The Living Murray Initiative: Lindsay-Mulcra-Wallpolla Islands and Hattah Lakes Icon Sites 2006-7 condition monitoring program data.

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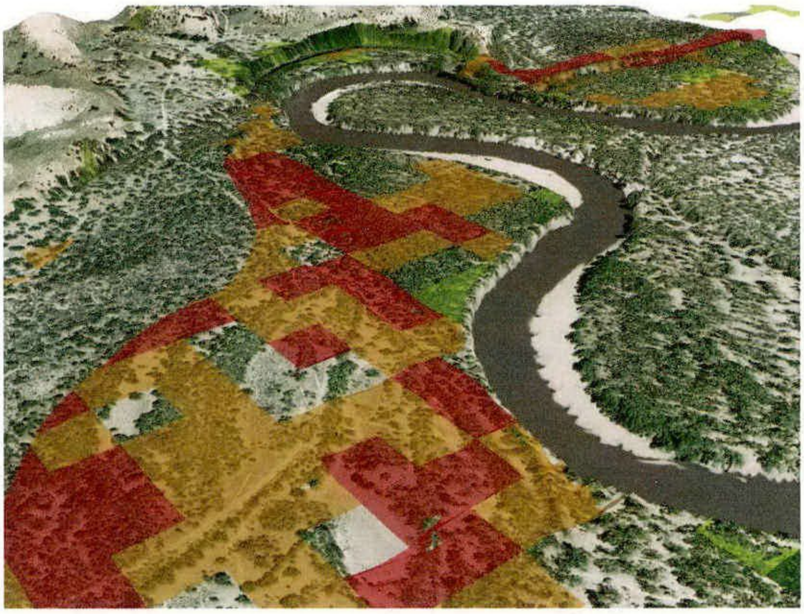

Murray-Darling Freshwater Research Centre
Lower Basin Laboratory

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Report prepared for the Mallee Catchment Management Authority.

The Murray-Darling Freshwater Research Centre

CSIRO

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Cover: Change in river red gum cover between 2003 and 2006 for a section of Hattah Lakes as determined from NDVI remote sensing (Aerometrex Pty Ltd and Sunrise 21 Inc.).

Summary

The ecological condition of many Murray River floodplain ecosystems has suffered as a consequence of changes to their flow regime. The Living Murray Initiative (TLM) aims to return the Murray River system to a healthy working river through the delivery of environmental flows to six 'Icon Sites'. The ability to deliver these flows and to demonstrate environmental benefits during the life time of TLM (2002-2012) will involve both on-ground structural works and the implementation of long-term monitoring programs.

Two Icon Sites occur within the Mallee Catchment Management Authority (CMA) region; the Victorian component of the Chowilla Floodplain comprising Lindsay-Mulcra-Wallpolla Islands (LMW), and Hattah Lakes (HL). Monitoring of these Icon Sites is being undertaken at two different scales; Icon Site (*i.e.* condition monitoring) and sub-Icon Site (*i.e.* intervention monitoring). In contrast to intervention monitoring, condition monitoring makes no attempt to demonstrate cause-and-effect relationships with managed changes in flows but rather attempts to provide a 'snap-shot' of community/population condition. Ensuring the consistency of objectives, experimental design and methods employed for monitoring at these scales between each of the Icon Sites within the Murray-Darling Basin will provide the best means for assessing the overall system scale efficacy of environmental flow allocations under TLM.

A condition monitoring program was designed that is capable of testing key objectives developed for vegetation (wetland and terrestrial assemblages, river red gums, black box, lignum and cumbungi), fish and waterbird communities/populations within the LMW and HL Icon Sites (refer to Scholz *et al.* 2007a). Condition assessments focus on determining species diversity, abundance, spatial distribution, population structure (*e.g.* whether recruitment is occurring) and 'health' (*e.g.* 'greenness' for trees and lignum).

Here we present the condition monitoring data collected during the 2006-07 reporting period for vegetation, fish and birds from the LMW and HL Icon Sites. This initial 'snapshot' of Icon Site biotic condition provides the basis against which future changes and the achievement of TLM targets can be assessed. Key outcomes and recommendations for the current reporting period include the following:

Wetland and terrestrial vegetation assemblages

Condition assessment protocols for wetland and terrestrial understorey vegetation and the identification of wetland sites within the LMW Icon Site were finalised in March 2007, too late for their implementation during the current reporting period. Condition monitoring within the LMW Icon Site will commence during late 2007-early 2008. Nine wetland sites were surveyed within the HL Icon Site during current reporting period as part of the TLM intervention monitoring program. The results of this initial survey, which will be used as the initial condition assessment, have been presented in a separate document.

River red gums and black box

Assessing the viability of river red gum (RRG) and black box (BB) communities within the LMW and HL Icon Sites involved quantifying their distribution, population age structure and crown condition.

Community distribution ranges were examined using existing GIS vegetation layers. As it is not feasible within the context of TLM to re-survey these boundaries at regular intervals, it will not be possible to examine temporal shifts in community distributions.

RRG and BB population size (*cf.* age) classes were neither uniformly distributed throughout the surveyed distribution range or population elevation ranges. Although size class frequency structures varied greatly between RRG sites at both Icon Sites, small trees (<10 cm DBH; trunk diameter at breast height) were generally associated with localised depressions throughout the population elevation range and concentrated at lower elevations. In contrast, the population size class frequency structures of BB within both Icon Sites were dominated by mature individuals (between 10 cm and 50 cm DBH) and, in all but one site surveyed, the relative paucity of smaller trees (<10 cm DBH).

These data suggest that whilst the potential for regeneration is greater for RRGs than it is for BB, these communites may not be viable across their current distribution ranges, and that their ranges are at risk of contracting to lower elevations over the longer term as a consequence of reductions in flood return frequencies and magnitudes.

Tree condition was assessed as crown condition (*i.e.* chlorophyll concentration signatures) for momentary ('snap shot') assessments and as changes in canopy cover (*cf.* density) for comparisons between time intervals using Normalised Difference Vegetation Index (NDVI) analyses of aerial images captured during 2003 and 2006.

Within the LMW Icon Site, crown condition was greatest during 2003 within Mulcra and the western half of Wallpolla Islands. By 2006, the condition of these areas had declined. For the Hattah system, RRG condition tended to decline with distance from either the Murray River or Chalka Creek, and this gradient increased between 2003 and 2006. Whilst variations in the condition of BB within the HL Icon Site were patchier than that determined for RRGs, one area adjacent to the Murray River within the Kulkyne Park, especially, was identified as being most stressed during 2003. By 2006, the condition of this area had increased.

Within the LMW Icon Site, canopy cover increased in 25.1% and 21.3 % of total RRG and BB areas, respectively, and decreased in 21.4% and 20.1% of total RRG and BB areas, respectively. For RRG, most increases in canopy cover occurred in areas adjacent to anabranch channels (Lindsay River, Mullaroo Creek, the lower half of Potterwalkagee Creek, and Wallpolla Creek). For BB, most increases in BB canopy cover occurred within the area bound by the Murray River, Lower Lindsay River and Mullaroo Creek of Lindsay Island. Of the three Islands, Mulcra Island was most impacted by declines in both RRG and BB canopy cover. Elsewhere, significant decreases in RRG canopy cover were identified within Lindsay Island in areas adjacent to the Murray River and the upper reaches of the Upper Lindsay River. Decreases in BB canopy cover were identified within the eastern half of Wallpolla Island and, to a lesser extent within Lindsay Island in areas adjacent to the Murray River.

Within the HL Icon Site, canopy cover increased in 16.6% and 14.4% of total RRG and BB areas, respectively, and decreased in 22.7% and 21.1% of total RRG and BB areas, respectively. Increases in RRG canopy cover were concentrated in areas near the confluence of Chalka Creek (north arm) and Murray River and for both RRG and BB within the Kulkyne Park. Decreases in RRG canopy cover were identified along the Murray River downstream of Chalka Creek (south arm), in areas adjacent to Chalka Creek and to the north-west of Lake Hattah. Decreases in BB canopy cover were patchier and distributed thoughout the Icon Site.

As change-in-NDVI canopy cover images are derivative functions of successive temporal images, their interpretation requires that differences in initial canopy cover between localities be considered. In the absence of separate NDVI canopy cover images for each time interval, current assessments were based on the available NDVI crown condition images. The NDVI-based assessments presented here will be validated by field surveys during the next reporting period.

Normalised Difference Vegetation Index (NDVI) analyses allow for the identification of both momentary crown condition and changes in canopy cover between time periods. These provide an integrated measure of community 'health' and, together with measures of distribution and community structure, the capcity to address TLM targets. Whilst outside the scope of the current condition monitoring program, this approach also allows for the identification of areas of potential management concern and offers the capacity to more effectively target the delivery of environmental flows.

Lignum

Lignum condition was assessed at sites distributed across the elevation range occupied by lignum within the LMW and HL Icon Sites. At most sites within the LMW Icon Site, generally less than 50 % of the above ground biomass of individual plants was alive, and there was little evidence of recent growth. The exceptions to this were plants at sites situated at the lowest and most recently inundated elevations where generally more than 95 % of above ground biomass was alive and the plants showed signs of recent growth. A similar relationship between plant condition and elevation was apparent within the HL Icon Site, albeit weaker due to a flush of new growth at all sites stimulated by rainfalls shortly prior to the survey.

Because of its tuberous habit, lignum is more resilient to desiccation stress than momentary measures of above ground condition alone would suggest. Given the difficulties associated with mapping distribution ranges (*cf.* RRG and BB) and determining population age structures, population viability is being assessed as the resilience of established individuals to dry periods, *i.e.* the capacity to recover following flooding or significant rainfall. During the current survey, 15.3 % and 0.7 % of the plants examined within the LMW and HL Icon Sites showed no visible signs of life. Future annual surveys will establish the viability of these and the other plants, and thus of the exant lignum populations at both Icon Sites.

Cumbungi

Cumbungi is a potential threat to aquatic ecosystems throughout the Mallee region due to its vigorous growth, and its ability to both displace other plant species and to reduce the hydraulic capacity of floodplain channels and flood runners.

Field surveys indicated that cumbungi was present in all flow habitats surveyed within the LMW Icon Site and the adjacent 'impounded' sections of the Murray River. Greatest stand densities were encountered within the smaller slow flowing anabranches and flood runners, with sections of the Upper Lindsay River and Potterwalkagee Creek, especially, currently completely obstructed by cumbungi. In contrast, no cumbungi was observed within the HL Icon Site and adjacent 'free flowing' section of the Murray River.

In addition to annual condition assessments of changes in cumbungi distribution, rates of stand expansion are being examined as part of concurrent TLM intervention monitoring at two sites (Webster's Lagoon and Potterwalkagee Creek). As cumbungi has the capacity to grow in water up to 2 m deep, we recommend the incorporation of longitudinal measures of channel morphometry (width, maximum depth) within the condition monitoring program to facilitate the identification of narrow/shallow reaches most at risk of hydraulic obstruction by cumbungi.

Fish

The current fish surveys of both the LMW and HL Icon Sites indicated the presence of recent recruits (*i.e.* young-of-the-year) in most small bodied native fish species, suggesting that these populations are sustainable into at least the next spawning season; September-April. However, no recent recruits of Murray cod or golden perch were encounterd in either Icon Site. Whilst local annual spawning and larval recruitment is not necessary to maintain the viability of populations of large bodied, longer lived species, suitable local spawning conditions will be required in the medium term (1-3 years), especially where rates of immigration are low.

Based on considerations discussed in Section 3, the following actions are recommendaed to increase the overall effectiveness of the monitoring initiative and the management of key icon fish species:
- Implement sampling gear targeting larvae,
- Incorporate macro- and microhabitat assessments as part of the condition assessment,
- Incorporate otolith based aging of juvenile golden perch to more accurately identify spawning dates and recruitment events, and
- Investigate fish movements at a range of spatial scales (*i.e.* between micro- and macrohabitats and Icon Sites).

Birds

Condition assessment protocols for birds were developed in early 2007, too late for their implementation during the current reporting period. In conjunction with the commencement of monitoring, which is planned for late spring 2007, we recommend that a review of existing long term waterbird data sets be initiated to provide a larger spatial context within which collected Icon Site data sets and the assessment of TLM targets may be interpreted.

1 Introduction

The ecological condition of many Murray River floodplain ecosystems is widely believed to have suffered as a consequence of changes to their flow regime (*e.g.* Margules *et al.* 1990, MDBC 2002a,b). The Living Murray Initiative (TLM), established in 2002, aims to return the Murray River system to a healthy working river through the annual delivery of 500 GL of environmental flows designed to achieve ecological objectives at six Icon Sites along the Murray River: Barmah-Millewa Forests, Gunbower-Koondrook-Pericoota Forests, Hattah Lakes, Chowilla Floodplain (including the floodplain components Lindsay, Mulcra and Wallpolla Islands), the Murray Mouth (including the Coorong and the Lower Lakes), and the River Murray Channel (Figure 1.1). The restoration of each of these Icon Sites through the provision of environmental flows and the management of key identified threats is to be achieved through the development of Icon Site Water Management Plans, part of which will involve both on-ground structural works and the implementation of long-term monitoring programs capable of demonstrating environmental benefits during the life time of TLM (2002-2012).

Two Icon Sites occur within the Mallee Catchment Management Authority (CMA) region; the Victorian component of the Chowilla Floodplain comprising Lindsay, Mulcra and Wallpolla Islands (LMW), and Hattah Lakes (HL). LMW extends from 40 km west of Mildura to the South Australian border. Lindsay Island lies within the Murray-Sunset National Park and is bounded by the Murray River and the Lindsay River anabranch. Mulcra Island State Forest lies between Lindsay and Wallpolla islands and is bounded by the Murray and the Potterwalkagee Creek anabranch. Wallpolla Island State Forest, also an anabranch of the Murray River, is bounded by the Murray River and by Wallpolla Creek. The Hattah Lakes Icon Site, which lies within the Hattah-Kulkyne National Park, is located adjacent to the Murray River 70 km upstream of Mildura.

Monitoring of Icon Sites within the Mallee region as part of TLM is being undertaken at two different scales; Icon Site (*i.e.* condition monitoring) and sub-Icon Site (*i.e.* intervention monitoring). In contrast to intervention monitoring, condition monitoring makes no attempt to demonstrate cause-and-effect relationships with managed changes in flows but rather attempts to provide a 'snap-shot' of community/population condition that will allow for the determination of whether pre defined condition targets are being met. To date, ecological objectives have been developed for vegetation, fish and waterbirds, and key response variables for each identified (Table 1.1). Response variable targets, whether spatially or temporally quantitative or directional, will define what constitutes a sustainable or viable assemblage or population of icon species for each Icon Site. However, specific targets for each response variable have yet to be formally defined. Once this is completed, reporting of the condition at each Icon Site in relation to set targets will be summarized as shown in Table 1.2.

Monitoring activities undertaken at both condition and intervention scales within the Mallee CMA region as part of TLM by the MDFRC LBL since late 2004 have been reported by Scholz *et al.* (2005 and 2006). Here we report on the first year of data collected as part of TLM condition monitoring programs for vegetation, fish and birds within the LMW and HL Icon Sites during 2006-07. Details regarding the design and survey methods developed for TLM condition monitoring program have been presented separately in Scholz *et al.* (2007a). Intervention scale monitoring data collected during the 2006-07 reporting period have also been presented separately in Scholz *et al.* (2007b) and McCarthy *et al.* (2007a).

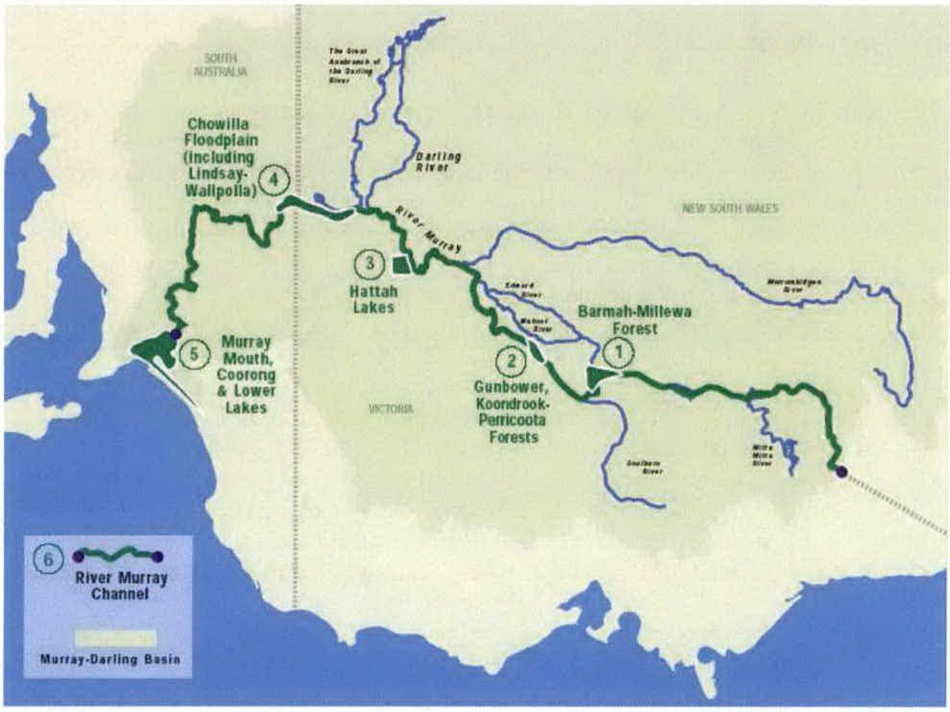


Figure 1.1: Locations of the six Living Murray Icon Sites (source Mallee CMA 2005).

Biota		Objective	Response variables
Vegetation	Assemblage	Sustainable communities of wetland aquatic and terrestrial plant assemblages.	Species diversity Relative abundance Distribution
	Species	Viable populations of river red gums, black box and lignum. Restrict spread of cumbungi.	Relative abundance Distribution Age structure/recruitment Condition
Fish	Assemblage	Sustainable communities of Murray River channel and floodplain native fish assemblages.	Species diversity Relative abundance Distribution Age structure
	Species	Viable populations of Murray cod, golden perch, and catfish. Restrict populations of common carp.	Relative abundance Distribution Age structure/spawning/recruitment
Birds*	Assemblage	Sustainable communities of colonial nesting waterbirds, waterfowl, waders and passerine birds.	Species diversity Relative abundance Distribution Breeding/recruitment
	Species	None.	None.

Table 1.1: Icon Site condition monitoring objectives and response variables identified for key biotic groups (adapted from MDBC 2006). * Objectives and response variable subject to modification as recommended by Scholz *et al.* 2007a.

Condition	Target	Action
Good	Currently satisfied	Intervention unlikely to be required during the current water year to continue to meet target.
Moderate	At borderline of satisfaction	Intervention may be required within the next 1-2 years to meet target.
Poor	Trending down	Requiring urgent action in the current season to meet the target.

Table 1.2: Categories developed for reporting of Icon Site condition for each objective/response variable (source: MDBC 2006).

2 Vegetation

2.1 Lindsay-Mulcra-Wallpolla Islands

2.1.1 Wetland and terrestrial assemblages

Condition assessment protocols and the identification of wetland sites were finalised in March 2007, too late for their implementation during the current reporting period. Condition monitoring within the LMW Icon Site will thus commence during late 2007-early 2008.

The ecological objective of maintaining viable assemblages of wetland and terrestrial vegetation within the LMW Icon Site will be assessed by quantifying species diversity and their relative abundances and elevational distributions using the methods described by (Scholz *et al.* 2007a) at targeted wetlands (Table 2.1.1) and permanent floodplain sites identified using satellite imagery and GIS models (*e.g.* RiM FIM, DTM). Such assessments are to be made during mid-late summer each year to standardise for season and to incorporate the peak growing period for many species (January-February; *cf.* Mitchell and Rogers 1985).

Location	Wetland
Lindsay Island	Crankhandle Billgoes Billabong Bottom Island Upper Lindsay Wetland Complex Webster's Lagoon Upper Mullaroo Wetland Complex
Mulcra Island	Breached dam site
Wallpolla Island	-none identified-

Table 2.1.1: Wetlands within the LMW Icon Site targeted for assessments of vegetation condition.

2.1.2 River red gums

Distribution

Five Ecological Vegetation Classes (EVCs) were recognised for river red gums (*Eucalyptus camaldulensis* Dehnh. Myrtaceae) (RRG) by White *et al.* (2003). These were reduced for current assessment to three water regime classes ranging from highest to lowest inundation frequency: Red Gum Forest (RGF), Fringing Red Gum Woodland (FRGW), and Red Gum with Flood Tolerant Understorey (RGFTU) (*cf.* Ecological Associates 2006 and Scholz *et al.* 2007a). The distribution and area (ha) of each of these vegetation classes within the LMW Icon Site were examined using GIS layers available for each EVC.

The distribution of each RRG class throughout the LMW Icon Site is shown in Figures 2.1.1-2.1.3. RRG communities cover a combined area of 8,709 ha (Table 2.1.2). RGF (12.23 % of total RRG cover) is largely restricted to the inside bends of the Murray River, where littoral elevations are lower relative to the outside bends of meanders and hence more prone to inundation. FRGW (87.64 % of total RRG cover) occupies lower lying areas of the floodplain surrounding water courses and wetlands. RGFTU accounted for < 0.13 % of the total RRG cover and was restricted to one patch along the margin of an un-named Mulcra Island wetland between the Murray River and Breached dam (*cf.* site E; SKM 2004).

Vegetation class	Area (ha) within Icon Site components			Total
	Lindsay Is.	Mulcra Is.	Walpolla Is.	
RGF	622	185	258	1,065
FRGW	4,438	1,296	1,899	7,633
RGFTU	0	11	0	11
Total	5,060	1,492	2,157	8,709

Table 2.1.2: Areas (ha) of river red gum classes (RGF, FRGW, RGFTU) within the LMW Icon Site.

Community structure

Assessments of RRG community structure, *i.e.* mature tree stand density and population size frequency distribution, were based on DBH (trunk diameter at breast height) measurements obtained from transect surveys conducted at 13 sites (4 RGF, 9 FRGW) distributed throughout the LMW Icon Site (Table 2.1.3, Figures 2.1.1-2.1.3). Transects (10-20 m wide) were set perpendicular to key environmental gradients, such as water courses, wetlands and elevation, so as to capture as much of the within site variation as possible. The RGFTU class was not surveyed due to its relatively small area (11 ha).

Surveyed areas accounted for 0.4 % and 0.09 % of the total area occupied by RGF and FRGW classes within the LMW Icon Site, respectively. This, in conjunction with surveys of other vegetation species/ classes, represented the maximum level of sampling effort that could be allocated during the current reporting period.

RRG seedlings in dry environments, such as the LMW Icon Site, suffer high rates of mortality during the 2-3 years following opportunistic germination events due to the lack of water and self thinnning. As such, seedlings and saplings may not be considered to be true recruits until they reach a greater size. Thus, and in conforming to the methodology used by George *et al.* (2005) in their work at Banrock Station SA, individuals < 10 cm DBH were excluded from determinations of tree density.

Mature tree stand densities (sites pooled) did not differ significantly between RRG classes; RGF mean density 106.8 trees ha^{-1} and FRGW mean density 102.9 trees ha^{-1} (t-test P=0.407) (Table 2.1.3). Figure 2.1.4 shows the community size class (DBH) frequency distributions determined for RGF and FRGW communities (site data pooled). Far greater relative numbers of smaller trees (individuals <10 cm DBH) were encountered in the FRGW sites than in RGF sites, although there was considerable variability in size class frequency distributions between sites within communities (Figure 2.1.5).

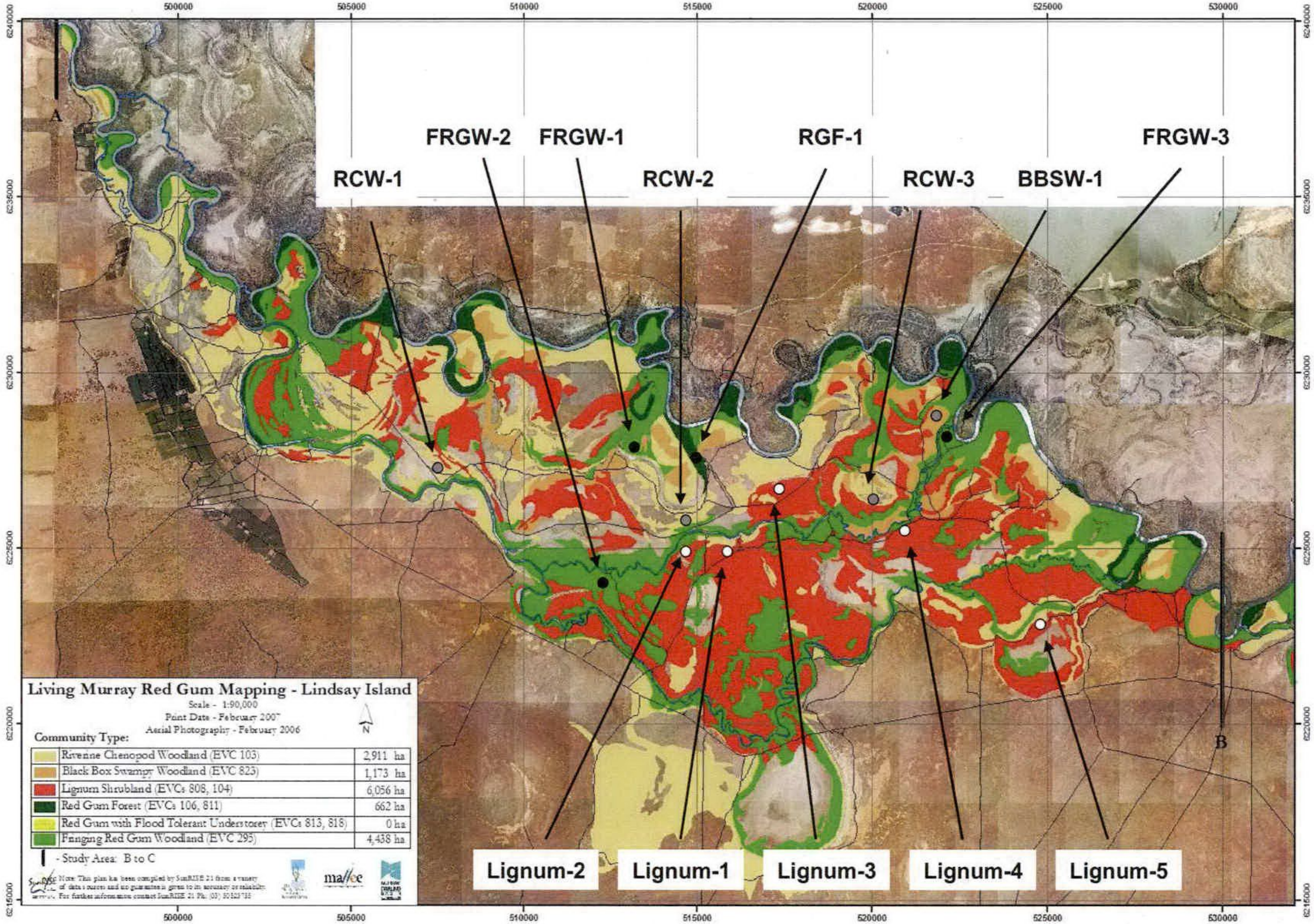


Figure 2.1.1: Distributions of the river red gum (•), black box (•) and lignum (○) communities and sampling sites on Lindsay Island.

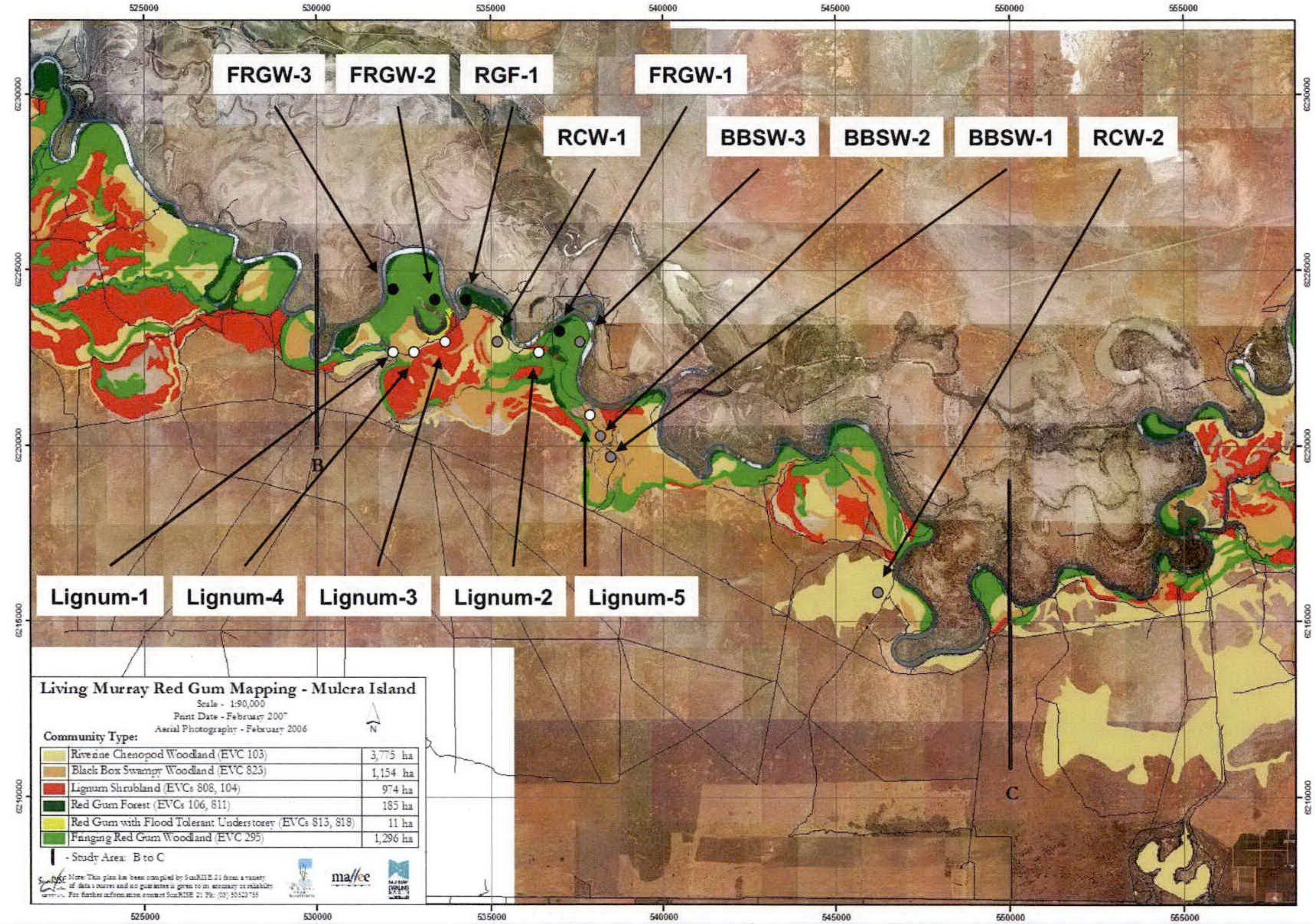


Figure 2.1.2: Distributions of river red gum (•), black box (•) and lignum (○) communities and sampling sites on Mulcra Island.

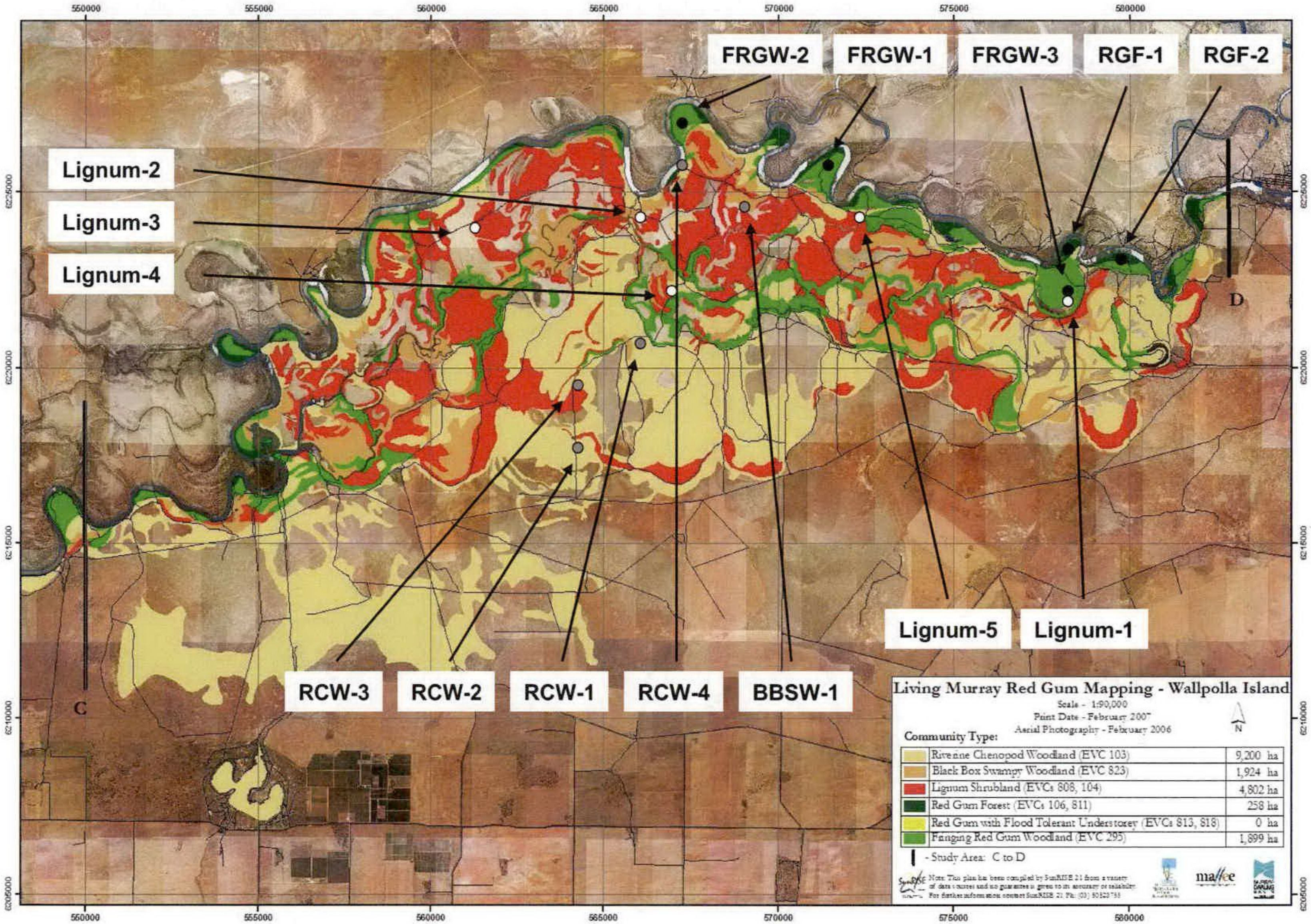
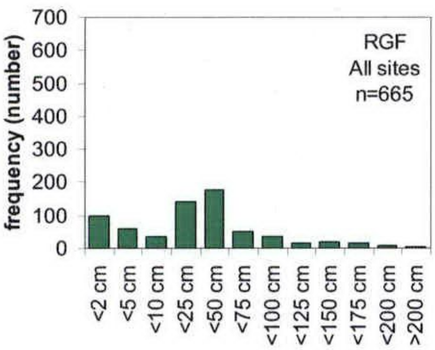


Figure 2.1.3: Distributions of the river red gum (•), black box (•) and lignum (○) communities and sampling sites on Wallpolla Island.

RRG size classes were neither uniformly distributed throughout the surveyed distribution range or population elevation ranges for both RGF and FRGW communities (Figures 2.1.6 and 2.1.7). Within the RGF sites surveyed, the smallest trees (<10 cm DBH) were present at all but the highest elevations and were generally concentrated at the lowest elevations along the margins of the Murray River. Whilst trees <10 cm DBH were present throughout the FRGW community elevation range, they also tended to be concentrated at lower elevations.

EVC	Icon Site component	Site No.	Site GPS (GDA94 datum) Easting	Northing	Area surveyed (ha)	Total no. of trees surveyed	No. of trees (>10 cm DBH) surveyed	Trees ha^{-1} (>10 cm DBH)
RGF	Lindsay Is.	1	515080	6227618	2.10	89	89	42.4
	Mulcra Is.	1	534113	6224451	1.04	229	121	226.0
	Wallpolla Is.	1	578510	6223711	0.49	191	127	398.0
		2	579984	6223248	0.80	156	136	213.75
					4.43	665	473	106.8
FRGW	Lindsay Is.	1	512813	6227863	1.48	124	74	50.0
		2	512415	6224296	0.94	174	128	136.2
		3	522071	6228122	0.43	133	32	74.4
	Mulcra Is.	1	537025	6223444	0.56	177	64	114.3
		2	533648	6223803	1.05	138	93	88.6
		3	532017	6224639	0.46	432	31	67.4
	Wallpolla Is.	1	571666	6226274	0.41	160	93	226.8
		2	567325	6226644	0.68	255	111	163.2
		3	578175	6221732	0.52	196	46	88.5
					6.53	1789	672	102.9

Table 2.1.3: RGF and FRGW survey site locations and tree densities determined within the LMW Icon Site.



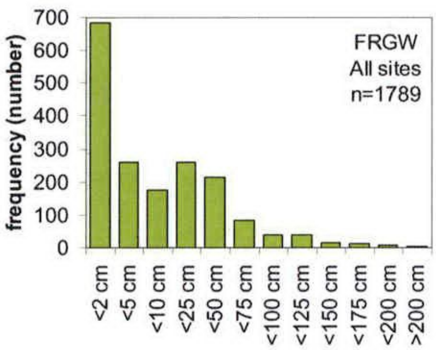


Figure 2.1.4: Size class (cm DBH) frequency distributions determined for RGF and FRGW classes within the LMW Icon Site (surveyed site data pooled).

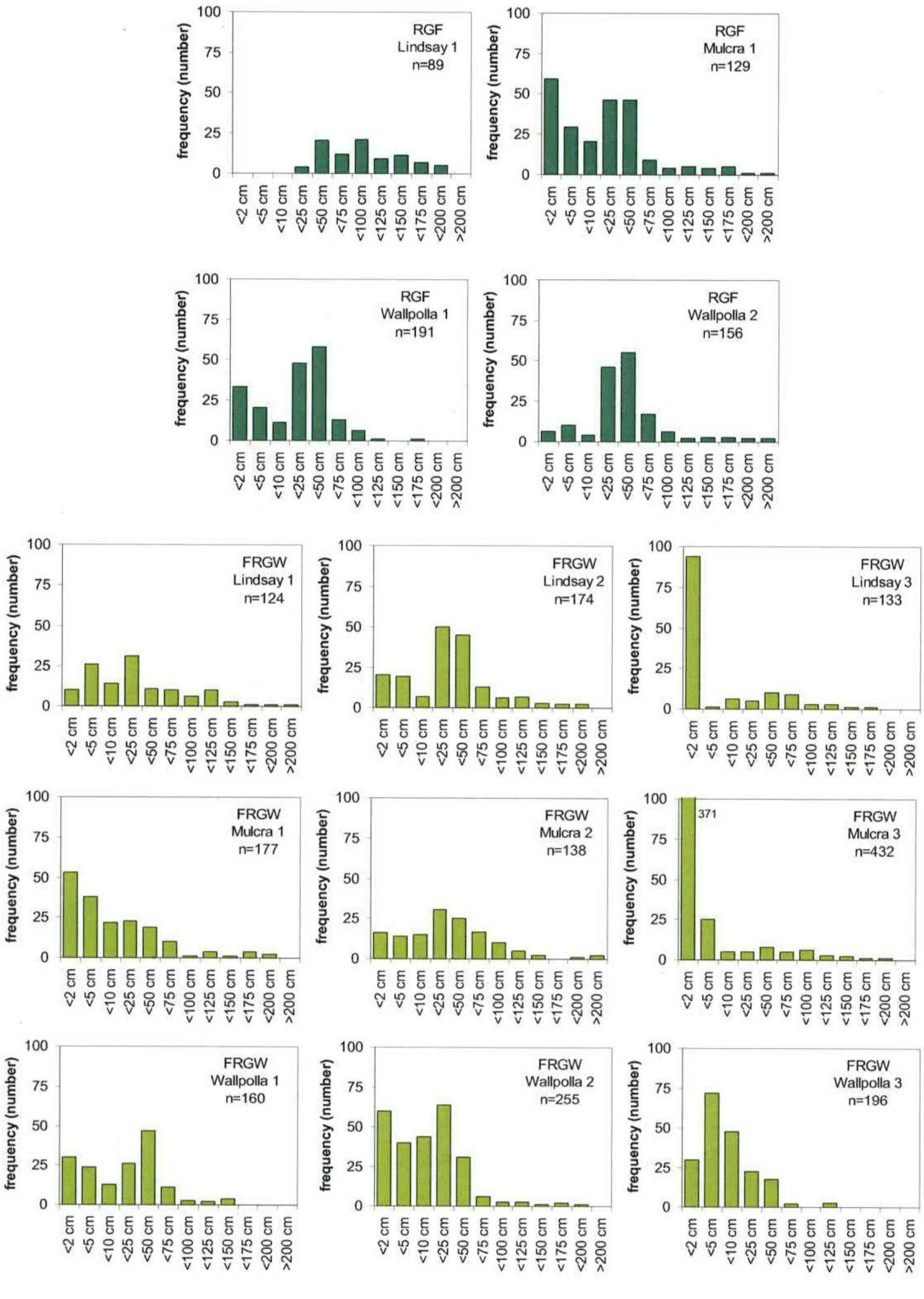


Figure 2.1.5: Size class (cm DBH) frequency distributions determined for RGF and FRGW sites surveyed within the LMW Icon Site.

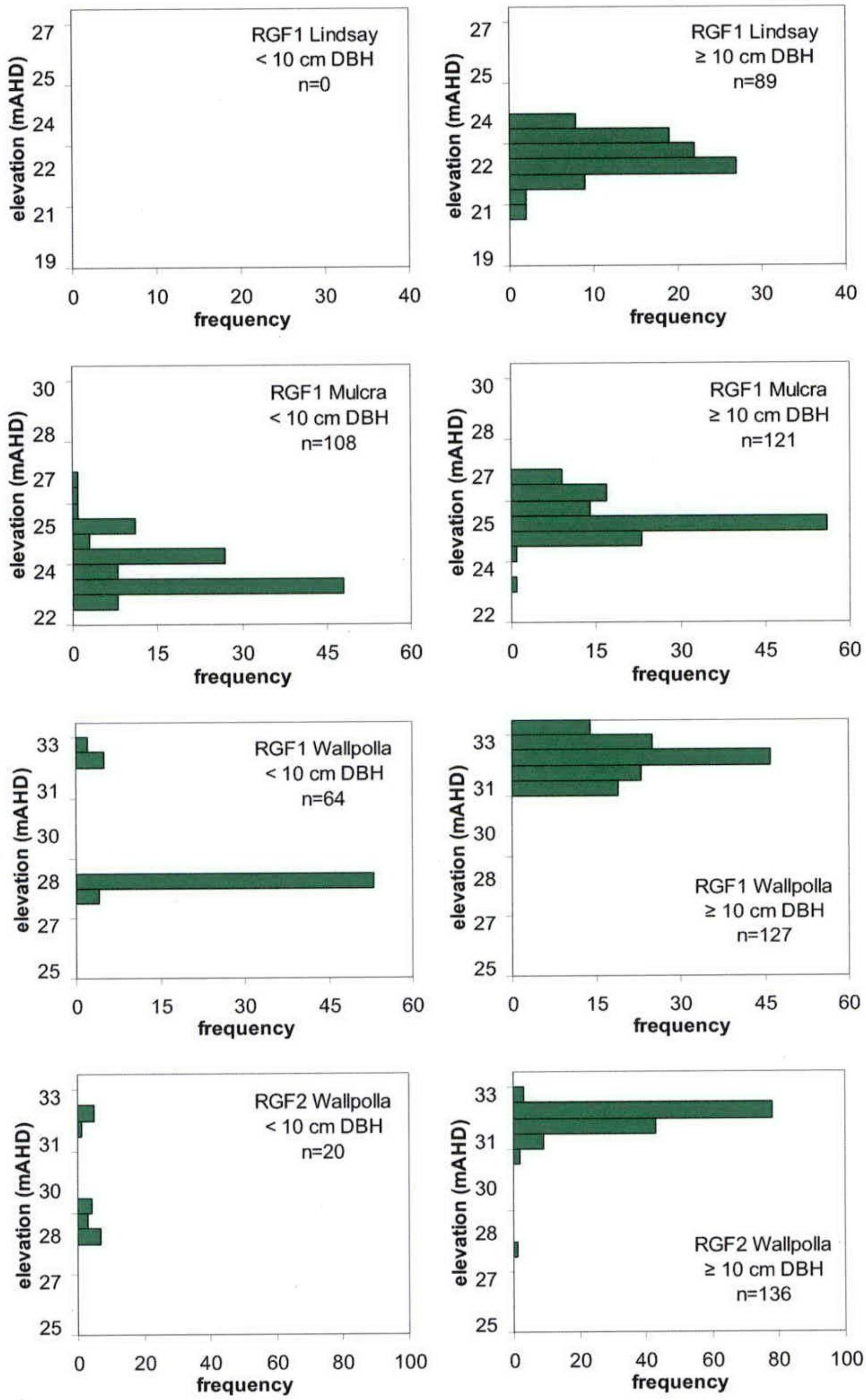


Figure 2.1.6: Elevation frequency distributions for <10 cm DBH and ≥10 cm DBH size classes determined for RGF sites surveyed within the LMW Icon Site.

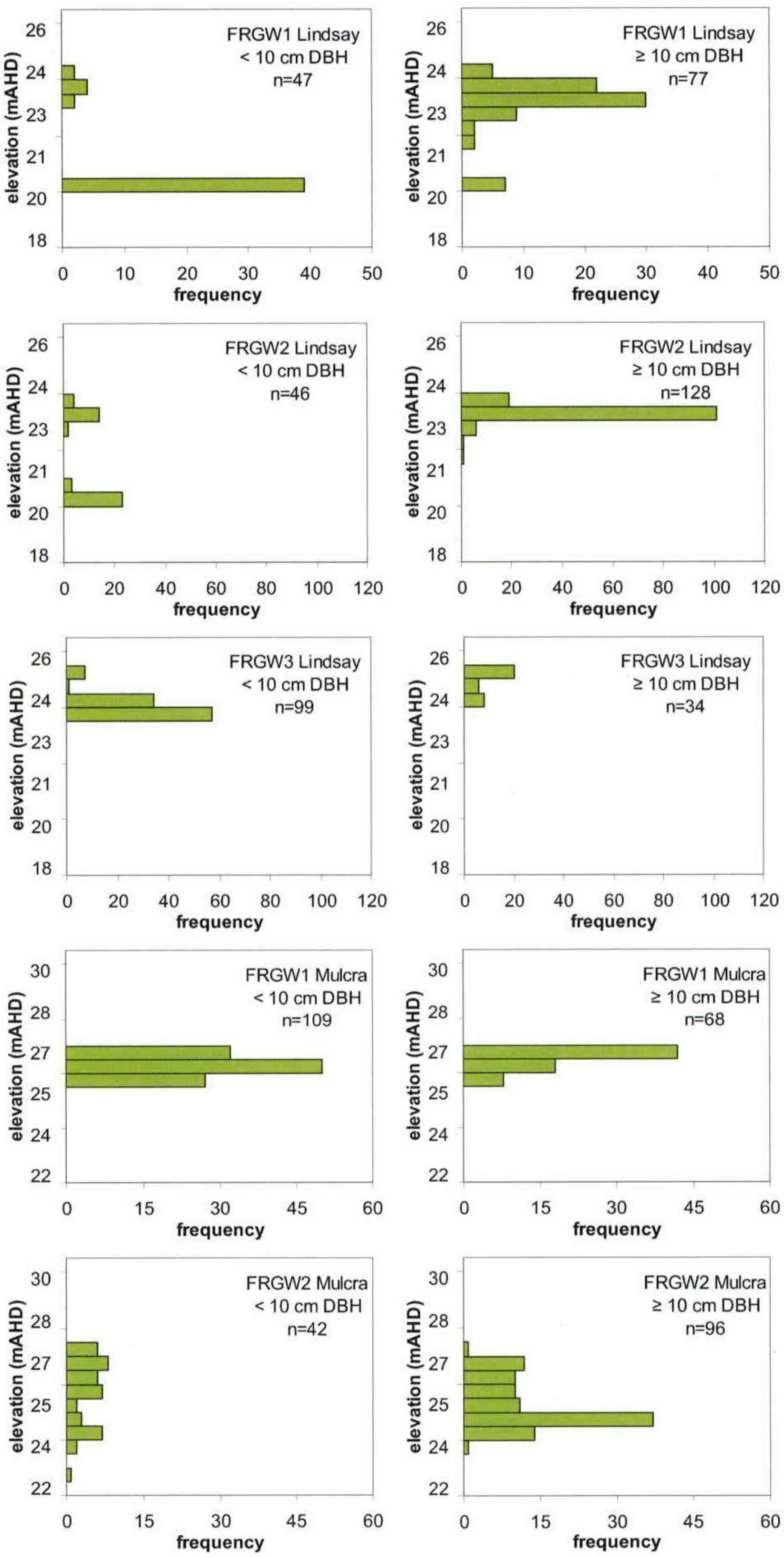


Figure 2.1.7: Elevation frequency distributions for <10 cm DBH and ≥10 cm DBH size classes determined for FRGW sites surveyed within the LMW Icon Site.

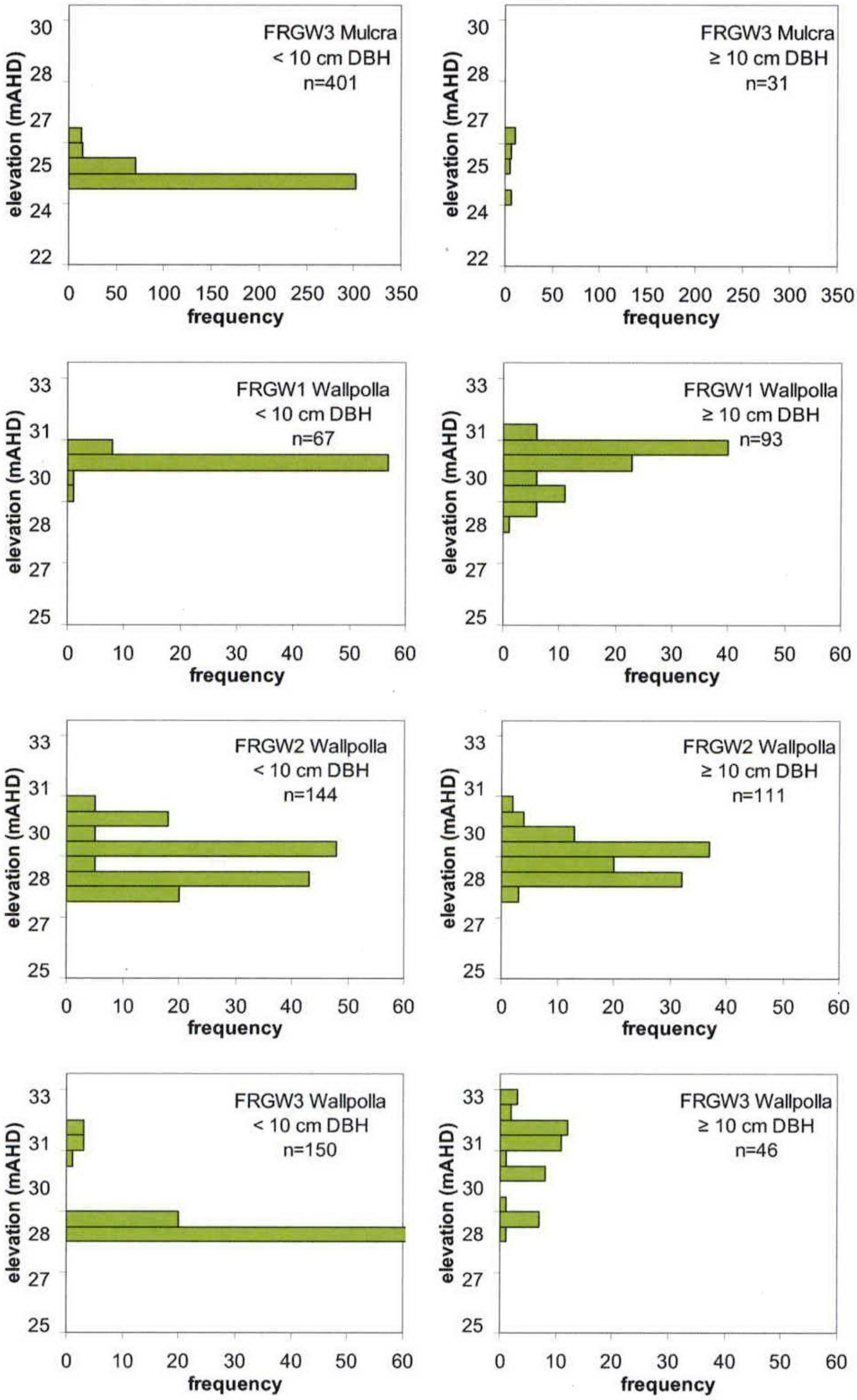


Figure 2.1.7 cont.: : Elevation frequency distributions for <10 cm DBH and ≥10 cm DBH size classes determined for FRGW sites surveyed within the LMW Icon Site.

Condition

Variation in the condition (or vigour) of eucalypts may occur across a range of temporal scales and may be reflected in more rapid variations in leaf chlorophyll concentrations and slower variations in canopy density (*i.e.* leaf shedding and regrowth). Accordingly, tree condition was assessed as crown condition (*i.e.* chlorophyll concentration signatures) for momentary ('snap shot') assessments and as changes in canopy cover (*cf.* density) for comparisons between time intervals using Normalised Difference Vegetation Index (NDVI) analyses of aerial images captured during February 2003 and January 2006. In contrast to NDVI crown condition images, which have a pixel resolution ranging from 0.2-0.3 m, producing change-in-NDVI canopy cover images required corrections for differences in 'tree lean-over' (*cf.* parallax) between time intervals, which necessarily reduced pixel resolution to 100 m. Refer to Scholz *et al.* (2007a) for details of image processing and NDVI methodology. All NDVI image processing and analyses were undertaken by Aerometrex Pty. Ltd. and Sunrise 21 Inc.

Crown condition

Figure 2.1.8 shows 2003 and 2006 NDVI crown condition images generated for the entire LMW Icon Site (vegetation classes not delineated). The spectrum of crown condition ranges from red (*i.e.* best condition - highest chlorophyll signature) to blue (*i.e.* worst condition - lowest chlorophyll signature). Overall, crown condition for the LMW Icon Site during February 2003 was greatest throughout Mulcra Island and the eastern half of Wallpolla Island. Whilst overall crown condition was more uniform throughout the LMW Icon Site during January 2006, strongest chlorophyll signatures were recorded within Lindsay Island in areas adjacent to the margins of the Murray River.

Canopy cover

Figures 2.1.9 – 2.1.11 show the changes-in-NDVI canopy cover identified between 2003 and 2006 for each RRG class within each component of the LMW Icon Site. Changes in canopy cover for each 100 m square were assigned to one of five categories ranging from large increase (green) to large decrease (red). Summary statistics for each category of change in canopy cover for each RRG class are shown in Table 2.1.4.

Both localised increases and decreases in RRG canopy cover were evident between 2003 and 2006. For Lindsay Island between 2003 and 2006, increases in total RRG canopy cover (40% of total area) exceeded decreases (9% of total area). Most increases in RRG canopy cover were associated with areas of FRGW adjacent to Lindsay River and Mullaroo Creek. Decreases were confined to smaller areas of both RGF and FRGW adjacent to the Murray River and within the upper reaches of the Upper Lindsay River (Figure 2.1.9).

For Mulcra Island between 2003 and 2006, decreases in total RRG canopy cover (57% of total area) exceeded increases (1% of total area). Decreases in RRG canopy cover were distributed throughout each RRG class across the Island. Least change in canopy cover was determined for areas adjacent to to Potterwalkagee Creek between Breached Dam and Lock 8 (Figure 2.1.10).

For Wallpolla Island between 2003 and 2006, decreases in total RRG canopy cover (27% of total area) exceeded increases (6% of total area). Decreases in RRG canopy cover were identified for areas of both RGF and FRGW classes adjacent to the Murray River (mainly RGF class), and increases were largely restricted to the upper and lower reaches of Wallpolla Creek (Figure 2.1.11).

Change in canopy cover	Lindsay Island RGF	FRGW	RGFTU	TOTAL
Large decrease	6 %	1 %	0 %	2 %
Medium decrease	16 %	6 %	0 %	7 %
No change	69 %	48 %	0 %	51 %
Medium increase	8 %	32 %	0 %	28 %
Large increase	1 %	13 %	0 %	12 %

Change in canopy cover	Mulcra Island RGF	FRGW	RGFTU	TOTAL
Large decrease	10 %	20 %	0 %	19 %
Medium decrease	42 %	38 %	55 %	38 %
No change	44 %	41 %	45 %	42 %
Medium increase	4 %	1 %	0 %	1 %
Large increase	0 %	0 %	0 %	0 %

Change in canopy cover	Wallpolla Island RGF	FRGW	RGFTU	TOTAL
Large decrease	23 %	9 %	0 %	11 %
Medium decrease	23 %	15 %	0 %	16 %
No change	52 %	70 %	0 %	67 %
Medium increase	1 %	5 %	0 %	5 %
Large increase	1 %	1 %	0 %	1 %

Table 2.1.4: Percentage change in NDVI canopy cover of RRG classes within Lindsay, Mulcra and Wallpolla Islands between February 2003 and January 2006.

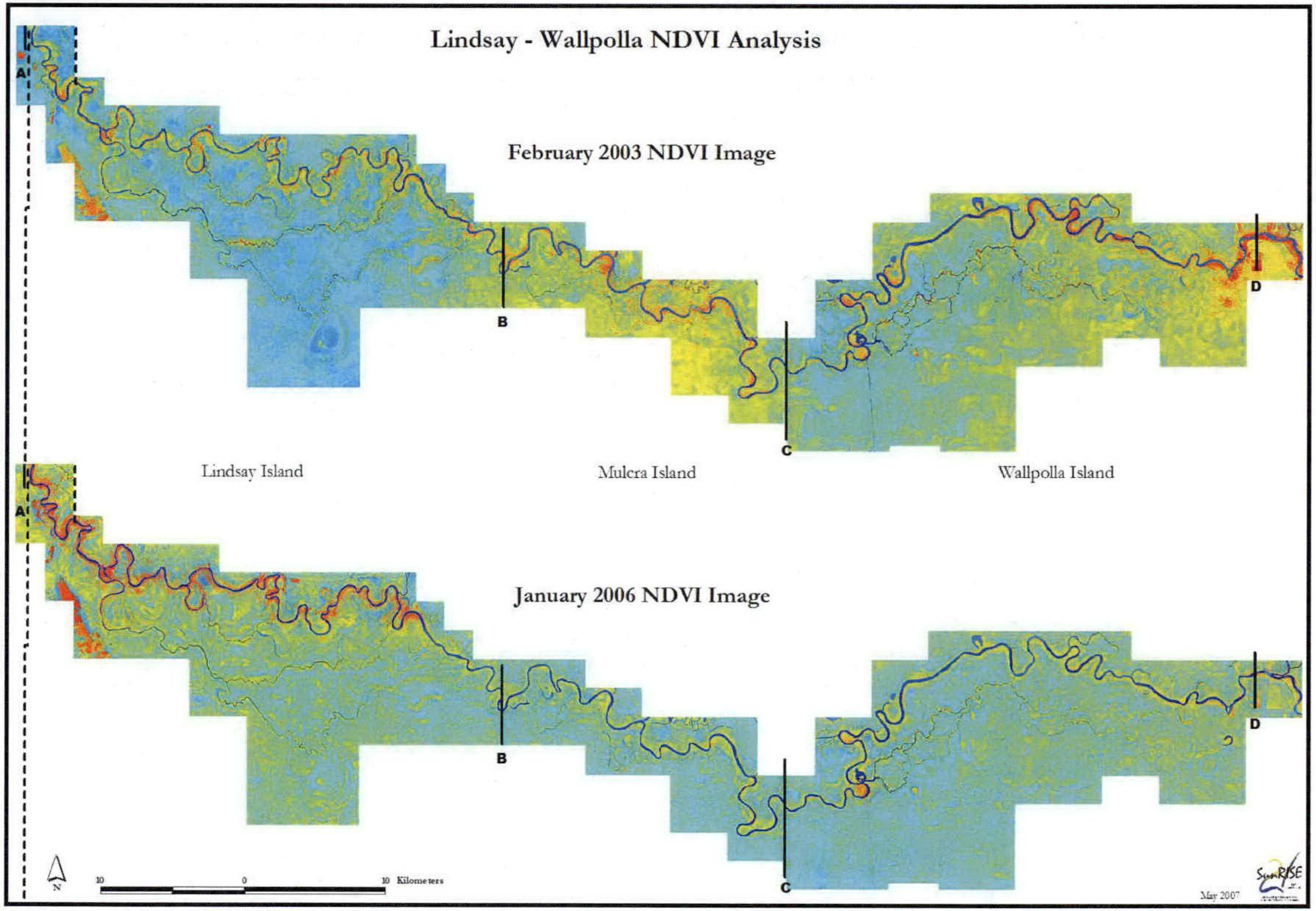
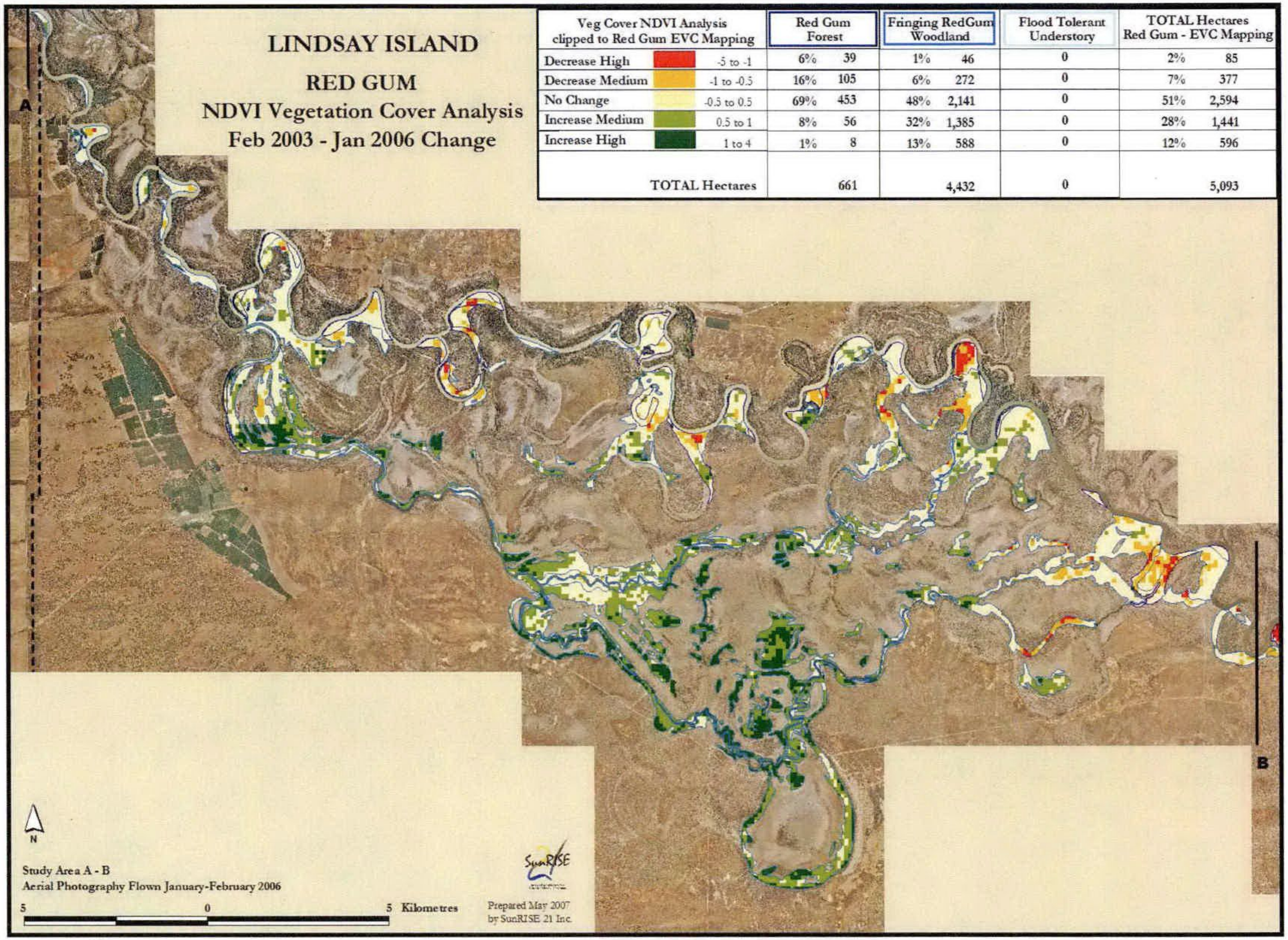
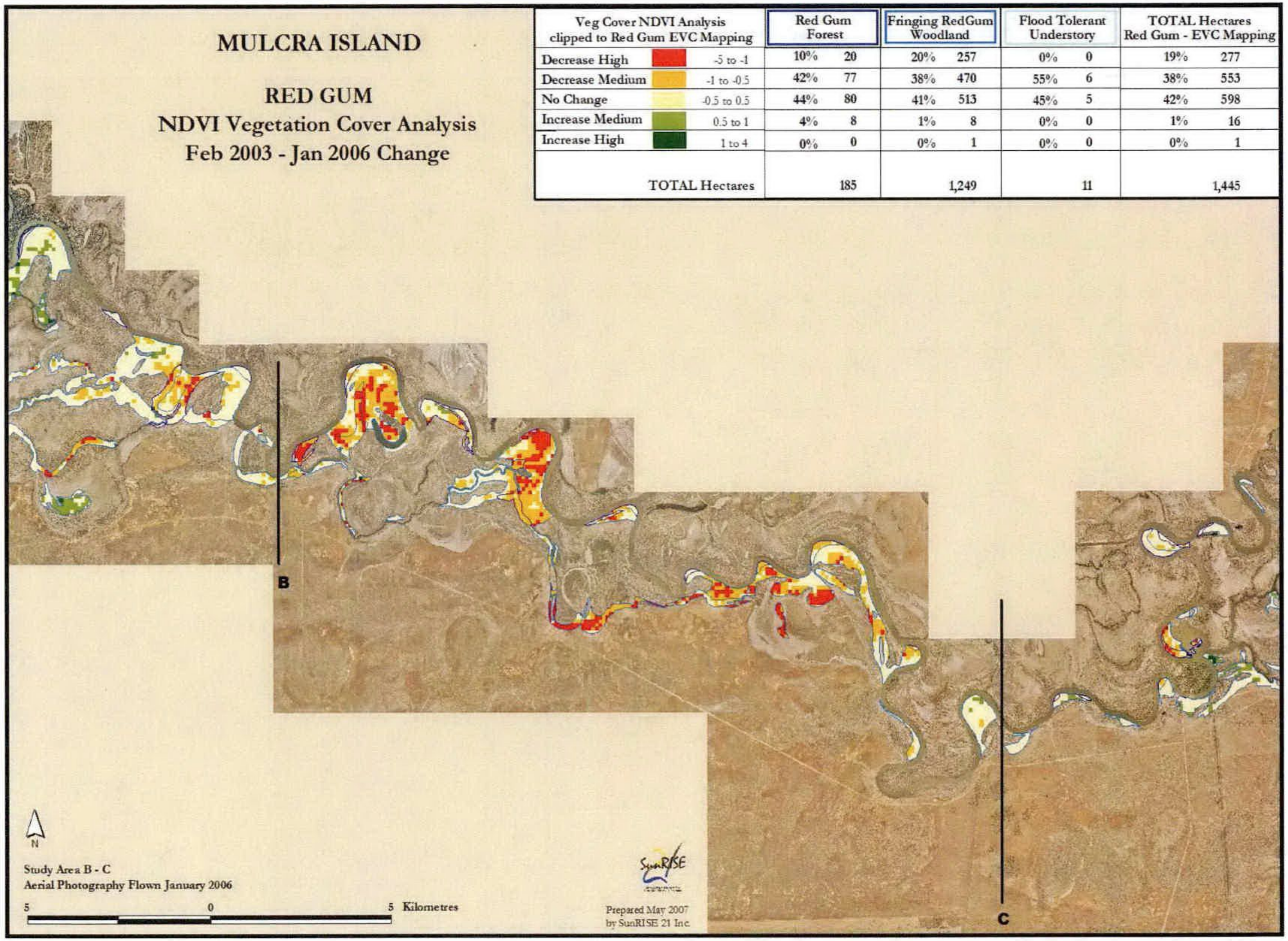


Figure 2.1.8: 2003 and 2006 NDVI crown condition images generated for the entire LMW Icon Site. Vegetation classes not delineated. Condition colour scale ranges from red (best) to blue (worst).



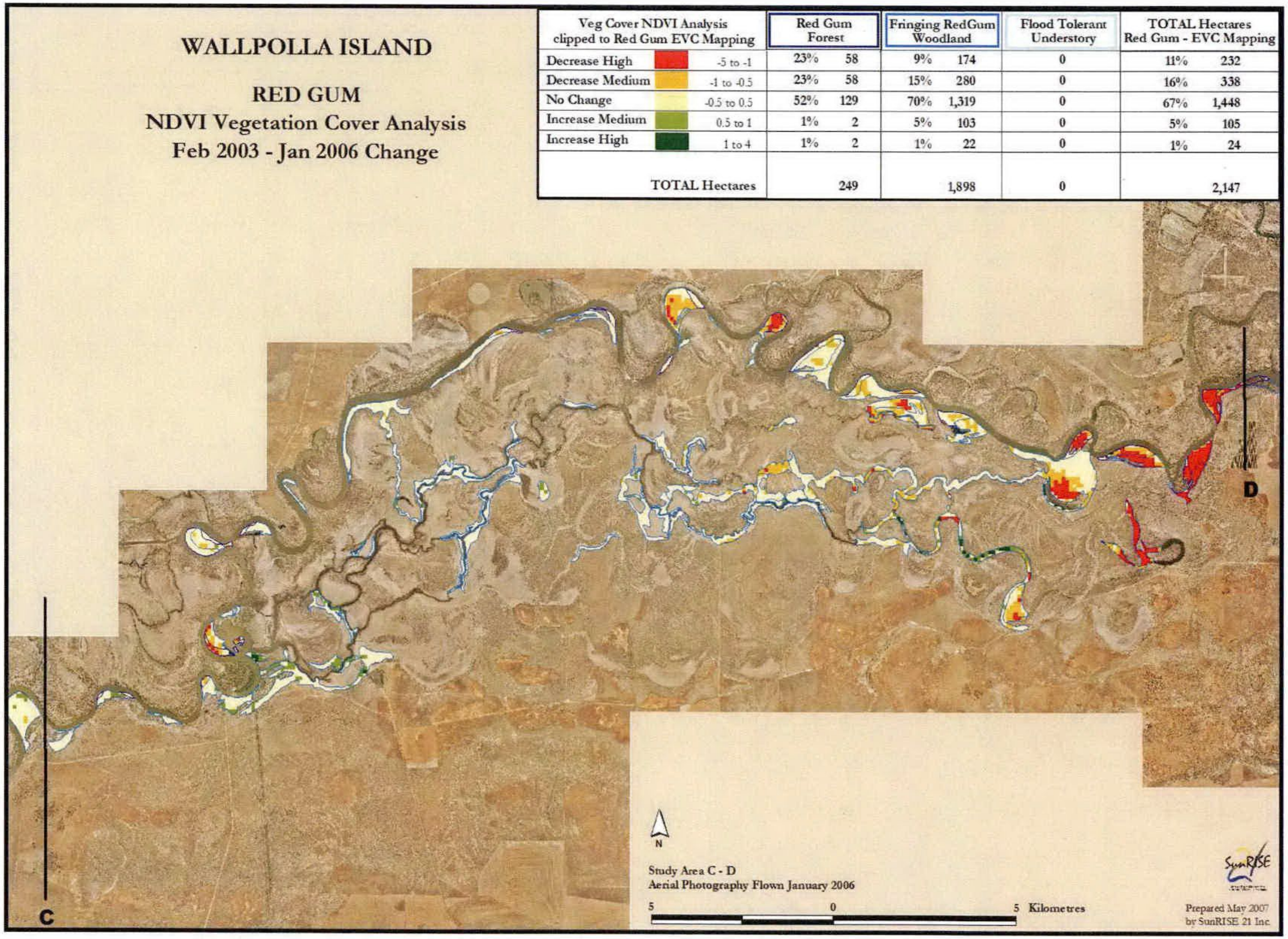
Veg Cover NDVI Analysis clipped to Red Gum EVC Mapping			Red Gum Forest		Fringing RedGum Woodland		Flood Tolerant Understory	TOTAL Hectares Red Gum - EVC Mapping	
Decrease High		-5 to -1	6%	39	1%	46	0	2%	85
Decrease Medium		-1 to -0.5	16%	105	6%	272	0	7%	377
No Change		-0.5 to 0.5	69%	453	48%	2,141	0	51%	2,594
Increase Medium		0.5 to 1	8%	56	32%	1,385	0	28%	1,441
Increase High		1 to 4	1%	8	13%	588	0	12%	596
TOTAL Hectares				661		4,432	0		5,093

Figure 2.1.9: Change-in-NDVI canopy cover of RRG within Lindsay Island between February 2003 and January 2006.



Veg Cover NDVI Analysis clipped to Red Gum EVC Mapping		Red Gum Forest		Fringing RedGum Woodland		Flood Tolerant Understory		TOTAL Hectares Red Gum - EVC Mapping	
Decrease High	-5 to -1	10%	20	20%	257	0%	0	19%	277
Decrease Medium	-1 to -0.5	42%	77	38%	470	55%	6	38%	553
No Change	-0.5 to 0.5	44%	80	41%	513	45%	5	42%	598
Increase Medium	0.5 to 1	4%	8	1%	8	0%	0	1%	16
Increase High	1 to 4	0%	0	0%	1	0%	0	0%	1
TOTAL Hectares			185		1,249		11		1,445

Figure 2.1.10: Change-in-NDVI canopy cover of RRG within Mulcra Island between February 2003 and January 2006.



Veg Cover NDVI Analysis clipped to Red Gum EVC Mapping		Red Gum Forest		Fringing RedGum Woodland		Flood Tolerant Understory	TOTAL Hectares Red Gum - EVC Mapping	
Decrease High	-5 to -1	23%	58	9%	174	0	11%	232
Decrease Medium	-1 to -0.5	23%	58	15%	280	0	16%	338
No Change	-0.5 to 0.5	52%	129	70%	1,319	0	67%	1,448
Increase Medium	0.5 to 1	1%	2	5%	103	0	5%	105
Increase High	1 to 4	1%	2	1%	22	0	1%	24
TOTAL Hectares			249		1,898	0		2,147

Figure 2.1.11: Change-in-NDVI canopy cover of RRG within Wallpolla Island between February 2003 and January 2006.

2.1.3 Black box

Distribution

Two Ecological Vegetation Classes (EVCs) were recognised for black box (*Eucalyptus largiflorens* F. Muell.) (BB) by White *et al.* (2003): Riverine Chenopod Woodland (RCW) and Black Box Swampy Woodland (BBSW). The distribution and area (ha) of each of these vegetation classes within the LMW Icon Site was examined using GIS layers available for each EVC.

The distribution of each BB class throughout the LMW Icon Site is shown in Figures 2.1.1-.2.1.3. BB communities cover a combined area of 20,137 ha (Table 2.1.5). RCW (78.89 % of total BB cover) tend to occupy higher elevations of the floodplain than BBSW (21.11 % of total BB cover).

Vegetation class	Area (ha) within Icon Site components			Total
	Lindsay Is.	Mulcra Is.	Walpolla Is.	
RCW	2,911	3,775	9,200	15,886
BBSW	1,173	1,154	1,924	4,251
Total	4,084	4,929	11,124	20,137

Table 2.1.5: Areas (ha) of black box classes (RCW, BBSW) within the LMW Icon Site.

Community structure

Assessments of BB community structure, *i.e.* mature tree stand density and population size frequency distribution, were based on DBH (trunk diameter at breast height) measurements obtained from transect surveys conducted at 14 sites (9 RCW, 5 BBSW) distributed throughout the LMW Icon Site (Table 2.1.6, Figures 2.1.1-2.1.3). Transects (10-20 m wide) were set perpendicular to key environmental gradients, such as water courses, wetlands and elevation, so as to capture as much of the within site variation as possible.

Surveyed areas accounted for 0.07 % and 0.14 % of the total area occupied by RCW and BBSW classes within the LMW Icon Site, respectively. This, in conjunction with surveys of other vegetation species/classes, represented the maximum level of sampling effort that could be allocated during the current reporting period.

BB seedlings in dry environments, such as the LMW Icon Site, suffer high rates of mortality during the 2-3 years following opportunistic germination events due to the lack of water and self thinnning. As such, seedlings and saplings may not be considered to be true recruits until they reach a greater size. Thus, and in conforming to the methodology used by George *et al.* (2005) in their work at Banrock Station SA, individuals < 10 cm DBH were excluded from determinations of tree density.

Mature tree stand densities (sites pooled) did not differ significantly between BB classes; RCW mean density 71.8 trees ha^{-1} and BBSW mean density 50.2 trees ha^{-1} (t-test $P=0.384$) (Table 2.1.6). Figure 2.1.12 shows the community size class (DBH) frequency distributions determined for RCW and BBSW communities (site data pooled). Overall, few small trees (individuals <10 cm DBH) were encountered within both BB communites, with the majority of trees at all sites surveyed having trunk diameters ranging from ≥10 cm to <50 cm (53.6 % of RCW trees and 54.7 % of BBSW trees). However, both mature tree densities and size class frequency distributions did vary considerably between sites surveyed (Figure 2.1.13).

Within locations (Lindsay Is., Mulcra Is. and Wallpolla Is.), RCW and BBSW generally extended over a narrower and higher elevation range than did RRGs. At sites where small trees (<10 cm DBH) were encountered, they were distributed across the elevation range occupied by larger trees (Figures 2.1.14 and 2.1.15). No elevation data was available for sites lying outside the DEM range (RCW Mulcra-2, Wallpolla-2 and 3).

EVC	Icon Site component	Site No.	Site GPS (GDA94 datum) Easting	Northing	Area surveyed (ha)	Total no. of trees surveyed	No. of trees (>10 cm DBH) surveyed	Trees ha^{-1} (>10 cm DBH)
RCW	Lindsay Is.	1	507954	6227016	1.80	168	99	55.0
		2	515050	6226323	2.00	84	83	41.5
		3	520629	6226836	2.18	133	130	59.6
	Mulcra Is.	1	535395	6223086	0.84	45	44	52.4
		2	546573	6215933	1.45	95	95	65.5
	Wallpolla Is.	1	565987	6220822	0.37	110	109	294.6
		2	564248	6217604	1.56	95	95	60.9
		3	564270	6218910	0.32	206	41	128.1
		4	567346	6225857	1.30	217	153	117.7
					11.82	1153	849	71.8
BBSW	Lindsay Is.	1	521350	6227196	2.20	75	72	32.7
	Mulcra Is.	1	539224	6219716	1.02	42	42	41.4
		2	537497	6221004	1.55	27	25	16.1
		3	537384	6222709	0.61	90	67	110.7
	Wallpolla Is.	1	569784	6224945	0.63	104	95	150.8
					6.00	338	301	50.2

Table 2.1.6: RCW and BBSW survey site locations and tree densities determined within the LMW Icon Site.

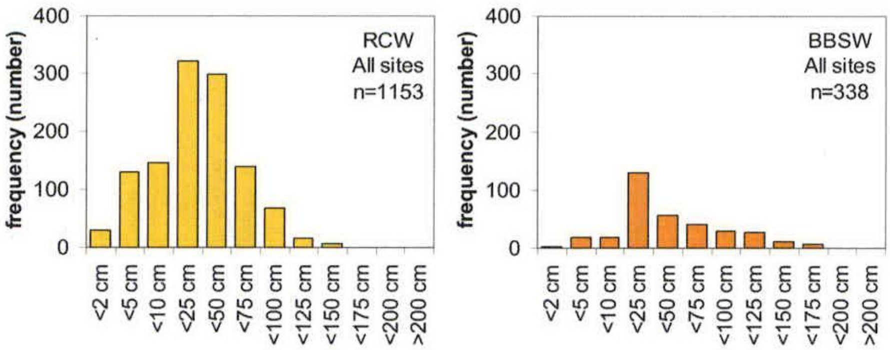


Figure 2.1.12: Size class (cm DBH) frequency distributions determined for RCW and BBSW classes within the LMW Icon Site (surveyed site data pooled).

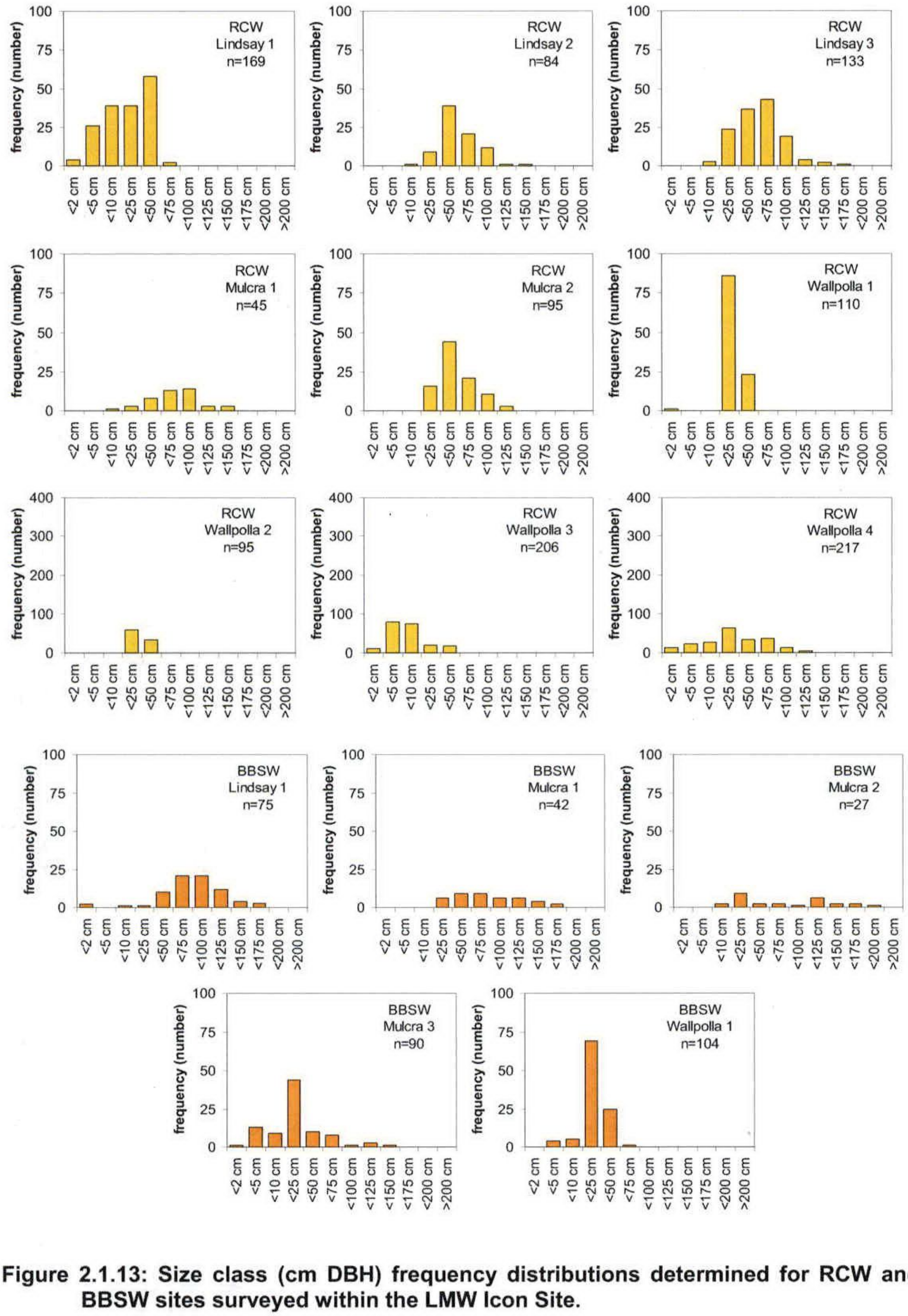


Figure 2.1.13: Size class (cm DBH) frequency distributions determined for RCW and BBSW sites surveyed within the LMW Icon Site.

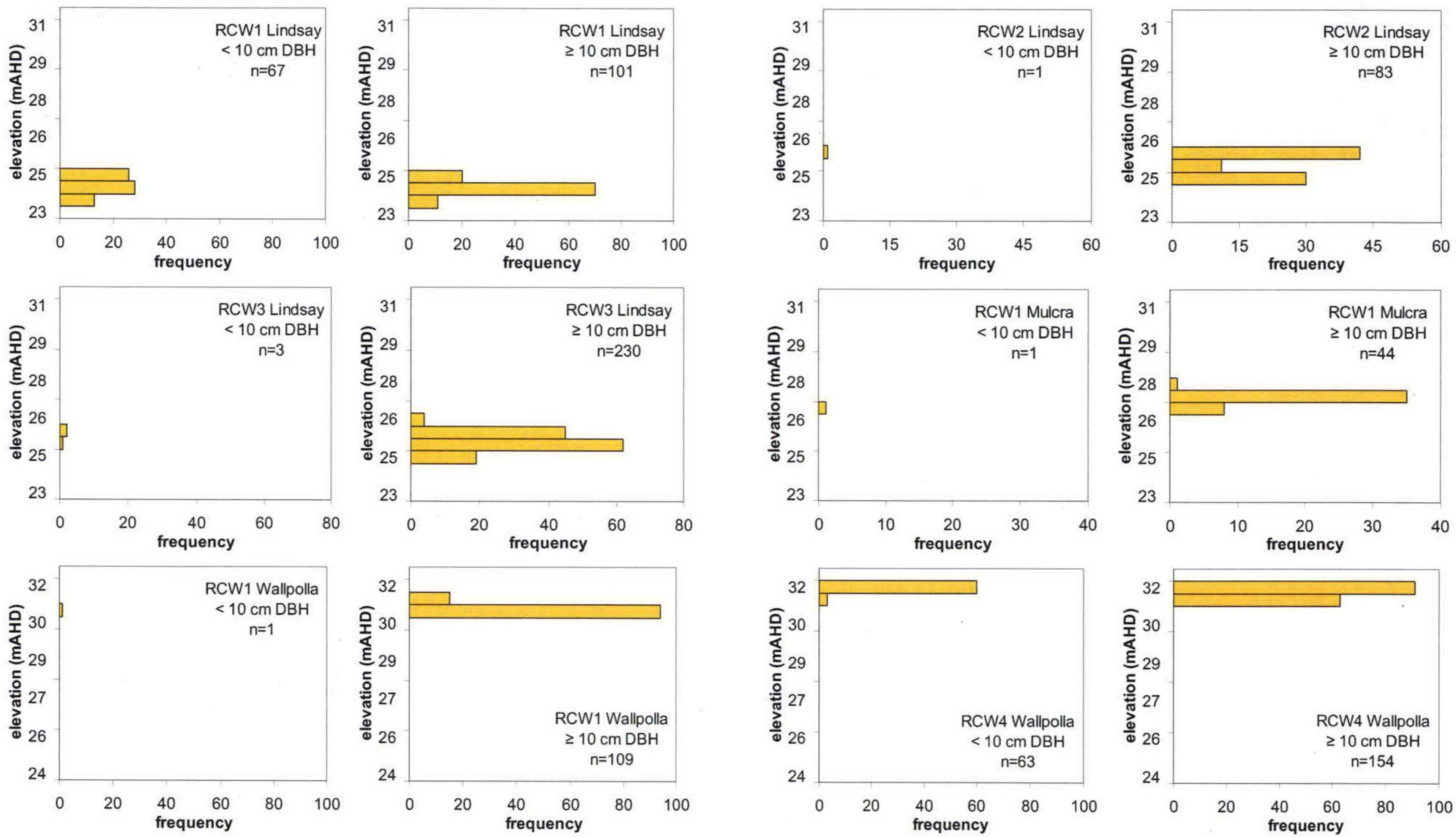


Figure 2.1.14: Elevation frequency distributions for <10 cm DBH and ≥10 cm DBH size classes determined for RCW sites surveyed within the LMW Icon Site. No elevation data was available for the following sites; Mulcra-2 and Wallpolla-2 and 3.

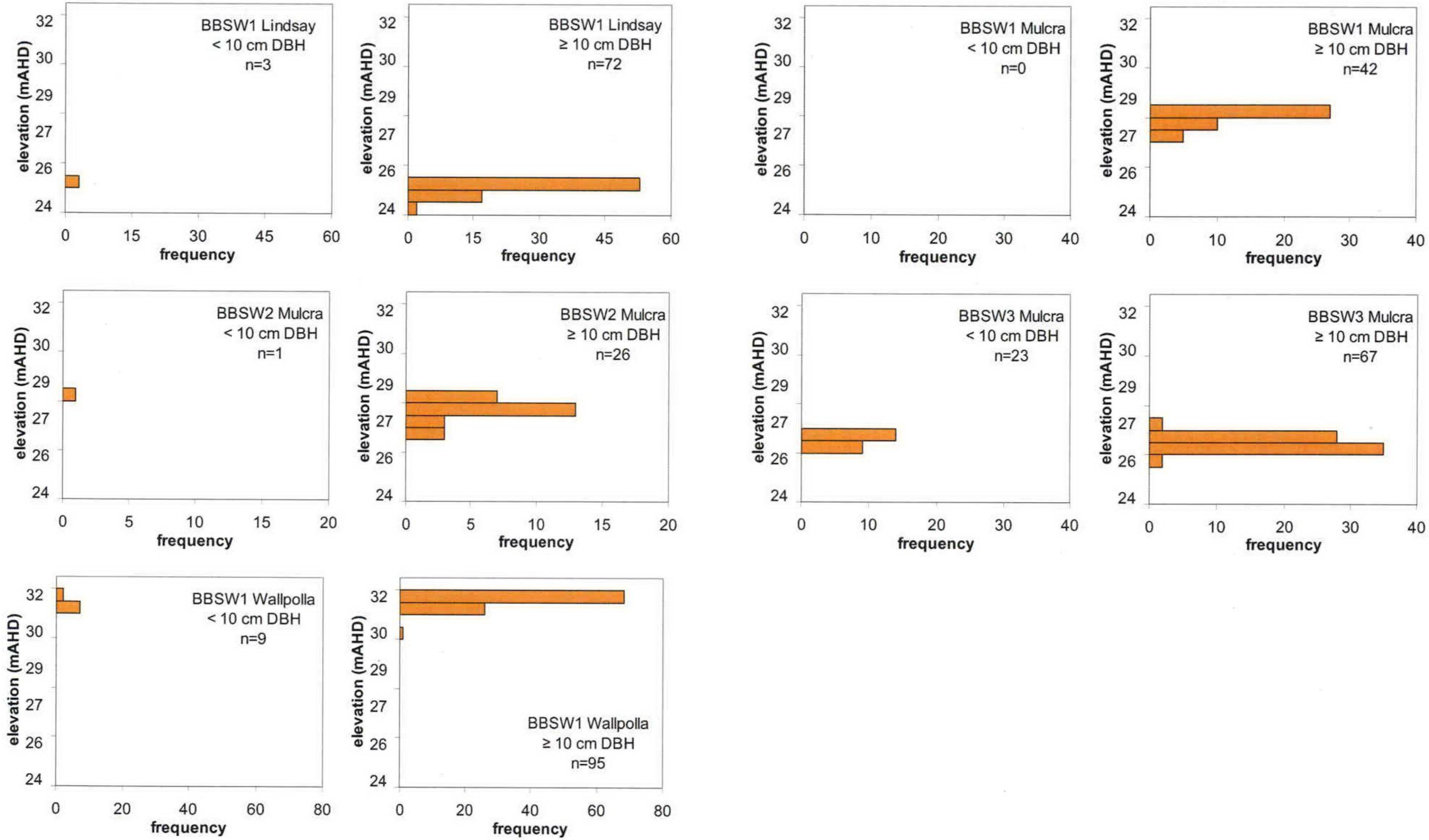


Figure 2.1.15: Elevation frequency distributions for <10 cm DBH and ≥10 cm DBH size classes determined for BBSW sites surveyed within the LMW Icon Site.

Condition

Variation in the condition (or vigour) of eucalypts may occur across a range of temporal scales and may be reflected in more rapid variations in leaf chlorophyll concentrations and slower variations in canopy density (*i.e.* leaf shedding and regrowth). Accordingly, tree condition was assessed as crown condition (*i.e.* chlorophyll concentration signatures) for momentary ('snap shot') assessments and as changes in canopy cover (*cf.* density) for comparisons between time intervals using Normalised Difference Vegetation Index (NDVI) analyses of aerial images captured during February 2003 and January 2006. In contrast to NDVI crown condition images, which have a pixel resolution ranging from 0.2-0.3 m, producing change-in-NDVI canopy cover images required corrections for differences in 'tree lean-over' (*cf.* parallax) between time intervals, which necessarily reduced pixel resolution to 100 m. Refer to Scholz *et al.* (2007a) for details of image processing and NDVI methodology. All NDVI image processing and analyses were undertaken by Aerometrex Pty. Ltd. and Sunrise 21 Inc.

Crown condition

Figure 2.1.8 (in preceding RRG section) shows 2003 and 2006 NDVI crown condition images generated for the entire LMW Icon Site (vegetation classes not delineated). The spectrum of crown condition ranges from red (*i.e.* best condition - highest chlorophyll signature) to blue (*i.e.* worst condition - lowest chlorophyll signature). Overall, crown condition for the LMW Icon Site during February 2003 was greatest throughout Mulcra Island and the eastern half of Wallpolla Island. Whilst overall crown condition was more uniform throughout the LMW Icon Site during January 2006, strongest chlorophyll signatures were recorded within Lindsay Island in areas adjacent to the Murray River.

Canopy cover

Figures 2.1.16 – 2.1.18 show the changes-in-NDVI canopy cover identified between 2003 and 2006 for each BB class within each component of the LMW Icon Site. Changes in canopy cover for each 100 m square were assigned to one of five categories ranging from large increase (green) to large decrease (red). Summary statistics for each category of change in canopy cover for each BB class are shown in Table 2.1.7.

Both localised increases and decreases in BB canopy cover were evident between 2003 and 2006. For Lindsay Island between 2003 and 2006, increases in total BB canopy cover (53% of total area) exceeded decreases (6% of total area). Most increases in BB canopy cover were associated with areas of both RCW and BBSW bound by the Murray River, Lower Lindsay River and Mullaroo Creek. Decreases were confined to smaller pockets of both BB classes distributed throughout the Island adjacent to the Murray River (Figure 2.1.16).

For Mulcra Island between 2003 and 2006, decreases in total BB canopy cover (65% of total area) exceeded increases (0% of total area). Decreases in BB canopy cover were distributed throughout the Island within each BB class (Figure 2.1.17).

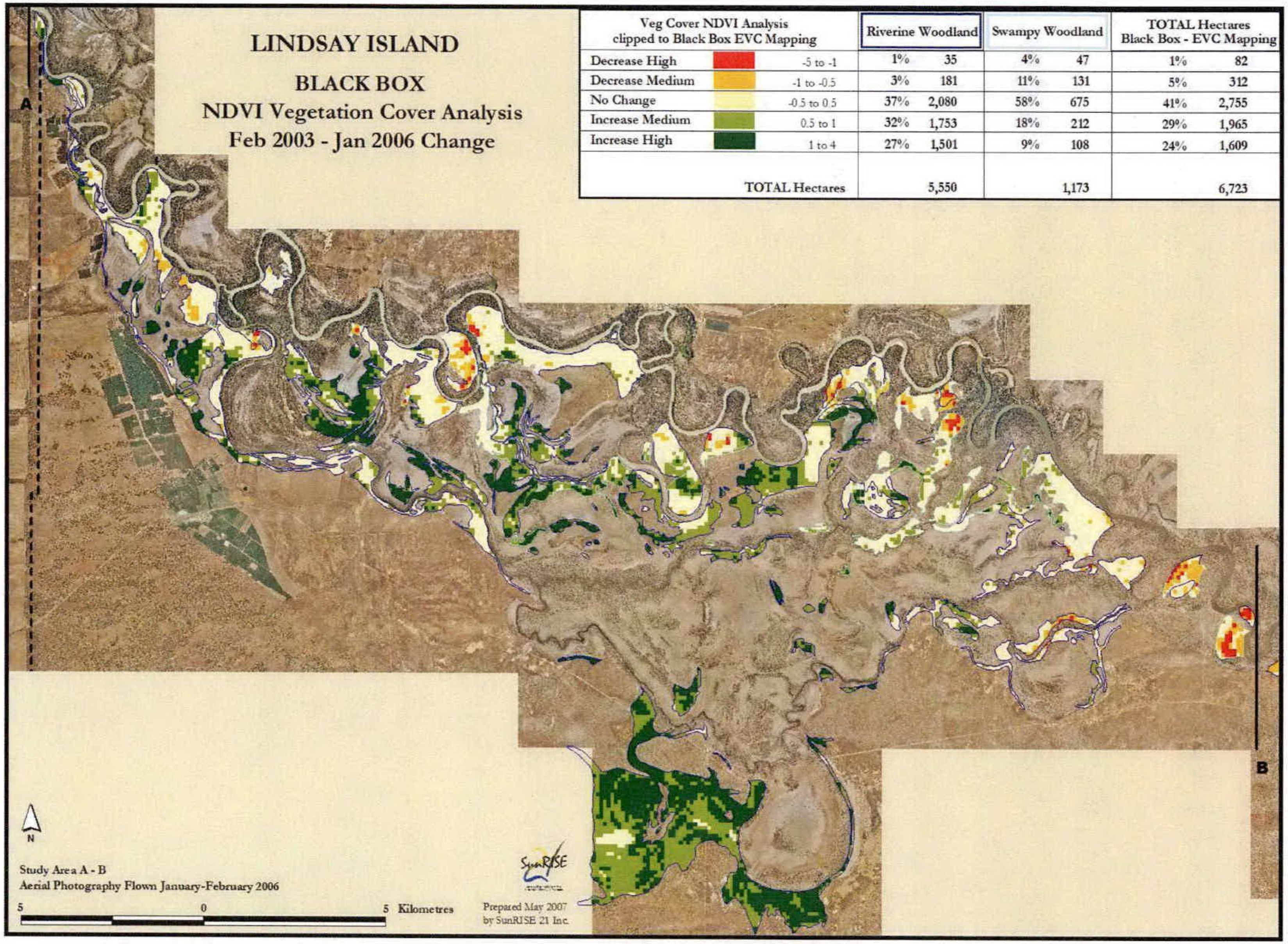
For Wallpolla Island between 2003 and 2006, decreases in total BB canopy cover (20% of total area) exceeded increases (6% of total area). Decreases in canopy cover in both BB classes were most pronounced within the eastern half of the Island, especially on the floodplain associated with the upper most reaches of Upper Wallpolla Creek. In contrast, most areas of increased canopy cover were identified within the western half of the Island (Figure 2.1.18).

Change in canopy cover	Lindsay Island RCW	Lindsay Island BBSW	TOTAL
Large decrease	1 %	4 %	1 %
Medium decrease	3 %	11 %	5 %
No change	37 %	58 %	41 %
Medium increase	32 %	18 %	29 %
Large increase	27 %	9 %	24 %

Change in canopy cover	Mulcra Island RCW	Mulcra Island BBSW	TOTAL
Large decrease	36 %	32 %	34 %
Medium decrease	30 %	31 %	31 %
No change	34 %	36 %	35 %
Medium increase	0 %	1 %	0 %
Large increase	0 %	0 %	0 %

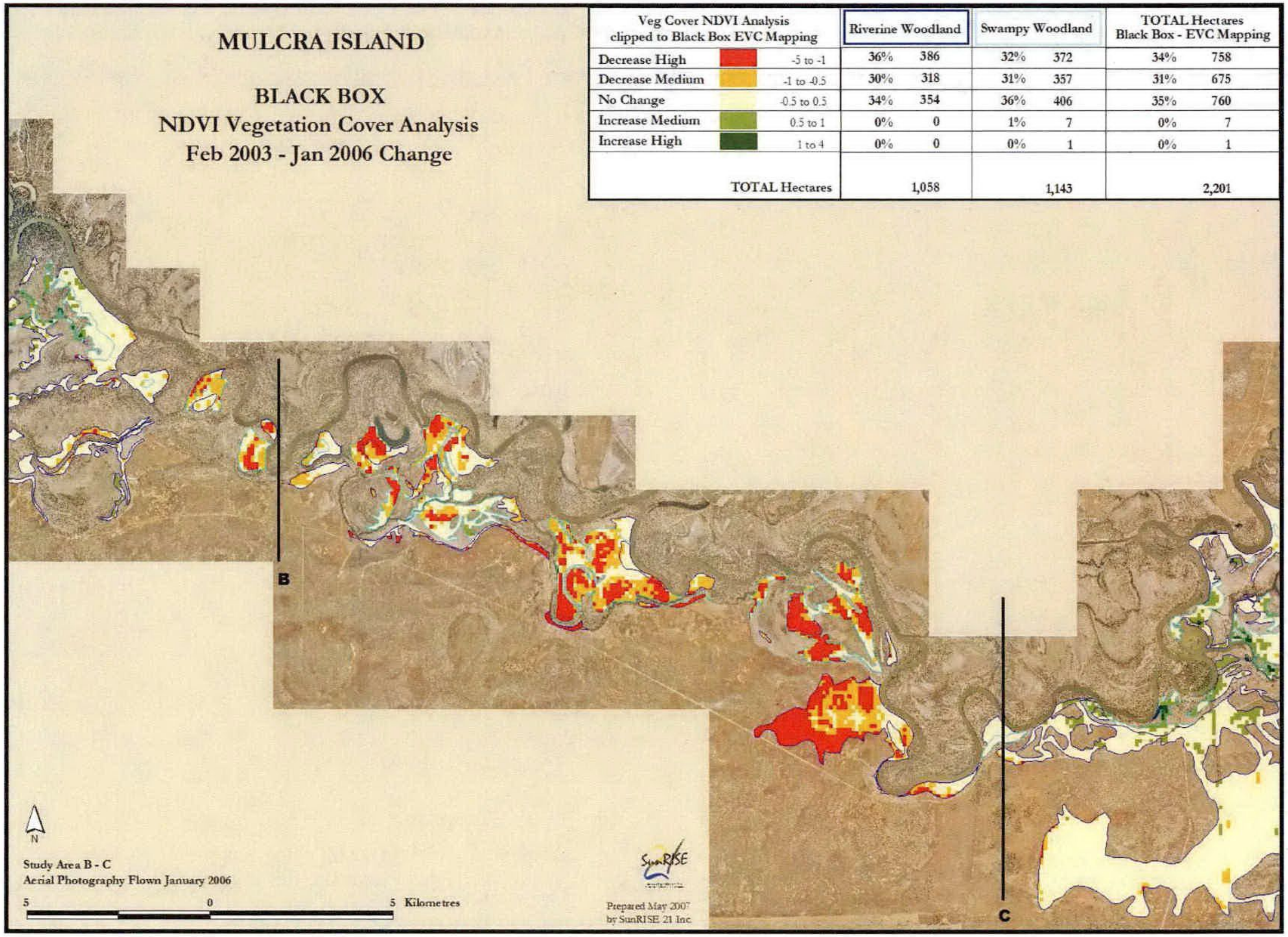
Change in canopy cover	Wallpolla Island RCW	Wallpolla Island BBSW	TOTAL
Large decrease	8 %	8 %	8 %
Medium decrease	10 %	19 %	12 %
No change	77 %	64 %	74 %
Medium increase	5 %	8 %	6 %
Large increase	0 %	1 %	0 %

Table 2.1.7: Percentage change in NDVI canopy cover of BB classes within Lindsay, Mulcra and Wallpolla Islands between February 2003 and January 2006.



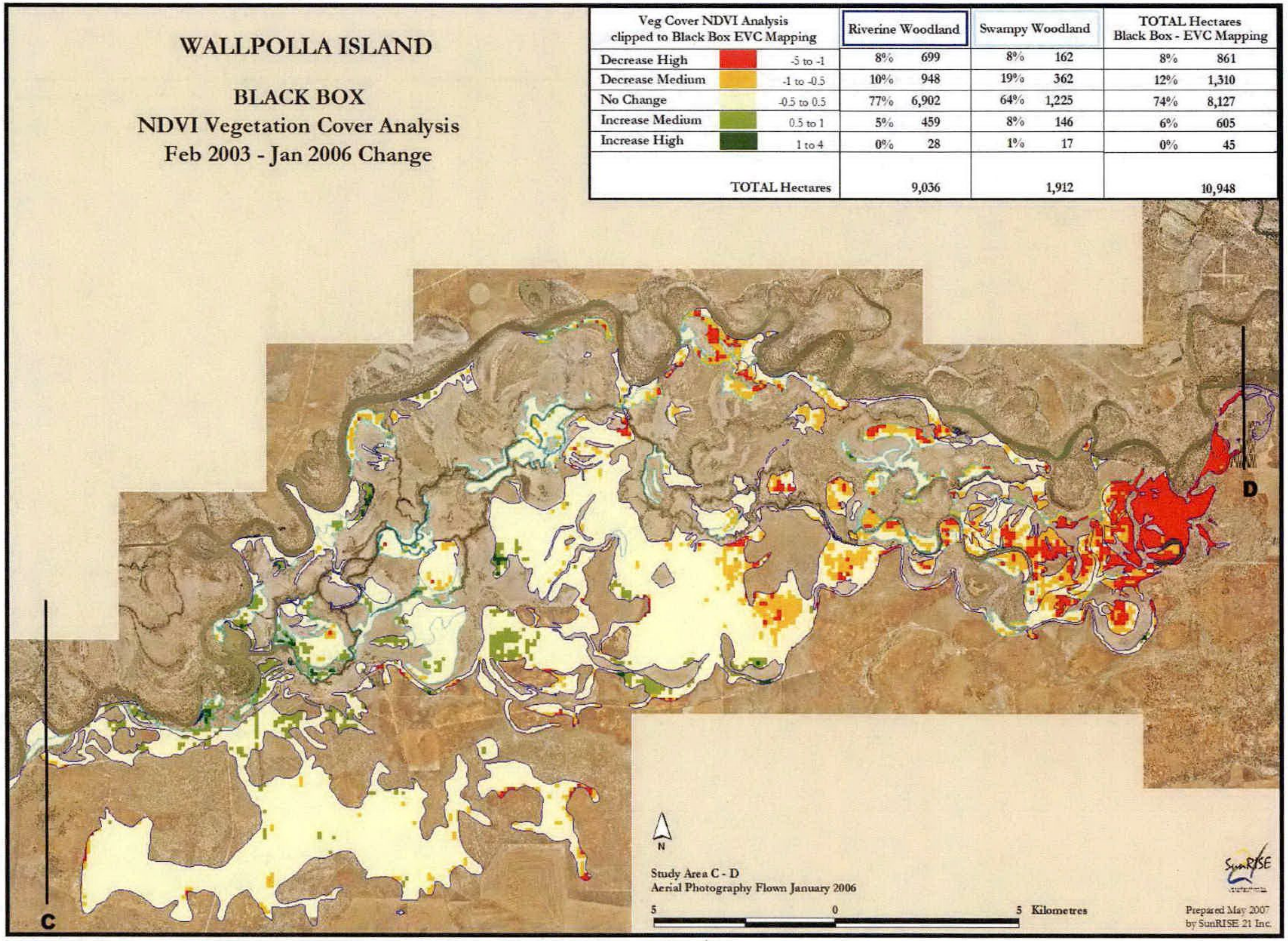
Veg Cover NDVI Analysis clipped to Black Box EVC Mapping		Riverine Woodland		Swampy Woodland		TOTAL Hectares Black Box - EVC Mapping	
Decrease High	-5 to -1	1%	35	4%	47	1%	82
Decrease Medium	-1 to -0.5	3%	181	11%	131	5%	312
No Change	-0.5 to 0.5	37%	2,080	58%	675	41%	2,755
Increase Medium	0.5 to 1	32%	1,753	18%	212	29%	1,965
Increase High	1 to 4	27%	1,501	9%	108	24%	1,609
	TOTAL Hectares		5,550		1,173		6,723

Figure 2.1.16: Change in NDVI canopy cover of BB within Lindsay Island between February 2003 and January 2006.



Veg Cover NDVI Analysis clipped to Black Box EVC Mapping		Riverine Woodland		Swampy Woodland		TOTAL Hectares Black Box - EVC Mapping	
Decrease High	-5 to -1	36%	386	32%	372	34%	758
Decrease Medium	-1 to -0.5	30%	318	31%	357	31%	675
No Change	-0.5 to 0.5	34%	354	36%	406	35%	760
Increase Medium	0.5 to 1	0%	0	1%	7	0%	7
Increase High	1 to 4	0%	0	0%	1	0%	1
TOTAL Hectares			1,058		1,143		2,201

Figure 2.1.17: Change in NDVI canopy cover of BB within Mulcra Island between February 2003 and January 2006.



Veg Cover NDVI Analysis clipped to Black Box EVC Mapping		Riverine Woodland		Swampy Woodland		TOTAL Hectares Black Box - EVC Mapping	
Decrease High	-5 to -1	8%	699	8%	162	8%	861
Decrease Medium	-1 to -0.5	10%	948	19%	362	12%	1,310
No Change	-0.5 to 0.5	77%	6,902	64%	1,225	74%	8,127
Increase Medium	0.5 to 1	5%	459	8%	146	6%	605
Increase High	1 to 4	0%	28	1%	17	0%	45
	TOTAL Hectares		9,036		1,912		10,948

Figure 2.1.18: Change in NDVI canopy cover of BB within Wallpolla Island between February 2003 and January 2006.

2.1.4 Lignum

Distribution

Two Ecological Vegetation Classes (EVCs) were recognised for lignum (*Muehlenbeckia florulenta* Meissn.) by White *et al.* (2003); Lignum Shrubland (EVC 808) and Lignum Wetland (EVC 104). These were combined for current analyses. The distribution of lignum throughout the LMW Icon Site is shown in Figures 2.1.1-2.1.3. Lignum communities within the Icon Site cover a total area of 11,832 ha (Lindsay Is. 6,056 ha, Mulcra Is. 974 ha, and Wallpolla Is. 4,802 ha).

Condition

Lignum condition was assessed during January-February 2007 at 15 sites distributed throughout the LMW Icon Site (Table 2.1.8). Sites were chosen to encompass the elevation range occupied by lignum within each Island (Figure 2.1.19). At each site 30 individual plants were scored using the Lignum Condition Index (LCI) (Table 2.1.9). The condition of individual plants varied both within and between sites (Figure 2.1.20). Median site LCI 'viability' scores at most sites ranged from 1-3.5 (*i.e.* generally < 50 % of above ground biomass was alive). The two exceptions to this were at Site 1 Mulcra Island (upstream of the Breeched Dam causeway), and Site 1 Wallpolla (on the dry bed of Horseshoe Lagoon) where median LCI 'viability' scores were 5 and 6, respectively (*i.e.* generally > 95 % of above ground biomass was alive). Of all of the sites, these two were situated at the lowest elevations and were the only ones to have been recently (and frequently) inundated (Table 2.1.8). Similarly, median site LCI 'colour' scores at most sites ranged from 2-3 (*i.e.* the viable component of most plants ranging from half-green to mainly-yellow/brown). Sites 1 on Mulcra and Wallpolla Islands were the only places where plants showed signs of recent growth (median LCI 'colour scores of 4 and 5, respectively).

Whilst intra- and inter-site relationships are informative, the key objective of maintaining sustainable populations of lignum is being met by monitoring the survival of individual plants. No assessments of community age structure were undertaken due to difficulties associated with measuring the size of individual plants, validating age-size relationships, and with distinguishing between clones and separate plants. Because of its tuberous habit, lignum is more resilient to desiccation stress than its above ground biomass (or LCI scores) alone would suggest. This allows lignum to respond rapidly to rainfall or flooding by producing shoots, leaves, flowers and seeds (Craig *et al.* 1991, Roberts and Marston 2000). Thus, the key test for resilience/viability is the presence of any sign of life following a flooding or significant rainfall event. Of the 450 plants examined, 69 (15.3 %) showed no signs of life. Future annual surveys are required to establish the viability of these and the other plants, and thus of lignum populations throughout the LMW Icon Site.

Icon Site component	Site No.	Site GPS (GDA94 datum)		Median LCI scores	
		Easting	Northing	Viability	Colour
Lindsay Island	1	515811	6224729	2.0	2.0
	2	521051	6225699	2.0	3.0
	3	517840	6226712	1.5	2.0
	4	524743	6223053	3.5	3.0
	5	514750	6225334	1.0	3.0
Mulcra Island	1	537683	6224729	5.0	4.0
	2	536588	6225699	1.0	2.0
	3	533628	6226712	3.0	2.0
	4	532494	6223053	3.0	3.0
	5	532235	6225334	2.0	3.0
Wallpolla Island	1	515811	6221794	6.0	5.0
	2	521051	6224405	1.0	2.0
	3	517840	6224170	1.0	3.0
	4	524743	6224394	2.5	2.5
	5	514750	6221776	2.0	3.0

Table 2.1.8: Lignum sampling site locations within the LMW Icon Site, and median Lignum Condition Index (LCI) scores.

Lignum Condition Index (Scholz)		
Score	% of above ground biomass that is viable	Colour of viable crown
6	> 95%	
5	75 < x ≤ 95 %	All green
4	50 < x ≤ 75 %	Mainly green
3	25 < x ≤ 50 %	Half green, half yellow/brown
2	5 < x ≤ 25 %	Mainly yellow/brown
1	0 < x ≤ 5 %	All yellow/brown
0	0 %	No viable stems

Table 2.1.9: The Lignum Condition Index used for current assessments.

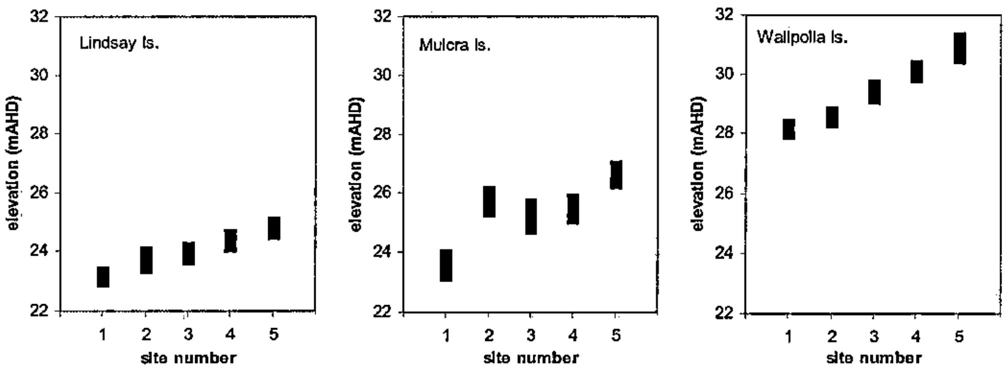


Figure 2.1.19: Site elevation (mAHD) ranges of lignum sampled within the LMW Icon Site.

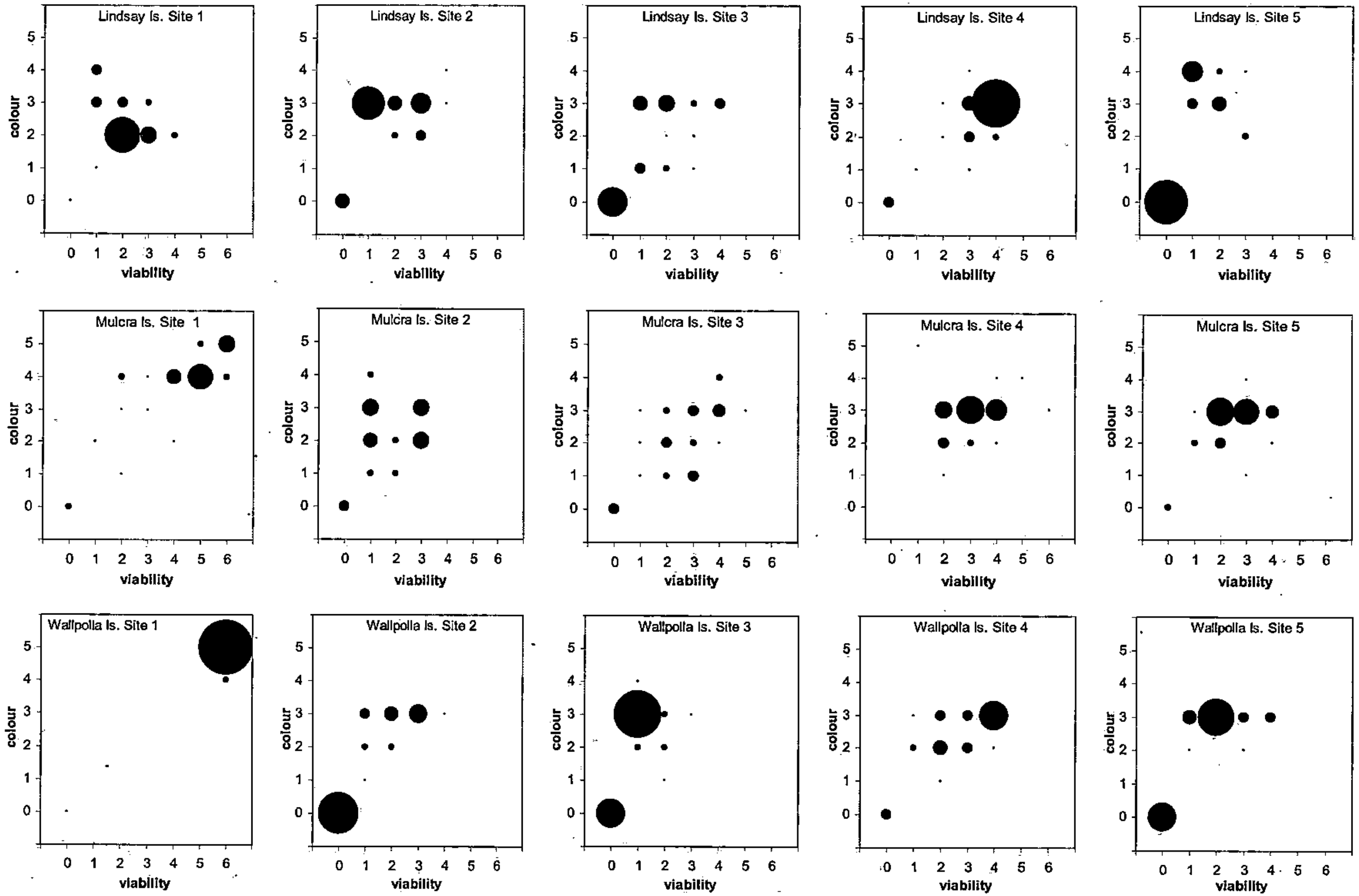


Figure 2.1.20: Lignum condition at sites 1-5 on Lindsay, Mulcra and Wallpolla Islands, where condition is defined by viability (0-6) and colour (0-5), and bubble diameter is proportional to frequency of each viability and colour score pair (n=30 per site).

2.1.5 Cumbungi

Cumbungi is a potential threat to aquatic ecosystems throughout the Mallee region due to its vigorous growth, and its ability to both displace other plant species and to reduce the hydraulic capacity of floodplain channels and flood runners (*e.g.* Roberts and Wylks 1992, Roberts and Marston 2000). Recent work at Webster's Lagoon (Lindsay Island) and Potterwalkagee Creek (Mulcra Island) has highlighted the rapidity with which cumbungi has appeared and expanded since 2000 (Scholz *et al.* 2006).

Distribution

Field surveys were undertaken during November and December 2006 to identify the distribution of cumbungi throughout the LMW Icon Site. Channel surveys covering a total of 78 km were made of representative sections of the primary anabranch channels and the adjacent Murray River (Table 2.1.10). Cumbungi was present in all reaches surveyed (Figures 2.1.21-23). Stand densities were greater in anabranch channels (8.7 stands km^{-1}) than they were in the Murray River (0.5 stands km^{-1}). Greatest stand densities were recorded in the Upper Lindsay River and in Potterwalkagee Creek. In the upper and lower sections of Potterwalkagee Creek, especially, cumbungi growth was extensive and extended across the entire channel width. The expansion of cumbungi within Potterwalkagee Creek is being examined in greater detail within the TLM intervention monitoring program (refer to Scholz *et al.* 2007b).

Although not examined directly, differences in cumbungi stand density between anabranch and Murray River reaches likely reflect differences in channel morphometry (*e.g.* steeper littoral gradients within the Murray River) (*cf.* Figure 3.1.3). As cumbungi has the capacity to grow in water up to 2 m deep (Roberts and Marston 2000), incorporating longitudinal measures of channel morphometry (width, maximum depth) in future surveys would assist with identifying narrow/shallow reaches most at risk of hydraulic obstruction by cumbungi.

Location	Reach	Length (km) of reach surveyed	No. of stands	Stands km^{-1}
Murray River	Lock 6	17.5	7	0.4
	Lock 7	8.2	5	0.6
	Lock 9	9.1	7	0.8
Lindsay Island	Lower Lindsay River	4.9	12	2.4
	Upper Lindsay River	2.7	52	19.3
	Toupnein Creek[a]	7.3	3	0.4
	Mullaroo Creek[a]	8.6	23	2.7
Mulcra Island	Potterwalkagee Creek[a]	11.1	140[b]	12.6
Wallpolla Island	Lower Wallpolla Creek	7.6	50	6.6
	Deadmans Creek[a]	1.0	10	10

Table 2.1.10: Density of cumbungi stands within surveyed reaches of the LMW Icon Sitea and adjacent Murray River reaches. [a] - Entire length surveyed. [b] - Estimate only due to merging of stands.

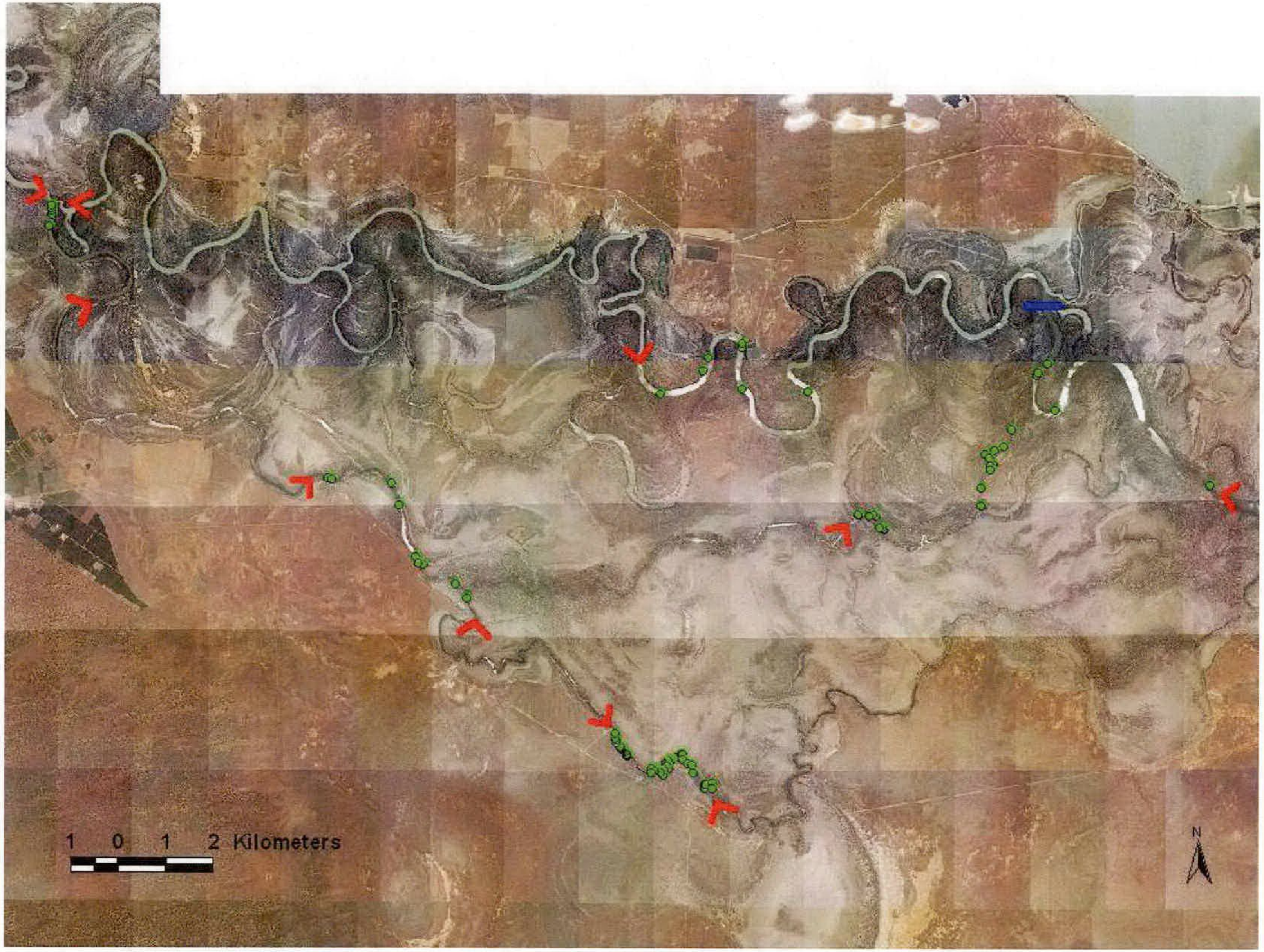


Figure 2.1.21: Distribution of cumbungi stands (•) within surveyed reaches (indicated by > and <) of Lindsay Island.

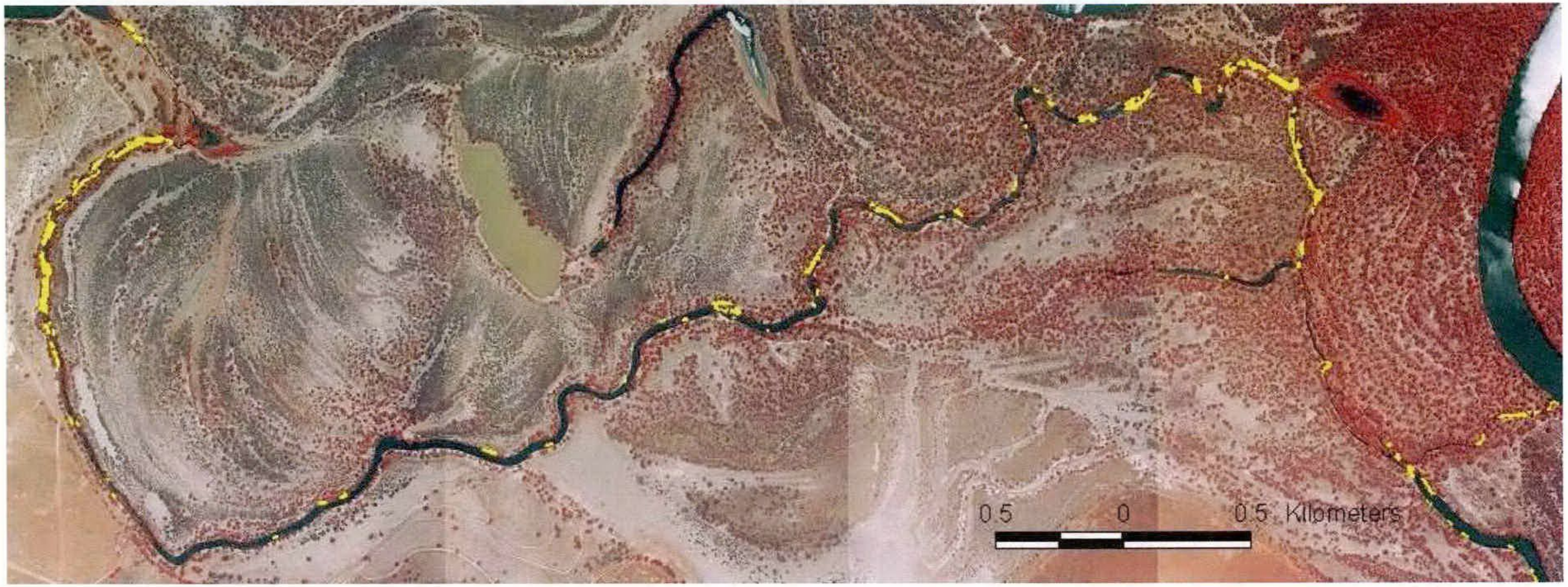


Figure 2.1.22: Distribution of cumbungi stands (•) within surveyed reaches of Mulcra Island.

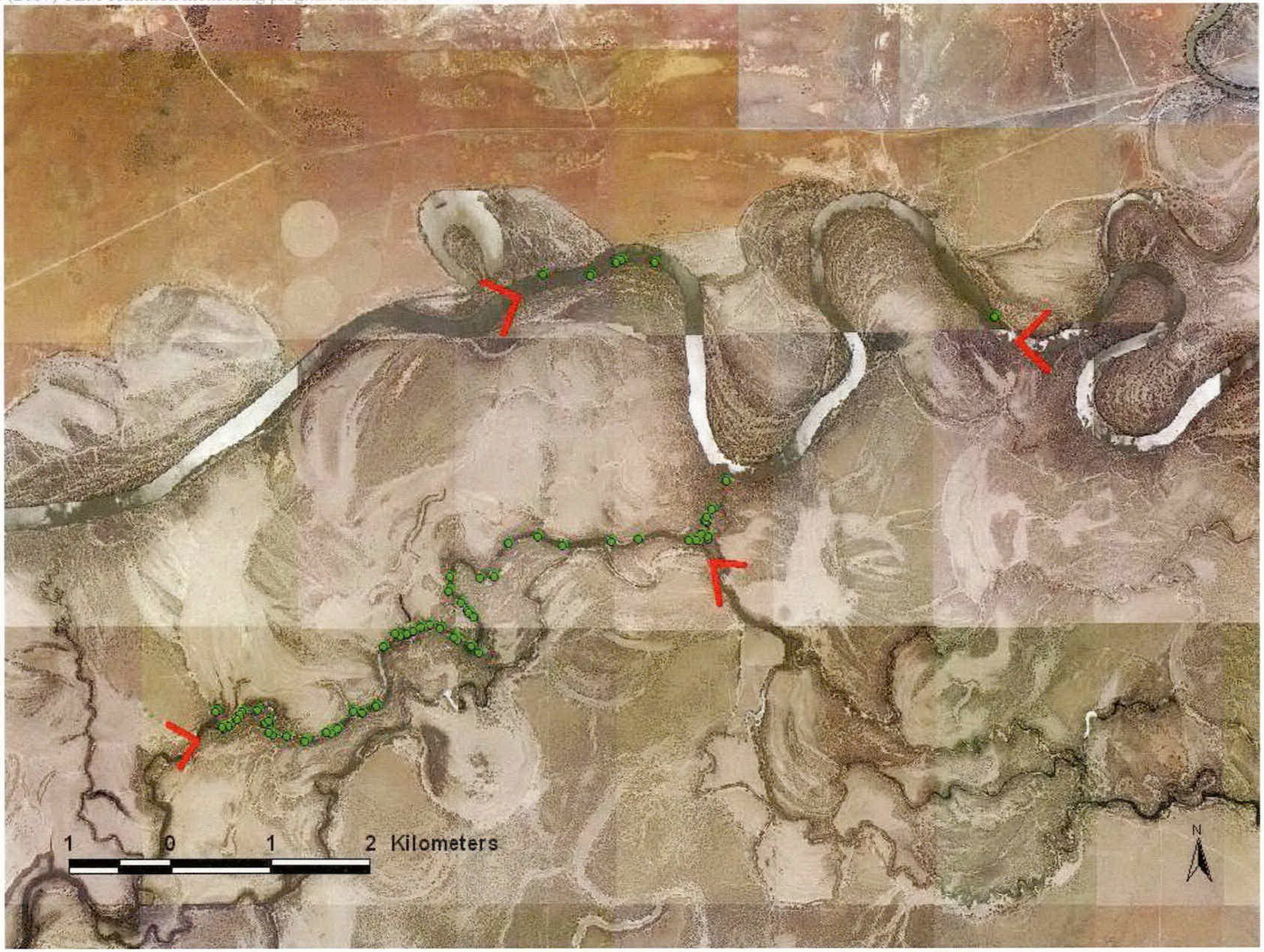


Figure 2.1.23: Distribution of cumbungi stands (•) within surveyed reaches (indicated by > and <) of Wallpolla Islands.

2.2 Hattah Lakes

2.2.1 Wetland and terrestrial assemblages

Wetland and terrestrial vegetation assemblages within the HL Icon Site were examined at nine sites between October 2006 and April 2007 (Table 2.2.1). The results of this initial survey, which will provide the baseline data against which future changes in condition will be assessed, have been presented as part of the TLM intervention monitoring program (McCarthy *et al.* 2007a).

The ecological objective of maintaining viable assemblages of wetland and terrestrial vegetation within the HL Icon Site was assessed by quantifying species diversity and their relative abundances and elevational distributions. Such assessments will be repeated annually during mid-late summer to standardise for season and to incorporate the peak growing period for many species (*cf.* Mitchell and Rogers 1985).

Location	Wetland
Hattah Lakes	Lake Mournpall Lake Yerrang Lake Lockie Lake Little Hattah Lake Hattah Lake Bulla Lake Arawak Lake Brockie Chalka Creek

Table 2.2.1: Wetlands within the HL Icon Site targeted for assessments of vegetation condition.

2.2.2 River red gums

<u>Distribution</u>

Five Ecological Vegetation Classes (EVCs) were recognised for river red gums (*Eucalyptus camaldulensis* Dehnh. Myrtaceae) (RRG) by White *et al.* (2003). These were reduced for current assessment to three water regime classes ranging from highest to lowest inundation frequency; Red Gum Forest (RGF), Fringing Red Gum Woodland (FRGW), and Red Gum with Flood Tolerant Understorey (RGFTU) (*cf.* Ecological Associates 2006, and Scholz *et al.* 2007a). The distribution and area (ha) of each of these vegetation classes within the HL Icon Site were examined using GIS layers available for each EVC.

The distributions of each RRG class within the HL Icon Site are shown in Figure 2.2.1. RRG communities cover a combined area of 8,109 ha (Table 2.2.2). RGF (15.98 % of total RRG area) occurs along the margins of Chalka Creek South and along the inside bends of the Murray River. FRGW (44.53 % of total RRG area) occupies lower lying areas of the floodplain surrounding water courses and wetlands, and RGFTU (39.49 % of total RRG area) is associated with elevated drier areas of the floodplain.

Vegetation class	Area (ha) Hattah Lakes
RGF	1,296
FRGW	3,611
RGFTU	3,202
Total	8,109

Table 2.2.2: Areas (ha) of river red gum classes (RGF, FRGW, RGFTU) within the Hattah Lakes Icon Site.

<u>Community structure</u>

Assessments of RRG community structure, *i.e.* mature tree stand density and population size frequency distribution, were based on DBH (trunk diameter at breast height) measurements obtained from transect surveys conducted at 17 sites (4 RGF, 4 FRGW, 3 RGFTU) distributed throughout the HL Icon Site (Table 2.2.3, Figure 2.2.1). Transects (10-20 m wide) were set perpendicular to key environmental gradients, such as water courses, wetlands and elevation, so as to capture as much of the within site variation as possible.

Surveyed areas accounted for 0.29 %, 0.12 % and 0.09 % of the total area occupied by RGF, FRGW and FRGW classes within the HL Icon Site, respectively. This, in conjunction with surveys of other vegetation species/classes, represented the maximum level of sampling effort that could be allocated during the current reporting period.

RRG seedlings in dry environments, such as the HL Icon Site, suffer high rates of mortality during the 2-3 years following opportunistic germination events due to the lack of water and self thinnning. As such, seedlings and saplings may not be considered to be true recruits until they reach a greater size. Thus, and in conforming to the methodology used by George *et al.* (2005) in their work at Banrock Station SA, individuals < 10 cm DBH were excluded from determinations of tree density.

Mature tree stand densities (sites pooled) did not differ significantly between RRG classes; RGF mean density 138.2 trees ha^{-1}, FRGW mean density 92.6 trees ha^{-1} and RGFTU 112.2 trees ha^{-1} (One-way ANOVA P=0.473) (Table 2.2.3). Figure 2.2.4 shows the community size class (DBH) frequency distributions determined for RGF, FRGW and RGFTU communities (site data pooled). Small trees (individuals < 10 cm DBH) accounted for 35.0 %, 27.0 % and 18.7 % of all trees surveyd in RGF, FRGW and RGFTU communities, respectively. Whilst these data are indicative of a positive correlation with flood inundation frequency, there was considerable variability in size class frequency distributions between sites within communities (Figure 2.2.5).

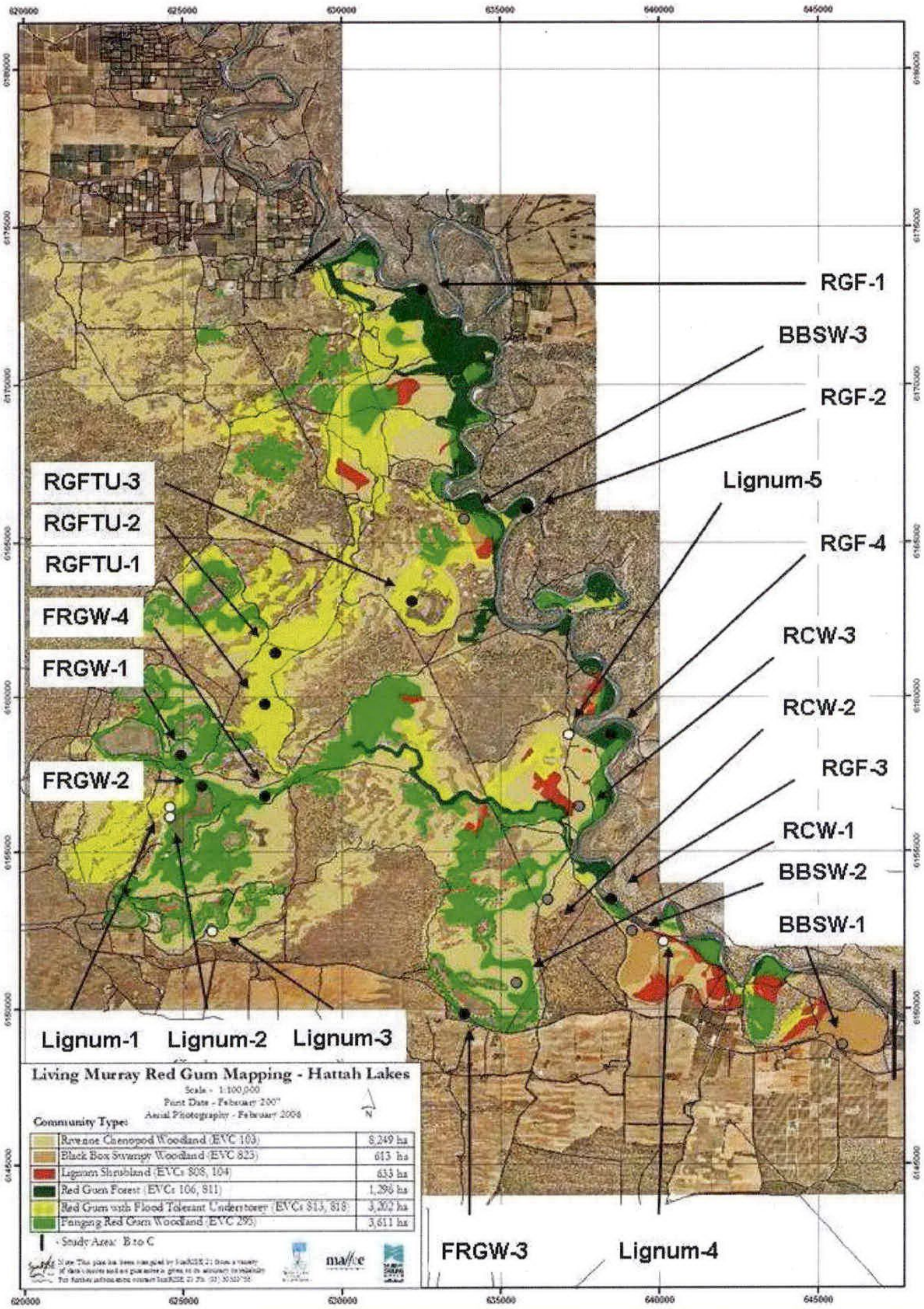
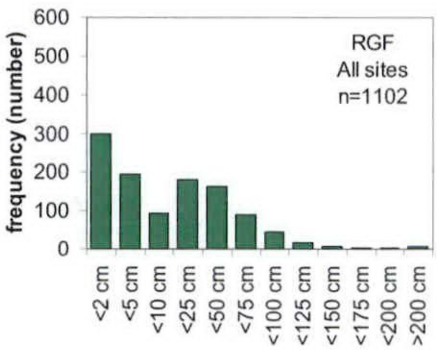


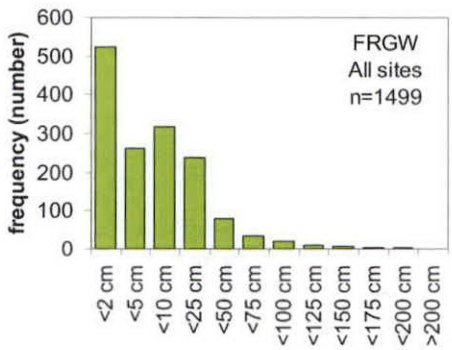
Figure 2.2.1: Distributions of the river red gum (•), black box (•) and lignum (○) communities and sampling sites within the HL Icon Site.

RRG size classes were neither uniformly distributed throughout the surveyed distribution range or population elevation ranges for each RRG water regime class (Figures 2.2.6-8). For most sites examined, the smallest trees (<10 cm DBH) were restricted to lower elevations or localised depressions. Note that no elevation data was available for one site lying outside the DEM range (RGF-3).

EVC	Site No.	Site GPS (GDA94 datum) Easting	Northing	Area surveyed (ha)	Total no. of trees surveyed	No. of trees (>10 cm DBH) surveyed	Trees ha^{-1} (>10 cm DBH)
RGF	1	632044	6173084	1.12	453	128	114.3
	2	635242	6166055	1.17	246	223	190.6
	3	638736	6152960	0.76	140	67	88.2
	4	638042	6158893	0.69	263	99	143.5
				3.74	1102	517	138.2
FRGW	1	624589	6158207	1.00	351	160	160.0
	2	625498	6157169	1.91	366	114	59.8
	3	633591	6150302	1.08	717	81	75.0
	4	627939	6157013	0.27	65	39	144.4
				4.26	1499	394	92.6
RGFTU	1	628228	6159943	2.00	224	156	78.0
	2	628306	616537	0.19	294	89	459.9
	3	632077	6162374	0.61	293	69	114.0
				2.80	811	314	112.2

Table 2.2.3: RGF, FRGW and FRGW survey site locations and tree densities determined within the HL Icon Site.





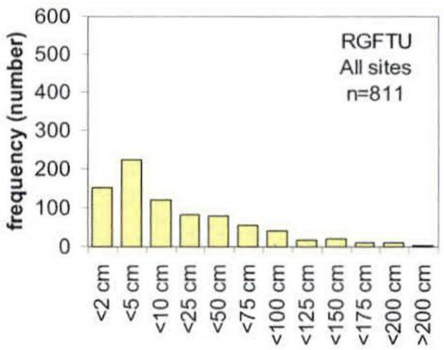


Figure 2.2.4: Size class frequency distributions determined for RGF, FRGW and RGFTU classes within the HL Icon Site (surveyed site data pooled).

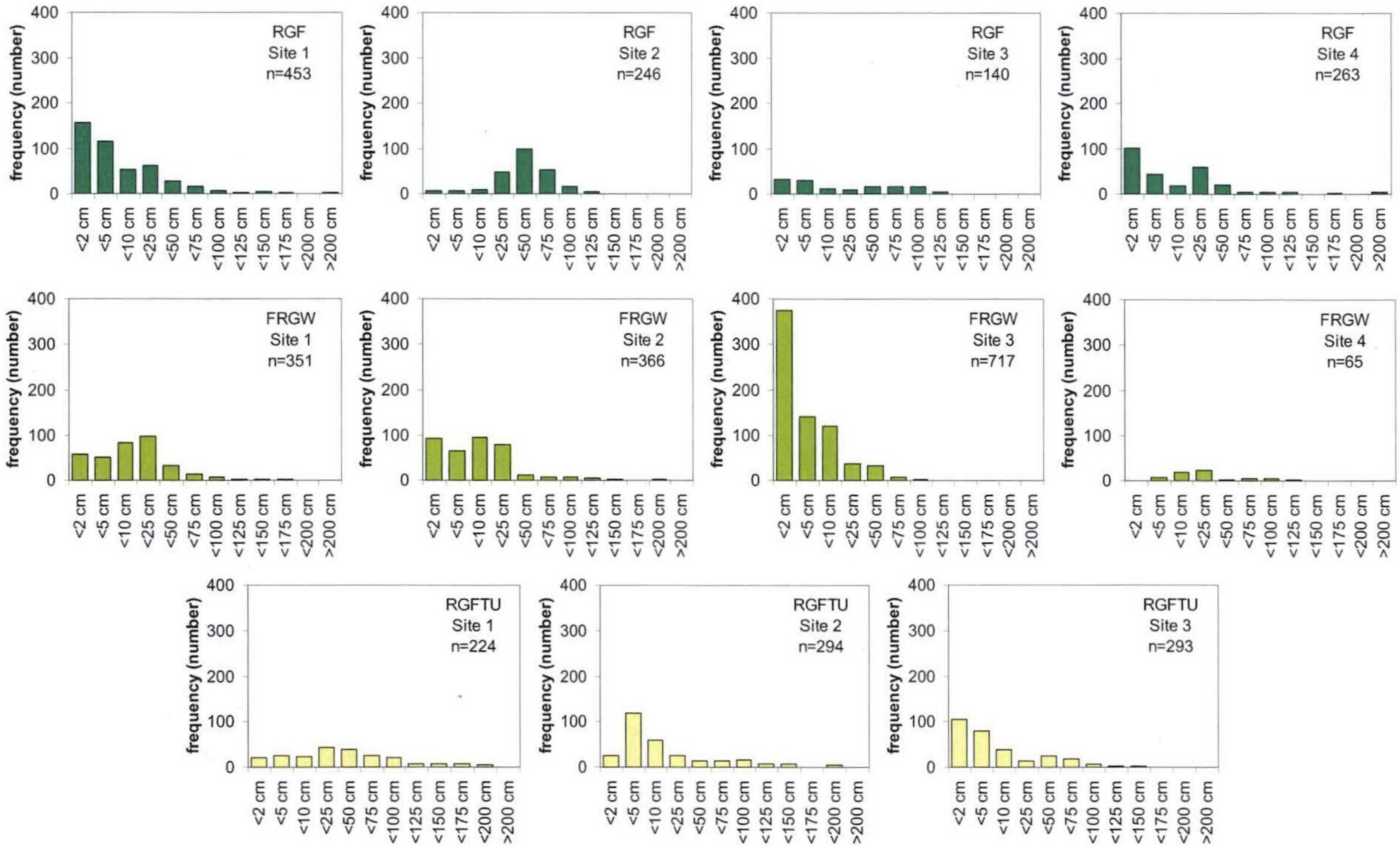


Figure 2.2.5: Size class frequency distributions determined for RGF, FRGW and RGFTU sites surveyed within the HL Icon Site.

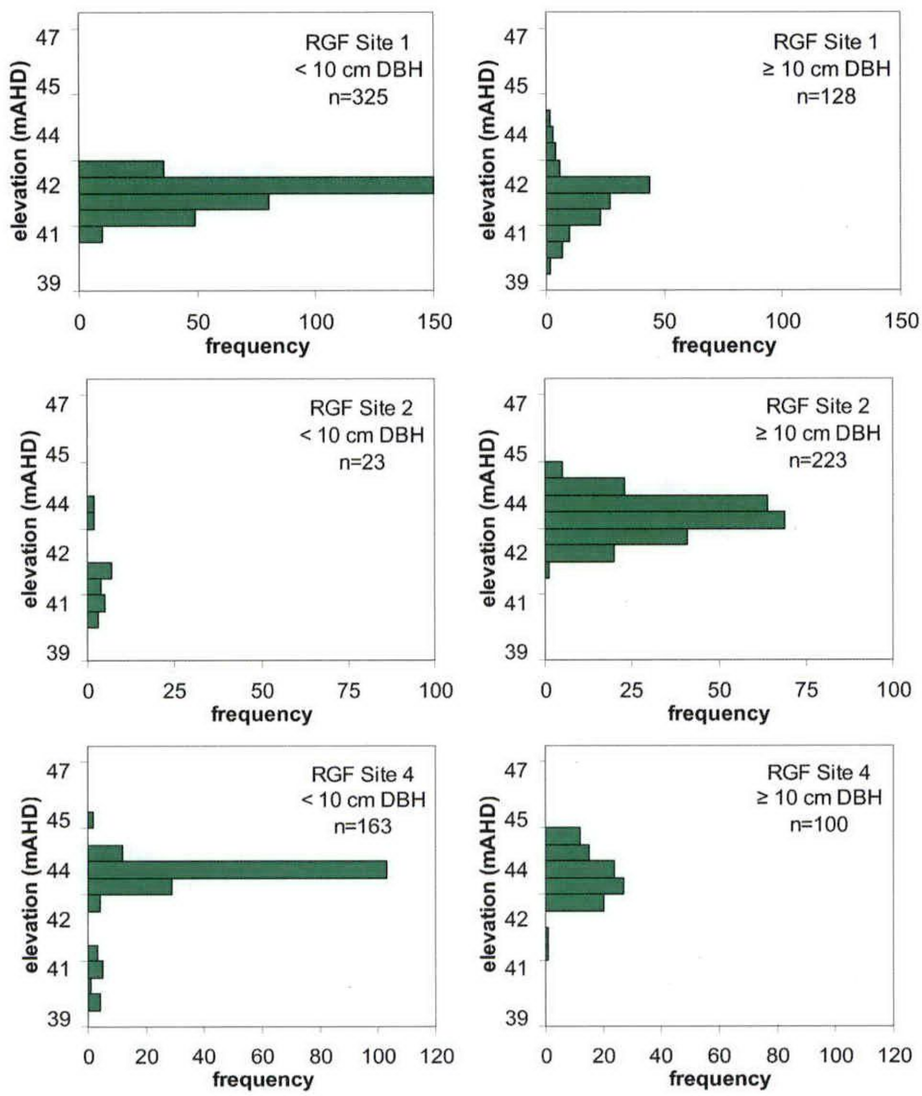


Figure 2.2.6: Elevation frequency distributions for <10 cm DBH and ≥10 cm DBH size classes determined for RGF sites surveyed within the HL Icon Site. Note – no elevation data was available for Site 3.

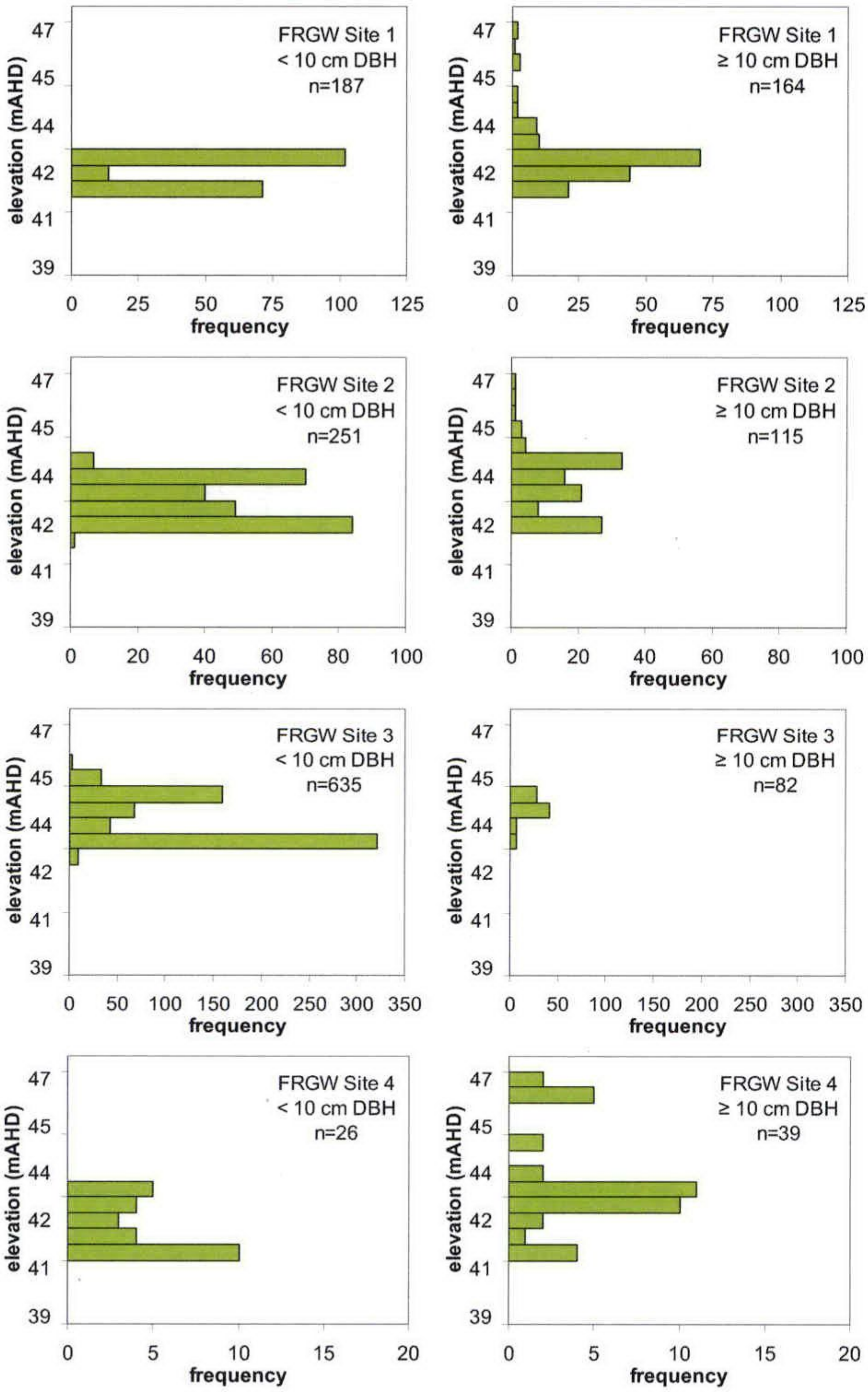


Figure 2.2.7: Elevation frequency distributions for <10 cm DBH and ≥10 cm DBH size classes determined for FRGW sites surveyed within the HL Icon Site.

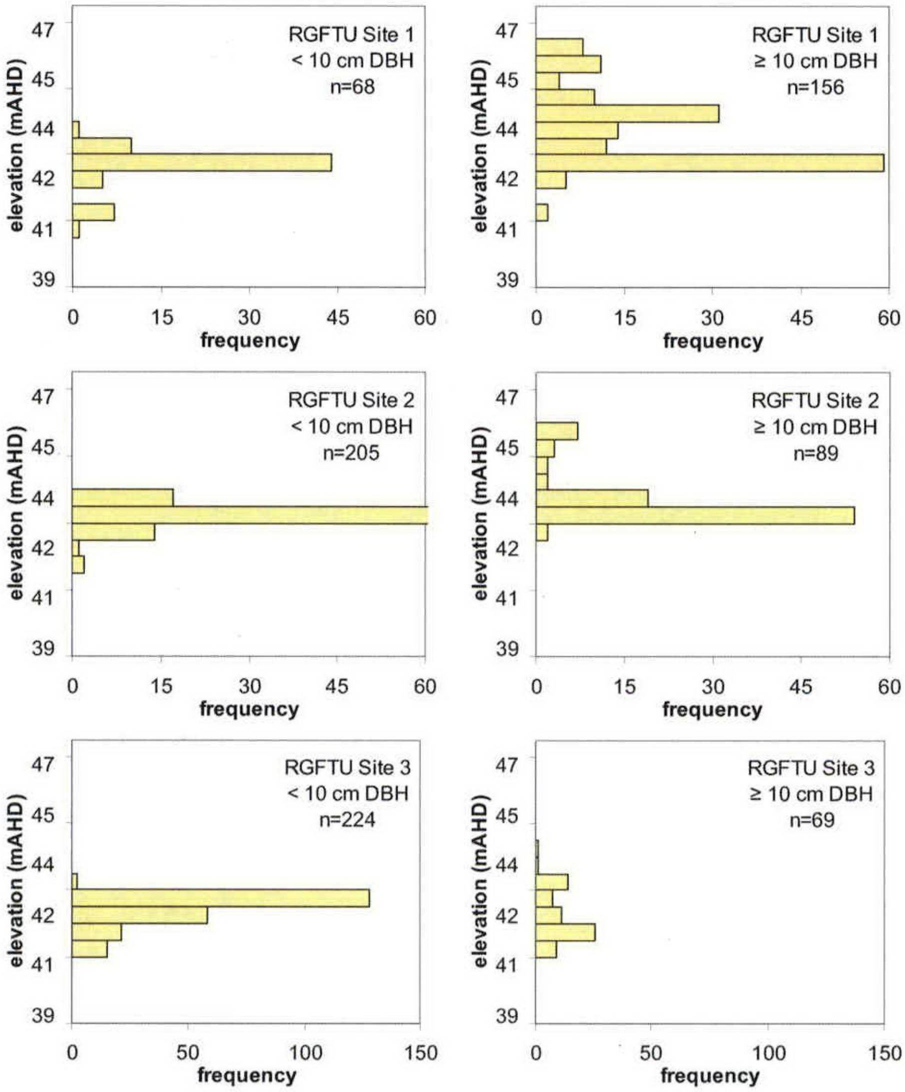


Figure 2.2.8: Elevation frequency distributions for <10 cm DBH and ≥10 cm DBH size classes determined for RGFTU sites surveyed within the HL Icon Site.

Condition

Variation in the condition (or vigour) of eucalypts may occur across a range of temporal scales and may be reflected in more rapid variations in leaf chlorophyll concentrations and slower variations in canopy density (*i.e.* leaf shedding and regrowth). Accordingly, tree condition was assessed as crown condition (*i.e.* chlorophyll concentration signatures) for momentary ('snap shot') assessments and as changes in canopy cover (*cf.* density) for comparisons between time intervals using Normalised Difference Vegetation Index (NDVI) analyses of aerial images captured during February 2003 and January 2006. In contrast to NDVI crown condition images, which have a pixel resolution ranging from 0.2-0.3 m, producing change-in-NDVI canopy cover images required corrections for differences in 'tree lean-over' (*cf.* parallax) between time intervals, which necessarily reduced pixel resolution to 100 m. Refer to Scholz *et al.* (2007a) for details of image processing and NDVI methodology. All NDVI image processing and analyses were undertaken by Aerometrex Pty. Ltd. and Sunrise 21 Inc.

Figures 2.2.9 and 2.2.10 show 2003 and 2006 NDVI crown condition images generated for RRG within the HL Icon Site (vegetation classes not delineated). The spectrum of crown condition ranges from red (*i.e.* best condition - highest chlorophyll signature) to blue (*i.e.* worst condition - lowest chlorophyll signature). Overall, RRG crown condition in both 2003 and 2006 images tended to decrease with distance from the Murray River and Chalka Creek. This gradient was stronger in 2003 than it was in 2006.

Crown condition

Figure 2.2.11 shows the change-in-NDVI canopy cover identified between 2003 and 2006 for each RRG class within the HL Icon Site. Changes in canopy cover for each 100 m square were assigned to one of five categories ranging from large increase (green) to large decrease (red). Summary statistics for each category of change in canopy cover for each RRG class are shown in Table 2.2.4.

Canopy cover

Both localised increases and decreases in RRG canopy cover were evident between 2003 and 2006, with net decreases in total RRG canopy cover (22% of total area) exceeding net increases (17% of total area). Least change in canopy cover was identified for RGFTU; the driest RRG class. Much of the changes in canopy cover of FRGW and RGW classes were located within the meanders of the Murray River, *e.g.* large increases upstream and large decreases downstream of Messenger's Crossing (Chalka Creek south). Significant areas of deceased canopy cover were also identified adjacent to Chalka Creek and north-west of Lake Hattah. Also identified was an area of increased canopy cover over a wide area near the confluence of Chalka Creek north with the Murray River.

Change in canopy cover	Percentage of total area			TOTAL
	RGF	FRGW	RGFTU	
Large decrease	13 %	10 %	5 %	8 %
Medium decrease	13 %	16 %	13 %	14 %
No change	44 %	59 %	69 %	61 %
Medium increase	17 %	11 %	11 %	12 %
Large increase	13 %	4 %	2 %	5 %

Table 2.2.4: Change in NDVI canopy cover of RRG classes within the HL Icon Site between February 2003 and January 2006.

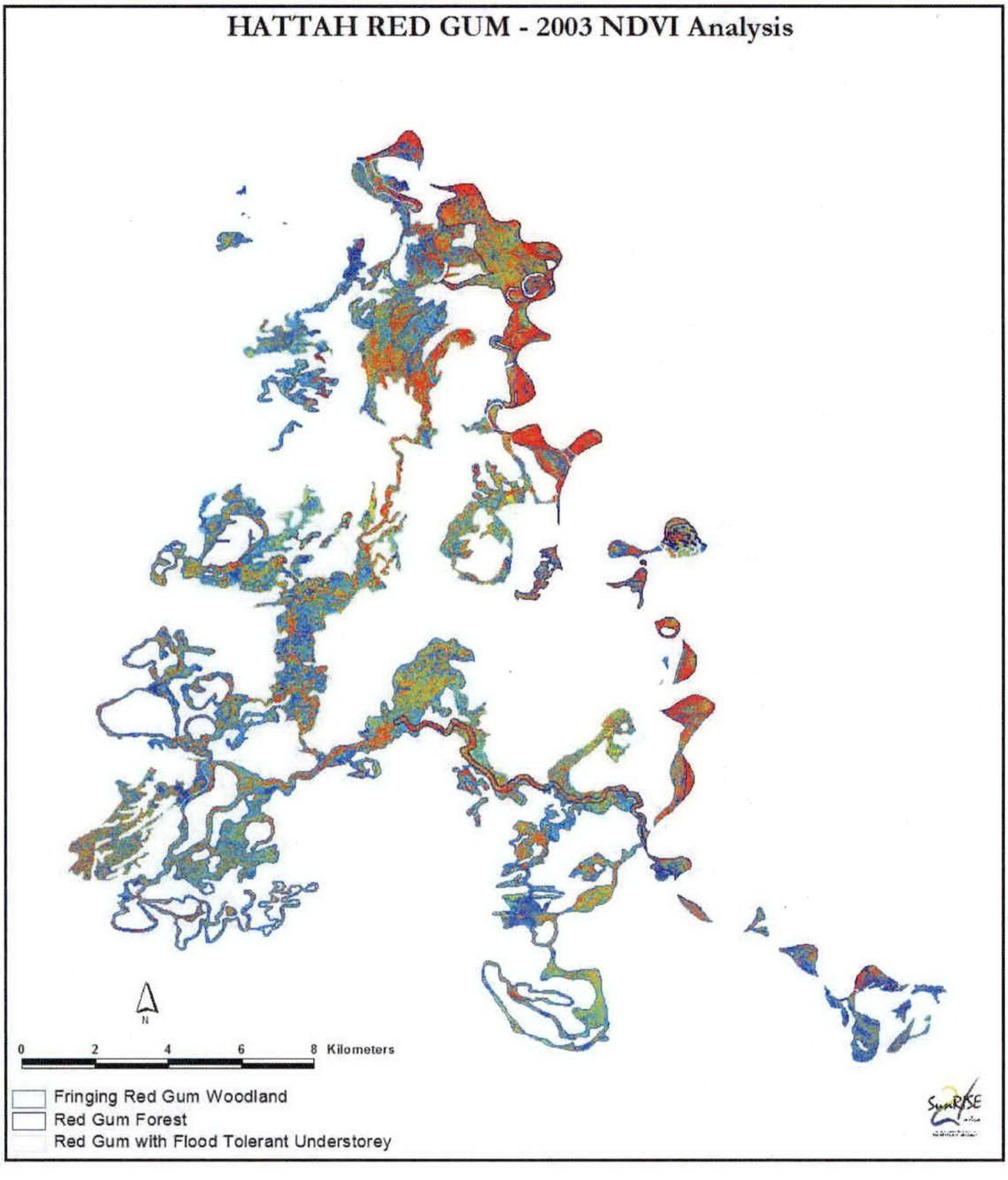


Figure 2.2.9: NDVI crown condition of RRG within the HL Icon Site during February 2003. Condition colour scale ranges from red (best) to blue (worst).

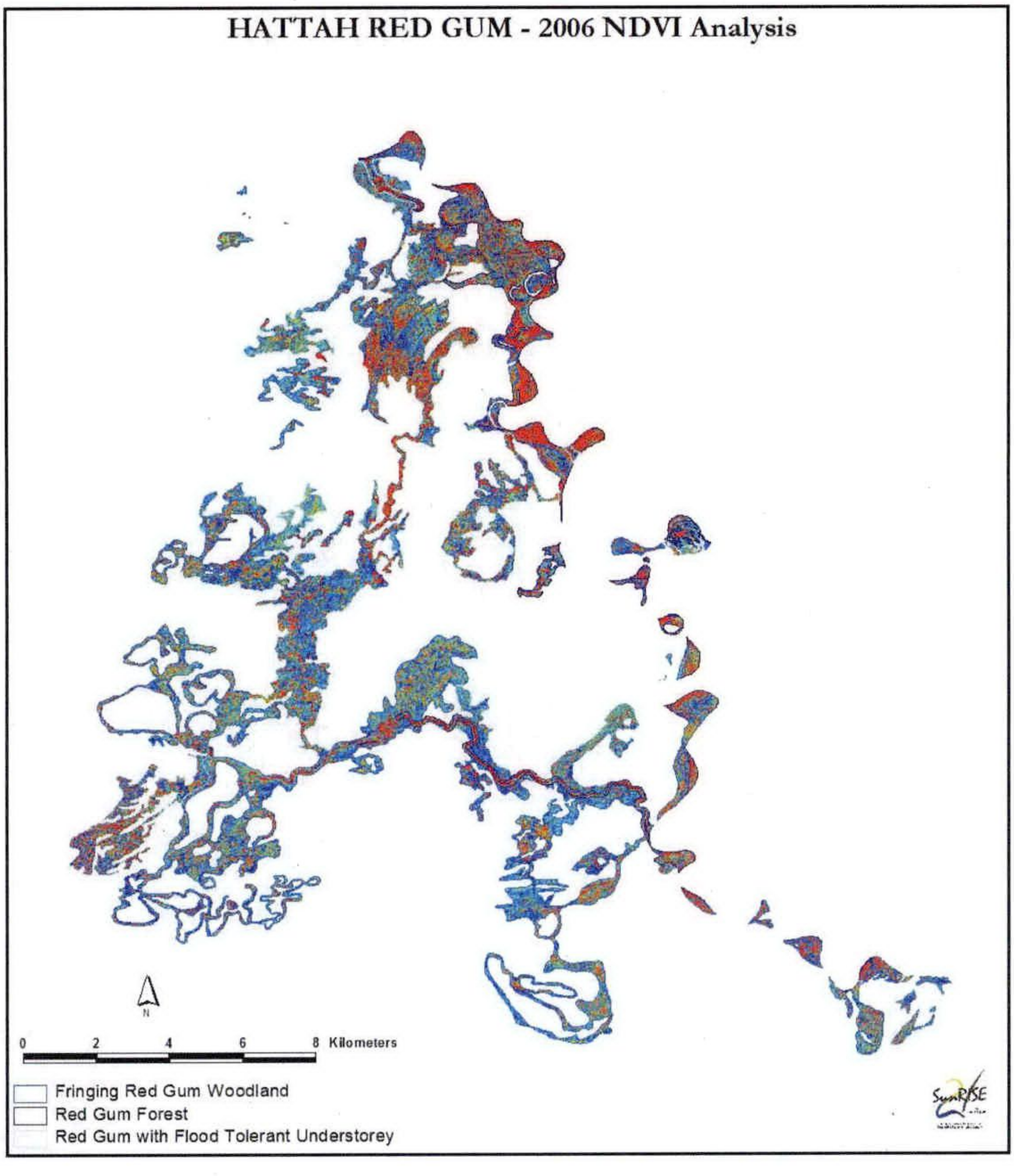
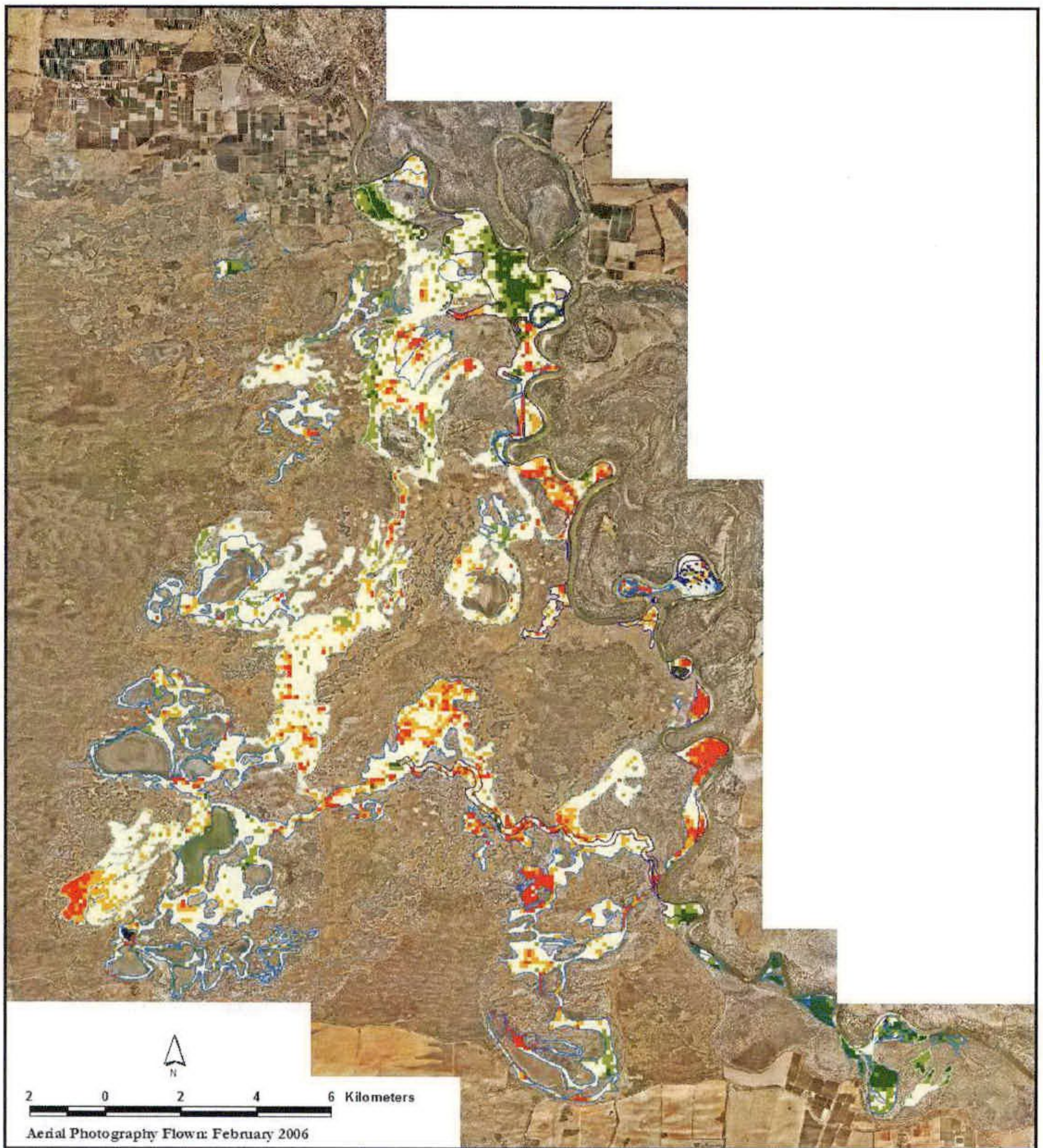


Figure 2.2.10: NDVI crown condition of RRG within the HL Icon Site during January 2006. Condition colour scale ranges from red (best) to blue (worst).



HATTAH RED GUM NDVI - Vegetation Cover Analysis
Feb 2003 - Feb 2006 Change

Using Veg Cover NDVI Analysis clipped to Red Gum EVC Mapping		Red Gum Forest		Fringing RedGum Woodland		Flood Tolerant Understory		TOTAL Hectares Red Gum - EVC Mapping	
Decrease-high	-5 to -1	13%	162.9	10%	345.2	5%	167.0	8%	675.1
Decrease-medium	-1 to -0.5	13%	163.7	16%	594.8	13%	419.3	14%	1,177.8
No Change	-0.5 to 0.5	44%	569.8	59%	2,151.2	69%	2,226.3	61%	4,947.3
Increase-medium	0.5 to 1	17%	224.2	11%	392.1	11%	362.8	12%	979.1
Increase-high	1 to 4	13%	175.7	4%	142.2	2%	52.6	5%	370.5
	TOTAL Hectares		1,296.3		3,625.5		3,228.0		8,149.8

Figure 2.2.11: Change in NDVI canopy cover of RRG within the HL Icon Site between February 2003 and January 2006.

2.2.3 Black box

Distribution

Two Ecological Vegetation Classes (EVCs) were recognised for black box (*Eucalyptus largiflorens* F. Muell.) (BB) by White et al. (2003); Riverine Chenopod Woodland (RCW) and Black Box Swampy Woodland (BBSW). The distribution and area (ha) of each of these vegetation classes within the HL Icon Site was examined using GIS layers available for each EVC.

The distribution of BB throughout the HL Icon Site is shown in Figure 2.2.1. BB communities cover a total area of 8,862 ha. RCW (8,249 ha or 93.08 % of total BB cover) tend to occupy higher elevations of the floodplain than BBWS (613 ha or 6.92 % of total BB cover).

Community structure

Assessments of BB community structure, *i.e.* mature tree stand density and population size frequency distribution, were based on DBH (trunk diameter at breast height) measurements obtained from transect surveys conducted at 6 sites (3 RCW, 3 BBSW) distributed throughout the HL Icon Site (Table 2.2.5, Figure 2.2.1). Transects (10-20 m wide) were set perpendicular to key environmental gradients, such as water courses, wetlands and elevation, so as to capture as much of the within site variation as possible.

Surveyed areas accounted for 0.03 % and 0.80 % of the total area occupied by RCW and BBSW classes within the HL Icon Site, respectively. This, in conjunction with surveys of other vegetation species/classes, represented the maximum level of sampling effort that could be allocated during the current reporting period.

Black box seedlings in dry environments, such as the HL Icon Site, suffer high rates of mortality during the 2-3 years following opportunistic germination events due to the lack of water and self thinnning. As such, seedlings and saplings may not be considered to be true recruits until they reach a greater size. Thus, and in conforming to the methodology used by George *et al.* (2005) in their work at Banrock Station SA, individuals < 10 cm DBH were excluded from determinations of tree density.

Mature tree stand densities (sites pooled) did not differ significantly between BB classes; RCW mean density 88.9 trees ha^{-1} and BBSW mean density 115.3 trees ha^{-1} (t-test $P=0.915$) (Table 2.2.5). Figure 2.2.12 shows the community size class (DBH) frequency distributions determined for RCW and BBSW communities (site data pooled). Overall, there were few small trees (individuals <10 cm DBH) within the BBSW class, and their presence within the RCW class was attributable to a single site (Site 2) (Figure 2.2.13). Whilst only a relatively low number of sites were surveyed, these data are indicative of the spatially patchy distribution of small trees and of the variability of both mature tree densities and size class frequency distributions (Scholz pers. obs.).

For the sites surveyed, RCW and BBSW extended over a narrower and higher elevation range than did RRGs. At sites where small trees (<10 cm DBH) were encountered, they were distributed across the elevation range occupied by larger trees (Figures 2.2.14 and 2.2.15). No elevation data was available for sites lying outside the DEM range (BBSW-1 and 2).

EVC	Site No.	Site GPS (GDA94 datum) Easting	Site GPS (GDA94 datum) Northing	Area surveyed (ha)	Total no. of trees surveyed	No. of trees (>10 cm DBH) surveyed	Trees ha^{-1} (>10 cm DBH)
RCW	1	636101	6150807	0.26	178	46	176.9
	2	636101	6153457	0.48	886	53	110.4
	3	637227	6156591	1.60	232	109	68.1
				2.34	1296	208	88.9
BBSW	1	645693	6148743	1.93	355	299	154.9
	2	638973	6152424	0.98	196	160	163.3
	3	633895	6165942	2.00	229	107	53.5
				4.91	780	566	115.3

Table 2.2.5: RCW and BBSW survey site locations and tree densities determined within the HL Icon Site.

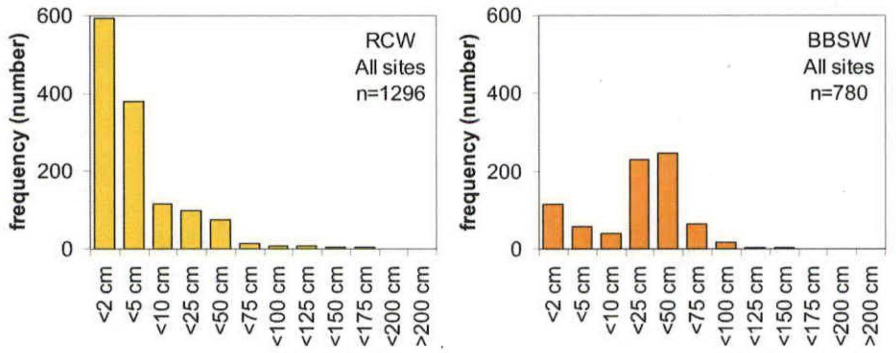


Figure 2.2.12: Size class frequency distributions determined for RCW (left) and BBSW (right) classes within the HL Icon Site (surveyed site data pooled).

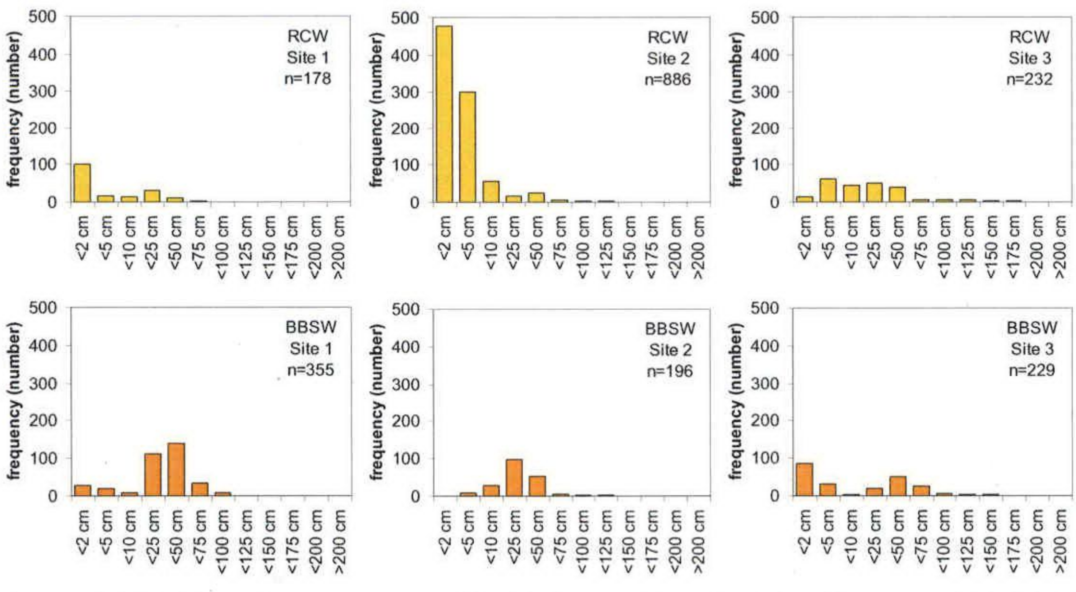


Figure 2.2.13: Size class frequency distributions determined for RCW and BBSW sites surveyed within the HL Icon Site.

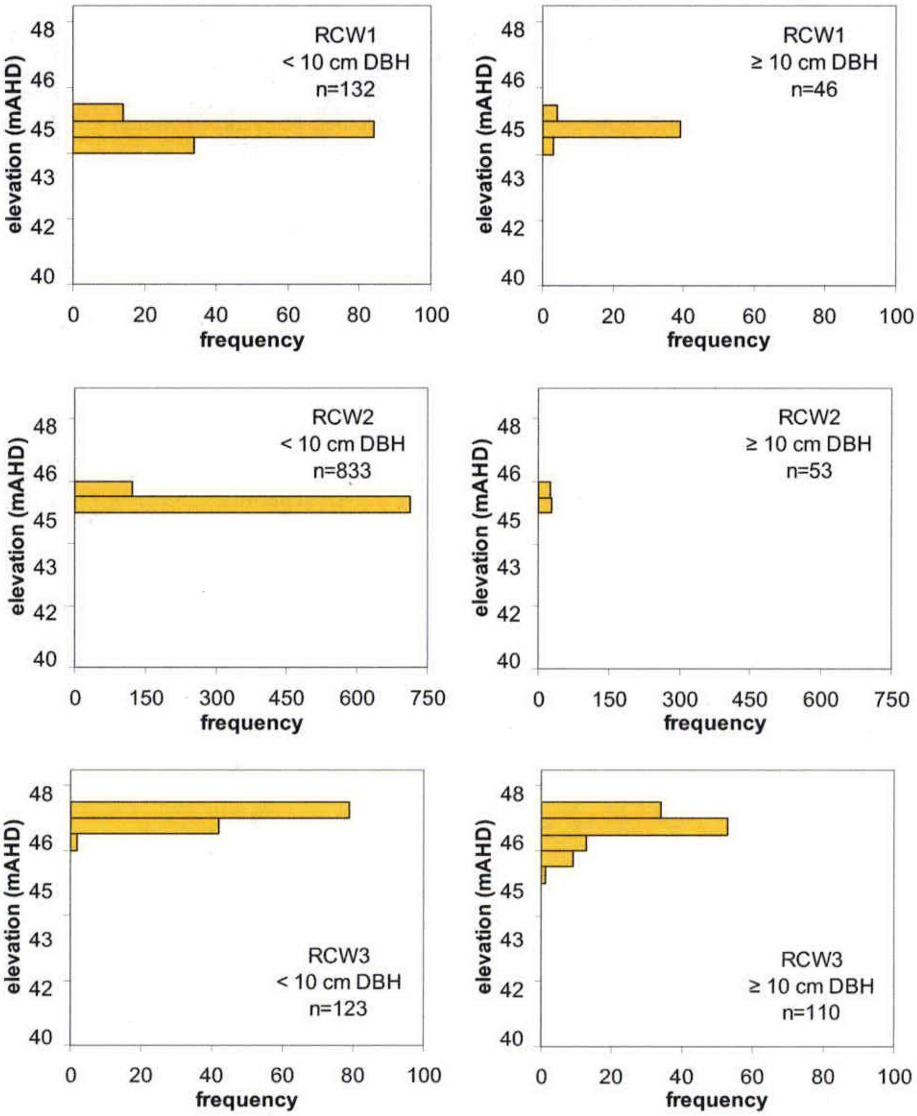


Figure 2.2.14: Elevation frequency distributions for <10 cm DBH and ≥10 cm DBH size classes determined for RCW sites surveyed within the HL Icon Site.

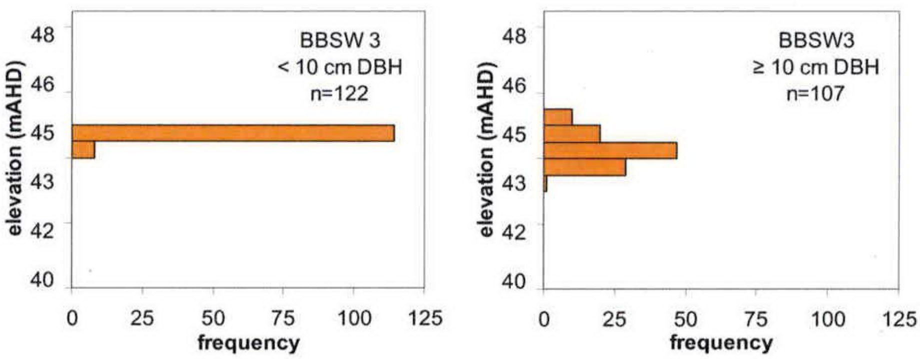


Figure 2.2.15: Elevation frequency distributions for <10 cm DBH and ≥10 cm DBH size classes determined for BBSW sites surveyed within the HL Icon Site. No elevation data was available for sites 1 and 2.

Condition

Variation in the condition (or vigor) of eucalypts may occur across a range of temporal scales and may be reflected in more rapid variations in leaf chlorophyll concentrations and slower variations in canopy density (*i.e.* leaf shedding and regrowth). Accordingly, tree condition was assessed as crown condition (*i.e.* chlorophyll concentration signatures) for momentary ('snap shot') assessments and as changes in canopy cover (*cf.* density) for comparisons between time intervals using Normalised Difference Vegetation Index (NDVI) analyses of aerial images captured during February 2003 and January 2006. In contrast to NDVI crown condition images, which have a pixel resolution ranging from 0.2-0.3 m, producing change-in-NDVI canopy cover images required corrections for differences in 'tree lean-over' (*cf.* parallax) between time intervals, which necessarily reduced pixel resolution to 100 m. Refer to Scholz *et al.* (2007a) for details of image processing and NDVI methodology. All NDVI image processing and analyses were undertaken by Aerometrex Pty. Ltd. and Sunrise 21 Inc.

Crown condition

Figures 2.2.16 and 2.2.17 show 2003 and 2006 NDVI crown condition images generated for BB within the HL Icon Site. The spectrum of crown condition ranges from red (*i.e.* best condition - highest chlorophyll signature) to blue (*i.e.* worst condition - lowest chlorophyll signature). During February 2003, BB crown condition varied over small spatial scales, with local maxima identified in patches towards the northern border of the Icon Site, and local minima within the Kulkyne Park located on the southern margins of the Icon Site adjacent to the Murray River. A similar spatial distribution of crown condition was identified during January 2006, although BB condition within the Kulkyne Park was in relatively better condition.

Canopy cover

Figures 2.2.18 shows the change-in-NDVI canopy cover identified between 2003 and 2006 for each BB class within each component of the HL Icon Site. Changes in canopy cover for each 100 m square were assigned to one of five categories ranging from large increase (green) to large decrease (red). Summary statistics for each category of change in canopy cover for each RRG class are shown in Table 2.2.6.

Both localised increases and decreases in BB canopy cover were evident between 2003 and 2006, with net decreases in total BB canopy cover (21 % of total area) exceeding net increases (14 % of total area). Least change in canopy cover was identified for the driest BB class – RCW. Most of the decreases in canopy cover occurred in patches distributed throughout the Icon Site. In contrast, much of the increases in canopy cover was located within 1-2 km of the Murray River upstream of Messenger's Crossing (Chalka Creek south) within the Kulkyne Park, an area within which increases in RRG canopy cover over the same period were identified.

Change in canopy cover	Percentage of total area		TOTAL
	RCW	BBSW	
Large decrease	5 %	5 %	5 %
Medium decrease	16 %	8 %	16 %
No change	67 %	31 %	65 %
Medium increase	9 %	30 %	10 %
Large increase	3 %	26 %	4 %

Table 2.2.6: Change in NDVI canopy cover of black box classes within the HL Icon Site between February 2003 and January 2006.

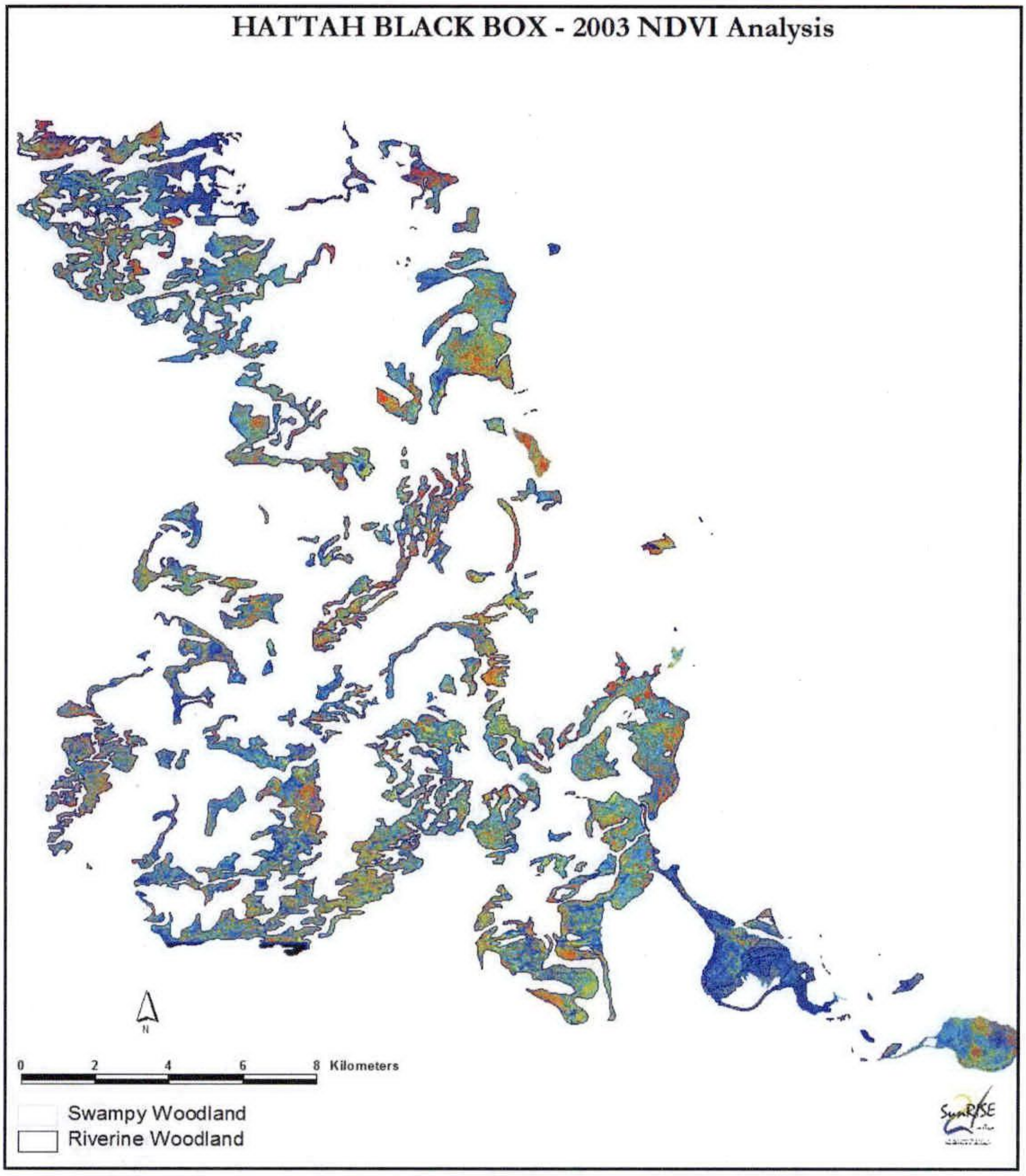


Figure 2.2.16: NDVI crown condition of black box within the HL Icon Site during February 2003. Condition scale ranges from red (best) to blue (worst).

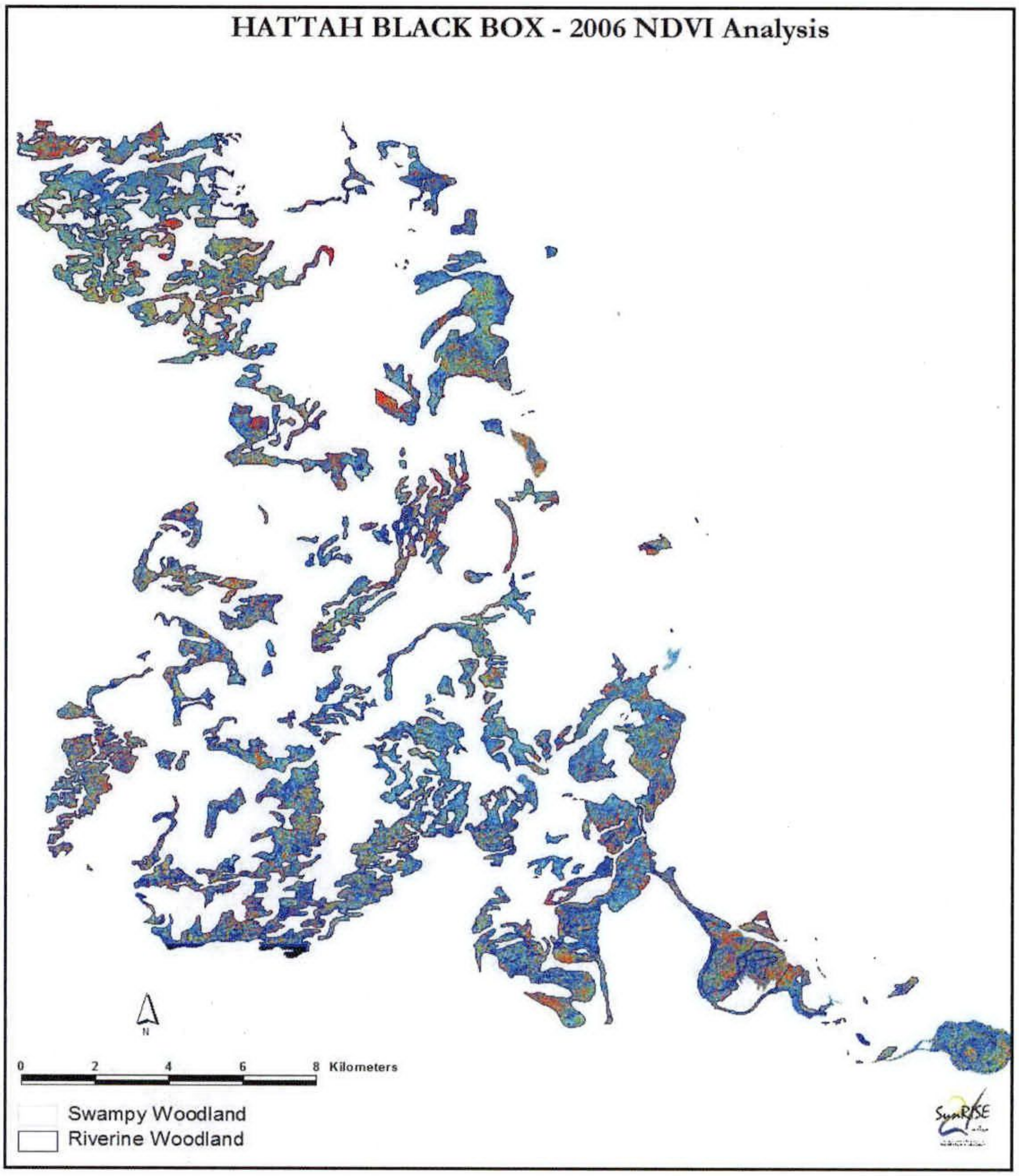
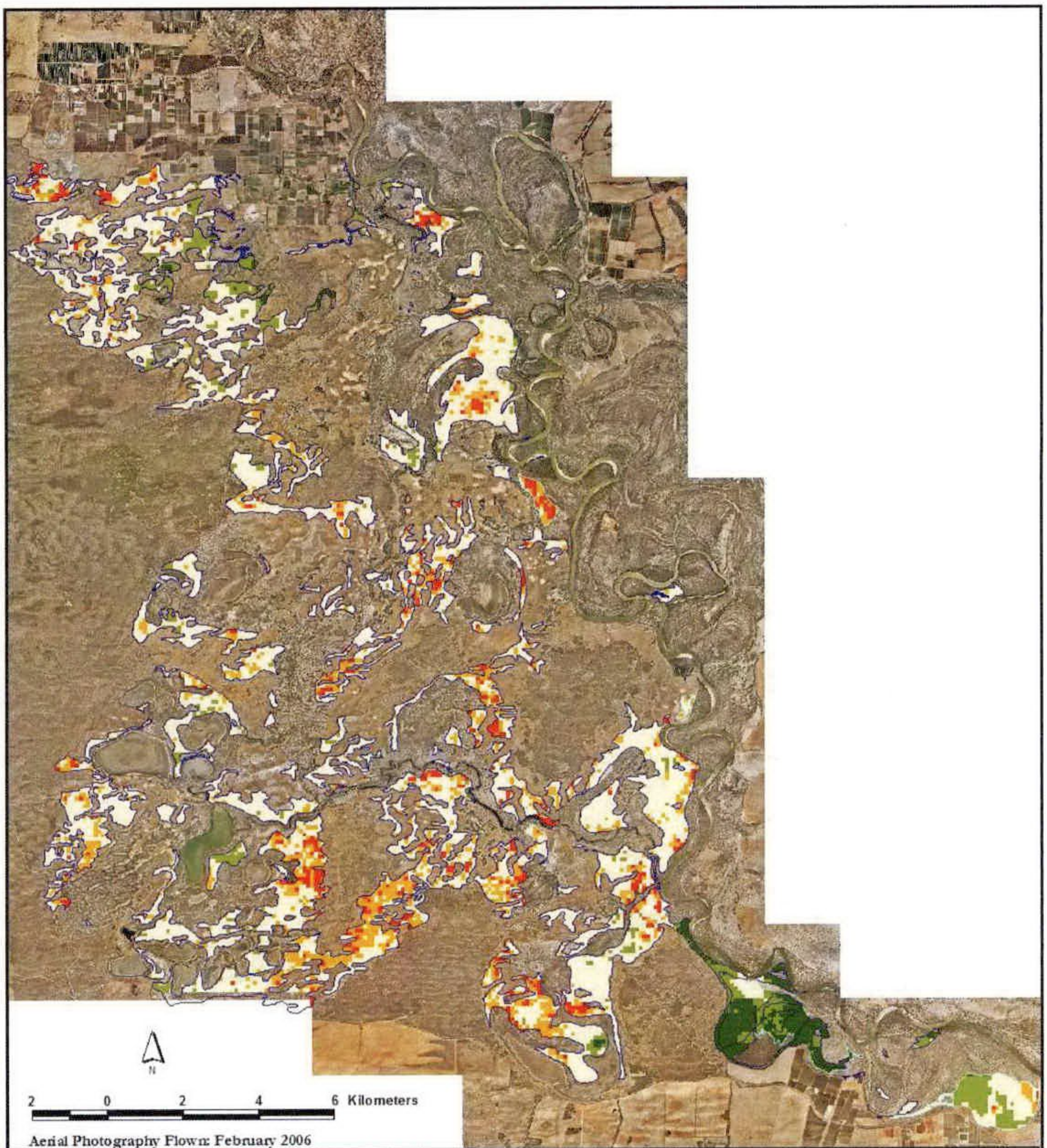


Figure 2.2.17: NDVI crown condition of black box within the HL Icon Site during January 2006. Condition scale ranges from red (best) to blue (worst).



HATTAH BLACK BOX - NDVI Vegetation Cover Analysis
Feb 2003 - Feb 2006 Change

Using Veg Cover NDVI Analysis clipped to Black Box EVC Mapping		Riverine Woodland		Swampy Woodland		TOTAL Hectares Black Box- EVC Mapping	
Decrease-high	-5 to -1	5%	439.7	5%	29.0	5%	468.7
Decrease-medium	-1 to -0.5	16%	1,329.6	8%	49.7	16%	1,379.3
No Change	-0.5 to 0.5	67%	5,474.8	31%	187.9	65%	5,662.7
Increase-medium	0.5 to 1	9%	715.6	30%	183.6	10%	899.2
Increase-high	1 to 4	3%	201.9	26%	163.1	4%	365.0
	TOTAL Hectares		8,161.6		613.3		8774.9

Figure 2.2.18: Change in NDVI canopy cover of black box within the HL Icon Site between February 2003 and January 2006.

2.2.4 Lignum

Distribution

Two Ecological Vegetation Classes (EVCs) were recognised for lignum (*Muehlenbeckia florulenta* Meissn.) by White *et al.* (2003); Lignum Shrubland (EVC 808) and Lignum Wetland (EVC 104). These were combined for current analyses. The distribution of lignum throughout the HL Icon Site is shown in Figure 2.2.1. Lignum communities cover a total area of 633 ha.

Condition

Lignum condition was assessed during January-February 2007 at 5 sites distributed throughout the HL Icon Site (Table 2.2.7). Sites were chosen to encompass the elevation range occupied by lignum within the Icon Site (Figure 2.1.19). At each site 30 individual plants were scored using the Lignum Condition Index (LCI) (Table 2.2.8). The condition of individual plants varied both within and between sites (Figure 2.2.20). Median site LCI 'viability' scores tended to decrease with increasing site elevation, *i.e.* plants at higher elevations tended to have more dead than living above ground biomass, suggesting (though not demonstrating) a causal link with inundation frequency. In contrast, LCI 'colour' scores varied much less between sites, with the viable component of most plants ranging from half- to mainly-green. This relative uniformity may be at least in part attributable to a flush of new growth stimulated by recent heavy rains.

Whilst intra- and inter-site relationships are informative, the key objective of maintaining sustainable populations of lignum is being met by monitoring the survival of individual plants. No assessments of community age structure were undertaken due to difficulties associated with measuring the size of individual plants, validating age-size relationships, and with distinguishing between clones and separate plants. Because of its tuberous habit, lignum is more resilient to desiccation stress than its above ground biomass (or LCI scores) alone would suggest. This allows lignum to respond rapidly to rainfall or flooding by producing shoots, leaves, flowers and seeds (Craig *et al.* 1991, Roberts and Marston 2000). Thus, the key test for resilience/viability is the presence of any sign of life following a flooding or significant rainfall event. Of the 150 plants examined, only 1 showed no signs of life (site 5). Future annual surveys are required to establish the viability of this and the other plants, and thus of lignum populations throughout the HL Icon Site.

Icon Site	Site No.	Site GPS (GDA94 datum)		Median LCI scores	
		Easting	Northing	Viability	Colour
Hattah Lakes	1	624425	6155637	5.0	4.0
	2	623132	6153574	3.0	3.5
	3	642232	6150523	4.0	4.0
	4	640093	6152258	3.0	4.0
	5	637224	6159158	2.0	3.0

Table 2.2.7: Lignum sampling site locations within the HL Icon Site, and median Lignum Condition Index (LCI) scores.

Lignum Condition Index		
Score	% of above ground biomass that is viable	Colour of viable crown
6	> 95%	
5	75 < x ≤ 95 %	All green
4	50 < x ≤ 75 %	Mainly green
3	25 < x ≤ 50 %	Half green, half yellow/brown
2	5 < x ≤ 25 %	Mainly yellow/brown
1	0 < x ≤ 5 %	All yellow/brown
0	0 %	No viable stems

Table 2.2.8: The Lignum Condition Index used for current assessments.

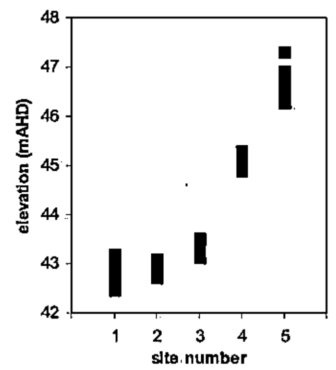


Figure 2.2.19: Site elevation (mAHD) ranges of lignum sampled within the HL Icon Site.

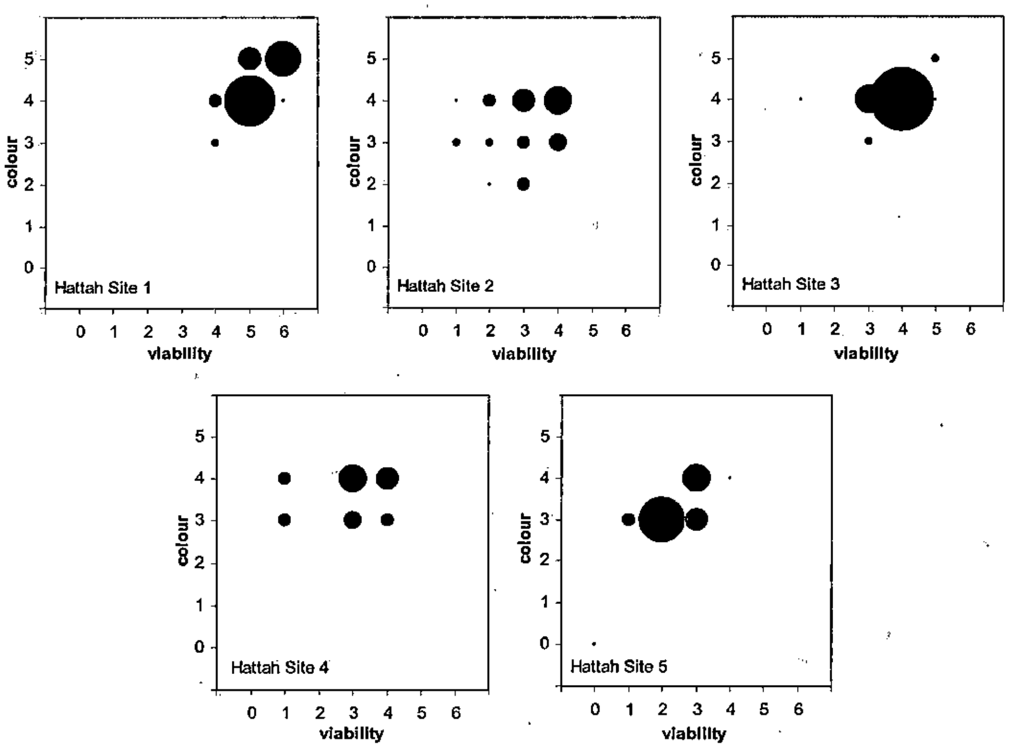


Figure 2.2.20: Lignum condition at sites 1-5 within the HL Icon Site, where condition is defined by viability (0-6) and colour (0-5), and bubble diameter is proportional to frequency of each viability and colour score pair (n=30 per site).

2.2.5 Cumbungi

Cumbungi is a potential threat to aquatic ecosystems throughout the Mallee region due to its vigorous growth, and its ability to both displace other plant species and to reduce the hydraulic capacity of floodplain channels and flood runners (*e.g.* Roberts and Wylks 1992, Roberts and Marston 2000). Recent work at Webster's Lagoon (Lindsay Island) and Potterwalkagee Creek (Mulcra Island) has highlighted the rapidity with which cumbungi has appeared and expanded over recent years (Scholz *et al.* 2006).

Distribution

No cumbungi was observed during field surveys undertaken between November 2006 and April 2007 of the Murray River (between 5 km downstream and 1 km upstream of Messengers crossing), Chalka Creek (between Messengers crossing and Lake Lockie) and of lakes Lockie, Yerrang, Mourmpall, Little Hattah, Hattah, Bulla and Arawak. The (apparent) absence of cumbungi from the Hattah Lakes system constrasts with its ubiquitous presence throughout each of the reaches surveyed within the LMW Icon Site (refer to Section 2.1.5).

2.3 Conclusions/recommendations

Wetland and terrestrial vegetation assemblages

Lindsay-Mulcra-Wallpolla Islands

No assessment of wetland and terrestrial vegetation assemblage condition within the LMW Icon Site was undertaken during the current reporting period due to delays in finalising the list of wetlands to be targeted, and in generating flood inundation images from satellite imagery and GIS models, which will be used to identify terrestrial sites. Condition monitoring will commence during late 2007 - early 2008 and will provide the baseline data against which future changes in condition with respect to condition targets will be assessed. As yet, suitable condition targets have not been developed.

Hattah Lakes

Nine wetland sites within the HL Icon Site were surveyed for wetland vegetation during current reporting period as part of the TLM intervention monitoring program. The results of this initial survey have been presented separately (McCarthy *et al.* 2007a).

River red gums and black box

The viability of river red gum (RRG) and black box (BB) communities within the LMW and HL Icon Sites was assessed by quantifying their distribution, population age structure, crown condition and canopy cover.

Distribution

Community distribution ranges were examined using existing GIS vegetation layers. Whilst we recognise the presence of irregularities between digitised and actual vegetation boundaries within the ECV based GIS layers used for this analysis, these are generally only minor (*e.g.* Lake Cullulleraine [555000E, 6205500N] erroneously marked as BB; refer to Figure 2.2) and are unlikely to significantly distort the overall description of vegetation distribution and cover presented here. As it is not feasible within the context of TLM to re-survey these boundaries at regular intervals, it will not be possible to examine temporal shifts in community distributions as a consequence of managed flow interventions.

Size structure

Establishing the age of eucalypts in semi-arid regions is problematic, where rainfall and aseasonal temperatures constrain the production of annual tree rings (*cf.* George *et al.* 2005 and references therein). Instead, tree size measured as trunk (or bole) diameter at breast height (DBH) was used as a surrogate for tree age (*cf.* Roberts and Williams 2004, George *et al.* 2005). Whilst this surrogate for age is widely used, the age-DBH relationship remains to be validated for RRG and BB, especially for multi stemmed trees (a consequence of historical logging) which constituted a large proportion of the surveyed BB. As the strength of correlations between size and age is likely to decline with increasing size, inferences between relative cohort strength and historical flood regime are not readily possible. Further, the presence of smaller trees does not necessarily imply recruitement success to larger size classes and thus longer-term population viability. This is especially true for seedlings (<2 cm DBH), which are most vulnerable to grazing, and whose survival following an opportunistic germination event (*i.e* flooding or significant rainfall) is reliant on follow-up watering.

RRG and BB surveys of size classes undertaken during the current reporting period covered a combined area of 28.8 ha of the LMW Icon Site and 18.1 ha of the HL Icon Site. This represented *ca.* 0.13 % and 0.9 % of the total areas occupied by RRG and BB, respectively, within each Icon Site. Whilst this level of sampling effort falls short of the ≥1 % of the total sample area commonly targeted by similar studies (*e.g.* George *et al.* 2005), it represented the maximum level of sampling effort that could be allocated at the time. Successive annual assessments will be integrated to provide a more comprehensive spatial assessment of community structure.

RRG and BB population size (*cf.* age) classes were neither uniformly distributed throughout the surveyed distribution range or population elevation ranges. Although size class frequency structures varied greatly between RRG sites at both Icon Sites, smaller trees (<10 cm DBH) tended to be concentrated within those communities subject to higher inundation frequencies (RGF and FRGW) than in the presumably drier RGFTU class. Within these RRG classes, smaller trees were generally associated with localised depressions throughout the population elevation range and concentrated at lower elevations. In contrast, the population size class frequency structures of BB within both Icon Sites were dominated by mature individuals (between 10 cm and 50 cm DBH) and, in all but one site surveyed, the relative paucity of smaller trees (<10 cm DBH).

These data suggest that whilst the potential for regeneration is greater for RRGs than it is for BB, these communites may not be viable across their current distribution ranges, and that their ranges are at risk of contracting to lower elevations over the longer term as a consequence of reductions in flood return frequencies and magnitudes.

Condition

Variation in the condition (or vigor) of eucalypts may occur across a range of temporal scales and may be reflected in more rapid variations in leaf chlorophyll concentrations and slower variations in canopy density (*i.e.* leaf shedding and regrowth). For example, the condition of water stressed trees may change rapidly (*i.e* weeks) following a watering event, tree condition may vary cyclically (*i.e.* intra-annually) in response to seasonal changes in rainfall and day length and longer-term (*i.e.* inter-annual) responses may arise through changes in climatic or hydraulic regimes (*i.e.* drought, El Niño events, and flow regulation). Chlorophyll signatures were considered too temporally variable to warrant comparisons between time intervals. Accordingly, tree condition was assessed as crown condition (*i.e.* chlorophyll concentration signatures) for momentary ('snap shot') assessments and as changes in canopy cover (*cf.* density) for comparisons between time intervals.

Measures of RRG and BB crown condition and canopy cover (were based on Normalised Difference Vegetation Index (NDVI) analyses of aerial images captured during February 2003 and January 2006. Essentially, NDVI analyses allow for the isolation of multi-spectral signatures of trees from background noise (*i.e.* water bodies, exposed soil, dead vegetation and shadows) and the calculation of summary statistics of tree condition within spatial boundaries defined by prevailing water regime (*i.e.* EVCs). Refer to Scholz *et al.* (2007a) for details of image processing and NDVI methodology.

NDVI crown condition images generated for each Icon Site highlighted areas of relative greater and lesser physiological stress (as inferred indirectly from chlorophyll concentrations). Within the LMW Icon Site these images indicated that the vegetation of Lindsay and the western half of Wallpolla Islands was more stressed than Mulcra and the eastern half of Wallpolla Islands in early 2003 and that the condition of Mulcra and Wallpolla Islands had declined by early 2006. Over this period also, the condition of vegetation within Lindsay Island in areas adjacent to the Murray River increased. For the Hattah system, RRG condition tended to decline with distance from either the Murray River or Chalka Creek, and this gradient increased between 2003 and 2006. Whilst variations in the condition of BB within the HL Icon Site were patchier than that determined for RRGs, one area adjacent to the Murray River within the Kulkyne Park, especially, was identified as being most stressed during 2003. The condition of RRG and BB within this area had increased by 2006.

Lindsay-Mulcra-Wallpolla Islands

Change-in-NDVI canopy cover images generated for each Icon Site highlighted areas where leaf shedding and regrowth had occurred between early 2003 and early 2006. Within the LMW Icon Site, increases in canopy cover accounted for 25.1% of total RRG area and decreases accounted for 21.4% of total RRG area. Most increases in canopy cover were associated with areas adjacent to anabranch channels (Lindsay River, Mullaroo Creek, the lower half of Potterwalkagee Creek, and Wallpolla Creek) and decreases were concentrated in areas adjacent to the Murray River and the upper reaches of the Upper Lindsay River. Of the three Islands, Mulcra Island was most impacted by declines in RRG canopy cover.

Within the LMW Icon Site, increases in canopy cover accounted for 21.3% of total BB area and decreases accounted for 20.1% of total BB area. Most increases in canopy cover were associated with

Lindsay Island (within the area bound by the Murray River, Lower Lindsay River and Mullaroo Creek). Of the three Islands, Mulcra Island was most impacted by declines in BB canopy cover, although significant areas of decreased cover were identified within the eastern half of Wallpolla Island and, to a lesser extent within Lindsay Island in areas adjacent to the Murray River.

Hattah Lakes

Within the HL Icon Site, increases in canopy cover accounted for 16.6% of total RRG area and decreases accounted for 22.7% of total RRG area. Similarly, increases in canopy cover accounted for 14.4% of total BB area and decreases accounted for 21.1% of total BB area. Increases in RRG canopy cover were concentrated in areas adjacent to the confluence of Chalka Creek (north arm) and Murray River and for both RRG and BB within the Kulkyne Park, upstream of Chalka Creek (south arm). Decreases in RRG canopy cover were identified along the Murray River downstream of Chalka Creek (south arm), in areas adjacent to Chalka Creek and to the north-west of Lake Hattah. Decreases in BB canopy cover were patchier and distributed thoughout the Icon Site.

As change-in-NDVI canopy cover images are derivative functions of successive temporal images, their interpretation requires that differences in initial canopy cover between localities be considered. For example, areas where increases in canopy canopy cover are indicated need not indicate 'healthy' trees, especially where the initial canopy cover was very low (*e.g.* along the southern margins of Lake Wallawalla; pers. obs. O. Scholz). And conversely, areas where small increases or even decreases in canopy cover are indicated need not imply reduced 'health', especially where the initial condition was very high. The NDVI-based assessments presented here will be validated by field surveys during the next reporting period (refer to Scholz *et al.* 2007a for methods).

Normalised Difference Vegetation Index (NDVI) analyses allow for the identification of both momentary crown condition and changes in canopy cover between time periods. These provide an integrated measure of community 'health' and, together with measures of distribution and community structure, the capcity to address TLM targets. Whilst outside the scope of the current condition monitoring program, this approach also allows for the identification of areas of potential management concern and offers the capacity to more effectively target the delivery of environmental flows.

Lignum

Lignum condition was assessed during January-February 2007 at sites distributed across the elevation range occupied by lignum at LMW and HL Icon Sites. At most sites within the LMW Icon Site, generally less than 50 % of the above ground biomass of individual plants was alive, and there was little evidence of recent growth. The exceptions to this were plants at sites situated at the lowest and most recently inundated elevations where generally more than 95 % of above ground biomass was alive and the plants showed signs of recent growth. A similar relationship between plant condition and elevation was apparent within the HL Icon Site, albeit weaker due to a flush of new growth at all sites presumably stimulated by rainfalls shortly prior to the survey.

Lignum often appears to be in poor condition, with dry, brown stems and no leaves during dry periods. However, because of its tuberous habit, lignum is more resilient to desiccation stress than momentary measures of above ground condition alone would suggest. This allows lignum to respond rapidly to rainfall or flooding by producing shoots, leaves, flowers and seeds (Craig *et al.* 1991, Roberts and Marston 2000). As the seeds produced by lignum are thought not to persist for long on the parent plant or in the soil, and seeds germinate opportunistically regardless of season, the persistence of lignum in environments prone to erratic wet/dry cycles appears to depend mainly on its capacity to tolerate dry periods and its capacity to respond quickly to watering (*i.e.* set seeds and germinate) (Chong and Walker 2005).

Given the difficulties associated with mapping distribution ranges (*cf.* RRG and BB) and determining population age structures due to difficulties associated with measuring the size of individual plants, validating age-size relationships, and with distinguishing between clones and separate plants, population viability is being assessed as the resilience of established individuals to dry periods, *i.e.* the capacity to recover following flooding or significant rainfall. During the current survey, 15.3 % and 0.7 % of the plants examined within the LMW and HL Icon Sites, respectively, showed no visible signs of life. Future annual surveys will establish the viability of these and the other plants, and thus of the exant lignum populations at both Icon Sites.

Cumbungi

Cumbungi poses a threat to aquatic ecosystems throughout the Mallee region due to its vigorous growth, and its ability to both displace other plant species and to reduce the hydraulic capacity of floodplain channels and flood runners.

Field surveys undertaken during November and December 2006 indicated that cumbungi was present in all flow habitats surveyed within the LMW Icon Site and the adjacent 'impounded' sections of the Murray River. Greatest stand densities were encountered within the smaller slow flowing anabranches and flood runners, with sections of the Upper Lindsay River and, especially, Potterwalkagee Creek currently completely obstructed by cumbungi. In contrast, no cumbungi was observed within the HL Icon Site and adjacent 'free flowing' section of the Murray River.

Several factors may account for the differences in cumbungi distribution observed between the two Icon Sites. Firstly, cumbungi is present within the Murray River weir pools adjacent to the permanently hydraulically connected Lindsay Island system, thereby providing a ready source of both wind and water-borne propagules to and from the Island. This contrasts with the absence of cumbungi within the free-flowing sections of the Murray River adjacent to the Hattah Lakes and the episodic hydraulic connectivity between the Murray River and the Hattah Lakes floodplain, thereby reducing opportunities for the passive dispersal of water-borne seeds. And secondly, the Hattah Lakes system has been dry for extended periods over recent years, increasing the potential for desiccation of any already established plants and reducing the potential for seedling recruitment.

Regulation has reduced the frequency and duration and altered the timing of episodes of wetland flooding compared with what would have occurred naturally within the Hattah system (SKM 2002). Current efforts to reinstate a more natural wet/dry regime through the pumping of water, whilst benefiting a number of key ecological assets and processes, may increase the potential for cumbungi establishment. Annual condition assessments will allow for this risk to be assessed.

In addition to annual condition assessments of changes in cumbungi distribution, rates of stand expansion are being examined as part of concurrent intervention monitoring at two sites (Webster's Lagoon and Potterwalkagee Creek; Scholz *et al.* 2006, 2007b). As cumbungi has the capacity to grow in water up to 2 m deep, we recommend that incorporating longitudinal measures of channel morphometry (width, maximum depth) within the condition monitoring program occurs to facilitate the identification of narrow/shallow reaches most at risk of hydraulic obstruction by cumbungi.

3 Fish

The objectives developed for fish at the Icon Site scale are to maintain sustainable communities of native fish, with special emphasis placed on vulnerable/endangered populations of Murray cod, golden perch and catfish, and to restrict populations of common carp. Fish condition surveys were undertaken between mid-November and mid-December 2006 within the Lindsay-Mulcra-Wallpolla Islands (LMW) and Hattah Lakes (HL) Icon Sites. Data for each Icon Site are presented separately below.

3.1 Lindsay-Mulcra-Wallpolla Islands

3.1.1 Methods

A nested sampling design was used to assess the condition of fish assemblages within the LMW Icon Site; sites within reaches within macrohabitats. At the highest level of sampling, macrohabitats were defined *a priori* as the Murray River, larger no/slow flow anabranches and flood runners, smaller faster flowing connecting channels between the Murray River and the anabranches, and floodplain wetlands. Accordingly, 4 Murray River, 5 no/slow flowing and 2 fast flowing reaches were identified (Table 3.1.1). Webster's Lagoon (wetland macrohabitat) was dry during the survey period and thus was not surveyed. Three sites were electrofished (boat mounted) within each reach, except for Dedmans Creek for which only two sites were possible due to its short length. Sampling each site involved 12 x 90 second shots covering approximately 300-400m of channel length. Sampling site location details are provided in Table 3.1.1 and Figures 3.1.1 and 3.1.2.

Figure 3.1.3 shows how channel morphology (mean width and maximum depth determined at 6 locations within each reach) varied between macrohabitats and between reaches within macrohabitats. Microhabitat characteristics, such as flow velocity and the presence/absence of over hanging vegetation/macrophytes/snags were not examined as these varied considerably at spatial scales smaller than that of the smallest sampling unit (sites), are difficult to assess accurately in turbid waters, and not required for the current purpose of condition assessment.

3.1.2 Results

A total of 3,742 fish from 13 species (9 native, 4 alien) were recorded in electrofishing catches from LMW (Table 3.1.2). All species previously reported from LMW were recorded during the current survey except for freshwater catfish. Whilst freshwater catfish have been reported as being present within the last 2 years at sites both immediately upstream and downstream of LMW (on the Chowilla floodplain - Zampatti *et al.* 2006, and in Dedmans Creek and in the Murray River - MDFRC unpublished data), it is not possible to establish whether their absence during the current survey was either real or a bias associated with electrofishing. The species assemblage recorded in the current survey largely reflects that reported for the adjacent South Australian Chowilla system (Zampatti *et al.* 2006). Notable species differences between the LMW and Chowilla systems include the presence of redfin (1.2 % of the total catch) within the LMW system and the presence of dwarf flatheaded gudgeon (0.03 % of the total catch) within the Chowilla sysem.

Of the large to medium bodied species bony herring and carp were numerically most abundant, accounting for 7.8 % and 7.1 % of the total catch, respectively. Of the small bodied species flyspecked hardyhead and carp gudgeon were most abundant, accounting for 47.6 % and 17.8 % of the total catch, respectively. Alien species accounted for 10.8 % of the total catch (Table 3.1.2).

Mean total catches did not vary significantly between reaches (One-way ANOVA $P=0.062$, $n=32$) (Figure 3.1.4). Most species were widespread (Figure 3.1.5). Exceptions included silver perch and redfin, which despite their low abundances in catches were recorded in at least one reach of each macrohabitat. Murray cod were caught only within the Murray River and the fast flowing Mullaroo Creek. However, one individual (*ca.* 300-400 mm SL) was observed but not caught in Potterwalkagee Creek (no/slow flow macrohabitat).

Size frequency distributions for each species are shown in Figure 3.1.6. For the large bodied species, recent recruits were recorded only for bony herring (min. SL 34.8 mm), goldfish (min. SL 16.0 mm) and redfin (min. SL 29.4 mm). The smallest bony herring (<80 mm SL) were only encountered within

Lindsay Island (TC–58 %, ULR–3 %, and LLR–1 %) and in the adjacent section of the Murray River (L6–35 %). The smallest goldfish (<40 mm SL) were only encountered in the Murray River (L7-86 %, L9-14 %). The smallest redfin (<60 mm SL) were caught in the Lindsay River (ULR–85 %, LLR–5 %) and the Murray River (L6–8 %, L9–3 %). The smallest sized Murray cod, golden perch, silver perch and carp caught were 145 mm SL, 120 mm SL, 120 mm SL and 112 mm SL, respectively. Fish of these sizes are likely to have been more than one year old. However, otolith based aging would be required to validate this.

Only one Murray cod greater than 430 mm SL was recorded (850 mm SL). Such discontinuities/ truncations in population size frequency distribution may be attributable to a combination of factors including sampling technique selection, the low number of individuals encountered, migration, and recreational fishing pressure (minimum recreational size limit in VIC and NSW = 500 mm TL).

In contrast to the larger bodied and longer lived species, which do not require successful recruitment every year to maintain viable populations, small bodied fish tend to be short lived, surviving for only 1-2 years. Accordingly, the sustainability of local populations is much more dependent on the success of annual recruitment events, which generally occurs between September – April (Meredith and Conallin 2006). Recent recruitment (within the previous 12 months) was observed for all small bodied species (Figure 3.1.6). Future comparisons of young-of-the-year cohort abundances will allow for the determination of relative recruitment success, and hence of population viability.

Macrohabitat	Location	Reach	Site GPS (GDA94 datum)	
			Easting	Northing
Murray River		Lock 6 weir pool (L6)	521824 514425 501033	6230303 6228614 6232834
		Lock 7 weir pool (L7)	529087 527624 522856	6223833 6225771 6229527
		Lock 8 weir pool (L8)	548859 547750 537547	6216056 6214105 6221773
		Lock 9 weir pool (L9)	568355 567174 564752	6226746 6226320 6227006
No/slow flow anabranches	Lindsay Island	Lower Lindsay R. (LLR)	510309 508008 503297	6224530 6226944 6231123
		Upper Lindsay R. (ULR)	515751 514744 513837	6219814 6220574 6221152
		Toupnein Ck (TC)	512079 510109 509377	6227332 6227751 6228933
	Mulcra Island	Potterwalkagee Ck (PC)	535633 534170 533183	6222224 6221602 6221200
	Wallpolla Island	Lower Wallpolla and Mullroo cks (WMC)	565369 563511 561280	6224332 6223334 6222570
Fast flow channels	Lindsay Island	Mullaroo Ck (MC)	521924 521180 518947	6227820 6226119 6225931
	Wallpolla Island	Dedmans Ck (DC)	565942 565812	6224740 6224463
Wetland	Lindsay Island	Webster's Lagoon (WL) – not sampled (dry)	513233	6227495

Table 3.1.1: Location of fish sampling sites within each macrohabitat and reach.

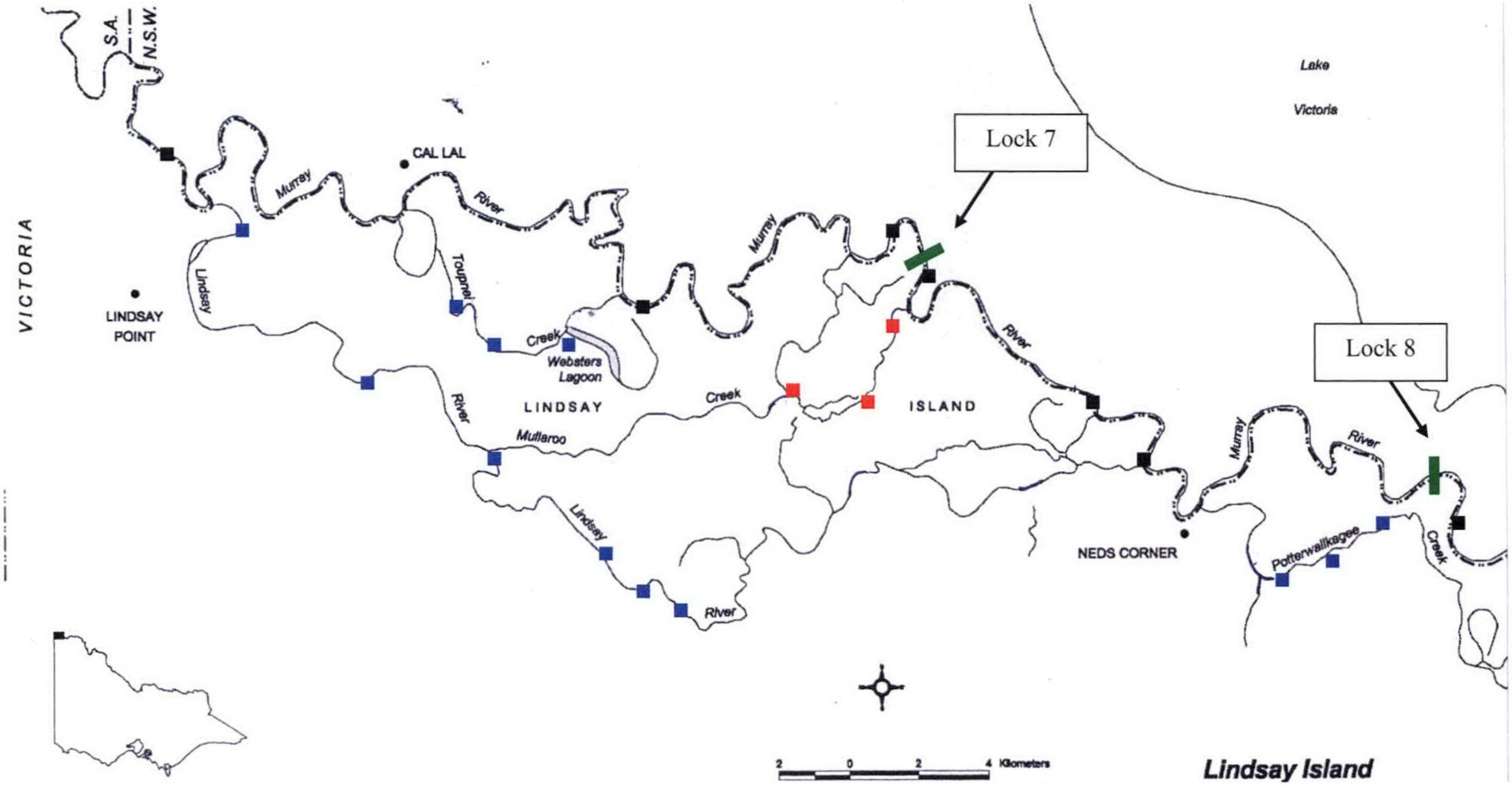


Figure 3.1.1: Location of sites sampled within Murray River (■), fast flow (■), and no/slow flow (■) macrohabitats on Lindsay and Mulcra Islands.

Figure 3.1.2: Location of sites sampled within Murray River (■), fast flow (■), and no/slow flow (■) macrohabitats on Wallpolla Island.

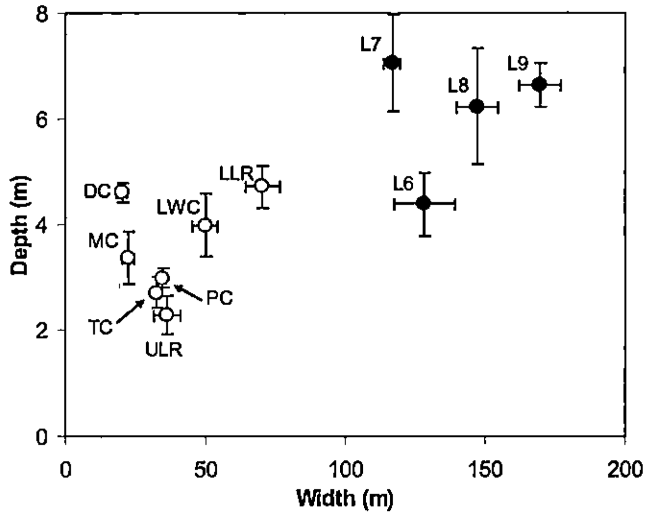


Figure 3.1.3: Channel morphology (mean width and maximum depth) of sampled reaches within Murray River (•), no/slow flow (○) and fast flow (○) macrohabitats (mean ± se, n=6). Refer to Table 3.1.1 for details of reach abbreviations.

	Common name	Scientific name	Previously reported	Current survey total caught	Current survey % of total
Native	Murray cod	*Maccullochella peelii peelii*	•	22	0.6
	Golden perch	*Macquaria ambigua*	•	103	2.8
	Silver perch	*Bidyanus bidyanus*	•	7	0.2
	Freshwater catfish	*Tandanus tandanus*	•	-	-
	Flyspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	•	1782	47.6
	Carp gudgeon	*Hypseleotris* spp.	•	665	17.8
	Australian smelt	*Retropinna semoni*	•	297	7.9
	Bony herring	*Nematalosa erebi*	•	293	7.8
	Crimsonspotted rainbowfish	*Melanotaenia fluviatilis*	•	117	3.1
	Flatheaded gudgeon	*Phylipnodon grandiceps*	•	49	1.3
Alien	Carp	*Cyprinus carpio*	•	267	7.1
	Goldfish	*Carassius auratus*	•	51	1.4
	Redfin	*Perca fluviatilis*	•	46	1.2
	Gambusia	*Gambusia holbrooki*	•	43	1.2
			14	3742	

Table 3.1.2: Fish species previously reported from Lindsay, Mulcra and Wallpolla Islands (Douglas *et al.* 1998, SKM 2004, Scholz *et al.* 2006) and summary statistics of total fish catches for November-December 2006.

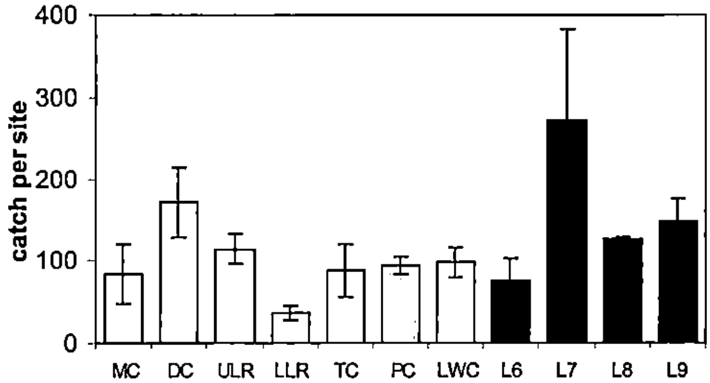


Figure 3.1.4: Numbers of fish caught per site within Murray River (•), no/slow flowing anabranches (•) and fast flowing channel (○) reaches (mean CPUE ± se). Refer to Table 3.1.1 for details of reach abbreviations.

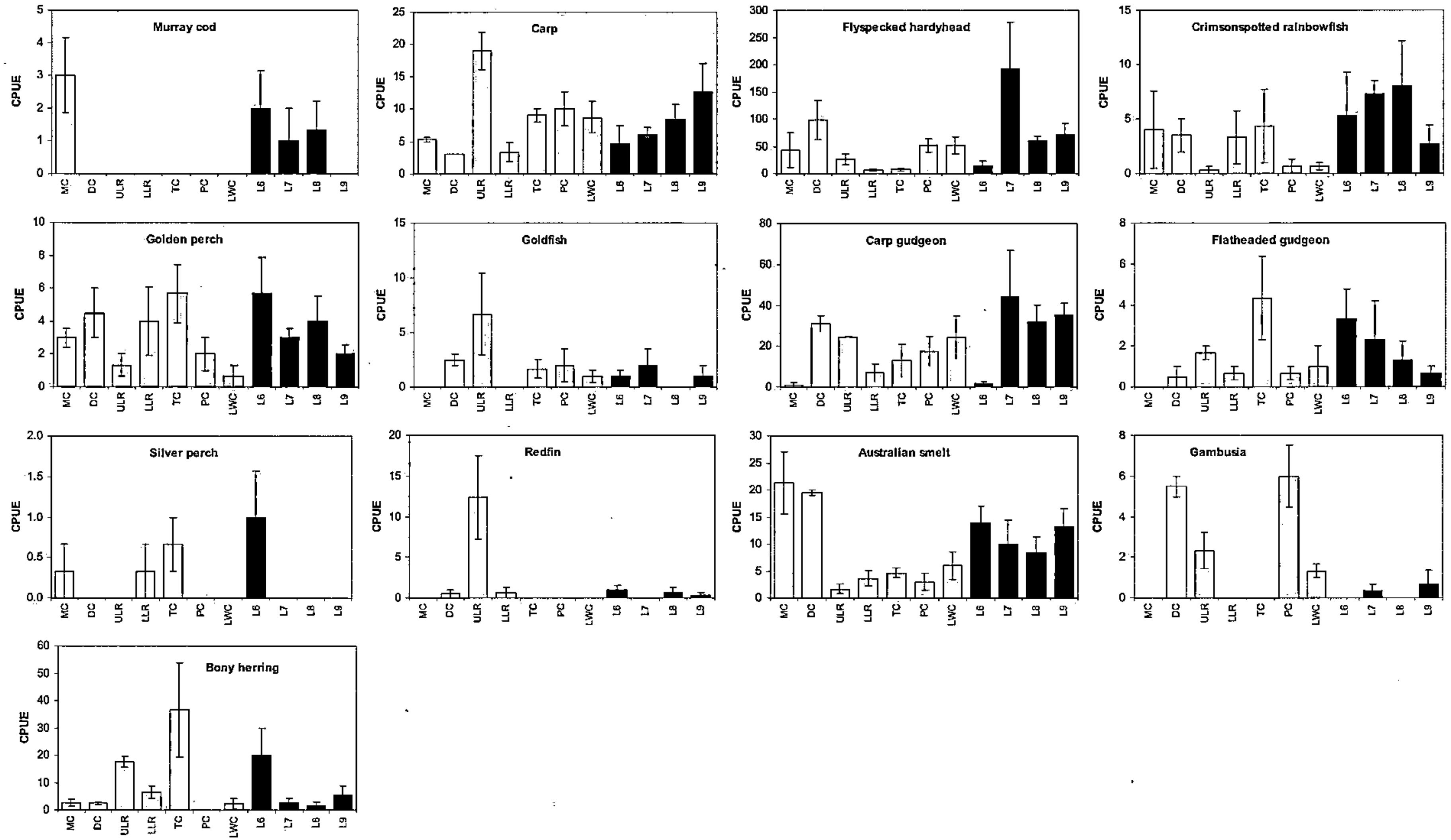


Figure 3.1.5: Spatial distribution of species caught (mean catch per site ± se) from reaches within the Murray River (•), no/slow flowing anabranches (•) and fast flowing channels (○).

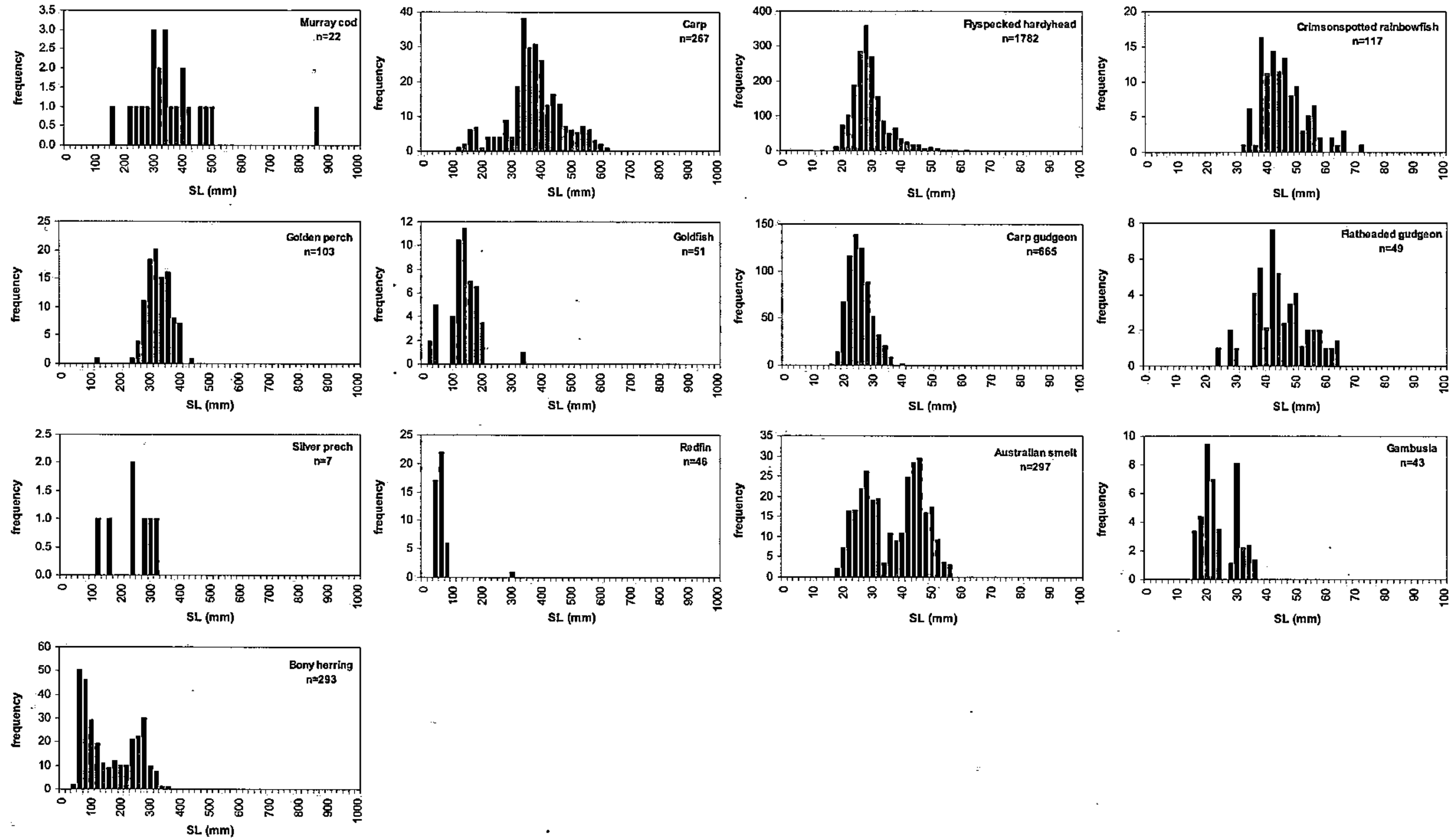


Figure 3.1.6: Length (SL mm) frequency distributions of species caught (total survey catch).

3.2 Hattah Lakes

Pumping onto the Hattah Lakes floodplain from the Murray River via Messengers Crossing on Chalka Creek commenced in April 2005, prior to which the floodplain was completely dry. Four separate pumping events were instigated prior to early December 2006. These delivered 1,200 ML, 4,211 ML, 6,900 ML, and 13,545ML of water, respectively, and resulted in the sequential filling/topping up of the serially connected wetlands associated with the northern arm (Lockie→Yerang→Mournpall) and southern arm (Lockie→Little Hattah→Hattah→Bulla→Arawak) of the system. The timing of these initial inflows into Chalka Creek and each wetland are summarised in Table 3.2.1.

3.2.1 Methods

A nested sampling design was used to assess the condition of fish assemblages within the Hattah Lakes Icon Site; sites within reaches within macrohabitats. At the highest level of sampling, macrohabitats were defined *a priori* as the Murray River, Chalka Creek, and 7 floodplain wetlands that were inundatad at the time of the survey. Fish assemblages were surveyed at three sites per reach (Table 3.2.1, Figure 3.2.1). Sites in the Murray River were electrofished (boat mounted); 12 separate runs of 90 second machine time duration. For all other macrohabitats where habitat shallowness precluded the use of boat mounted electrofishing, 3 pairs of small and large fyke nets (SFN, LFN) were deployed at each site. Fyke nets were set in the afternoon and collected the following morning. Set and pull times were recorded and total catches per SFN/LFN pair per reach expressed as individuals per 24 hours (I. CPUE).

Macrohabitat	Reach	Commencement dates of pumped inflow events	Site GPS (GDA94 datum)	
			Easting	Northing
Murray River	Upstream of Lock 11 weir pool	Permanent	637366 638464 637956	6154888 6157821 6158935
No/slow flow anabranches	Chalka Ck	April 2005 15 September 2005 22 March 2006 12 September 2006	637053 634560 629487	6155415 6156670 6157704
Wetland	Lake Lockie	26 September 2005 29 March 2006 September 2006	624497 624488 624429	6155282 6155738 6155150
	Lake Yerrang	21 April 2006 September 2006	624775 624376 624828	6158033 6157954 6157957
	Lake Mournpall	27 September 2006	622696 623924 624314	6158988 6158083 6158083
	Lake Little Hattah	15 November 2005 18 April 2006 September 2006	623121 623031 623228	6153653 6153758 6153583
	Lake Hattah	16 May 2006 30 November 2006	623340 623570 622635	6153359 6152725 6152758
	Lake Bulla	20 June 2006 30 November 2006	624440 623758 623985	6153066 6153322 6153180
	Lake Arawak	5 July 2006 30 November 2006	624386 624346 624434	6152490 6152851 6152996

Table 3.2.1: Location of fish sampling sites within each macrohabitat and reach, and dates of pumped inflows into each wetland (source Andy Wise MCMA).

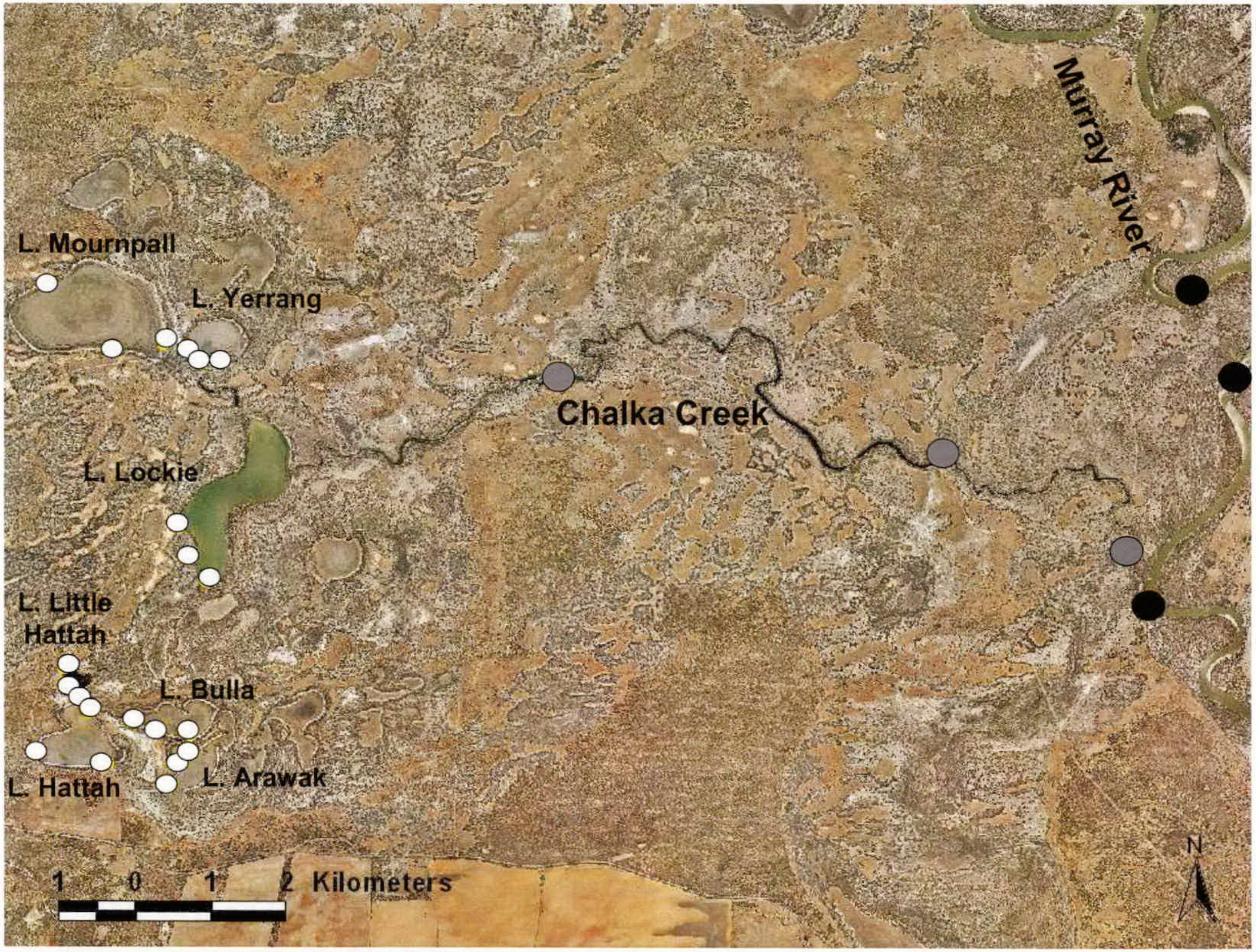


Figure 3.2.1: Location of sites sampled within the Murray River (•), Chalka Creek ( ), and wetland (○) macrohabitats at Hattah Lakes.

3.2.2 Results

A total of 6,980 fish from 6 species (5 native, 1 alien) were recorded in fyke nets set on the Hattah Lakes floodplain (Table 3.2.2). Murray cod, silver perch and flyspecked hardyhead were not recorded, although these species were present on the floodplain during January 2006 (Scholz *et al.* 2006), and flyspecked hardyhead were encountered in surveys undertaken by MCCarthy *et al.* (2007) over the same period. No freshwater catfish were encountered in either survey. Whilst catfish have been reported as being present within the last 2 years at sites downstream of the Hattah Lakes (on the Chowilla floodplain - Zampatti *et al.* 2006, and in Dedmans Creek and the Murray River - MDFRC unpublished data) and upstream near Euston (Washpen Creek – McCarthy *et al.* 2007b), it is not possible to establish whether their absence during the current survey was either real or a bias associated with sampling.

Mean total catches (CPUE) varied significantly between reaches (One-way ANOVA P=0.011, n=24). Catches in Lake Arawak were significantly greater than they were in Chalka Creek, and lakes Mounpall, Yerang, Lockie and Little Hattah, but not significantly greater than in lakes Hattah and Bulla (Tukey *post hoc* comparisons, P≤0.05) (Figure 3.2.2). More intensive temporal replication of sampling is required to examine the occurrence of productivity pulses associated with the filling of each wetland as predicted by available conceptual models (*e.g.* Gawne and Scholz 2006). This aspect will be reported on separately as part of the intervention monitoring program (McCarthy *et al.* 2007)

Wetland Sites

Of the large to medium bodied species encountered on the floodplain, golden perch were numerically most abundant, although they accounted for only 0.9 % of the total catch. Of the small bodied species carp gudgeons, Australian smelt and flatheaded gudgeons were most abundant, accounting for 94.1 % 2.9 % and 2.1 % of the total catch, respectively. Goldfish (alien species) accounted for <0.1 % of the total catch (Table 3.2.2). No carp or other alien species were recorded on the floodplain. Most species recorded on the floodplain were widespread (Figure 3.2.3). Exceptions included goldfish (only in Chalka Creek and Lake Little Hattah) and bony herring (only in Lake Yerang), of which only a few individuals were caught (n= 2 and n=1, respectively).

More species were recorded in surveys following the 1993 flooding event (n=11; Souter 1996, Puckridge *et al.* 1997, SKM 2002) than have been recroded since pumping into the previously dry system commenced in April 2005 (n=8; Table 3.2.2 and Scholz *et al.* 2006). Such differences in species richness between modes of filling may be attributable to factors including differences in the pool of species present in the Murray River at the time of inflows, and the restriction of fish passage through the pumps used. For example, all fish caught during January 2006 following the pumping operations of 2005 were <100 mm TL. This is consistent with the maximum passage diameter of 3 inches of the impeller type pumps used. Other factors that could explain the differences between surveys include differences in sampling effort and the loss of species through predation and/or failure to recruit (*e.g.* flyspecked hardyheads were recorded during the January 2006 survey but not during the present survey).

River/Creek Sites

A total of 169 fish from 9 species (7 native, 2 alien) were recorded from electrofishing within the Murray River (Lock 11) adjacent to Messengers Crossing on Chalka Creek (Table 3.2.2). These included 4 species that were not recorded on the floodplain (Murray cod, silver perch, carp, and flyspecked hardyhead). Size frequency distributions for each species recorded from floodplain and Murray River sites are shown in Figure 3.2.4. The smallest individuals of Murray cod, golden perch, silver perch, carp and goldfish caught in the Murray River were 286 mm SL, 230 mm SL, 208 mm SL, 225 mm SL and 145 mm SL, respectively. Fish of these sizes are likely to have been more than one year old. However, otolith based aging is required to validate this.

The minimum sizes of Murray cod, golden perch, silver perch, carp and goldfish encountered in electrofishing catches in the Murray River were larger than the diameter of the pumps used (3 inch diameter). It is hypothesised that this would preclude their passage onto the floodplain during managed (pumped) flooding and may explain the absence of Murray cod in the SFN/LFN surveys. Alien species (carp and goldfish) accounted for 13.6 % of the total catch in the Murray River (*cf.* <0.1 % of the total floodplain catch).

In contrast to the larger bodied and longer lived species, which do not require successful recruitment every year to maintain viable populations, small bodied fish tend to be short lived, surviving for only 1-2 years Meredith and Conallin 2006). Accordingly, the sustainability of local populations is much more dependent on recruitment driven either by spawning on the floodplain or by immigration from the Murray River. Young-of-the-year cohorts were identified on the floodplain for carp gudgeons, flatheaded gudgeons and Australian smelt. The absence of smaller sized cohorts of carp gudgeons and flatheaded gudgeons within the Murray River for suggests that these populations had recruited on the floodplain. As Australian smelt of all size classes were present in both the Murray River and on the floodplain, it was not possible to resolve the contribution made by riverine immigrants to the maintenance of the floodplain population.

	Common name	Scientific name	Previously reported	Current survey			
				SFN/LFN		Electrofishing	
				total caught	% of total	total caught	% of total
Native	Murray cod	*Maccullochella peelii peelii*	•	-	-	6	3.6
Native	Golden perch	*Macquaria ambigua*	•	65	0.9	9	5.3
Native	Silver perch	*Bidyanus bidyanus*	•	-	-	2	1.2
Native	Freshwater catfish	*Tandanus tandanus*	•	-	-	-	-
Native	Bony herring	*Nematalosa erebi*	•	1	>0.1	11	6.5
Native	Carp gudgeon	*Hypseleotris* spp.	•	6567	94.1	3	1.8
Native	Flatheaded gudgeon	*Phylipnodon grandiceps*	•	145	2.1	-	-
Native	Australian smelt	*Retropinna semoni*	•	200	2.9	114	67.5
Native	Flyspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	•[1]	-	-	1	0.6
Native	Crimsonspotted rainbowfish	*Melanotaenia fluviatilis*	•	-	-	-	-
Native	Flatheaded galaxis	*Galaxias rostratus*	•	-	-	-	-
Alien	Carp	*Cyprinus carpio*	•	-	-	20	11.8
Alien	Goldfish	*Carassius auratus*	•	2	>0.1	3	1.8
Alien	Gambusia	*Gambusia holbrooki*	•	-	-	-	-
Alien	Redfin	*Perca fluviatilis*	•	-	-	-	-
Alien	Brown trout	*Salmo trutta*	•	-	-	-	-
Alien	Tench	*Tinca tinca*	•	-	-	-	-
			17	6980		169	

Table 3.2.2: Fish species previously reported from the Hattah Lakes (Souter 1996, Puckridge *et al.* 1997, Scholz *et al.* 2006) and and summary statistics of total fyke net and electrofishing catches for November-December 2006. •[1] SKM (2002) indicated the presence of the endangered/vulnerable Murray hardyhead (*Craterocephalus fluviatilis*), but this is a likely mis-identification of the more common flyspecked hardyhead (*Craterocephalus stercusmuscarum fulvus*).

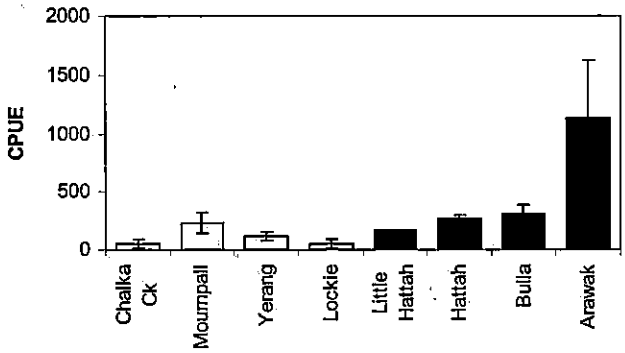


Figure 3.2.2: Total catch per SFN/LFN pair per site within Chalka Creek (○), and each of the floodplain wetlands associated with the northern (•) and southern (•) arms of Chalka Creek (mean CPUE ± se).

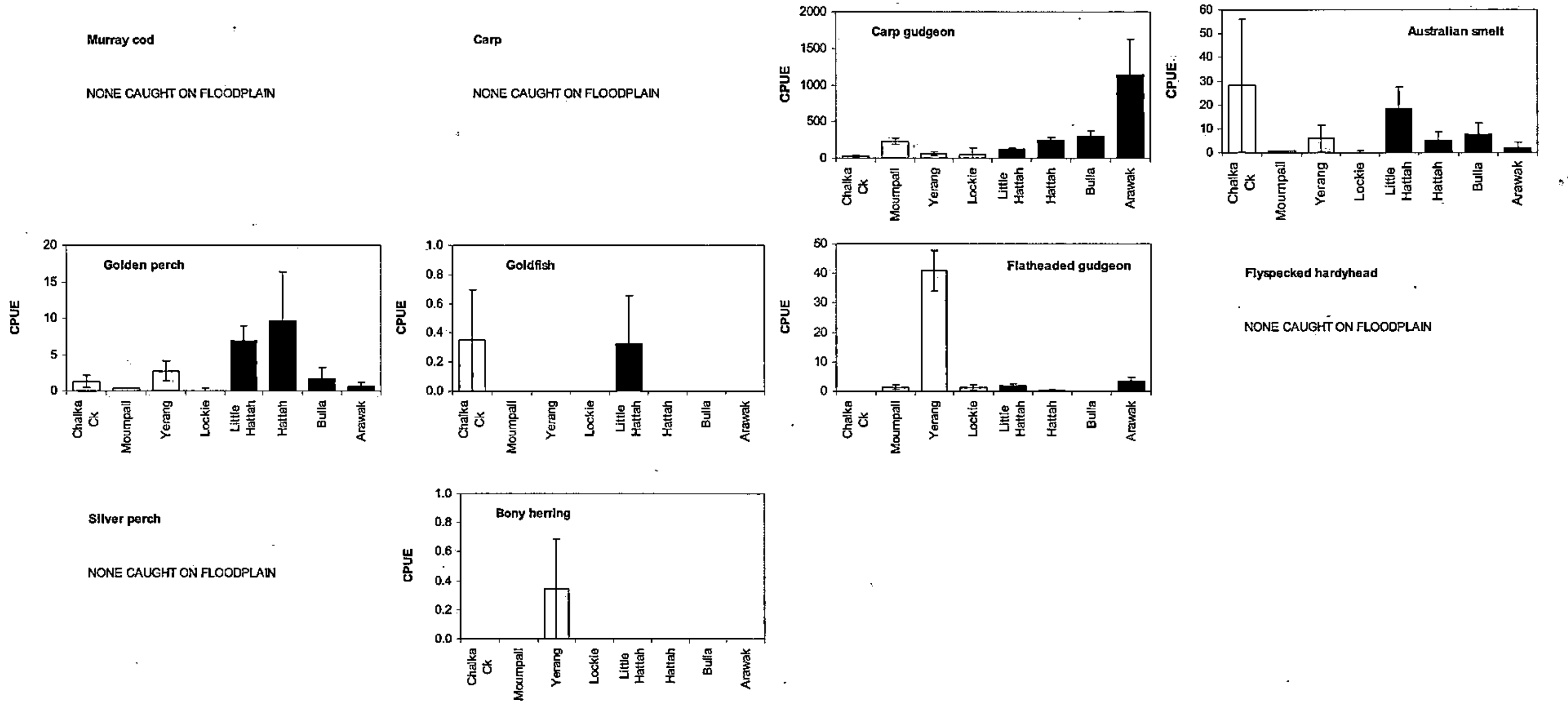


Figure 3.2.3: Spatial distribution of species caught per SFN/LFN pair per site (mean ± se) from Chalka creek (○), and each of the floodplain wetlands associated with the northern (◉) and southern (•) arms of Chalka Creek.

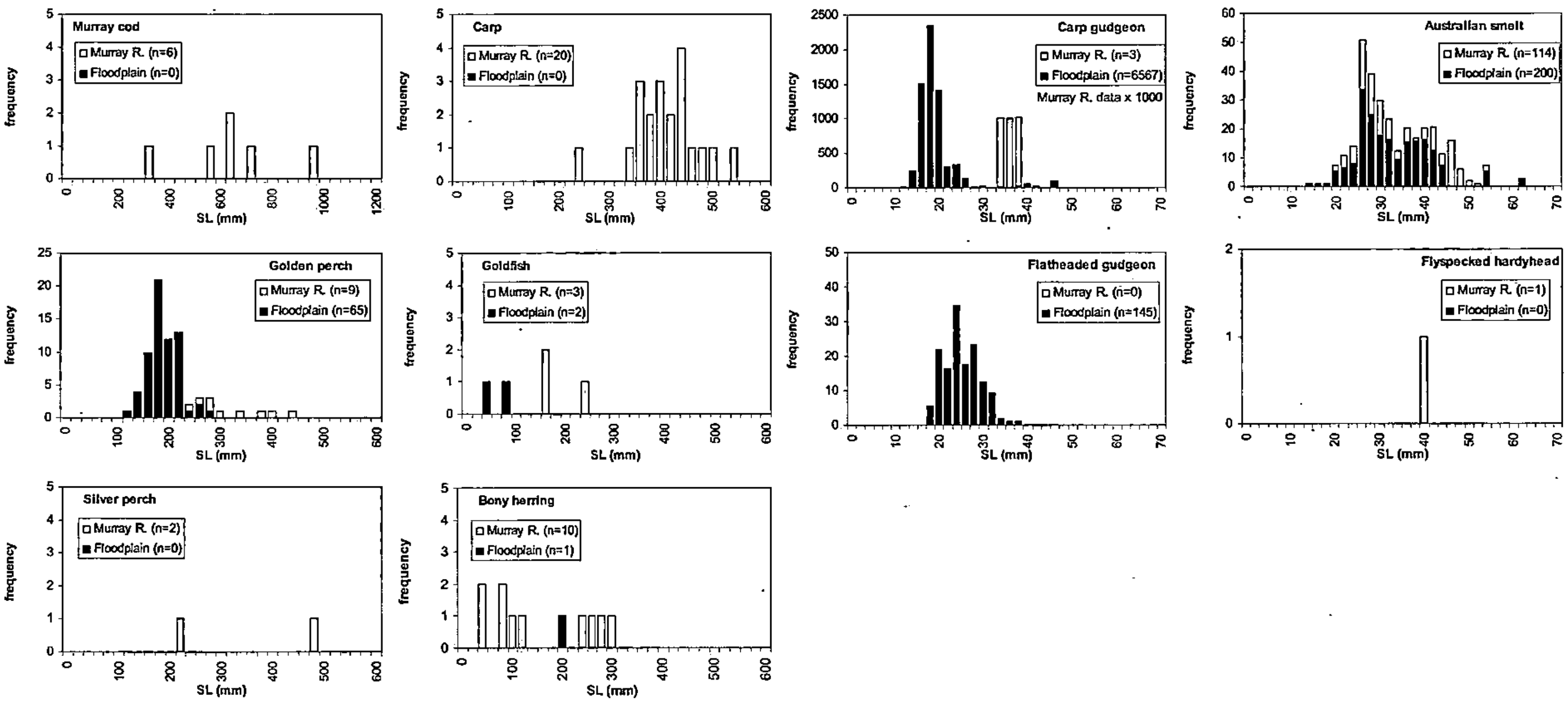


Figure 3.2.4: Length (SL mm) frequency distributions of species caught (total catch) on the floodplain (•) and from the Murray River (•).

3.3 Conclusions/recommendations

Key to achieving the objectives developed for fish is the identification of species present and whether recruitment is sufficient to sustain extant populations at the Icon Site scale. As recruitment may occur through local spawning events and through immigration from other populations, it is important that accurate assessments both of population age frequency distributions and of movements to and from the (Icon Site scale) population be made. This initial 'snapshot' of Icon site fish condition provides the basis against which future changes and the achievement of TLM targets can be assessed.

Sampling was stratified across four *a priori* identified macrohabitats; Murray River, no/slow flowing anabranches, fast flowing channels, and floodplain wetlands. Stratifying sampling at the Icon Site scale between macrohabitats increased the probability of encountering rare species and/or age class cohorts whose distributions are discontinuous. The effort employed in sampling fish populations using boat mounted electrofishing and fyke netting has proven capable of generating the size frequency distributions required for most species present (or likely to be present). However, as these gear types do not capture larvae, there exists the risk that spawning events may be missed, particularly if larval mortality prevents successful recruitment into the larger size classes that can currently be caught. Consideration in future surveys should thus be given to implementing gear types capable of sampling larval fish (*e.g.* light traps, plankton net trawls and drift nets).

Although not a key requirement of condition assessment, further refining the assessment of macro- and micro-habitat characteristics and incorporating this into the monitoring program will assist with the identification of ontogenetic shifts in habitat preference, and thus the identification of potentially critical habitats for each species-age class. This information will fill a major current knowledge gap.

The current surveys of both the LMW and HL Icon Sites indicated the presence of recent recruits (*i.e.* young-of-the-year) in most small bodied native fish species, suggesting that these populations are sustainable into at least the next spawning season; September-April (*e.g.* Meredith and Conallin 2006). However, based on size (SL mm) distribution of captured fish no recent recruits of Murray cod or golden perch were encounterd in either Icon Site. Whilst size provides a ready means for discriminating between age cohorts, especially within the smaller size range, otolith based aging is required to determine spawning dates as differences in growth rates, specific to habitats may result in over- or under-estimation of actual age. Accordingly, we recommend that otolith based aging of the smallest individuals of these large bodied species should be incorporated into subsequent condition surveys.

Whilst local annual spawning and larval recruitment is not necessary to maintain the viability of populations of large bodied, longer lived species, suitable local spawning conditions will be required in the medium term (1-3 years), especially where rates of immigration are low. This situation is exacerbated at Hattah Lakes, where the pumps used to provide flows onto the floodplain prevent the passage of large sexually mature individuals, or where the timing of pumping operations does not coincide with the presence of larvae/juveniles in the source waters. Whilst golden perch already present within the Hattah Lakes system will likely reach sexual maturity within the next 3-4 years, the recruitment potential for Murray cod on the floodplain is low. Further, the restriction of passage of all fish back into the Murray River by the levee bank and Messenger's regulator effectively isolates floodplain populations, eliminating the potential for emigration thereby compromising the resilience of populations across larger spatial scales until natural overbank flows reconnect the river and floodplain. However, a concurrent benefit to the current watering regime is that the operation of the pumps at Hattah Lakes has greatly reduced the potential for movement of large bodied alien species (carp and goldfish) onto the floodplain, thereby assisting the management objective for these species.

Key to the success of the Living Murray Initiative is the demonstration that sustainable native fish populations are being maintained. Whilst this is currently being examined individually for each Icon Site, interactions between Icon Sites via immigration and emigration may provide they key to maintaining sustainable meta-populations over larger spatial scales. Therefore, it is important that effort be directed towards quantifying fish movements at these larger scales and identifying potential impediments, such as regulating structures that may impinge upon the overall viability of (or connectivity between) meta-populations.

Based on the above considerations, the following actions are recommended to increase the overall efficacy of the monitoring initiative and the management of key icon fish species:

- Implement sampling gear targeting larvae (*cf.* MDFRC Lindsay Island larval monitoring program),
- Incorporate macro- and microhabitat assessments as part of the condition assessment,
- Incorporate otolith based aging of juvenile golden perch to more accurately identify spawning dates and recruitment events. Consideration should be given to whether such 'destructive' sampling is appropriate for Murray cod and other threatened species (*e.g.* silver perch, freshwater catfish), and
- Investigate fish movements at a range of spatial scales (*i.e.* between micro- and macrohabitats and Icon Sites).

4 Birds

Monitoring protocols developed to assess the condition of birds within the LMW and HL Icon Sites recommend that annual sampling be conducted at the same time each year, ideally during late spring (over a six week period from late September to early November). This timing will maximise the opportunity to guage breeding across the widest range of species, the detecability of most species, and will coincide with the long term annual eastern Australian aerial waterbird survey program that is currently in place (*cf.* Kingsford *et al.* 1999) (Scholz *et al.* 2007a).

As the recommended monitoring protocols were developed in early 2007 and their adoption by the TLM TRC is pending, it was not possible to implement surveys during the current reporting period. Condition monitoring of birds will thus commence during late spring 2007.

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