Riverine and wetland plants in the ACT: a knowledge appraisal

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PHOTOGRAPH: Naas Creek, Naas Valley, Namadgi National Park, ACT: April 2021

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Summary

This report describes the state of knowledge of non-woody riverine and wetland plants and plant communities in the ACT, as revealed in a project that evaluated documents located via web searches, library catalogues, and personal contacts.

Aims: The first aim of the project was to summarise the state of the following types of knowledge: occurrence and distribution of species and communities; species biology and ecology; resilience and recovery of species and communities; status, particularly conservation status; the critical drivers and how plants respond to them. The second aim was to evaluate the potential for using use historical records (ie records from before 2000) to help build contemporary knowledge. Both these help to lay the foundations for building knowledge and planning further work.

Description: The search located 76 documents with some knowledge, information or data about riverine and wetland non-woody plants. Most of the documents were government and consulting reports. There were four university theses and 10 journal papers. The 76 documents spanned more than fifty years, from 1966 to 2020. Output was fairly steady from 1970 to 2010 and then it virtually doubled, largely due to high effort in two subject areas: peatlands and restoration, and threats.

Findings: The documents cover seven subject areas: problem plants; habitat descriptions; aquatic resources; survey and mapping; peatlands and restoration; condition; and threats. Two documents (‘miscellaneous’) do not fit in any of those subject areas. This report summarises each subject area.

Knowledge in these 76 documents is mostly to do with the *occurrence and distribution* of species and communities, with occurrence presented as maps, text descriptions and co-ordinates for sampling sites. The knowledge is biased towards aquatic systems that are large, perennial, in upland areas, or already in the ACT reserve system. Little is known about small, intermittent, non-natural and natural but modified aquatic systems, especially in lowland ACT. These types of systems are used by iconic aquatic fauna such as platypus and rakali, and they are under constant pressure from urbanisation and associated disturbances.

Historical perspective: More than half of these documents are deemed historical, meaning they were issued before 2000, so their knowledge is dated. The year 2000 is significant because since then there has been a sequence of climatic extremes (droughts, floods, wildfires): except in peatlands, the effects of these extremes on riverine and wetland plants are unknown. This report discusses the value of these ‘historical’ documents, noting that the sites in approximately 10 of the documents would be worth re-surveying to learn about persistence and resilience.

Ways forward: A number of small projects and activities are outlined that enthusiasts and citizen scientists could undertake to build on existing knowledge.

Contents

1: Introduction

Plants are important in all ecosystems, both for their biodiversity value and for their functional importance. In aquatic systems, riverine and wetland plants provide services and functions that parallel the services they provide in terrestrial systems: structural habitat under, on and above water; energy in the form of carbon; regulation of micro-environments.

From an ecological perspective, the aquatic resources of the Australian Capital Territory (ACT) are reasonably diverse, comprising an array of natural, modified and constructed aquatic systems: but little documented, except for a few high profile systems. The ecological value of these aquatic resources is shaped by the plants that grow there, and their condition. Knowledge of plants and their relationship to their aquatic environment is needed for managing these systems.

As part of its commitment to the national Native Vegetation Framework, the ACT Government has (along with other jurisdictions) committed to five goals and 14 targets (ACT Environment and Planning 2015). Delivering on these goals and targets will require strengthening the evidence base for decision-making, and improving understanding of processes across all ecosystem types and all levels of ecological organisation, from ecosystem to species. Knowledge of species is particularly relevant for areas of vegetation management such as: biodiversity conservation; determining population status, whether stable or expanding or in decline; building concepts of condition; designing monitoring programs; tracking effects of catastrophic and insidious disturbances; and setting management priorities.

This report is an appraisal of the state of knowledge about non-woody riverine and wetland plant species in the ACT, as described in available documents.

1.1: Aims

The project had two aims.

The first aim was to summarise the state of knowledge of riverine and wetland plants and communities by establishing the types of information and scope of work done in the ACT. The five types of information are: occurrence and distribution of species and communities; species biology and ecology; resilience and recovery; status particularly in relation to conservation (abundant v rare; stable, expanding or in decline); the critical environmental drivers, and how plants respond to these.

The second aim was to evaluate if and how historical documents can contribute to contemporary knowledge. For this project, ***historical*** means before the year 2000. Since 2000, aquatic systems in the ACT and their biota have been subjected to a series of extreme events: the Millennium Drought (1997–2009), the floods of 2010–2011, the catastrophic wildfires of January 2003 and 2020, the warmest and driest calendar year on record for Australia in 2019 (BoM 2020), and the scouring rainstorms of autumn 2020. The cumulative effect of these on aquatic biota is little known.

1.2: Scope

The project focused on riverine and wetland plants in the ACT, and was restricted to non-woody species because those are generally less well-known and understood than the woody riverine and wetland species. Documents were the only source of information considered, and all the documents used in this appraisal are listed in Appendix 1. Herbarium specimens and photographic records are distinctive types of records, that are best evaluated separately and are not included here.

For this project, the terms 'riverine and wetland' correspond with the Ramsar definition of non-marine wetlands (see https://www.environment.gov.au/water/wetlands/ramsar). That is, riverine and wetland plants are those that have adaptations to growing and completing their life cycle in in lentic and lotic environments. Broadly, ***riverine*** refers to lotic (ie flowing) environments: ie major rivers, minor streams and ephemeral creeks, waterfalls as well as modified and constructed channels. Riverine includes all habitats affected by flowing water: river itself, the river's edge, in-channel, and riparian, with flow regimes ranging from permanent, to seasonal to ephemeral. ***Wetland*** refers to lentic (ie standing water) environments: ie natural aquatic systems such as bogs, fens, swamps and marshes as well as constructed ones such as farm dams, urban lakes, storages, wetlands constructed for water quality treatment, and flood retention basins. The term also includes very small natural systems where surface water is present only some of the time or rarely, such as such as springs and soaks, but long enough to develop an aquatic or semi-aquatic flora.

For this project, the terms 'upland' and 'lowland' correspond to the areas west and east of the Murrumbidgee River, respectively. The project defined 'upland' as high-altitude country, with relatively cool climate and steep topography, and 'lowland' as relatively low-altitude undulating or hilly areas.

Species names in this report are as given in original documents. For clarification, contemporary usage or revised names are given in Appendix 2, mainly taken from Australian Plant Name Index.

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2: Project

2.1: Search method

Documents, published and unpublished, were located by searching on-line catalogues in research and tertiary institutions (CSIRO Research Publications Depository, ANU, University of Canberra), and web pages and archives of federal and territory governments (ACT Heritage Library, National Archives Australia, National Library of Australia) as well as Google Scholar and Trove. Draft and progress reports were included only where no final report was located. Organisations consulted included Greening Australia, Biosis, Eco Logical Australia and Conservation Council ACT Region.

The search terms used, singly or in combinations, were: ecological descriptors such as *vegetation*, *plants*, *macrophyte*, *weeds*; habitat descriptors such as *aquatic*, *water*, *wetland*, *riparian*, *riverine*, *river*, *lake, creek;* specific geographic places such as *Molonglo*, *Murrumbidgee, Cotter, Naas, Ginnini, Burley-Griffin, Ginninderra, Namadgi, Tidbinbilla*; and general terms such as *aquatic resources*. Specific geographic names were essential because the obvious geographic search term "ACT" (for Australian Capital Territory) picks up every bit of legislation. Searching for studies of individual species in scientific journals was also not practicable, given that there are over 200 such species. In addition, professional contacts and colleagues assisted with tips, and with locating older material.

Digital copies (pdf) were obtained whenever possible. Paper copies were the only form available for some documents. They were read at the Australian Heritage Library or the National Library of Australia, or were made available by colleagues.

The search process was as thorough and wide-ranging as feasible on limited resources, but not 100% successful. Citations in documents such as ANCA (1996), Hope (2006), and Wild and Magierowski (2015) revealed a small number of reports, likely to be internal documents, that had not been located by the search. The number of consultancy reports is possibly also an underestimate. In contrast, the number of scientific publications and theses is considered reliable. Despite these shortcomings, the 76 documents used in this appraisal are considered a robust representation of the work done in the ACT on riverine and wetland plants.

2.2: About the documents

The project located over 80 documents that, from their title, location, keywords or catalogue description, looked likely to be informative about riverine and wetland plants in the ACT. However, several were not relevant, despite their titles. For example: the Paddys River Weed survey (Wright 1995), about terrestrial weeds; a checklist of species for Tidbinbilla Nature Reserve (Ward and Ingwersen 1984) with no indication of species locality; survey and mapping reports on the Molonglo River (Eco Logical 2008, Eco Logical 2009) ignoring in-stream vegetation. Removing these reduced the number for appraisal down to 76 documents.

Subject areas: The preliminary screening showed that the 76 documents fell easily into seven broad subject areas (Table 1) that were suggested by the contents of the documents themselves, rather than by any *a priori* expectations. Several documents contributed to more than one subject area.

Two documents did not fall neatly into any of the seven subject areas, so were grouped as 'miscellaneous'.

Document types: The project included documents of various types, ranging from 'grey literature' and technical reports to more formal scientific writing such as conference papers or book chapters, as well as peer-reviewed journal papers. Table 1 shows the number of types by subject area.

Table 1: Subject area by type of document

Subject area	Govt Reports	Consult Reports	Conf paper	Sci paper	Book chapt	Thesis	Other	TOTAL
A: Problem Plants	10	1	2	1		1	1	**16**
B: Habitat Descriptions	6							**6**
C: Aquatic Resources	2	6			2		2	**12**
D: Survey & Mapping	3	7		3			1	**14**
E: Peatlands & Restoration	1	4	2	5	3			**15**
F: Condition	3	3						**6**
G: Threats	4	3				3	1	**11**
X: Miscellaneous				1			1	**2**
SUM	**29**	**24**	**4**	**10**	**5**	**4**	**6**	
ADJUSTED	**27**	**20**	**4**	**10**	**5**	**4**	**6**	**76**
Adjusted as % of TOTAL	35.5	26.7	5.3	13.2	6.6	5.3	7.9	

Some documents contribute to more than one subject area, inflating the row and column totals; the 'Adjusted' value is the actual number of documents. Two technical reports issued by ACT and NSW governments respectively (Hope 2009, Hope 2012) are considered 'consultancy'.

More than half of the documents (47 out of 76) were reports produced by government or consultants (Table 1). The consultancy reports were mostly for ACT Government, with a few exceptions: Barlow et al (2005), Helman and Gilmour (1985), Roberts (2006a), Roberts (2006b), and Roberts and Sharp (2020). Relatively few were published in peer-reviewed journals (10) or monographs, and these were mostly on one subject area (peatlands and restoration): authorship for these was dominated by researchers from universities or inter-state institutions. There were four theses: two Honours and one Masters from University of Canberra, and one doctoral thesis from Australian National University. The 'Other' category was a grab-bag comprising two field guides, an entry in the Heritage Register, a factsheet, an excerpt from an EIS, and a spreadsheet for a digital vegetation map (ACT 2018).

The 76 documents had dates of issue ranging from 1966 to 2020, so spanned 54 years (Table 2). The number of documents per decade was initially fairly steady, at 10 to 15 per decade, then abruptly increased to nearly double between 2010–2019.

Taken collectively over this 50-year period, there is a progressive shift in content: most documents about *problem plants* are from the 1970s and 1980s; *habitat descriptions* are mostly from the 1990s; *peatlands and restoration* documents are from 2000s and 2010s; and documents about *threats* are mostly from 2010–2019. This parallels the general advance in knowledge and information about river and wetlands in Australia, moving from asset description to resource management.

Table 2: Subject area by year of issue

Subject area	1970 to 1979	1980 to 1989	1990 to 1999	2000 to 2009	2010 to 2019	ND	TOTAL
A: Problem Plants	6	6	3		1		**16**
B: Habitat Descriptions		1	5				**6**
C: Aquatic Resources	1	3	3	1	3	1	**12**
D: Survey & Mapping	1	3	2	4	4		**14**
E: Peatlands & Restoration		1		7	7		**15**
F: Condition			1	1	4		**6**
G: Threats			1	2	7	1	**11**
X: Miscellaneous	2						**2**
TOTAL	**10**	**14**	**15**	**15**	**26**	**2**	
ADJUSTED TOTAL	**10**	**13**	**15**	**12**	**24**	**2**	**76**
Adjusted as % of TOTAL	13.2	17.1	19.7	15.8	31.6	2.6	

The document for 1966 is included in 1970 to 1979, and the document for 2020 is included in 2010 to 2019.

3: Subject areas and knowledge

3.1: Problem plants

This subject area refers to riverine or wetland plants considered to be a nuisance or be 'weedy'. Most of the 16 documents in this subject are to do with one particular problem: aquatic plants in Canberra's first two urban lakes – Lake Burley Griffin and Lake Ginninderra – which were deemed to be 'weeds' and created a management headache. The early documents do not say why these plants were seen as a nuisance. Later documents mention interference with recreational use (swimming, sailing).

The weed situation is routinely summarised in annual reports and research reports (Boden 1966, Nazer 1975, Evans 1977, King 1979, Wotzko 1982, Adams 1986, Woodruff et al 1987). They describe the general extent of the weeds, sometimes broken down to species, and report on management actions undertaken (chemical control initially, later cutting by Wilder boat). Extent is quantified as area (in hectares) based on aerial photographs, and is presented as maps, with notes on distribution of main weed species. This mapping is robust rather than precise, because of the early techniques and tools being used for recording spatial data.

An identification guide, *Guide to identifying troublesome aquatic macrophytes in Canberra's urban lakes* (King and Wotzko 1978), reveals that in the 1970s some managers held attitudes and perceptions of 'aquatic weeds' that are rather different from present-day perceptions. The guide profiles 12 species. Three were introduced (*Elodea canadensis*, *Egeria densa*, *Paspalum paspaloides*), and the other nine were native wetland species that are now hardly ever considered 'troublesome', such as *Chara* sp., *Nitella* sp., *Marsilea drummondii*: if these were present now, they would likely be valued as part of aquatic biodiversity with a role in ecosystem functioning. Some government staff (eg Nazer 1986) are careful to emphasise the functional importance of macrophytes in the lakes while reporting on control activities.

Collectively, the annual reports reveal a changing situation in Lake Burley Griffin and Lake Ginninderra. Initially the weeds are reported as being diverse and abundant, but as time moves on the annual reports mention fewer species and smaller areas. Managers begin to recognise that lake turbidity in spring determines weed extent in summer (Nazer 1982a, Nazer 1986, Woodruff et al 1987). By the 1990s, only one species is reported as a problem: Ribbon Weed in Lake Ginninderra, variously reported as *Vallisneria spiralis* and *Vallisneria gigantea* (see Appendix 2). This plant is the subject of an ecological study (Moore 1992).

The ecological information recorded in these annual reports is fairly basic: occurrence of species, and abundance (as area) of the main weed species. The annual maximum area (in hectares) of aquatic weeds in Lake Burley Griffin from 1966 to 1987 is tabulated in a paper describing a research program on the lake's nutrient status (Cullen 1991). This paper does not establish why the lake switched from being macrophyte-dominated to phytoplankton-dominated (Cullen 1991).

The other three documents in this subject area are: a rapid appraisal of macrophytes in Corin Dam, an upland storage (Nazer 1978a); a survey of environmental weeds (Berry and Mulvaney 1995); and a research project testing hypotheses about factors causing plant communities being 'disturbed' or invaded by exotic species (Quinn et al 2011), which has one set of sites in the ACT. The environmental weed survey is ambitious. It targets the entire ACT, and all terrestrial habitats as well as riverbanks but not waterbodies (ie not pools, rivers, dams, lakes) so does not include aquatic species such as submerged or floating-leafed macrophytes. The report is a compilation of occurrence information for 532 taxa using 10904 records, collated from existing records (1929-1995) and from field surveys. A listing (Table 2.1, Berry and Maloney 1995) of common weeds of riverbank habitats shows that the most frequently recorded non-woody species up to the early 1990s are *Juncus articulatus*, *Veronica anagallis-aquatica* and *Myosotis laxa*. This listing for woody and non-woody species includes several species that thrive on damp disturbed ground but which do not fall within the definition of riverine and wetland plants as used here (Section 1.2).

3.2: Habitat descriptions

The six documents in this subject area are all habitat descriptions for fish, done as a routine part of fish surveys. These are useful as information about in-channel vegetation because they give both species occurrence and location. In contrast, many fauna studies lack details, using short descriptions such as "a medium-tall sedgeland", over a broad area. Their usefulness is compromised by lack of detail on species names, location and physical attributes. This is why descriptions of wetland vegetation as habitat, such as given for Latham's Snipe (Lintermans 1993b), are not included in this appraisal.

Five of the six documents give habitat descriptions on upland rivers and their tributaries: the Lower Cotter and adjacent Paddys River; the Upper Cotter River, meaning upstream of Corin Dam; Naas–Gudgenby Rivers; and Tidbinbilla River (Ingwersen and Ormay 1988, Lintermans 1993a, Lintermans and Rutzou 1990a, Jones et al 1990a, Rutzou et al 1994). The sixth is on a lowland stream, Ginninderra Creek (Lintermans et al 1990a). (Fish surveys and habitat descriptions began in the 1970s but the early ones on mid and lower Cotter River and a later survey of the Molonglo River were not written up: Mark Lintermans, pers. comm. 30 July 2021.) In all of six, the habitat description includes riverine and in-stream plants, and in all documents except one (Ingwersen and Ormay 1988) the description includes physical characteristics of the site.

These habitat descriptions follow a similar (but not identical) format, namely: presence of plant species or growth forms variously referred to as 'in-stream' or 'aquatic', and 'ground cover', 'understorey' and 'overstorey' as well as 'riparian'. Stream width, stream depth, flow velocity, substrate, degree of shading per site, and water temperature are part of the physical descriptions, and sometimes there is comment on recent fire history. The descriptions have date and location details, with site name and location either on map and/or as grid reference (6 digit and named on a 1:25,000 map), as well as altitude and stream order. Site photographs are inserted into a few reports (Lintermans et al 1990b, Ingwersen and Ormay 1988).

Collectively, these habitat descriptions provide an extensive coverage, with over 100 sites surveyed in just a few years, at similar seasons (mostly summer, occasionally extending to autumn).

Finding these habitat descriptions was fortuitous. Curiously, most of these habitat descriptions are not in the research reports of the fish surveys, but are instead issued separately as internal reports, and somewhat forgotten. Paper copies of these internal reports were found during an office re-location, and made available for this review. Other copies may exist but were not located by the search.

3.3: Aquatic resources

The term 'aquatic resources' is used here in an ecological sense, to refer to aquatic systems and their value for biodiversity (see also Introduction). Five of the 12 documents in this subject area are appraisals to inform strategic government planning, and seven are consolidations of contemporary knowledge. All use information already existing at the time, rather than generating new data such as by undertaking systematic surveys. In the consolidations, the existing information is mostly from the grey literature in the form of short internal government reports that are now either lost or inaccessible, augmented by personal observations and anecdotal information.

Three of the five appraisals (Greenham 1981, Kendall and Lansdowne 1981, Grimes and Norris 1994) are high-level overviews with few ecological details. Riverine and wetland plants get little consideration; thus these three have no potential as a source of information or knowledge, unlike the other two appraisals. One of the other two is a technical summary of biodiversity values for a part of the ACT lowlands scheduled for residential development (Mulvaney 2012). Although its focus is largely terrestrial, it includes wetland plants in its listing of locally rare species (Table 5), and it profiles Horse Park Wetland, which is one of the wetlands in the ACT listed in the *Directory of Important Wetlands in Australia*. The other focuses on aquatic resources across the Territory (Hogg and Wicks 1989). It brings together the field experience of the authors and their colleagues, records such as herbarium specimens, discussions with field workers, plus scattered informal knowledge, to paint a generalised picture of species occurrence. This is presented as a habitat x species matrix, with 58 species and 10 habitats, and a bias towards lowland habitats. The 58 species cover a range of growth forms, and the habitats are described, for example as 'open still water' and 'saturated mud or soil', as well as conventional 'rivers or creeks' and 'wetlands'. The matrix includes comments on individual species which give a contemporary view and could inform an historical comparison.

The seven consolidation documents bring together facts, knowledge and other forms of information, synthesise it, and make it readily accessible. Because consolidation is done for various reasons, the seven consolidation documents are quite diverse: five are government publications, and two are guides to water plants.

The five government publications are to do with conserving wetlands, in different ways: an entry to ACT Heritage Register, a contribution to the *Directory of Important Wetlands in Australi*a, an Ecological Character Description of a Ramsar-listed site, a resource description and a conservation strategy (ACT Heritage Register 2013, ANCA 1996, Wild et al 2010, Barlow et al 2005, Scott and Furphy Pty Ltd and David Hogg Pty Ltd 1992). All give considerable amounts of information, not just on plant species and vegetation but also on physical context such as climate, landscapes, hydrology and geomorphology. As with the appraisals, the government publications make much use of internal unpublished reports. With the *Directory*, the second edition has most detail making it the most informative (ANCA 1996). Directory entry for each of the 13 wetlands nominated has a sub-heading *Notable Flora* which gives the occurrence of rare plant species, as recognised at that time.

The two guides are separated by more than 30 years. One is a draft book chapter (apparently never published), covering 15 species (Nazer 1978b); the other is a 'glove box guide' for over 60 species, native and introduced, mostly reliant on photographs (Molonglo Catchment Group not dated).

Most of these documents contribute some ecological knowledge, but the two water plant guides are of very limited value: they do not give any spatial information such as specific sites or habitat preferences, and do not cover species abundance. No rationale is given for including the featured 15 and 60 species, and the selection appears idiosyncratic. For example, the draft book chapter does not include milfoils *Myriophyllum* spp or buttercups *Ranunculus* spp, even though *Myriophyllum verrucosum* had been mapped as a weed in Lake Burley Griffin (Evans 1977); and the glovebox guide includes ten terrestrial weeds such as *Echium plantagineum*, *Conyza albida*, *Lactuca serriola*.

3.4: Survey and mapping

This subject area comprises 14 documents that describe plant communities and their distribution. In most documents, the study area is entirely within the ACT, the exceptions being plant communities of the upper Murrumbidgee catchment (Armstrong et al 2013), the treeless vegetation of high mountainous country in three jurisdictions (McDougall and Walsh 2007), and wetland vegetation of Monaro lakes (Benson and Jacobs 1994) which is included here because of its relevance to natural lowland communities in the ACT. Descriptions covering large areas (Armstrong et al 2013, McDougall and Walsh 2007) incorporate data from earlier studies (Helman et al 1988, Gilmour et al 1987).

Most of these 14 documents give descriptions only, with little consideration of the environmental drivers affecting distribution, except for the following: the importance of altitude, drainage and aspect for determining the species composition of high-altitude plant communities (Helman and Gilmour 1985, Gilmour et al 1987, Helman et al 1988); the influence of slope and geomorphic position on abundance of marginal vegetation in Cotter Reservoir (Roberts 2006a). Two documents define plant communities using woody species only, although non-woody species are also recorded (Gilmour et al 1987, Helman et al 1988). Most of these 14 documents note species that were considered unusual or rare at that time.

The documents use three approaches: survey, which means numerical analyses of quantitative floristic data to determine plant communities, collected from sites distributed according to a structured sampling design; mapping, which means interpreting aerial imagery to determine homogenous vegetation units which are ground-truthed and sampled (or simply described) for characteristic structure and species; typology, which means using field observations rather than quantitative methods or image interpretation to recognise and describe plant communities.

Six of the documents use survey (Armstrong et al 2013, Benson and Jacobs 1994, Gilmour et al 1987, Helman and Gilmour 1985, Helman et al 1988, McDougall and Walsh 2007); four use mapping (Eco Logical 2014, Johnston et al 2009, Barlow et al 2005, Peden et al 2011); two rely on typology (Barrer 1992, Roberts 2006a); and two are different (see below).

Study areas range in size from small and local, such as an 8 km stretch of the lower Molonglo River (Barrer 1992) and a 40 ha freshwater marsh (Barlow et al 2005) and 201 ha of a modified floodplain (Eco Logical Australia 2014), through to 1.74 million ha of a large river catchment, the upper

Murrumbidgee (Armstrong et al 2013). Hence, descriptions are pitched at various spatial scales. Study areas are quite diverse as habitats: large lowland rivers (Barrer 1992, Johnston et al 2009); main upland rivers (Peden et al 2011); margins of an upland storage (Roberts 2006a); a modified lowland floodplain and its backwaters (Eco Logical Australia 2014); small lowland sedgeland (Barlow et al 2005); treeless landscapes at high altitude (Helman and Gilmour 1985, McDougall and Walsh 2007).

The level of detail and hence the information value varies between the three approaches. Survey, with its emphasis on sampling design and use of numerical analyses, provides the most detail on species composition and relationships between communities: this objectivity is essential when producing definitive descriptions of plant communities over large areas (eg Armstrong et al 2013, McDougall and Walsh 2007). At the other extreme, typology provides the least detail, partly because it is observational so potentially subjective, and partly because the plant communities so described tend to be near mono-specific stands or patches. Six of the documents provide maps of plant communities (Eco Logical 2014, Helman and Gilmour 1985, Johnston et al 2009, Mulvaney 2012, Peden et al 2011, Roberts 2006a); four provide precise records of sampling (ie quadrat) location – or at least as precise as was feasible prior to availability of hand-held GPS and satellite technology (Armstrong et al 2013, Gilmour et al 1987, Helman and Gilmour 1985, Helman et al 1988); and two provide no maps and no detail of plant community distribution within their study area (Barrer 1992, Benson and Jacobs 1994).

The last two documents in this subject area are slightly different. One is a rapid scan of aquatic macrophytes in Ginninderra Creek upstream of Lake Ginninderra (Nazer 1973), and the other is a spreadsheet summarising all the vegetation units used in vegetation mapping of the ACT (ACT 2018).

For the scan of Ginninderra Creek, Nazer (1973) focuses on aquatic species (rather than plant communities) considered likely to become problematic downstream in the (then) new urban lake, Lake Ginninderra. Twelve species are noted and presented by growth form: floating anchored (2 species), submerged anchored (1 species), emergent aquatic (9 species) and two algae (2 species, charophytes). Species occurrences are poorly recorded, being simply names typed onto a map. Species abundance is described qualitatively as ‘extensive’ (eg *Potamogeton tricarinatus*, *Myriophyllum propinquum*, *Typha domingensis*), ‘considerable’ (*Chara*, *Nitella*), ‘localised’ (*Ottelia ovalifolia*) or ‘limited’. This survey could have been of considerable interest but its historical value is constrained by its timing (early winter which is out of season for plant survey), by the state of the creek (most tributaries dry: main stem reduced to long pools) and by inadequate documentation (it names no sites and gives no site locations).

The spreadsheet (ACT 2018) is included here, although it is not strictly a text document, because of its relevance and because it covers the whole ACT. There is a web-based version of this vegetation map available on the ACT Government geospatial platform ***ACTmapi,*** based on extensive surveys and mapping projects, including some listed here (notably Armstrong et al 2013). The spreadsheet gives details for each mapping unit such as vegetation code and name, dominant species, structure and formation to which each mapped unit belongs, and area for over 12,000 mapped polygons. The vegetation classification recognises two of the seven formations as riverine and wetlands

(Freshwater Wetlands, Forested Wetlands): these comprise eight plant communities, of which only three are non-woody: "Fen Sedge – Small River Buttercup- Common Reed aquatic herbfield of waterways" (code = a9), "Freshwater sedge-herb marsh of shallow, commonly inundated wetlands "(code = L12) and "Aquatic fringing vegetation" (code = AFV): all three are in the freshwater wetlands formation. Many of the mapped polygons for these three plant communities are small to tiny, less than 1 ha. "Fen sedge – small river buttercup – common reed aquatic herbfield of waterways" has the largest patches, some bigger than 20 ha. "Freshwater sedge-herb marsh of shallow, commonly inundated wetlands" is the rarest, with just two mapped polygons, both just under 0.5 ha. "Aquatic fringing vegetation" is the most common, present in multiple places (150 polygons) but always as small areas (max = 4 ha).

Not surprisingly given the subject area, these 14 documents contribute substantially to knowledge about occurrence and distribution of species and communities. This information is given in various ways: maps showing sampling sites (Armstrong et al 2013), species (Nazer 1973) or communities (ACTmapi); tables showing species occurrence by mapping unit (Eco Logical 2014, Johnston et al 2009); tables showing quadrat geo-coordinates (Helman and Gilmour 1985); habitat descriptions for communities (Armstrong et al 2013, Benson and Jacobs 1994, McDougall and Walsh 2007); and general text description (Barrer 1992, Roberts 2006a).

3.5: Peatlands and restoration

The 15 documents in this subject area have two themes: a description of peatlands, their floristics and development; and the restoration of peatlands, learning through experiments following catastrophic wildfires in January 2003. There are almost certainly more documents than this project located, including several referred to by Hope (2006) and Whinam and Chilcott (2002). The 15 documents include two that contribute to other subject areas: *survey and mapping* (Helman and Gilmour 1985), and *threats* (Guja and Brindley 2017).

The descriptions of the floristics and ecology of peatlands show a progression from original studies with sampling sites either entirely (Helman and Gilmour 1985, Hope 2006) or partly in the ACT (Whinam and Chilcott 2002) to syntheses over large geographic areas, with ACT peatlands becoming a relatively smaller and smaller part of peatland diversity across Australasia (Whinam et al 2003, Whinam and Hope 2005). There are also more general descriptions, such as main types of peatlands in the ACT, and descriptions of particular sites (Hope 2006, Hope et al 2009), maps of peatlands extent (Hope et al 2009), and descriptions of peatlands as functioning ecosystems in the ACT (Hope et al 2009) and NSW (Hope et al 2012).

Recovery of burned bogs and fens became a significant management issue for three jurisdictions (ACT, NSW and Victoria) following the 2003 bushfires. A long-term inter-state experimental program was set up to determine the most effective techniques and strategies to accelerate recovery, particularly of *Sphagnum*, as the dominant characteristic and keystone species. That program brought together experts from ACT and Tasmania. As far as could be determined by the search method, there was a progress report (Macdonald 2009) but no final report. There is information about the experimental design, and some results with varying amounts of detail and analyses at various times: after 3 years (Hope 2006), after 4 years (Whinam et al 2010), and after 13 years (Hope et al 2016). The important roles of hydrology and UV are highlighted separately (Good et al 2010a, Good et al 2010b). Recently, an assumption made by many restoration practitioners, that Sphagnum Bogs and Fens form viable seedbanks, has been tested in a burial experiment involving 13 species including three non-woody 'wetland' species (Guja and Brindley 2017), and found to be sound.

The strategies found most effective for restoring ACT bogs and fens have strong parallels with restoration approaches useful for restoring restiad bogs in New Zealand, and for restoring bogs and peatlands elsewhere across the world, as described in a comparative synthesis paper (Clarkson et al 2016).

The recent wildfires of January–February 2020 burnt several high-country bogs and fens in the ACT, and a rapid appraisal rated the risk to these assets as 'extreme' (ACT/NSW Rapid Risk Assessment Team 2020); no field report has been located.

3.6: Condition

Of the six documents in this subject area, only one considers the condition of non-woody riverine or wetland plants and communities in the ACT (Wild and Magierowski 2015). The other five are about riparian zones (four) or catchments (one), and they are included here because riparian condition directly affects in-stream functioning and condition.

Wild and Magierowski (2015) include *current state* as the third part of their VPSIRR framework (Vulnerability – Pressure – State – Impact – Risk – Response) for managing alpine Sphagnum bogs and associated fens. Current state means condition in a functional sense, which emphasises bog and fen attributes related to biophysical processes, as well as more conventional attributes such as structure, floristics and weediness. Five condition states are recognised (based on work by Roger Good), ranging from good to highly disturbed (terms applied by this author). As far as can be determined in this project, these ideas have not progressed to become a condition protocol or to be applied to any field sites.

The four documents on riparian condition consider woody and non-woody species (Douglas 1996) or woody vegetation of major rivers such as the Murrumbidgee, Naas, Cotter, Gudgenby, Paddys and Molonglo rivers (Johnston et al 2009, Peden et al 2011), as well as major and minor streams in the Upper Murrumbidgee catchment (Douglas 1996, O'Reilly et al 2020). The attributes and scoring systems used are broadly similar but subtly different. The site-based assessment devised by Douglas (1996) uses abundance and diversity of plant growth forms in the riparian zone but does not include in-channel plants; the polygon-based assessment of Johnston et al (2009) for the Murrumbidgee River combines nativeness of each vegetation stratum, weed abundance, regeneration and fire damage; Peden et al (2011) modify that assessment to focus on structure and extent rather than species or nativeness. The Upper Murrumbidgee Waterwatch (O'Reilly et al 2020) use RARC (Rapid Appraisal of Riparian Condition), which is a widely accepted protocol that focuses on the functional role of the riparian zone in riverine ecology. Outputs are available in map form for two of these (Johnston et al 2009, Peden et al 2011) but are apparently lost for one (Douglas 1996).

The sixth document in this subject area establishes a baseline and considers condition of alpine areas (Worboys and Good 2010). Individual sub-catchments are categorised, based on what is known by field staff across three jurisdictions, as being in *good*, *moderate* or *poor* condition and as showing an i*mproving*, *declining* or *no change* trend in condition. Condition is based on six areas of management concern, two of which deal with vegetation attributes, and is presented in the form of maps (eg Figure 3.3 and 3.4, Worboys and Good 2010).

A characteristic of these six condition appraisals is their extensive coverage, either in the form of maps (Johnston et al 2009, Peden et al 2011) or via the large number of sites such as 235 sub-catchments in the Australian Alps (Worboys and Good 2010), and 374 and 219 sites in the Upper Murrumbidgee catchment (Douglas 1996, and O'Reilly et al 2020 respectively).

3.7: Threats

The 11 documents in this subject area address three types of threats to riverine and wetland species and communities: climate change (3 documents), impact of non-native fauna (2 documents), effect of development (3 documents). Resilience is included here because it is the capacity to recover from disturbance and threats (4 documents). One document (Satyanti 2017) contributes twice, to climate change and to resilience, but is only counted once in the documents total (Table 1).

Climate change is considered by modelling and by experimentation. Modelling explores the likely effects of different climate scenarios on wetlands in the ACT (Cowood et al 2017), and considers the thermal range of a suite of 151 species that includes several non-woody riverine and wetland species (Mackenzie et al 2019). Experimentation tests the germination responses of 39 alpine species, including a few non-woody 'wetland' species, to two temperature regimes crossed with two 'winter' durations and the results are interpreted as three germination strategies (Satyanti 2017).

Two of the documents focus on the effects of **non-native fauna** on riverine and wetland vegetation: one on Common Carp (Swirepik 1999) and one on feral horses (Robertson et al 2015). The experiment testing the effect of Common Carp uses large outdoor ponds and finds that compared to well-established plants, regenerating plants of *Potamogeton tricarinatus* are more sensitive and vulnerable to disturbance by benthivorous carp (Swirepik 1999). Robertson et al (2015) compare the condition of alpine streams in treeless areas where horses are present with streams in areas with no horses. Four of the 186 study sites are in the ACT. (Note that there are other documents on Common Carp and on feral horses but they are not included in this appraisal because they do not have sites in the ACT.)

Development, as used here, means any construction or expansion or modification of infrastructure. Just three documents address effects of development. One suggests options for mitigating the effects of urban development on a significant lowland wetland (Barlow et al 2005); one scopes the likely effect of drawing down Cotter Dam on littoral vegetation, believed to be important habitat for the endangered fish Macquarie perch (Roberts 2006b); and one uses the abundance (as area) of selected species of macrophytes as indicators to monitor possible effects of urban development on ecological values of a small tributary to the Murrumbidgee River (Roberts and Sharp 2020).

Four documents use seed and seed bank studies to explore **resilience and persistence** of wetland plants in three habitats: alpine Sphagnum bog and fens (Guja and Brindley 2017, National Seed Bank undated); alpine Australia (Satyanti 2017); and constructed wetlands in suburban Canberra (McGrath 2019).

Some of the documents in this subject area (eg on climate change, and on resilience) contribute original information to knowledge of riverine and wetland plants, but this knowledge is somewhat skewed to particular habitats.

3.8: Miscellaneous

Two documents do not readily fit into any of the above subject areas ('Miscellaneous' in Tables 1 and 2). Each targets a type of aquatic system (chain-of-ponds) or group of plants (submerged river plants) little considered in other documents.

Chain-of-ponds is a type of stream or river, characteristic of the Southern Tablelands, that has been much degraded or irreversibly changed as a consequence of European settlement. Although this document is mainly about hydrology and geomorphology, it describes the ponds as habitat, and names the principal plant species typically occurring there some 45 years ago (Eyles 1977). The second document makes a few observations on the distribution and abundance of two species of in-stream plants, *Isolepis fluitans* and *Vallisneria* sp, in the Molonglo River upstream of Lake Burley Griffin: this is part of Environmental Impacts Statement for Googong Dam (Russell 1973).

4: Discussion

4.1: General

State of knowledge: According to this project, the knowledge base for riverine and wetland plants in the ACT is biased towards occurrence and distribution and away from ecology and environmental relationships. That implies that such knowledge or expertise needs to be imported from elsewhere. Further, this project finds there is a real role for fine-scale vegetation mapping: a small but strategic library of fine-scale mapping of particular riverine and wetland habitats would contribute to general ecological knowledge of lentic and lotic systems. Implications and possible consequences of sparse knowledge about occurrence and distribution of inconspicuous species are explored below.

Occurrence and distribution of species and communities is the type of knowledge most evident in these 76 documents. It features in five of the seven subject areas (problem plants, habitat descriptions, aquatic resources, survey and mapping, peatlands and restoration), and is presented in diverse forms, such as maps (eg Johnston et al 2009, Eco Logical 2014), geo-referenced quadrats and sampling sites (eg Helman and Gilmour 1985, Jones et al 1990b), summarised statistics (ACT 2018) and text descriptions (eg Barrer 1992). Occurrence and distribution are given for aquatic systems of various sizes and types, but not all types of aquatic systems are covered. Notable gaps are: small systems such as soaks, springs, temporary streams, and urban aquatic systems. Only some of this information is recent and current: many studies were before 2000.

Two other types of knowledge, *species status* and *environmental drivers*, occur in several documents. *Status of species* is reported in several ways; for example, the risk categorisation of Briggs and Leigh (c1988) is used by Helman and Gilmour (1985), Gilmour et al (1987) and Helman et al (1988); known occurrence within the ACT is used by Mulvaney (2012); and relative frequency at field sites along the Murrumbidgee River is used by Johnston et al (2009; Appendix 1 and 2). Only a Few documents seek to explore *environmental drivers and responses*: Quinn et al. (2011) consider the role of adjacent land use in determining abundance of non-native species; Moore (1992) investigates which aspects of water quality explain the cover of aquatic weeds in Lake Ginninderra; Swirepik (1999) assesses whether numbers of introduced fish account for decline in macrophyte cover; Roberts (2005a) looks at the influence of slope and geomorphic position on the abundance of marginal vegetation in Cotter Reservoir. With the exception of Quinn et al (2011), these are site-specific studies that were not designed to reveal general principles about environmental drivers.

The remaining types of knowledge (Section 1.1) are poorly covered. The single document on *species biology and ecology* is an Honours thesis on *Vallisneria* sp (Moore 1992). Four documents about seedbanks contribute to understanding *resilience and recovery* (Guja and Brindley 2017, National Seed Bank undated, McGrath 2019, Satyanti 2017).

Diversity and Richness: As part of *occurrence and distribution*, several documents provide maps or descriptions of communities at a fine-scale. There are helpful in describing the richness and diversity of riverine and wetland plant communities in the ACT. In nearly all instances, fine-scale mapping and description has been done for a special reason rather than as a planned contribution to regional mapping. Examples of these special reasons are: characterisation of the marginal vegetation of

Cotter Reservoir (Roberts 2006a); description of wetland diversity of Jerrabomberra Wetlands (Eco Logical 2014); description of the ecological values of lower Molonglo River (Barrer 1992). This richness and diversity disappears at a coarser scale such as that used in regional or whole-of-jurisdiction vegetation mapping (eg ACT 2018). The nine in-channel communities recognised by Barrer (1992) on the lower Molonglo River are not evident in current ACT vegetation mapping (ACTmapi); similarly, the nine in-channel plant communities recognised by Johnston et al (2009) along the Murrumbidgee River are just part of a single vegetation type "River She-oak riparian forest on sand-gravel alluvial soil along major water courses".

Such simplifications are inevitable but carry the risk that fine-scale ecological features and inconspicuous elements are forgotten (which is a concern for conservation), or are simply assumed to be present (which is potentially misleading and therefore is a knowledge risk). In addition, some knowledge about habitat preferences (eg pools versus runs on streams, zonation patterns around waterbodies) is lost. Fine-scale vegetation mapping would fill in much-needed detail and build knowledge of particular riverine and wetland habitats and general ecological knowledge of lentic and lotic systems. Ideally these would be carefully selected, and for diverse reasons: representative, explanatory, under threat of change, or high value.

Submerged macrophytes: In field guides and reference books (eg Sainty and Jacobs 2004), species of riverine and wetland plants are generally grouped by growth form. Growth forms range from tall emergent macrophytes such as *Typha* spp and *Phragmites australis*, which are conspicuous, to tiny mat-forming species such as *Elatine gratioloides* and *Glossostigma* spp, and submerged macrophytes such as *Potamogeton crispus* that are inconspicuous. Submerged macrophytes are plants that normally have all their foliage underwater, making them awkward to collect or photograph without specialist gear. Consequently, submerged macrophytes tend to be ignored in field surveys, under-collected, or simply not included in plant community descriptions.

According to the ACT Plant Census, there are 10 species of submerged macrophytes in the ACT, excluding charophytes. Records in Atlas of Living Australia show that six of these have ten or more herbarium or photographic records for the ACT (*Vallisneria australis*, *Isoetes muelleri*, *Potamogeton crispus*, *Ludwigia palustris*, *Ranunculus trichophyllous* and *Potamogeton ochreatus*) and four are poorly documented, with four or fewer records (*Ceratophyllum demersum*, *Isolepis fluitans*, *Egeria densa* and *Potamogeton perfoliatus*). One of these poorly documented species, *Isolepis fluitans*, is used here as a case history for an inconspicuous species of submerged macrophyte to explore the implications and possible consequences of sparse knowledge about occurrence and distribution.

Isolepis fluitans is a sedge, with long (to 1 metre) fine trailing stems, that grows mostly submerged, usually in flowing water; paradoxically, there is also a short, stunted form that is more terrestrial. Little is known about its distribution and status within the ACT. Herbarium specimens are sparse and dated, with just two collecting localities in the Upper Cotter, one for December 1960 and one for December 1987, and no photographic record in Canberra Nature Map or Atlas of Living Australia (ALA). It also occurred in the Molonglo River, where it formed a Closed Sedgeland in the main channel and tributaries of Molonglo River upstream of its confluence with the Murrumbidgee River (Barrer 1992), and was vigorous and healthy upstream of Lake Burley Griffin (Russell 1973). Currently it is present in the Naas Valley, where it is locally abundant in at least two unburnt sites (Naas River, and Grassy Flats Creek: Cover Photo) (pers. obs. October 2020).

This level and quality of information is inadequate for knowing whether *Isolepis fluitans* is stable or not, making its conservation status unknowable, a situation that likely applies to other submerged and inconspicuous plants. Such species may undergo a decline or be lost, without being detected. Even if loss was detected, with this level of knowledge as a baseline, it would be difficult to establish a trend in terms that would satisfy conservation criteria.

The situation in lowland rivers and streams is particularly concerning as many of these have undergone considerable ecological change, due to stock access, prevalence of Common Carp, river regulation, catchment erosion. As these ecological changes are unlikely to be reversed, lowland rivers will remain unsuitable habitats for *Isolepis fluitans* (and for other submerged macrophytes), and upland rivers such as Naas Creek may become regional 'refuges'.

4.2: On using documents

Using publicly accessible documents for evaluating state of knowledge is generally valid except for topics benefiting from technological advances, such as spatial information in particular, where documents are becoming somewhat inadequate. Technological advances since the 1970s mean that species occurrences and distributions are no longer recorded mainly in reports but instead can be logged or photographed and then instantaneously saved into a digital archive. Digital archives, although not problem-free, can save original documents from physical damage and deterioration as can happen in domestic storage (Figure 1).

Technological advances enable a move away from conventional reporting to formats better suited to spatial information. This is a shift in presentation, rather than a trend in activity, and can be misleading. For example, the temporal pattern in number of documents for aquatic weeds (Table 2) shows a decline from several in the 1970s down to none by the year 2000. While that might appear to show the weed problem has been overcome, the situation is actually due to a combination of technological advances, a shift in management emphasis, and redundancy.

As of 2021, responsibility for aquatic weeds is vested in the Invasive Plants Program which is also responsible for controlling aquatic, riparian and terrestrial weeds across the ACT. For its annual reports, the Program draws on geo-spatial technology and prepares web-based maps of weed control activities, with legends: these are in sharp contrast to the text and diagram conventions of the 1970s and 1980s.

Concurrently, emphasis has shifted from problem description (such as rough maps prepared by Evans 1977) to problem control; and from 'nuisance' species to meeting statutory obligations, and pre-emptive strikes. The listed weeds and prescribed species include several aquatic WONS (Weeds of National Significance) such as Alligator Weed, *Sagittaria* and *Salvinia* as well as Yellow Flag Iris and Yellow Water Lily. The principal weeds reported by Evans (1977) and by King and Wotzko (1978) are *Vallisneria spiralis*, *Potamogeton crispus*, and *Myriophyllum verrucosum*, which are all native species. The few WONS species present in the mid-late 1970s were localised in their occurrence in Lake

Burley Griffin, with *Elodea canadensis* and *Egeria densa* in front of Parliament House (King 1979) and *Sagittaria graminea* in Yarramundi Reach (Evans 1977).

Redundancy refers to the fact that the problem of aquatic weeds in Canberra's two biggest urban lakes, Burley Griffin and Ginninderra, effectively disappeared during the 1990s. The exact cause of this decline has not been rigorously explained (Cullen 1991, Swirepik 1999) although it is widely accepted that Common Carp have contributed to this. With this decline, and the loss of the ecosystem functioning of aquatic macrophytes as well as gradual conversion of natural lakeshore to concrete walls, the management issues for these lakes have shifted to managing blue-green algal blooms. Thus, the management of 'aquatic weeds' as recognised in 1970s and 1980s has become redundant.

Figure 1: Value of digital copies of paper-based materials
Condition of original vegetation map for Helman and Gilmour (1985) when retrieved from domestic storage in 2020. This shows the value of timely digital archiving of paper-based materials. Photograph provided by Carole Helman, 2020.

4.3: Historical records

Historical records are valuable, and in various ways.

First, they can be a 'window' into the occurrence of riverine and wetland species some 20 to 40 years ago, and changes since then. The synthesis by Hogg and Wicks (1989) is valuable as an ecological snapshot for the mid-1980s for 58 species across the ACT. However, the information it gives on species distribution and abundance is qualitative and rather sparse, and hence making a temporal comparison is feasible for only a very few species. One such species is Water Plantain *Alisma plantago-aquatica* (native) which appears to have declined. In the 1980s, this was 'Found along creeks and riverbanks in ACT including backwaters of LBG' (Hogg and Wicks 1988) whereas now it is recorded only rarely along creeks and rivers (eg Johnston et al 2009) and not in backwaters of Lake Burley Griffin. Similarly, the emergent macrophytes *Schoenoplectus validus* and *Bolboschoenus medianus* also appear to have declined. In the 1980s these occurred on shores and margins of Lake Burley Griffin but are now no longer evident there. As both species are weak competitors, it is likely these have been displaced by *Typha* spp and *Phragmites australis*.

Second, systematic historical records can inform understanding of broad-scale distribution patterns. The series of habitat descriptions for fish, although not specifically designed to survey in-stream vegetation, provide a solid record of presence–absence at 95 sites on six streams. When all 110 sets of observations are brought together (Appendix 2), the following patterns are apparent: in-stream plants are sparsely and patchily distributed and species richness is very low in most upland streams; the Naas–Gudgenby system is an exception with higher species richness (6 species recorded) and higher, less patchy abundance (present at 41% of sites); species assemblages in lowland creeks differ from upland ones (occurrence of *Potamogeton* spp in Ginninderra Creek). These patterns are certainly worth confirming, and understanding.

Third, historical records with habitat variables can be analysed to explore plant–environment relationships, without the effort of extensive field work, so are potentially useful as a pilot study. The fish surveys listed above under Habitat Descriptions recorded the physical characteristics of each site, such as gradient, flow (estimated or measured), average depth, degree of shading, type of substrate: all these are known to directly or indirectly influence abundance of in-stream vegetation (eg Riis and Biggs 2003, Mackay et al 2003). Although the range of site variables is not comprehensive (no water quality information for example), analysis might produce some ideas on what makes the Naas–Gudgenby system different.

Finally, something can be learned about resilience of species or community by re-surveying sites after a gap in time that includes a series of extreme conditions, such as have occurred since year 2000. The definition of historical records used here (pre-2000) refers to a period some 20–40 years ago, before the extreme disturbances; examples are shown in Figure 2. However, certain criteria must be met if historical records are to be useful as a benchmark. These are: the original methods must be clearly and comprehensively described (ie must be *repeatable*) with dates; location of study sites must be accurately described (be *re-findable*); and the original results must be available. Only 10 of the 39 documents issued before 2000 meet these criteria: six are habitat descriptions in rivers and streams, one is on the Lower Molonglo River (Barrer 1992) and three are surveys of high-altitude vegetation (Helman and Gilmour 1985, Gilmour et al 1987, Helman et al 1988). Results are included in all these except for the high-altitude studies which have large data matrices, unfortunately often poorly reproduced and not very legible: it is assumed the ACT Government holds digital versions of these. Several documents failed to meet these criteria, for various reasons such as not having the original results (Douglas 1996), or not giving re-findable locations (Nazer 1973, Hogg and Wicks 1989), or having already changed by 2000 (aquatic weeds).

Whether or not it is worthwhile repeating a survey to make a temporal comparison depends on quality and content of the data, and how it might be used or analysed, and on how strong a statistical inference can be made by a temporal comparison. This varies between the three main historical observations. There are no units of measurement for the nine plant communities described by Barrer (1992); therefore, repeating his work would need to be simply based on field searches, and no statistical analysis. In contrast, quadrat data with species abundances are suitable for more robust analysis. For a comprehensive picture, one approach would be to repeat all historical observations and compile the outcomes into a 'big picture', looking for patterns in systems or plant groups.

4.4: Conclusions

The 76 documents in this appraisal show there is relatively little ecological knowledge about riverine and wetland plants in the ACT. What is known is skewed to one particular area of knowledge, namely *occurrence and distribution.* Although there is some valuable groundwork on *climate change* and *resilience*, the other types of knowledge outlined above (Section 1.2) are lacking. Two of these, *species biology and ecology,* and *critical environmental drivers,* can draw on knowledge from elsewhere, but only to a certain extent, and once priority species have been established: site-specific understanding is still needed to apply that locally to the ACT. The low level of knowledge about *species status* and population trend is a significant gap.

The appraisal reveals an information bias towards aquatic systems that are relatively large, in upland areas, and already reserved. Relatively little is known about riverine and wetland plants in lowland parts of the ACT, such as urbanised and modified streams which are still habitat for aquatic fauna such as iconic platypus, rakali or crayfish. This understanding is needed, because most natural aquatic systems in lowland ACT have been modified or lost through urbanisation, and are subject to considerable anthropogenic disturbances. The effects on aquatic fauna or on ecosystem services appear not to have been well considered.

Equally, very little is known about small or temporary systems in the ACT such as ephemeral creeks, springs and soaks, which are likely to make a distinctive contribution to plant (and aquatic) biodiversity, or unusual types of wetlands such as the elevated bedrock wetlands of the Murrumbidgee River Corridor.

Ways forward

Some ideas are given below for projects or activities to do with riverine and wetland plants and communities. These should not be considered as research agenda which requires more structured consideration and long-term goals. These ideas are a mix of generating new knowledge, or building stepping-stones towards new knowledge: some are field-based and some are desk-top. The projects can be done simply or more intensively as small or large projects, by enthusiasts, researchers, students or citizen scientists, in the field or as desk-top studies.

a: Repeat the habitat description and observations of in-stream vegetation at fish survey sites in ACT rivers, and infer persistence and resilience of in-stream species by comparing with observations from late 1980s-early 1990s.

b: Using records in ALA, define distribution patterns of riverine and wetland plants within the ACT in terms of elevation and bioregion, and across Australia in terms of elevation, bioregion and area of occurrence.

c: Establish what can be learned, if anything, from a time series of photographs, historical to contemporary, about persistence and variability of riverine and wetland plants. Two examples of historical time series are site photographs from fish surveys (multiple sites over decades), and habitat photographs at photopoints used to monitor Lathams Snipe at Jerrabomberra Wetlands, both held by Mark Lintermans, University of Canberra: doubtless there are other historical collections.

d: Document riverine and wetland plant species or communities present in urban and rural lowland streams; and then evaluate these as habitat for aquatic fauna such as platypus, rakali, water dragon and eastern long-necked turtles.

e: Record occurrence of riverine and wetland plant species in small or temporary aquatic habitats typical of lowland ACT, such as soaks, springs, and dams, and determine their biodiversity value.

f: Establish a series of photopoints and a monitoring protocol to test ideas of persistence in different types of aquatic systems, natural and modified, small and large.

g: Fine-scale mapping (planform, transects or zonations for example) of riverine and wetland plants in smaller aquatic systems such as dams, springs, soaks, temporary creeks, wet meadows in grasslands, constructed wetlands, urban lakes.

i: Using historical data and/or contemporary data for upland rivers, determine the physical characteristics of sites in upland areas which have in-stream vegetation with sites with no-instream vegetation. Is there something distinctive about Naas-Gudgenby system? Data source is historical records for Habitat Descriptions.

Figure 2: Post fire sediment deposits, autumn 2020 and Dry and desiccated aquatic habitats, summer 2019-2020 .
Top Left: Gudgenby River, downstream of Smiths Rd bridge, showing sand and charcoal layered deposit, approx. 1 m deep, 27 March 2020. Top Right: Murrumbidgee River, from Taemas Bridge nr Yass showing extensive fine chocolate-coloured silt-like drapes over sandbars, 21 Feb 2020.
Bottom Left: Side channel of Numeralla River at Numeralla, showing dry hard condition, with dying riparian shrubs in background, 24 December 2019. Bottom Right: Former farm dam on slopes of Mount Majura just prior to completely drying out for first time that locals could remember, 16 January 2020.

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(Documents per Subject Area are in Appendix 1).

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Appendix 1: Documents per subject area

Documents are shown by author(s) only. Full citations are in References at end of main report.

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X: Miscellaneous

Eyles RJ (1977), Russell VS (1973).

Appendix 2: Species names

The table below is a guide to the contemporary names for plant species. Original species names are used in the text.

Name as used in text	Notes on contemporary usage
Myriophyllum propinquum	The genus *Myriophyllum* was revised by Orchard (1985) and *M. propinquum* no longer exists. Specimens that were previously designated *M. propinquum* are now *M. papillosum*, *M. crispatum*, *M. simulans* or *M. variifolium*. There is no automatic translation from *M. propinquum* to any one of these. Observations of *M. propinquum* thus remain ambiguous, unless a specimen was also collected that can be identified. Orchard AE (1985). *Myriophyllum* (Haloragaceae) in Australasia. II. The Australian Species. *Brunonia* 8: 173-291.
Paspalum paspaloides	*Paspalum paspaloides* is now recognised as *Paspalum distichum*
Potamogeton tricarinatus	As part of a revision, specimens known as *Potamogeton tricarinatus* were referred to *Potamogeton sulcatus* or *Potamogeton cheesemanii*.
Scirpus fluitans	Now revised to *Isolepis fluitans*
Vallisneria gigantea *Vallisneria spiralis*	Taxonomy of *Vallisneria* was problematic for several years. It is reasonable to assume that in south-eastern Australia, records of *Vallisneria spiralis* and of *Vallisneria gigantea* are probably *Vallisneria australis*, an Australian species.

Appendix 3: Summary of fish habitat descriptions

This is a summary of the information on in-channel riverine and wetland (R & W) species as recorded in seven descriptions of fish habitat, covering five rivers: four are upland (Cotter, Paddy's, Naas-Gudgenby, Tidbinbilla) and one is lowland (Ginninderra). Surveys were done over summer, mostly in late summer for upland sites. Species names are as per original documents. Rows 1 to 9 summarise species records per survey; Rows a and b are derived information.

Table A3: Summary of aquatic macrophytes recorded in fish habitat descriptions
Rows 1 to 10: number of sites per survey where each R & W species was recorded.
Rows a and b: number of R & W species per survey, and the percentage of sites with R & W species present per survey.

	Study Area	**Cotter - Upper**	**Cotter – Upper**	**Cotter – Lower & Paddy's**	**Ginninderra Ck**	**Naas-Gudgenby**	**Tidbinbilla**
		upland	**upland**	**upland**	**lowland**	**upland**	**upland**
	Authors	Ingwersen and Ormay (1988).	Lintermans and Rutzou (1990b)	Lintermans (1993)	Lintermans et al (1990b)	Jones et al (1990b)	Rutzou et al (1994)
	Sampled	***February 1988***	***Feb-Mar 1988, Jan-Feb 1989***	***Feb to May 1992***	***December 1988***	***Dec 1986 to Feb 1987***	***Feb and May 1992***
	Number of sites in survey	**15**	**28**	**16**	**13**	**22**	**16**
1	*Glossostigma*					1	
2	*Gratiola latifolia*	2				3	1
3	*Myriophyllum propinquum*	3	4	1		5	
4	*Potamogeton crispus*				1		
5	*Potamogeton ochreatus*					3	
6	*Potamogeton ??sulcatus*				1		
7	*Utricularia dichotoma*					1	
8	*Veronica anagallis-aquatica*					1	
9	*Myosotis sp*	1					
10	Unspecified				1		
a	**Number of R & W species in survey**	**3**	**1**	**1**	**3**	**6**	**1**
b	**Number (and %) of sites with R & W species**	4 (26.7%)	4 (14%)	1 (6%)	3 (23%)	9 (41%)	1 (6%)

Appendix 4: Fish Survey Site Numbers re-aligned

There are two sets of habitat descriptions for the Upper Cotter River: Ingwersen and Ormay (1988) and Lintermans and Rutzou (1990b). Although made at similar seasons and intended to be at the same sites, descriptions were actually on differing dates, using different site numbers, with slightly different content: only Lintermans and Rutzou (1990b) recorded physical characteristics of the site.

Different site numbers could lead to errors and confusion if these sites are re-visited, so the two sets of observations are aligned in the table below. Sites are treated as being the same if: the name is similar; and if altitude is within +/- 15 m of each other; and if mapping corresponds. Observations in sequential years (CS012, CS014, CS015) should be treated as separate.

	Ingwersen and Ormay (1988)		**Lintermans and Rutzou (1990b)**
Site **(altitude)**	**Locality** **Sampling Date**	**Site** **(altitude)**	**Site Name** **Sampling Date**
CS001 1110 m	Cotter R at Rolleys Flat 17 Feb 1988	3 1110 m	Cotter River at Rolleys Flats 18 Feb 1988.
CS002 1095 m	Porcupine Creek 17 Feb 1988	1 1095 m	Porcupine Creek (lower) 11 Feb 1988.
CS003 1060 m	Jacks Creek at crossing on Cotter 17 Feb 1988	4 1070 m	Jacks Creek 19 Feb 1988
CS004 1060 m	Junction Cotter River and Jacks Creek 17 Feb 1988	2 1070 m	Cotter R at Jacks Creek 11 Feb 1988.
CS005 1060 m	Cotter River above Little Bimberi Creek 17 Feb 1988	5 1055 m	Cotter R above Bimberi Creek 19 Feb 1988
CS006 1055 m	Bimberi Creek at Cotter Crossing 17 Feb 1988	6 1055	Bimberi Creek 19 Feb 1988
CS007 1035 m	Licking Hole Creek above Cotter Hut 17 Feb 1988	7 1035 m	Licking Hole Creek (lower). 19 Feb 1988
CS008 1045 m	Cotter River above crossing near Cotter Hut 17 Feb 1988	10 ?? 1030m	Possibly #10. 4 Mar 1988
CS009 1020 m	Cotter River at bridge on Cotter Hut track 17 Feb 1988	12 1015 m	Cotter River at bridge 7 Mar 1988
CS010 1045 m	Pond Creek 23 Feb 1988	8 ?? 1020 m	Possibly #8 . 3 Mar 1988
CS011 1005 m	Cotter River, 1 km below bridge on Cotter Hut Road 23 Feb 1988		*No obvious equivalent*
CS012 975 m	Cotter at Lickhole Track ford near de Salis Creek 23 Feb 1988	22 985 m	Cotter R at Lick Hole Track 10 Feb 1989
CS013 985 m	Cribbs Creek 23 Feb 1988	9 985 m	Cribbs Creek (lower) 3 Mar 1988
CS014 985 m	Gingera Creek 23 Feb 1988	21 990 m	Gingera Creek 10 Feb 1989
CS015 963m	Gallipoli Flat 23 Feb 1988	20 955 m	Cotter River at Gallipoli Flats 3 Feb 1989