Occurrence of freshwater macrophytes in the catchments of the Parramatta River, Lane Cove River and Middle Harbour Creek, 2007 – 2008

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ACKNOWLEDGEMENTS

This study is one part of a series of activities by NSW DPI in conjunction with the Sydney Metropolitan Catchment Management Authority (SMCMA) and NSW Maritime. In the first phase, NSW Maritime invited DPI to update distribution maps of estuarine macrophytes of Parramatta River/Sydney Harbour (West *et al*. 2004), an exercise funded through the Sydney Harbour Catchment Management Board by the Federal government. A second phase, incorporating data from the first phase, was also funded through the SMCMA from Federal government monies. Phase two involved three projects in the estuarine portion of the Parramatta River: the distribution of saltmarsh around the estuarine foreshore (Kelleway *et al*. 2007, Williams *et al*. in press), the historical distribution and likely future distribution of seagrass around the estuary (West and Williams 2008), and the extent of terrestrial vegetation along the foreshore (Allen *et al*. 2008). This, the third phase, was again underwritten by the SMCMA from Federal government funding and deals with the freshwater vegetation of the catchment.

Lesley Diver of the SMCMA provided oversight of the project. John Martyn of STEP Inc. arranged access to digital map data of the Lane Cove River and Middle Harbour Creek. Andrew Petroeschevsky, Australian National Aquatic Weeds Coordinator, advised on the status of aquatic weeds. Greg West assisted with the design of the project, and Tony Fowler, Andrew Boomer, Ben Kearney, Michael Rodgers and Brooke McCartin assisted in the field. Tracey McVea very patiently assisted with corrections arising during proof reading.

NON-TECHNICAL SUMMARY

Occurrence of freshwater macrophytes in the catchments of the Parramatta River, Lane Cove River and Middle Harbour Creek, 2007 – 2008

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OBJECTIVES:

(a) Create a methodology by which to assess the extent and type of freshwater macrophytic vegetation in the coastal rivers of NSW;
(b) Conduct an assessment of the macrophytic vegetation of the freshwater portion of the Parramatta River of 2007;
(c) Create ArcView shapefiles and associated data tables to indicate the area of cover;
(d) Provide a report to the Sydney Metropolitan Catchment Management Authority.

NON TECHNICAL SUMMARY:

The distribution of the freshwater macrophytes of NSW has been little studied, and an acceptable methodology by which to undertake such a task has not been devised. This project adapted techniques used to determine the cover of estuarine vegetation for the purpose of assessing cover of freshwater vegetation. The locations of interest were the three main tributaries of the Parramatta River: Middle Harbour Creek, the Lane Cove River, and the upstream portion of the Parramatta River. Auxiliary tributaries of these main components were also assessed.

Observations were made at 386 sites. Freshwater aquatic vegetation was present at 175 sites and was categorised as 'submerged', 'emergent', or 'floating', and differentiated as native or exotic species. The underlying substrata was recorded at all sites, as was flow and turbidity. To provide an indication of the extent of the complexity of the drainage system, as well as indicate the extent of fieldwork, inspection sites are shown in a series of maps.

Initiation of the project was hampered by a lack of accuracy in maps; more specifically, many small tributaries were not shown on the standard digital map of streams for the Sydney metropolitan area. For example, the standard digital map showed 17 tributaries entering Middle Harbour Creek, but examination of other maps and field inspection revealed 47 small creeks flowing into this major tributary. Similar situations prevailed for the Lane Cove River and to a smaller extent the Upper Parramatta River. It was therefore necessary to initiate the project by creating an accurate stream network. This new network will be of use in monitoring the distribution of native and introduced species, and in weed eradication projects. While the presence of aquatic weeds was surprisingly low compared to the Hawkesbury River (the only other location in NSW coastal catchment for which aquatic vegetation has been surveyed), steps should be taken to contain or eradicate these weeds before their distribution increases.

1. INTRODUCTION

Since the arrival of the First Fleet, extensive portions of the banks of the Parramatta River have been cleared of vegetation. In some cases this has enhanced the movement of sediments into the river and/or increased nutrient levels. Unfortunately, sediment deposition can smother in-stream vegetation, and elevated levels of nutrients can stimulate algal blooms. Other threats to freshwater habitat have come about through the invasion of pest species of plants. Some plant pests, such as Alligator Weed have a high national profile due to their occurrence in several of the Australian states (Commonwealth Research Centre for Weed Management 2003), and are listed as Weeds of National Significance. Other weed species, due to regional or local distribution, do not have a national profile. The combination of the sedimentation, nutrient enhancement and pest invasion can impact on native fauna.

At present, there is no accepted methodology by which the freshwater aquatic vegetation of the coastal rivers of New South Wales is determined. Some efforts have been initiated (e.g., Thiebaud and Williams 2008, West *et al*. in prep.) but much more needs to be done to resolve the logistic base on which cost-effective surveys are conducted. Issues such as ease of access, type of terrain, and seasonal rainfall patterns can have a major impact on the design of, and results from, aquatic vegetation surveys.

The Sydney Metropolitan Catchment Management Authority (SMCMA) has a major interest in the well-being of its catchments and rivers, not the least of which is the Parramatta River. To date, no surveys of the freshwater aquatic vegetation of the river have been done, and such baseline data are necessary for appropriate management strategies and catchment investment plans. At the request of the SMCMA this project to define the freshwater vegetation of the Parramatta River was initiated. The objectives of this project were to:

1. create a methodology by which to assess the extent and type of freshwater macrophytic vegetation in the coastal rivers of NSW;
2. conduct an assessment of the macrophytic vegetation of the freshwater portion of the Parramatta River of 2007;
3. create ArcView shapefiles and associated data tables to indicate the area of cover;
4. provide a report to the Sydney Metropolitan Catchment Management Authority.

It was not within the scope of this project to create a distribution model of the aquatic vegetation of other sandstone-based estuaries of the central portion of the NSW coast. Nevertheless, it is assumed that the data collected in this project would contribute to such a model.

2. METHODS

2.1. Study area

The catchment of the Parramatta River/Port Jackson/Sydney Harbour is 347 km^2 in area, while the water area is of the order of 62 km^2 (Department of Environment and Climate Change NSW online). Figure 1 depicts the catchment of Parramatta River/Sydney Harbour.

To assess small scale distribution patterns of freshwater vegetation within the catchment, three smaller geographical entities were recognised. Two of these were considered major subcatchments:

Middle Harbour Creek: enters Sydney Harbour at Balmoral. Much of this subcatchment is forested, particularly in Garigal National Park.

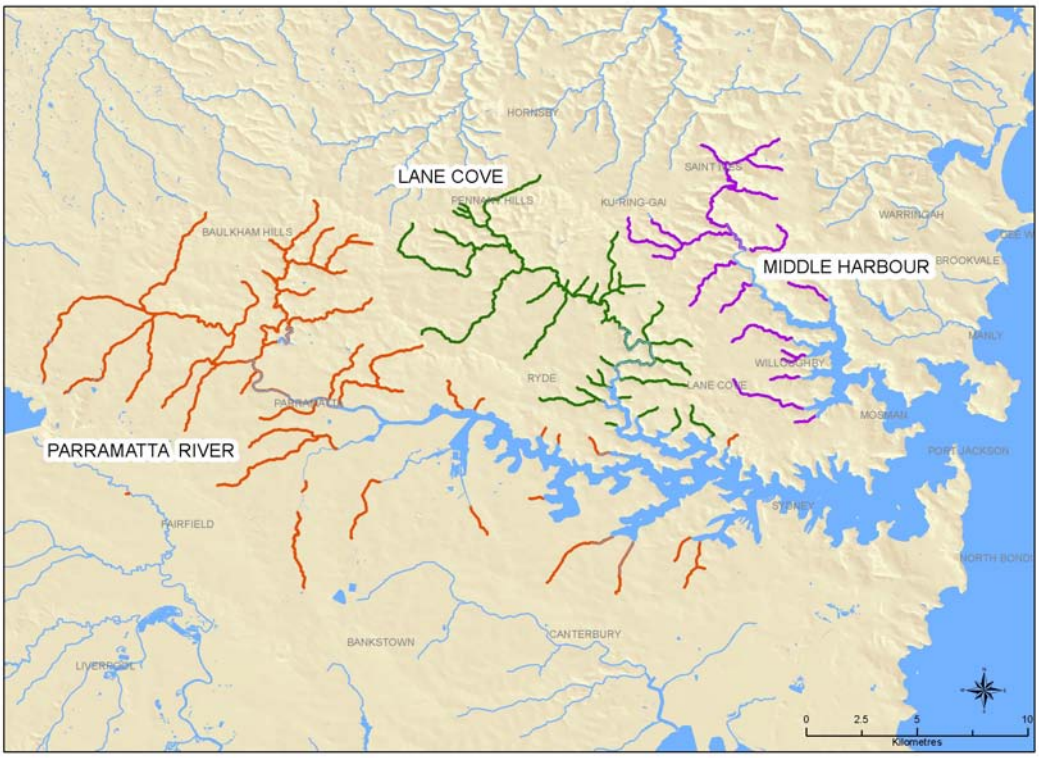

Figure 1. Map of the Parramatta River/Sydney Harbour catchment.

Parramatta River: becomes Port Jackson at the former's confluence with the Lane Cove River at Hunters Hill. Land clearing for agricultural purposes in the 1800s and rapid urban development in more recent times have reduced the natural forest extensively. Remnant natural forest is mainly in the Darling Mills Creek subcatchment, where there is a major conservation reserve forming a continuous corridor along Darling Mills Creek, Hunts Creek and the upper Toongabbie Creek.

One secondary subcatchment is also present:

Lane Cove River: joins the Parramatta River at Hunters Hill to become Port Jackson. Much of this subcatchment is forested, being in the Lane Cove National Park, Pennant Hills Park and Twin Creeks Reserve.

Classically, for hydrologic purposes such as estimating water yield or determining erosive/sedimentary characteristics, tributaries within catchments have been categorised on the basis of the Strahler (1957) or the Shreve (1966) methods. Both techniques begin at the top of a catchment and use an escalating number system when two small tributaries join to make a larger one.

We applied neither the Strahler nor the Shreve numbering system in this project, but instead used the tidal plane as the fundamental reference point and numbered the tributaries proceeding from downstream to upstream. There were several reasons for doing this:

1. The project did not focus on hydrology *per se* but on the distributions of freshwater macrophytes.
2. The distribution of freshwater macrophytes in the lower reaches of the tributaries is mediated by the presence of saltwater. While variations in penetration of saltwater along tributaries are brought about by changes in rainfall (and changes in sealevel), the tidal plane offers a common reference point across subcatchments.
3. Depending on slope, two tributaries given the same reference number based on the Strahler (1957) or the Shreve (1966) methods might have fundamentally different characteristics. For example, many tributaries of in the steep portions of a catchment can be ephemeral, carrying water only during wet weather intervals, whereas equivalently numbered tributaries of lower relief may be permanently inundated.

To put this in a more specific context, both the Middle Harbour Creek and Lane Cove River systems are in steep terrain and have many more tributaries than the Upper Parramatta River system. Because of this, the order numbers of their lower tributaries will be higher than for those of the Upper Parramatta. This means that direct ecological comparisons of vegetation types are not possible. By reversing the Strahler and Shreve methods, and using a common datum in the form of tidal limit, tributaries can be compared from the bottom of the subcatchment progressively upwards.

The whole of the lower portion of the Parramatta River, from the heads to the most downstream of the Parramatta weirs, is tidal and therefore considered estuarine. The second main arm of the estuary is Middle Harbour Creek. Because of their direct contribution to the river system these elements were considered to be "subcatchments" and assigned the "1st tributary" category. The Lane Cove River drains into the Parramatta River, hence it was considered a "sub-subcatchment" and given "2nd tributary" status. The other small creeks flowing into directly into Middle Harbour Creek and the Parramatta River were also given 2nd tributary status. Upper branches were then numbered as 3rd tributary, 4th tributary, etc.

The first data layer we used to record tributaries was the NSW Land and Property Information (LPI) streamflow network. There were deficiencies in this data set, and these were of two types. Not all creeks were marked even though in many cases the drainage lines were obvious. This is not an uncommon occurrence for NSW waterways (A. Creese, NSW DPI, pers. comm., 2007). In the second situation creeks were marked but were not named, or the branch to which a name had been provided was unclear, and this made record keeping difficult.

We therefore checked other sources that might provide more information. Sydney metropolitan street directories were consulted, as were staff of Parramatta City Council. In some cases one data source was more comprehensive than the other and/or the LPI streamflow network in terms of defining the network and naming the tributaries. For Middle Harbour Creek and Lane Cove River another source of data was found in the form of hardcopy maps produced by STEP Inc., a non-profit association of urban bushwalkers numbering of the order of 450 individuals (J. Martyn, pers. comm., 2007). STEP has compiled observations made by its members over many years of hiking and added them to base maps provided by the NSW Department of Lands (STEP Inc. 2000, 2004a, 2004b). These data layers were added to the LPI streamflow network to create composite maps for each of the subcatchment. Much of the additional creeks obtained this way had no name and so they had to be given a temporary name for identification purposes.

2.2. Preliminary assessment

Three reconnaissance visits were made, one to each of Middle Harbour Creek (12/12/06), the Lane Cove River (8/04/07), and the upper Parramatta River (11/01/07). Preliminary observations were made on type of freshwater macrophytes, and also on accessibility/terrain, which was of critical importance for in-stream observations. Many problems were encountered with access to the Lane Cove River and Middle Harbour Creek tributaries where it was in some cases near impossible to descend a steep bank to approach the water's edge. The limitation of access negated any possibility of setting up a sampling routine at fixed distances. Instead, observations would have to be taken where access was safe and feasible.

Examination of topographic maps and aerial photographs confirmed an assumption made at the project's outset – that there were some geomorphic similarities between Middle Harbour Creek and the Lane Cove River in terms of steepness of terrain and extent of vegetative cover, and that these two waterways differed considerably from the upper Parramatta River. These differences exist because the Cumberland Basin, which encompasses the upper Parramatta River, forms a topographically low area lying between Port Jackson and Botany Bay, while the Hornsby Plateau rises to the north of Port Jackson (Herbert 1983) and is the major influence on the Lane Cover River and Middle Harbour Creek. In terms of physiographic distinctions, the lower portions of Middle Harbour Creek and Lane Cove River are within the "Harbour Foreshores", while their upper tributaries are in the "Hornsby Plateau", and while much of the Parramatta River is also in the Harbour Foreshores region, its upper part is within the Cumberland Lowlands (Chapman and Murphy 1989).

The data retrieved from the three reconnaissance visits were studied and an assessment was made of common observations and the feasibility of acquiring data in each of the three subcatchments.

2.3. Identification of features of relevance

Information in the form of point data (explained below) was sought to map features of interest. These features included:

- **Vegetation type:** The distribution of species of emergent, submerged or floating aquatic vegetation was mapped. Some exotic aquatic plants are considered weeds of national significance (WoNS), but technically speaking there is no formal list of "aquatic" weeds (A. Petroeschevsky, pers. comm., 2008). The aquatic weeds that are included in the WoNS are *Alternanthera philoxeriodes, Cabomba caroliniana* and *Salvinia molesta.* A second list, the national alert list, includes the aquatic plants *Gymnochoronis spilanthoides, Lagarosiphon major,* and *Equisetum arvense*. In addition, in all states and territories, several other exotic aquatic plants individually have been declared noxious, i.e., aquatic plants declared noxious weeds in NSW may not be so declared in other states.

- **Flow type:** If the watercourse was dry this feature was logged. The presence of pools, runs, riffles, rapids and waterfalls was logged.
- **Substrata type:** Features such as bedrock, boulder, cobble and soft sediment (gravel, sand or mud) were logged. The presence of concrete channels was logged.
- **Water clarity:** The clarity of the water was logged (turbid, clear).

2.4. Fieldwork: the data logging process

As indicated previously, much of the land surrounding Lane Cove River and its tributaries and Middle Harbour Creek and its tributaries was inaccessible. It was therefore necessary to devise a procedure by which to assess common features in similar categories of tributaries, and record features of interest in individual tributaries. The field exercise had to be efficient but not overly consumptive of time and money.

A real-time field mapping system was used to position the site and log its characteristics. Sites were chosen on the basis of accessibility along established tracks. Where the track paralleled the tributary, observations were made at intervals where either substrata, flow, water quality or macrophytes differed. A 'site' was defined as the immediate vicinity (2 – 3m) within which the position was logged. Field gear included a PDA (Personal Digital Assistant), a GPS (Global Positioning System) and a Bluetooth (Figure 2). This array of hardware was particularly well suited for fieldwork as it fits in the palm of the hand and can be carried while wandering along creek banks or wading through shallow water. A photograph was taken at all sites.

Data were logged using a program created with ArcPad Studio containing dropdown menus with categories for each of the various submerged, emergent and floating macrophytes (Figure 3). The logging program automatically collected date, time and latitude/longitude. The operator selected features of interest from dropdown menus and logged them while walking along the creek banks. Data were downloaded in the office and imported as a shapefile. Copies of this shapefile were provided to SMCMA.

Appendix A sets out the dates when fieldwork was conducted in each subcatchment. An attempt was made to visit all known tributaries greater than 500m in length. Appendix B provides the scientific and common names of the species encountered.

Figure 2. Mapping hardware used in this project.

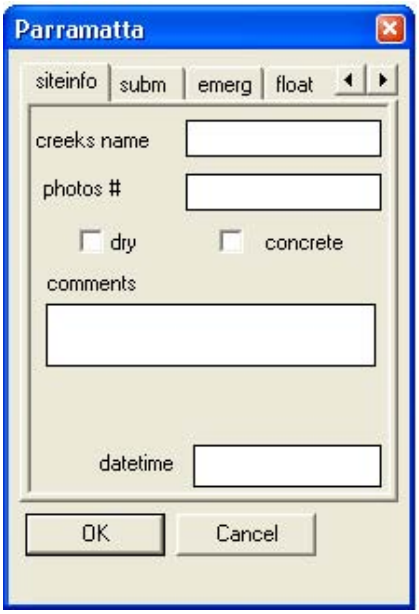

Figure 3. Logging program developed and used to collect data in the field.

3. RESULTS

After comparison of the various data sources, the number of tributaries in each category was noted. Appendices C, D and E indicate the number of tributaries found in each of the subcatchments, and Table 1 is a summary of these appendix data. The table shows large discrepancies between the number of tributaries revealed by the LPI streamflow network and the number of tributaries generated by our composite maps. There are nearly three times as many for Middle Harbour Creek (47 vs. 17), and twice as many tributaries for Lane Cove River (73 vs. 32) as compared to the LPI shapefile. These differences may be due to the dense ground cover in Garigal National Park and Lane Cove River National Park, respectively, making it difficult for the cartographers who used air photos to discern the presence of small and/or ephemeral creeks. There was somewhat better correspondence between the LPI streamflow network for the Parramatta River and our composite map (50 vs. 29), but, because there was no equivalent STEP map for the upper Parramatta River catchment, there may have been other small tributaries that were not discovered.

Sites visited in the field are shown in Figures 4 – 6. Site inspections were made at 98, 152 and 136 locations at each of the Parramatta River, Lane Cove River, and Middle Harbour Creek subcatchments, respectively. On average, two visits were made to each tributary; in reality, some tributaries were only inspected once due to steep terrain and the difficulty of access.

The substrata at each site within each subcatchment were identified (Table 2). Given the area that represented a 'site' (see Methods), on some occasions multiple substrata were recorded. Nearly 10% of sites had a concrete channel, and most of these were in the Upper Parramatta River. Many sites had mixed substrata, but bedrock was predominant (42%), followed by cobble (19%). As was to be expected, bedrock was found most commonly in the Lane Cove River and Middle Harbour Creek, and mud in the Upper Parramatta River.

Flow characteristics also differed between subcatchments. In only a few cases were the tributaries dry: one site in the Upper Parramatta, four sites in each of the Lane Cover and Middle Harbour Creek (Table 3). Pools were a larger component of the sites in Middle Harbour Creek (44%), than at Lane Cove River (18%) or Upper Parramatta River (15%). Runs were more prevalent at Upper Parramatta (79%), than at Lane Cove (64%) or Middle Harbour Creek (42%). In effect, Middle Harbour Creek was comprised nearly equally of pools and runs, whereas the other subcatchments had a greater variety of flow characteristics.

Water clarity was determined at all sites where water was present (Table 4). In most situations the water was clear, but more so at Middle Harbour Creek than the other subcatchments. As might be expected, water was more often turbid in the Upper Parramatta (47%) than elsewhere. An orange colour was noted on 10 occasions, and in each of the subcatchments. This colour usually denotes the presence of iron, and can be indicative of the presence of acid sulphate soils.

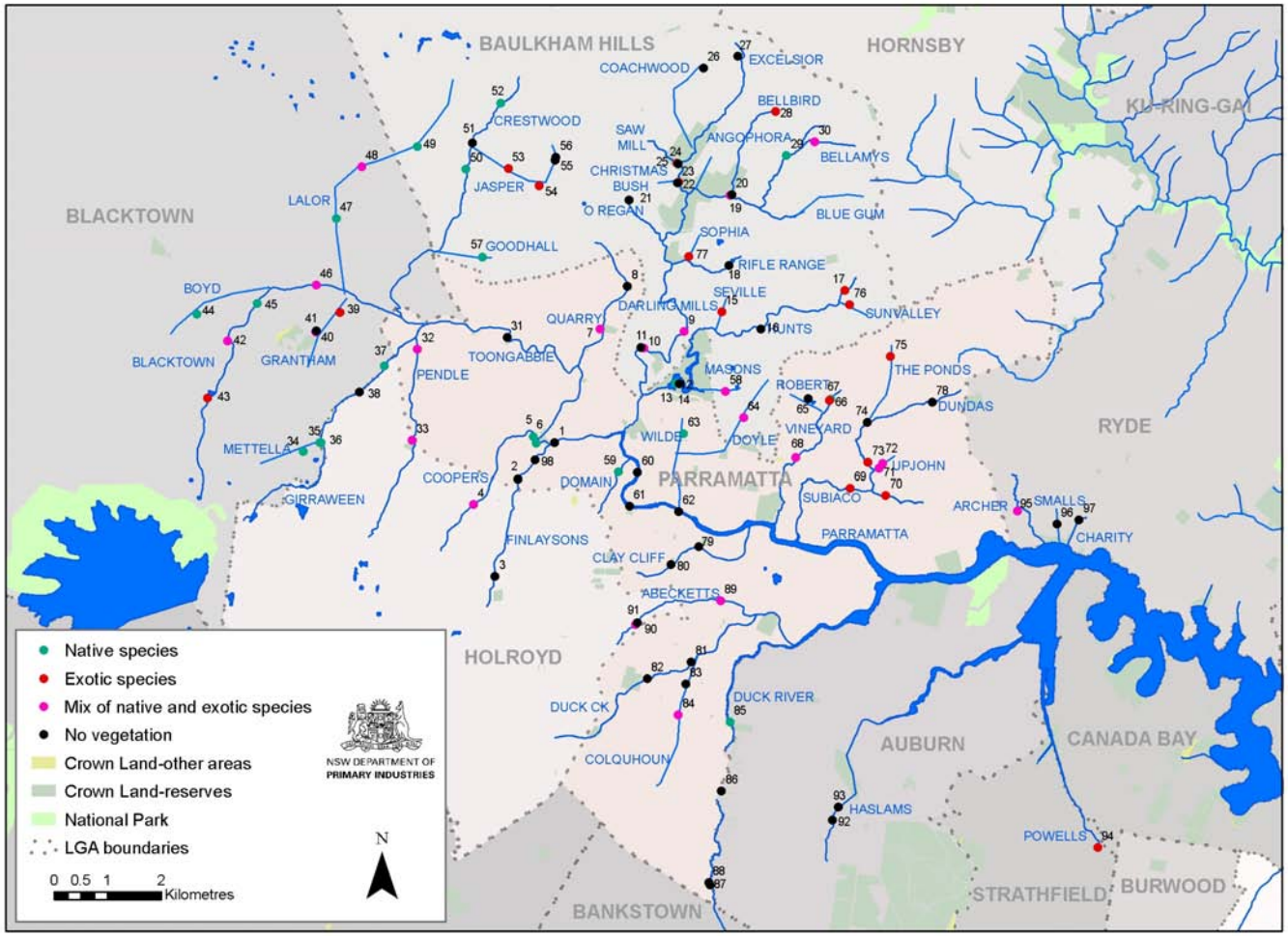

Figure 4. Map of the sites visited in the Upper Parramatta River subcatchment.

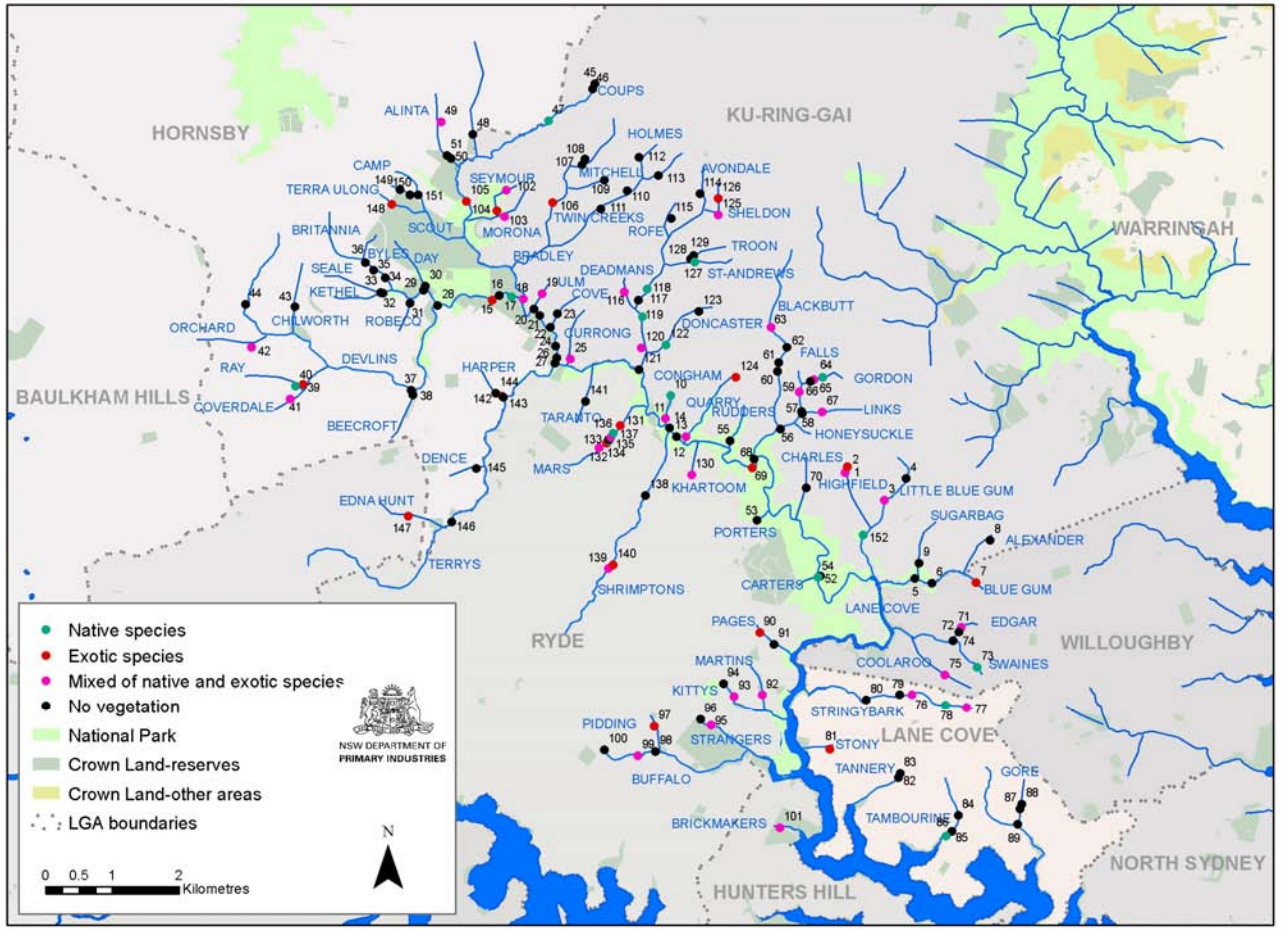

Figure 5. Map of the sites visited in Lane Cove River subcatchment.

Figure 6. Map of the sites visited in Middle Harbour Creek subcatchment.

Table 1. Number and order of tributaries in the subcatchments of interest.

Subcatchment	1st order	2nd order	3rd order	4th order	5th order	6th order	TOTAL
Upper Parramatta River	1	15	21	13	0	0	50
Lane Cover River	NA	1	34	27	10	1	73
Middle Harbour Creek	1	18	24	4	0	0	47

Table 2. Summary of **substrata** characteristics, 2007 – 2008. Where mixed substrata were observed (e.g., boulder/others), the major and secondary components are indicated; see Appendix F for details.

Subcatchment	Field inspection	No. of sites inspected	Concrete	Bedrock	Bedrock/ others	Boulder	Boulder/ others	Cobble	Cobble/ others	Gravel	Gravel/ others	Sand	Sand/ others	Mud	Unknown
Upper Parramatta River	Mar. – Apr. 2008	98	22	3	15	1	5	1	14	6	1	3	0	25	1
Lane Cove River	Dec. 2007 – Feb. 2008	152	2	42	36	5	9	6	26	2	1	11	1	9	2
Middle Harbour Creek	Sept. – Dec. 2007	136	11	61	16	4	5	9	5	2	2	7	1	12	1

Table 3. Summary of **flow** characteristics, 2007 – 2008. See Appendix F for details.

Subcatchment	Field inspection	No. of sites inspected	Dry	Pool	Run	Riffle	Rapid	Waterfall
Upper Parramatta River	Mar. – Apr. 2008	98	1	15	78	4	0	0
Lane Cove River	Dec. 2007 – Feb. 2008	152	4	30	97	7	12	2
Middle Harbour Creek	Sept. – Dec. 2007	136	4	58	56	9	3	6

Table 4. Summary of **water clarity** characteristics, 2007 – 2008. See Appendix F for details.

Subcatchment	Field inspection	No. of sites inspected	No water	Turbid	Cloudy	Clear	Orange colour
Upper Parramatta River	Mar. – Apr. 2008	98	1	46	2	46	3
Lane Cove River	Dec. 2007 – Feb. 2008	152	4	52	20	72	4
Middle Harbour Creek	Sept. – Dec. 2007	136	4	19	18	92	3

Table 5 indicates the site-by-site presence of aquatic vegetation within the subcatchments. Overall, more than half the sites (55%) were bare of vegetation, but this ranged from 41% of sites being bare in Upper Parramatta River to 64% of sites in Middle Harbour Creek having no vegetation. The Upper Parramatta River also had the greatest percentage of sites with only native vegetation (20%). All subcatchments had about the same proportion of sites with only exotic species (12 – 18%).

Table 6 lists the taxa of aquatic vegetation found in the study area as well as at each of the subcatchments. Twenty eight taxa were encountered, of which more species of emergent vegetation were found (14) than of submerged plants (8) or floating plants (6). Of the 28 taxa, 17 were native and 11 were exotic. More species were found in the Upper Parramatta River and in Lane Cove River (in both cases 19 total; 11 native and 8 exotic) than in Middle Harbour Creek (16; 9 and 7).

Differences in species composition between the subcatchments are also shown in Table 6, and the number of occurrences of the individual taxa are presented in Tables 7, 8 and 9. The eight taxa of **submerged** vegetation were found only infrequently (Table 7), and of the native submerged taxa, *Chara* spp. and *Hydrilla verticillata* were the most common but occurred at few sites. *Vallisneria gigantea*, a species considered of value to native fish such as the Australian bass (Harris 1988), was not located. Also of note, given the difficulties that the pest *Egeria densa* has caused elsewhere (e.g., Hawkesbury River; Thiebaud and Williams 2008), is the limited presence of this species. It was found at only six sites, three in each of Lane Cove River and Middle Harbour Creek. Another pest species, *Myriophyllum aquaticus*, was found at only five sites, all within the Upper Parramatta River.

Table 5. Summary of the presence of native, mixed and exotic vegetation, 2007 – 2008. See Appendix E for details.

Subcatchment	**Dates of field inspection**	**Number of tributaries**	**Number of sites inspected**	**Number of sites with no vegetation**	**Number of sites with only native species**	**Number of sites with native and exotic species**	**Number of sites with only exotic species**
Upper Parramatta River	Mar. – Apr. 2008	50	98	40 (41%)	20 (20%)	21 (21%)	17 (18%)
Lane Cove River	Dec. 2007 – Feb. 2008	73	152	84 (55%)	18 (12%)	32 (21%)	18 (12%)
Middle Harbour Creek	Sept. – Dec. 2007	47	136	87 (64%)	14 (10%)	12 (9%)	23 (17%)
Total		170	386	211 (55%)	52 (13%)	65 (17%)	58 (15%)

The **emergent** plants were far more abundant than either the submerged or floating plants (Table 8). The exotic *Cyperus eragrostis* was the most common species, followed by the natives *Juncus usitatus*, *Persicaria decipiens* and *Typha orientalis*. Species composition was somewhat unique in each subcatchment. For example, *T. orientalis* was more prevalent in the Upper Parramatta River than elsewhere.

In addition to *C. eragrostis*, the most prevalent exotic (present at nearly 25% of sites), seven other species were alien (Table 8). The next most common introduced species, *Ranunculus repens*, *Cyperus involucratus* and *Juncus articulatus* were present at only ten, eight and four sites, respectively. The introduced *Juncus acutus*, which is a problem further downstream in the brackish waters of the Parramatta estuary (Paul and Young 2007), was not found.

Of the six taxa of **floating** plants, the introduced *Callitriche stagnalis* occurred more frequently than any other (30 sites), and was present mostly in Middle Harbour Creek subcatchment (Table 9). *Alternanthera philoxeroides* (alligator weed), a severe pest in the Hawkesbury River, was found at only one site, and this was in the Upper Parramatta subcatchment.

At a number of sites more than one weed species was encountered. Four species of pest were found at Ulm Creek (Lane Cove River, Site 19, Appendix G2). Three exotic species were located at Archer Creek (Upper Parramatta River, Site 95, Appendix G1), Links and Doncaster Creeks (Lane Cove River, Sites 67 and 120, respectively, Appendix G2) and Carroll Creek (Middle Harbour Creek, Site 115, Appendix G3). The reasons for these multiple occurrences are not known.

As part of the arrangements made with the Sydney Metropolitan Catchment Management Authority for this study, a shapefile of results was provided and can be distributed such that further in-field observations might be made by local government or non-governmental organisations. These observation can be photo recorded and compared to the on-hand archive.

Table 6. Summary of the taxa of aquatic vegetation found in the three subcatchments of the Parramatta River/Sydney Harbour.

		Native	Exotic	Upper Parramatta River	Lane Cove River	Middle Harbour Creek
Submerged	*Ceratophyllum demersum*	X			X	
	Chara spp.	X			X	X
	Egeria densa		X		X	X
	Hydrilla verticillatta	X		X	X	X
	Nitella spp.	X				X
	Potamogeton crispus	X		X		
	Potamogeton ochreatus	X			X	X
	Myriophyllum aquaticum		X	X		
Subtotal	***8***	***6***	***2***	***3***	***5***	***5***
Emergent	*Baumea articulata*	X			X	
	Bolboschoenus caldwellii	X		X		
	Cyperus congestus		X		X	
	Cyperus eragrostis		X	X	X	X
	Cyperus involucratus		X	X	X	X
	Juncus articulatus		X		X	X
	Juncus usitatus	X		X	X	X
	Ludwigia peruviana		X	X		
	Persicaria decipiens	X		X	X	X
	Phragmites australis	X		X		X
	Ranunculus repens		X	X	X	X
	Schoenoplectus validus	X		X		X
	Sagittaria platyphylla		X	X	X	X
	Typha orientalis	X		X	X	X
Subtotal	***14***	***7***	***7***	***11***	***10***	***10***
Floating	*Alternanthera philoxeroides*		X*	X		
	Azolla spp.	X		X	X	
	Callitriche stagnalis		X	X	X	X
	Lemna spp.	X			X	
	Nymphaea spp.	X		X	X	
	Potamogeton sulcatus	X		X		
Subtotal	***6***	***4***	***2***	***5***	***4***	***1***
Total	**28**	**17**	**11**	**19**	**19**	**16**

** designated as a Weed of National Significance (WoNS) (A. Petroeschevsky, pers. comm., 2008).*

Table 7. Summary of the occurrences of **submerged** vegetation, 2007 – 2008. See Appendix E for details.

Subcatchment	**Dates of field inspection**	**Number of sites inspected**	**Native species**							**Exotic species**		
			Ceratophyllum demersum	*Chara* spp.	*Hydrilla verticillatta*	*Nitella* spp.	*Potamogeton crispus*	*Potamogeton ochreatus*	All	*Egeria densa*	*Myriophyllum aquaticum*	All
Upper Parramatta River	Mar. – Apr. 2008	98	0	0	1	0	1	0	2	0	5	5
Lane Cove River	Dec. 2007 – Feb. 2008	152	1	5	3	0	0	1	10	3	0	3
Middle Harbour Creek	Sept. – Dec. 2007	137	0	3	1	2	0	1	7	3	0	3
Total		387	1	8	5	2	1	2	19	6	5	11

Table 8. Summary of the occurrence of native **emergent** vegetation, 2007 – 2008. See Appendix E for details.

Subcatchment	**Field inspection**	**Number of sites inspected**	**Native species**								**Exotic species**							
			Baumea articulata	*Bolboschoenus caldwellii*	*Juncus usitatus*	*Persicaria decipiens*	*Phragmites australis*	*Schoenoplectus validus*	*Typha orientalis*	All	*Cyperus congestus*	*Cyperus eragrostis*	*Cyperus involucratus*	*Juncus articulatus*	*Ludwigia peruviana*	*Ranunculus repens*	*Sagittaria platyphylla*	All
Upper Parramatta River	Mar. – Apr. 2008	98	0	1	15	21	5	1	13	56	0	31	2	0	1	2	1	37
Lane Cove River	Dec. 2007 – Feb. 2008	152	1	0	33	19	0	0	4	57	3	43	1	2	0	6	2	57
Middle Harbour Creek	Sept. – Dec. 2007	137	0	0	12	7	5	2	4	30	0	13	5	2	0	2	1	23
Total		387	1	1	60	47	10	3	21	143	3	87	8	4	1	10	4	117

Table 9. Summary of the presence of **floating** vegetation, 2007 – 2008. See Appendix E for details.

Subcatchment	**Dates of field inspection**	**Number of sites inspected**	**Native species**					**Exotic species**		
			Azolla spp.	*Lemna* spp.	*Nymphaea* spp.	*Potamogeton tricarinatus*	All	**Alternanthera philoxeroides*	*Callitriche stagnalis*	All
Upper Parramatta River	Mar. – Apr. 2008	98	1	0	1	1	3	1	1	2
Lane Cove River	Dec. 2007 – Feb. 2008	152	1	1	2	0	4	0	12	12
Middle Harbour Creek	Sept. – Dec. 2007	137	0	0	0	0	0	0	17	17
Total		387	2	1	3	1	7	1	30	31

** designated as a Weed of National Significance (WoNS) (A. Petroeschevsky, pers. comm., 2008).*

4. DISCUSSION

There are two main components to the Discussion, one in relation to the underlying streamflow network on which the mapping was based, and the other on the distribution of the native and exotic species in the three subcatchments of the study area. In the case of the underlying network, the streamflow mapped by NSW Land and Property Information (LPI) for Lane Cove River and Middle Harbour Creek provided only a portion of the tributaries that we encountered in the field (Appendices C – E). This was unfortunate as there may be assumptions made at the catchment level, the local government level and as well for NGOs that the readily available topographic maps for these subcatchments provide an adequate basis on which to conduct floral or fauna inventories. Presumably, STEP Inc. had attempted to use the LPI maps, found them inadequate for their purposes and so created new versions with an enhanced amount of detail. No analogous maps to those prepared by STEP Inc. were available for the Upper Parramatta River and this may be because of a lack of local need (for example for bushwalking), or because the existing LPI streamflow network is considered adequate. Nevertheless, there were still many more tributaries shown in a street directory than in the LPI network for the upper Parramatta River subcatchment.

The level of detail provided in streamflow maps is dependent on vegetation cover which in turn is related to the underlying topography. As indicated in Herbert (1983) and Chapman and Murphy (1989), there are distinct differences in the geology of the subcatchments and their tributaries. The tributaries of Middle Harbour Creek and Lane Cove River are predominantly sandstone bedrock, while those of the Upper Parramatta River are primarily unconsolidated sediments (Table 2). Theoretically, vegetative assemblages are influenced by these natural features. Gross differences in species composition were not apparent, the reasons for similarity, whether in terms of substrata, water permanence or flow characteristics, need further clarification.

The presence of unnatural features, and more specifically, concrete drains in all subcatchments, suggests there may be inhibitions to the colonisation and/or maintenance of native species at some locations. Sites where unnatural substrata occur might be considered for rehabilitation initiatives to recapture the original substrata characteristics. Concrete channels were observed at 21 sites in the Upper Parramatta River, 12 in Middle Harbour Creek, and two in the Lane Cove subcatchment.

The flow of water within tributaries varies within subcatchments but also between subcatchments. Our observations on water flow were dependant on the local rainfall events that preceded field observations. During two fieldtrips, in December 2007 (Lane Cove) as well as in February 2008 (Upper Parramatta), heavy rainfall was experienced in the Sydney district, and the flow characteristics shown in Appendix F reflect these rainfall conditions. Nevertheless, all three catchments were comprised more of pools and runs than of riffles, rapids and waterfalls (Table 3).

With respect to water clarity, this survey extended over a lengthy interval (September 2007 to April 2008) and turbidity would be expected to vary in relation to localised rainfall events and perhaps even seasonally. Some sites were visited during the warmer temperatures of summer and hence algal densities may have been greater than in the cooler months, hence reducing water clarity. Overall, the sandstone catchments of Middle Harbour Creek and Lane Cover River showed more frequent instances of clear water than the Upper Parramatta River (Table 4).

Relative to the number of sites visited, aquatic vegetation was found at slightly less than half the total (175 of 386 sites; Table 5). While this might be suggestive of bias, the lack of vegetation at these sites provides a baseline against which recovery of native species and/or expansion of alien species can be measured.

Unfortunately, introduced species were present in all subcatchments, but few species co-occurred in all three subcatchments (Tables 7 – 9). Individual pest species were confined to certain locations.

Of the two exotics with a submerged lifestyle, *E. densa* was only found in the Lane Cove River and Middle Harbour Creek, whereas *M. aquaticum* only appeared in the Upper Parramatta River. Of the two floating exotics, *C. stagnalis* occurred in all subcatchments but *A. philoxeroides* was found at only one site, in the Upper Parramatta River. These limited occurrences will facilitate control operations.

Most exotic species were of the emergent form, with *C. eragrostis* particularly prevalent (Table 8). Fortunately, *J. acutus*, an emergent pest that has been difficult to eradicate in the estuarine portion of the river valley, was not found. These limitations of distribution of species with subcatchments, as well as the few locations at which some species occur, imply that removal projects are feasible.

Among the native species, *V. gigantea*, considered of value to native fish (Harris 1988), was not located. It may have once been present or is only now in such limited abundance as to be difficult to find. Another native, *T. orientalis*, was more prevalent in the Upper Parramatta River than elsewhere. A better understanding of the existing and potential distribution of all species could be obtained by applying a multivariate analysis to attempt to stratify habitat subunits (e.g., Gilligan and Heath in prep.). Additionally, an analysis of landuse change in the catchment (such as that done by Williams and Thiebaud 2007 for downstream portions of the Hawkesbury River) may assist in identifying sites for which there is an enhanced susceptibility for weed invasion.

Subsequent to the commencement of this study, the results of an investigation commissioned by SMCMA and undertaken by Earth Tech Pty. Ltd. (2007) were provided by the former agency. The investigation, titled the Waterway Health Study (WHS), was commissioned to assess aspects of conservation, vegetation, geomorphic condition, recreation and flood control over all of the Sydney metropolitan waterways. A DVD report was generated and includes maps of sites where types of vegetation had been determined. The presence of bankside vegetation was noted in the WHS, an important initiative as this type of vegetation is particularly relevant in terms of detrital input to sustain fish populations (Reid *et al*. 2008). When the WHS vegetation map was overlain on the map produced in our study (Figure 7) the degree of overlap in the two investigations could be compared. There is a fundamental spatial difference between the two studies. The WHS shows a concentrated series of field observations in relatively few of the tributaries of the Parramatta River, whereas our study covered the whole of the catchment, but necessarily made fewer site intensive examinations.

Other data to emerge from the WHS showed that two exotic emergent, two exotic floating and three exotic species of riverine (i.e., plants on the *banks* of the waterways) vegetation had been encountered along the Parramatta River. A summary of the number of locations at which these plants were found in the two studies (Table 10), as well as a more general comparison (Appendix H), have been prepared. In most cases there is little overlap between the studies, reflecting their different methodologies. For example, the exotic species *Hyparrhenia hirta*, *Ludwigia longifolia* and *Paspalum quadrifarium* were not seen in our study as they are riverine in habitat and were not part of our brief. Further, *Eichornia crassipes* and *Salvinia molesta*, two floating species, were encountered on one (Middle Harbour Creek) and eight (seven in the Upper Parramatta River and one in Middle Harbour Creek) occasions, respectively, in the WHS but were not encountered by us, reflecting the greater intensity of WHS spatial effort put into examining selected tributaries with in the Upper Parramatta River and Middle Harbour Creek. Of the exotic emergents, *Gymnocoronis spilanthoides* was found in the WHS but only in the Upper Parramatta River, and not at all by us, while *Ludwigia peruviana* was identified in the WHS as the most ubiquitous of all the introduced species. We found the latter species at only one site – in the Upper Parramatta subcatchment. Further effort should be made to consolidate the two data sets, refine the distributions of the alien species, and establish a common protocol for future monitoring.

A metadata statement for this project is included in Appendix I.

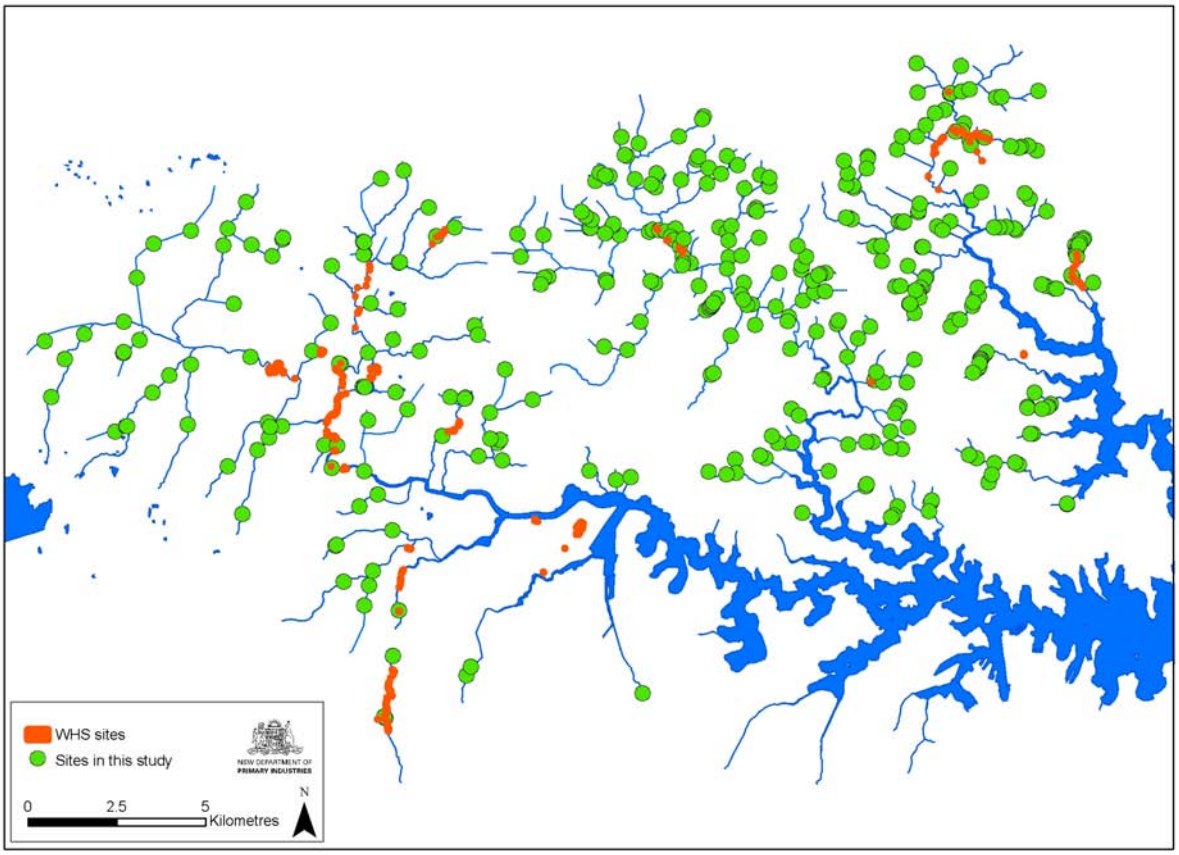

Figure 7. Degree of overlap in site selection between the WHS (2007) and this study.

Table 10. Comparison of number of sites at which introduced species were located: WHS and this study. See Appendix B for common names. Type of vegetation: S = submerged; E = emergent; F = floating; R = riverine (on-bank).

Introduced Species	Type	Upper Parramatta River		Lane Cove River		Middle Harbour Creek	
		WHS (2007)	This study	WHS (2007)	This study	WHS (2007)	This study
Egeria densa	S	0	0	0	3	0	3
Myriophyllum aquaticum	S	0	5	0	0	0	0
Subtotal		**0**	**5**	**0**	**3**	**0**	**3**
Cyperus congestus	E	0	0	0	3	0	0
Cyperus eragrostis	E	0	31	0	43	0	13
Cyperus involucratus	E	0	2	0	1	0	5
Gymnocoronis spilanthoides #	E	17	0	0	0	0	0
Juncus articulatus	E	0	0	0	2	0	2
Ludwigia peruviana	E	108	1	1	0	82	0
Ranunculus repens	E	0	2	0	6	0	2
Sagittaria platyphylla	E	0	1	0	2	0	1
Subtotal		**125**	**37**	**1**	**57**	**82**	**23**
Alternanthera philoxeroides *	F	0	1	0	0	0	0
Callitriche stagnalis	F	0	1	0	12	0	17
Eichornia crassipes	F	0	0	0	0	1	0
Salvinia molesta *	F	7	0	0	0	1	0
Subtotal		**7**	**2**	**0**	**12**	**2**	**17**
Hyparrhenia hirta	R	78	NA	0	NA	0	NA
Ludwigia longifolia	R	6	NA	6	NA	0	NA
Paspalum quadrifarium	R	43	NA	0	NA	0	NA
Subtotal		**127**	**-**	**6**	**-**	**0**	**-**
Total		**259**	**44**	**7**	**72**	**84**	**43**

** designated as a Weed of National Significance (WoNS) (A. Petroeschevsky, pers. comm., 2008).*
 # included on the National Alert List (A. Petroeschevsky, pers. comm., 2008).
NA = terrestrial vegetation and hence not surveyed.

5. CONCLUSIONS

1. The LPI streamflow network for the subcatchments of the Parramatta River was inadequate for the purpose of this survey. To cater for this deficiency we created a more robust base map of tributaries.
2. A useful baseline of the submerged, emergent and floating freshwater macrophytes of the Parramatta River has been created.
3. The distributional data acquired can be used to assess change over time.
4. Neither the native *Vallisneria gigantea* nor the alien *Juncus acutus* were found. The latter was not necessarily expected as its distribution is reported to only be in tidal water.
5. Two aquatic Weeds of National Significance, *Alternanthera philoxeroides* and *Salvinia molesta*, and one weed on the National Alert List, *Gymnocoronis spilanthoides*, show limited distribution and should be of high priority for eradication.
6. Because other aquatic weeds appear to be limited in their distribution, eradication projects appear to be viable.
7. Distinct differences in the geology of the subcatchments do not appear to markedly influence the species composition of freshwater aquatic vegetation in each.
8. The data obtained in this project would be useful in modelling the distribution of aquatic vegetation in the sandstone formed estuaries of NSW.

6. RECOMMENDATIONS

1. The methodology in this report should be combined with the WHS methodology (Earth Tech 2007) such that future surveys would simultaneously note riverine (on-bank) and in-stream (submerged, emergent and floating) native vegetation.
2. The data in this report should be combined with the WHS data (Earth Tech 2007) to elicit relationships between riverine and in-stream native vegetation.
3. The combined data set should be used to refine the distributions of alien species and implement appropriate management plans. Some sites may need to be mapped in more detail.
4. A pest species eradication project should be initiated, particularly at those sites where more than one exotic species was located (Upper Parramatta River: Archer Creek; Lane Cove River: Ulm, Links and Doncaster Creeks; Middle Harbour Creek: Carroll Creek).
5. A follow-up survey should be conducted in two years to assess whether pest and/or native plant species have increased in range.
6. Contingent on #4 (above), an analysis of change of landuse in the subcatchments should be undertaken to assist in identifying sites for which there is an enhanced susceptibility of weed invasion.
7. An assessment of landuse should include an integration of aquatic plant distribution data with the locations and characteristics of stormwater outlets and sewage overflows. Other data as acquired from future monitoring should also be applied. The output will further focus management plans and additional investigations.
8. Multivariate analysis of the data acquired in this report should be undertaken to stratify habitat subunits.
9. Habitat subunits should be sampled to identify *in situ* fish assemblages after the method of Gilligan and Heath (in prep.).
10. Surveys of the freshwater aquatic vegetation of other rivers in the SMCMA should be initiated, with close attention paid to the accuracy of available maps and the need to make corrections to the tributary network.

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