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Gentiana wingecarribiensis L.Adams (Gentianaceae)

Review of Current Information in NSW

June 2008

Current status:

Gentiana wingecarribiensis (Wingecarribee Gentian) is currently listed as Endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The NSW Scientific Committee recently determined that *Gentiana wingecarribiensis* meets criteria for listing as Critically Endangered in NSW under the *Threatened Species Conservation Act 1995* (TSC Act), based on information contained in this report and other information available for the species.

Species description:

Gentiana wingecarribiensis is an erect to somewhat decumbent, glabrous, short-lived, annual (often acting as a biennial or ephemeral) herb 2.5–12 cm high (single-flowered plants can form buds and flower from *c.* 1 cm high). Stem often purplish or reddish tinged, minutely scabrous above, smooth below (leafless in lower 10–25 mm and basal leaves absent), usually simple or sparsely branched (sometimes many-branched with up to 9 or possibly more branches that each terminate with a single flower). Leaves all cauline, dark green, opposite, *c.* 4–7 pairs, sessile, broad or oblong-ovate, 2–9 mm long, 2.5–6 mm wide. Flowers *c.* 1–9 (taller plants often produce more flowers), solitary, terminal, usually 5-merous, usually opening in succession over a period of 2–3 months from *c.* September/October; opening of the corolla (anthesis) occurs in bright sunlight (photonastic) and/or as a response to change in temperature (thermonastic); calyx 6–10 mm long, with ribs not winged, lobes lanceolate, 2–4 mm long; corolla narrow-campanulate, 10–17 mm long, *c.* 4–11 mm diam., greenish ribbed outside, sky blue (purple- or mauve-blue with cream stripes down tube) inside, with 5 (rarely 4) spreading major lobes 2–3 mm long and smaller folded lobes between them; stipe (floral stalk) 2–3 mm long, elongating in fruit to 15–25 mm long. Fruit a broadly ovoid dehiscent capsule (1–) 4–6 mm long (occurs at the end of the long fruiting stipe), 2-valved with a distinctive flared, 2-lipped apex when open; seeds numerous (up to several hundred per capsule), orange-brown, 0.25–0.35 mm long (Adams & Williams 1988; Harden 1992; Kodela *et al.* 1994a; Adams 1996; Robertson 1997; Kodela 2008).

Taxonomy:

One of four species in Australia, *Gentiana wingecarribiensis* was described by L. Adams in Adams & Williams (1988). The four species belong in *Gentiana* section *Chondrophyllae* Bunge, which is a typically montane and predominantly Northern Hemisphere group, the southern limit being significantly extended by the Australian species (Pringle 1979; Adams & Williams 1988). All four species are rare and endemic to New South Wales (with restricted distributions on the Tablelands) and are considered endangered or vulnerable.

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Distribution and number of populations:

The only known (two) populations of *Gentiana wingecarribiensis* are from the type locality Wingecarribee Swamp, (first recorded in the 1960s and later 'rediscovered' with new interest in 1992), and south-west at Hanging Rock Swamp (discovered at this second location in 1994). Both swamps occur on the New South Wales Central Tablelands, and general distribution maps are provided by Nash & Matthes (1995), NSW National Parks and Wildlife Service (1999), DECC (2005a) and Department of the Environment, Water, Heritage and the Arts (2008). Since the early 1990s the Gentian has been recorded from six main sites (occurring as discrete or very localised patches): four subpopulations on the southern side of Wingecarribee Swamp and two subpopulations at Hanging Rock Swamp (Robertson 1997; Kodela *et al.* 2001b; Parsons Brinckerhoff 2007a; expert advice).

Another subpopulation was reported from 1992 from the north-western side of Wingecarribee Swamp (Parsons Brinckerhoff 2007a), however this site cannot be substantiated.

It appears that *G. wingecarribiensis* was more common and widespread (though possibly still only scattered or sparsely distributed) at Wingecarribee Swamp prior to permanent flooding of the western part of the Swamp for the creation of Wingecarribee Reservoir. The Gentian population at this wetland has probably been reduced to the current small remnants. The small subpopulations are possibly the result of fragmentation in distribution (i.e. there are large areas of unsuitable habitat in the swamp separating sites – being either too wet with tall dense vegetation in intact areas or too dry in collapsed fragmented areas). Fragmentation results naturally from variations in the wetland ecosystem with a diversity of microhabitats, as well as fragmentation caused by human disturbance. The small subpopulations also result from loss and degradation of habitat (e.g. potential habitat lost in the western part of Wingecarribee Swamp from reservoir flooding; past clearing and drainage of swamp margins for agriculture; post-1998 loss of potential ecotone habitat on the collapsed margins on parts Wingecarribee Swamp; and drying of ecotone habitat near collapsed areas where the viability of the sites could gradually decline). Loss and degradation of habitat lead to low germination rates, low viability and/or low seedling survival rate. (expert advice; Kodela *et al.* 1994; Nash & Matthes 1995). The Gentian's population size and distribution on the swamp may have also varied naturally over time depending on climatic factors and moisture levels in the wetland, which would influence the extent of suitable habitat on the swamp (including during the time before the reservoir was established).

Gentiana wingecarribiensis would be considered as a discontinuous or disjunct population with a large gap of mostly unsuitable habitat between the two localities (swamps) where it occurs. *G. wingecarribiensis* has not been found in other wetland areas with potential habitat that have been searched in the Southern Highlands district (Kodela *et al.* 1994a, Kodela & Matthes 1994, Nash & Matthes 1995, Matthes *et al.* 1996, Robertson 1997).

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Ecology:

Key habitat requirements

At Wingecarribee Swamp, *Gentiana wingecarribiensis* has been recorded growing in ecotone areas, mainly within 15 m distance from the swamp margin where the saturated peatland supporting sedgeland, with scattered or patches of low shrubs, intergrades with the surrounding terrestrial grassland/pasture, also often with patches of shrubs. The Gentian occurs mostly in relatively small patches where there is a microhabitat of damp peat or peaty loam to clay loam and a low, open vegetation cover c. 5–60 cm high of predominantly sedges, grasses and other herbs, as well as mosses and nearby shrubs (sometimes described as herbland with scattered shrubs). The soil is damp or occasionally saturated; plants have been reported growing c. 15 cm or more above the watertable and do not grow in standing water. Plants root directly in the ground (sometimes on low rises amongst grasses and other herbs but also in hollows) or occur on low *Sphagnum* moss hummocks. (Adams & Williams 1988; Kodela *et al.* 1994a). A list of associated species is provided by Cohn (undated) and Kodela *et al.* (1994a). The Gentian has also been found in an area of spring-fed wet shrubland/sedgeland (with *Sphagnum* hummocks) perched on the edge of the Swamp, and a rare record of several plants in damp to drying intact remnant peatland. Further information on Wingecarribee Swamp is provided by Hope & Southern (1983), Kodela & Hope (1992) and Stricker & Stroinovsky (undated).

At Hanging Rock Swamp the species has been recorded growing on both the drier margin of the Swamp in the ecotone area and in wetter open hummocky grassland/herbfield in the *Leptospermum* dominated shrubland/sedgeland swamp. One location is between two low spring mounds (soakages formed by underground springs) and a narrow creek, with the Gentian being associated with *Poa labillardieri*, *Isachne globosa*, *Tetrarrhena turfosa*, *Geranium neglectum*, *Hydrocotyle* sp., *Pratia surrepens*, *Viola caleyana*, *Drosera binata*, *Centella cordifolia*, **Trifolium repens*, *Luzula* sp., *Carex* spp., other herbs and sometimes *Sphagnum* amongst *Leptospermum obovatum* and *L. juniperinum* shrubs. Plants have been observed growing on paths made by macropods and amongst grasses and in herbfield cropped short by macropods, as well as on mounds of *Poa* tussocks above the saturated surface. (Kodela *et al.* 1994b, 2008; Kodela & Matthes 1994; Matthes *et al.* 1996; Robertson 1997; herbarium specimen collections).

The ecotone habitats will be dynamic with wetting and drying cycles (responding to climate patterns and altered water levels), that alter the location and extent of the area at different times. Hydrological and moisture regimes in the swamps are therefore important in the way they can affect the Gentian's habitats.

The Gentian is usually restricted to habitat conditions where the vegetation is low in stature and open, and the substrate is not too wet or too dry. Most of the intact peatland areas in Wingecarribee Swamp have vegetation that is too dense with water levels that are unsuitable

* Naturalised/introduced species

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for the species, and there are now large degraded, fragmented and drying areas after the collapse of much of the peatland in 1998. Available moisture would appear to be a significant factor affecting the appearance of the Gentian in its habitat. The quantity, timing, duration, frequency and extent of water available in the habitat could be important, which can be affected by water levels elsewhere in the wetland (Nash & Matthes 1995). Drought may have restricted the appearance of plants above ground in some years.

In the 1990s cattle grazing was observed as a threat to the Gentian, however it also reduced competition from shrubs and groundcovers, hence provided some benefit to the species by keeping the habitat open. Negative impacts of the stock included compaction damage in soft soils next to the swamp and ground distortion from hoof marks, direct trampling and increased nutrients from dung. Without grazing pressure grass and shrub growth is likely to alter the habitat to the detriment of the Gentian since it prefers open areas and does not tolerate competition with taller perennials. Surveys at Hanging Rock Swamp at one site found that growth of grasses on the hummocks where the Gentian plant grew appeared to cause high mortality and low fruit production in individuals that did not survive. The site was kept in check by wombats, kangaroos and goats which grazed over winter, cropping the grass sufficiently for the Gentian to germinate and grow. In spring 1996 the plants only had a short window of opportunity to complete their life cycle before the growth rate of grasses exceeded rates of grazing and the habitat became unsuitable (Robertson 1997). The amount of competition may be a very critical factor influencing the appearance and survival of the species (expert advice).

Wingecarribee Gentian may rely on environmental disturbance to help maintain habitat that is open and free of excessive competition (for resources of space, light, moisture and nutrients) from other species, including possible overcrowding and shading by shrubs. Grazing by kangaroos, wallabies and wombats, as well as occasional fires would have played a role in opening up suitable habitat areas, which was later largely replaced at Wingecarribee Swamp by clearing, cattle grazing and regular burns on the swamp. While fires needed to be stopped and prevented since the major threat they now cause in the drying peatland after the swamp collapsed (and human-induced fires were probably too frequent prior to this), there will be impacts on the vegetation from the current policy of total absence of fire. Likewise, cattle trampling and grazing were seen as major threats to the Gentian in the 1990s (Robertson 1997) and stock was eventually restricted or excluded from most sites (e.g. fencing and enclosures at sites A, B & C at Wingecarribee Swamp), however, this has probably increased the threat of competition from weeds and shrubs at these sites. Disturbance by fire or physical means such as slashing or the re-introduction of stock grazing, in the absence of grazing by native herbivores, may be a necessary management tool to reduce competition with other species (including weeds) and promote an open vegetation structure that provides sufficient light and other habitat conditions for the Gentian (Kodala *et al.* 1994a, 2008). However, the timing and levels of any grazing or slashing regime require careful management and controls that take into consideration the life cycles of the Gentian and nearby endangered species such as the *Prasophyllum uroglossum* (Wingecarribee Leek Orchid) (Kodala *et al.* 2008).

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Life history

Wingecarribee Gentian is an annual or possibly biennial that can also display ephemeral behaviour (i.e. appearing only under suitable conditions), with a potential growing season between August and January. Under suitable conditions seeds germinate and plants emerge between August and October, though new plants can appear later in the season. The cues for germination remain largely unknown, and the seed may require stratification (a cold phase) or a period of after ripening. There may also be a symbiotic relationship with a soil fungal mycorrhiza, as seen in some European species (expert advice). Plants usually flower from September to December, but have also been observed flowering in early January. Flowering can occur in single-stemmed plants a few centimetres high to taller multi-stemmed plants in which the inflorescences can be at different stages of development (i.e. a plant may have buds, flowers and capsules present at the same time). The fruiting capsules and seed appear to mature rapidly within about one month of flowering and the plants wither and die completely within about two months (Kodala *et al.* 1994a). Field surveys have found that plants can emerge between August and January, and they wither and disappear within two to three months of appearance above ground. They take three to four months to complete the above ground part of their life cycle. Habitat quality may affect the number of capsules produced and the longevity of plants in a season. It has also been observed and speculated that plants have timed their reproduction to produce fruit and seed before being smothered and outcompeted by rapidly growing grasses and other herbs in the later part of the season (Nash & Matthes 1995; Matthes *et al.* 1996; Robertson 1997).

An alternative growth pattern could be that the plant occurs as a tiny rosette of basal leaves for sometime before producing (under suitable conditions/when conditions become favourable) a flowering stem (expert advice). When plants have been observed and collected there have been only cauline (stem) leaves present (a feature separating *G. wingecarribiensis* from other Australian *Gentiana* species), so the basal leaves would have withered and been lost by this stage.

Reproduction is by seed only, and *G. wingecarribiensis* produces a relatively large quantity of seed (c. 300 per capsule), which appears to have a restricted distribution (Kodala *et al.* 1994a; Matthes *et al.* 1996; Robertson 1997). However, while seeds are very locally dispersed (reflected by plants growing within the same area as a previous year's population), there may also be some longer distance dispersal by wind turbulence and water movement (Kodala *et al.* 1994a). The viability of the seeds is unknown, and understanding the seed bank dynamics will be critical in management of the species (Nash & Matthes 1995; Matthes *et al.* 1996).

Being a short-lived plant, changes in population size can be dramatic (NSW National Parks and Wildlife Service 1999). For example, over three years one subpopulation at Wingecarribee Swamp (at site B) changed from c. 500, 30, 0 individuals (Table 1). The absence of above ground plants some years implies the species possesses a persistent seedbank and the seeds possess a dormancy mechanism enabling survival through unfavourable conditions such as dry periods, competition and unsuitable years. The failure to

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observe above ground plants in any one year does not therefore mean the population is extinct or absent, as the species may be present as a seedbank. While low population numbers or the absence of plants at sites during recent growing seasons shows the Gentian's vulnerability, there have been past dramatic population fluctuations that also indicate the species ability to 'come-back' and survive. (Kodela *et al.* 1994a, 2008; Nash & Matthes 1995; Robertson 1997; NSW National Parks and Wildlife Service 1999).

Further investigation and monitoring

There are many gaps in the knowledge of the species, particularly population dynamics, which limits the understanding of the reasons for the rarity of species (Robertson 1997). Further investigation is required on the ecology, size, longevity and dynamics of the soil seedbank, controls on dormancy, triggers for germination (requirements, mechanisms, viability), population dynamics (in relation to environmental conditions such as soil moisture, climatic factors and physical disturbance), recruitment, reproduction and mortality (in relation to fire, grazing and physical disturbance) and other suitable habitats. Little is known about the Gentian's pollination mechanisms, life history and growth calendar (e.g. the rates, timing and causes of flowering and seed production), breeding system, sensitivity to added nutrients (e.g. superphosphates used around Wingecarribee Swamp), growth and fruit production in relation/with respect to soil moisture, temperature and light, fecundity and population biology. The inability to germinate the seeds hampers the understanding of the processes controlling the distribution and numbers of plants (Robertson 1997). Without knowledge of the longevity of seed, dormancy and conditions required for triggering germination the ability to make management recommendations is limited (Robertson 1997). Fluctuations and absence of any pattern in numbers found each year highlight the need for continued monitoring. With such small, localised populations the likelihood of extinction is high (Robertson 1997).

Number of mature individuals:

Only a small number of specimen collections and records have been made since the species was found at Wingecarribee Swamp in the 1960s up to the early 1990s when targeted surveys began recording population sizes, which have been relatively low and greatly fluctuating from zero to several hundred plants (Table 1). There is no stable recurring population or regular pattern in periodicity of occurrence or population size. Some early herbarium collections and records indicate that there may have been a larger population at Wingecarribee Swamp in the past, particularly prior to construction of Wingecarribee Reservoir. Even when the Gentian was recorded as sparse, the potential area of distribution would have been larger and hence the possibility for more plants. The Gentian was evidently more common than at present, especially compared to more recent times where the population has dramatically declined to zero and the degradation of sites has been witnessed. Since 1992, when the numbers of plants started to be recorded, information on the distribution and population size of the Gentian at Wingecarribee Swamp is limited by the irregular nature of the surveys which often did not cover all the known sites with subpopulations. The main periods of targeted surveys occurred 1992–1996 by NPWS for recovery plans, 2001–2002 by Sainty & Associates during

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vegetation surveys (including monitoring rare plant habitats) for Sydney Catchment Authority (SCA), and since 2004 by Parsons Brinckerhoff (rare plant monitoring and management in relation to weed control program) for SCA.

Records are only available for Hanging Rock Swamp since 1994. At this locality one subpopulation (at site E) increased over the three growing seasons between 1994 and 1996, while the other subpopulation (at site F) declined. The total population has varied from 203 plants in 1996 to none during the 2007/2008 growing season.

The largest total number of plants recorded during a growing season is in the hundreds despite potentially tens of thousands of seeds being produced the previous season. In 1996 the total number of 357 is more than double the total number of plants found at the same sites before that (Robertson 1997). During the most recent potential growing season of spring/summer 2007–2008 no plants were observed (Kodela *et al.* 2008).

The data used to evaluate the species against criteria involving population size (Table 1) includes a degree of uncertainty as well as lacking some data for some sites in some seasons. Population numbers can only be treated as estimates because of:

- the difficulty in locating plants due to plant size (their inconspicuous small habit),
- density of surrounding vegetation (possibility for plants to be hidden by other vegetation),
- the tendency of flowers to only open in bright sunlight (most likely to locate plants when in open flower or with characteristic capsules), and
- the plant's short life span above ground (which could be missed without regular surveys during the entire potential growing season).

Due to these factors some individuals were probably not located during surveys, hence subpopulation sizes are likely to be underestimated. Also total population numbers would also be underestimated since not all of the sites/subpopulations were investigated each year (e.g. Hanging Rock Swamp was not included till 1994 and one site at Wingecarribee Swamp was not investigated till 1999). However, while population sizes have probably been underestimated the numbers still indicate that they have been relatively low.

Threats:

The survival of the species depends on maintaining viable habitat which is very limited, often degraded, declining and currently threatened. Potential threats to the species and its habitats include altered hydrological conditions (especially extreme, sudden and/or permanent changes in water quantity), changes in water quality, altered soil nutrient status (e.g. from fertilisers and other chemicals used by nearby agricultural practises of improved pastures and crops), competition from weeds and dense shrub vegetation, grazing by stock and rabbits, and physical disturbance from trampling (by vehicles, humans and stock where hooves can form deep depressions and create quagmires), ploughing, soil top-dressing and land clearing.

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For many years Wingecarribee Gentian was indirectly threatened by peat extraction at Wingecarribee Swamp which was causing drawdown of the watertable elsewhere in the swamp and weakened the peatland structure which ultimately gave way and enabled the collapse and fragmentation of most of the Swamp during a large rainfall/flood event in 1998. It was often argued that the mining operation did not only have immediate local impacts at the extraction site but could have a wider impact on the wetland, its vegetation communities and rare species, habitat values, hydrological functions, water quality filtration processes and other catchment issues. The collapse of much of the peatland has created one of the greatest threats to the Gentian through altered hydrological regimes and degraded drying habitats which have also allowed the invasion of numerous terrestrial weeds (e.g. pasture grasses and other herbs) and a population explosion of **Salix cinerea* (Pussy Willow). The area of functioning peatland is no longer continuous and has greatly declined. As a result, extensive areas of ecotone have been lost or are threatened.

Gentiana wingecarribiensis is likely to be sensitive to soil moisture and changes in water levels (related to the hydrological regime and fluctuations in watertable), and at Wingecarribee Swamp the species may have occurred more widely in areas now flooded by Wingecarribee Reservoir (which effectively would have more or less halved potential habitat in the swamp). Also, damming part of the swamp may have increased watertable levels in the remaining swamp which could have affected the distribution of *G. wingecarribiensis*. Fluctuations have potentially been more exaggerated since the dam was built and water levels in the reservoir manipulated. In the early 1960s the Gentian was observed growing in more central parts of the swamp prior to construction of the reservoir (expert advice). The species' survival depends largely on protecting its supporting wetland habitats from extreme and/or sudden alterations of water levels. A functioning peatland maintained as a whole ecosystem will help maintain the sensitive marginal ecotone habitats where the Gentian grows. The remaining ecotone habitats are now at greater risk from drying since much of the Wingecarribee Swamp peatland collapsed in August 1998, resulting in changed hydrological conditions within the swamp (rather than a raised watertable much of the area is now drained by channels). These changes threaten the survival of the species at this wetland. It has been suggested that the Gentian's long-term survival could depend on the watertable remaining relatively high and fluctuating only within limits of a few centimetres for lengthy and possibly critical seasonal periods (Adams & Williams 1988). At Wingecarribee Swamp there are places near the ecotone where the watertable has permanently dropped by over a metre (leading to the drying of the swamp margin). Where once the continuous peatland would have helped buffer the swamp to some extent against changing moisture levels (Robertson 1997), now fragmented and largely lost there is the potential for larger fluctuations in water levels during periods of low rainfall and drying of the ecotone areas could result. Ecotone habits could move away from present distribution of seed in the soil permanently. For the plant's survival the ecotone habitat would need to return within the life cycle of the plant or within the viability period of the seed. (Robertson 1997). 'Alteration to the natural flow regimes of

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rivers and streams and their floodplains and wetlands' is listed as a Key Threatening Process under the TSC Act in NSW.

Habitats, especially at Wingecarribee Swamp, have been threatened by drainage channels associated with agricultural activities. Subpopulations along the margins of the swamp could well have been affected in the past by clearing and drainage for the introduction of improved pastures and grazing.

Gentiana wingecarribiensis is threatened by the limited amount of suitable habitat where it grows. Adams & Williams (1988) stated that viable populations are probably dependent on a stable habitat of short, damp turf of sedges, grasses, mosses and other herbs. Prior to European settlement grazing by native herbivores may have played an important role in maintaining short 'turf' and open vegetation conditions in this type of habitat (Adams & Williams 1988). In the absence of these herbivores (e.g. Wingecarribee Swamp) other forms of disturbance may be needed to maintain suitable habitat conditions. The limited suitable habitat has been modified by and continues to be threatened by stock trampling, drainage, burning, weed invasion and clearing.

Weed invasion and competition is a major threat to *G. wingecarribiensis* (e.g. site A), particularly aggressive introduced pasture grasses such as **Anthoxium odoratum* and **Holcus lanatus*. There is the threat of overcrowding and shading by shrubs such as *Leptospermum* spp. (Cohn undated; Kodela *et al.* 2008).

Trampling by people has affected several sites, particularly site A which was regularly traversed to gain access to Wingecarribee Swamp for weed control of **Salix cinerea*. The Gentian could also be affected by other activities associated with weed eradication at this Swamp (e.g. in the use of chemicals or other procedures such as cutting and stacking willow branches, potential for off-target spraying aimed at blackberries or juvenile willows, etc.).

At Hanging Rock Swamp the ecotone habitat in one site occurs in a firebreak area between the swamp and a pine forest plantation. A threat to the Gentian at this site is the possibility of an inappropriate slashing regime (slashing, mowing or fires should be avoided during the Gentian's growing season). Another threat at this swamp is the problem of **Pinus radiata* seedlings and juvenile plants that are establishing themselves in the swamp (seeds spread from the adjacent pine plantations). Pines will shade ground vegetation and have the ability to alter the soil chemically (acidification of the soil from fallen leaves) (Robertson 1997).

The importance of protecting Wingecarribee Gentian in its natural habitat is highlighted by the unsuccessful propagation attempts and poor prospects for *ex situ* conservation to the present time. Cultivation trials at Mount Annan Botanic Gardens failed to germinate Gentian seeds (Errington & Offord 1997; Donaldson 2003). As an annual the Gentian cannot simply be transplanted and maintained in cultivation, and even if seed germination and plant survival to maturity could be achieved *ex situ* it would be an ongoing and probably impractical means of conservation relative to the more ideal situation of maintaining populations in the wild. Its survival largely depends on maintaining viable habitat (Kodela *et al.* 2008).

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Population size fluctuations at the sites could indicate high sensitivity to environmental conditions such as moisture levels. Low total numbers, reliance of the species on a stored seedbank (for its long term survival), and sensitivity to environmental conditions render species susceptible to stochastic events. A series of events could lead to extinction. For example, several seasons of good conditions for germination followed by a drought could prevent fruiting and the entire seedbank at a site could be exhausted, or there could be a drought one year followed by fire the next (Robertson 1997).

The Gentian appears to have specific regeneration requirements, and if these are not met the species could disappear from sites. It is also threatened by having small fragmented subpopulations. Dearson (1999) cites inbreeding depression as an additional threat.

There is the longer term question of unknown potential impacts of climate change on the species since it appears to be a relic of cooler climates. Overseas studies on other *Gentiana* species indicate a cold phase may be required for germination. The Gentian being absent from all sites during the 2007/2008 growing season (and possibly over the past few years), including sites where there appears to be suitable physical habitat conditions remaining locally, suggests a more regional environment factor such as climate could be controlling germination and the occurrence of plants (Kodela *et al.* 2008). 'Anthropogenic Climate Change' is listed as a Key Threatening Process under the TSC Act in NSW.

The above threats have been described in more detail by Cohn (undated), Kodela *et al.* (1994a, 2001a, b, 2003), Nash & Matthes (1995), Matthes *et al.* (1996), Robertson 1997, Kodela (1998), Dearson (1999), Sainty & Associates (2003), Parsons Brinckerhoff (2004, 2005, 2007a, b) and most recently (for each site) by Kodela *et al.* (2008).

Extreme fluctuations:

Estimates of the total number of individuals of *Gentiana wingecarribiensis* occurring in a growing season have ranged from zero to hundreds since observations targeting the species began in 1992. The number of plants at a site can vary from 300–500 (recorded as *c.* 300 and *c.* 500 plants by different field observers) one year to *c.* 30 the next year followed by none after that (i.e. Wingecarribee Swamp site B), demonstrating extreme fluctuations within the species. The size of subpopulations fluctuates greatly from year to year (see Table 1 and Robertson 1997).

Population reduction and continuing declines:

It is likely that the population of *Gentiana wingecarribiensis* has been reduced at Wingecarribee Swamp, since the formation of the western reservoir flooded approximately half the original peatland and there have been numerous threatening processes in the wetland that have probably reduced suitable viable habitat, including drainage, vehicle and stock trampling, regular burns and weed invasion associated with agricultural activities. Population size may further decline with the reduction or degradation of habitat since much of the Wingecarribee Swamp peatland collapsed with resulting major hydrological changes (e.g. loss

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of damp ecotone areas over much of the swamp margin that were potential Gentian habitat). One of the habitat areas (site C) has been cleared (including disturbance of the topsoil) for grazing and this subpopulation may have been permanently lost. Trampling and competition by weeds at site A may be responsible for the decline and possible ultimate loss of plants at this site. It is unknown what impacts continuing drought and possible climate change might have on the species. However, given the number of ongoing threats to the species it is reasonable to infer a projected further decline in populations in the future. At Wingecarribee Swamp in particular the species is likely to decline due to the altered hydrology and competition with weeds.

Parsons Brinckerhoff (2007a) have estimated that at Wingecarribee Swamp the species is declining at a rate of 11.5% per year (90% confidence interval 0 to 46% per year) without a decline in extent (90% confidence interval 0 to 1%). However, the data records used to calculate these estimates appear to be incomplete (e.g. did not take into account the 1999 record of several hundred plants at one site). Furthermore, there has been a decline in the extent of the species with the loss of some habitat (e.g. one site).

Extent of Occurrence (EEO) & Area of Occupancy (AOO):

The EEO that encompasses the overall distribution (spatial spread of the areas occupied by the taxon) of the species is estimated at 76 km² (based on 4 km² minimum cells; *c.* 33 km² based on 1 km² cells, while the EEO excluding the discontinuities within the overall distribution (i.e. the large area between the two swamp locations) is estimated at 20 km² based on the two swamps occupying five 4 km² cells (2 × 2 km grids); however the total area of the two swamps combined would be less than 4 km². Whichever EEO appropriately represents the Gentian's distribution the result remains less than 100 km². The AOO is 8–12 km² (based on a 2 x 2 km grid, the spatial scale of assessment recommended by IUCN 2008; the known Gentian sites fit within two or three 4 km² cells), however it is important to note that the subpopulations are generally small and very localised, and have been recorded covering areas of *c.* 1 m² to 700 m² (with a total area of occupancy probably less than 2 km²).

Severe fragmentation:

The population of *Gentiana wingecarribiensis* has been severely fragmented at Wingecarribee Swamp since much of the peatland collapsed and fragmented in 1998. It is no longer large continuous intact functioning peatland with a high watertable and continuous vegetation cover. Most of the Swamp's ecological integrity and degree of hydrological stability that would have helped maintain and buffer the Gentian's habitat (e.g. ecotone areas) has been lost. There remains several intact peatland areas with ecotone habitat but these areas are now largely separated (since the fragmentation of the Swamp) by collapsed, broken-up drying peat blocks and free-draining gullies. There is also no longer a continuous ecotone margin around the swamp since large stretches of the swamp edge collapsed several metres. The known Gentian sites or not connected with suitable habitat. All four small subpopulations at Wingecarribee Swamp occur in remnant peatland and ecotone areas surrounded by altered

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wetland and cleared farming areas. The population of *G. wingecarribiensis* has undergone severe fragmentation.

The two swamps supporting the Gentian populations are separated by c. 33 km of mostly unsuitable non wetland habitat.

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Explanatory note

Between 2007 and 2009 the NSW Scientific Committee undertook a systematic review of the conservation status of a selection of plant and animal species listed under the Threatened Species Conservation Act. This species summary report provides a review of the information gathered on this species at the time the Review was undertaken.

The Scientific Committee's report on the Review of Schedules project and final determinations relating to species that were either delisted or had a change in conservation status can be found on the following website: www.environment.nsw.gov.au .

The Committee gratefully acknowledges the past and present Committee members and project officers who ably assisted the Committee in undertaking the Review of Schedules Project. Information on the people involved in the project can be found in the Acknowledgement section of the project report entitled "Review of the Schedules of the Threatened Species Conservation Act 1995. A summary report on the review of selected species" which is available on the abovementioned website.

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