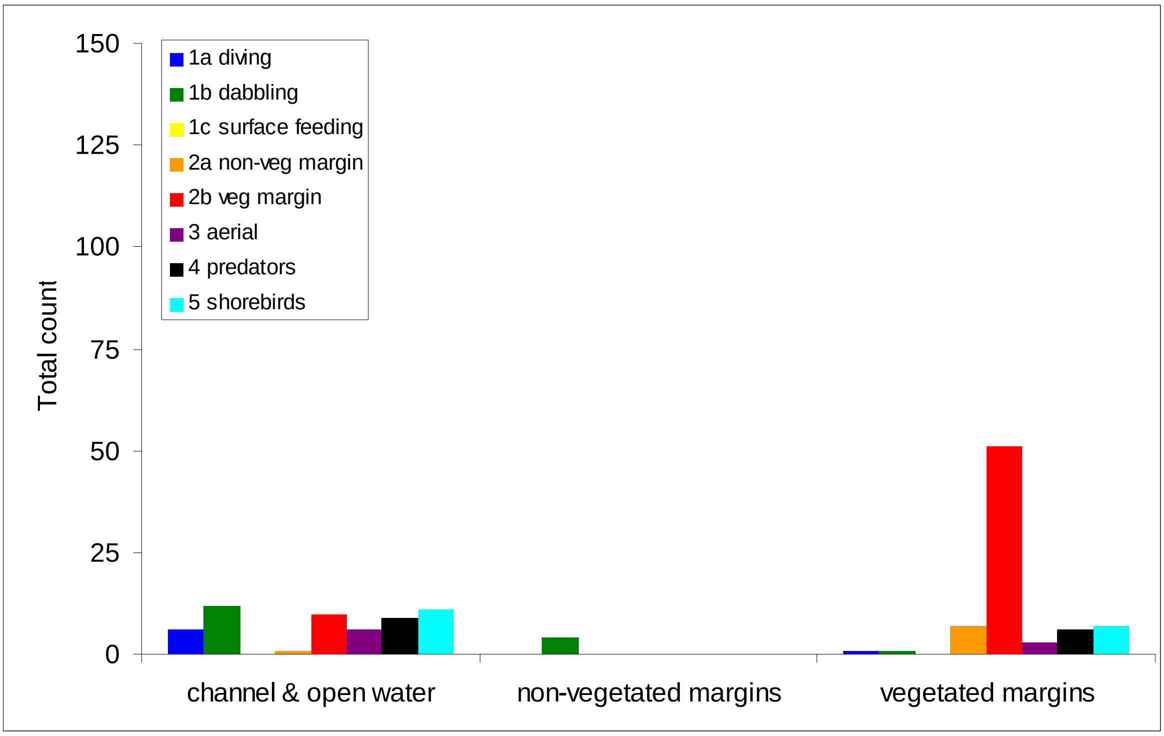
d) Hovells



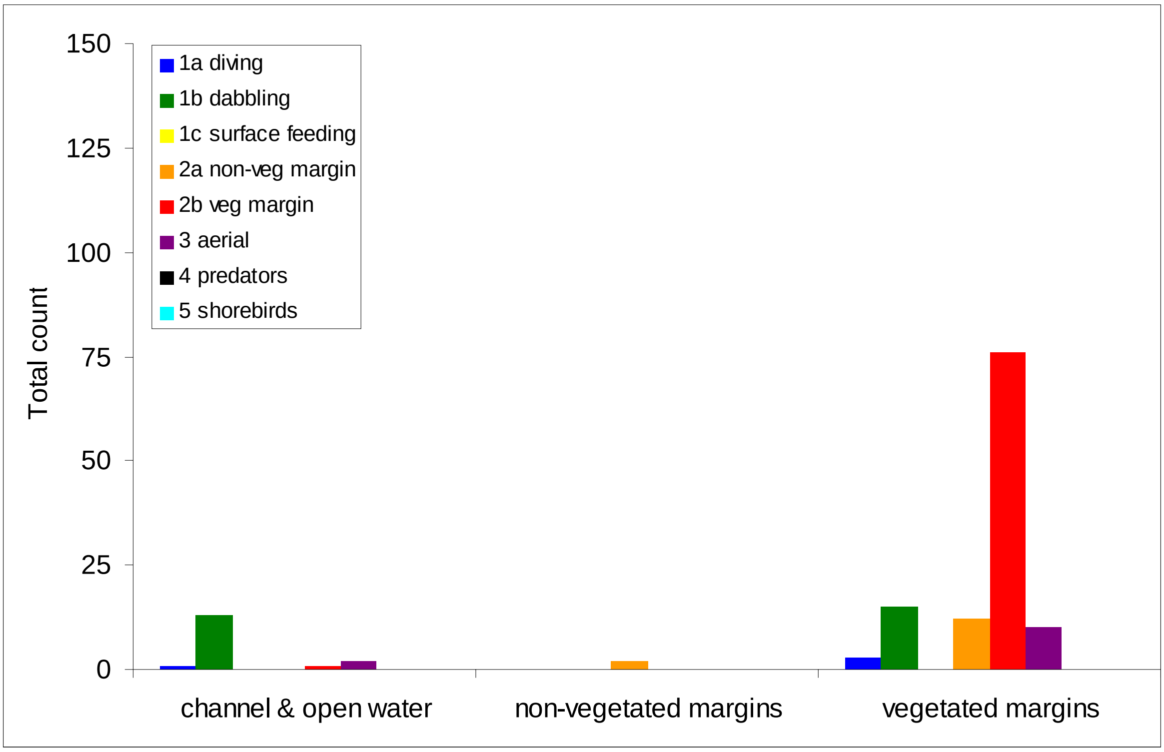
e) Thompson



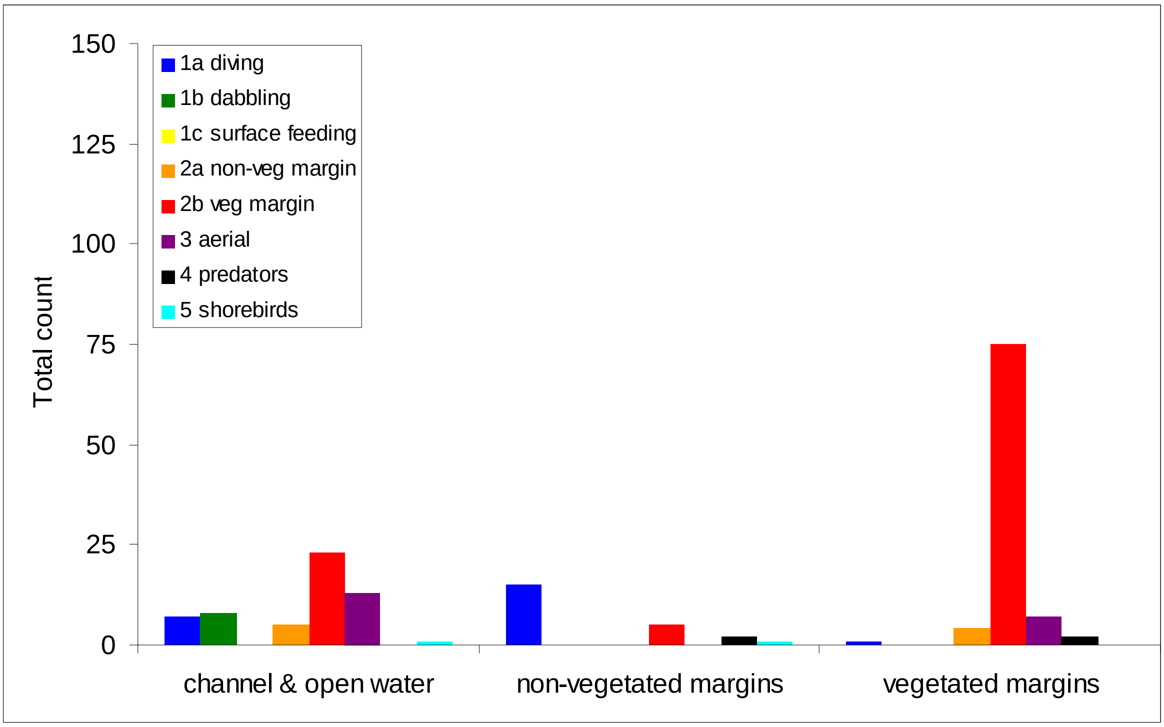
f) Anglesea



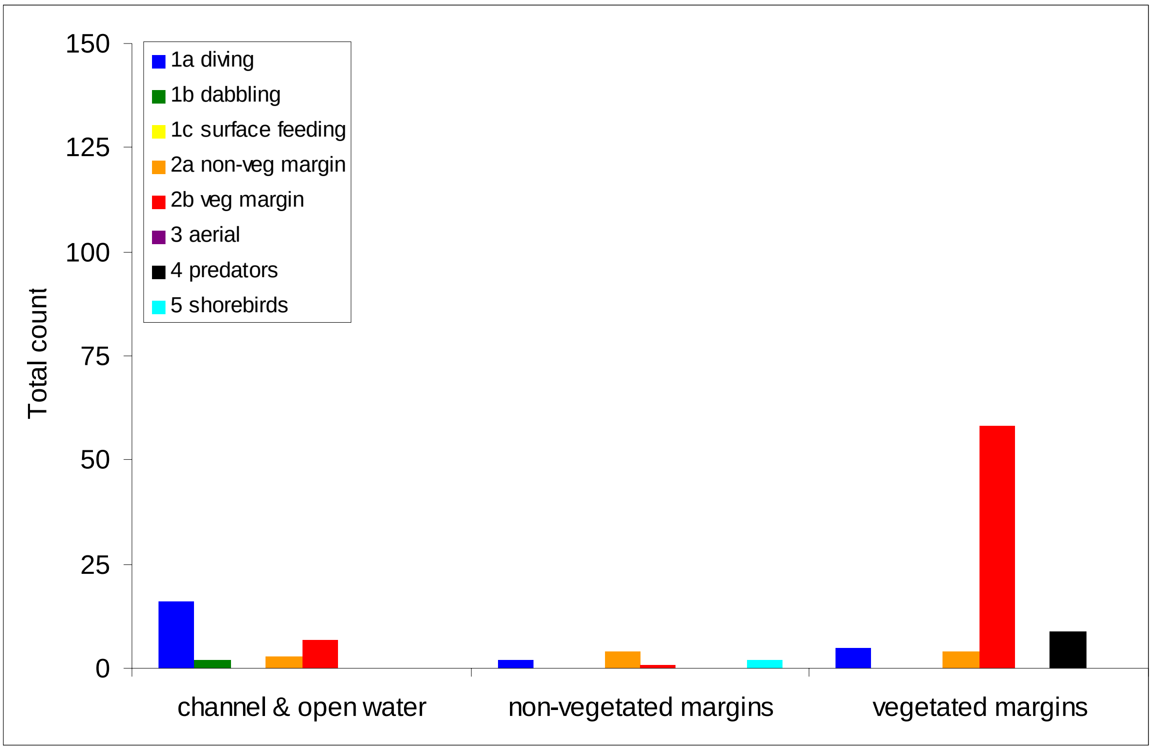
g) Painkalac



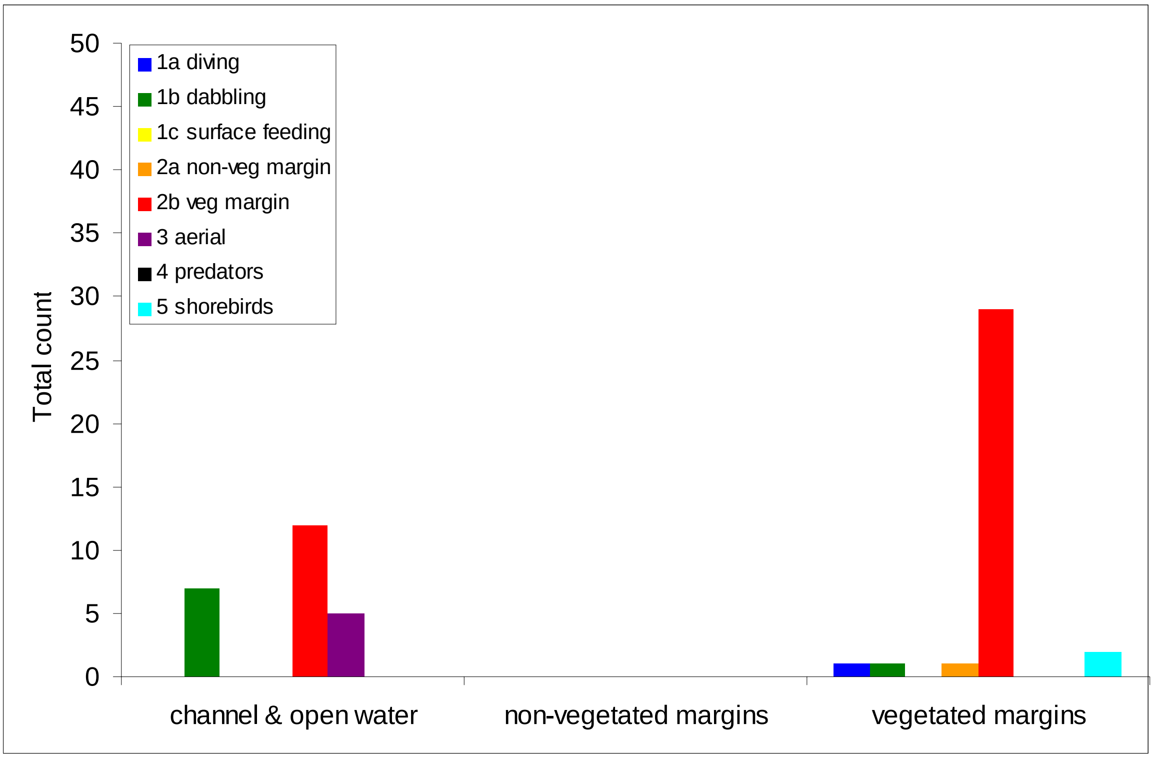
h) Barham



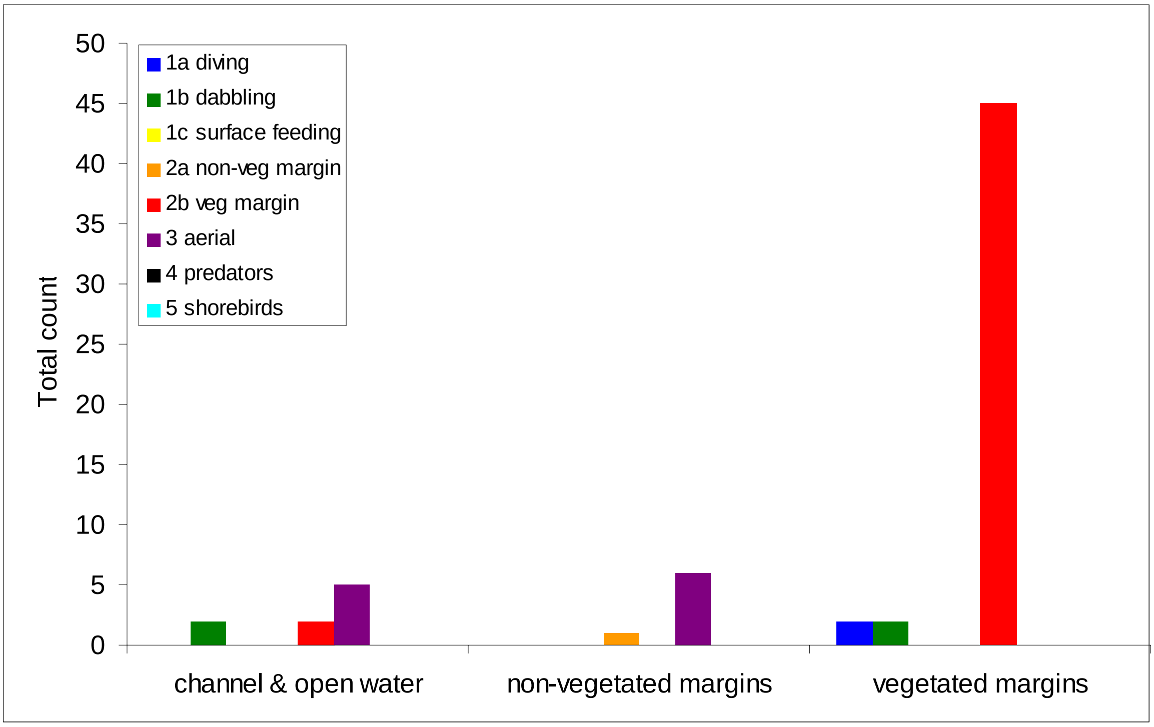
i) Spring



j) Erskine



k) Kennett



3.5 Mapping

The boundary of the survey area in each estuary was created by delineating the outermost edges of overlapping polygons representing each functional group. In the case of Aire, an area that was not fully surveyed occurs within that boundary but was not excised due to the observation of waterfowl and raptors flying over those areas. Therefore, it was deemed simpler and more representative to leave these polygons intact in order to illustrate the maximum survey coverage at any given estuary. Updated EVCs were not available for Kennet, Erskine and Hovells estuaries. EVC codes (ESRI shapefile field name: EVC_poten (number)) are provided in map legends and correspond to the EVC that the site could now support if revegetated, given changes in hydrology and landform that have taken place (S.Sinclair *pers.comm.*). Figures showing individual estuaries and the maximum extent of surveys are provided in Appendix 2.

A number of functional groups were poorly represented in counts of some estuaries, which precluded mapping of every group in every estuary. The most notable functional group absent from surveys was functional group 1c (surface-feeding waterbirds) for which only a single species (Australasian Shoveler *Anas rhynchotis*) was recorded and only in a single estuary (Aire). In some of the smaller estuaries, species representing more common functional groups were only occasionally recorded, also precluding meaningful mapping of that group's distribution. Cases where functional groups were inadequately represented to guide mapping were:

- functional group 1b: Spring estuary
- functional group 3: Aire, Hovells, Spring and Thompson estuaries
- functional group 4: Barham, Erskine, Kennett, Painkalac, Spring and Thompson estuaries
- functional group 5: Barham ,Erskine, Gellibrand, Kennett, Painkalac and Spring estuaries

Low resolution figures showing the distribution of each mapped group in each estuary are provided in Appendix 3 (and as separate high resolution files lodged with CCMA).

3.6 Species records for Corangamite estuaries from other data sources

There were numerous species in the Atlas of Australian Birds that were not recorded during the present study. The most common of these were migratory waders. As their absence was most likely due to timing of surveys, wader data was extracted from the Atlas for the period 1987-2009. Thompson, Curdies and Hovells estuaries had the largest number of migratory wader records of all estuaries (Table 6).

Table 6. Details of waders recorded in the Atlas of Australian Birds (1987-2009)

Estuary	No. wader species recorded	No. migratory wader species	Abundance migratory waders
Curdies	17	9	20
Gellibrand	7	1	1
Aire	2	0	0
Barham	14	3	7
Kennett	0	0	0
Erskine	0	0	0
Painkalac	7	3	13
Anglesea	7	1	7
Spring	3	1	1
Thompson	16	8	54
Hovells	16	8	9

Atlas data from the most recent atlas period (1998-2002) is considered more appropriate for use as precise locations of each surveys were recorded (A. Silcocks, *pers.comm.*). Data from the new Atlas was available for eight estuaries. There were numerous other species (aside from shorebirds) representing waterbird, margin-dwelling and sandy shorebird functional groups recorded in the Atlas that were not observed during surveys (Table 7). The most common of these were Australasian Darter, Australian Reed-Warbler, Black-tailed Native-hen, Blue-winged Parrot, Buff-banded Rail, Eurasian Coot, Great Cormorant, Grey Teal, Hooded Plover, Little Black Cormorant, Pacific Gull, Pied Cormorant and White-necked Heron.

Table 7. Comparison of survey results (present study) with bird records derived from the new Atlas of Australian Birds (1998-2002).

Species lists exclude any records of seabirds and vagrant species to Australia.
* values in parentheses are the number of species representing waterbird, margin-dwelling and/or sandy shorebird functional groups

Estuary	No. species present study	No. species Atlas *	No. Atlas surveys	No. species recorded in present study but not in the Atlas
Curdies	69	164 (27)	154	2 (2)
Gellibrand	48	88 (22)	24	11 (5)
Aire	61	74 (12)	21	18 (12)
Barham	37	118 (37)	94	2 (0)
Kennett	16	47 (7)	4	4 (1)
Erskine	17	38 (6)	6	5 (2)
Painkalac	32	129 (41)	131	2 (0)
Anglesea	39	138 (28)	71	1 (1)

4 Discussion

The premise that estuaries are important habitat for birds is supported in this study. Large numbers of many different species, spanning the whole suite of functional groups of birds, were recorded across all estuaries. This is despite surveys being conducted at a time of the year (winter) when a significant proportion of the expected estuarine avifauna is absent. This is also despite the lack of replication of surveys at each estuary. These points are discussed in more detail below.

The most notable pattern that arose from this study was the tendency for every estuary to differ from every other in terms of both bird community composition and available estuarine habitats. There were loose groupings of estuaries in terms of region (Aire, Gellibrand and Curdies; Erskine and Kennett; Spring and Anglesea), made largely on the basis of visible differences like dominant vegetation communities, estuarine geomorphology and levels of coastal development. However, these groupings are very arbitrary and do not reflect any quantitative analyses of physical and ecological attributes of each estuary. This categorisation issue is symptomatic of previous attempts to establish a meaningful estuarine classification system for Victoria for the purpose of undertaking condition assessments (NLWRA 2002, Mondon et al 2003, Roy et al 2003, Barton et al 2008a).

The majority of absent species were trans-equatorial migratory waders. Waders are a specialist group of waterbirds that use intertidal areas of south-eastern Australia during their non-breeding season (Bamford et al 2008). Downward population trends suggest that these species may be constrained by the availability of suitable foraging habitat in parts of their migratory travel path (flyway). Loss of intertidal habitat elsewhere in the flyway is considered the biggest threat to waders in the East Asian-Australasian Flyway (Figure 3). Given the loss of habitat elsewhere and the pressure already placed on birds during their migration, the protection or augmentation of estuarine habitats in southern Australia is important to the conservation of waders in their non-breeding range.

Other notable absences were seasonally-transient species like Hardhead (*Aythya australis*), Pink-eared duck (*Malacorhynchus membranaceus*), Whiskered Tern (*Chlidonias hybrida*) and Australian Reed-Warbler (*Acrocephalus australis*). Rare and threatened species that were absent were Orange-bellied Parrot (*Neophema chrysogaster*), Ground Parrot (*Pezoporus wallicus*), Freckled Duck (*Stictonetta naevosa*) and Australian Painted Snipe (*Rostratula australis*). Their absence from surveys is more likely to be due to their general rarity (which is reflected in their national conservation status) rather than a false absence (failure to detect them when they are actually present). Species like Magpie Goose (*Anseranas semipalmata*) and Osprey (*Pandion cristatus*) are generally uncommon in Victoria and are unlikely to make a significant contribution to Victorian estuarine avifauna even when present, especially as ospreys occur as vagrants, and a reintroduced population of Magpie Geese is strongly associated with non-coastal freshwater wetlands.

Figure 3. The East-Asian Australasian Flyway

(Image supplied by R. Jessop, Australasian Wader Studies Group)

4.1 Comparison with other data sources

Data from Birds Australia (as well as anecdotal evidence provided by locals – data not shown) confirmed that there was an unexpected absence of a variety of species from surveys. Migratory waders were the largest grouping of birds consistently absent from surveys. Using these data it was found that the greatest numbers of species (and in some cases, highest abundances) of migratory waders occurred in Thompson, Curdies and Hovells estuaries. Using this in a predictive manner, it is probable that the lower Thompson, Curdies inlet and Hovells inlet harbour relatively high numbers of shorebirds during the spring-through-autumn months compared to any other Corangamite estuary.

Other species that were recorded in the Atlas but absent from surveys were seasonal migrants like Australian Reed-Warbler, Whiskered Tern, swifts, and flycatchers. Some resident shorebird species like oystercatchers were under-represented. There was also a notable absence of a number of waterbirds, most likely due to inland water availability during the winter months, which attracts birds away from the coast. Surveys conducted during mid-late summer would be informative in determining waterbird habitat use in these estuaries.

Whilst data from sources like Birds Australia can give an indication of species likely to be present, they do not provide any abundance or fine-scale distribution estimates. This is because records are usually obtained from opportunistic observations, and do not reflect any systematic survey or (hypothesis-driven) experimental design. In addition, Atlas records are often biased in their distribution and tend to originate from areas that are more easily accessible. In order to obtain relatively unbiased estimates of bird abundance and distribution, targeted surveys are required. In this context, Atlas data are useful as a guide only.

4.2 The influence of estuarine form on bird distribution

Several geomorphic features of the 11 estuaries had a marked influence on the distribution of birds, especially those species representing waterbird functional groups. These were the presence of in-channel lakes, off-stream swamps and inlets. Such geomorphic features allow for substantial congregations of birds, which is a pattern seen in estuarine marsh habitats elsewhere (Craig and Beal 1992), and was reflected in very high counts in channels and open water for estuaries like

Curdies, Hovells, Gellibrand and Aire. Anglesea, which is a modified estuary with an artificial backwater network, had a number of waterbird and margin-dwelling species that were not represented in the main channel. The relatively high numbers recorded on these waterbodies occurred despite each having different hydrological regimes – Curdies and Anglesea were flooded due to a closed entrance, Hovells is tidal, and Gellibrand has a naturally intermittently open entrance that only allows minimal hydrological exchange with the marine environment. It is clear that these geomorphic features of estuaries have a strong influence on bird distribution and abundance and, combined with the effect of season, that influence may be greater than the status of the estuary entrance.

What is not clear from these surveys is changes in the relative importance of these water bodies with changes in water level and tides. In Connecticut River estuary (North America), water cover, habitat heterogeneity (in terms of vegetation and bathymetry) and configuration of swamps were found to strongly influence avian species richness, with avifauna of small strongly tidal marshes differing significantly from that of freshwater, weakly tidal marshes (Craig and Beal 1992). The water level in Curdies inlet was high during surveys and there was little exposed mud. In contrast, Hovells inlet was strongly tide-influenced and areas of mud were exposed at the start of the survey. These differences are reflected in the relatively greater number of non-vegetated margin-dwelling and shorebird numbers recorded in Hovells compared to Curdies (Figure 2c & 2d). Thus, changes in water level are accompanied by a shift in relative representation of functional groups, but the nature of that shift is complicated by the influence of tides (salinity), and bathymetry.

Estuarine water levels and wetland area have implications for the management of estuaries across broader coastal regions. Many of the species that constitute EEMSS functional groups are highly mobile. Whilst some are known to be relatively site faithful during their non-breeding season (e.g. migratory waders; Victorian Wader Study Group, *unpub. data*), others move in response to spatial (and temporal) shifts in important resources (Chambers and Loyn 2006). The dynamic nature of Victorian estuary entrances means that different estuaries may have different water levels and salinity regimes at the same time. Therefore, at any one time, a network of estuaries may collectively provide the full suite of conditions and resources that supports estuarine avifauna. This may require a shift in entrance management focus from the scale of an individual estuary to a coastal landscape scale. Simultaneous counts of a set of key Corangamite estuaries, with surveys being conducted before and after entrance openings, would be required to test this hypothesis.

4.3 Limitations of survey approach

Bird surveys were conducted during the period May-July when many important estuarine species are often absent. Late spring is the time of northward migration of a number of estuarine passerines and waterbirds, for example, Australian Reed-Warbler and Whiskered Tern. The 2010 temperate Australian winter was also a time of abundant inland water, meaning that many transient waterfowl species (for example, Grey Teal, Hardhead and Pink-eared Duck) were largely absent from coastal habitats. Furthermore, resident shorebird species like oystercatchers tend to congregate in non-breeding flocks during winter months (Kraajeveld-Smit *et al* 2001, Hansen *et al* 2009), which may account for their unexpected absence from several estuarine sites.

Most significantly, the survey period coincides with the breeding season of migratory waders, meaning that most adult birds of those species will be absent from southern latitudes. Occasionally, small numbers of immature birds may remain over winter and congregate at key coastal and estuarine habitats along Victoria’s coast, but these (a) do not include all migratory wader species, and (b) tend to occur predominantly in high quality habitats like Port Phillip, Western Port, Corner Inlet and key locations in Tasmania (Gosbell and Clemens 2006). Therefore, the surveys conducted here have failed to capture any information about usage of Corangamite estuaries by most waders. Further surveys are imperative for these estuaries, especially those having previous records of shorebird and those having shallow bathymetry in the lower estuary, which may provide suitable intertidal foraging habitat (for example, Curdies, Hovells and Thompson estuaries).

In addition to timing of surveys, there is the issue of replication. It is widely understood that birds are quite transient and mobile compared with other taxa. Surveys of birds conducted at the same place but at different times can vary markedly. For example, a survey of a key high tide roost for waders may find the birds absence due to a number of factors including prevailing weather conditions, disturbance or tidal range. Therefore, for surveys to provide an accurate measure of avifauna use and distribution within each estuary, surveys need to be replicated over different time periods (e.g. different seasons).

4.4 Limitations of mapping approach

Mapping has been done by delineating the distribution of birds representing each functional group using polygons in ArcView. The major drawback of this method is that neither the density nor relative abundance of each species are reflected in the mapping. Therefore, an area which delineates the spatial use of an estuary for each functional group may differ in its relative importance between estuaries. For example, 355 birds representing eight species in the functional group “vegetated-margin dwellers” were recorded in Curdies estuary. By contrast, only 23 birds representing three species were recorded in Spring estuary. However, the mapping indicates that the majority of both estuaries were used by this group of birds, which may be misinterpreted to mean that those areas are equivalent in their importance.

4.5 EEMSS considerations

The Estuary Entrance Management Support System provides a mechanism for estuary managers to determine the relevant benefits and disadvantages of artificial estuary entrance openings for a variety of environmental “values”. Birds are a key component of estuaries and are sensitive to changes in estuarine conditions. Where large areas of intertidal habitat are inundated for lengthy periods by freshwater in-flows, these habitats become unsuitable for a suite of intertidal foraging species (particularly migratory waders). In contrast, they may become more suitable for a number of waterfowl species which prefer open water to forage or rest. Furthermore, low flows and subsequent entrance closures result in increased wetland area, making estuaries potentially important refuges during periods of drought. Thus, estuaries with closed entrances may be more suitable to waterfowl, whereas open entrances may benefit waders and large wading birds by increasing mud flat exposure. Paradoxically, the estuary entrance openings that may benefit numerous margin-dwelling species may have negative consequences for particular foraging guilds, such as fish-eating birds, as a result of fish kills from oxygen depletion (Arundel 2006, Zydelis and Kontautas 2008). Therefore, the decision to open an entrance is complicated by many interacting considerations.

Of all management considerations, one should be the impact of changes in water levels on wetlands (this includes lakes, swamps and other estuarine waterbodies). In the St Lawrence estuary (Québec, Canada), estuarine wetlands are of paramount importance for the conservation of avian (and other) biodiversity and are significant contributors to biological production (Desgranges and Jobin 2003). Similar patterns were found for a massively altered estuary, the Passaic River (New Jersey, U.S.A.) where the loss of wetland and associated shoreline habitat has severely constrained use by birds (Ludwig et al 2010). In the drier and more water-depauperate climates of temperate Australia, these wetlands are likely to be even more significant to avifauna. The encroachment of urban development on important estuarine ecosystems hastens the need to protect key habitat areas and carefully manage those threatened resources. In the context of this project, the decision to open an estuary entrance should be viewed in terms of the likely impacts on estuarine wetlands and mudflat availability.

4.5.1 Appropriateness of EEMSS bird functional groups

It was clear when making assessments of habitat use by different species that the EEMSS functional groups where not adequately representative of actual groupings of birds and their dominant habitat associations. The most notable of these were the Crested Tern, which tends to forage for fish off-shore and congregates on shorelines (and artificial shoreline structures) to roost, and the Australian Pelican, which is a fish-eating bird. It is possible that surveys conducted in spring / summer seasons may reveal patterns of habitat use more consistent with the current EEMSS groupings. Nevertheless, this study highlights the need to review and potentially revise functional group membership as data becomes available in the future through studies like this one. It is suggested that Crested Tern should be placed in group five with shorebird species, to reflect its use of habitat within estuaries (for roosting rather than feeding).

4.6 Future research priorities

This project makes an important contribution to our understanding of the avifauna of Victorian estuaries. However, the quality of surveys was limited by the seasonal timing and the lack of replication. Surveys in the late spring–early autumn period are critical to gain an understanding of how migratory species use estuaries. In addition, repeat surveys during both summer and winter would substantially improve representation of avian use of these estuaries. One approach which has been used elsewhere (Ravenscroft and Beardall 2003) that would apply in these systems is to identify and regularly count targeted subsets of each estuary that represent key habitat areas (e.g. Curdies inlet), rather than trying to regularly repeat whole estuary surveys. In particular it is important to simultaneously assess the use of estuaries by all functional groups of birds, if a valid application of the EEMSS is to be undertaken.

It is clear from this work that the majority of these estuaries are important habitat for birds. Given increasing anthropogenic pressures on these estuaries, especially those in the Surf Coast region, it will be important to quantify the spatial and temporal distribution of key bird groups in order to identify important areas that require protection or augmentation.

References

Arundel, H. (2006) *The Estuary Entrance Management Support System (EEMSS) database*. Deakin University, Warrnambool.

Bamford, M., Watkins, D., Bancroft, W. et al. (2008) *Migratory shorebirds of the East Asian - Australasian flyway: Population estimates and internationally important sites*. Wetlands International – Oceania, Canberra.

Barton, J.L., Pope, A.J., Quinn, G.P. and Sherwood, J.E. (2008a) *Identifying threats to the ecological condition of Victorian estuaries*. Department of Sustainability and Environment Technical Report

Barton J, Pope A, Quinn G, Sherwood J (2008a) Victorian estuary extent shapefiles from the DSE-funded project: *Identifying threats to the ecological condition of Victorian estuaries,* Deakin University, School of Life and Environmental Sciences, Warrnambool. Updated 2009.

Chambers, L.E. and Loyn, R.H. (2006) The influence of climate variability on numbers of three waterbird species in Western Port, Victoria, 1973–2002. *International Journal of Biometeorology*, **50**, 292-304.

Christidis, L. and Boles, W.E. (2008) *Systematics and Taxonomy of Australian Birds*. CSIRO Publishing, Melbourne.

Craig, R.J. and Beal, K.G. (1992) The Influence of Habitat Variables on Marsh Bird Communities of the Connecticut River Estuary. *Wilson Bulletin*, **104(2)**, 295-311.

Dann, P., Arnould, J.P.Y., Jessop, R. and Healy, M. (2003) Habitat use and group size of pied cormorants (*Phalacrocorax varius*) in a seagrass ecosystem: possible effects of food abundance and predation risk. *Emu*, **103**, 307-313.

Desgranges, J.-L and Jobin, B. (2003) Knowing, mapping and understanding St. Lawrence biodiversity, with special emphasis on bird assemblages. *Environmental Monitoring and Assessment*, **88**, 177-192.

Geering, A., Agnew, L. and Harding, S. (2007) *Shorebirds of Australia*. CSIRO publishing, Collingwood. Australia.

Gosbell, K. and Clemens, R. (2006) Population monitoring in Australia: some insights after 25 years and future directions. *Stilt* **50**, 162-175.

Hansen, B.D., Minton, C.D.T., Jessop, R. and Collins, P. (2009) Biometrics, sexing criteria, age structure and moult of Sooty Oystercatchers in south-east Australia and north-west Australia. *Emu* **109**, 25-33.

Heithaus, M.R. (2005) Habitat use and group size of pied cormorants (*Phalacrocorax varius*) in a seagrass ecosystem: possible effects of food abundance and predation risk. *Marine Biology*, **147**, 27-35.

Kraaijeveld-Smit, F., Minton, C., Jessop, R. and Collins, P. (2001) Sexing criteria, age structure, biometrics, and moult of the Pied Oystercatcher, *Haematopus longirostris* in Victoria. *Stilt* **40**, 29-37.

Loyn, R.H. (1978) A survey of birds in Westernport Bay, Victoria, 1973-74 *Emu* **78**, 11-19.

Ludwig, D.F., Iannuzzi, J., Iannuzzi, T.J. and Shisler, J.K. (2010) Spatial and Temporal Habitat Use Patterns by Water Birds in an Urban Estuarine Ecosystem: Implications for Ecosystem Management and Restoration. *Human and Ecological Risk Assessment*, **16**, 163–184.

Mondon, J., Sherwood, J. and Chandler, F. (2003) *Western Victorian Estuaries Classification Project*. Prepared for the Western Coastal Board, Warrnambool, Victoria, 120p.

NLWRA (2002) *Australian Catchment, River and Estuary Assessment 2002*. National Land and Water Resources Audit, Land & Water Australia, Canberra, 386 p.

Ravenscroft, N.O.M. and Beardall, C.H. (2003) The importance of freshwater flows over estuarine mudflats for wintering waders and wildfowl. *Biological Conservation*, **113**, 89-97.

Rosa, S., Palmeirim, J.M. and Moreira, F. (2003) Factors Affecting Waterbird Abundance and Species Richness in an Increasingly Urbanized Area of the Tagus Estuary in Portugal. *Waterbirds*, **26(2)**, 226-232.

Trayler, K.M., Brothers, D.J., Wooller, R.D. and Potter, I.C. (1989) Opportunistic foraging by three species of cormorants in an Australian estuary. *Journal of Zoology, London*, **218**, 87-98.

West, A.D., Goss-Custard, J.D., Durell, S.E.A.Le.V.d. and Stillman, R.A. (2005) Maintaining estuary quality for shorebirds: towards simple guidelines. *Biological Conservation*, **123**, 211-224.

Yates, M.G., Goss-Custard, J.D., McGrorty, S., Lakhani, K.H., Durell, S.E.A.Le.V.d., Clarke, R.T., Rispin, W.E., Moy, I., YATES, T., Plant, R.A. and Frost, A.J. (1993) Sediment characteristics, invertebrate densities and shorebird densities on the inner banks of the Wash. *Journal of Applied Ecology*, **30**, 599-614.

Žydelis, R. and Kontautas, A. (2008) Piscivorous birds as top predators and fishery competitors in the lagoon ecosystem. *Hydrobiologia*, **611**, 45-54.

Appendix 1 List of all species recorded and functional group for each.

Species are listed in taxonomic order, following Christidis and Boles (2008). Estuary names are abbreviated and provided across the top. P indicates species recorded in that estuary.

Species (common name)	EEMSS group	Curdies	Gelli	Aire	Barham	Kenn	Erskine	Pain	Angle	Spring	T'son	Hovell
Musk Duck	1a	P										
Black Swan	1b	P	P	P				P	P		P	P
Australian Shelduck	2b	P	P	P							P	
Australian Wood Duck	2b	P	P	P	P	P	P	P	P	P		
Australasian Shoveler	1c			P								
Grey Teal	1b		P					P				
Chestnut Teal	1b	P	P	P					P		P	P
Northern Mallard	7								P			
Pacific Black Duck	1b	P	P	P	P	P	P	P	P	P		P
Australasian Grebe	1a	P	P	P					P			
Hoary-headed Grebe	1a			P								
Great Crested Grebe	1a	P										
Feral (Rock) Pigeon	7									P		P
Spotted Dove	7								P	P		
Crested Pigeon	8									P		
Australasian Darter	1a	P					P					
Little Pied Cormorant	1a	P	P	P	P	P		P	P	P	P	P
Great Cormorant	1a	P	P	P							P	
Little Black Cormorant	1a	P		P	P					P		P
Pied Cormorant	1a											P
Australian Pelican	1b & 2a	P										P
Australasian Bittern	2b	P	P	P								
Eastern Great Egret	2a & 2b	P	P	P	P	P		P	P	P	P	
Cattle Egret	2b	P			P							
White-faced Heron	2a & 2b	P	P	P			P	P		P	P	P
Little Egret	2a & 2b	P										P

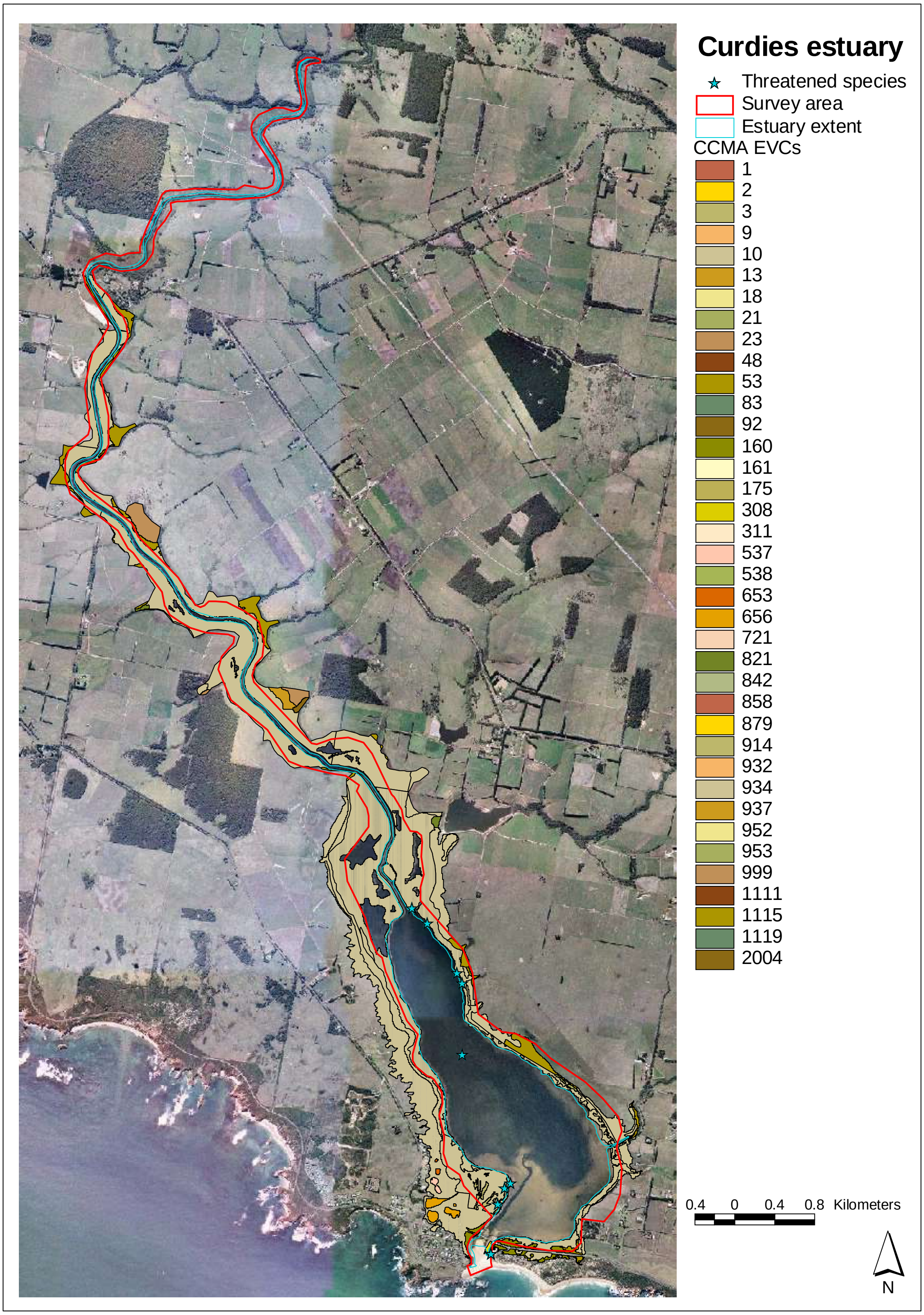
Species (common name)	EEMSS group	Curdies	Gelli	Aire	Barham	Kenn	Erskine	Pain	Angle	Spring	T’son	Hovell
Australian White Ibis	2a & 2b	P		P								P
Straw-necked Ibis	2a & 2b	P		P								
Royal Spoonbill	2a & 2b	P									P	P
Yellow-billed Spoonbill	2a & 2b	P		P				P			P	
Black-shouldered Kite	4				P							P
White-bellied Sea-Eagle	4	P										
Whistling Kite	4	P										P
Brown Goshawk	4			P								P
Grey Goshawk	4			P					P			
Swamp Harrier	4	P	P	P								
Wedge-tailed Eagle	4	P	P								P	
Nankeen Kestrel	4		P								P	
Brown Falcon	4	P	P									
Brolga	8										P	
Purple Swamphen	2a & 2b	P		P	P				P	P		
Lewins Rail	2b	P	P	P								
Buff-banded Rail	2b				P					P		
Spotless Crake	2b	P	P	P								
Dusky Moorhen	2b	P	P	P	P				P	P		
Eurasian Coot	1a	P										
Australian Pied Oystercatcher	5											P
Black-winged Stilt	2a	P										
Red-capped Plover	5										P	
Double-banded Plover	5										P	
Black-fronted Dotterel	2b								P			P
Hooded Plover	5			P								
Masked Lapwing	2a & 2b	P	P	P	P			P		P	P	P
Fairy Tern	5											P
Caspian Tern	1a 2a & 5				P						P	
Crested Tern	1a 2a & 5	P		P							P	P
Pacific Gull	5										P	P

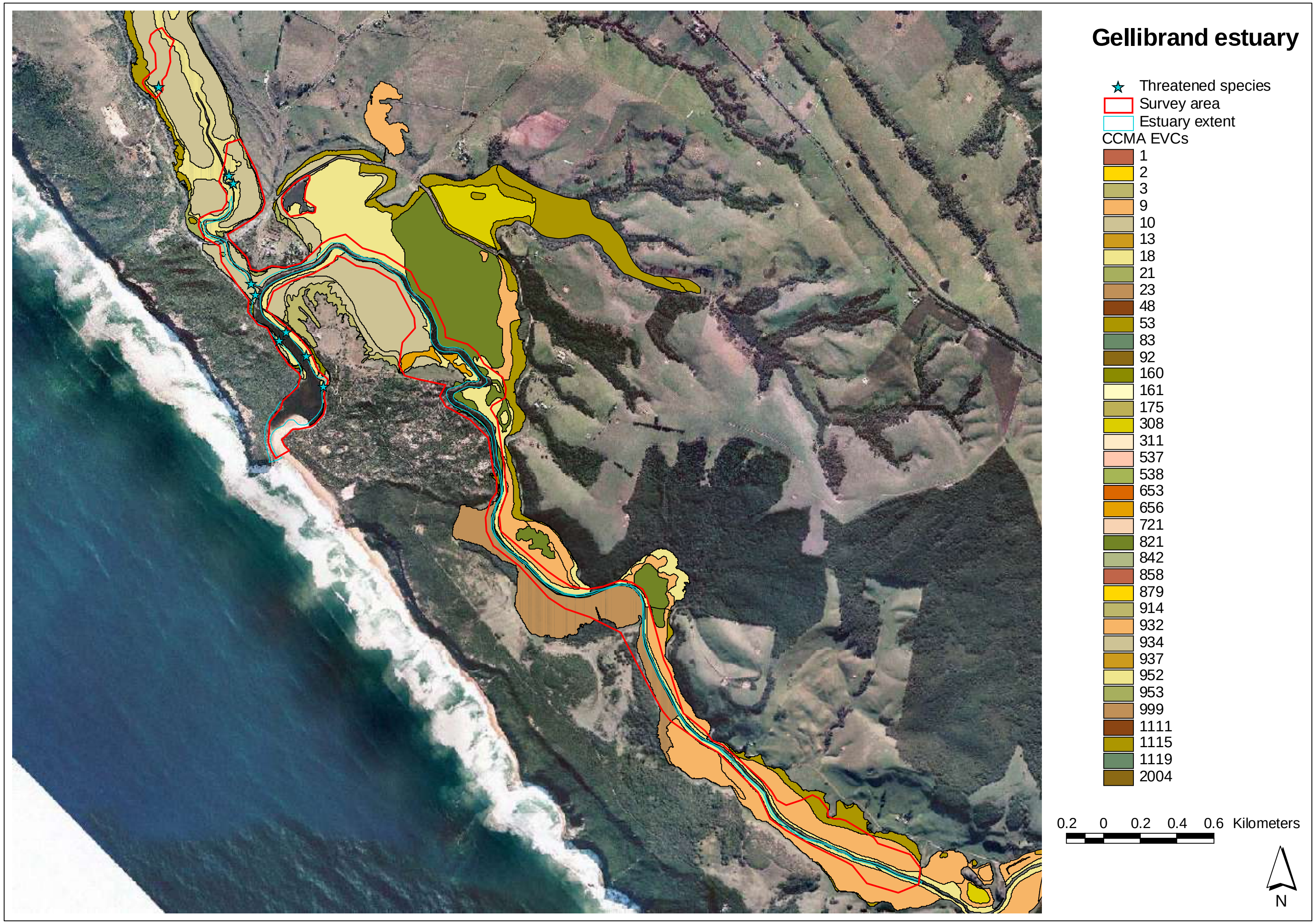
Species (common name)	EEMSS group	Curdies	Gelli	Aire	Barham	Kenn	Erskine	Pain	Angle	Spring	T’son	Hovell
Silver Gull	5	P		P	P		P		P	P	P	P
Galah	8									P		
Sulphur-crested Cockatoo	8			P			P		P	P		
Crimson Rosella	6	P	P	P	P	P		P		P		
Eastern Rosella	8									P		
Red-rumped Parrot	8										P	
Blue-winged Parrot	2b	P									P	
Horsfield’s Bronze-cuckoo	6										P	
Fan-tailed Cuckoo	6								P	P	P	
Azure Kingfisher	1a & 2b		P	P								
Laughing Kookaburra	6			P		P	P	P	P			
White-throated Treecreeper	8	P										
Satin Bowerbird	8				P							
Superb Fairy-wren	2b	P	P	P	P	P	P	P	P	P	P	P
Southern Emu-wren	2b	P	P	P								
Rufous Bristlebird	8	P				P						
White-browed Scrubwren	6	P	P	P	P		P	P		P	P	P
Striated Fieldwren	2b	P		P	P						P	
Striated Thornbill	6			P				P	P			
Yellow Thornbill	6									P		
Yellow-rumped Thornbill	6							P		P	P	
Brown Thornbill	6	P	P	P	P			P	P		P	
Spotted Pardalote	6	P					P		P	P		
Striated Pardalote	6						P					
Eastern Spinebill	6								P	P		
Yellow-faced Honeyeater	6								P	P		
Singing Honeyeater	6	P	P	P				P			P	
White-eared Honeyeater	2b & 6	P	P	P					P			
White-plumed Honeyeater	6							P		P	P	
Noisy Miner	8	P										
Spiny-cheeked Honeyeater	6									P	P	

Species (common name)	EEMSS group	Curdies	Gelli	Aire	Barham	Kenn	Erskine	Pain	Angle	Spring	T’son	Hovell
Little Wattlebird	6		P									
Red Wattlebird	6				P		P	P	P	P	P	
White-fronted Chat	2b	P	P	P							P	
Crescent Honeyeater	6		P	P								
New Holland Honeyeater	6	P	P	P	P		P	P	P	P	P	P
White-naped Honeyeater	6							P		P		
Golden Whistler	6	P		P	P		P					
Grey Shrike-thrush	6	P	P	P				P		P		
Olive-backed Oriole	6									P		
Grey Butcherbird	6									P		
Australian Magpie	8	P	P	P	P			P	P	P	P	P
Pied Currawong	6						P	P		P		
Grey Fantail	6	P	P	P	P			P	P	P		P
Willie Wagtail	2b & 6	P	P	P	P				P	P	P	
Australian Raven	4		P									
Forest Raven	4	P	P	P	P				P			
Little Raven	4	P							P	P	P	P
Magpie-lark	2b	P	P	P	P	P		P		P	P	P
Flame Robin	6				P			P				
Eastern Yellow Robin	6			P				P	P		P	
Eurasian Skylark	7	P	P	P	P						P	
Golden-headed Cisticola	2b	P	P	P	P						P	P
Little Grassbird	2b	P	P	P	P				P		P	P
Silvereye	2b & 6	P	P	P	P	P	P	P	P	P	P	P
Welcome Swallow	3	P	P	P	P	P	P	P	P		P	P
Tree Martin	3					P						
Bassian Thrush	6					P						
Common Blackbird	7	P		P	P	P			P	P	P	
Common Starling	7	P	P	P	P			P		P	P	P
Red-browed Finch	2b	P	P	P		P		P	P			
Beautiful Firetail	2b		P	P								

Species (common name)	EEMSS group	Curdies	Gelli	Aire	Barham	Kenn	Erskine	Pain	Angle	Spring	T’son	Hovell
House Sparrow	7				P	P			P			P
Australasian Pipit	2b										P	
European Goldfinch	7 & 2b	P	P	P	P							
European Greenfinch	7	P			P						P	

Appendix 2 Maps of survey extent in each estuary




Gellibrand estuary
Threatened species
Survey area
Estuary extent
CCMA EVCs
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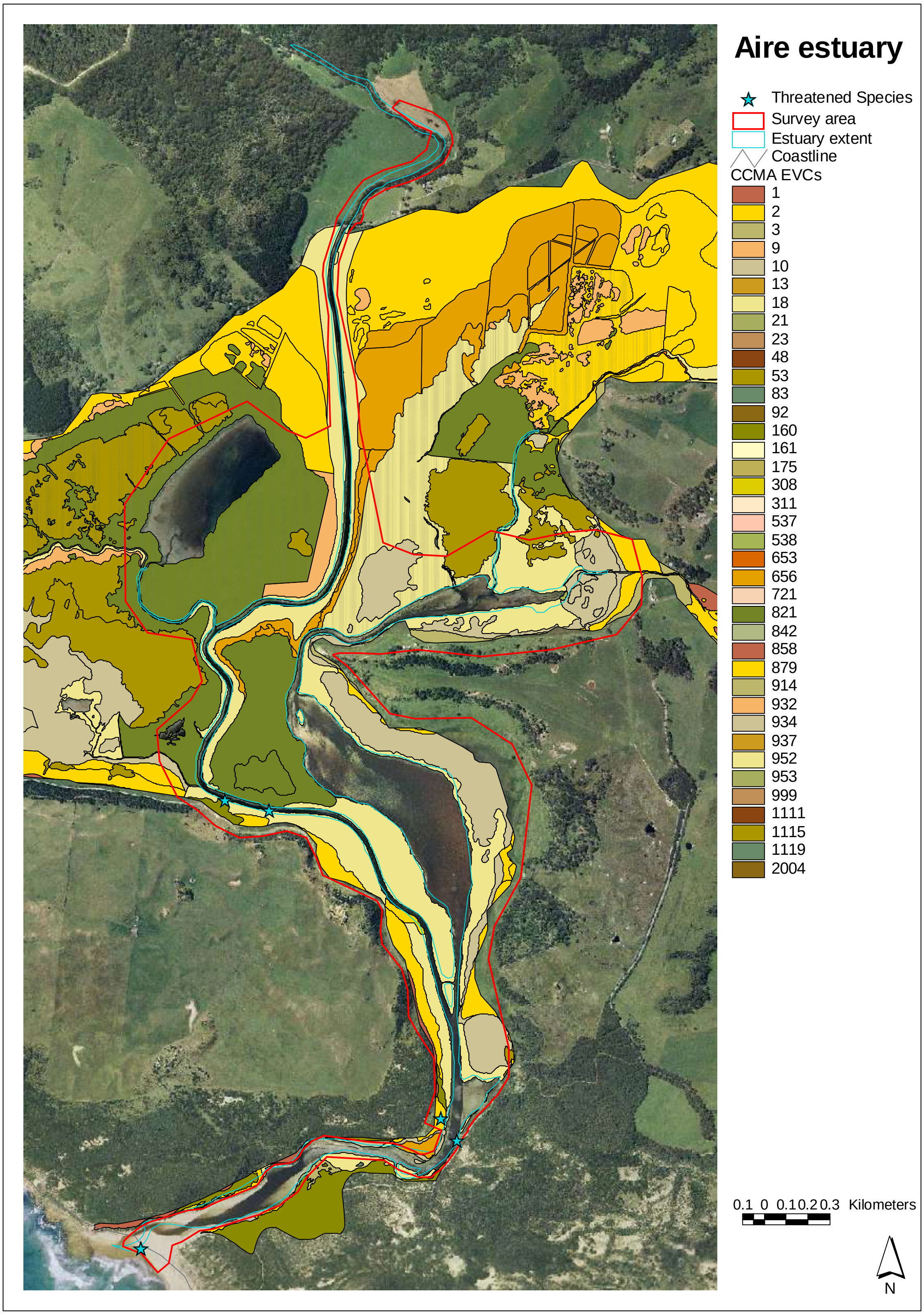
Aire estuary
Threatened Species
Survey area
Estuary extent
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Barham estuary
Threatened Species
Survey area
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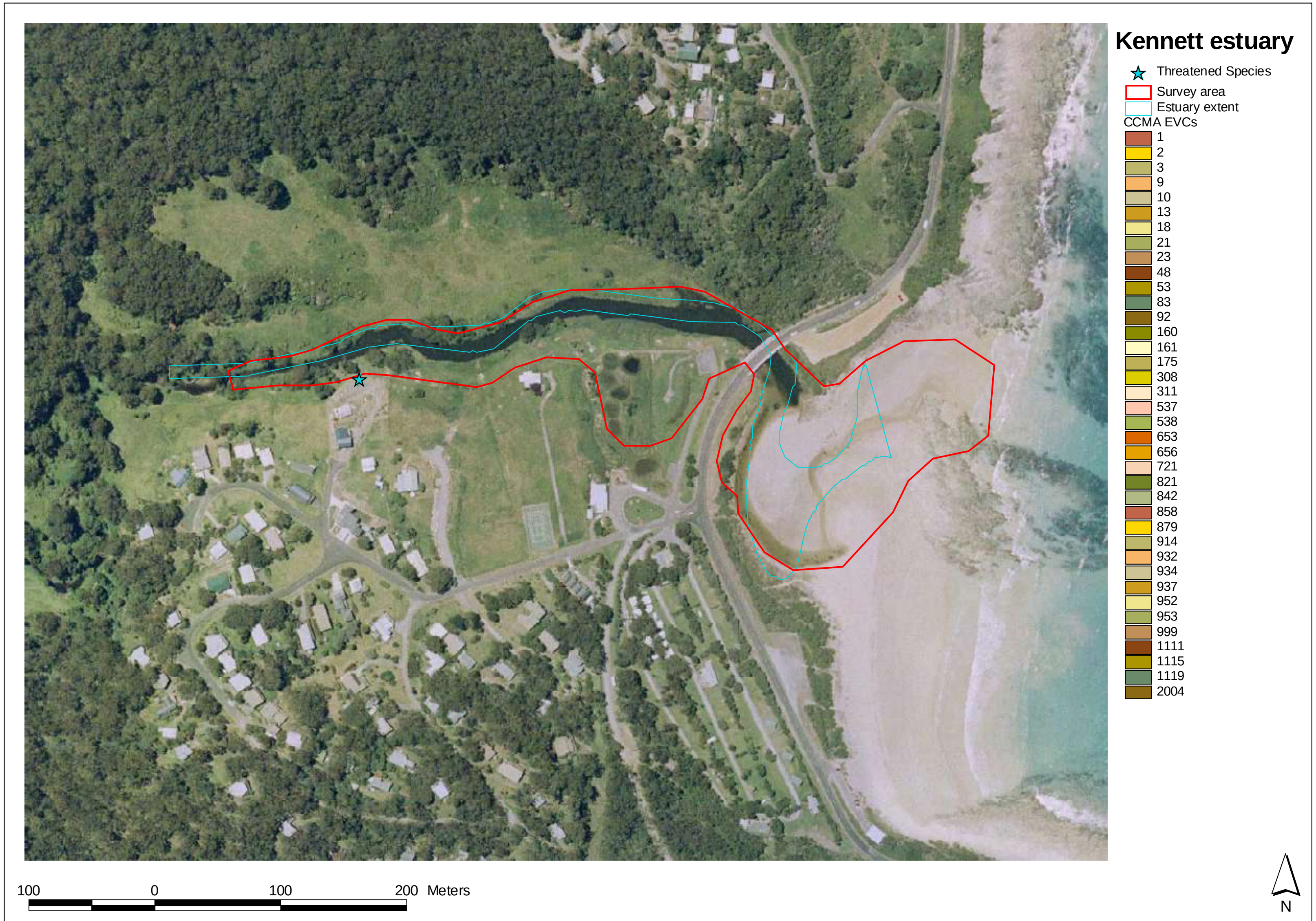
Kennett estuary
Threatened Species
Survey area
Estuary extent
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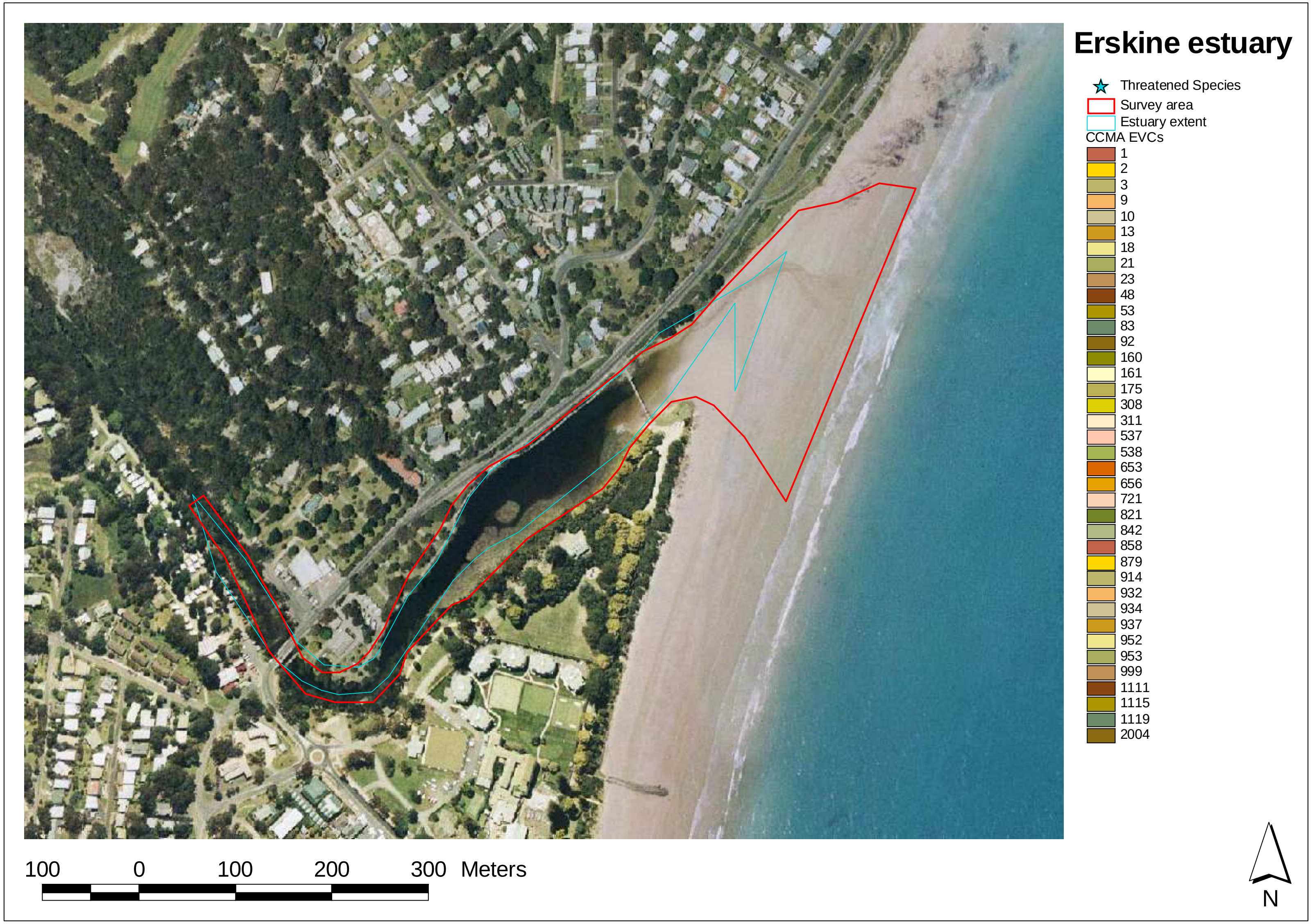

Erskine estuary
Threatened Species
Survey area
Estuary extent
CCMA EVCs
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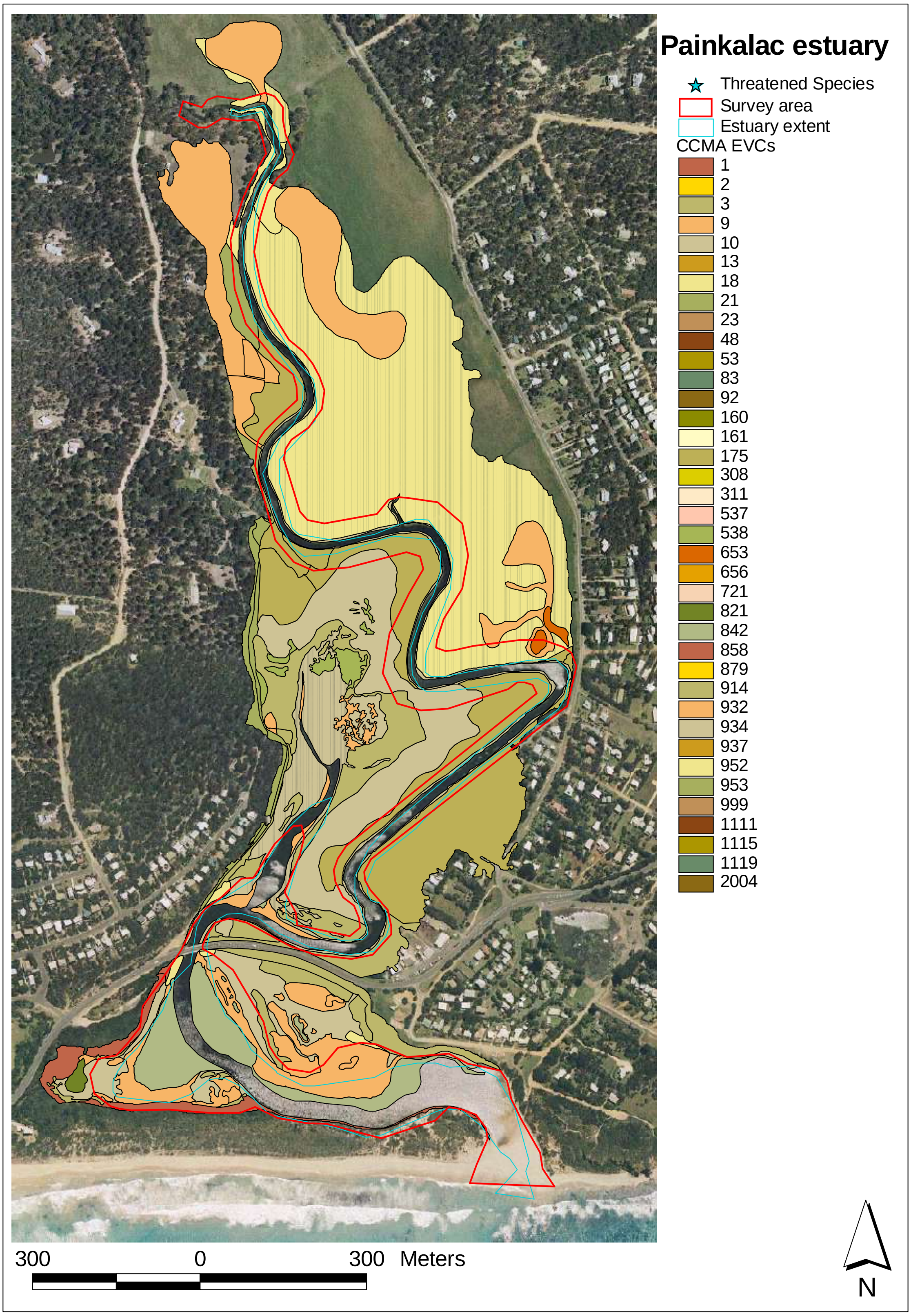
Painkalac estuary
Threatened Species
Survey area
Estuary extent
CCMA EVCs
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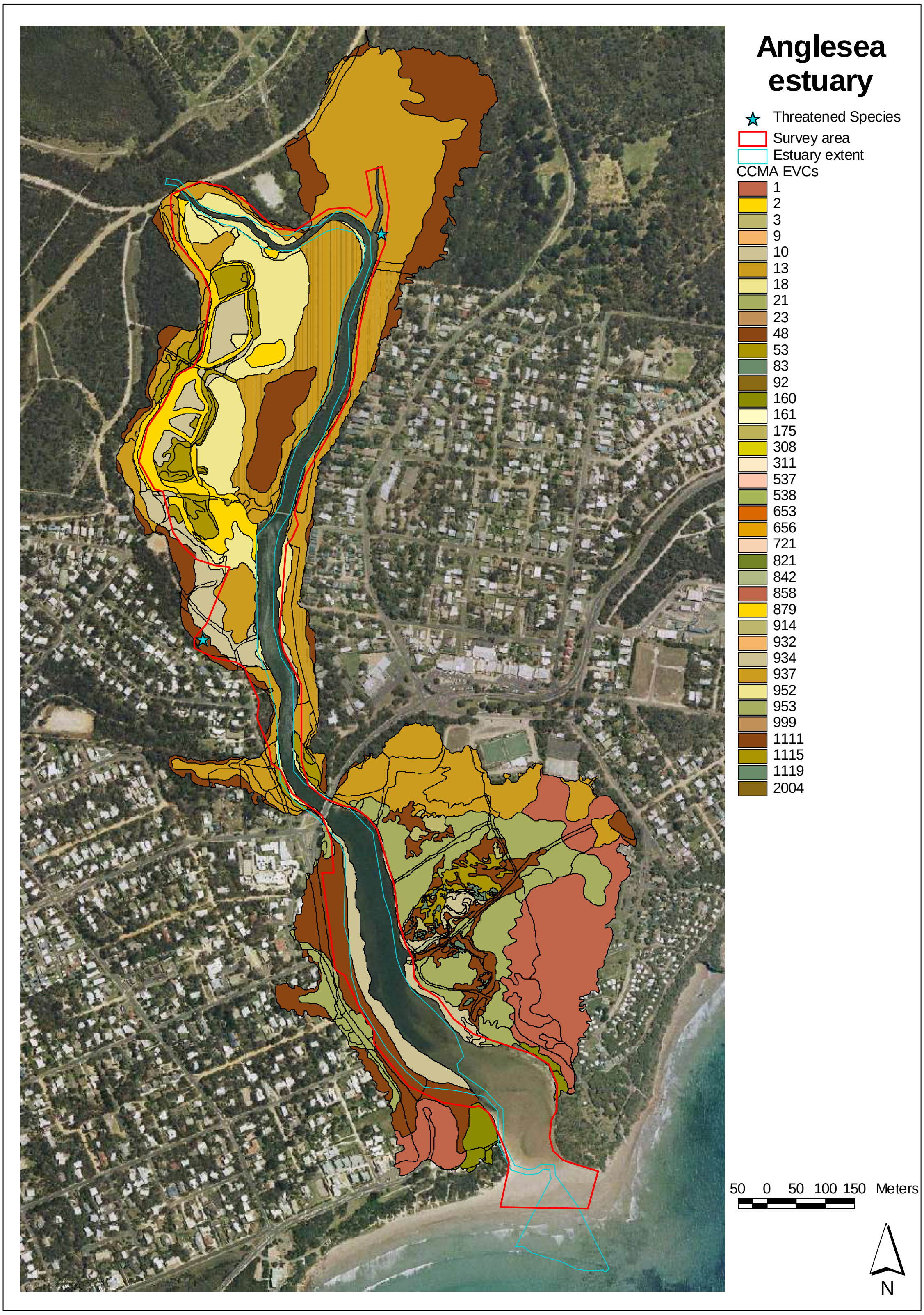
Anglesea estuary
Threatened Species
Survey area
Estuary extent
CCMA EVCs
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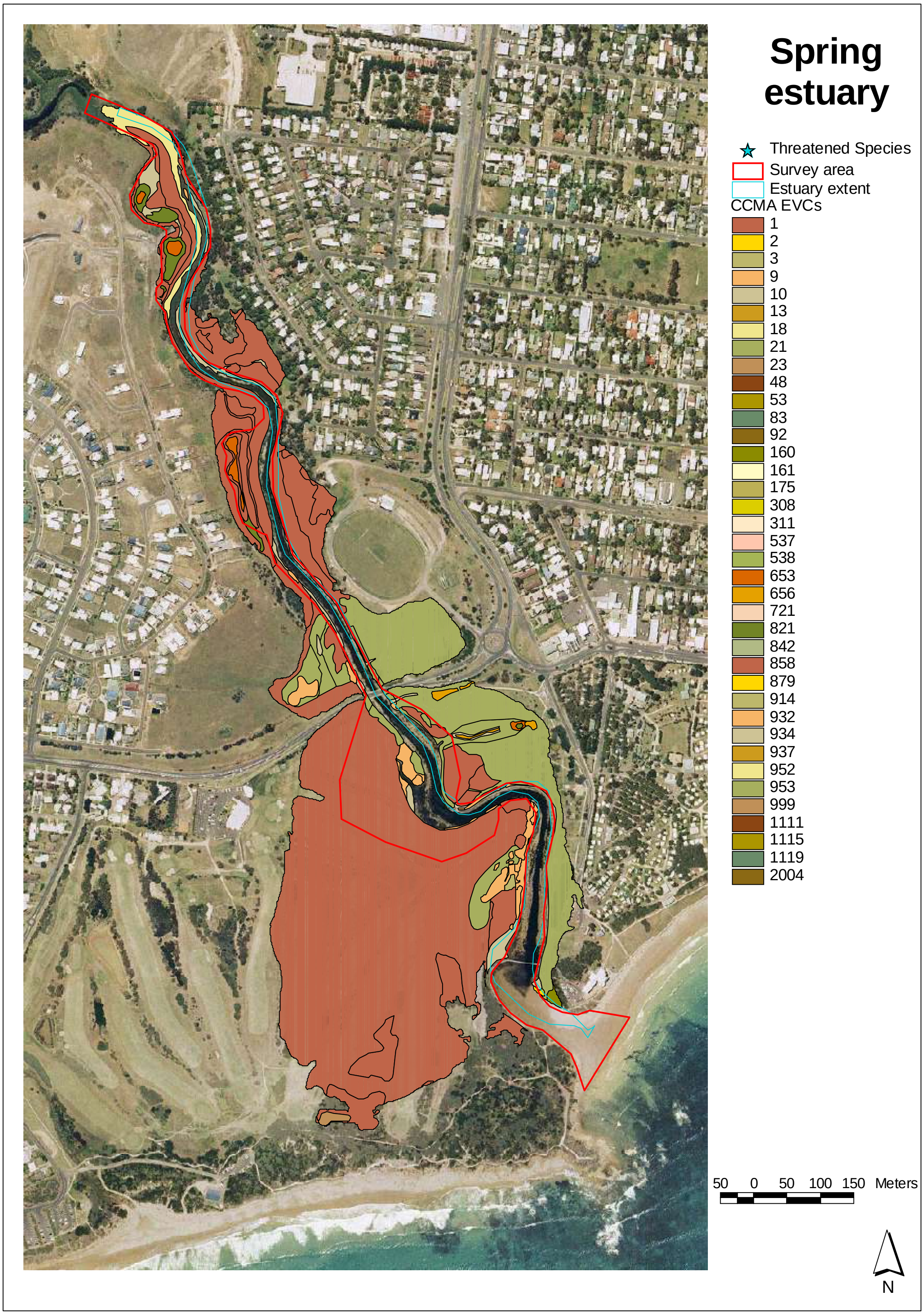
Spring estuary
Threatened Species
Survey area
Estuary extent
CCMA EVCs
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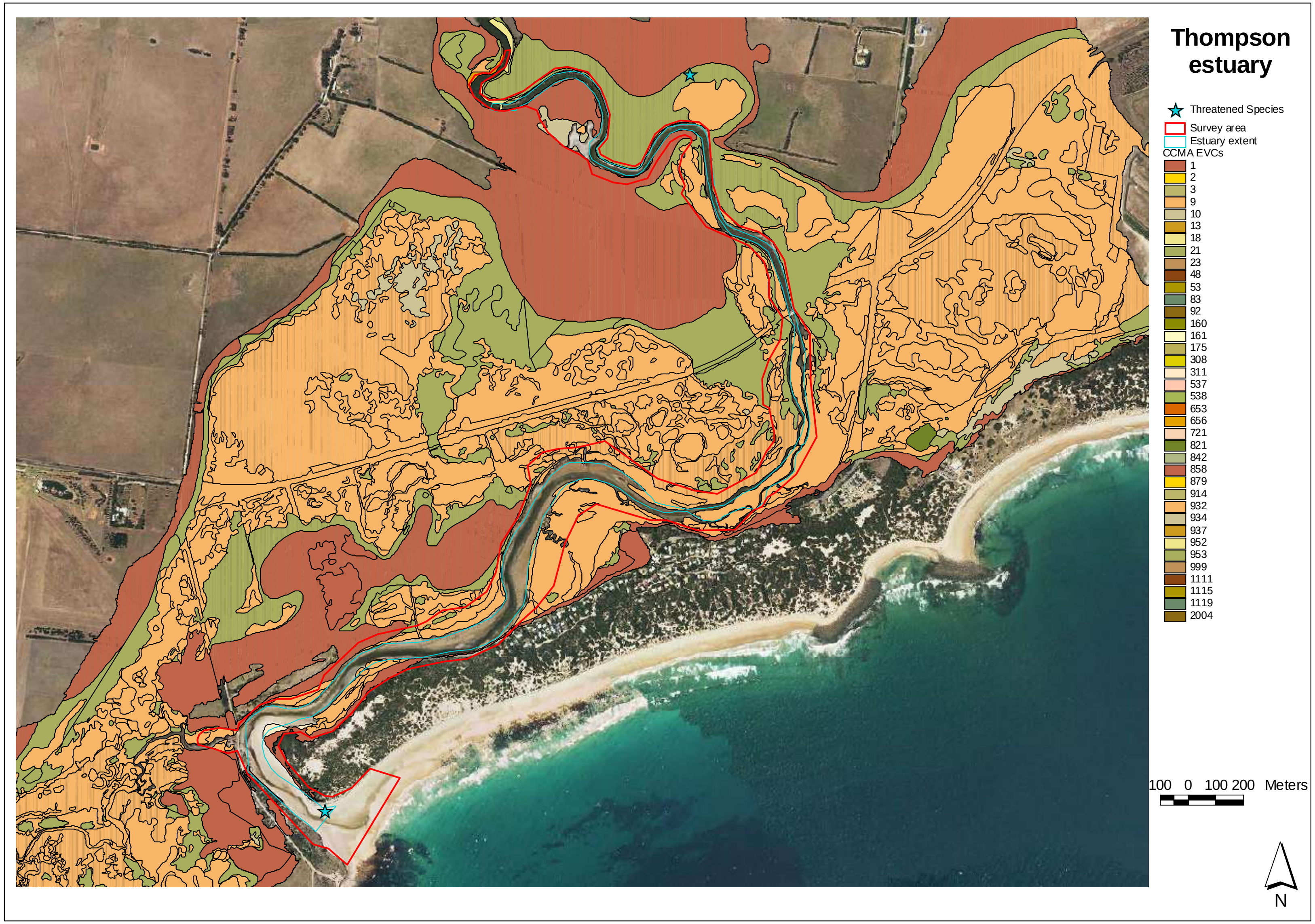
Thompson estuary
Threatened Species
Survey area
Estuary extent
CCMA EVCs
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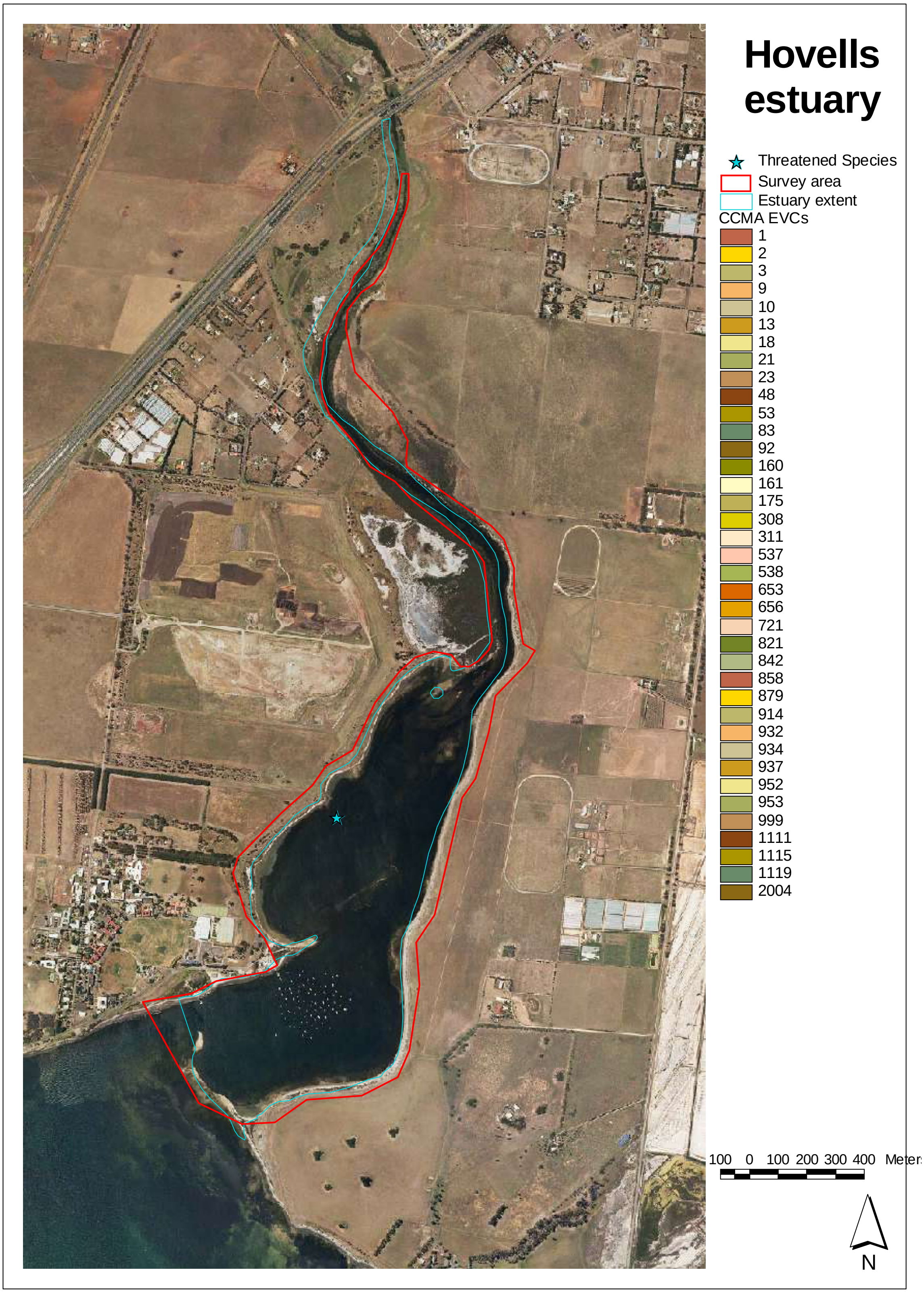
Hovells estuary
Threatened Species
Survey area
Estuary extent
CCMA EVCs
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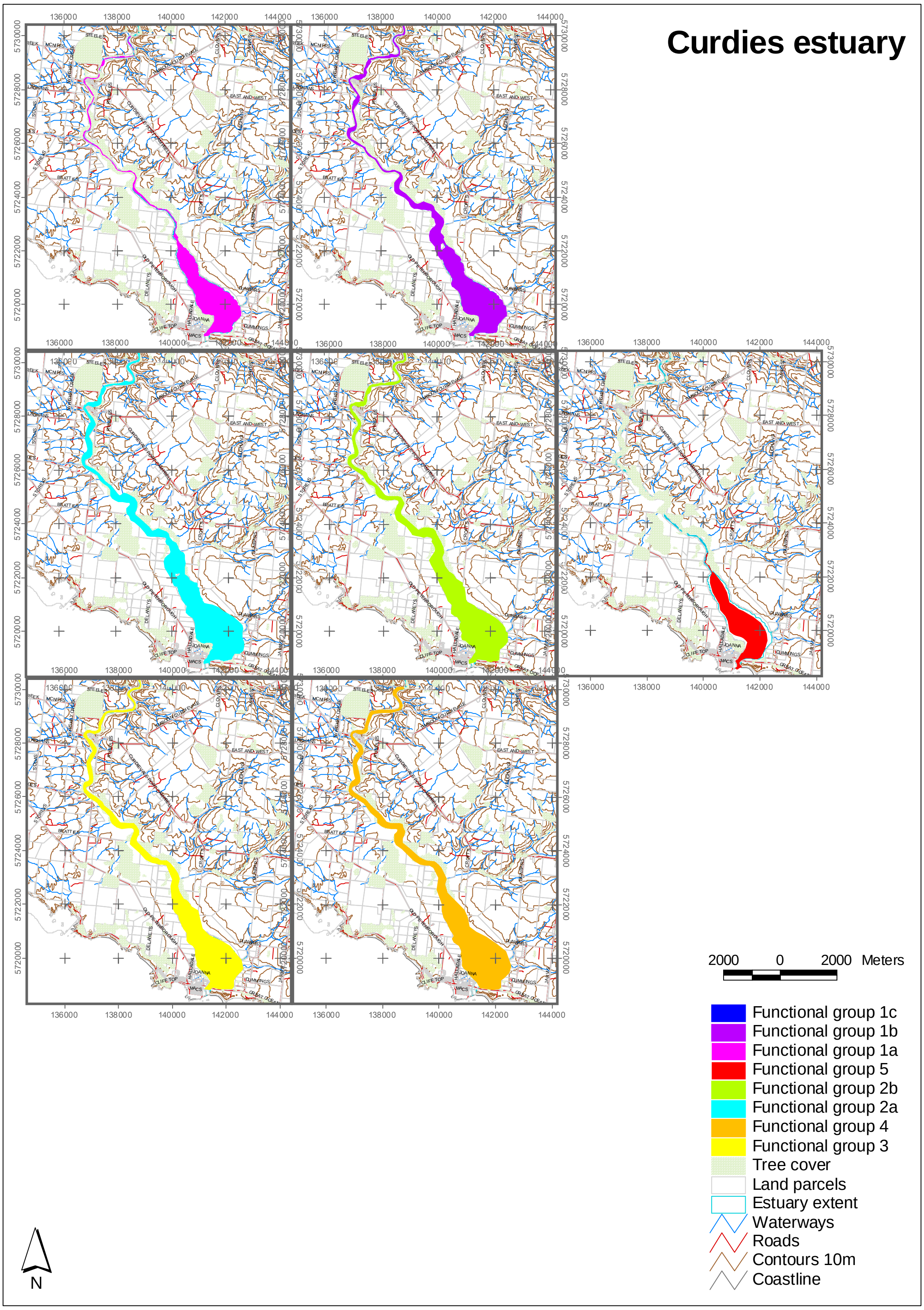
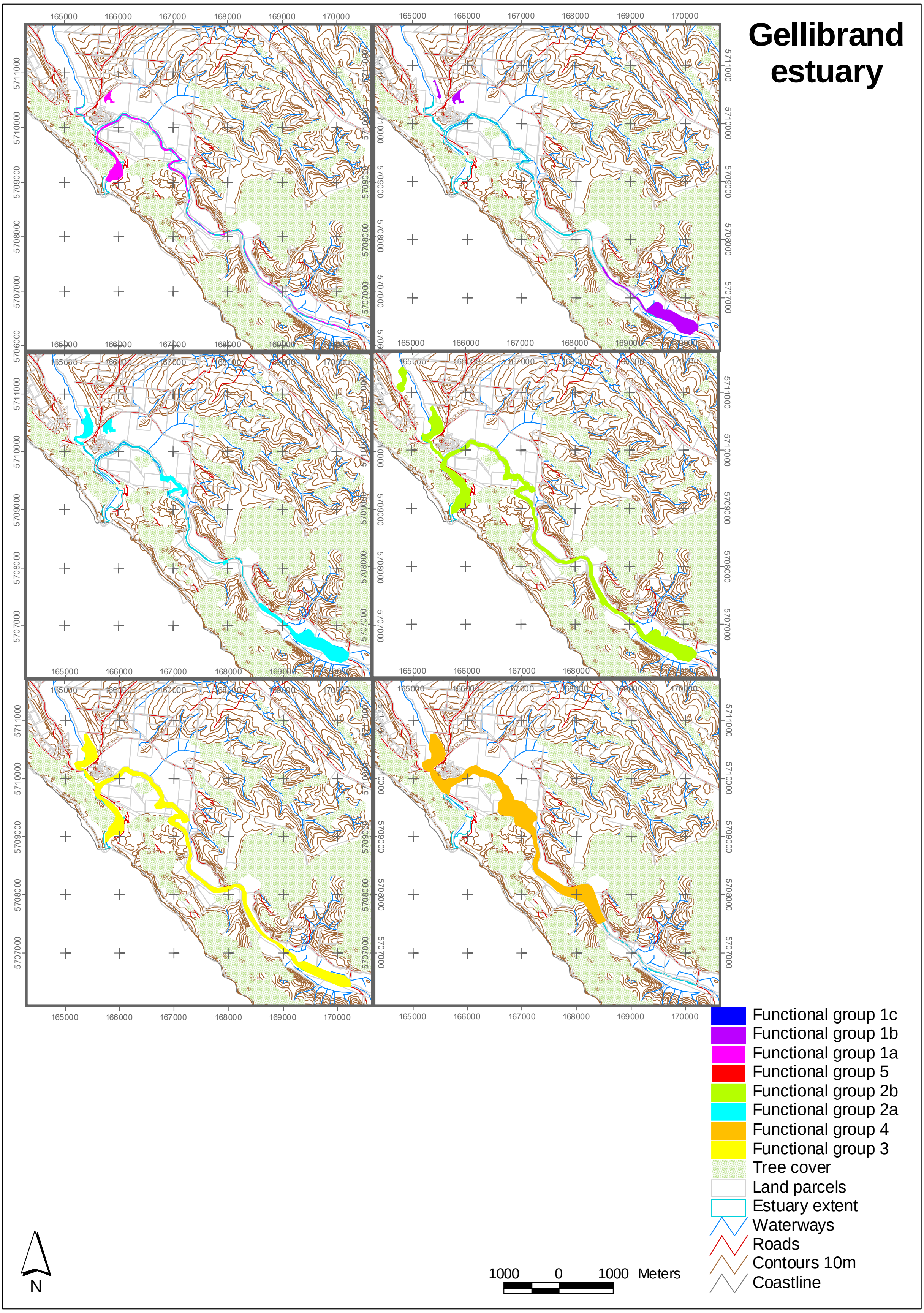
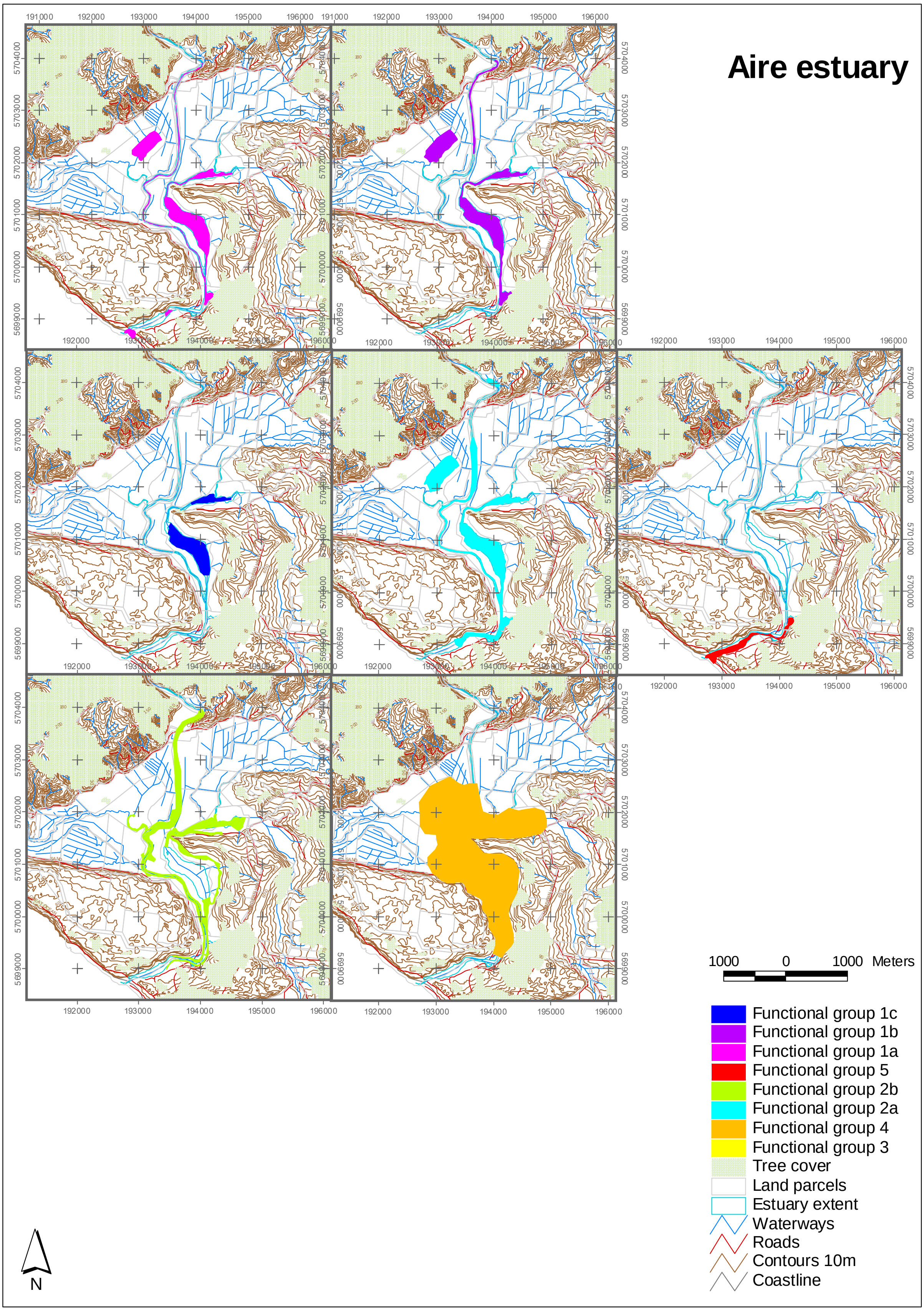
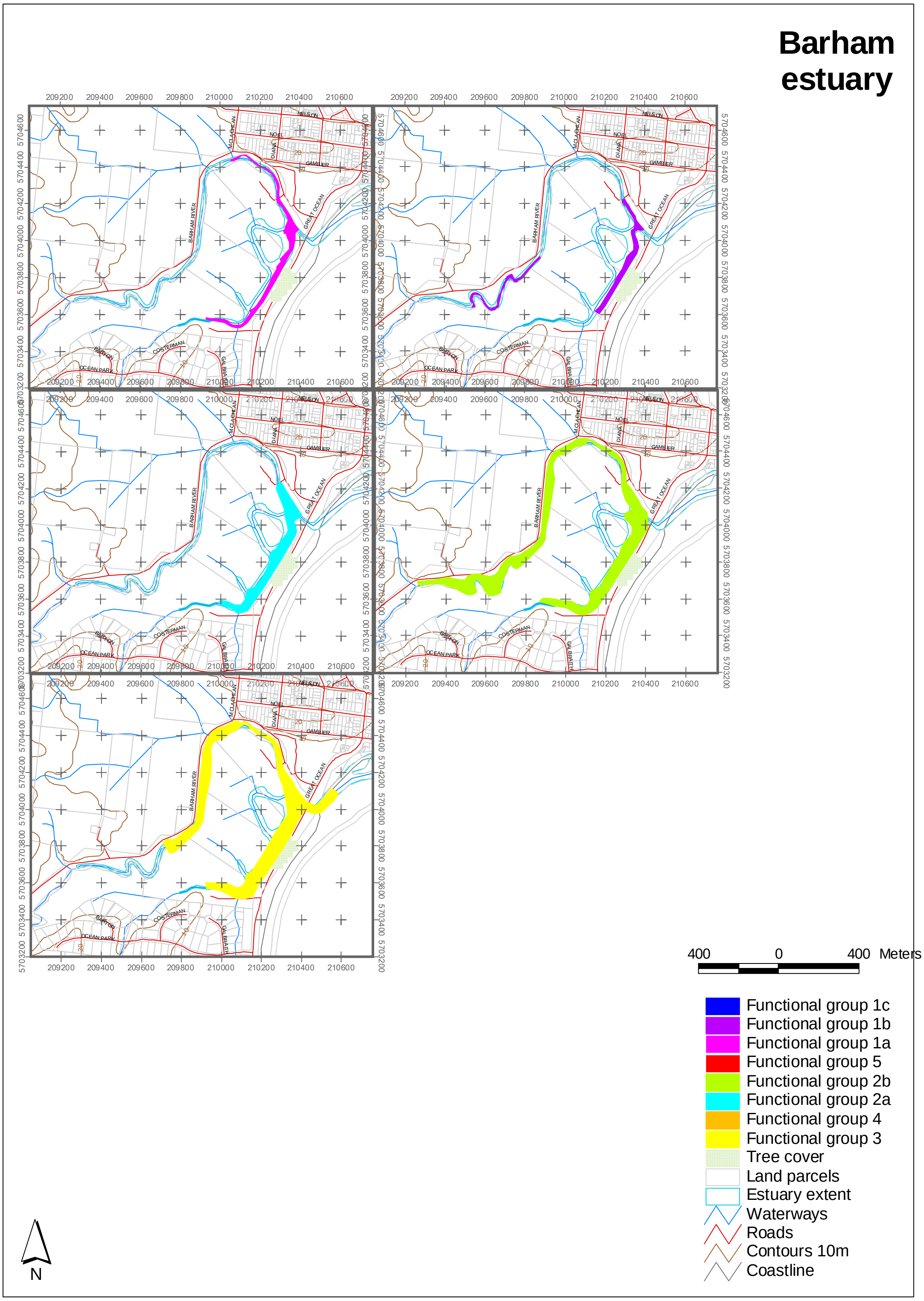
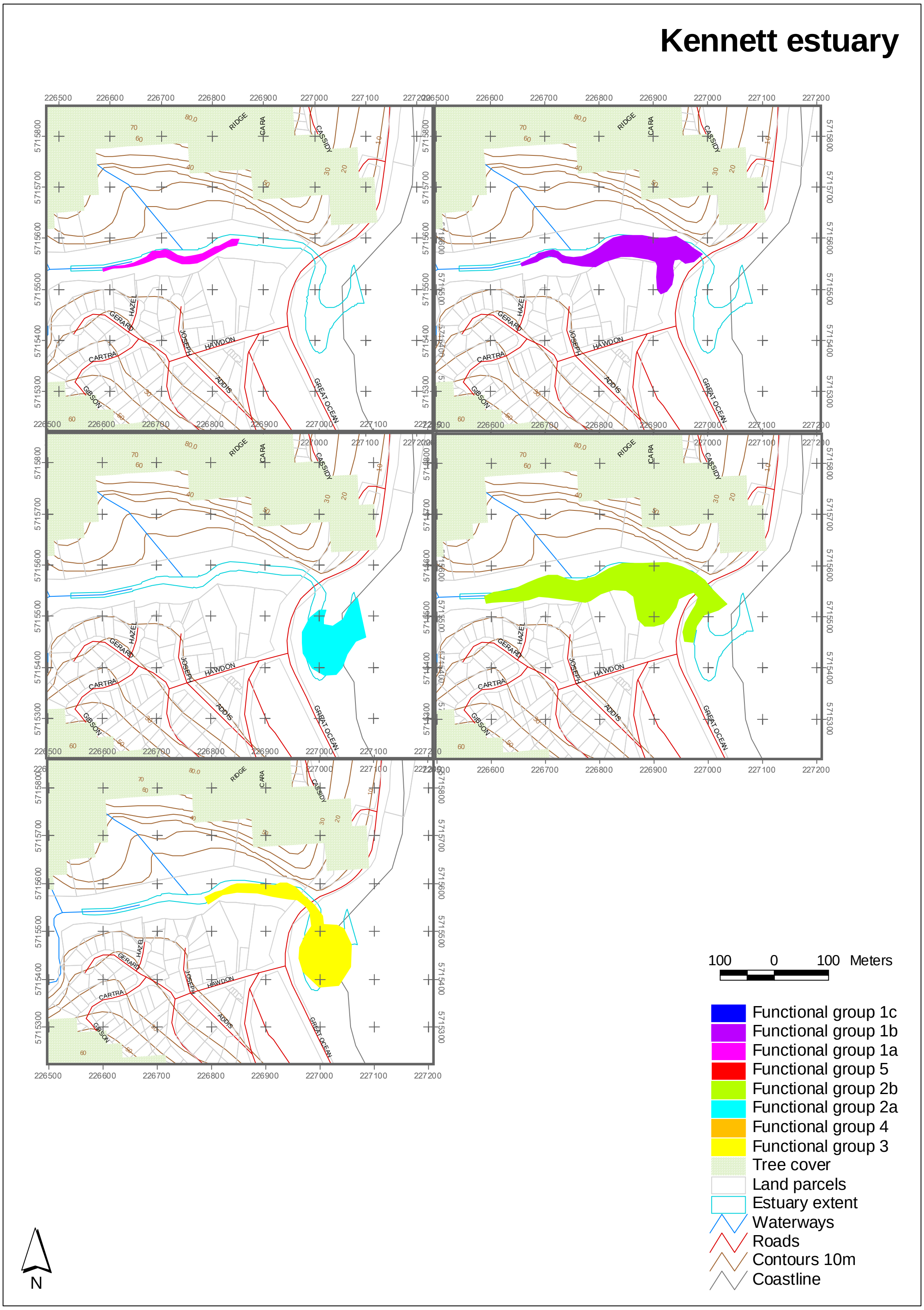
Appendix 3 Maps of the distribution of EEMSS functional groups in each estuary

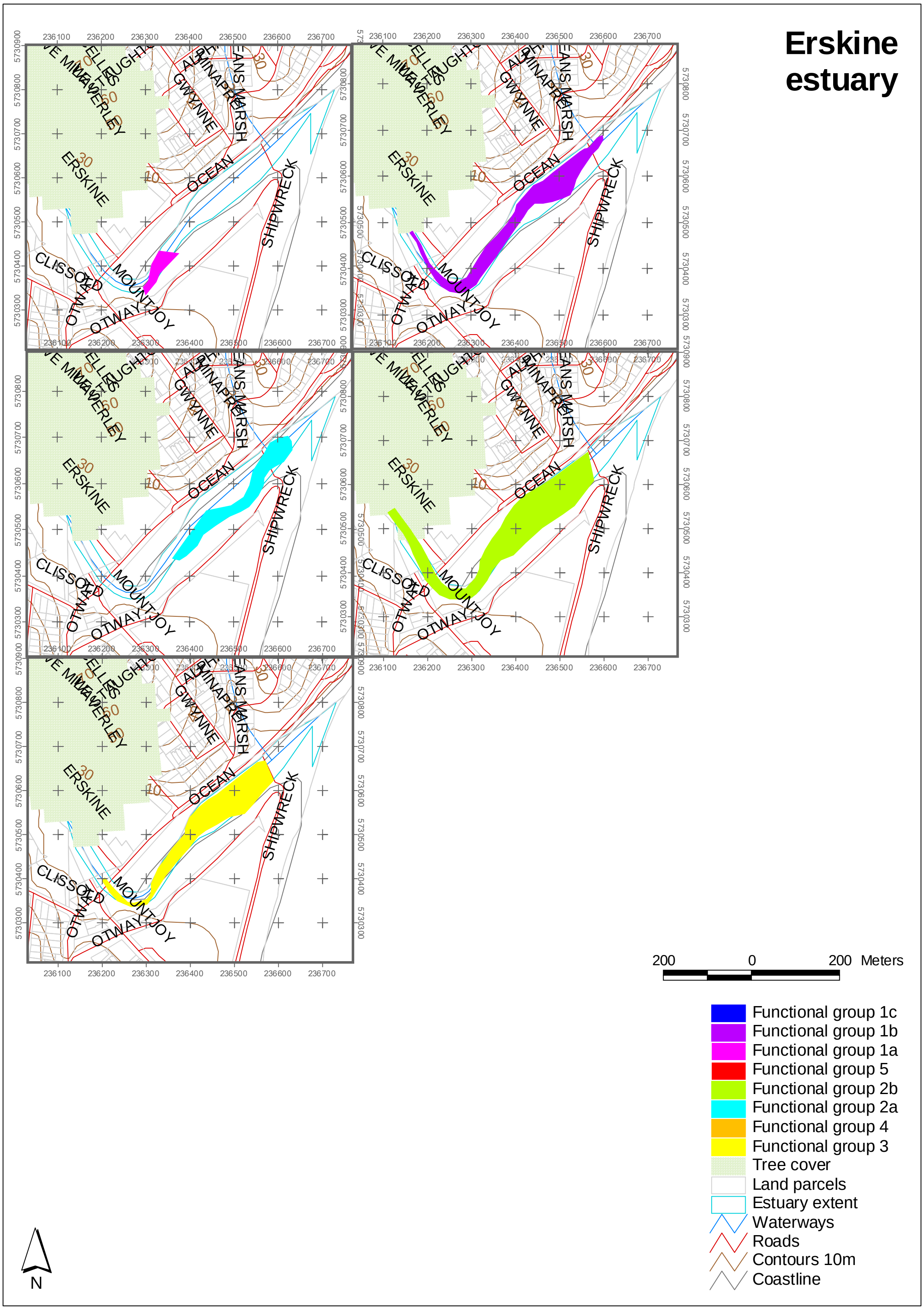


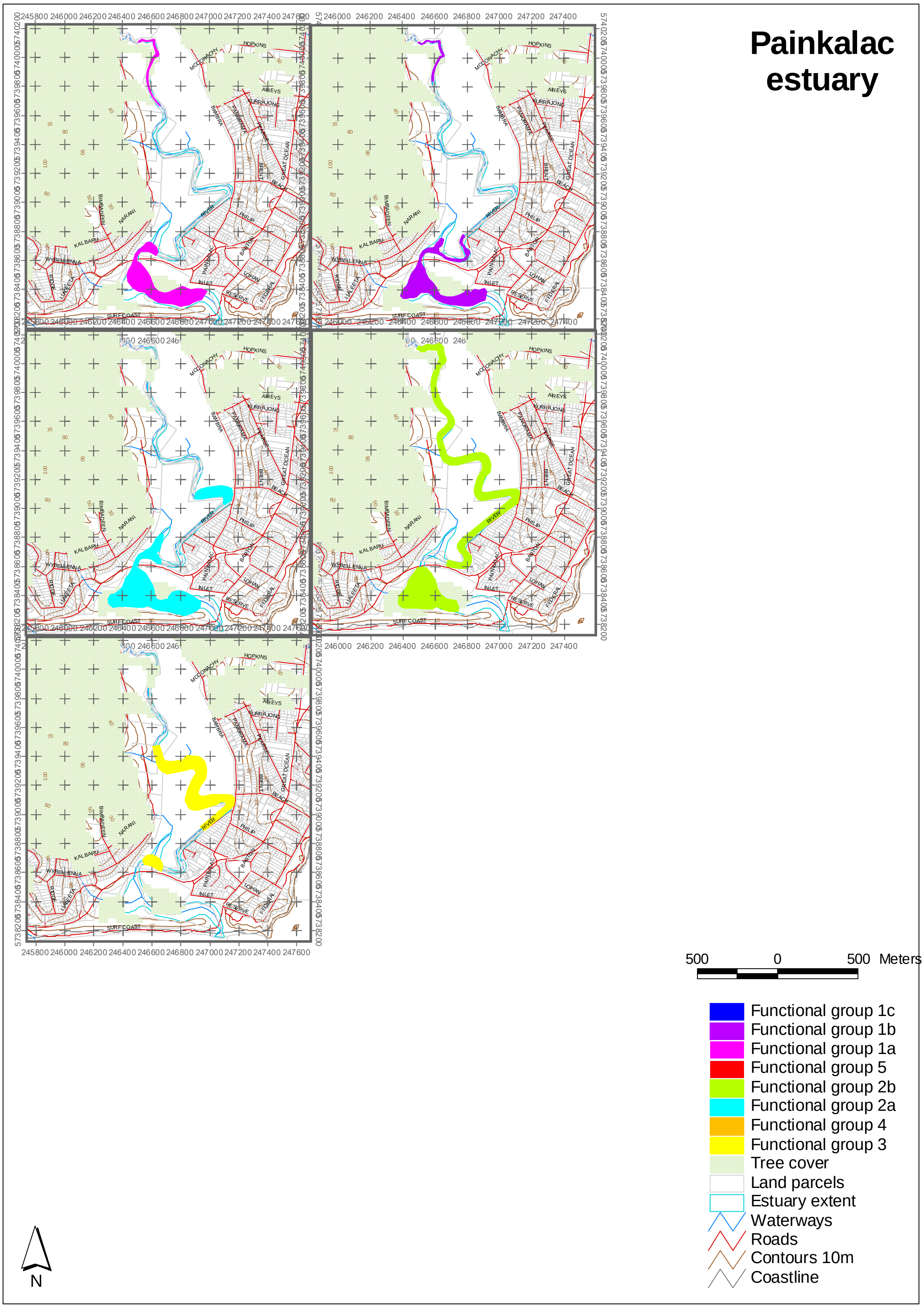

Gellibrand estuary
Functional group 1c
Functional group 1b
Functional group 1a
Functional group 5
Functional group 2b
Functional group 2a
Functional group 4
Functional group 3
Tree cover
Land parcels
Estuary extent
Waterways
Roads
Contours 10m
Coastline
N
1000 0 1000 Meters


Aire estuary
1000 0 1000 Meters
Functional group 1c
Functional group 1b
Functional group 1a
Functional group 5
Functional group 2b
Functional group 2a
Functional group 4
Functional group 3
Tree cover
Land parcels
Estuary extent
Waterways
Roads
Contours 10m
Coastline
N

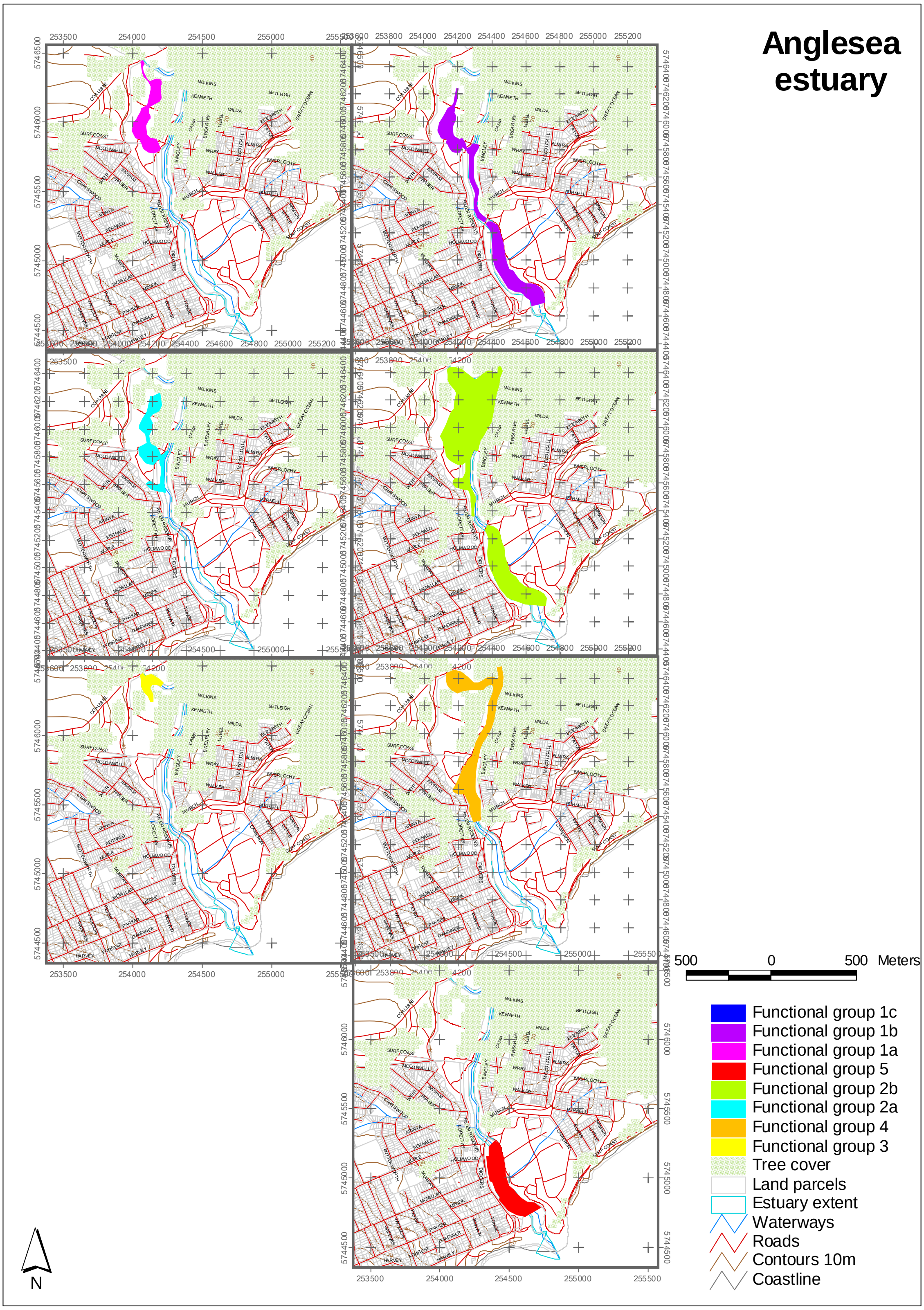

Barham estuary
400 0 400 Meters
Functional group 1c
Functional group 1b
Functional group 1a
Functional group 5
Functional group 2b
Functional group 2a
Functional group 4
Functional group 3
Tree cover
Land parcels
Estuary extent
Waterways
Roads
Contours 10m
Coastline
N

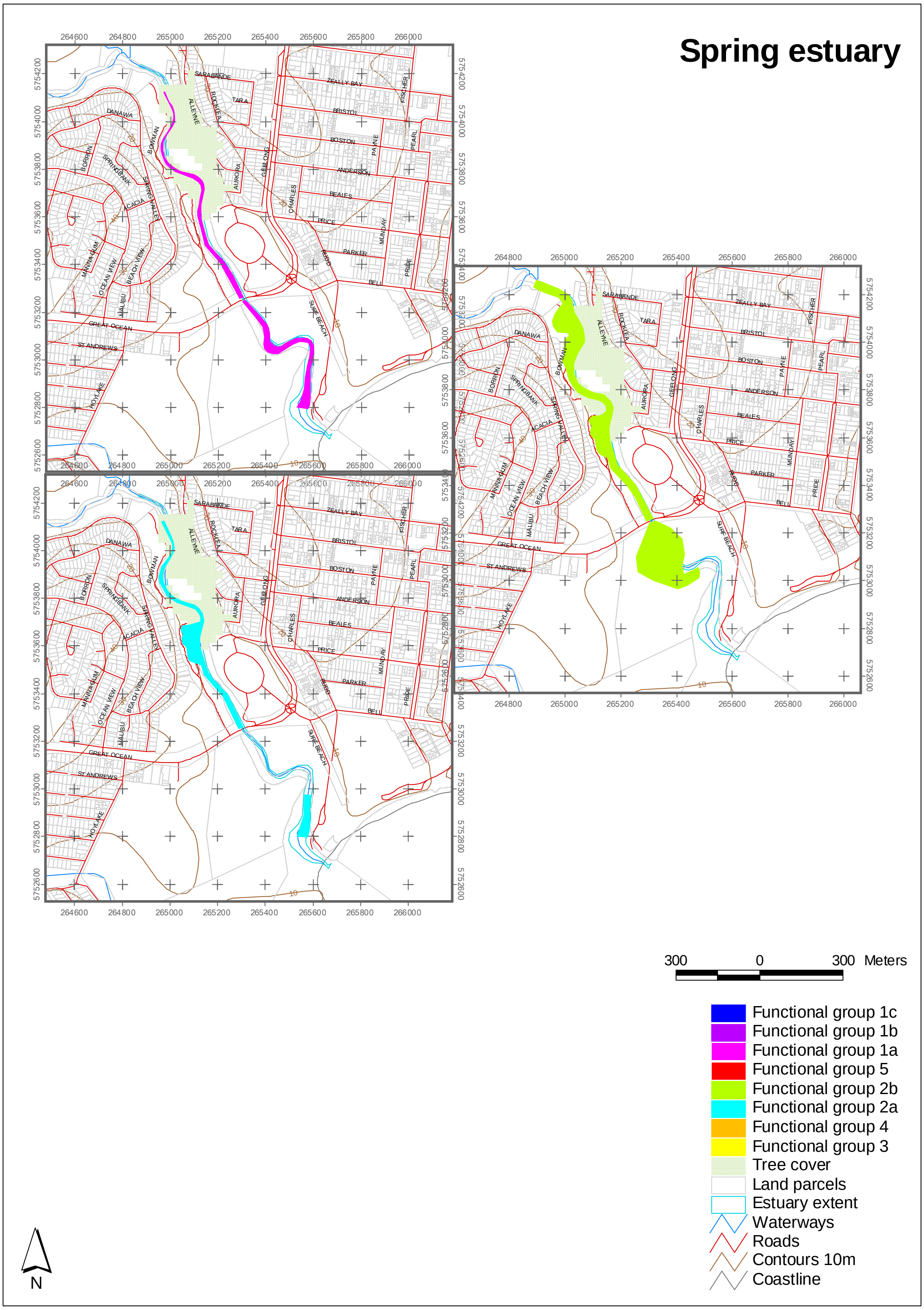

Kennett estuary
RIDGE
CARA
CASSIDY
HAZEL
GERARD
JOSEPH
HAWDON
CARTRA
GIBSON
ADDIS
GREAT OCEAN
100 0 100 Meters
Functional group 1c
Functional group 1b
Functional group 1a
Functional group 5
Functional group 2b
Functional group 2a
Functional group 4
Functional group 3
Tree cover
Land parcels
Estuary extent
Waterways
Roads
Contours 10m
Coastline
N

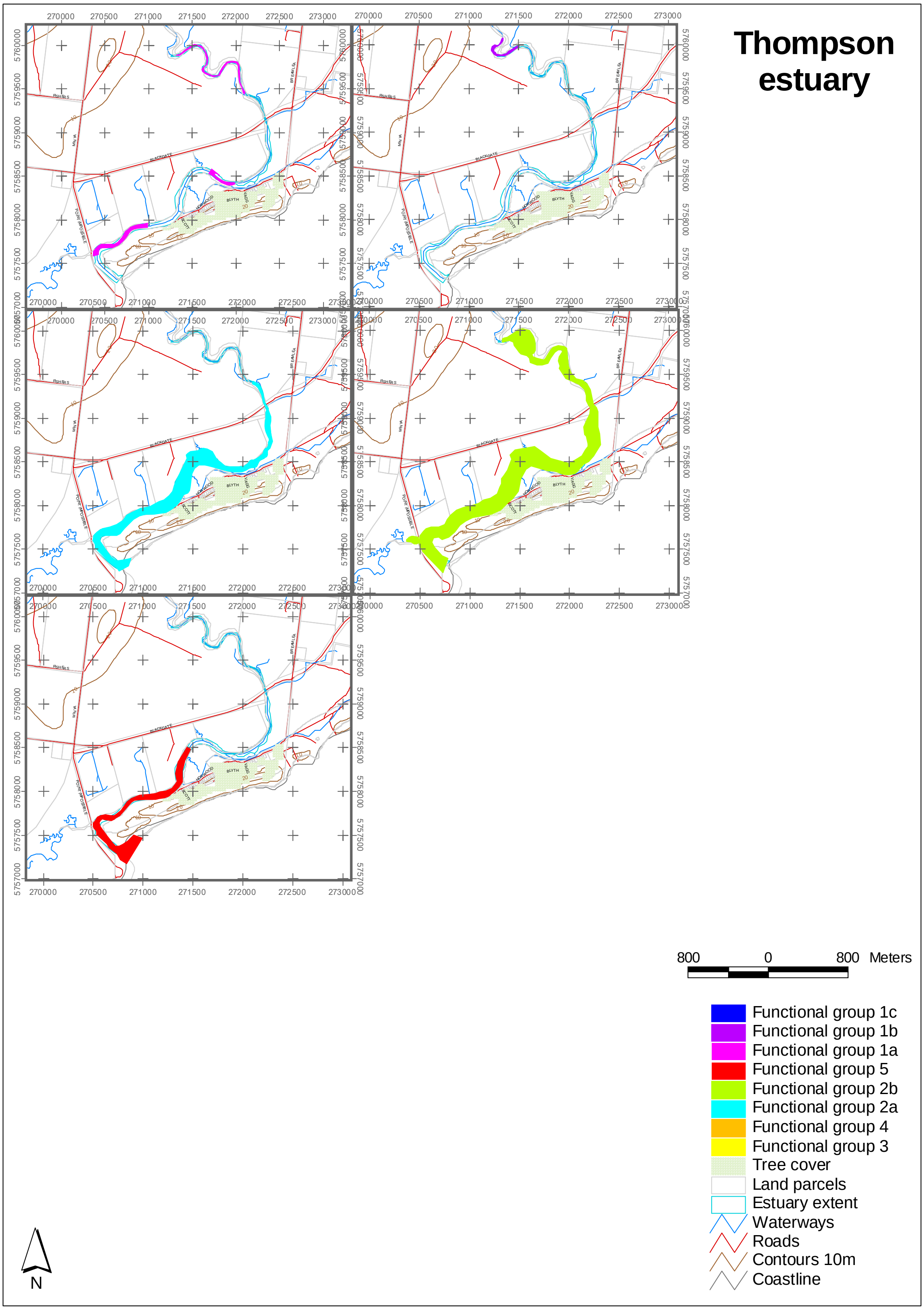

Erskine estuary
200 0 200 Meters
Functional group 1c
Functional group 1b
Functional group 1a
Functional group 5
Functional group 2b
Functional group 2a
Functional group 4
Functional group 3
Tree cover
Land parcels
Estuary extent
Waterways
Roads
Contours 10m
Coastline
N
ERSKINE
OCEAN
SHIPWRECK
CLISSOLD
MOUNTJOY
OTWAY
GWYNNE

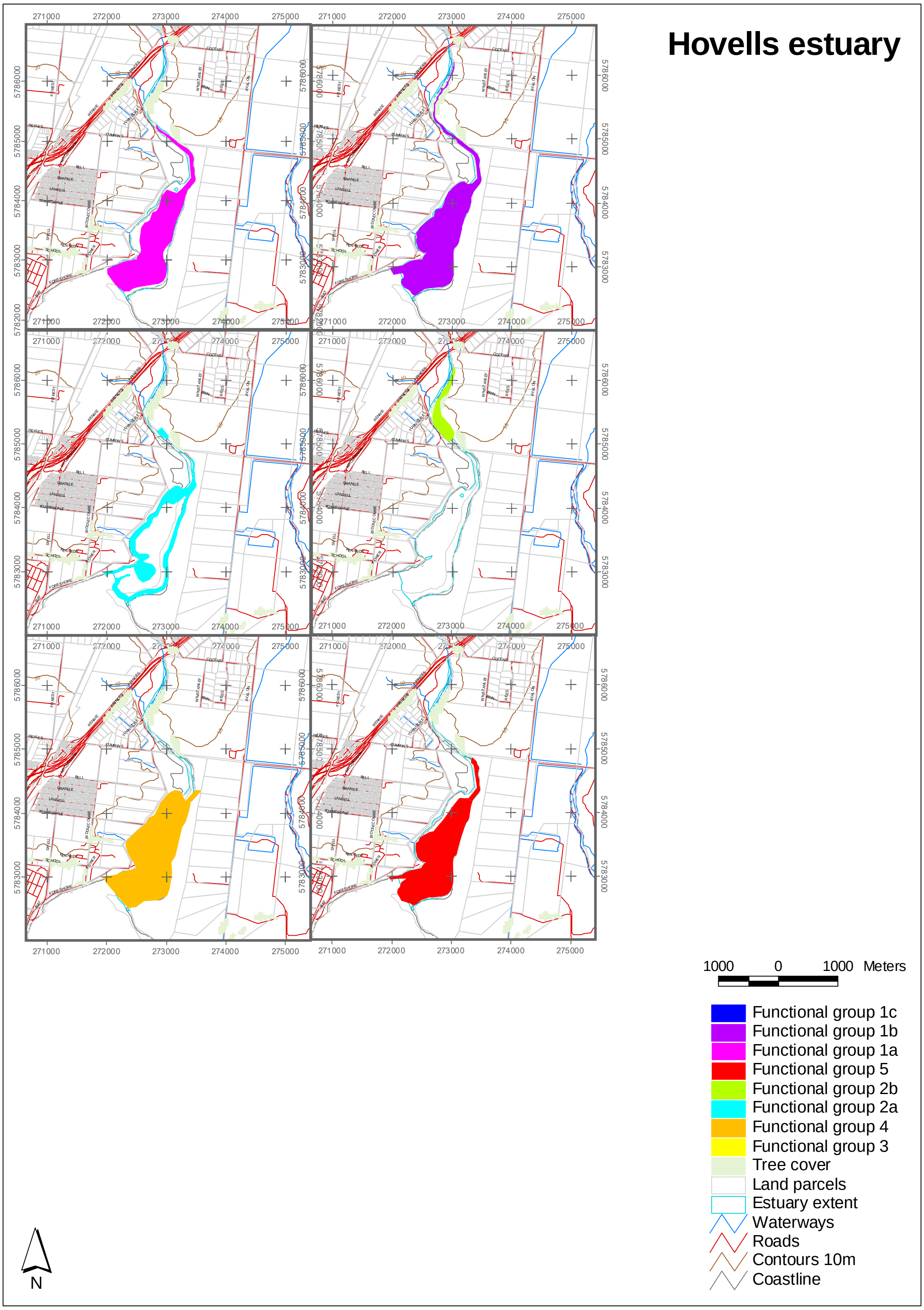


Painkalac estuary
500
0
500 Meters
Functional group 1c
Functional group 1b
Functional group 1a
Functional group 5
Functional group 2b
Functional group 2a
Functional group 4
Functional group 3
Tree cover
Land parcels
Estuary extent
Waterways
Roads
Contours 10m
Coastline
N


Anglesea estuary
500 0 500 Meters
Functional group 1c
Functional group 1b
Functional group 1a
Functional group 5
Functional group 2b
Functional group 2a
Functional group 4
Functional group 3
Tree cover
Land parcels
Estuary extent
Waterways
Roads
Contours 10m
Coastline
N


Spring estuary
300
0
300 Meters
Functional group 1c
Functional group 1b
Functional group 1a
Functional group 5
Functional group 2b
Functional group 2a
Functional group 4
Functional group 3
Tree cover
Land parcels
Estuary extent
Waterways
Roads
Contours 10m
Coastline
N


Thompson estuary
800
0
800 Meters
Functional group 1c
Functional group 1b
Functional group 1a
Functional group 5
Functional group 2b
Functional group 2a
Functional group 4
Functional group 3
Tree cover
Land parcels
Estuary extent
Waterways
Roads
Contours 10m
Coastline
N


Hovells estuary
1000 0 1000 Meters
Functional group 1c
Functional group 1b
Functional group 1a
Functional group 5
Functional group 2b
Functional group 2a
Functional group 4
Functional group 3
Tree cover
Land parcels
Estuary extent
Waterways
Roads
Contours 10m
Coastline
N

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