2018 Hattah Lakes Icon Site feral pig damage mapping

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Contents

Executive summary

The Mallee Catchment Management Authority (Mallee CMA) engaged EcoKnowledge to undertake feral pig (*Sus scrofa*) damage mapping at the Hattah Lakes Icon Site. Anecdotally, feral pig activity is believed to have increased at this site following environmental water delivery in recent years. The aim of this project was to quantify the extent, age and severity of feral pig damage around the lakes. Between November 6–15th 2018, a total of 18 lakes in the Hattah Lakes Icon Site were surveyed. A total of 3231 diggings were mapped and assessed.

Damage and disturbance associated with feral pigs digging was documented at all lakes. The age, severity and extent of diggings varied between the lakes and was not related to lake-perimeter. Digging attributes were mapped for all 18 lakes. At the time of the survey, feral pig activity was generally more recent in the Mournpall Lake complex (north) than the Hattah Lake complex (south).

A small pilot vegetation impact survey was also undertaken at Lake Cantala. The results of this survey suggest that at this lake feral pig diggings promote weed growth and a general degradation of the ground layer. Typically, if weeds are found in the vicinity of a disturbance, it is generally recognised that they will capitalise on the disturbance. However, the temporal dimensions of this disturbance are unknown. Further monitoring is recommended to determine the resistance and resilience of terrestrial vegetation surrounding the lakes to feral pig disturbance.

There was no perceived impact directly on native vegetation. At one site weed invasion was more intense where there were pig diggings. This would be a useful longer-term indicator of impact.

Importantly, our initial field observations suggest that another potential negative impact is pig consumption of aquatic macroinvertebrates (e.g. molluscs and crustaceans). Unsustainable consumption of these species could have negative flow-on effects for resident and migratory bird species in terms of resource provisioning and could threaten the ecological character of these Ramsar listed wetlands. This matter requires immediate attention and further investigation. If macroinvertebrates are keystone species as has been suggested, their decline could be a threatening process in this wetland ecosystems.

As macroinvertebrates shells were present more broadly, we recommend using this group of species as an indicator to help set pig density/removal targets and direct control efforts, rather than just the level of activity of pig diggings. This is because it would be relatively easy to visit all or some of the sites and measure the degree to which macroinvertebrates are being removed and how this varies between sites and across pig densities, thus providing a measure of the success of control operations over time.

1 Introduction

The Mallee Catchment Management Authority (Mallee CMA) engaged EcoKnowledge to undertake feral pig (*Sus scrofa*) damage mapping at the Hattah Lakes Icon Site. The Hattah Lakes comprise one of six Living Murray Icon Sites, and are listed as wetlands of international importance under the Ramsar Convention. Anecdotally, feral pig activity is believed to have increased at this site following environmental water delivery and natural flood events in recent years. This project quantified the extent, age and severity of feral pig damage around the wetlands. This will be used as baseline data for future monitoring.

2 Survey methods

2.1 Pig activity survey

Between November 6–15th 2018, a total of 18 lakes in the Hattah-Kulkyne National Park (Figure 1) were surveyed for signs of pig damage (Table 1). At the time of the survey, only three lakes were completely dry (Kramen, Little Hattah, Marramook). Lake Lockie had a stagnant, shallow pool of water in the middle measuring less than 20 m² in extent. All other lakes had reasonable bodies of water remaining.

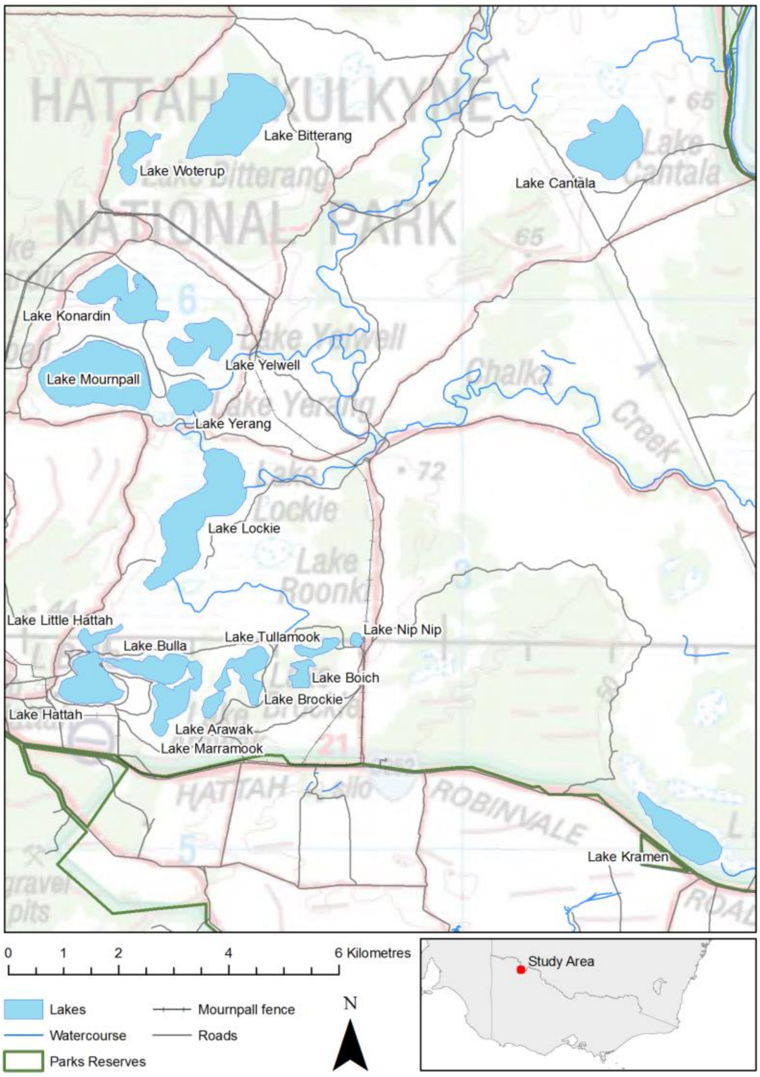

Figure 1 Study area – Hattah Lakes Icon Site.

At each lake, two staff walked in concentric transects parallel to the lake edge. The inner transect followed a path 5 m from the water edge and surveyed 5 m either side of this line (i.e. 0–10 m from the water edge). The outer transect followed a path 20 m parallel to the water edge (i.e. surveyed 15–25 m from the water edge of the lake). The distance of each surveyor relative to the lake edge was checked using a range finder. For dry lakes, the most recent area of inundation was determined from a combination of visibly moist lake bed sediments and the growth of post-drying lake bed vegetation (principally, native licorice *Glycyrrhiza acanthocarpa*). Transects were positioned up-bank from the edge of this transition zone.

Table 1 Summary of lakes surveyed within the Hattah Lakes Icon Site.

Lake	Type	Perimeter (m)
Arawak	Semi-permanent wetland	4534
Bitterang	Persistent temporary wetland	5716
Boich	Persistent temporary wetland	2289
Brockie	Semi-permanent wetland	4734
Bulla	Semi-permanent wetland	3852
Cantala	Persistent temporary wetland	4515
Hattah	Semi-permanent wetland	3741
Konardin	Persistent temporary wetland	5978
Kramen	Episodic wetland	4277
Little Hattah	Persistent temporary wetland	2657
Lockie	Persistent temporary wetland	8404
Marramook	Semi-permanent wetland	1544
Mournpall	Temporary wetland	5482
Nip Nip	Persistent temporary wetland	499
Tullamook	Persistent temporary wetland	2102
Woterap	Persistent temporary wetland	3321
Yelwell	Persistent temporary wetland	4448
Yerang	Persistent temporary wetland	2663

The GPS location (centre point) of each feral pig digging was recorded along each transect as they were encountered. The length and breadth of each area of digging was estimated with the aid of a 1 m^2 quadrat. For large diggings, the quadrat was placed at the edge of the digging and flipped in a grid pattern to obtain an estimate of area (m^2). Diggings were recorded independently if they were few and scattered. However, in areas of intense diggings, the combined area of two or more diggings was approximated by estimating the total area over which the diggings were spread (within each transect), and then estimating the percentage of this area that had been disturbed. Where relevant, examples of pig damage/activity were photographed.

Adopting the guidelines developed by Lethbridge et al. (2014), estimates of the age and severity of each digging were also recorded, along with the presence of other feral pig sign (faeces, footprints, rubbing trees). A summary of the data attributes is provided in Appendix 1. A sample datasheet is provided in Appendix 2.

The locations of all GPS coordinates and digging data were mapped (Appendix 3).

2.2 Vegetation impact pilot survey

To ascertain the impact of feral pigs on the terrestrial vegetation surrounding the lakes we conducted a small pilot survey using 1 m^2 quadrats. This was undertaken in a grassy, *Eucalyptus camaldulensis* (river red gum) woodland adjoining Lake Cantala. The vegetation around this lake had a higher weed abundance and diversity than the other lakes visited and was therefore chosen for the pilot study. Twenty-one quadrats were surveyed; 11 with pig disturbance, and 10 reference quadrats without.

Quadrats were randomly thrown in areas disturbed by feral pigs and in nearby reference areas (i.e. no pig disturbance). Plants within the 1 m^2 quadrats were identified to species or genus and assigned an estimated percent cover. The quadrats were also used to visually estimate vegetative cover, rock cover, bare ground, cryptogam, organic litter, and coarse woody debris ≥ 10 cm in circumference. The total of the estimated cover components within each quadrat must sum to 100%.

2.3 Informal observations

Although not part of the formal survey method, additional observations about pig activity and impacts have also been presented in Results.

3 Results

3.1 Pig activity

During the survey, 3231 individual feral pig diggings were recorded and assessed. The number of pig diggings recorded for each lake was not a function of perimeter (Figure 2). Lake Mournpall has the fourth largest perimeter (km) but had comparatively few pig diggings. Conversely, one of the smaller lakes, Lake Marramook, had the highest incidence of diggings.

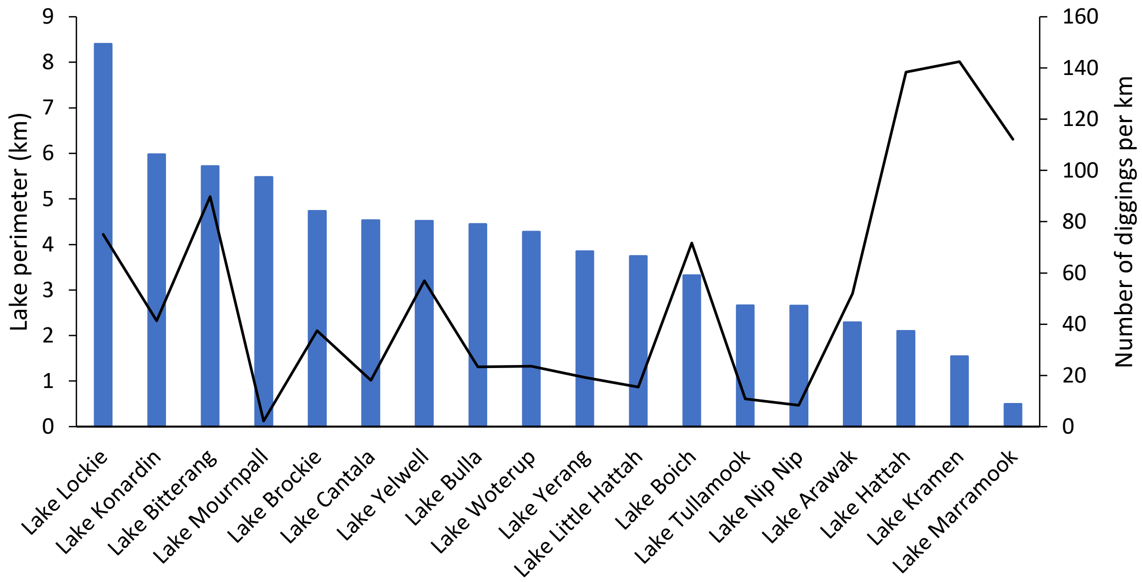

Figure 2 A comparison of the number of diggings encountered per km (line) of transect with lake perimeter (columns).

The average extent (m^2) of feral pig diggings per kilometre of transect varied considerably by lake (Figure 3). Two lakes with high average digging extents (Lake Marramook and Lockie) were effectively dry at the time of the survey.

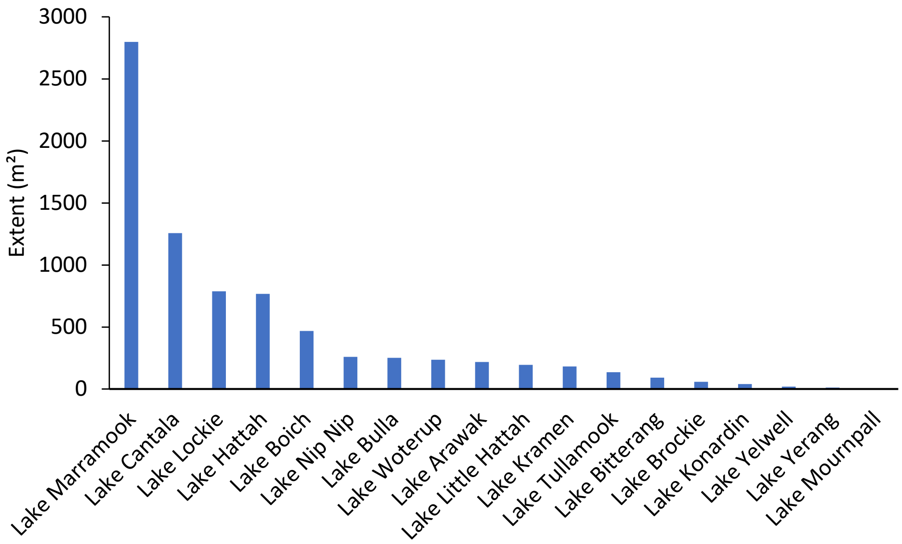

Figure 3 Average extent (m^2) of feral pig diggings per kilometre of transect.

The age of feral pig diggings was variable across the study area (Figure 4). Older diggings were more commonly encountered in the southern lakes (Lake Hattah complex), whilst more recent diggings were generally observed in the northern lakes (Mournpall complex).

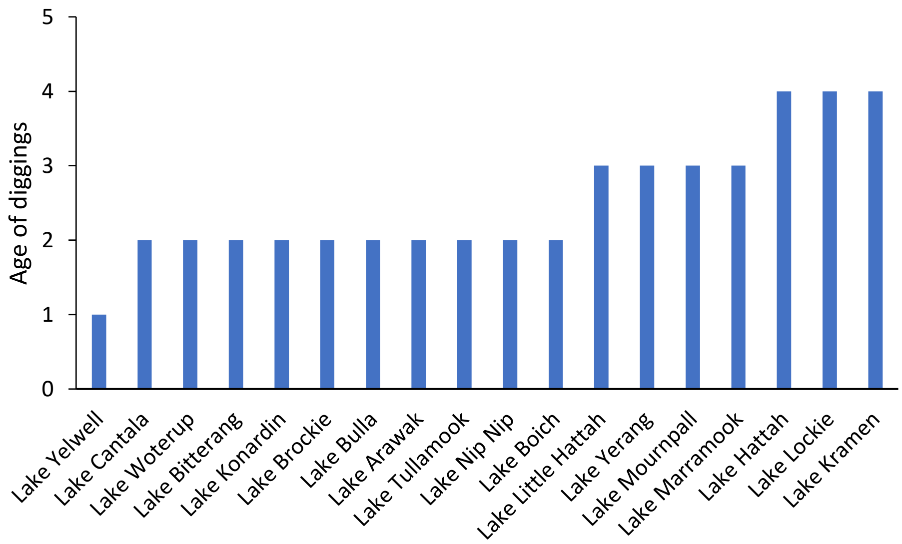

Figure 4 The most commonly recorded value for age of diggings by lake (scoring criteria for age follows Lethbridge et al., 2014); 1) Recent; 2) Less than 30 days; 3) More than 30 days; 4) Old.

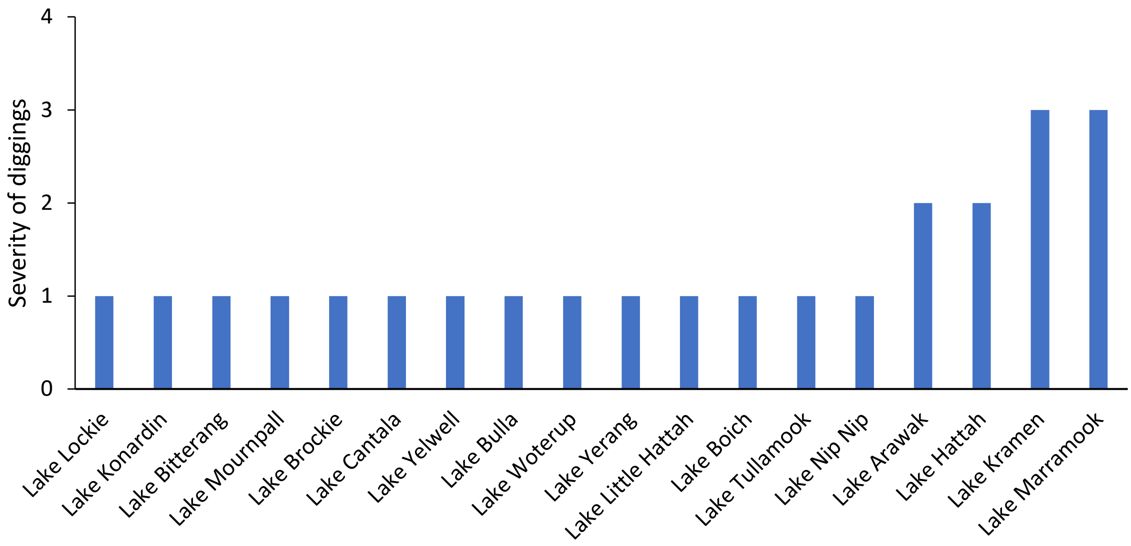

Figure 5 The most commonly recorded value for severity of diggings by lake (scoring criteria for severity follows Lethbridge et al., 2014); 1) Superficial; 2) Moderate; 3) Severe; 4) Wallow.

The severity of feral pig diggings was generally classed as 'Superficial' at most lakes (Figure 5; Appendix 1). However, 'Moderate' to 'Severe' diggings were recorded at Lake Arawak, Lake Hattah, Lake Marramook and Lake Kramen.

3.2 Vegetation impact pilot survey

Weed cover in soils disturbed by feral pigs at Lake Cantala was more than double (78%) that of nearby undisturbed reference areas (31%; Figure 6).

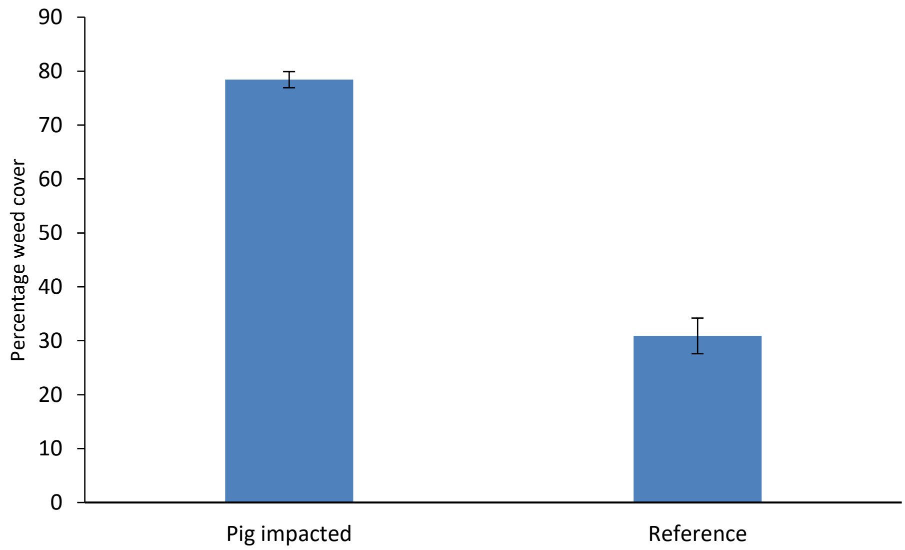

Figure 6 Comparison of weed cover (%) in quadrats ($n = 21$) with ($n = 12$) and without ($n = 9$) feral pig disturbance, Lake Cantala. Standard error bars shown.

On average, quadrats in areas of feral pig disturbance had three weed species. Adjacent areas with no pig disturbance had on average one weed species (Figure 7). Average plant species richness was higher in undisturbed areas.

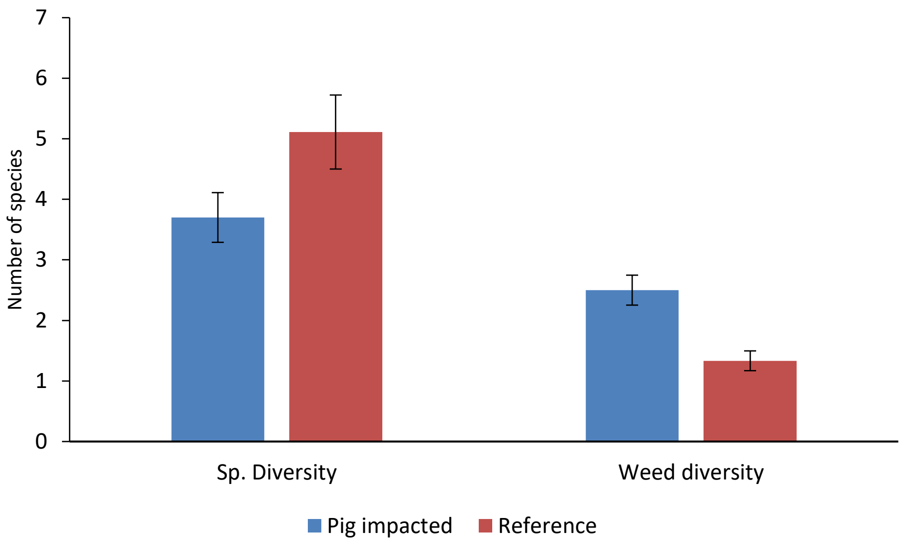

Figure 7 Comparison of total plant species diversity and weed species diversity in quadrats (*n = 21*) with (*n = 12*) and without (*n = 9*) feral pig disturbance, Lake Cantala. Standard error bars shown.

Vegetative cover was marginally higher in reference quadrats than in areas of feral pig disturbance (Figure 8). Percentage of bare ground was higher in areas disturbed by feral pigs and the cover of organic litter was lower (Figure 8).

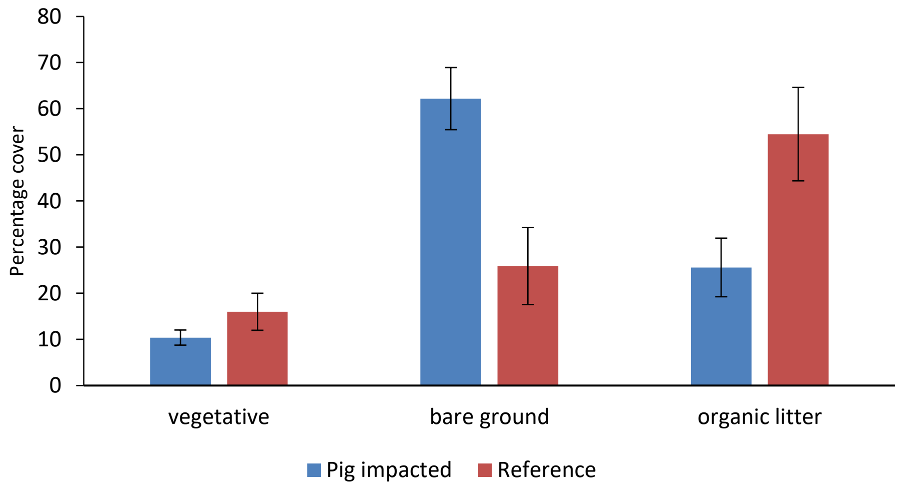

Figure 8 Comparison of vegetative cover, bare ground and organic litter in quadrats *(n = 21)* with (*n = 12*) and without (*n = 9*) feral pig disturbance, Lake Cantala. Standard error bars shown.

3.3 Informal observations

At most locations around the Hattah Lakes, recent pig activity was concentrated immediately at the water's edge. At lakes where the water level was low or receding, this meant that pigs were foraging in recently exposed lake sediment, which was largely free of vegetation. This suggests that pigs are targeting non-plant food resources around the Hattah Lakes wetlands. In numerous places we observed broken mussel shells and crayfish exoskeletons within the disturbed sediment and suspect that feral pigs are preferentially foraging for these high-protein macroinvertebrates. This was only discovered a few days into the survey, thus we were not able to formally summarise these findings in terms of numbers, size, or percentage of diggings where they were found.

The chronology of observed feral pig diggings suggests that a possible link exists between the present drying or wetting phase of a lake and the timing of feral pig activity. Quite often two or more concentric rings of diggings were observed around the edge of a lake. These rings were often well-spaced suggesting periodic occupancy by the feral pigs. These rings presumably corresponded to different water levels/sediment exposure. Once a lake has dried, the feral pigs then proceed to turn-over the lake bottom (e.g. Lake Marramook).

The intensity of diggings also varied between the lakes and appeared related to the character and productivity of the lake sediments. Lakes with darker sediments (suggestive of high organic content) generally had higher digging activity than lakes with sandy substrates (e.g. Lake Mournpall).

Feral pigs were observed opportunistically during the survey. Four pigs were observed wallowing at Lake Bitterang, one pig was observed digging at dusk at Lake Lockie, and a sow and six piglets were observed at Lake Brockie.

4 Discussion

Feral pigs are omnivores and have a broad dietary range. This makes quantifying their ecological impact difficult. Here we define impact as cumulative disturbances that exceed the ability of a species or system to recover to its prior state (e.g. a species is consumed faster than it can reproduce). By contrast, we define damage as small, reversible disturbances within the compensatory bounds of the species or system.

Rooting by pigs may cause considerable soil disturbance, and for this reason pigs may in some contexts be considered 'ecosystem engineers' (Barrios-Garcia and Ballari, 2012 and references therein). However, diggings themselves do not necessarily constitute an impact on the local ecosystem. This is because lake sediments resettle, and these systems can be effectively 'reset' after each flooding event. Consequently, the location, age and extent of feral pig digging quantified in this survey provide a record of feral pig damage around the Hattah Lakes, but do not identify impacts per se.

4.1 Feral pigs as weed dispersers

Feral pigs are known to be vectors of wetland weed dispersion. Although the same is true of other pest and overabundant species (e.g. feral goats, kangaroos), the soil disturbance created from pig diggings provides ideal germination and growth conditions for wetland weed species. Based on a visual assessment of weed diversity and extent, Lake Cantala was the most impacted of all the lakes visited. Noogoora Burr (*Xanthium strumarium*) was observed at this site. Feral pigs are a vector of Noogoora Burr (see Plate 1). A weed of similar ilk, Angel's Trumpet (*Datura inoxia*), was also more abundant at Lake Cantala than elsewhere.

Plate 1 A feral pig covered in *Xanthium* seed at a study site in NSW.

Xanthium strumarium (Noogoora burr) is a Declared noxious weed in Victoria and in several other states. As an environmental weed, dense stands compete with ground-level flora (i.e. grasses, herbs and forbs), and it has the potential to compete with native plants around the Hattah Lakes if it were to spread. This species also impacts upon pastoral (fleece contamination), agricultural, and horticultural enterprises. Disturbance favours its establishment and persistence (Agriculture Victoria 2018).

Lake Cantala is the closest of the Hattah Lakes to the main channel of the River Murray. Patterns of pig movement within the Hattah Lakes are unknown. This lake has the potential to act as an invasion pathway for weedy wetland plant species into the lakes further from the Murray River. Although not surveyed, Chalka Creek provides another potential movement corridor. Pig activity was noted to be high at several receding pools along the creek that were visited by EcoKnowledge staff. Discussions with Parks Victoria staff also suggested that feral pigs are increasingly camping in non-wetland habitats, e.g. mallee woodlands and hopbush (*Dodonaea viscosa*) shrublands. More needs to be understood about the occupancy and movement of feral pigs within the Hattah Lakes Icon Site, particularly in relation to the drying and wetting cycles of the lakes and Chalka Creek.

4.2 Consumption of aquatic macroinvertebrates

Based on the foraging patterns observed during this survey, one of the potential impacts of feral pigs in lake/wetland sediments in this system may be their consumption of crayfish and freshwater mussels. If left unchecked, this could affect the viability of these species and degrade the ecosystem more widely, but without confirming which species are involved it is difficult to determine if this is problematic at this stage.

Our observations of broken mussel shells indicate that pigs are predating these bivalve molluscs by digging them out of mud at the water's edge, and from drying lake beds. Some of the shells were very large, upwards of 10 cm in length, and are likely to be the species *Velesunio ambiguus,* based on size, lacustrine habitat and known presence in the Mallee region (Walker, 2001; Mallee Catchment Management Authority, 2006). Predation by feral pigs has been identified as a hypothetical problem in the conservation of freshwater mussels in Australia, based on their known consumption of mussels on other continents (Walker et al. 2014), but to our knowledge this has not been demonstrated in any Australian habitat. Mussels are regarded as 'keystone' taxa in freshwater habitats, with their role as filter-feeders playing a major, yet underappreciated, role in maintaining water quality, and thus biodiversity (Aldridge et al., 2007). Unsustainable consumption of mussels at Hattah Lakes by feral pigs could impact on water quality, and thus have negative flow-on effects for other taxa, including resident and migratory bird species. This has the potential of threatening the ecological character of the Ramsar listed wetlands.

We could not identify the species of crayfish that were apparently being consumed by the feral pigs, but two or more species may have been involved based on differences in size and colour. The Mallee Wetland Strategy 2006–2011 lists the Common Yabby *Cherax destructor* and the Hairy Burrowing Cray *Engaeus sericatus* as present in the Mallee region, but the Atlas of Living Australia does not have a record of either species for Hattah Lakes. Predation on any other macroinvertebrates or invertebrates were not observed during this survey but should also be considered for investigation based on studies in other locations where, for example, extensive predation on worms has been found (e.g. DEH 2005). Impact on soft-bodied invertebrates would of course be much harder to measure because they are wholly consumed.

5 Summary and recommendations

5.1 Are feral pigs a problem within the Hattah Lakes Icon Site?

The methods used in this survey only quantify pig damage and cannot give an indication of the likely abundance of feral pigs in the Hattah Lakes Icon Site. Without an evidential link between pig activity and broad-scale population density, the damage/impact and activity/density relationship is unknown. As such, conceptually it is not possible to determine whether the observed damage has resulted from one pig digging for ten days or ten pigs for one day. The resultant damage would be the same.

It also remains to be determined what impact (if any) the pigs are having on the ecological values of the Icon Site at current population densities. Until a relationship between population density, digging activity and ecological impact can be established, it is not possible to judge the current state of pig impact.

To be clear, the methods used in this survey are not intended to provide an indication of the likely abundance of feral pigs in the Hattah Lakes complex and ideally a robust population estimate of pigs is required to provide an evidential link between pig density and the level of pig damage.

There is also a diminishing return for effort when removing any pest because there is an increasing cost per head as their densities drop over time. However, without having defensible target pig densities based on impact, it would be difficult estimate the ongoing commitment and cost of control efforts, and how this would be affected by the diminishing return for effort problem.

While camera traps can provide a range of information, estimating population density using this technology is difficult. We have also found that camera trap data needs to be calibrated against known broad-scale densities obtained by other methods. Models that have purported to provide this link (e.g. Rowcliffe et al. 2008) need much modification and testing. Nevertheless, the use of camera traps in place of aerial surveys holds some promise for estimating pig density, but more testing and calibration is required.

Conversely, airborne thermal cameras have been used successfully to estimate pig density in NSW (e.g. Riverine Local Land Services). UAVs are being tested in NSW as well. In fact, better detection rates result from using UAVs flown at night with thermal cameras because the confounding effects of the sun are removed. These technologies probably present the most cost-effective means of determining feral pig abundance and density in the Hattah Lake Icon Site.

The damage assessment methods used in this report captured both recent and historical diggings. In terms of the historical diggings, it is hard to know over exactly what period these have accrued; possibly several years. As such, the damage assessed in this report should be considered a cumulative measure (i.e. recent and historical), and indicative of continued site occupation. Future assessments of pig damage should limit observations to recent pig diggings so as not to confound the data with historical activity mapped in the 2018 survey. The frequency of the future damage impact monitoring method will likely be dictated to some degree by the wetting and drying cycles of the lakes.

Overall, our observations suggest that there are some potential negative impacts by feral pigs. These include the potential to disperse weeds and the consumption of aquatic macroinvertebrates. We suggest that these would serve as better indicators of pig impact in this particular area because they are measureable and can potentially demonstrate ‘effect’. The decline of native plants would be much harder to measure.

In the case of weeds, like all plants they transition through different states and can propagate after fire and where there is soil disturbance. However, they must be first introduced into the system and we need to stress we did not find them present at all sites. This can complicate their role as an indicator of impact.

Conversely, macroinvertebrates such as freshwater mussels are considered to be keystone species and their decline could lead to many possible flow-on effects in these wetland ecosystems. Moreover, it would appear from our observations that it may be much easier to measure the degree to which macroinvertebrates are being removed (e.g. a rate or percentage of sites with shells found) and how this changes between sites and pig density, thus acting as a measure of success of control operations over time.

In summary, we recommend:

1. Future assessments of feral pig damage on lake sediments should limit their observations to recent pig diggings so as not to confound the data with historical activity mapped in the 2018 survey. The frequency of the damage impact monitoring method will likely be dictated to some degree by the wetting and drying cycles of the lakes.

2. Further investigation is required of the impacts of feral pigs on the aquatic macroinvertebrate communities present within the lake sediments, particularly freshwater mussels and crayfish. Ideally this investigation would consist of two parts:

    - An applied research project examining the aquatic macroinvertebrate communities of the Hattah Lakes and their contribution to ecosystem function and in parallel;
    - The development of a ‘rapid’ assessment method of impact using the number of samples with shells as a measure of their impact.

    The latter would provide a justification for feral pig control, and probably be a better way to measure of success of control operations. This is because it would be easy to implement and the measures are relatively simple. A research study could run in parallel because there is sufficient mention of macroinvertebrates in the context of pigs in the literature and it may take some time for macroinvertebrate impact in this system to be fully understood. For example, research may indicate the impact on macroinvertebrates is seasonal and there is recovery. Conversely, there may be an aging and declining population of macroinvertebrates. Cumulative effects may also confound any measures of impact. For example, a declining population of aquatic macroinvertebrates may mean recovery occurs over a much longer period. The timing, magnitude and duration of flood events and environmental watering will also influence the status of macroinvertebrates communities within the lakes and the severity of feral pig predation on these communities. Nevertheless, as an indicator of impact, we believe it presents a useful and contrasting measure that can be related to feral pig density targets. A similar “simple indicator to target” approach has been adopted for the *Strategic Action Plan for Feral Goats on Public Land in North-West Victoria* (Parks Victoria 2017).

3. Weeds invasion, measured in terms of extent, type and percentage of sites affected, appears to remain another important longer-term indicator of impact, despite it not being present at all lakes. We recommend this measure of impact is continued. Direct impacts on native vegetation were not apparent at this time, but may develop temporally.

4. More needs to be understood about the occupancy and movement of feral pigs in relation to the drying and wetting cycles of the lakes.

5. Repeated monitoring at all sites or select sites (if budgetary constraints do not permit the former) should be undertaken to better understand the temporal implications of repeated feral pig disturbance on weeds, macroinvertebrates and possibly native vegetation condition.

6. Ideally, an aerial survey should be undertaken to obtain estimates of feral pig density, distribution and abundance and relate this to impact. This allows agencies to set density targets, provides an indication of control efforts required, justifies budget projections/funding and is a better evidential link in reporting the success of programs.

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Appendix 1 – Data attributes

Extent of diggings

The length and width of individual diggings was recorded to the nearest 0.1 of a metre. An extent (m^2) was estimated for each digging based on these recordings. A 1 m^2 quadrat was used to aide estimates of extent. For large diggings, the quadrat was placed at the edge of the digging and flipped in a grid pattern to obtain an estimate. An estimated area calculation (width by length) was used for long digging trenches.

Diggings were recorded independently if they were few and scattered. However, in areas of intense diggings, the area of two or more diggings was approximated by estimating the total area over which the diggings are spread (within each transect) and then estimating the percentage of this area that has been disturbed. For example, if the transect is 10m wide with 50m of constant diggings and an estimated 75% of the ground area has been dug then the area of these diggings is 75% of 10m x 50m (500 m^2) = 375 m^2.

Criteria for estimating the age of feral pig diggings (from Lethbridge et al. 2014)

Category 1: Recent diggings

- Freshly overturned soils with little or no effect of wind or rain marks
- Overturned vegetation can be green to yellowing in colour with little to moderate wilting.
- Exposed roots still intact and pliable
- Little leaf litter or animal tracks
- No germination of seeds in the diggings

Category 2: Less than 30 days

- Overturned soil shows some sign of weathering
- Overturned vegetation yellowing and wilting
- Exposed roots are dry and brittle
- Some signs of regrowth from disturbed vegetation
- Leaf litter and animal tracks throughout the diggings (depends on seasonal factors)
- Some sprouting of seeds

Category 3: Greater than 30 days

- Overturned soil has signs of weathering and flattening
- Overturned vegetation is mostly dead (dependant on soil adherence to roots)
- Exposed roots are dry and brittle and beginning to break off.
- Disturbed vegetation shows signs of regrowth
- Germinating seeds throughout the diggings
- Leaf litter, animal tracks etc throughout the diggings

Category 4: Old diggings over 90 days

- Overturned soil is weathered and flattened out
- Overturned vegetation is dead and decomposing
- Exposed roots and dead and broken off, soil not adhering to roots.
- Disturbed vegetation in full regrowth.
- Seedlings growing throughout
- Full coverage of leaf litter' and animal tracks similar to non-dug areas.

Criteria for determining the severity of feral pig diggings

Category 1: Superficial diggings

- Soil disturbance from scratching on the surface to 100mm in depth
- Disturbed soil usually a single snout hole to a snout trench up to 1m in length
- Vegetation usually pushed to the side and not completely turned over or covered by disturbed soils
- Plant roots exposed within the digging walls
- Intermittent small areas of soil disturbance up to $0.5m^2$ in area

Category 2: Moderate diggings

- Soil disturbance 100mm to 200mm in depth
- Disturbed soil rolled over or pushed into small mounds.
- Some vegetation covered with disturbed soil
- Some plant roots exposed
- Individual soil disturbance sites up to $2m^2$ in area and not linked together

Category 3: Severe diggings

- Soil disturbance greater then 200mm in depth
- Disturbed soil pushed in mounds or deep trenches
- Most of vegetation is overturned and covered by disturbed soil
- Plant roots exposed
- Continuous soil disturbance sites greater then $2m^2$ in area

Category 4 : Wallow

- Soil disturbance created by pigs rolling in wet soil. Usually devoid of all vegetation.
- Greater then 100mm in depth and contains (or has contained) water
- Outline of pigs body and tracks seen in the wet (or dried) mud.
- Usually associated with rub trees in the vicinity

Microhabitats	1	Water edge – wet area within 1 m of water
	2	Moist soil
	3	Bare/ exposed soil
	4	Swampy area/ drainage lines (seasonally dry)
	5	Dense vegetative cover (native)
	6	Dense vegetative cover (exotic)
	7	Grassland
Other pig signs	1	Tracks
	2	Faeces
	3	Rub trees

Appendix 2 – Field datasheet

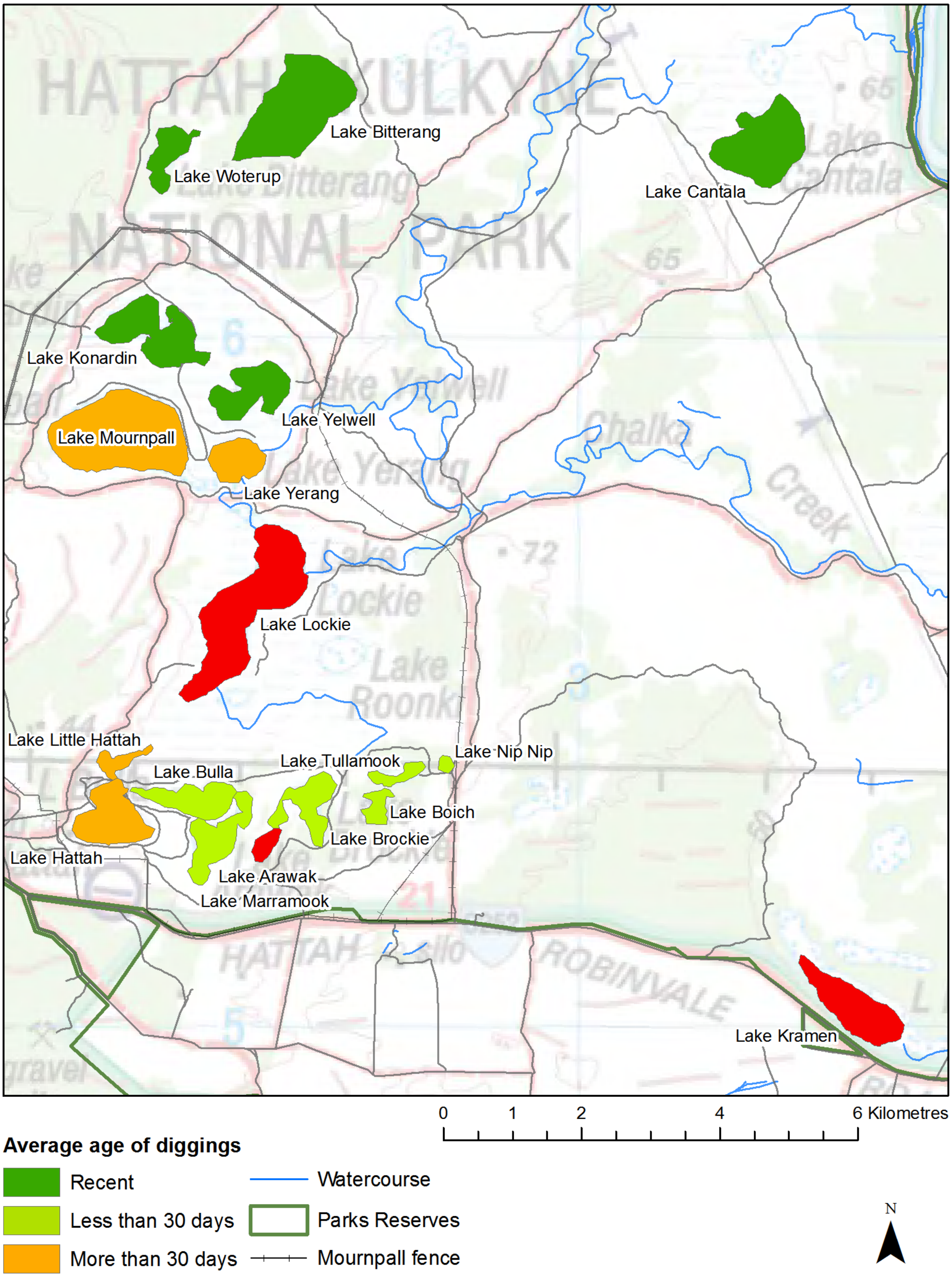
Date: **Location:** **Observer:** **Ring:**

Easting	Northing	Length (m)	Width (m)	Extent (m^2)	Age of diggings[1]	Severity of diggings[2]	Sign[3]	Micro-habitat[4]	Other/Image no.

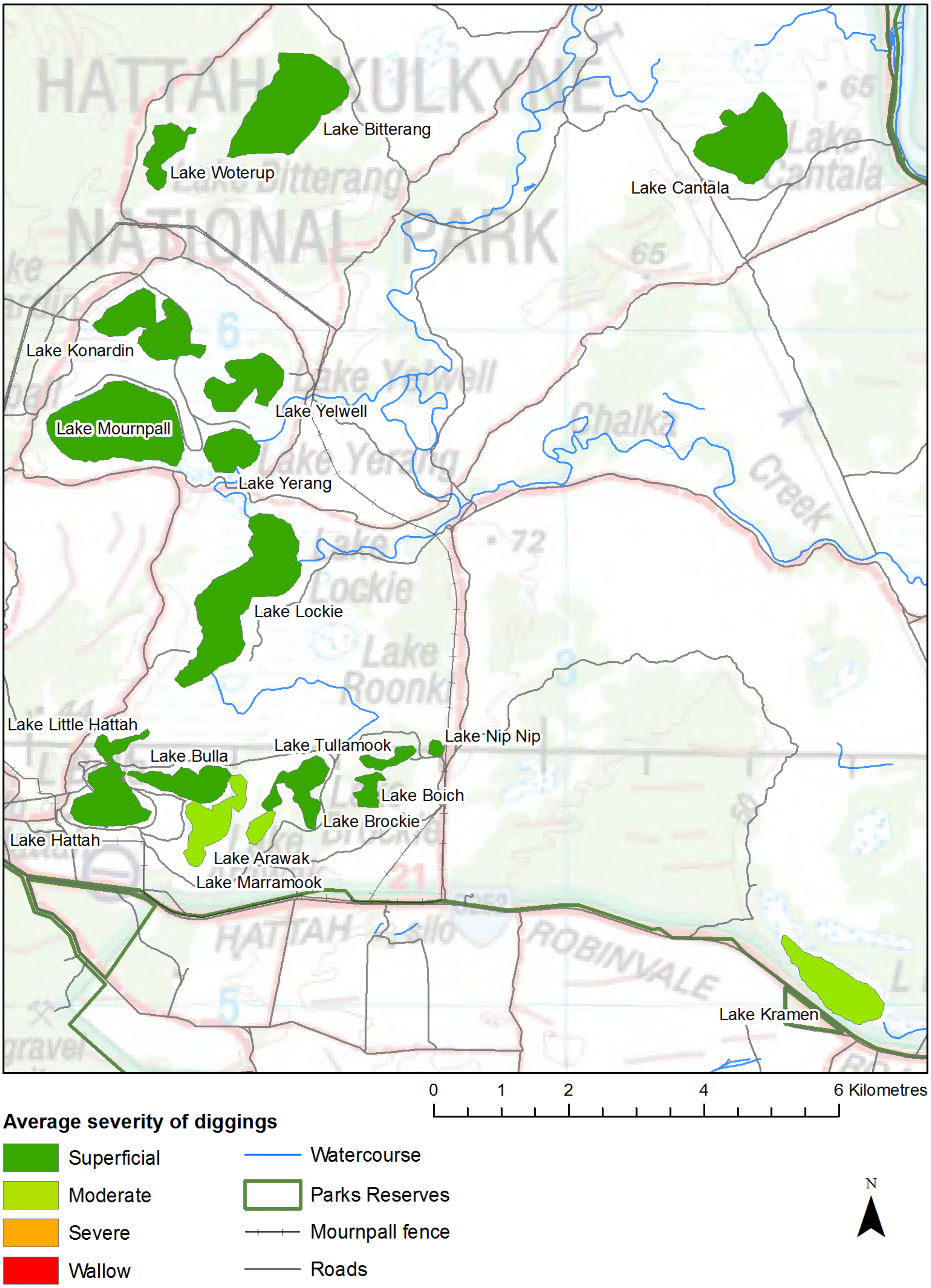
[1]Age: 1) Recent; 2) Less than 30 days; 3) More than 30 days; 4) Old
[2]Severity: 1) Superficial; 2) Moderate; 3) Severe; 4) Wallow
[3]Sign: 1) Tracks; 2) Faeces; 3) Rub tree
[4]Microhabitats: 1) Water edge – within 1 m of water; 2) Moist soils; 3) Bare/ exposed soil; 4) Swampy area/ drainage line; 5) Dense vegetative cover (native); 6) Dense vegetative cover (exotic); 7) Grassland

Appendix 3 – Feral pig damage mapping

Average age of feral pig diggings across Hattah Lakes Icon Site

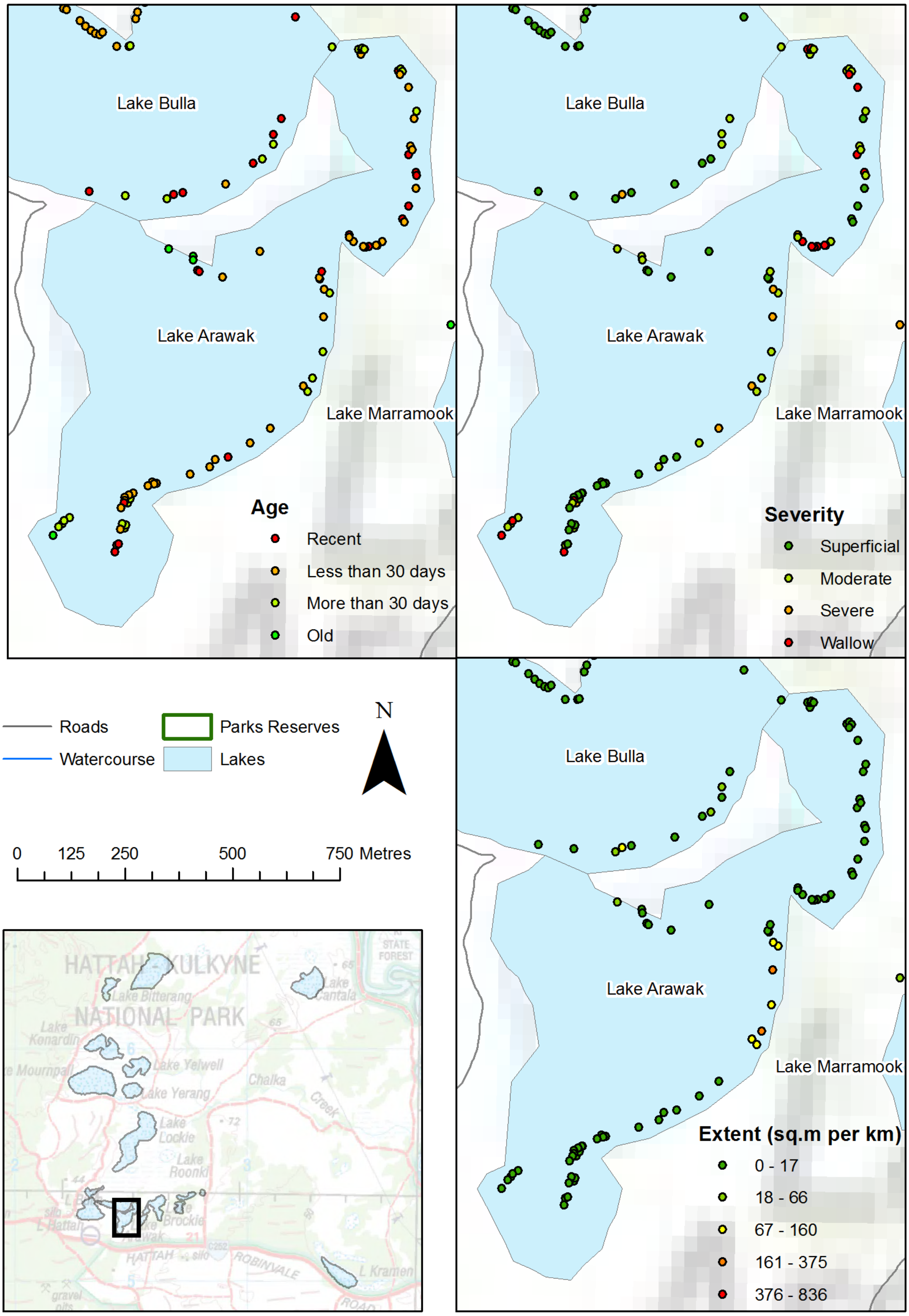


Average severity of feral pig diggings across Hattah Lakes Icon Site

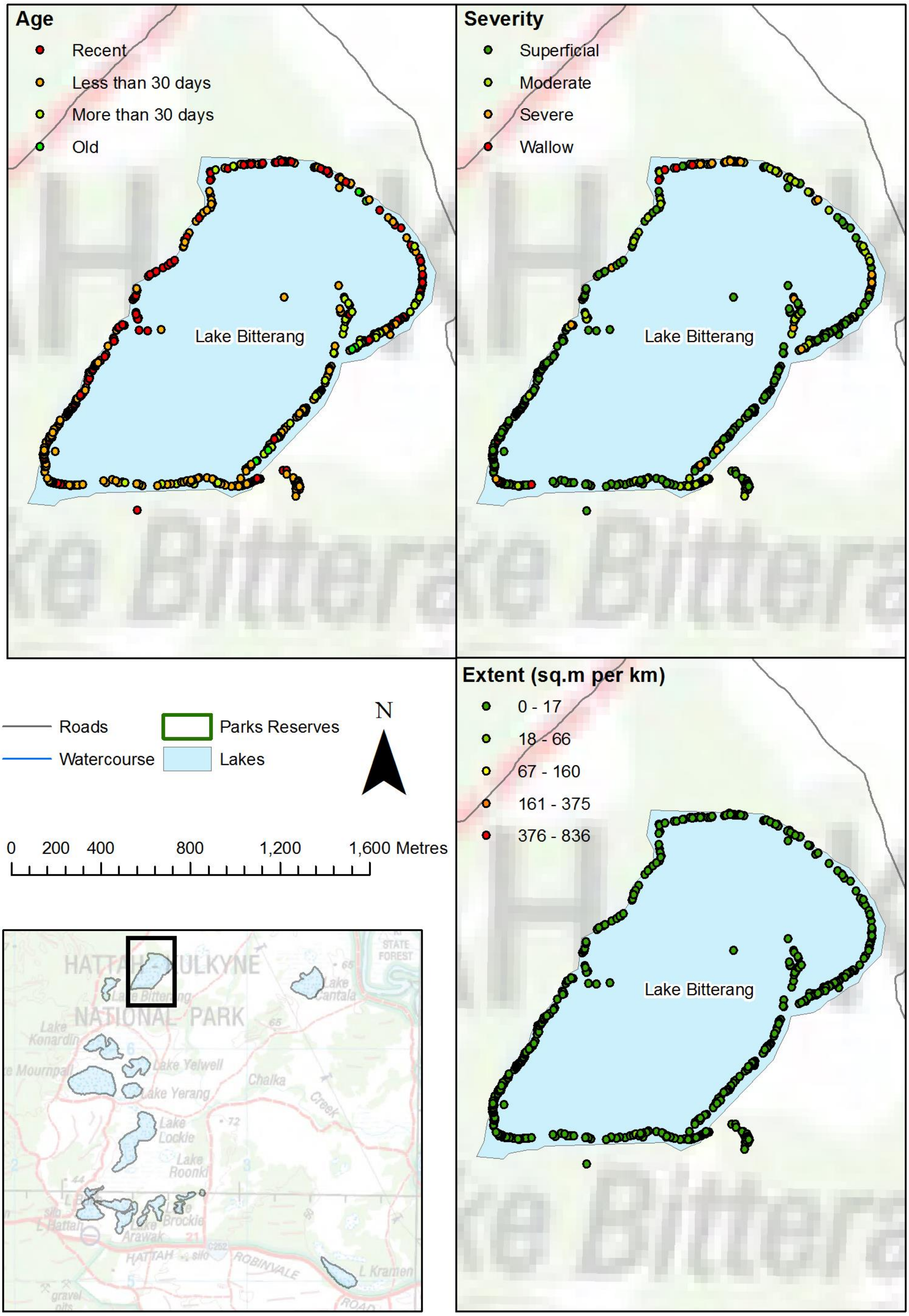


Feral pig digging attributes by lake

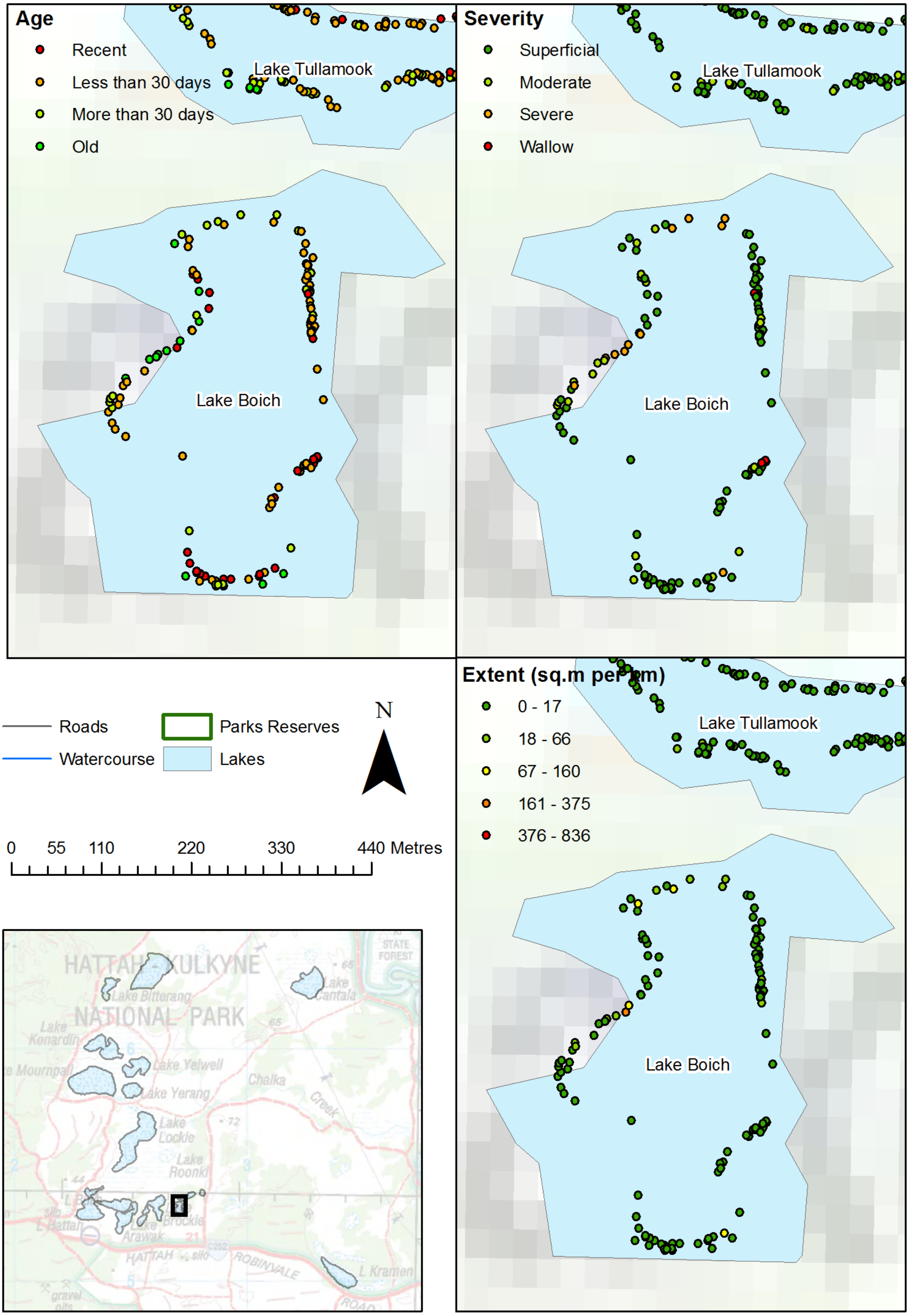
Lake Arawak



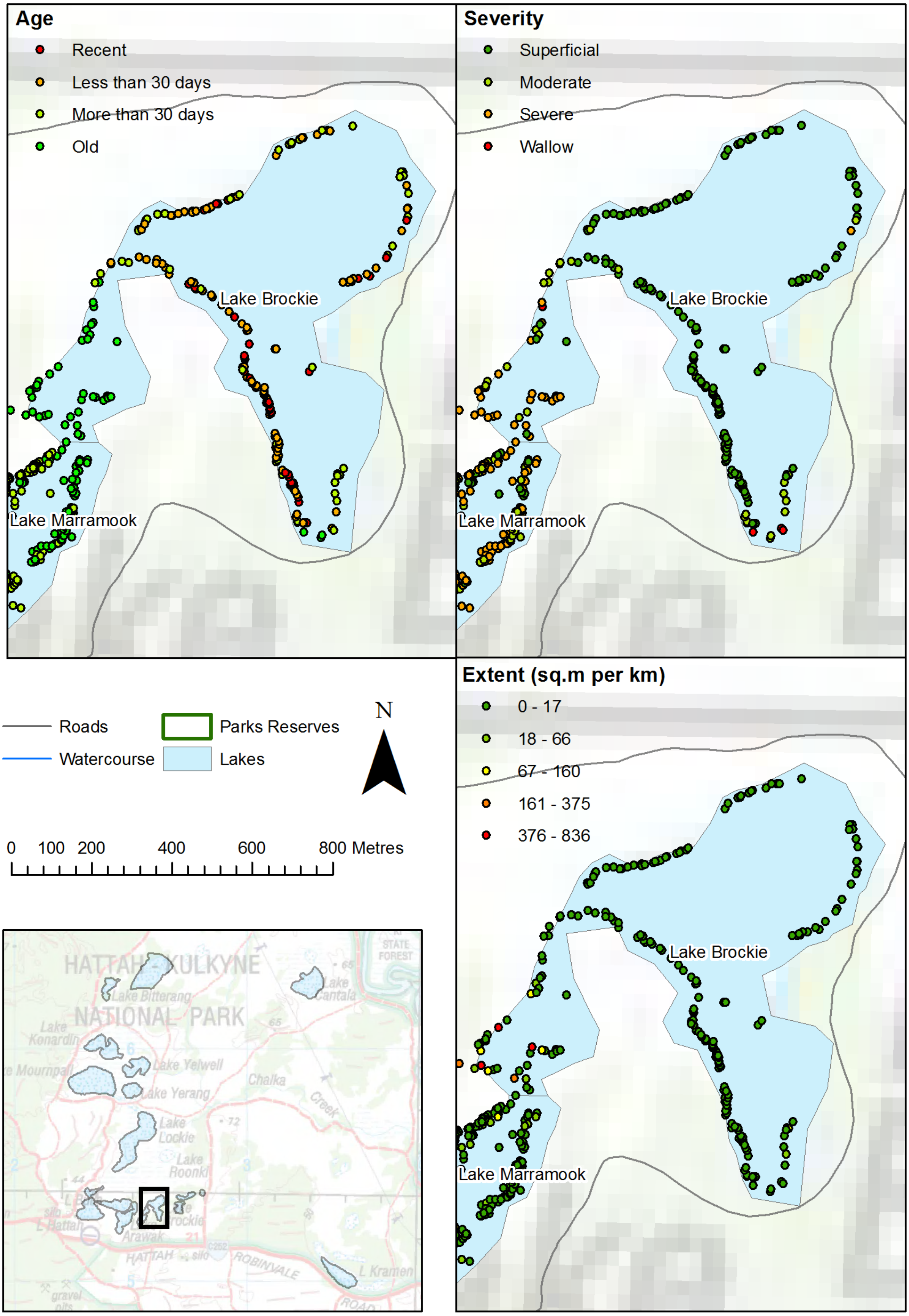
Lake Bitterang



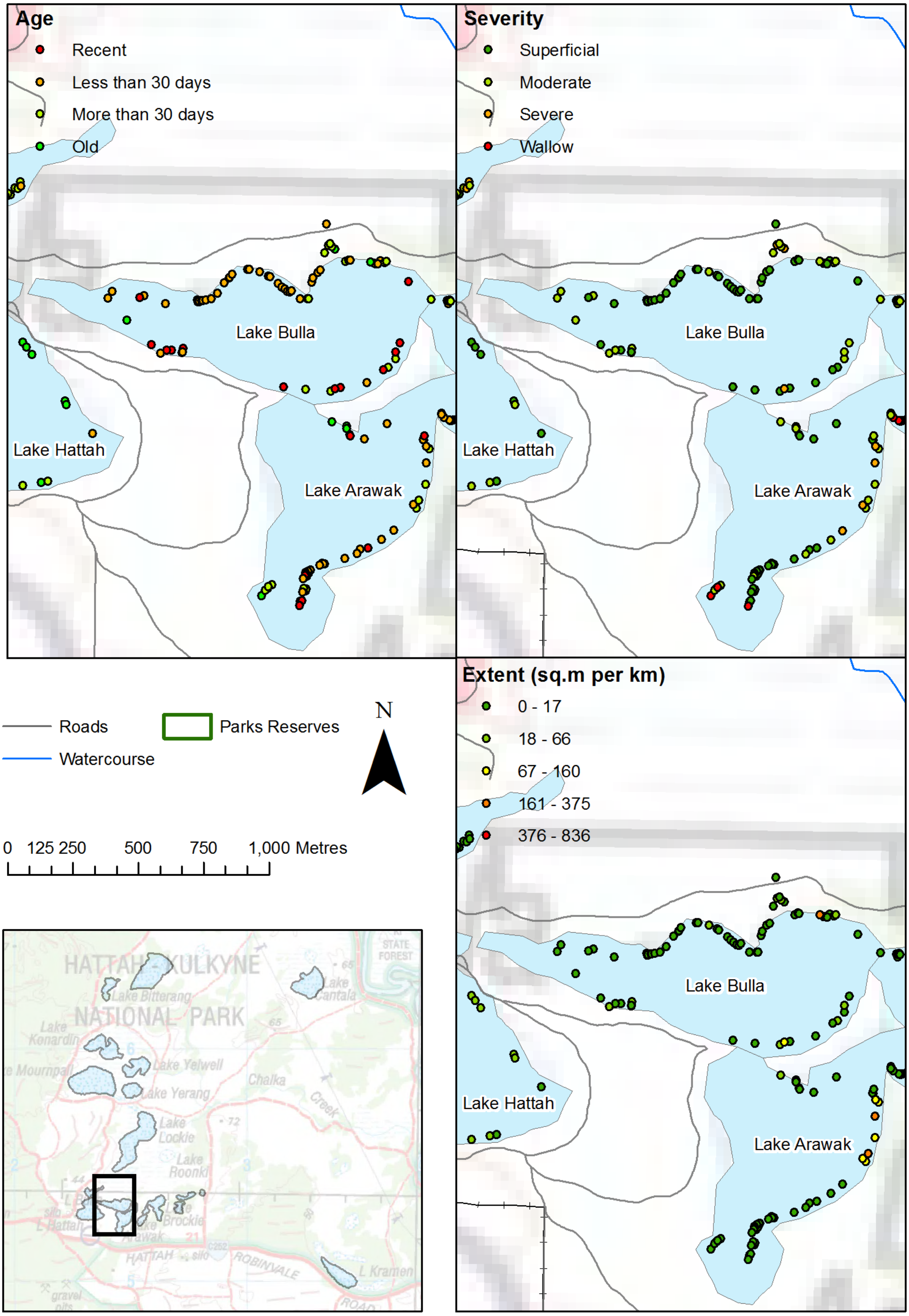
Lake Boich


Age
Recent
Less than 30 days
More than 30 days
Old
Lake Tullamook
Lake Boich
Severity
Superficial
Moderate
Severe
Wallow
Lake Tullamook
Lake Boich
Extent (sq.m per km)
0 - 17
18 - 66
67 - 160
161 - 375
376 - 836
Lake Tullamook
Lake Boich
Roads
Watercourse
Parks Reserves
Lakes
N
0 55 110 220 330 440 Metres
HATTAH - KULKYNE
NATIONAL PARK
Lake Bitterang
Lake Cantala
Lake Kenardin
Lake Yelwell
Lake Yerang
Chalka
Creek
Lake Lockie
Lake Roonki
Lake Arawak
Brockie
L Hattah
HATTAH
ROBINVALE
L Kramen
STATE FOREST

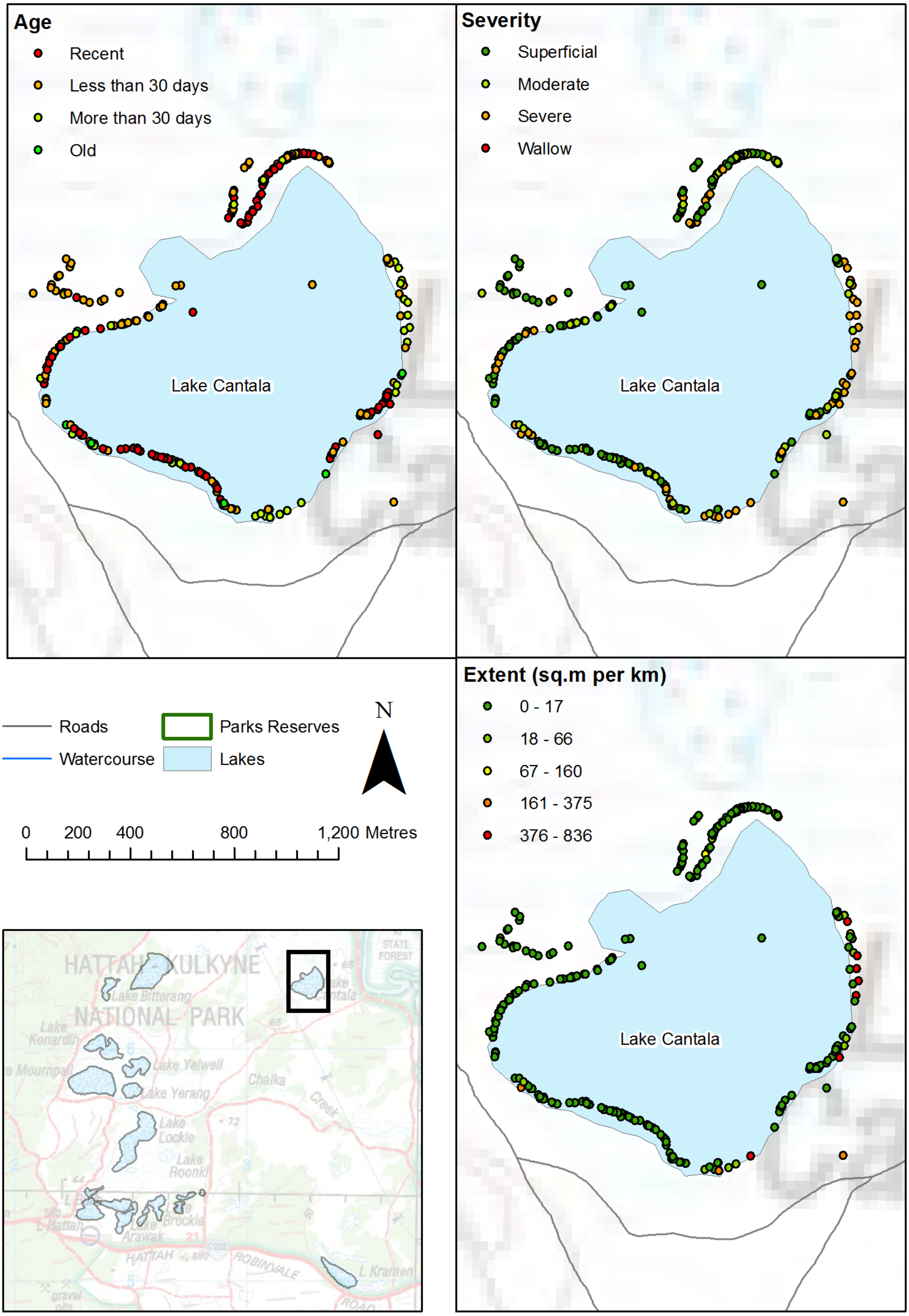
Lake Brockie



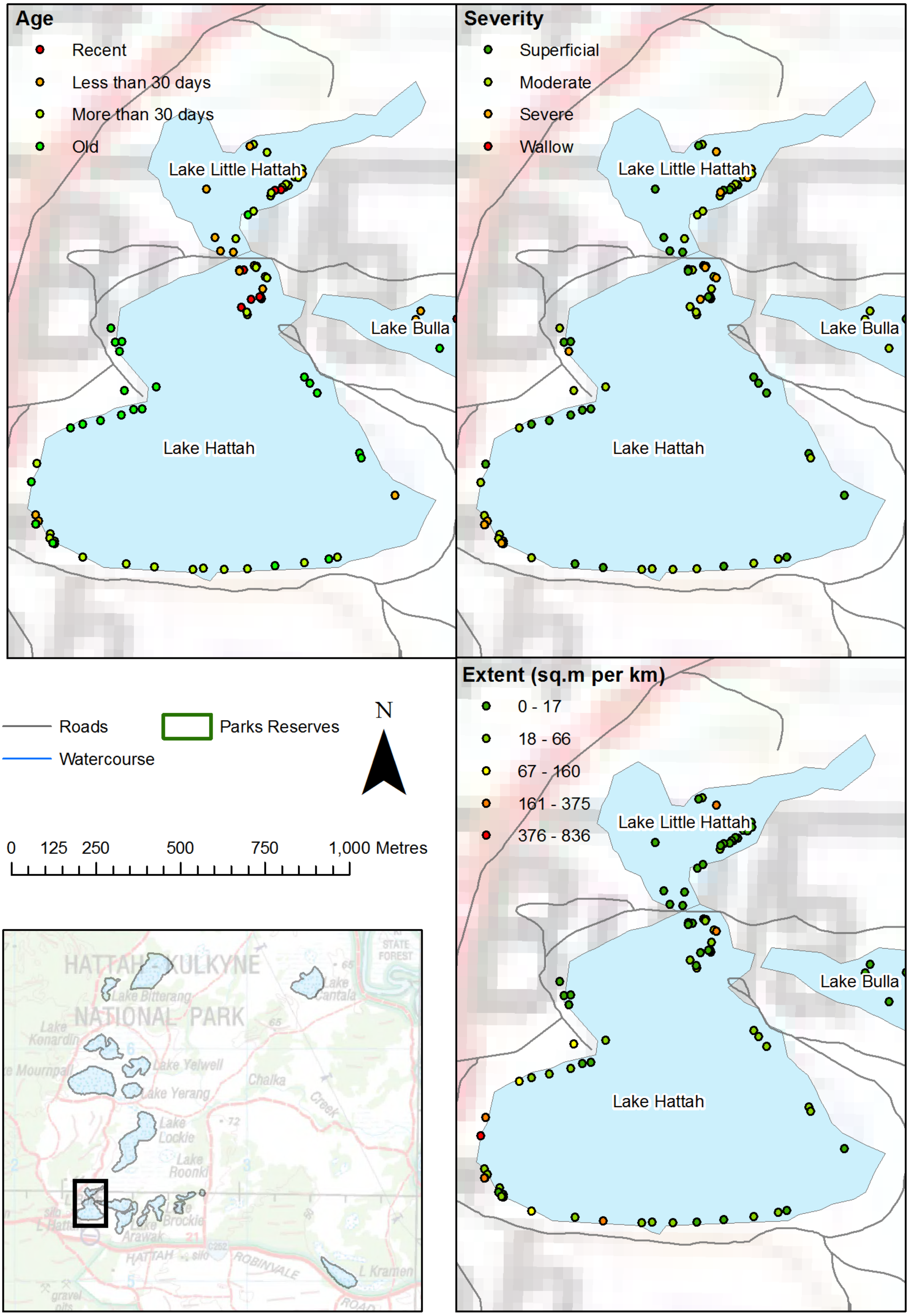
Lake Bulla


Age
Recent
Less than 30 days
More than 30 days
Old
Lake Bulla
Lake Hattah
Lake Arawak
Severity
Superficial
Moderate
Severe
Wallow
Lake Bulla
Lake Hattah
Lake Arawak
Roads
Watercourse
Parks Reserves
N
0 125 250 500 750 1,000 Metres
Extent (sq.m per km)
0 - 17
18 - 66
67 - 160
161 - 375
376 - 836
Lake Bulla
Lake Hattah
Lake Arawak
HATTAH - KULKYNE
NATIONAL PARK
Lake Bitterang
Lake Cantala
Lake Yelwell
Lake Yerang
Lake Lockie
Lake Roonki
Chalka
Creek
HATTAH
ROBINVALE
L Kramen

Lake Cantala

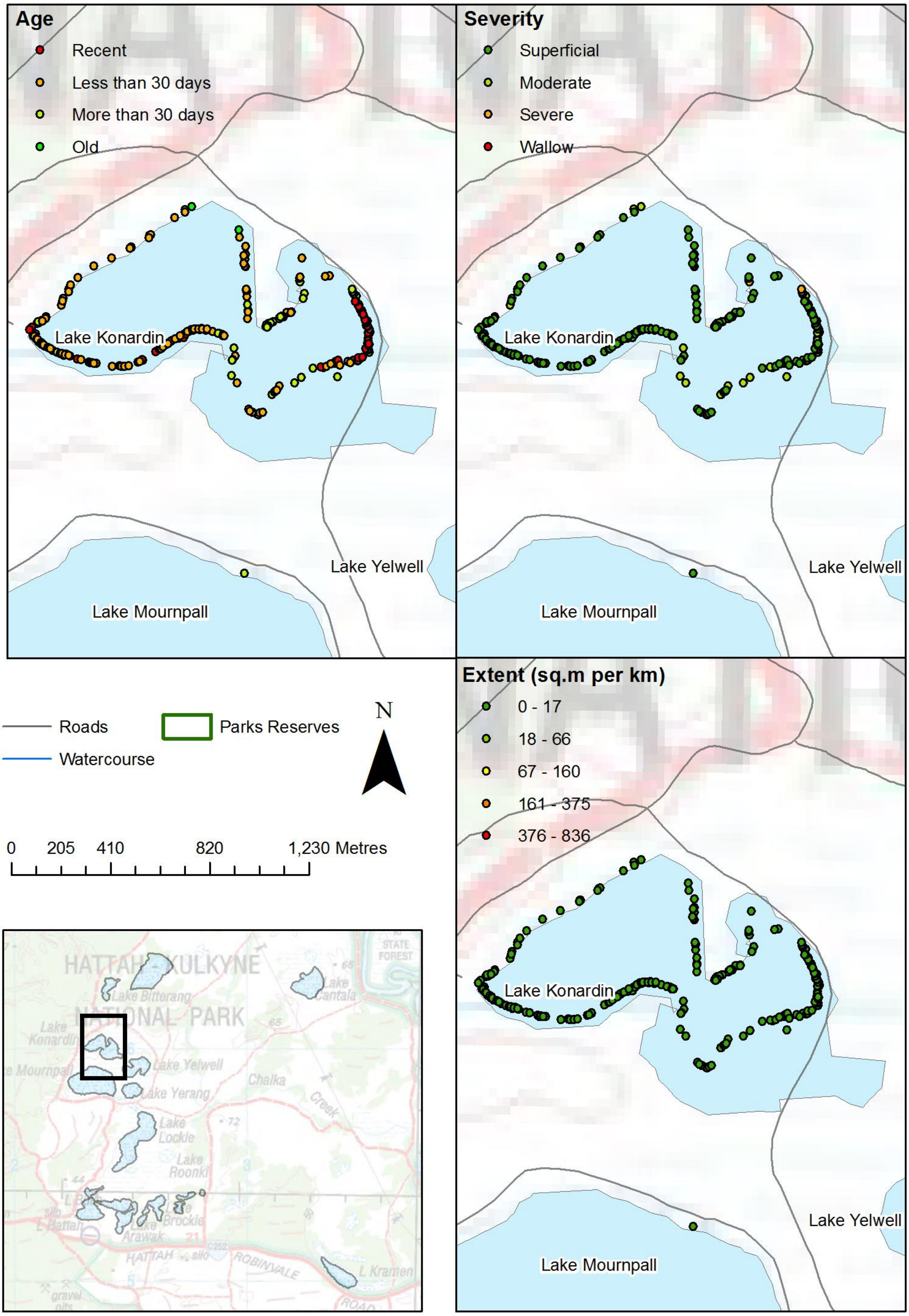


Lake Hattah

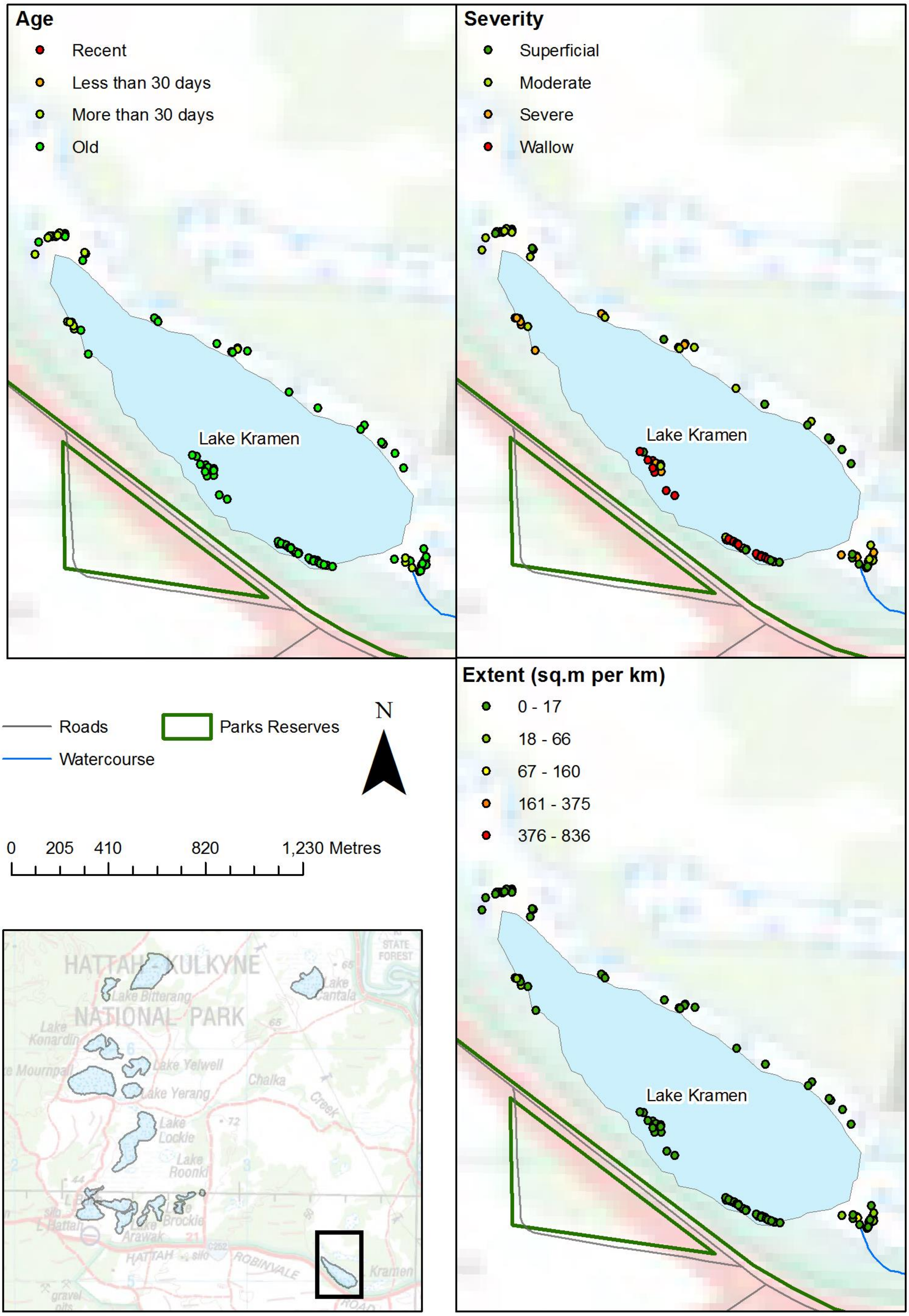


Age
Recent
Less than 30 days
More than 30 days
Old
Lake Little Hattah
Lake Bulla
Lake Hattah
Severity
Superficial
Moderate
Severe
Wallow
Extent (sq.m per km)
0 - 17
18 - 66
67 - 160
161 - 375
376 - 836
Roads
Watercourse
Parks Reserves
N
0 125 250 500 750 1,000 Metres
HATTAH - KULKYNE
NATIONAL PARK

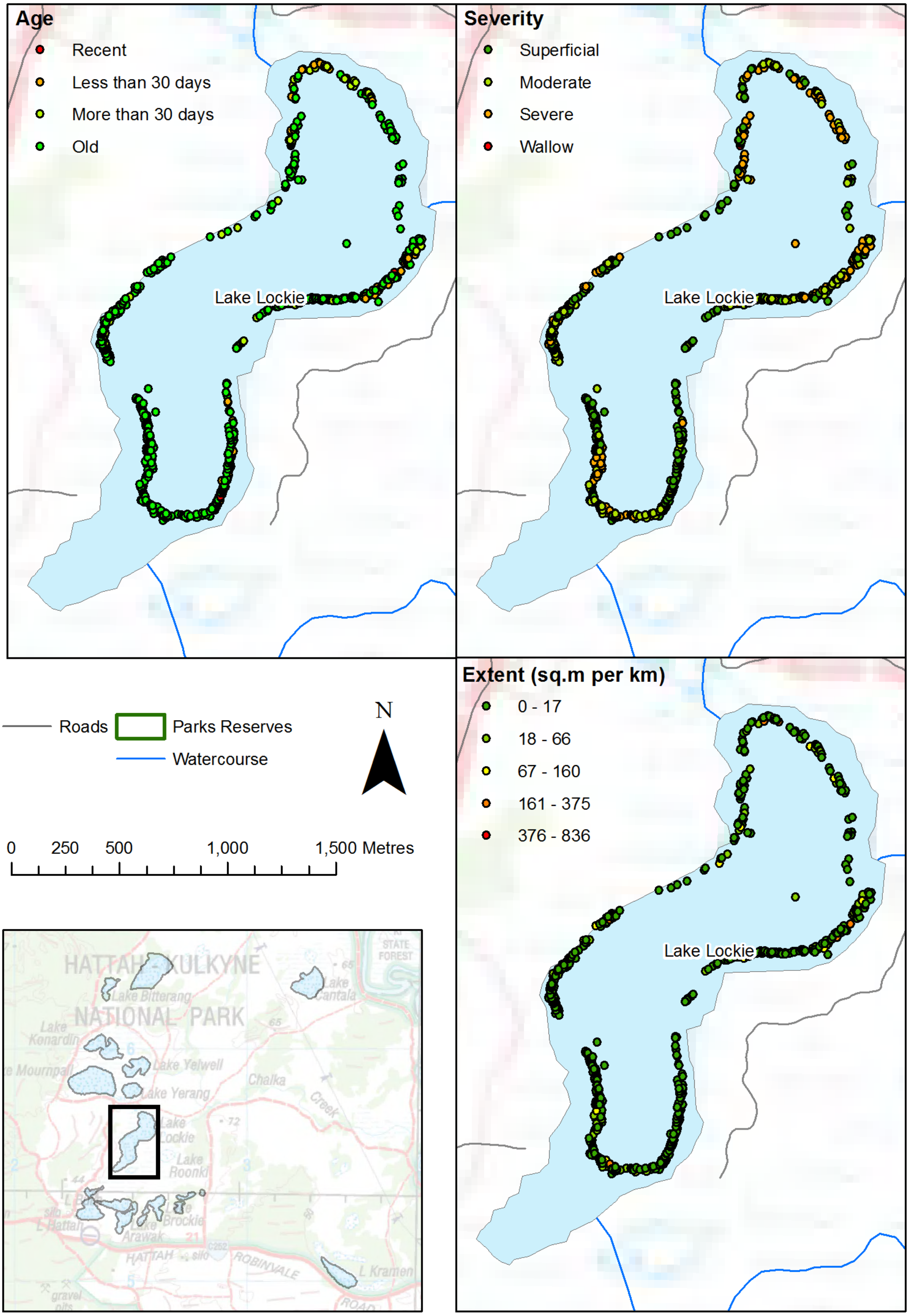
Lake Konardin



Lake Kramen

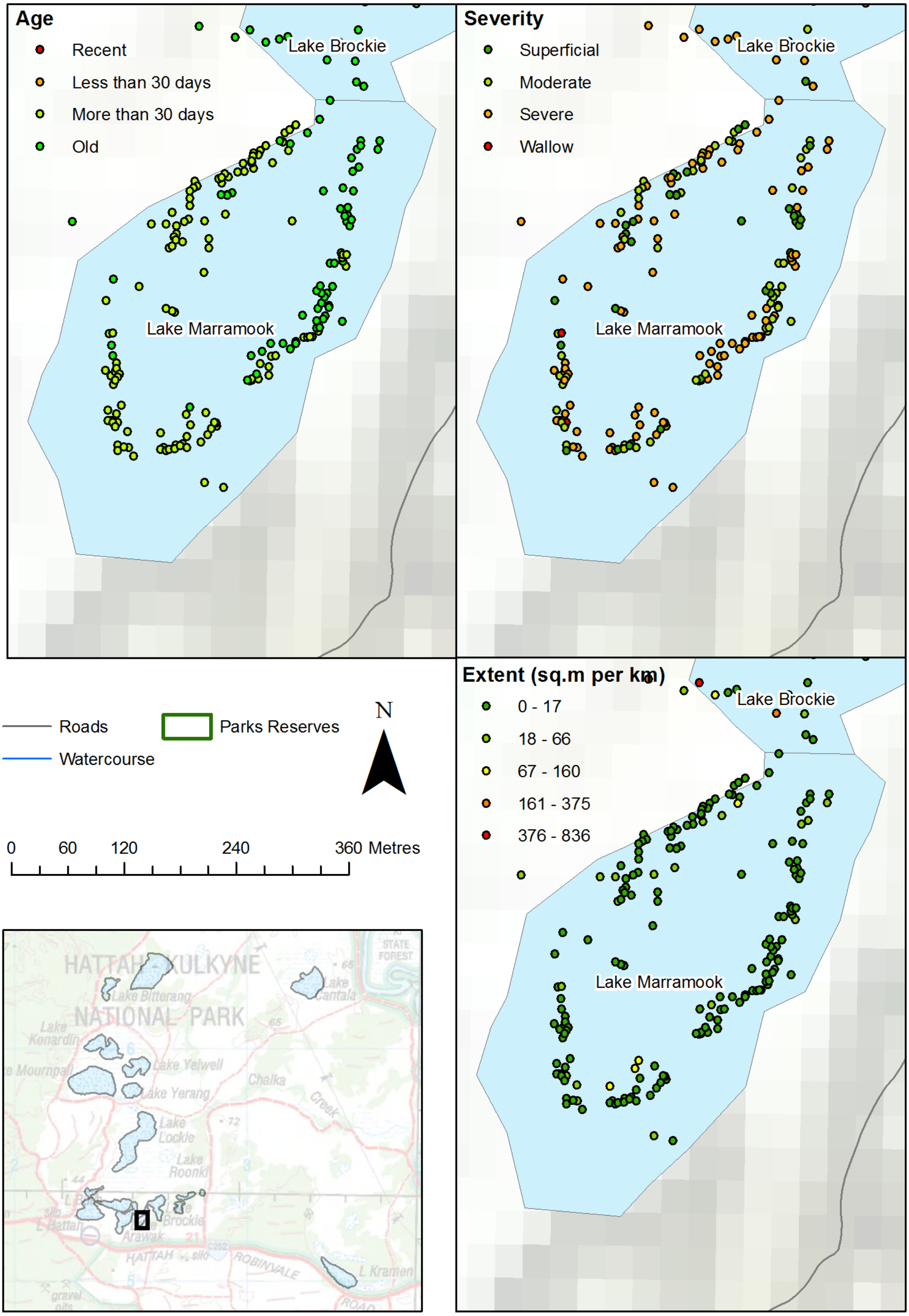

Age
Recent
Less than 30 days
More than 30 days
Old
Lake Kramen
Severity
Superficial
Moderate
Severe
Wallow
Lake Kramen
Roads
Watercourse
Parks Reserves
N
0
205
410
820
1,230 Metres
Extent (sq.m per km)
0 - 17
18 - 66
67 - 160
161 - 375
376 - 836
Lake Kramen
HATTAH - KULKYNE
NATIONAL PARK
Lake Bitterang
Lake Cantala
STATE FOREST
Lake Kenardin
Lake Yelwell
Lake Yerang
Chalka
Creek
Lake Lockie
Lake Roonki
Lake Brockie
Arawak
HATTAH
ROBINVALE
Kramen

Lake Lockie

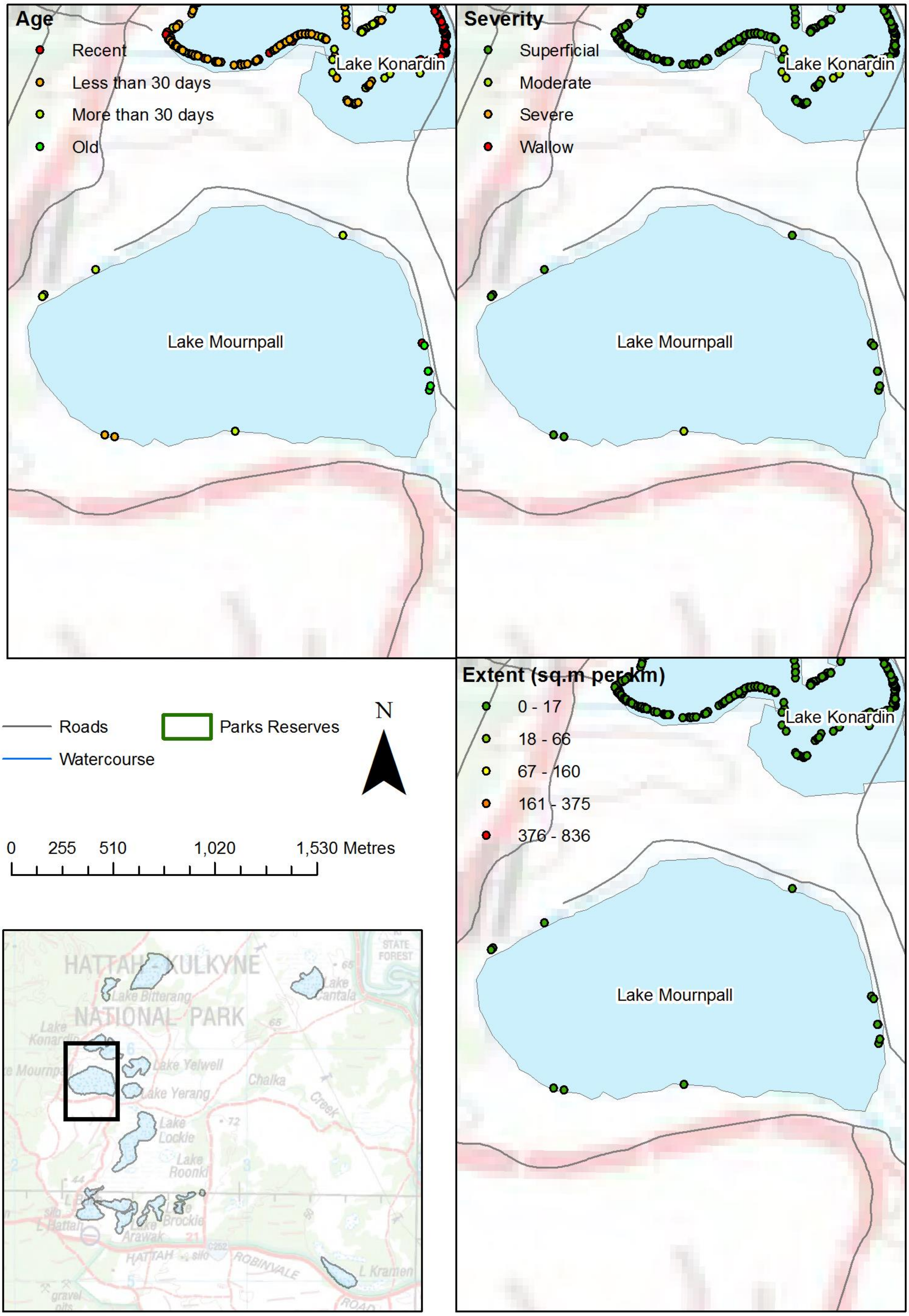


Age
Recent
Less than 30 days
More than 30 days
Old
Lake Lockie
Severity
Superficial
Moderate
Severe
Wallow
Lake Lockie
Roads
Parks Reserves
Watercourse
N
0
250
500
1,000
1,500 Metres
Extent (sq.m per km)
0 - 17
18 - 66
67 - 160
161 - 375
376 - 836
Lake Lockie
HATTAH - KULKYNE
NATIONAL PARK
Lake Bitterang
Lake Cantala
Lake Kenardin
Lake Yelwell
Lake Yerang
Lake Lockie
Lake Roonki
Chalka
Creek
Lake Brockie
Lake Arawak
HATTAH
ROBINVALE
L Kramen
STATE FOREST

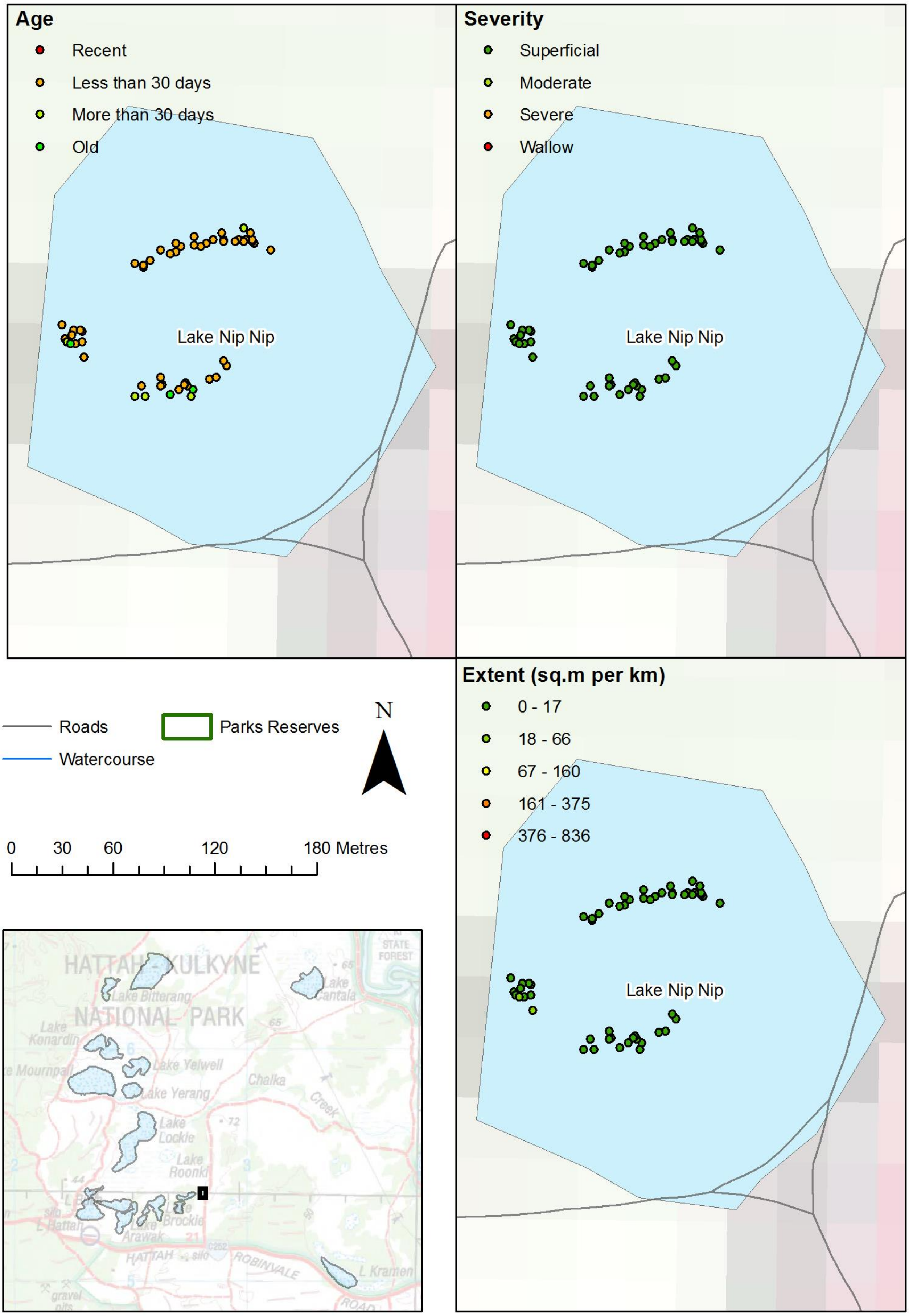
Lake Marramook



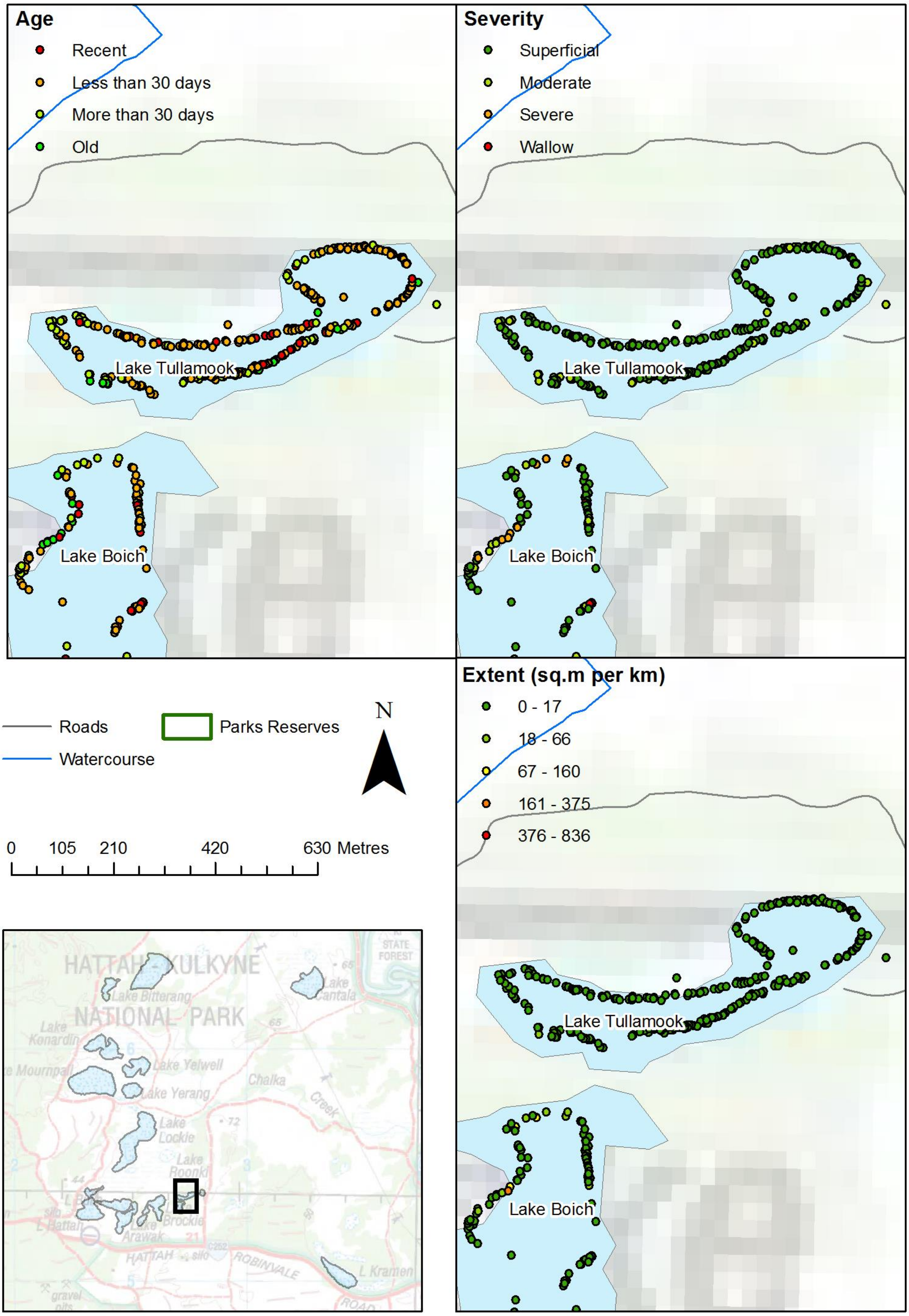
Lake Mournpall



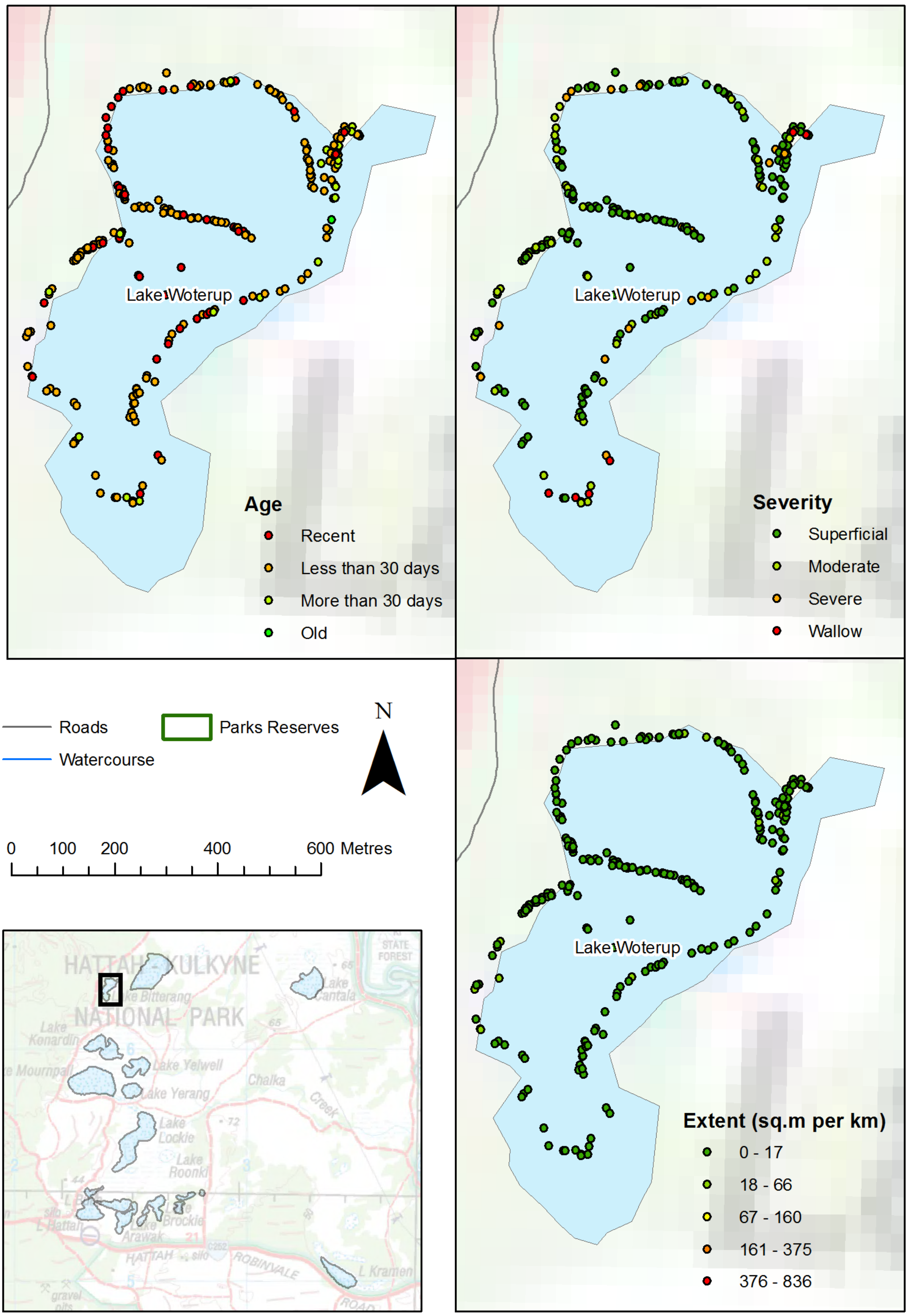
Lake Nip Nip


Age
Recent
Less than 30 days
More than 30 days
Old
Lake Nip Nip
Severity
Superficial
Moderate
Severe
Wallow
Lake Nip Nip
Extent (sq.m per km)
0 - 17
18 - 66
67 - 160
161 - 375
376 - 836
Lake Nip Nip
Roads
Watercourse
Parks Reserves
N
0
30
60
120
180 Metres
HATTAH - KULKYNE
NATIONAL PARK
Lake Bitterang
Lake Cantala
Lake Yelwell
Lake Yerang
Lake Lockie
Lake Roonki
Chalka
Creek
Brockie
Arawak
HATTAH
ROBINVALE
L Kramen

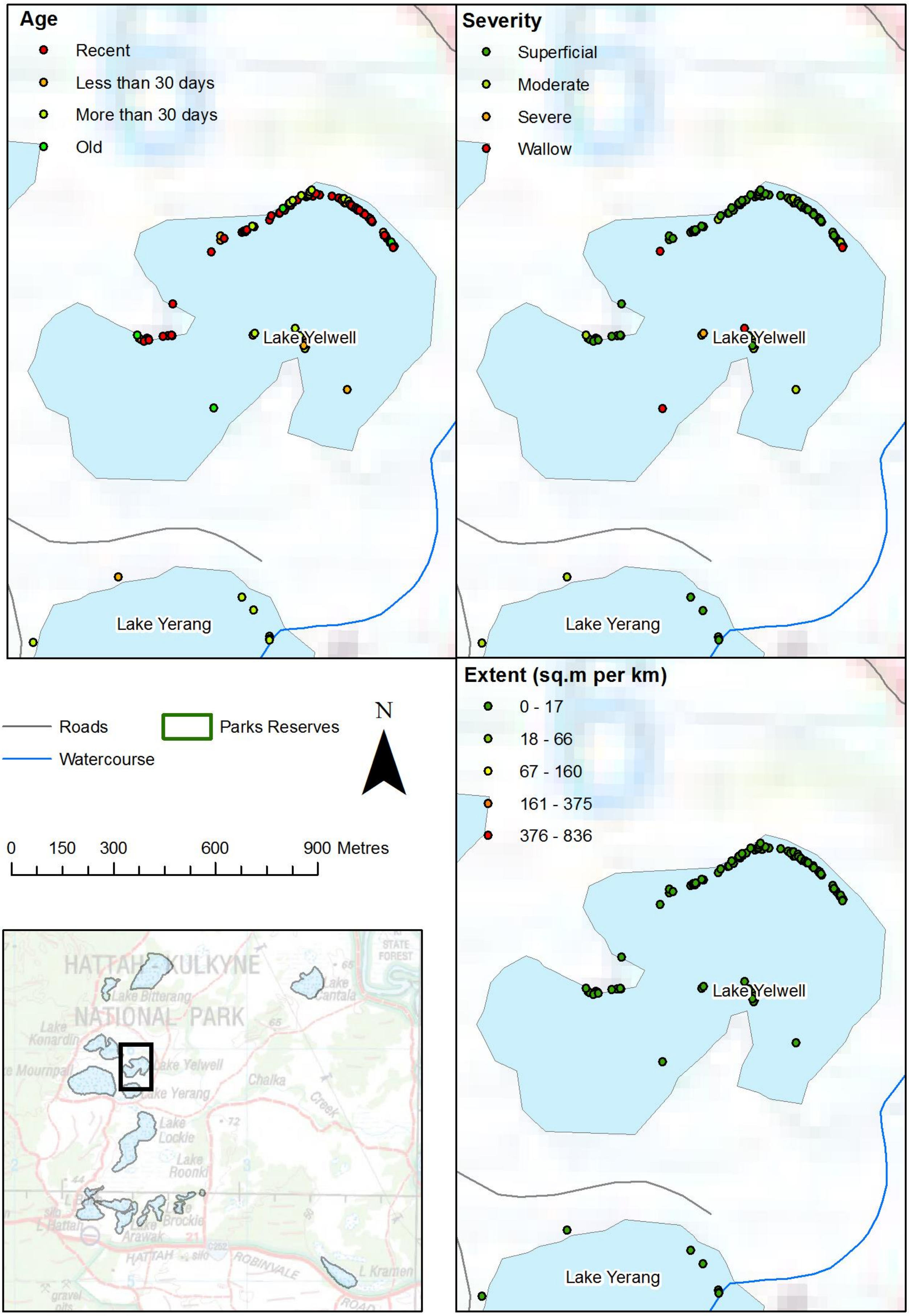
Lake Tullamook



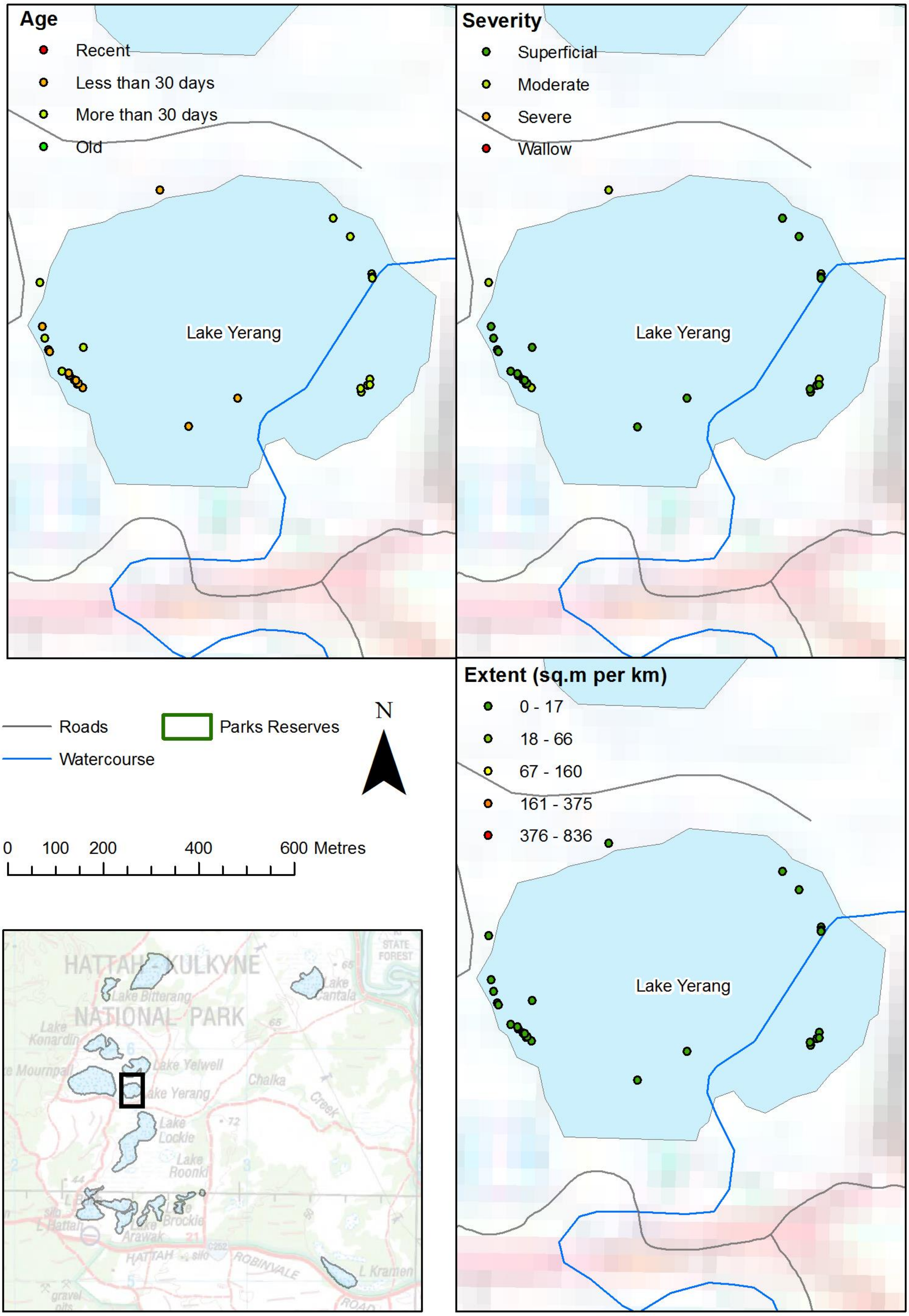
Lake Woterup



Lake Yelwell



Lake Yerang


Age
Recent
Less than 30 days
More than 30 days
Old
Lake Yerang
Severity
Superficial
Moderate
Severe
Wallow
Lake Yerang
Extent (sq.m per km)
0 - 17
18 - 66
67 - 160
161 - 375
376 - 836
Lake Yerang
Roads
Watercourse
Parks Reserves
N
0 100 200 400 600 Metres
HATTAH - KULKYNE
NATIONAL PARK
Lake Bitterang
Lake Kenardin
Lake Yelwell
Lake Yerang
Lake Cantala
Lake Lockie
Lake Roonki
Chalka
Creek
Lake Arawak
Brockie
HATTAH
ROBINVALE
L Kramen
STATE FOREST