Scoping Survey of arrowhead (*Sagittaria platyphylla*) invasion in the Barmah Ramsar Wetland

May 2012 surveys

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Cover image: Arrowhead infestation between War Creek and Cutting Creek (Maxwell 22/05/2012).

Executive Summary

This report adds to the data collected from surveys conducted in 2006, 2008 and 2010, and aims to quantify the changes in infestation levels of *Sagittaria platyphylla* (common name 'arrowhead') and to discuss potential issues (real or perceived) confronting the control process.

The 2012 surveys were conducted during May, and resultant data will be used in developing a management or control program for *S. platyphylla* in the Barmah Ramsar wetlands.

Surveys were conducted of all known infestation sites and new areas considered to be at risk. GPS coordinates recorded of all findings with data classified by total area covered, density and ease of access.

Over the four survey years covered the changes in area and number of infestation changed significantly due to the prevailing environmental conditions, but the spread is continuing into new areas and expanding at existing sites with one site in excess of 3 hectares of dense growth. Control is urgently required before more of the at risk areas are infected.

Contents

List of photographs

Introduction

This report adds to the data collected from surveys conducted in 2006, 2008 and 2010. It is by no means definitive and is intended as an initial discussion paper based on current observations. This survey of the Barmah Ramsar Wetlands, *excludes the Millewa Forests covered in the 2006 and 2008 surveys*, and aims to quantify the changes in infestation levels of *Sagittaria platyphylla* (common name 'arrowhead') and to discuss potential issues (real or perceived) confronting the control process. Control options remain as discussed in 2006 ([1]Maxwell 2006).
The plant referred to in 2006 and 2008 as *Sagittaria graminae was the subspecies platyphlla (NSW, DPI) and* reference will now only be made to *S. platyphylla*.

The 2012 surveys were conducted during May, but due to recent floods and the resultant high water level in many areas, development of the weed may not have as advanced as expected for this time of the year. In effect this means that areas not showing plants where past infestations occurred may still have viable seeds or plant material that can develop under more favourable conditions. It was also impossible to reach a few of the sites of previous inspections due to the high water levels and recent strong growth of *Juncus ingens*.(Giant Rush). Consequently the failure to find *S. platyphylla* cannot be extrapolated to infer the control or removal of the weed from particular locations. Despite not finding *S. platyphylla* in some previously identified areas, the overall result shows the survival and expansion of infestations in most areas and spread into some new areas. The War Creek-Cutting Creek area identified in 2002 as having *S. platyphylla* continues to spread at an alarming rate and is an indication of the risk to the forest if *S. platyphylla* spreads to remaining wetlands in the reserve.

Project Aims

This project aims to quantify the changes in infestation levels of *Sagittaria platyphylla* and to provide data on which to base control strategies of Sagittaria in the Barmah Ramsar Wetland .

Project Background

This report adds to the data collected from surveys conducted in 2006, 2008 and 2010. (Maxwell 2006, 2008, 2010)

Project Objectives

This project aims to:

- Identify the location of *S. platyphylla* plants through the Barmah Ramsar wetlands.
- Discuss the change in distribution pattern from 2006 (first year monitored) to 2012.(Current)
- Record the level of difficulty of accessing each point for control purposes.

Method

The complex nature of the forest terrain, the relatively short available time and the funding limitations of this study precluded checking every drainage line, potential wet/swampy area in the forest or areas inundated by recent floods that may have Sagittaria present. Therefore, a structured approach was taken to get data from a range of sites considered to be suitable for *S. platyphylla* growth as well as actual infestation data from previously visited sites.

Surveying of the Barmah wetlands was conducted during May 2012 when opportunity of improved forest access arose following recession of prior prolonged flooding in the forests. The survey results from 2006, 2008 and 2010 were loaded into a GPS unit so that sites with previous infestations could be revisited and assessed. Access within the forest is generally difficult so all sites were inspected on foot and all previously infested sites were visited *if they could safely be reached.* More extensive surveys were conducted of these areas to record the degree of infestation change. Further exploration was conducted on areas where conditions were considered likely to have been favourable but where there had been no previous reports.

Area of infestation in most cases is a calculated area based on estimated or paced out length and width of each patch of weed. The exception was the two main infestations where the perimeter was walked and the area calculated on the computer.

This procedure does not provide definitive results because the observed presence or absence of the species at any particular location is affected by many variables including:

- the accuracy of the coordinates given for an infected site
- time since last watering
- depth of water and length of inundation at the location
- impact of animals
- density of competing vegetation
- seasonal variations including temperature and frost events.

The procedure does provide identification and the current status of locations that have, or have had, infestations and sites that have never had observed plants. This survey records changes in the area of *S. platyphylla* at these sites, but it also leaves un-surveyed area as a questionable area. This is highlighted by the identification of isolated *S. platyphylla* plants through the forest away from swamps. The main advantage of this survey method is the identification of the most 'at risk' environmental conditions and the recording of the patterns of spread at identified sites, but this report makes only a limited attempt to qualify the reason for any changes.

Definitions

Density

Dense infestation	Thick growth	80–100% ground cover
Medium infestation	Variable cover	40–80% ground cover
Sparse infestation	Scattered cover	10–40% ground cover
Scattered infestation	Scattered plants	<10% ground cover
Undefined	Density not recorded	

Access

Easiest access	Accessible by vehicle
Moderate access	Almost accessible by vehicle last distance on foot
Difficult access	No vehicular access without vegetation clearing
Very difficult access	No vehicular access
Almost impossible	Difficult even for foot access
Impossible to check	Access impossible
Undefined	not recorded

Site

A site is the centre of a group of plants which may include one continuous clump or a group of smaller clumps over a 10–20 m radius.

Results & Discussion

The following results are for the Barmah Ramsar site only.

Density of infestation

Table 1. Density of *S. platyphylla* infestation in the Barmah Ramsar Wetland, 2006–2012.

Density of *S. platyphylla* growth	Square meters of wetland surveyed per year (number of sites)							
	2006		2008		2010		2012	
Dense	9,627	(58)	1,295	(17)	8,795	(62)	43,802	(237)
Medium	35,545	(97)	347	(33)	4,336	(84)	4,816	(138)
Sparse	1,956	(39)	2,182	(37)	2,547	(40)	1,694	(102)
Scattered	-	-	3,740	(54)	3,015	(42)	4,178	(26)
Undefined	658	(24)	16	(4)	-	-	-	-
Total area with *S. platyphylla*	**47,789**	**(218)**	**7,580**	**(145)**	**18,694**	**(227)**	**54,491**	**(504)**

Size of infestation patches

Table 2. Size of *S. platyphylla* patches in the Barmah Ramsar Wetland, 2006–2012.

Size of infestation (sq m)	Number of sites surveyed per survey year			
	2006	2008	2010	2012
<2	29	33	45	85
2–5	37	16	50	85
6–10	27	29	21	88
11–20	25	15	24	72
21–50	42	17	39	86
50–100	18	16	11	50
101–200	10	7	16	15
201–500	9	7	11	18
501–1000	1	3	8	2
1000–3000	1	2	2	2
3000+	1	0	0	1
	218	**145**	**227**	**504**

Accessibility of monitoring sites

Table 3. Accessibility to monitoring sites, 2006–2012.

Level of accessibility	Square meters of wetland surveyed per year (number of sites)							
	2006		2008		2010		2012	
Easiest	5,237	(68)	6,356	(77)	4,622	(93)	3,780	(65)
Moderate	184	(26)	1,924	(25)	1,286	(38)	3,250	(92)
Difficult	5,374	(102)	1,086	(27)	1,519	(37)	1,196	(24)
Very difficult	22,482	(15)	18	(10)	11,266	(59)	46,265	(322)
Impossible to check	0	(0)	-	-	-	-	-	(4)
Undefined	460	(5)	0	(16)	-	-	-	(1)
Total		**(216)**		**(155)**		**(227)**		**(508)**

Labour input for survey

The time spent surveying these sites was two weeks for field work with a further 2 weeks for map production and data analysis.

Site specific information

Table 4 lists the specific sites surveyed. The following notes and photographs describe changes and observations at these specific locations as described in the maps in Appendix 1.
The area described as War Creek/Plains in previous reports has been broken down into smaller areas as indicated on the map 6 in Appendix 1 because this area has shown the most significant changes, and has the greatest area of *S. platyphylla* in the forest. Data from previous surveys was recalculated to allow these smaller areas to be discussed in more detail.

Table 4. Number of survey sites and area of infestation at specific locations 2006–2012.

Site		2006	2008	2010	2012
Island Creek	Sites	2	8	14	30
	Area (Sq m)	91	1,324	116	1,683
Sapling Creek	Sites	13	2	6	17
	Area (Sq m)	402	295	803	2,618
Boals Creek	Sites	29	13	24	21
	Area (Sq m)	613	462	1,077	290
Tongalong/Black Engine Creeks	Sites	20	5	11	0
	Area (Sq m)	715	19	59	0
Barmah Creek	Sites	16	5	11	0
	Area (Sq m)	2,296	1,137	1,781	0
Gulf Creek	Sites	1	1	7	0
	Area (Sq m)	4	1	38	0
Budgee Creek	Sites	14	26	24	26
	Area (Sq m)	64	662	1,003	198
Punt Paddock Lagoon	Sites	4	0	2	2
	Area (Sq m)	442	0	<1	89
Barmah Lake (south / North)	Sites	0	5 / 4	Inaccessible	0
	Area (Sq m)	0	14 / 3		0
War Creek/Plain	Sites	45	22	62	38
	Area (Sq m)	3,553	594	4,731	1,460
Cutting Swamp East	Sites	3	2	20	114
	Area (Sq m)	231	60	5,573	3,064
Cutting Swamp North West	Sites	12	0	16	156
	Area (Sq m)	36,751	0	3,172	42,712
Cutting Creek	Sites	21	2	9	39
	Area (Sq m)	1,219	900	1,218	400
Bunnydigger Creek	Sites	1	15	7	15
	Area (Sq m)	4	575	20	89
Big Woodcutters Creek	Sites	2	0	1	50
	Area (Sq m)	56	0	24	1,722

Tongalong/Black Engine Creek Photos 1–4

The recent floods appear to have drowned all vegetation apart from some very tall Red Gum saplings which have been bent over by the fast current. There was no evidence of *S. platyphylla* even in the surrounding area, as depicted in photos 6 and 7 taken at Tongalong creek. Similar impacts of flooding were evident at Barmah and Tullah Creeks,

Photo 1 - Black Engine Creek 2008

Photo 2 - Black Engine Creek 2010

Photo 3 - Tongalong Creek 2012

Photo 4 - Tongalong Creek 2012

Boals Creek Photos 5–6

In 2012 Boals Creek has a few less infestation sites and significantly reduced infestation area most likely as a result of the recent floods, and Photo 6 shows either that the plant survives extreme conditions or it could be a new (late season) growth after the floods. Water depth and rush growth limited the area able to be surveyed downstream.

Photo 5 – Boals Creek 2010

Photo 6 – Boals Creek 2012

Sapling Creek (between Budgee and Island creeks) Photos 7–10

There has been a significant increase in both the number and area of sites infested at Sapling Creek. Floods do not appear to have had the reducing/tempering impact, as recently flooded sites have dense infestations choking the whole system. As with so many sites, the impact of feral pigs can be seen in the wallows and tracks visible in Photo 9.

Photo 7 – Sapling Creek 2008

Photo 8 – Sapling Creek 2010

Photo 9 – Sapling Creek 2012 Photo 10 – Sapling Creek 2012

Island Creek Photos 11–14

In 2008 this area of the creek was drying out but the full length of the damp bed was sprouting a sparse to medium density of new plants that appeared to be growing from seed (Photo 11). A higher water level in 2010 meant we could not determine the status of these plants but there was still an increase in the number of recorded sites along the edges that indicated the plants were still well established. 2012 has proved this belief with a doubling of sites from 2010 and a greater area covered than in 2008.

Photo 11 – Island Creek 2008 Photo 12 – Island Creek 2010

Photo 13 – Island Creek 2012 Photo 14 – Island Creek 2012

Budgee Creek Photos 15–18

This area continues to have infestations along much of the water course. Total number of sites has stayed about the same but the plant area has reduced significantly. The location of plants has changed, indicating both a spread but also a removal from some sites. The impact of the recent floods is evident in Photo 18.

Photo 15 –Budgee Creek 2008

Photo 16 - Budgee Creek 2010

Photo 17 – North end, Budgee Creek 2012

Photo 18 – South end, Budgee Creek 2012

Swamp north of War Plain Track Photos 19–20

This swamp had *S. platyphylla* in 2010 but there was no evidence of the plant in 2012, despite the environment appearing to be unchanged and favourable for the weeds growth (photos 19 & 20).

Photo 19 – North of War Plain Track 2012

Photo 20 – North of War Plain Track 2012

Cutting Swamp North West Photos 21–28

This site shows the most dramatic change. In 2006 the area was a quagmire of pig routed, dense arrowhead for over 700 sq m as shown in Photo 21. In 2008 no *S. platyphylla* was found due to the extremely dry conditions shown in Photo 22, taken in the same area.
In 2010 the conditions reverted to extensive watering and the Giant Rush and other vegetation has established over much of the area affected in 2006. Despite this competition, *S. platyphylla* was prolific in most gaps between the rushes (Photo 23) and had extended its range significantly around the wetland and extending well under the tree canopy as evident in Photo 24, taken in the same area. This area now consists of one continuous patch covering 30,780 sq m (Photo 25). Of greater concern is the area immediately west in another low lying area that has in excess of 175 identified patches evenly spread over an area of 100,000 sq m. The actual *S. platyphylla* plant cover in this new area is 45,700 sq m (Photos 26–28).

Photo 21 – Cutting Swamp NW 2006

Photo 22 - Cutting Swamp NW 2008

Cutting Swamp North West (continued)

Photo 23 – Cutting Swamp NW 2010

Photo 24 - Cutting Swamp NW 2010

Photo 25– Cutting Swamp NW 2012

Photo 26 - Cutting Swamp NW 2012

Photo 27– Cutting Swamp NW 2012

Photo 28 - Cutting Swamp NW 2012

Cutting Creek Photos 29 & 30

S. platyphylla was again found in all previously identified locations along the creek and in a large number of new locations. The overall area of infestations was reduced, but this indicated an active spread despite less favourable conditions caused by the high water levels that have impacted other areas. As with other areas the spread is away from the main creek where the water depth would likely be more favourable.

Photo 29 – Cutting Creek 2010

Photo 30 – Cutting Creek 2012

Barmah Creek Photos 31–33

This site had no *S. platyphylla* visible. The creek has been inundated with a deep cover of fast flowing water for an extended time and all growth appears to have died. If *S. platyphylla* has survived will be unknown until vegetation re-grows in the creek.

Photo 31 - Barmah Creek 2008

Photo 32 - Barmah Creek 2010

Photo 33 - Barmah Creek 2012

Barmah Lake Photos 34 & 35

Barmah Lake shows a dramatic change since 2010. The Giant Rush appears to have been drowned and the five sites in the main body of the lake have no sign of *S. platyphylla*. The five locations at the top of the lake were inaccessible at the time of the survey in May 2012 due to the strong growth of J. ingens at the lower end of Cutting Creek and the deep mud if approaching from the south.

Photo 34 – Barmah Lake 2010

Photo 35 – Barmah Lake 2012

Isolated plants Photos 36–37

Isolated plants were found in a number of locations well away from the expected habitat. This is of concern because it is impossible to check every location in the forest. Photos 36 and 37 show single plants found at different sites in the Cutting creek area and located more by chance than intention, and even with a detailed grid search of the area many plants could be missed because of their immature growth stage. The finding of these plants suggests the recent floods have spread viable seed widely through the forest.

Photo 36 – Isolated plants, Cutting Creek 2012

Photo 37 – Isolated plants, Cutting Creek 2012

Surviving competition Photos 38–39

These photos were taken in the lagoon at the top end of Big Woodcutter Creek, on the edge of the Murray River. Since 2010 the Giant Rush has expanded but the Sagittaria still survives in its original location. Photo 39 is a close up of the centre of Photo 38 and shows plants surviving despite competition from the *J. ingens* . These plants are at the GPS location recorded in 2010

Photo 38 – *S. platyphylla* and Giant Rush 2012

Photo 39 – *S. platyphylla* and Giant Rush 2012

Control Options

Control options include Biological, chemical or physical methods with some of the suggestions obtained through personal communications listed below as a guide for future discussions.

Impact of "Doing nothing"

A control site of *S. platyphylla* covering 150 sq meters was identified in 2002/03 on the Murray River mid way between Echuca and Torumbarry. With no treatment this site grew to cover 600 sq meters in four years. Also in the Murray River treated sections over these four years there was an increase in the number of infestations, despite the spray treatment, (Personal communication) and this occurred in an environment considered less favourable than the shallow wetlands of the Barmah- Millewa and Gunbower Forests. The recorded expansion over the four surveys of the Barmah wetlands from 2006 to the current year further highlight the potential for rapid growth and the potential ecological threat posed by this invasive aquatic menace.

Desiccation/Flooding

Anecdotal evidence/observations has indicated that prolonged drying of the weed can kill or significantly affect its survival. Also *S. platyphylla* cannot establish in deep water so if the water levels were managed to take advantage of these concepts new seeding/growth would be drowned before establishment, then desiccated during the hot summer or if exposed in the winter affected by seasonal frosts.
This is a difficult control option given the current irrigation water management where water is transferred at high levels during Summer, and winter flows are lower due to water storage for irrigation, reversing the pre-settlement high winter – low summer flow of water through the forests.

Spraying

These options are as suggested to the author. All chemical use would need the appropriate risk analysis and approvals to protect native and non target flora and fauna.

Aqualin (Acrolein) is the chemical of choice but has limitations (as highlighted below in GM-W experience) of being less effective in deeply submerged weeds or where significant recreational boating occurs as is the case along the Murray River where many of the infestations appear to originate. Access to many areas within the forest is restricted and would need ATV's, back-pack units and spray units with hoses up to 200 meters long. Spraying along the major waterways can be done from a boat and two men can cover about 30 Km of frontage in a day. (GMW experience)

Residual chemicals

A more (cost) effective spray program for the small isolated sites (3/4 of sites being less than 50 sq meters) could be the use of a residual chemical like 'Casoron' (dichlobenil). This is a granular chemical that is reputably non-mobile through the environment profile, has a very effective kill rate and would potentially be easier to spread in isolated sites and require one visit per year rather than three. Chemical cost would be significantly higher, but would be offset by lower labour costs. This type of control may have more impact on the non target species. (refer to GM-W experience) and would require detailed evaluation before implementation.

Biological control

Biological control is considered by many to hold the greatest opportunity for long-term control / eradication. The process for trialing and releasing biological control agents is however long and arduous and until the profile status of the weed is raised it is not going to provide a control option in the short term. Given arrowheads potential rate of spread, the existence of two native related species from the same

genus and the normal time frame to find a control agent and to get permission for its release this option has to be considered a long term objective.

GM-W experience

GM-W has been spraying arrowhead in irrigation channels for at least 20 years but in the four years from 2002 to 2006 has had a more documented spray program in the Murray River between Echuca and Torrumbarry. The following comments are based on the observations and notes of the project manager and relate to control in the river system more than control in the Barmah wetlands. (Personal communication)

It 1996 there were 215 recorded sites with Arrowhead along the Echuca to Torrumbarry reach. At the start of 2003 there were 613 recorded sites with a calculated area of 33,000 Sq meters. Despite three spray applications this increased to 653 sites by the end of the year and at May 2006 there are 976 recorded sites covering 3000 sq Meters (88% reduction).

Based on these figures and the fact that some sites have been eradicated completely it is believed control is possible if there are appropriate changes to the river management combined with an intensive spray program.

The windows of opportunity for a three spray application program based on temperature and water levels are December, February and May. Water level is also a significant control issue. Where arrowhead is permanently below the water level, spraying is not as effective. Lowering the water level by as little as 50 cm to allow spraying may give significant improvement in kill rates through better spraying and would also reduce the impact of recreational water users. Currently skiers and wake-boarders are very active on the river during these months and the bow waves often wash the chemical off the weed before there is a chance of uptake. Lower water levels would increase the sprayable weed area and increase the efficacy.

Other Observations

S. platyphylla is frost sensitive and is seen to be significantly affected in the open irrigation channels and exposed areas in the forests. This sensitivity is negated by forest canopy and rushes in some areas of the Barmah Forest.

S. platyphylla appears to establish where water is maintained at a constant level in a slow flow area for significant periods of time and where water is held-up at an ideal flooding depth (0 – 300mm), during the warm summer months eg. at forest regulators along the Murray River.

Spread of the weed is by seed, rhizome and cutting and is potentially aided by the feeding habits of a range of fauna. European carp in waterways uproot the weed allowing cuttings and rhizomes to float downstream. The foliage, seed heads and corms are a food resource favored at different times by feral horses, emu's, waterbirds (ie.ducks and swans) and feral pigs. Feral pigs also cause extensive damage to the ground when rooting up the rhizomes. These feeding patterns appear to spread seed and cuttings through the drainage lines. The foraging habits of the introduced / feral livestock and native fauna is a two edged sword. Firstly it suppresses the growth and may reduce the development of seed-heads (observation from Barmah Forest) which may decrease the rate of spread, but this can be offset by the distribution of cuttings created by the feeding habits. These large hard hoofed herbivores (cattle, horses and pigs) also appear to promote the spread through their selective grazing habits preferentially feeding on Moira grass, sedges, reeds and rushes which would otherwise proliferate in the 0 to 300mm flooding zone. Hard hoofed stock also contribute to the spread of the weed by severely pugging the shallow margins of wetlands and waterways and through the creation of tracks through wetland vegetation as these tracks are more often infested and provide an opening in the niche which would normally be occupied by a dense sword of rushes, reeds, sedges / Moira grass.

Conclusions

The overall perception from these current surveys is that the *S. platyphylla* is likely to exist or have viable seed at every site identified in 2006, 2008 or 2010, with a few minor exceptions (e.g. where *J. ingens* has increased in density). Furthermore, the seed is likely to have spread into the wider forest area. This belief is based on several findings of single developing plants in totally unexpected locations as I walked from one low area to another. These were random and very lucky findings where as little as one leaf was initially visible in the dense vegetation (Photos 36 and 37). The 2012 survey also identified a number of locations where *S. platyphylla* survives despite competition from the rushes. Photo 39 is a close up of Photo 38.

The floods over the past two years have had an impact on the *S. platyphylla* but the impact has not been consistent across the forest.

Smaller but persistent infestations remain along the banks of the Murray River, providing an ongoing source of re-infesting the watercourses flowing into the forest. These creeks and watercourses remain a concern with Island, Sapling and Boals creeks maintaining significant and increasing populations of *S. platyphylla*. Big Woodcutters Creek has recorded *S. platyphylla* at the regulator where it leaves the Murray River over past surveys, but in 2012 there are extensive infestations extending over two kilometers along the creek that have not been recorded before.
These creeks highlight the risk of the plant establishing through the waterways that feed into the wider wetlands, and the need to continue control programs in the Murray River.

In comparison, the high water levels appear to have drowned most of the vegetation in Tongalong, Gulf, Barmah and the lower Budgee creeks as well as in the main Barmah Lake body, and no *S. platyphylla* was found at these locations. But as there is no growth of any other plants the question remains whether *S. platyphylla* will also regenerate when other plants do, or will *S. platyphylla* potentially gain a strong competitive advantage if it were to re-sprout before the other species in the bare substrate..

War Creek and Cutting Creek continue to have persistent but changing infestations but not to the degree of change found in the wetlands between these creeks (that I have called Cutting Swamp for lack of an existing name). These creek systems, I believe, show that the past high and/or persistent water has removed *S. platyphylla* from some sites but the tenacity of the plant has allowed it to establish at other sites

The greatest concern continues to be the areas around the Cutting Swamp region where *S. platyphylla* was initially identified in 2002 by Doug Frood (Frood 2005) but where extensive infestations have subsequently been mapped in 2006 and 2010 (Maxwell 2006, 2010). The Year 2006 was wet in the Cutting Swamp region when *S. platyphylla* established and presumably set seed over a large area. By contrast 2008 was dry when surveyed, being amidst drought years, with *S. platyphylla* not found in many areas although the area showed a big increase in the dominance / invasion by *J. ingens*. Repeat surveys in 2010 found an increase of *S. platyphylla* again over the 2008 survey records but not back to the same levels of the 2006 survey record levels. Unfortunately the most recent surveys in 2012 has shown large increases area of *S. platyphylla*.at Cutting Swamp To more clearly display, and discuss, the pattern of change in this area the data has been broken down for 2012 and previous years as shown in Map 1. The names of these sub-areas were my choice as I can find no detailed naming structure for this level of analysis.

My concern expressed in 2010 (Maxwell 2010) that this whole “Cutting Swamp” area could contain viable seeds appears to have been well-founded with the “Cutting Swamp North West” area in 2010 showing an increase in the infestation boundaries since 2006 and 2008, extending further into the tree line. This trend was continued in 2012, with one solid infestation of *S. platyphylla* over 30,000 square meters, and the neighboring 100,000 square meter area to the west of the initial infestation having distributed, but close-clumps of over 45,000 square meters of *S. platyphylla*, as well as the isolated plants through the wider forest. (These areas were calculated by walking and mapping the perimeter of the areas affected).

The prevailing water depth in much of this area appears to be ideal for a rapid expansion and potential joining of many of these sites as can be seen in photos 26 and 28.

Map 6 shows the Cutting Swamp area broken down even further and my ranking of the risk associated with different areas.

Area A is already mostly a solid expanse of weed, where Area B has extensive inundation of 10–20 cm of water and significant area of mud, as does Area C. These areas have extensive smaller (2 – 50 Sq m) clumps that have the potential to expand to join into a similar continuous patch as Area A and hence are the highest risk areas.
Area D is a narrower strip restricted on the east by *J. ingens* and Area F on the west. Area F is slightly higher and drier than areas B and D and therefore not quite as favorable a location for *S. platyphylla*.

Area E (The Cutting Swamp East) shows a continuing spread south east along the outside of the *J. ingens* beds, with an increase in the frequency of sites but not area. It has a wide distribution of smaller sites but the spread will likely be hampered by competition from existing beds of *J. ingens* on the south side, and by less favorable dry forest to the north. There is still potential for the *S. platyphylla* to spread further south east as has been the trend over the past two years, so I consider the risk of expansion to be moderate to high.

Area G is again a site restricted on the north by *J. ingens* and drier ground on the south, so although the *S. platyphylla* will continue to encroach there is a more limited area for expansion.

In 2010 I expressed concern for further expansion of *S. platyphylla* on the wetland to the north of War Plains track, displayed as Area "H" on Map 6, with several sites located as mapped. This year *S. platyphylla* was not found at any of those sites yet the conditions were similar to 2010 (Photos 19 and 20) with 10–20 cm water and minimal competition from *J. ingens* as several GPS points were well clear of *J. ingens* growth. The intervening flood regime may therefore have been too deep to have promoted *S. platyphylla* when surveyed in 2012.

Overall, the growth on the north edge of the main cutting swamp area is restricted from spreading south by the *J. ingens*, effectively stopping it from spreading into the wetter areas, yet competition remains strong for the areas between the clumps of Giant *J. ingens* and into the less dense stands of *J. ingens*. The spread continues north under the trees and as shown in 2008, there may be no sign of the plant if the season is dry but viable seed/ plants remain to grow when the seasons change. The area I have calculated as being favourable and at risk of infestation by *S. platyphylla* in the short term in the Cutting Swamp area is over 300,000 square meters - **not** including the creeks.

The difficulty of access to the whole Cutting Swamp area for control purposes remains a major concern.

Comment must also be made of the extensive impact made by feral pigs, which is far more significant than any prior year, and has the potential to assist the spread of the weed. Evidence of the pig damage can be seen in many of the photos that will accompany the digital copy of this report

Recommendations

Control programs need to be continued in the Murray River and at regulators at the entrance of drainage lines into the forest, as well as targeted control within the forest implemented as soon as possible because of the demonstrated survival and aggressive spread of *S. platyphylla* .

Priority should be given to control in the Cutting Swamp area because of the current establishment of *S. platyphylla,* the potential for increased spread into more inaccessible areas and the more limited accessibility resulting from inundation levels.
Drainage lines into the forest from the Murray River east of Picnic Point will be more readily accessible at other times through the year but need to be controlled to stop re-infestation.

Complimentary management of the river levels and forest flooding need to be considered as the current 'Low Winter - High Summer' flows appear to be favourable to the survival and spread of *S. platyphylla.*

Future monitoring on a yearly basis for the cutting swamp region would be advantageous as it would allow more data to be collected that would allow correlations to be investigated between seasonal variations and plant spread (i.e. improve habitat profiling). The areas like Tongalong, Tullah and Gulf creeks could be surveyed bi-annually as they do not pose as significant an immediate threat to the wetlands.

The management and control program should be a joint Barmah – Milllewa project to minimise cross border re-infestations.

A research project to investigate the viability of the seeds in the forest environment would be advantageous given the recent inundations have likely distributed seed through much of the forest, including the normally dry areas. These potential seed beds will pose a threat for an indeterminate time, and information on viability would help future control planning.

References

Frood, D.(2001). Mapping of the understorey vegetation in Barmah Forest, Victoria. Project report for Barmah Millewa Forum. 102pp. Pathways Experiences Pty Ltd.

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Maxwell, R., (2008). Scoping Survey of the Barmah and Millewa Forests to identify the extent of invasion of Arrowhead. Surveys conducted February-April 2008. Department of Primary Industries, Tatura. 22pp.

Maxwell, R., (2010). Scoping Survey of the Barmah Ramsar Wetland to identify the extent of invasion of Arrowhead (Sagittaria platyphylla). Surveys conducted February-April 2010. Department of Primary Industries, Tatura. 21pp,

NSW, DPI (2012). New South Wales Department of Primary Industries pest and weed management species identification.

Appendices

Appendix 1

Map 1 Names used in “Cutting Swamp” analysis

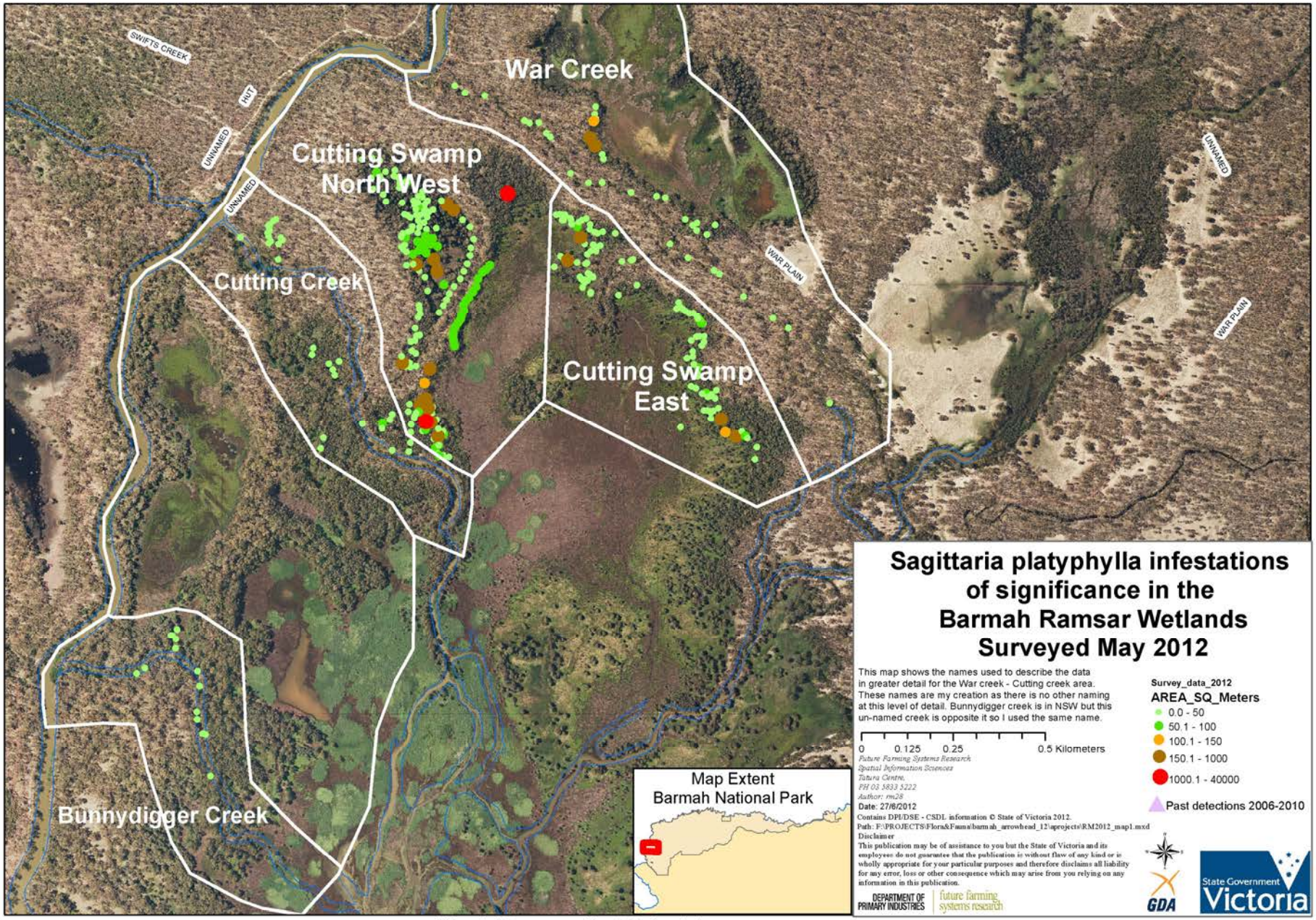
Map 2 Major sites inspected

Map 3 Comparison of past inspection sites to current survey data

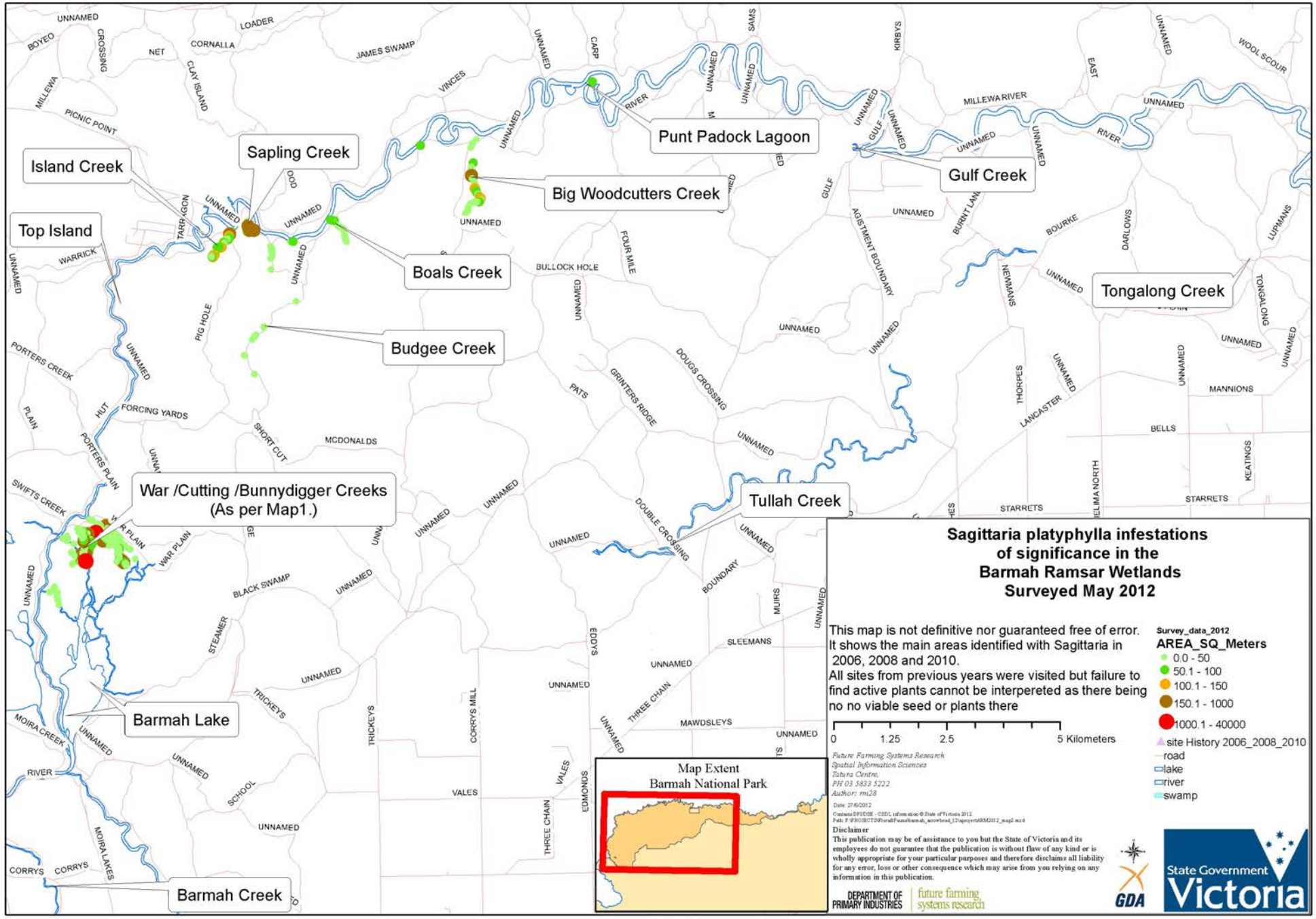
Map 4 Comparison of past inspection sites to current sites in the Cutting Creek / War Creek area

Map 5 Infestation densities in the Cutting Creek / War Creek area

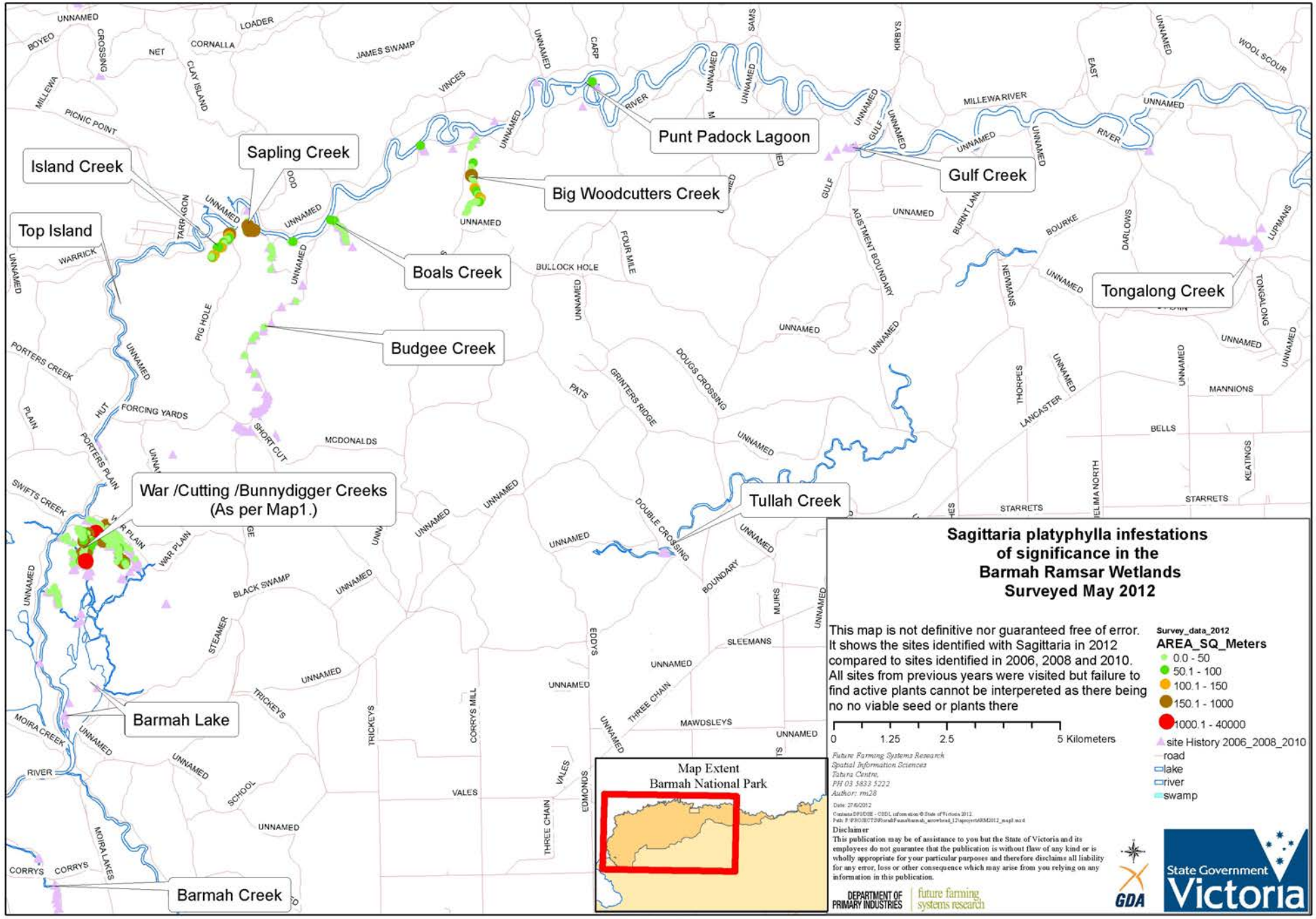
Map 6 Cutting Swamp details



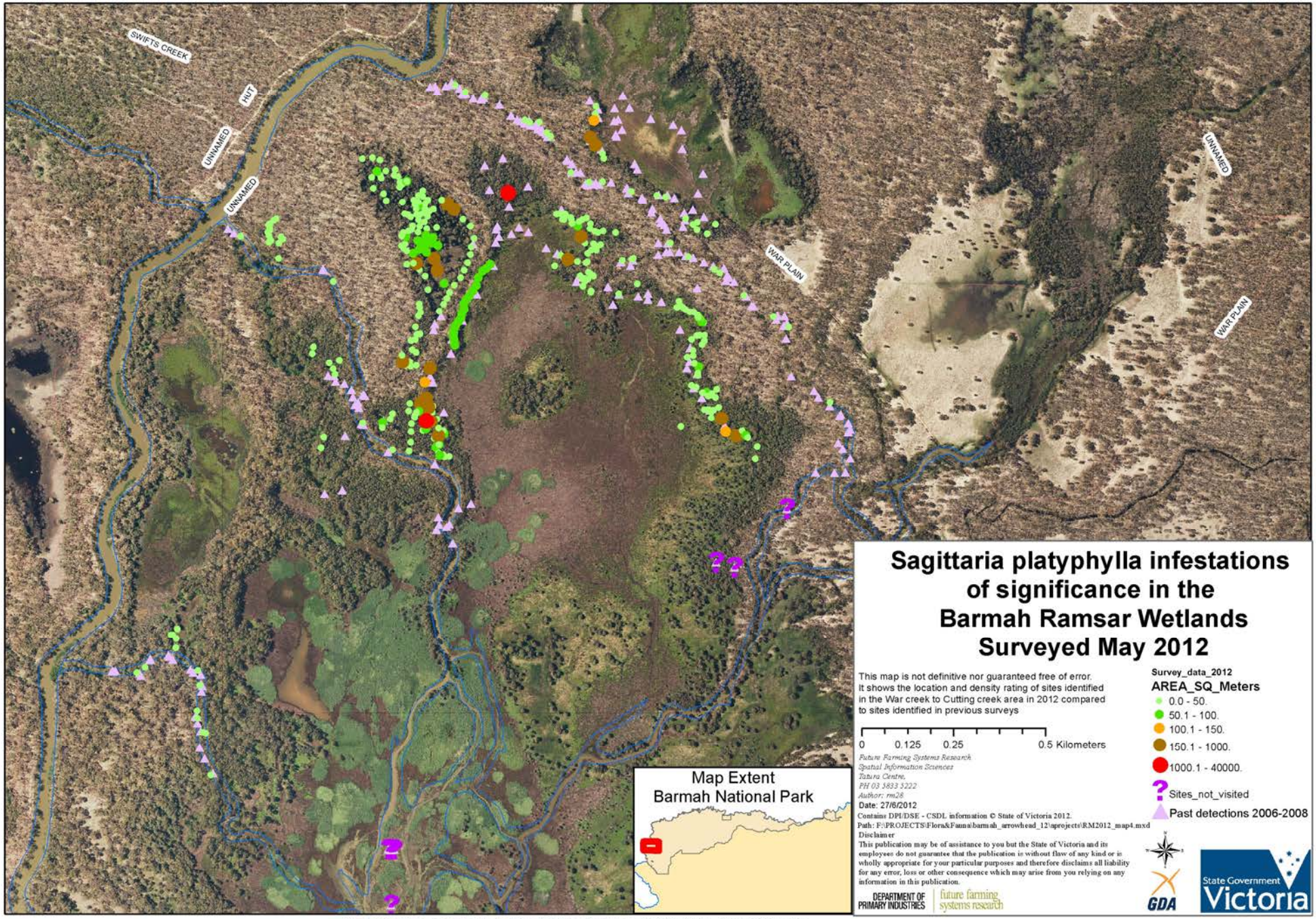
Map 1 : Names used in Data Analysis



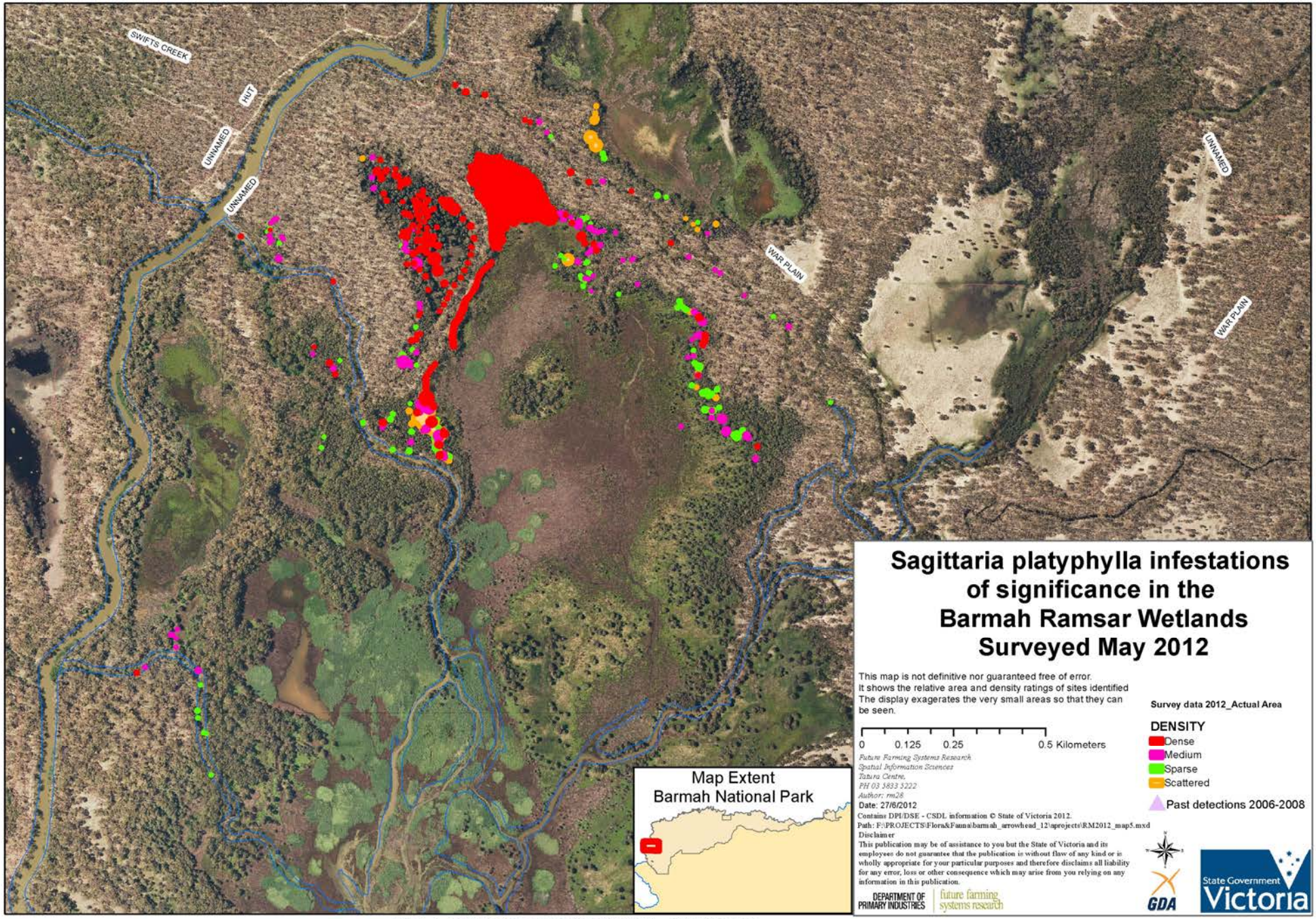
Map 2 : Major Sies Inspected



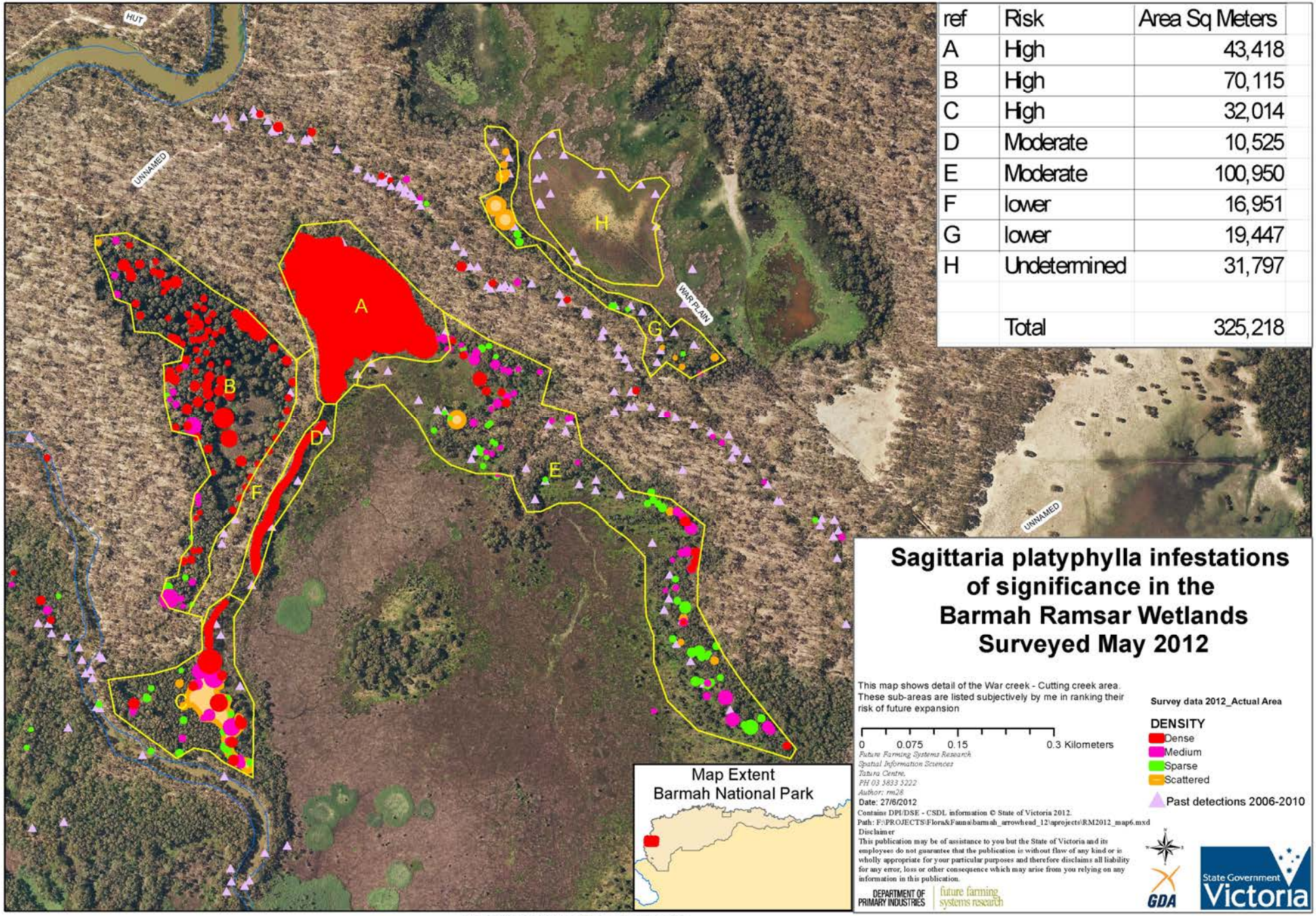
Map 3 : Comparison to past Infestations



Map 4 : Comparison to past Infestations at Cutting - War Creeks



Map 5 : Infestation densities Cutting - War Creeks



ref	Risk	Area Sq Meters
A	High	43,418
B	High	70,115
C	High	32,014
D	Moderate	10,525
E	Moderate	100,950
F	lower	16,951
G	lower	19,447
H	Undetermined	31,797
	Total	325,218

Map 6 : Cutting Swamp Details