



9. Wetland Plants in the Arid NT

Scope

Many wetlands may be dry when surveyed, and it may not be readily apparent that an area is a wetland or where its boundaries are. A good knowledge of the affinities of plants to various wetland habitats can be central in determining the wetland type of a particular wetland or even in determining if an area is a wetland. Developing the use of plant species to identify wetlands and describe their character has been a core element of this inventory.

Perennial plants are the most persistent element of the biota of temporary wetlands and consequently are the most consistently measurable element of the biota. Non-perennial plants may not always be visibly present when a wetland is visited. However, following inundation, non-perennials have an important role in defining the ecological character of some wetlands.

Greater survey effort was expended on plants than on the various animal groups in the field survey, for the following reasons:

- vegetation is often a key attribute in wetland classification and description;
- vegetation can be a key indicator that a dry area is a temporary wetland;
- vegetation is the longest lasting biological attribute of temporary wetlands and therefore can be more consistently surveyed than fauna;
- vegetation provides habitat for various wetland fauna;
- knowledge of the conservation status of plants is sufficiently advanced that some wetland species have rare or threatened status such that their presence is a basis for declaring a wetland as significant;
- many such plant species are small and hard to detect without systematic survey;
- several wetland plants have been assigned a conservation status of 'poorly known' (equivalent to 'data deficient') and systematic survey provided a basis for reevaluation of their status; and
- expertise within the Parks and Wildlife was sufficient to identify species and manage the resulting data through the NT Herbarium.

Goals for vegetation survey during the inventory were to:

- determine characteristic and important species for classification (determining and describing wetland types);
- record characteristics of specific important wetlands;
- add to species distribution knowledge;
- add to knowledge of the habitat preferences of wetland plants; and
- contribute to the NT Herbarium specimen collection.

In this chapter we report on the survey methods used for vegetation and soils, some preliminary results and an outline of planned future analysis. Various ways of classifying wetland plants are considered and an overview presented of characteristic species and groups of species in the arid NT.

Scientific and common names follow the digital checklist based on the *Vascular plant checklist for the southern bioregions of the Northern Territory* (Albrecht *et al.* 1997 and Albrecht *et al.* 1999).

9.1 Methods

Sampling Strategy Within Wetlands

Vegetation was systematically surveyed at a subset of the survey sites. The method used was flexible to be compatible with the overall survey goal of surveying a large number of sites. In order to meet the goals, we aimed to obtain full or representative species lists for whole wetlands and sub-habitats within wetlands. Where time permitted, cover and abundance were recorded using a modified Braun-Blanquet system, as presented in the survey proforma appended to this report. At some sites there was only time for recording dominant and characteristic species. At other sites a full species list was ascertained but without cover-abundance data and not subdivided by sub-habitat. At some large and complex wetlands, a full species list with cover abundance estimates was obtained for various sub-habitats.

Sub-habitats are defined here as zones or patches within a wetland with relatively uniform vegetation and substrate. In some instances sub-habitats corresponded to the different wetland types in the preliminary classification. The spatial patterning of sub-habitats may occur at various scales from patches of a few metres to patches of hundreds of square metres, and the survey method needed to account for this range of scales. The first step in sampling the sub-habitats was to subjectively identify them and write a brief description of their distinguishing features, including dominant species, topographic position, surface soil or rock type and presence of water. In most cases, a sketch map was drawn indicating the patterning of sub-habitats and the surrounding landscape of the wetland.

The size of sampling areas (quadrats) was not standardised. This allowed maximum flexibility in obtaining comprehensive species lists in the least amount of time. Systematic but representative sampling of sub-habitats would have required much more time than was available (e.g. several small fixed area plots in each zone and/or a gradient-transect method).

Vegetation sampling quadrats were positioned subjectively within subhabitats with the aim of recording data that were representative of the sub-habitat. Randomising the position would not have provided any advantage in this type of survey. At some smaller wetlands, the entire area of a particular sub-habitat patch was searched, or the entire extent of a sub-habitat searched. Many sub-habitats were bands that fringed the deepest part of the wetland, such as river banks and the shores of lakes. Where these were only a few metres wide they were observed by simply walking along the sub-habitat and the quadrat approximated a linear transect.

Some effort was expended to incorporate a draft Parks and Wildlife protocol for vegetation survey into the methods for this inventory. However, the draft Parks and Wildlife protocol included attributes that were not required for the wetland inventory and was based on fixed size quadrats of 30 m by 30 m or equivalent. For the wetlands survey a more flexible approach was required to maximise the amount of useful information that could be collected in a short time and from a wide variety of spatial patterns of habitat. Often an area of 30 by 30 m was too small to encompass the apparent variation within a sub-habitat, and in other cases, a 30 by 30 m quadrat incorporated several sub-habitats.

Vegetation structure was briefly described in terms of dominant species, estimated cover and height. At a subset of vegetation survey sites the vegetation structure and condition were recorded using the draft Parks and Wildlife protocols for vegetation survey. This was typically where the layout of the site was compatible with a rectangular plot equivalent to a 30 by 30 metre square.

A more formal method for surveying the variation within wetlands is described by Blackman *et al.* (1992). It includes a standard method for sampling various zones within a wetland, along a transect that intersects the zones. In their terminology a zone or sub-habitat is a 'segment' and the main transect is a 'gradsect'. In a reconnaissance level inventory, such as this one for the arid NT, their detailed method was too time consuming, as it did not allow the correct emphasis on sampling large numbers of wetlands.

Personnel and Species Identifications

A member of the survey team who specialised in botanical survey was available for most field trips (David Albrecht, Jenni Risler or Peter Latz). The unavailability of an experienced botanist for four survey trips meant that staff with general botanical skills conducted the vegetation assessments (principally Angus Duguid but also Jason Barnetson). Their expertise was sufficient to recognise distinct

species in the field and estimate cover and abundance classes, but it was necessary to collect a great many pressed and dried specimens for subsequent identification in the Herbarium (Alice Springs Desert Park). The floristic vegetation data sheets included a column for recording the initials of the person identifying the species.

Soils

For most of the sites where detailed vegetation survey was undertaken, one or more soil pits were dug. The standard depth was 300 mm, but where subsurface clay was expected, further depths were explored. In some cases shallower pits were dug to sample the top 10cm only, such as on the steep banks of watercourses and when there was insufficient time for more thorough sampling. At many sites, each individual sub-habitat was sampled with a separate soil pit.

Where soil pits were dug, the profiles were described including: horizonation, stoniness, presence of calcareous nodules and mottling. A sample was taken from each horizon when distinct horizons were observed. When distinct horizons were not observed, samples were taken at depth ranges of 50-100mm and 250-300mm. The nature and thickness of surface soil cracking was noted.

Texture, presence of carbonates, pH and abundance of coarse fragments were determined from soil samples using the methods described by McDonald *et al* (1990). Soil colour was recorded by comparing soils with colour charts, using the Munsell Colour system. Where time permitted these observations were made in the field; otherwise, they were made in the laboratory from the sample.

Soil conductivity was measured for all samples in the laboratory, as an indicator of salinity. A 1:5 mixture by weight of soil to water was prepared. A precision balance was used to weigh 8g of the aired dry soil, to which 40ml of demineralised water was added, in a small sample jar. The solution was vigorously shaken by hand for 1 minute and the conductivity measured using a TDScan 10/20-conductivity meter and recorded in micro semens ($\mu\text{S}/\text{cm}$). This method was deemed sufficient to indicate general levels of salinity in soils, following advice from soil scientists from the NT Government Natural Resource Assessment Branch (A. Kennedy pers. comm.).

A description including estimated surface soil texture was completed when time did not permit digging a soil pit. Where the wetland was mostly under water, some attempt was made to estimate the nature and/or soil texture of the inundated soil.

9.2 Preliminary Results

Wetland Plant Sub-habitats

Here we present some preliminary observations on the main habitats for wetland plants in the arid NT, referred to in this report as sub-habitats. These are based on observations at survey sites for the wetland inventory. In some cases, sub-habitats correspond to wetland types, but in general, they are at a finer scale and are components within a wetland type. Some of the common sub-habitats are listed below. This is a preliminary and incomplete list, and those sub-habitats that correspond to wetland types are generally not listed below, for example 'bluebush swamp'.

It is hoped that a more detailed account of this subject will be prepared following numerical analysis of the survey data, resulting in descriptions of the various small scale vegetation communities that make up arid NT wetlands.

Open water – fresh and saline – various floating and submerged aquatic plants occur.

Riverine – broad sandy river beds – generally very sparsely vegetated.

Riverine sandy islands with *Eucalyptus camaldulensis*.

Riverine waterholes with rocky substrate and banks.

Riverine waterholes with sandy substrate and banks.

Riverine waterholes with loam or clay substrates and banks.

Moist banks – loam or clay banks of watercourses and waterholes and typically with steep gradient.

Herbaceous herb banks – typically shallow loamy/clay banks of waterholes in north east.

Upper river banks – dominated by *Eucalyptus* species.

Fringing reed beds – *Phragmites australis*.

Fringing Bullrushes (*Typha domingensis*).

Moist fringes of wooded swamps – includes a rich mixture of herbaceous plants including sedges.

Moist edges of inundated bare claypans – various mat forming plants typically occur.

Fringing Coolabah woodland of unwooded swamps and claypans.

Upland fern beds associated with springs.

Upland fern walls – small ledges or cracks in steep sheltered rock walls, with seepage and ferns.

Damp shady upland creeks – support *Callistemon pauciflorus* for example.

Heavy clay pans – typically bare.

Lighter soil pans (sandy clays, clay loams, sand overlying clay) – relatively vegetated.

Stony clay pans.

Gilgais.

Riverine grassy swamps – adjacent to drainage lines or minor floodouts - typically dominated by *Eriachne* species, including *E. benthamii s.lat.*, but also *Imperata cylindrica*.

Sandy fringes of salt lakes – typically with a mix of species including grasses, notably *Eragrostis falcata* and sub-shrubs, such as *Lawrencia glomerata*, *Maireana luehmannii*, *Sclerostegia tenuis* and also *Halosarcia spp.* (Samphire).

Samphire fringes – typically on the edges of salt lakes, subject to inundation and dominated by *Halosarcia spp.*

Preserved Specimens

A huge amount of data was collected for wetland plant species, adding to both distributional and ecological knowledge. Confirmed species records were obtained for 321 sites, including 376 records of threatened, rare or poorly known (data deficient) taxa (269 taxa). Over 800 voucher specimens will be lodged with the NT Herbarium, providing a resource for taxonomic research. A preliminary list of wetland plants has been produced. Valuable distribution data for various weed species was recorded.

New Data for Assessing Conservation Significance

A great many new plant species records have been collected during the inventory. The data will allow the conservation status to be revised for some species. The survey data are also a basis for better descriptions of habitat preferences and threatening processes. A few examples are presented here.

Eleocharis papillosa was listed as nationally rare (R) by White *et al.* (2000a), however it was subsequently reassessed and listed under NT legislation as nationally vulnerable (V). Despite surveying several hundred wetlands for plants, following two years of exceptional rain, only one new location was recorded near Lake Mackay. This confirms its rarity. Searching at Illparpa Swamp could not relocate it and the area where it had previously been found was heavily infested with *Cynodon dactylon*. It was recollected at Stirling Swamp, but *Cynodon dactylon* is actively spreading there also. There is a reasonable case for revising its status to Endangered.

Isotoma luticola is listed as nationally rare (R) by White *et al.* (2000a). It is highly restricted to temporary swamps, but was abundant at several sites surveyed.

Several wetland plants were classified as ‘poorly known’ (data deficient) by White *et al.* (2000a). As a result of the inventory the conservation status of some can be revised. Examples include *Mimulus prostratus* (21 sites) and *Stemodia A57025 Manners Creek* (8 sites including a range extension of 200 km).

9.3 Ecological Attributes of Arid NT Plants

Various ways of classifying wetland plants are explored here as a framework for discussing their general ecology. This draws on observations of the authors including the ground survey component of the inventory, NT Herbarium records and published literature.

Definition of a Wetland Plant

Wetland plants are broadly defined here as plants species that occur more frequently in wetland environments than outside of them because of a requirement for abundant water at some point in their lifecycle. Since many wetlands of the arid NT are temporary it follows that many of the plants that live in them can tolerate long dry periods. Our definition includes all species that have some competitive advantage in, or adaptation to, periodic inundation. This does not mean that all wetland plants can thrive or survive prolonged inundation by water. Many species are killed by prolonged waterlogging or submersion but establish a new generation from seeds or spores during or immediately following inundation. It is not always known which environmental parameters are controlling species distributions. Some species are adapted to physical parameters other than abundant free water but which most often occur in wetlands, for example, saline soils. Thus, some of the species that typically grow on the margins of salt lakes may not have a requirement for abundant water, but nevertheless have a strong fidelity to saline wetlands.

It is also common to find non-wetland plants in wetlands. These are plants that occur widely across the landscape, including in wetlands. In some instances, such plants may establish in wetlands between inundation events but are killed at the next major inundation. Some non-wetland plants are able to survive limited periods of inundation but are nevertheless widespread outside of wetlands.

Our broad definition is in contrast to terms often used for plants in more persistently wet wetlands, such as 'aquatic plant', 'aquatic macrophyte' and 'hydrophyte'. Definitions for these terms and their applicability are discussed below. Most incorporate a stronger relationship with the presence of free surface water than our broad definition.

Pajmans *et al.* (1985) use a definition of temporary wetlands in which the occurrence of waterbirds or 'hydrophytic plants' is an essential criteria. The term 'hydrophyte' is given several definitions by Lincoln *et al.* (1998):

Hydrophyte:

1. Perennial plant with renewal buds below the water and submerged or floating leaves.
2. Any plant adapted to live in water or very wet conditions;
3. A plant requiring a large amount of water for optimum growth.

The third of these definitions comes closest to our broad definition of a wetland plant and could be adapted to further define a '**wetland plant**' in the arid NT as:

plant species that occur more frequently in wetland environments than outside of them, typically because relatively large amounts of water are required for optimum growth, at some stage in their life-cycle.

Fidelity of Wetland Plant Species to Wetlands

Our definition of a wetland plant is based on fidelity of species to wetlands. Those that are more often found in wetlands than in drylands are considered as having fidelity to wetlands. We have developed a coding system for fidelity and have used it to rate some of the arid NT wetland species. The resulting list of arid NT wetland plants is still in a preliminary state.

It is intended to rate species their fidelity with a numerical code of 1 (low fidelity) to 5 (high fidelity) but this task is incomplete. Those coded as 5 are rarely found outside of wetlands and include all aquatic and semi-aquatic plants. Species coded as 1 are often found outside of wetlands but are more likely to be found in wetlands. Plants that frequently occur in wetlands but with no clear fidelity were coded with a question mark '?', indicating that they may qualify for a code of 1 or higher but there was insufficient information to make that decision. Species that require or tolerate temporary waterlogging rather than inundation may have low fidelity, because waterlogged soil occurs at very small scales, scattered

throughout the landscape. Those that require long-term waterlogging have very high fidelity (5) to wetlands, even though they may be rarely inundated.

The assessment of fidelity was somewhat subjective but took into account survey data and Herbarium specimen label information as well as the general observations of the authors.

It is important to note that some species that have a wide distribution across the study area have a higher fidelity to wetlands in the more arid, southern part of the study area and a lower fidelity to the north, where the rainfall is higher and more predictable.

Plant Responses to Abundant Water

Most studies of plants in wetlands have been based in less arid regions than the arid NT, and many are focused on plants that predominantly grow in water. Our definition of wetland plants is much broader; however, the degree to which species live in or rely on surface water is still an important aspect of arid zone wetland plants. Surface water is water standing or running above the ground, during inundation. Those plants which are most reliant on surface water are loosely referred to as aquatics or aquatic macrophytes. Species that do not require inundation and have only limited tolerance of inundation are broadly grouped as 'dryland' (also termed 'non-aquatic' and 'terrestrial'), while species with intermediate requirements for and tolerance of free water are usually called 'semi-aquatic' or 'amphibious' (Aston 1977).

Brock (1994) provides an excellent introduction to the physical and characteristic attributes of aquatic environments as a medium for plant growth.

Definitions of Aquatic and Semi-aquatic Plants

There is no universally recognised definition for aquatic plants (Aston 1977). Lincoln *et al.* (1998) define aquatic simply as:

'living in or near water; used of plants adapted for a partially or completely submerged life.'

Williams defines macrophytes in *Life in Inland Waters* (1983) to include some algae, moss and liverworts, as well as vascular plants, that have their:

'principal food making structures submerged in, emergent from or floating upon bodies of inland water'.

Aston (1977, p.1-2) provides a more detailed definition of aquatic plants and discusses the often imprecise distinction between aquatics and semi-aquatics. Her definition is as follows.

'aquatic species are considered to be those adapted to growing in or on permanent water, either completely submerged or emergent, and having a definite life form (habit, structure) related to this aquatic environment. They are entirely dependent on the presence of permanent water for the survival of the individual plants, and can never be found far from it. When water levels recede, some aquatics may survive on the damp or saturated strand areas either by assuming a suitably modified life form which differs considerably from that shown by the same species when growing in water, or by means of resistant root systems which may allow survival for some months, but generally with a deterioration in the general vigour of the individual plants. With severe and prolonged dryness death occurs. Essentially, existence on damp land may be regarded as a survival mechanism only, and the main life form of the plant is adapted to a permanent aquatic environment. In contrast, terrestrial species are considered to be those which normally occur on damp or near-dry land, and which will survive for only a short time if inundated. They cannot live in permanent water. Between these extremes, environment involving alternate periods of inundation and of partial dryness, their life form remaining essentially unaltered throughout. Hence they are typically found bordering areas of permanent water, in bogs and shallow swamps, and in areas subject to only shallow, seasonal inundation. It is not always possible to decide if a species should be regarded as a true aquatic or as a semi-aquatic'.

A notable feature of Aston's (1977) definition of aquatic plants is the dependence on permanent water. In the arid NT 'permanent' must be replaced by 'long-lasting' for the definition to be meaningful. There are several arid NT plant species which complete all or virtually all of their life-cycle in free water that is not permanent; for example *Ruppia maritima* which only grows in surface water and can become abundant in temporary inundations in salt lakes. There are some species which predominantly grow in very long-term

to semi-permanent water but possibly none that are totally restricted to permanent waterbodies. The aquatic grass, *Phragmites australis*, is one of the species that is most reliant on permanent water, occurring mostly on the fringes of permanent waterholes plus at a few semi-permanent wetlands. Some essentially aquatic species are often found in isolated artificial water bodies, probably due to dispersal by birds, e.g. *Potamogeton spp.*

It is difficult to define semi-aquatic other than as intermediate between aquatic and non-aquatic. Boulton and Brock (1999, p.68) equate amphibious plants with semi-aquatic: '[amphibious plants] are considered semi-aquatics as they live on the margins of wetlands and can be subjected to periods of inundation or drying out'. Brock and Casanova (1997, p.184) define amphibious species as those 'that either tolerate or respond to the presence or absence of water'. The predominance of temporary wetlands in the arid NT means that most wetlands typically dry out completely between filling events. Accordingly, many semi-aquatic plants grow in the beds of drying out wetlands, not just on the margins. Typically these plants will establish and grow in water, following flooding, and continue to grow for some time after surface water has disappeared. Typically, they will then die when conditions become too dry, but occasionally, a subsequent flooding event will occur resulting in a return to an aquatic state.

It may be useful to distinguish those species that can survive without surface water but nevertheless require saturated soil from those that can also tolerate drying out of the surface soil. It may also be useful to distinguish species that require inundation to establish or reproduce from those that can complete their entire lifecycle without inundation, yet may also thrive in conditions of prolonged inundation. The former could be described as 'semi-aquatic' and the latter as 'amphibious', rather than the usage that treats the two terms as synonymous (e.g. Boulton and Brock 1999; Aston 1977). A possible example that meets this definition of 'amphibious' is *Isoetes muelleri* which may only require moist soil to germinate and reproduce. Due to lack of sufficient information about the requirements of individual species, this distinction is not adopted here for arid NT plants.

The following definitions for aquatic and semi-aquatic are adopted here.

Aquatic - grows predominantly in surface water and able to complete its lifecycle in water but may also tolerate limited periods without surface water and may persist in the seed bank of temporary wetlands. Those that quickly deteriorate if water dries up may be regarded as 'strictly aquatic', whilst those with mechanisms that sustain growth for longer dry periods can be regarded as 'generally aquatic'.

Semi-aquatic - mature plants can thrive for extended periods in surface water but can also thrive in drier conditions. Most semi-aquatic species require inundation at some stage of the lifecycle, typically for germination. Plants may be able to reproduce in water. Species that typically produce seeds or spores following drying (post-inundation) out are also included.

Categories of Response to Abundant Water

Many species that are not aquatic are nevertheless adapted to the inundation regimes of temporary wetlands. Adaptations may be in the form of an active morphological or life cycle response to the amount of water present or may be a tolerance of inundation (Brock & Casanova 1997). Similarly, species have various preferences for or responses to waterlogged (saturated) soils.

The life cycle responses to inundation may be classified according to the degree to which species rely on abundant water to germinate, establish and reproduce. Brock and Casanova (1997) identified functional groups based on numerical analysis of survey data from two temporary shallow wetlands on the Northern Tablelands of NSW. Although their study sites were relatively frequently inundated compared to many arid NT wetlands, they contained some of the same species as found in the arid NT, and the analysis is highly relevant to the arid NT situation. Several categories of response to temporary water regimes are listed below and are variously influenced by those of Brock and Casanova (1997).

Establishment for many arid wetland species occurs at the edge of receding water bodies, such as claypans and swamps and these were collectively referred to by Pajmans *et al.* (1985, p.37) as 'herbaceous shore plants'. Inundation probably triggers germination in most of these species, but the actual germination and early establishment of vegetative parts (shoots and leaves) is post-inundation in saturated soil. Wetland species may be grouped according to both the conditions which trigger germination and the amount of water present during actual germination and establishment.

Germination may be triggered by:

- persistent inundation (lasting weeks to months);
- persistently saturated soil (lasting weeks to months); or
- damp soil.

Germination and establishment may occur:

- under water;
- in saturated soil; or
- in damp to dry soil.

Turbidity and depth are also important influences on germination and establishment. Many species will not establish in relatively deep water. In our survey, germinants of *Marsilea sp.* were kicked off the bottom of water up to 1 metre deep, while wading. Germination may have occurred at greater depths; however, we did not sample plants below 1 m depth. *Typha domingensis* does not occur in highly turbid waters such as claypans, where little light penetrates to the substrate. For most species, germination requirements can only be inferred from where they are observed establishing, their topographic position in the wetland and associated inundation regime. Species that only require brief saturation to germinate may do so in response to rainfall, even when runoff is insufficient to substantially inundate a wetland. Such species are likely to also occur outside of wetlands unless other adaptations, such as tolerance of inundation, give them an advantage in wetlands.

The abundance of water that is required for reproduction, or the amount of water that is typically present at reproductive maturity may be useful in classifying plant responses to temporary inundation. Reproductive maturity is defined here as production of seeds or spores. Brock and Casanova (1997) differentiated two categories of surface water depth and two categories of soil moisture for when plants reproduce:

- shallow water (< 10 cm);
- deeper water (>10 cm);
- saturated soil;
- dry soil.

Some species produce seeds or spores in response to drying out, yet they not only establish under water, but also thrive for substantial periods in an aquatic state. Nardoo (*Marsilea spp.*) produce spores in storage tissues at the base of the stems, called sporocarps. In our survey these were only ever found in dry soil and not on plants that were in saturated soil or growing in water.

The amount of water present when plants do most of their growing may also be used to classify species as either:

- submerged in surface water;
- emergent from surface water;
- growing in saturated soil; or
- growing in damp to dry surface soil.

Some perennial wetland species appear to be favoured by reliable and long-term water availability but do not necessarily require saturated soil or inundation. This group includes woody perennials that predominantly grow on the edges of long-term waterholes in drainage lines and some of the relictual fern species that require mesic conditions.

Categories of Tolerance of Abundant Water

Adaptations to temporary water regimes may also be in the form of tolerance (survival) of inundation, rather than active responses to it. Adult plants of some non-aquatic wetland species are relatively tolerant of inundation, giving them a competitive advantage in wetlands, relative to those species which are more

readily killed by inundation. Similarly, some species have various tolerances of waterlogged (saturated) soils. Many annual species germinate in response to inundation and establish at the wet edges of receding surface waters, yet are not tolerant of subsequent inundation if it occurs during their lifespan.

Many species with erect habits are able to tolerate inundation as long as part of the plant remains out of the water (emergent). These include many grasses and other graminoid taxa such as sedges and rushes. Some are perennial and some are annual. Several species of woody trees and shrubs tolerate periods of sustained inundation but not complete submersion. For example, both *Eucalyptus camaldulensis* (River Red Gum) and *Eucalyptus victrix* (Gum-barked Coolabah) tolerate inundation, but *E. victrix* typically occurs in less sandy, more loamy or clayey soils where inundation lasts much longer. Two species of shrubs are common structural dominants in wetlands and tolerate inundation, but not complete submersion, lasting many months: *Chenopodium auricomum* (Northern, Queensland or Swamp Bluebush; Bluebush) and *Muehlenbeckia florulenta* (Lignum). Several *Melaleuca* (Tea Tree) species tolerate some inundation, but presumably only shorter lasting inundation than Bluebush and Lignum since *Melaleuca spp.* are relatively rare across the beds of basins but often occur on the fringes. However, in the survey, healthy *Melaleuca glomerata* plants were observed in surface water that had been present for four to five months.

The following categories may be useful, although they are subjectively derived and not based on survey or experimental data. They are based on the depth and duration of inundation which is tolerated.

Depth of submersion tolerated:

- root zone – waterlogged soil and very shallow surface water (< 5 cm);
- stems substantially inundated, but tops are emergent;
- entire plant submerged.

Duration of inundation tolerated:

- brief (< 1 week);
- moderate (> 1 week);
- long (> 1 month).

Brock and Casanova (1997) state only species that tolerate waterlogging and submersion will survive in the deeper areas of a wetland. They also note that some species or communities can tolerate variable conditions or move in or out of zones depending on conditions. In the arid NT the length of time between inundation events can be a matter of several years or decades, complicating the situation. Long dry periods allow wetland environments to be colonised by plants which do not tolerate inundation and which generally die when inundation reoccurs.

Plants Species as Indicators of Inundation Regime

Plant species that have strong responses to, or tolerance of, inundation have strong affinities to wetlands as opposed to drylands. Distribution records of such species may be a useful tool for mapping wetland distribution and indicating the water regime of individual wetlands. Some species only occur in long-term waterholes or river systems that contain them. Some species that occur in temporary wetlands may require relatively frequent inundation. Little information about these sorts of habitat preferences is available. The information that does exist may be a useful guide to the patterns of inundation that a wetland experiences, but this requires further testing.

Storrs and Finlayson (1997) include distribution maps of some wetland species using NT Herbarium data, as an indication of wetland distribution. The scale of presentation of their maps does not allow assessment of the utility of this approach. As a result of our inventory there is substantially more information about the location and nature of wetlands and new survey records for many plant species. This will allow further exploration of the use of 'indicator plants' as surrogates for other information on inundation regime.

Growth Form and Longevity Categories for Wetland Plants

Growth form and longevity are important ways of categorising plants. Not only do they relate to vegetation structure and other aspects of ecological function, they are readily understood by non-botanists. Characteristics that are pertinent to classifying wetland plants in relation to water regime are defined here, based on definitions applied in '*An Interactive Flora of the MacDonnell Ranges Bioregion*' (Albrecht and others in prep.). In some cases there is a strong correlation between growth form and particular taxonomic groups, such as grasses.

The longevity of plants is described as '*annual*' or '*perennial*'. Annual plants are those which usually live for only one year or growing season before dying with subsequent regeneration from seed. Those that live longer are perennial and can be divided into '*short lived*' (2-3 years) and '*long-lived*'. Boutin and Keddy (1993) included life span (or longevity) in their effort to classify wetland plants into guilds. There is considerable observational information on the longevity of arid NT species but it has not been fully collated.

Woody plants are those that have woody stems or trunks and are all perennial. Trees are tall woody plants and are defined here as follows.

Trees: tall woody plants which grow to taller than 2 m; typically with one or few dominant trunks with major branches well above the base. A single species of palm is included in this group although palm stems are more pithy than woody.

A '*shrub*' is defined here as follows.

Shrubs: woody plants that are smaller than trees and mallees, generally with multiple branches from the lower stem.

Shrubs are typically smaller than trees, however various mallee eucalypts and Coolabah trees (*Eucalyptus coolabah subsp. arida* & *Eucalyptus victrix*) can form very low woodlands of only 2 – 4 metres, even when several decades old. In contrast, some Acacia species can grow as tall shrubs and sometimes as trees.

The distinction between shrubs and non-woody plants is not always straightforward. An intermediate category called '*sub-shrub*' is defined here as follows.

Sub-shrubs: semi-woody plants which are intermediate between shrubs and forbs - generally smaller than 1m tall and somewhat woody at the base but herbaceous above.

All non-woody plants are '*herbs*'; a term which includes grasses, sedges, rushes, ferns and forbs (dicotyledenous herbs). Grasses and grass like taxa such as sedges and rushes may be collectively referred to as graminoid. Some graminoids are tussock forming. Most graminoids have an erect habit, with some important exceptions among the grasses. Grasses with a creeping habit may be stoloniferous, meaning they can develop new roots along the stems.

Some grasses and forbs are very tall, over two metres, and provide considerable structure in wetland vegetation.

Another growth form that is characteristic in some wetlands is succulence. Succulent plants have stems and/or leaves that are fleshy and have very high moisture content. Some, such as *Halosarcia* species are salt tolerant and typically form low succulent shrubs which are woody towards the base. Species of *Halosarcia* can form a low shrubland known as samphire.

Some wetland plants have a characteristic and relatively dense prostrate habit, referred to as 'mat-forming'.

For aquatic and semi-aquatic plants an important aspect of growth form is the location of parts of the plant relative to the water surface. Leaves, stems and flowers may be either:

- submerged;
- floating on the surface; or
- emergent above the surface.

Aquatic and semi-aquatic plants may also be divided on whether they are rooted in the substrate or free floating. In the arid NT, all vascular plants are primarily rooted, although some may be able to survive for some time if they subsequently become detached.

Brock and Casanova (1997) grouped growth forms of photosynthetic parts into:

- low-growing (e.g. prostrate);
- upright; and
- floating.

Other Habitat Attributes for Classifying Wetland Plants

Plant species may be grouped according to other aspects of the physical environment in addition to the water regime and their response to it. The most important is the nature of the substrate. For example, some plants are typically found on sandy soils, whilst others are favoured by clay soils and others by rocky areas. The chemistry of the substrate is also an important determinant of the species that will grow and particularly the salinity. Often the combination of substrate and topographic position within the wetland are the basis for defining habitats (or 'sub-habitats' in the terminology of our survey) which have relatively uniform vegetation.

Numerical analysis from survey data may reveal objective groupings of plants that are commonly found together. Such groups may be called plant communities and are often described in terms of their dominant species. Some species have a relatively high fidelity to particular habitats and are rarely found elsewhere. Thus, for some species, the habitat or plant community provides a basis for classifying them.

The following common broad habitats were used:

- saline habitats;
- aquatic habitats;
- clay soils (typically claypans);
- reliably mesic;
- waterhole margins;
- gypseous habitats;
- other

In the preliminary list of wetland plants the fidelity of species to some common habitats has been assessed. Currently the fidelity is ranked yes, maybe or no. In the future it would be preferable to code taxa from 1 (low fidelity) to 5 (high fidelity).

Classifications Combining Water Response, Growth Form and Habitat

There are various possible purposes for classifying wetland plants. These include understanding ecological function, delineating wetland environments or types and the identification of species. Typically, a variety of aspects of plants and their environment are combined to create useful groupings. Sometime aspects of taxonomy are included such that families or groups of families are distinguished; for example grasses, rushes and sedges may be treated separately.

Sainty and Jacobs in *Waterplants in Australia* (1998) define 7 groups of growth form to assist with identification of aquatic plants:

- free floating in water;
- floating attached;
- submerged or emergent with fine or feathery leaves;
- submerged, not feathery;
- emergent with narrow leaves (non-woody);
- emergent with broad leaves (non-woody);
- trees and shrubs.

Of these categories, only one - free floating - does not occur in the arid NT.

Boulton and Brock (1999) present a functional classification of photosynthetic aquatic producers, based on the following divisions, including growth form:

- suspended and free floating vs. attached;
- microscopic vs. macroscopic;
- rooted vs. not rooted (e.g. macro algae attached to plants or sediments);
- nature of leaves (floating, submerged or emergent) and dependence on surface water.

Rooted vascular plants that can grow in aquatic environments are further subdivided by Boulton and Brock (1999) into:

- floating;
- submerged;
- emergent;
- amphibious; and
- semi-terrestrial.

Additional categories are needed to usefully group all species that fit in our broad definition of 'wetland plant'. The following broad categories (box below) are proposed as useful for arid NT plants. They incorporate growth form characters and reliance on or tolerance of free water.

Aquatic herbs - only grow in surface water, requiring inundation for most of their life-cycle. All vascular aquatics in the arid NT are primarily rooted in the substrate. Any free floating plants are likely to be filamentous algae. Aquatic herbs are grouped for identification purposes into:

- submerged (at least partially) with fine or feathery leaves
(*Myriophyllum verrucosum*, *Ruppia maritima*)
- submerged, not feathery
(e.g. *Isoetes muelleri*)
- floating leaves on water surface
(*Ottelia ovalifolia*, *Nymphaea sp.*, *Nymphoides spp.*)
- emergent aquatic graminoids
(grasses, sedges, bullrushes)

Semi-aquatic herbs - thrive in or out of surface water. They typically require free water at some point in their life cycle, but can survive for some time without free water.

Non-aquatic graminoids - includes grasses, rushes and sedges, many of which have moderately high tolerance of inundation, when they are typically emergent, but they do not thrive indefinitely in water, and so are not semi-aquatic. A few species have prostrate growth forms. Species that require highly reliable damp or saturated soil are included.

Non-aquatic forb - many of these species probably require free water to germinate, including those that germinate whilst seeds are inundated and those that germinate when the free water has gone and typically grow to maturity in saturated or damp soil on the edges of receding waters. These may eventually cover the entire floor of a temporarily inundated basin. This category also includes species that grow in temporarily inundated riverine habitats. The species have a range in tolerance to soil drying and longevity and may be annual or perennial. Species that require highly reliable damp or saturated soil are included, such as relictual ferns. Typically these species grow less than 1 metre tall and many are prostrate. A subcategory of tall growing annuals may form dense stands in some wetlands (tall non-aquatic forbs) with all species being in the pea family (Fabaceae).

Trees that tolerate sustained inundation - non-aquatic.

Shrubs that tolerate sustained inundation - non-aquatic (e.g. *Chenopodium auricomum* & *Muehlenbeckia florulenta*).

Relatively intolerant perennials - various perennial species typically grow on the fringes of wetlands and in very temporary swamps and flood prone flats. Various growth forms are included and provide a basis for further subdivision: trees, shrubs and sub-shrubs. Various wetland types may also provide a basis for subdividing this category such as claypans, waterholes of sandy rivers, waterholes of rivers in clay plains and salt lakes.

9.4 Dominant and Characteristic Plants of Arid NT Wetlands

This section consists of brief descriptions of the characteristic native plants of arid NT wetlands. The aim is to provide an overview of wetland plant species of the arid NT to assist in future inventory and study of wetland ecology.

Some plants are structural dominants that strongly influence wetland appearance. Structural dominants also influence some ecological aspects, especially providing roosting and nesting opportunities for birds. A number of woody perennials are included which are not wetland plants, being widespread in drylands, but are nevertheless characteristic of some wetlands, typically but not always on the fringes.

Species are presented in groups based on growth form and reliance on free water. Some groups are also separated by taxonomic group (e.g. grasses are separated from sedges and rushes). The groupings are fairly loose as some species do not fall easily into them. They are designed to assist non-botanists in developing an awareness of the key wetland plants. A single heading is used for each major growth form of woody perennials (trees, tall shrubs, medium shrubs, low shrubs and sub-shrubs) without subdivision according to tolerance of inundation.

Common names are given where they are reasonably well known or usefully descriptive.

Introduced plant species (weeds) are discussed in chapter 16 on wetland management issues.

Aquatic Herbs

There are about 19 arid NT species that fit our definition of aquatic (see section 9.4). Most of these are floating or submerged in water. Two are tall emergents: a grass, *Phragmites australis* (Common Reed), and *Typha domingensis* (Bullrush or Cumbungi). Another emergent is *Carex fascicularis*, a sedge that grows on the edge of pools along a single permanent stream in the study area (populations outside arid NT may be semi-aquatic). Many of the floating or submerged aquatics are rare and some are only known from permanent or semi-permanent waterholes. Some species included here can persist on wet soil when waters recede, but are included here because they predominantly occur as aquatics and can carry out their entire lifecycle without a dry phase.

Phragmites australis (Common Reed) is a true aquatic that requires permanent water. It is restricted in the arid NT, being only known from the Finke River System in the MacDonnell, Krichauff and James Ranges and from the springs of Watarrka in the George Gill Range. It is the only native water reed in the arid NT (reeds are tall aquatic grasses with hollow jointed stalks).

Myriophyllum verrucosum is the most widespread and common of the aquatic plants in the arid NT. Strictly, it is amphibious rather than a true aquatic, because it can persist in wet soil without free water. However, in the arid NT it is predominantly found growing submerged in riverine rockholes and waterholes with low salinity, and both in permanent and temporary waterholes. It has a feathery appearance and looks similar to another *Myriophyllum* species that is used widely in aquariums (*M. aquaticum*). It does not require permanent water but generally occurs in waterholes where there are semi-permanent or permanent waterholes upstream in the same drainage, from which it can recolonise. In the temporary waterholes of the Davenport Ranges, it progressively colonises the waterholes, from the edges, following wet season flows most summers. There is anecdotal evidence from Peter Latz that fifty years ago it was absent from the upper Finke River (upstream from Running Waters) (P.Latz pers. comm.). Currently it is abundant in those sections, possibly indicating a change in the river to make it more suitable for *Myriophyllum*. However, an old photograph of a waterhole in the Finke River at Henbury by Baldwin Spencer in 1897, shows dense aquatic vegetation which appears to be *M. verrucosum*. Interestingly, it is absent from Illara waterhole, on the Palmer River section of the Finke system.

Ruppia tuberosa is the other submerged aquatic vascular plant with feathery leaves. A monocot, it is widespread but typically occurs in temporary lakes and can tolerate saline waters. At Lake Lewis it was abundant in water with a conductivity measured at 32,000 μ S/cm, which is approaching the salinity of seawater (51,500 μ S/cm). *Ruppia* plants are primarily rooted in the substrate but may be able to persist as free floating plants if they become detached. *Ruppia* plays a vital role in providing food for wetland birds

(P.Latz & R.Jaensch pers. comm.), either as a direct food source or as a foundation for invertebrates. A brief discussion of the distribution and environmental tolerances of *R. tuberosa* and other Australian *Ruppia* species is given by Brock (1985). Brock (1985) also discusses another genus of salt tolerant submerged plants, *Lepilaena*, which does not occur in the NT.

A second species of *Ruppia*, *R. maritima*, is known from the study area but only from artificial waterbodies.

Nymphaea species (Water lilies) are characterised by large rounded floating leaves (lily pads) and lotus like flowers on emergent stalks. In the arid NT they have a highly restricted distribution limited to waterholes in the Barkly Tableland (upper Georgina River system, including the James River), and to Wycliffe Creek at Thring Swamp. There is some uncertainty about the taxonomy of these populations, but the Barkly Tableland species may be *Nymphaea gigantea*, whilst the Wycliffe one may be *Nymphaea immutabilis*.

Nymphoides species are occasionally referred to as water lilies due to a general resemblance to *Nymphaea* species. There are three species of *Nymphoides* known in the study area and all have highly restricted distributions and co-occur with *Nymphaea* spp. *Nymphoides aurantiaca* is known from waterholes in the James River area of the Barkly Tableland. *Nymphoides indica* (Fringed Waterlily or Water Snowflake) is only recorded in the study area from Thring Swamp near Wycliffe Well. *Nymphoides crenata* (Wavy Marshwort) is recorded in the study area from both areas. At least some species of *Nymphoides* can persist for some time on wet mud at the waters edge, so strictly speaking they are semi-aquatics.

Ottelia ovalifolia (Swamp Lily) is an aquatic plant that is restricted to permanent and semi-permanent water. Despite its common name of Swamp Lily, it is not closely related to either *Nymphaea* or *Nymphoides*, being monocotyledonous (along with grasses and sedges). It is very rare in the study area, being restricted to two areas. One is in the Krichauff Ranges, in and around Palm Valley, and the other is in the George Gill Range, in and near Kings Canyon. Typically only a few plants have been observed in an area or waterhole, but hundreds were observed at a series of waterholes in upper Palm Creek in 2001 (D.Schunke pers. comm.). Anecdotal evidence suggests that it mostly grows in summer (D.Schunke pers. comm.).

Two species of *Najas* (water nymphs or naiads) occur in the arid NT; both are submerged aquatic herbs that are usually associated with long lasting water. They are both rare in the arid NT. *Najas marina* is known from two permanent waterholes in the Finke River system. *Najas tenuifolia* is known from a single natural wetland in the study area, a temporary swamp filled from the Elkedra River. It is also known from a dam in the west of the Burt Plain Bioregion. Neither species was encountered during this study.

Two species of Eel grass occur in the study area: *Vallisneria annua* and *Vallisneria nana*. These are monocotyledonous herbs that grow in long-term freshwater environments. In this inventory, *V. annua* was recorded from two long lasting waterholes in the east of the Davenport Ranges, including one in a river system with no known permanent waterholes. It was also recorded in a sparsely wooded floodout swamp to the north of the Davenport Ranges.

Three species of *Potamogeton* (pondweeds) occur in the study area: *P. crispus*, *P. pectinatus* and *P. tricarinatus*. All are strictly aquatic, and are rooted in the substrate with either floating (*P. tricarinatus*) or submerged leaves. However, Brock and Casanova (1997) classified *P. tricarinatus* as amphibious in the NSW New England Tablelands. All three species are strongly associated with long-term waterbodies but do not seem to require permanent water. *P. pectinatus* is only known in the study area from artificial water bodies. *P. crispus* is rare, being only known from four localities: Finke Gorge, Heavitree Gap, the Frew River, and Tarlton Downs Station on the Plenty River (possibly in an artificial wetland). *P. tricarinatus* is relatively widespread with records from the Chewings Range, the north side of Mount Zeil, Palm Valley, the George Gill Range, the Dulcie Ranges and Muranji Rockhole in the Great Sandy Desert (GSD) Bioregion. The occurrence at Muranji is the only record of a fresh water aquatic plant in the NT portion of the GSD bioregion. Muranji Rockhole is known to dry out (e.g. 1996 as reported by Wischusen 1998) as have most waterholes in the George Gill Range but *P. tricarinatus* has been repeatedly observed there, indicating some ability of seeds or vegetative parts to survive without free water. Also, the occurrence of *P. tricarinatus* in open stock water tanks indicates that it is probably dispersed by waterbirds. Accordingly, it is considered as a moderate indicator of long-term water bodies. The continuing presence of *P. crispus* at Heavitree Gap in the Todd River indicates a probable ability of

that species to survive periods of desiccation; either as seed or as dormant vegetative parts. The waterhole in the gap is often dry although the sediments are more often damp than wet; partially due to irrigation (runoff and elevated water table) in Alice Springs. The species was first recorded there following a prolonged wet period in the mid 1970s and was present again following a similar wet period in 2000-2002. The relative rarity of this species in the region counts against the likelihood that it recolonised in 2000-2002, although the possibility of dispersal by birds cannot be discounted. In 2001, Peter Latz searched Boggy Hole thoroughly for *P. crispus* without finding it, although the species has previously been found there. A dense population of *Myriophyllum verrucosum* was present and could have outcompeted *P. crispus* (P.Latz pers. comm.).

Table 17. Summary table of Aquatic Plants

Growth Form / Species name	Reliance on Surface Water	Dicot/Monocot/Fern
Predominantly Submerged Feathery Leaves		
<i>Ruppia tuberosa</i>	strong	Monocot
<i>Ruppia maritima</i> ♣	strong	Monocot
<i>Myriophyllum verrucosum</i>	mod.	Dicot
Predominantly Submerged & Leaves Not Feathery		
<i>Vallisneria annua</i>	strong	Monocot
<i>Vallisneria nana</i>	strong	Monocot
<i>Potamogeton crispus</i>	strong	Monocot
<i>Potamogeton pectinatus</i> ♣	strong	Monocot
<i>Najas marina</i>	strong	Monocot
<i>Najas tenuifolia</i>	strong	Monocot
Predominantly Floating Leaves		
<i>Potamogeton tricarinatus</i>	strong	Monocot
<i>Ottelia ovalifolia</i>	strong	Monocot
<i>Nymphaea gigantea</i>	strong	Monocot
<i>Nymphaea immutabilis</i>	strong	Monocot
<i>Nymphoides crenata</i>	strong - ?mod.	Monocot
<i>Nymphoides aurantiaca</i>	strong - ?mod.	Monocot
<i>Nymphoides indica</i>	strong - ?mod.	Monocot
Emergent		
<i>Carex fascicularis</i>	strong in arid NT	monocot (sedge)
<i>Phragmites australis</i>	v. strong	monocot (grass)
<i>Typha domingensis</i>	strong-mod.	monocot (bullrush)

♣ = Australian native but only known from artificial water bodies in the arid NT

Semi-aquatic Herbs

Semi-aquatic plant species are defined here as those for which mature plants can thrive for extended periods in free surface water but can also thrive in drier conditions. Inundation is required for some stage of the life cycle, typically including germination. There is a clear distinction between semi-aquatics and other species that require inundation to germinate and may tolerate some subsequent inundation but do not thrive in water. However, for many species there is insufficient ecological knowledge to determine whether they are semi-aquatic or non-aquatic wetland plants.

Marsilea species (Nardoo) are semi-aquatic fern allies with distinctive fronds shaped like clover leaves, which may be emergent or floating during inundation. Seven species are known in the arid NT. They are mainly distinguished from each other by their reproductive structures, which are called sporocarps and are located towards the base of the fronds. One species, *M. latzii*, is moderately salt tolerant and is rare. Many of the species readily grow in highly temporary water bodies such as very small clay depressions;

however, *M. mutica* may favour longer term and more frequently inundated wetlands. Standing water is probably required for the spores of all species to germinate, and many or all species thrive in shallow water for extended periods of many months.

Isoetes muelleri is a fern-like plant that is semi-aquatic or amphibious (Cowie *et al.* 2000) but has more of the appearance of a grass. It may not require free water to complete its life cycle.

Bolboschoenus caldwellii is a semi-aquatic sedge that may require permanently waterlogged soil. It is rare in the arid NT, known from just four places.

Pseudoraphis spinescens (Swamp Grass, Spiny Mudgrass, Water Couch) is a semi-aquatic grass that floats on the surface of water in fresh water swamps and riverine pools. It can form dense swards on the banks of waterholes and can be easily confused with the invasive weed *Cynodon dactylon* (Couch or Lawn Couch).

Eragrostis australasicus (Swamp Canegrass) is a structural dominant of some wetland habitats of claypans and swamps, forming large, sometimes tangled clumps, typically about 1.5m tall. It is particularly characteristic of stony claypans in the south west.

Persicaria lapathifolia is common in sandy rivers of the MacDonnell Ranges Bioregion, to which it is restricted in the arid NT. It is erect with fleshy stems and happily tolerates inundation in temporary waterholes. According to Peter Latz, this species was absent from the upper Finke River before fifty years ago but is now abundant in the Finke, Hugh and Todd Rivers. The species was collected by Winkworth in 1954 at Palm Valley. Interestingly, like *Myriophyllum* it is absent from Illara waterhole, a permanent waterhole on the Palmer River tributary of the Finke.

Rotala species are typically found in damp soil adjacent to water and occasionally in shallow water. It is assumed that they germinate in response to inundation and reach maturity after water has receded. The degree to which they can thrive in water is unknown, and it is likely that some or all species do not qualify as semi-aquatic under our definition.

Table 18. Summary table of Semi-aquatic Plants

Growth Form / Species name	Initial Reliance on Surface Water	Dicot/Monocot/Fern
Predominantly Floating Leaves in Aquatic State		
<i>Marsilea spp.</i> (7 species)	strong	Ferns
<i>Pseudoraphis spinescens</i>	?strong	monocot (grass)
Emergent in Aquatic State		
<i>Bolboschoenus caldwellii</i>	?	monocot (sedge)
<i>Eragrostis australasicus</i>	?	monocot (grass)
<i>Eriachne benthamii</i>	?	monocot (grass)
<i>Juncus spp.</i>	?weak	monocots (rushes)
<i>Persicaria lapathifolia</i>	?mod.	Dicots
Erect Leaves – Submerged or Emergent in Aquatic State		
<i>Isoetes muelleri</i>	mod. - ?weak	Fern
<i>Rotala spp.</i>	mod. - ?weak	dicots

Non-aquatic Graminoids - Sedges and Rushes

Sedges (Cyperaceae) and rushes (Juncaceae) are grass like plants (graminoids) that are not members of the grass family (Poaceae). Some are quintessential wetland plants, growing as emergents from water, whilst others occur on the fringes of wetlands and in areas where water has receded. They typically occur in freshwater wetlands but a few tolerate some salinity. Some sedges (Cyperaceae) do not grow in wetlands at all. Here, three other monocotyledonous families are included loosely under 'non-aquatic graminoids': Typhaceae (bullrushes), Juncaginaceae and Eriocaulaceae (pipeworts).

Typha domingensis (Bullrush or Cumbungi) is the tallest member of this group and is a true aquatic plant. It occurs in long-lasting fresh water wetlands, but as it appears to be a good coloniser, it does not necessarily indicate permanent water.

The group known as rushes has one genus in the arid NT: *Juncus* (Juncaceae) with 4 native species (and two introduced ones). *Juncus* species are semi-aquatic. All of the native *Juncus* spp. are moderately tall, typically greater than 30cm. In the arid NT all the native species occur predominantly in long-term wetlands and wetlands which experience relatively frequent inundation. *Juncus* spp. were recorded in several sandy rivers that were dry on the surface but may have had shallow water tables due to hyporheic flow.

Juncus aridicola (Tussock Rush) and *Juncus continuus* occur in several bioregions within the arid NT. However, populations of both are highly localised. *Juncus kraussii* subsp. *australiensis* is salt tolerant and is relatively common in coastal salt marshes. In the NT it is confined to the MacDonnell Ranges Bioregion where it is relatively uncommon, being restricted to saline and semi-saline environments. *Juncus* A87739 MacDonnell Ranges is probably endemic to the MacDonnell Ranges Bioregion, however, within it is the most common of the four species. All four are only known to the south of 22° latitude.

There are a great many wetland sedges (Cyperaceae) in the study area, and only the grass family has more wetland species (Poaceae). Cyperaceae includes wetland species of *Baumea*, *Bolboschoenus*, *Bulbostylis*, *Carex*, *Cyperus*, *Eleocharis*, *Fimbristylis*, *Fuirena*, *Isolepis*, *Lipocarpha*, *Schoenoplectus*, *Schoenus*, and *Scleria*. The species range in size from a few centimetres to between 50 and 100 cm and encompass a range of requirements for and tolerance of inundation. Some species form perennial tussocks, some have bulbous rootstock from which they can resprout, whilst others are annuals. Some species are widely distributed and are highly characteristic of certain wetland types, whilst others are rare. *Eleocharis papillosa* (Dwarf Desert Spike-rush) is nationally listed as vulnerable and is endemic to the arid NT.

Triglochin (Juncaginaceae) includes three species in the arid NT. These are tufted annual plants found in floodouts and on the margins of claypans. One species, *Triglochin hexagonum*, is moderately salt tolerant.

There are three species of *Eriocaulon* (Eriocaulaceae) in the arid NT. Commonly known as pipeworts, they are distinctive small (< 15 cm) herbs with leaves typically in a rosette from the base and seed heads that form a single tight ball on erect stalks rising above the rosette. Some species in the Top End of the NT may be aquatic or semi-aquatic, but in the arid NT, they are probably all annuals that develop in receding water or wet soil post-inundation.

Non-aquatic Grasses

A great many grass species occur in wetlands. Many species are ubiquitous while some fall within our broad definition of wetland plants. A selection of those that are characteristic of some wetlands and some that are structural dominants are discussed here.

Imperata cylindrica (Bladey Grass) is a structural dominant of a few small swamps and in the arid NT is restricted to a few permanent or near permanent springs in the MacDonnell Ranges bioregion plus the Dulcie Ranges in the Burt Plain bioregion. It apparently has a high requirement for moisture but not inundation and therefore is not listed as a semi-aquatic.

Leptochloa digitata (Umbrella Canegrass) is a tall erect grass found on the edges of waterholes and also in swamps. It can be visually prominent but does not provide dense cover for birds.

Eulalia aurea (Silky Browntop) often dominates the banks of larger watercourses and waterholes and some swamps but is under severe competition from the introduced pasture grass *Cenchrus ciliaris* (Buffel Grass).

Dichanthium sericeum (Silky Bluegrass) dominates some swamps, typically those that are relatively briefly inundated. It also occurs in watercourses.

Several species of *Eriachne* are dominant plants in some wetlands. *Eriachne benthamii* s.lat. (Swamp Wanderrie) forms moderately dense small grassy swamps in parts of the south of the study area. Other species occur in creeks and swamps in the north.

Elytrophorus spicatus (Spikegrass) is a distinctive small erect grass with high fidelity to wetlands, typically freshwater swamps. Another genera of small erect grasses, with high fidelity to wetlands, is *Ectrosia* (Hares-foot Grass) with three species in the arid NT.

There are 22 species of *Eragrostis*, some of which are very common in wetlands including *E. dielsii*, *E. falcata*, *E. setifolia*, *E. basedowii*, *E. cumingii*, *E. elongata*, *E. tenellula* (s.lat), *E. parviflora*, *E. leptocarpa*, *E. kennedyae* and *E. speciosa*.

Other genera of common wetland grasses include: *Themeda*, *Leptochloa*, *Digitaria*, *Cymbopogon*, and *Chloris*.

Sporobolus virginicus (Salt Couch) is a salt tolerant species that is common in coastal salt marshes but only has a sparse distribution in the arid NT, occurring at a few saline springs and on the edges of some salt lakes. *Eragrostis falcata* is the most salt tolerant grass in the arid NT and is a common element in the vegetation of saline wetlands. In saline environments it typically has an annual life-form although it may be perennial in less saline conditions (P.Latz pers. comm.).

Low non-aquatic forbs

There are a great variety of wetland plants that typically establish in moist soil on the edges of receding waterbodies, be they swamps, claypans, river beds, river banks or waterholes. This group includes many species that do not tolerate extended inundation but may require it for germination.

Several species grow flat to the ground and form mats with creeping stems. These include several *Bergia* species, *Elatine* spp. including *E. gratioloides*, *Glinus* spp., *Cressa australis* and *Dentella* spp. *Elatine gratioloides* was classified as amphibious in a study in the New England Tableland of NSW (Brock & Casanova 1997).

A number of non-aquatic wetland herbs are members of the family Asteraceae (daisies) which includes *Centipeda* spp., *Gnaphalium diamantinensis*, *Pseudognaphalium luteoalbum*, *Pterocaulon sphacelatum*, *Sphaeranthus indicus*, *Sphaeromorphaea australis* and some species of *Streptoglossa* and *Pluchea*.

Isotoma luticola is a characteristic wetland plant that is now known to be more common than previously realised, as a result of this inventory. Four species of sundew (*Drosera* species) occur but predominantly *D. burmanni* and *D. indica*. Several species of the family Euphorbiaceae are characteristic of wetlands including *Phyllanthus virgatus*. Other common wetland herbs include several *Alternanthera* spp., *Lotus cruentus*, *Trigonella suavissima*, *Hypericum gramineum*, *Centaurium spicatum*, some species of *Frankenia* and *Goodenia*, *Basilicum polystachyon*, *Mimulus prostratus* and *M. gracilis*, *Peplidium*, *Stemodia*, *Ammannia multiflora* and *Macgregoria racemigera* (Desert Snow).

Persicaria decipiens is known from a single small long-term swamp on the south side of the George Gill Range.

Tall non-aquatic forbs

A group of plants of tall forbs characterise some swamps in periods following inundation, as they thrive in water logged soil, often forming dense stands of over two metres tall. They are all members of the pea family, Fabaceae, and several species are widespread across the study area. *Aeschynomene indica* (Budda Pea) can have a quick life cycle and is often seen as desiccated standing stalks. It has fine, pinnate leaves and highly characteristic small seed pods, which readily snap between each segment. Other tall pea bushes include some species of *Cullen* (previously called *Psoralea*). Not all *Cullen* species have high fidelity to wetlands but most at least have some affinity. *Cullen australasicum* (Tall Verbine) and *Cullen cinereum* (Annual Verbine) are the most characteristic and widespread, sometimes covering large areas of swamp.

Trees

Four species of *Eucalyptus* are by far the most abundant of arid NT wetland trees, dominating the vegetation of most drainage lines and many swamps. They are:

Eucalyptus camaldulensis var. *obtusa* (River Red Gum);

Eucalyptus coolabah subsp. *arida* (Coolabah);

Eucalyptus victrix (Smooth-barked Coolabah); and

Eucalyptus barklyensis (Barkly Coolabah).

E. camaldulensis is the most widely distributed of all Australian Eucalypts. In the arid NT it is almost always associated with water courses and occasionally floodouts, with the size of the trees generally corresponding to the size of the watercourse, but frequently reaching 25 metres. In the arid NT it typically occurs in sandy soils but also on rockier substrates.

E. coolabah, *E. victrix* and *E. barklyensis* are part of the group of species separated from *E. microtheca* (Hill & Johnson 1994). They can be reasonably tall trees in the order of 15 to 20m but often occur with a smaller dominant stand height, particularly *E. victrix*. All three are usually found on clayey or silty soils. *E. barklyensis* is quite distinct, growing mainly on river banks in the Mitchell Grass Downs bioregion and having persistent rough fissured bark. By contrast, *E. victrix* and *E. coolabah* subsp. *arida* have overlapping distributions, occupy similar environments and appear to intergrade in morphology. They are indistinguishable by their fruit, being separated only by the height of persistent bark. *E. victrix* occurs to the north of the tropic of Capricorn. It is essentially smooth barked, with a basal stocking of rough bark, typically only to 1m up the trunk and rarely to 3m (Hill & Johnson 1994). *E. coolabah* extends north of the tropic line but occurs mainly to the south. It typically has rough persistent bark the full height of the trunk and on the major and some minor branches. However, the persistence and thickness of the rough bark is quite variable. Where the distributions overlap there are often but not always intermediate forms with rough bark persisting to various heights on the main trunk. Both species have strong fidelity to wetlands but also occur in non-wetland environments. In the north of the study area, *E. victrix* often occurs in open woodlands on plains that have few other wetland species. Possibly, heavy rainfall events in the monsoon season create sheet flow across the landscape that is sufficient to support seedling establishment. Despite its presence in marginal wetland environments, *E. victrix* was encountered as dominant in many more long-lasting wetlands than the other wetland *Eucalypts*. This may indicate a relatively high tolerance of inundation.

Corymbia flavescens, a species closely related to Ghost Gum, is an emergent or dominant in some of the floodout swamps on the north side of the Davenport Ranges. The species was recorded from two wooded/shrubby floodouts, which are relatively infrequently inundated and which apparently hold surface water only briefly.

Erythrina vespertilio (Bean Tree, Bats Wing Coral Tree) is a frequent but never dominant tree of the bigger watercourses to the north of the MacDonnell Ranges but does also occur away from wetlands.

Lysiphyllum gilvum (Bauhinia) occurs next to waterholes and other riverine habitats in the north of the study area. It usually co-occurs with other species such as *Eucalyptus barklyensis* and *Acacia georginae*.

Livistona mariae subsp. *mariae* (Red Cabbage Palm) is only known from the Finke River and its tributaries in and near to Palm Valley and downstream to Running Waters. Although this taxon has a very restricted distribution, it is a well known and interesting wetland plant.

Tall Shrubs and Shrubby Trees

Tall shrubs are often features of riverine wetlands and the fringes of swamps and claypans. Occasionally they form an overstorey in temporary swamps. The predominant genera are *Melaleuca* and *Acacia*.

Most species of *Melaleuca* in the study area are strongly associated with wetlands. They are features of wetlands across most of the study area apart from the higher rocky hills and the Simpson Desert (P.Latz pers. comm.). Many creeks have more than one species present and some have three (e.g. *M. dissitiflora*, *M. bracteata* and *M. glomerata* all grow in the same reach of Trephina Creek).

Melaleuca glomerata (Inland Tea-tree) is the most common. It occurs within and on the banks of rivers and creeks, paleodrainage areas, and on the fringes of claypans, swamps and salt lakes. It also forms quite extensive low shrublands on plains in the vicinity of salt lakes and sometimes claypans, in areas that are rarely inundated. This is probably due to its moderate tolerance of salinity and the fact that such plains have a relatively high water table, without being swamps.

Melaleuca bracteata (Black Tea-tree) and *Melaleuca dissitiflora* (Creek Tea-tree) are both associated predominantly with creeks and rivers. *Melaleuca bracteata* occurs only in the MacDonnell Ranges and Burt Plain Bioregions. *M. dissitiflora* is more common in the north of the study area and is the dominant *Melaleuca* species of creeks and rivers in and flowing out from the Davenport Ranges. However, it also occurs in the Petermann Ranges in the far south west of the arid NT and in the Musgrave Ranges in South Australia. It is strongly associated with higher nutrient rocks such as granites and gneisses.

Melaleuca viridiflora (Green or Broad-leaved Paperbark) occurs in the north of the study area and is a co-dominant in a section of the combined floodout of the Frew River and Teatree Creek. It is easily distinguished by its broad leaves and green bottle brush flower spikes. Compared to *M. dissitiflora* and *M. bracteata* it has a lower fidelity to wetlands within the arid NT.

Melaleuca uncinata (Broom Honey Myrtle) is a distinctive species with hooked, needle-like leaves. It has a central and western distribution in the study area, but in this inventory it was only encountered in the Petermann Ranges.

Melaleuca trichostachya (Narrow-leaved Paperbark) is restricted to drainage lines and the banks of waterholes in the MacDonnell Ranges Bioregion. This is the most restricted of the *Melaleuca* species in the study area.

Callistemon pauciflorus is a tall shrub restricted to waterholes of the MacDonnell Ranges Bioregion in the centre of the study area, and the Central Ranges Bioregion, in the south west. It is the only arid NT *Callistemon*; a common wetland genus in south eastern Australia.

Acacia stenophylla (River Cooba) is a low shrubby tree that is the dominant or co-dominant (with *Eucalyptus barklyensis*) overstorey species in a few of the minor creeks in the Mitchell Grass Downs Bioregion. To the north of the study area it occurs extensively in vast swamps of the Barkly Tableland.

Acacia salicina is an overstorey species of some river banks and is a significant component of the floodout 'forest' (thickets) of the Finke River, extending to the South Australian border. It grows to quite a tall tree.

Acacia cyperophylla (Mineritchie) is a distinctive tall shrub or tree with attractive curly red bark. This species almost always occurs in or adjacent to drainage lines. In the study area it has a very restricted distribution: Toko Ranges, Allitera Tableland, and the Stony Plains Bioregion on the South Australian border.

Acacia dolichophylla is a smaller, erect shrub that only grows in minor drainage lines in and below the Chewings Ranges. There is a group of *Acacias* (Wattles) that is common in, and somewhat characteristic of, the drainage lines in the northern part of the study area, although none is restricted to wetlands. They are *Acacia neurocarpa*, *Acacia colei*, *Acacia cowleana* (Halls Creek Wattle), *Acacia holosericea* (Candelabra Wattle) and *Acacia elachantha*. These five related species grow as relatively open shrubs up to about 4 m tall. They can be hard to distinguish, and the diagnostic features are beyond the scope of this report.

Acacia farnesiana, *Acacia georginae* (Gidgea) and *Acacia aneura* (Mulga) are all characteristic species in some wetlands but are also widespread in dryland habitats and are not wetland species under our definition. *A. farnesiana* is a frequent element of river bank vegetation and some swamps, across much of the study area. It is a shrub with dense thorns that appears to be favoured by disturbance, natural or otherwise. Its habitat and pinnate leaves resemble several noxious weeds of the Mimosaceae family (*Acacia nilotica*, *Mimosa pigra* and *Prosopis pallida*), and it is often treated as a weed by landholders. *Acacia georginae* (Gidgea) is a species that is widespread across the landscape in the east of the study area and is frequent along the banks of waterholes and drainage lines. *A. aneura* is an occasional element of the vegetation fringing rivers, swamps and claypans, although it is usually intolerant of extended inundation. It was the dominant species as a tall shrub or low tree in one floodout swamp encountered in

the survey, and in some other swamps, it was the dominant species of fringing vegetation and had apparently been inundated for periods of several months.

Medium Sized Shrubs

There are several wetland species of compact shrubs of medium size (0.5 – 2 m) in the study area. The two with highest tolerance of inundation are *Chenopodium auricomum* (Northern, Queensland or Swamp Bluebush) and *Muehlenbeckia florulenta* (Lignum). Both species predominantly occur in fresh water swamps and sometimes occur with a Coolabah (*Eucalyptus coolabah* and *E. victrix*) overstorey. In the arid NT there are numerous large swamps dominated by *C. auricomum*, and such areas are commonly described as Bluebush swamps. *C. auricomum* also occurs as a minor element in some other swamps. *Muehlenbeckia florulenta* is also widespread but rarely occupies such large areas. *M. florulenta* often occurs in the overflow swamps adjacent to drainage lines and along side channels, where as *C. auricomum* is rarely found along watercourses. *C. auricomum* is possibly more drought tolerant than *M. florulenta*, since many Bluebush swamps often go many years between major inundation events.

Chenopodium auricomum should not be confused with the various species of *Maireana* for which 'Bluebush' is a common name, but which are predominantly dryland species.

Chenopodium nitrariaceum can have a similar appearance to *C. auricomum*, and they co-occur at some wetlands. *C. nitrariaceum* is typically smaller and is distinguished by tangled spinose branch ends. The distribution of *C. nitrariaceum* is essentially restricted to the south west quadrant of the arid NT. It may form the dominant shrub cover over some swamps, but there is little data to confirm this.

Two other species that occasionally form the dominant shrub layer of swamps are *Atriplex nummularia* subsp. *nummularia* (Old Man Saltbush) and *Maireana aphylla* (Cottonbush, Leafless Bluebush). Both frequently occur outside swamps and probably only occur in very rarely inundated areas.

Typical medium to tall shrubs, of drainage systems, include *Myoporum acuminatum* (Boobiella) and *Dodonaea viscosa* subsp. *mucronata*.

Cullen leucanthum and *Cullen walkingtonii* form dense stands in some floodouts and swamps in the north.

Small Shrubs and Sub-shrubs

There are a great many small shrubs and sub-shrubs which occur in or fringing a wide variety of wetland types. Some of the more common and characteristic ones are described here.

There is a group of succulent leafless sub-shrubs of the genus *Halosarcia* (Chenopodiaceae) that dominate some saline swamps, and are often collectively referred to as samphire. Other wetland genera related to *Halosarcia* are *Sclerostegia* and *Tecticornia*. *Sclerostegia tenuis* sometimes grows on salt lake margins and *Tecticornia verrucosa* occurs on fresh water claypans and has a scattered distribution in the western half of the study area. All of the above species are moderately tolerant of inundation and could be classed as semi-aquatic.

Other important chenopod genera in both saline and fresh swamps are *Atriplex*, *Maireana*, *Sclerolaena*, and *Dysphania*.

Lawrenzia glomerata s.lat. is a common on the fringes of saline lakes. *Lawrenzia squamata* also occurs in saline environments and indicates the presence of gypsum.

Ludwigia octovalvis is an erect semi-woody annual that frequently grows on the edges of waterholes in and around the Davenport Ranges.

Teucrium racemosum is a moderately tall growing perennial (> 20 cm) that is abundant in many swamps in the central and particularly the southern latitudes of the study area.

Ferns of Shaded Moist Gullies and Gorges

About eleven species of fern in central Australia are restricted to mesic environments. Most are only known from relatively deep shaded gorges, but a few occur in association with running streams in moderately shaded gullies. Some grow in areas of saturated soil, while others are only known from seepage areas on rock walls with typically just a few plants. These latter are at the smallest end of the size spectrum of wetlands, but the dependence of the ferns on free water justifies their inclusion as wetlands. A few species may not require seepage, only deep shade, and so are not considered to be wetland plants nor indicators of micro-wetlands. Different species and groups of species are found in each moist gorge, and the extent to which this is a result of random survival and dispersal histories, as opposed to habitat differences between gorges, is not known.

Non-vascular Wetland Plants

Non-vascular wetland plants can be important in the overall biological productivity (Bunn & Davies 2001) but were not systematically sampled in survey work. Descriptive comments were recorded at detailed survey sites, concerning the abundance and habit of algae and some specimens were opportunistically collected. Forms of non-vascular plants commonly observed in arid NT wetlands include:

- filamentous algae such as *Chara spp.* and *Nitella spp.*;
- floating slime;
- submerged algal blooms;
- algae that coat rocks and plants stems .

9.5 Vegetation Assemblages

A national perspective on wetland vegetation is important for assessing the conservation importance of regional populations and assemblages. Brock (1994) gives a good overview of the nature and types of aquatic environments for plants in her chapter on aquatic vegetation of inland wetlands, in *Australian Vegetation* (Groves 1994).

Hatton and Evans (1997) review the dependence of Australian ecosystems on groundwater and include a useful summary of the vegetation of broad ecosystems. Information on wetland vegetation of the arid NT can be found in their appendix A, including physiographic descriptions for several broad geographic areas: 'The Central Lowlands and the South Australian Ranges', 'Arid Areas of Uncoordinated Drainage', 'Sandland', 'The Lander-Barkly Plains', and 'The Central Australian Ranges'. Hatton and Evans (1997) also provide broad vegetation descriptions for various wetland vegetation types, based largely on Briggs (1981).

9.6 Conservation Significance of Arid NT Plants

A full list of plants of conservation significance was collated in 2000 (White *et al.* 2000a), which also recorded the occurrence of each species in broad wetland types.

There are 10 species of vascular wetland plants that are endemic to the arid NT or a slightly larger area:

Acacia dolichophylla (R)

Coleocoma centaurea

Eleocharis papillosa (V)

Goodenia A44284 Subsaline (K)

Goodenia D70208 Barkly (K)

Juncus A87739 MacDonnell Ranges (V)

Livistona mariae subsp. mariae (V)

Marsilea latzii (R)

Pluchea A87409 Ormiston (K)

Stemodia A57025 Manners Creek (K)

A further 24 plants that occur in wetlands are endemic to the arid NT or slightly larger area but have unknown fidelity to wetlands.