Development of a *Typhonium* sp. (Araceae) from the east Kimberley, Western Australia

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ABSTRACT

Typhonium sp. Kununurra is an undescribed, perennial, cormous herb belonging to the Family Araceae. It produces leaves and flowers only during the northern Australian wet season. Its known distribution is restricted to grey vertisols ('black soils') on the ancestral flood plain of the lower Ord River in the east Kimberley, Western Australia and adjacent areas of the Northern Territory, northern Australia. It is Declared Rare Flora under Western Australian legislation (but its conservation status has not yet been assessed in the NT). Although several subpopulations are known, few are on land with conservation-secure tenure and no previous studies have distinguished immature from mature plants. This study had two objectives; to locate additional subpopulations on conservation-secure land and to identify development stages in the life history of the species so that immature plants can be identified and excluded from future population-size estimates. Because IUCN Red List guidelines for the estimation of population sizes require that only reproductively mature individuals are included (IUCN 2001, 2014), it is critically important that future subpopulation surveys for this species distinguish immature from mature plants and take into account possible hydrological/climatic conditions that might affect survey results.

Following exceptionally dry, hot conditions, many known subpopulations were still dormant at the time of the study (early March 2013) and, perhaps because of that, no new subpopulations were located. However, there had been sufficient, localised rainfall for some, isolated emergence. Three developmental stages are described, newly germinated seedlings, immature plants and reproductively mature plants, all of which were recognisable in the field. The overwhelming proportion of all subpopulations observed in this study consisted of immature plants and the proportion of immature to mature plants suggests a high mortality rate during the 3+ years plants can take to mature; however, an alternative explanation involving sustained dormancy of mature corms in 'dry' years is canvassed.

KEYWORDS: Development, *Typhonium*, demographic structure, conservation status, distribution

INTRODUCTION

Typhonium Schott is an old world genus of small, perennial herbs in the family Araceae. Many species occur in northern Australia where they grow in a variety of soil types but often have very restricted distributions (Hay 2011). That, coupled with often-unobtrusive foliage, flowers and fruits, all of which are present only in the wet season (when travel in northern Australia is difficult) has resulted in the genus being poorly known; of the 17 native Australian species recognised by Hay (2011), eleven (65%) had been described in the past ~20 years and several more undescribed species are known, including an undescribed species with the Western Australian Herbarium (PERTH) phrase name *Typhonium* sp. Kununurra (A.N. Start ANS 1467).

Typhonium sp. Kununurra was discovered in December 2001 approximately 5 km northwest of Kununurra airport (-15.78°, 128.70°) in Western Australia (WA). It has since been found at several more locations in WA and in the Northern Territory (NT). However, all known locations are on the Ord River's ancestral floodplain downstream of Carlton Gorge. Despite searches, there are no records from the river's modern floodplain below Tarara Bar (Kirby 2015). Tarara Bar is located at the point at which the lower Ord's current course deviates from an ancestral one (George *et al*. 2011) (Figure 1). In WA, the species is gazetted 'Flora that is considered likely to become extinct or is rare' under the State's *Wildlife Conservation Act 1950* (Western Australian Government Gazette 2015) and listed as 'Endangered' under IUCN criteria (IUCN 2001). Its status has not yet been assessed in the NT (Ian Cowie, NT Herbarium, Palmerston, personal communication).

Like other Australian *Typhonium* species, *T*. sp. Kununurra is a cormous perennial herb. But, unlike many other Australian species, all known subpopulations (the terms 'subpopulation' and 'population' follow definitions in IUCN 2001) of *T*. sp. Kununurra occur on grey vertisols ('black soils'). Through the dry season (usually about April to November) it persists as a dormant, subterranean corm. Leaves emerge after ~200 mm of rain have saturated the soil early in the wet season, usually in December or January (John Kirby, personal communication). Thereafter, leaves and, later, reproductive organs may be present for as long as soil moisture conditions allow. However, it seems not all mature plants emerge or flower every year (see below). When gilgais are flooded, leaves usually emerge from areas raised above the water surface but corms may be

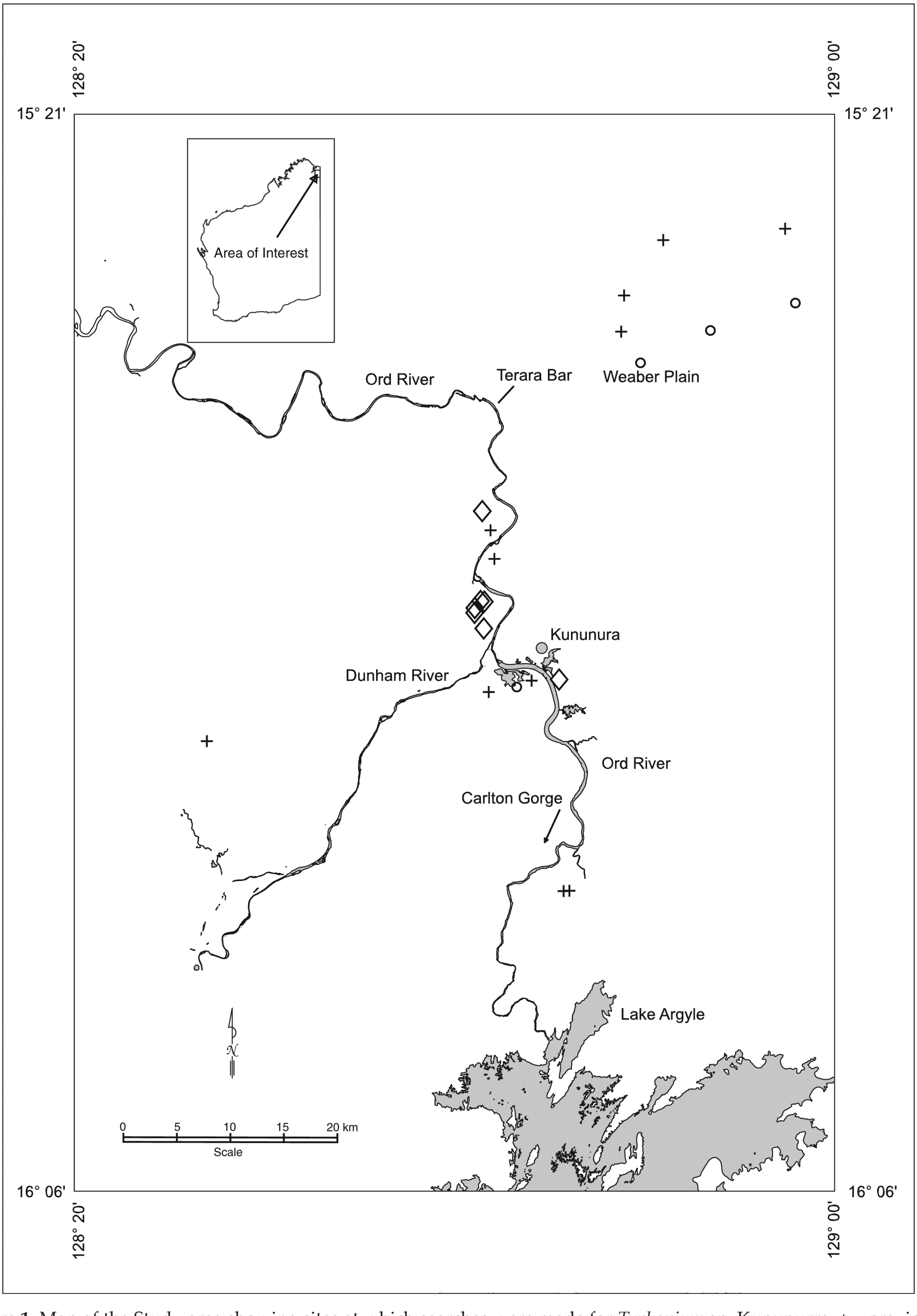

Figure 1. Map of the Study area showing sites at which searches were made for *Typhonium* sp. Kununurra. + = previously un-surveyed sites where the species was not located in this study. (two sites in this category south of lake Argyle and one site at the mouth of the Keep River to the north-east are beyond the limits of this map. Co-ordinates of these sites are given in table 1). O = sites at which the species has been previously recorded but was not seen during this (2013) study. ◊ = sites at which the species was located during this (2013) study.

situated below the inundation level and then the plants may appear to be emergent aquatics.

It is common in suitable habitat but, because much of its known range is within the proposed Ord Stage 2 irrigation area, where it inhabits soils favoured for irrigated agriculture (Western Australian Department of State Development 2016), on private property, on pastoral lease or on road reserves, its conservation status is tenuous; a number of surveys have attempted to locate subpopulations on land with conservation-secure tenures but none of the results have been published. Other, unpublished studies have attempted to estimate numbers in several subpopulations. Summaries of these unpublished studies are contained in submissions to the Western Australian Threatened Species Scientific Committee (WATSSC), the most recent being that of Kirby (2015). However, none of the reports or submissions is in the public domain and none of the surveys have taken account of the demographic structure of the surveyed subpopulations. The latter factor is important because the WATSSC uses IUCN criteria to assess the conservation status of taxa nominated for addition to, or deletion from, gazetted lists of threatened species under Western Australian legislation. Those criteria require that population size estimates are determined only by the number of (reproductively) mature individuals in a population (IUCN 2001, 2014).

The original objective of this study was to locate additional subpopulations, particularly on lands with conservation-secure tenure. However, the study was undertaken in an abnormally dry year, as a consequence of which, the species appeared to be absent (but may have remained dormant) at sites where it had been observed in previous years, indicating a significant probability that new subpopulations could have been missed. Although we searched new areas, as originally intended, we adjusted the objective to include an assessment of developmental stages of the species where there had been emergence because the ability to distinguish mature from immature plants, is critical to the assessment of a species' conservation status by IUCN guidelines (IUCN 2001), a factor that had been overlooked in previous assessments.

METHODS

Twenty four sites on black soils were surveyed between 3 and 6 March 2013. Four were adjacent to or above Carlton Gorge (i.e. up-stream of the lower Ord River's floodplain and up-stream of all previously known occurrences). One was on the catchment of the Dunham River, a tributary of the Ord River, the confluence of which is on the lower Ord floodplain between Carlton Gorge and Tarara Bar, i.e. within the known distribution of the species. The remainder were on the Ord River's ancestral floodplain (Table 1; Figure 1). Four of the latter were previously unsurveyed sites in the conservation buffer-zone surrounding proposed Ord Stage 2 irrigation

Table 1. Locations surveyed for *Typhonium* sp. Kununurra. In the 'presence' column, 0 = no previous surveys, not found; 1 = previous records but not found in 2013; 2 = previous records and present in 2013. Some site names are informal, local names. No new site records were made in this study.

Zone	Site Name	Lat	Long	Presence
Upstream of Carlton Gorge	South of Lake Argyle	16.7008	128.6906	0
Upstream of Carlton Gorge	Below Bow River diamond mine	16.5817	128.6156	0
Adjacent to Carlton Gorge	Long Michael Plain Billabong	15.9908	128.7561	0
Adjacent to Carlton Gorge	Howard Springs	15.9911	128.7511	0
Carlton Gorge to Tarara Bar	Ivanhoe Station Billabong	15.6758	128.6872	1
Carlton Gorge to Tarara Bar	Kirby Quadrat 1	15.7381	128.6808	2
Carlton Gorge to Tarara Bar	Kirby Quadrat 2 (Pole 80)	15.6589	128.6797	1
Carlton Gorge to Tarara Bar	Weero Road	15.7617	128.6814	2
Carlton Gorge to Tarara Bar	Darram Conservation Park (1)	15.8128	128.7101	1
Carlton Gorge to Tarara Bar	Darram Conservation Park (2)	15.8072	128.7231	1
Carlton Gorge to Tarara Bar	King Lot 710 (1)	15.7456	128.6733	2
Carlton Gorge to Tarara Bar	King Lot 710 (2)	15.7472	128.6733	2
Carlton Gorge to Tarara Bar	Racecourse Road	15.8058	128.7469	2
Carlton Gorge to Tarara Bar	Packsaddle behind Meatworks	15.8172	128.6856	0
Carlton Gorge to Tarara Bar	Reserve 50588	15.7378	128.6792	2
Dunhan River catchment	Middle Creek	15.8601	128.4392	0
Below Tarara Bar	Ord Stage 2, Buffer zone (lower west)	15.5022	128.8014	0
Below Tarara Bar	Ord Stage 2, Buffer zone (upper west)	15.4706	128.8039	0
Below Tarara Bar	Ord Stage 2, Buffer zone (north)	15.4222	128.8381	0
Below Tarara Bar	Ord Stage 2, Buffer zone (north-east)	15.4122	128.9447	0
Below Tarara Bar	Keep river mouth (NT)	15.2772	129.1351	0
Below Tarara Bar	Weaber Plains Rd (south)	15.5294	128.8183	1
Below Tarara Bar	Weaber Plains Rd (middle)	15.2835	128.8794	1
Below Tarara Bar	Weaber Plains Rd (north)	15.4308	128.9536	1

extensions and one was close to the mouth of the Keep River in the Northern Territory. *Typhonium* sp. Kununurra had previously been recorded from eleven of the 24 sites.

Transport to sites was by quad-bike, 4wd vehicle or helicopter but at all sites approximately 1 ha, often taken to the edge of the black soil occurrence, was searched on foot for one to three hours by two people, (ANS and John Kirby), who were both familiar with the species. Because *T*. sp. Kununurra is declared rare flora in WA, we were constrained in the extent to which specimens could be excavated and/or collected, however several plants were excavated, photographed and preserved by pressing or immersion in ethyl alcohol. All specimens were collected under a Wildlife Conservation Act permit to take declared rare flora (ANS Permit No. 128-1213), and have been deposited in the Western Australian Herbarium (PERTH accession numbers are 84889904, -12, -20, -39, -47, -55, -63, 84890015) however, in this account, original collector's field numbers are used. They may be tied to PERTH accession numbers through Table 2 or Specimen listings on FloraBase (available at https://florabase.dpaw.wa.gov.au/) [verified 06/02/2016].

Time constraints prevented us from determining the number of plants in any subpopulations and from accurately determining the ratios of immature from mature plants.

RESULTS

Distribution and habitat

Typhonium sp. Kununurra was found at only six of the 11 sites where it had been previously recorded and at no new sites (Table 1). At the eleven sites where it had been previously recorded, vegetation consisted of low, open to very open woodlands of *Bauhinia cunninghamii* (Benth.) Benth. (Fabaceae) over moderate to dense annual and/or perennial tussock grasses (Poaceae), the dead foliage of which often formed dense thatches. Other species that co-occurred at all sites included *Crinum angustifolium* R. Br. **(**Amaryllidaceae**)**, *Commelina ensifolia* R.Br., *Cyanotis axillaris* (L.) Sweet (both Commelinaceae) and *Polymeria ambigua* R. Br. (Convolvulaceae). This vegetation is similar to that at all other sites where the species has been located (unpublished data) and at most of the other sites we surveyed.

Collections

Numerous plants were examined *in situ* and 10 collections were made (Table 2). Except as noted below, all specimens included the corm and all were pressed. ANS 2238 and 2245B lacked corms. The former comprised one seed and five newly germinated seedlings, which were found as a cluster below the head of the peduncle from which the seed had been shed; they were preserved in alcohol. The latter comprised a single, more advanced seedling which was pressed. The only other alcohol-preserved specimen was one of four fruiting bodies from ANS 2240, the rest of which were left attached to the pressed specimen.

Morphology

Three developmental stages were observed, newly germinated seeds, immature plants and mature plants. Newly germinated seeds were detected at two sites but both immature and mature plants (i.e. those known to be capable of sexual reproduction) occurred at all six sites. However, the overwhelming majority of plants in every subpopulation we examined were immature. The morphological characteristics of the three stages were as follows.

Table 2. Specimens of *Typhonium* sp. Kununurra collected during the survey and lodged in PERTH. Seedlings were all acormous; immature plants had corms <~2 cm diameter and simple elliptic to lanceolate leaves <~10 cm long. Mature plants had corms >2 cm diameter and longer, polymorphic leaves. See Table 1 for location details.

Field Collection #	PERTH Accession #	Age	Leaf form	Depth to Corm	Location
ANS 2238	08490015	cluster of 6 seedlings,	not developed	no corm	Reserve 50588
ANS 2245 B	08489947	seedling, 1 leaf	narrow linear	no corm	Weero Road
ANS 2242	08489920	small, cormous plant 3- leaved	narrow oval to narrow obovate	3 cm	Racecourse Road
ANS 2245 A	08489947	small, cormous plant 2- leaved	narrow oval to narrow obovate	4-5 cm	Weero Road
ANS 2249	08489955	small, cormous plant 3- leaved	narrow oval to narrow obovate	3-4 cm	King Lot 710
ANS 2249 B	08489955	small, cormous plant, 3- leaved	narrow oval to narrow obovate	3-4 cm	King Lot 710
ANS 2239	08489904	Mature plant	tri-lobed, narrow lobes	~6 cm	Racecourse Road
ANS 2240	08489912	Mature plant	tri-lobed, broad lobes	5-6 cm	Racecourse Road
ANS 2241	08489939	Mature plant	Un-lobed, linear,	5-6 cm	Racecourse Road
ANS 2250	08489963	Mature plant	Un-lobed, linear	5-6 cm	King Lot 710

Figure 2. Seeds and newly germinated seedlings. Located as a cluster below the peduncle from which they had been shed.

NEWLY GERMINATED SEED

Observations are based on the five newly-germinated seeds in ANS 2238 and one seedling, ANS 2245B. Those in ANS 2238 varied in their degree of development, suggesting germination had been somewhat staggered (Figure 2). Only ANS 2245B had developed a distinct leaf lamina and was presumably a little older than those in ANS 2238.

In each case, the testa was lying on the ground surface. An exposed portion of the cotyledon had elongated to place the hypocotyl clear of the seed testa. In the more mature seedlings, the hypocotyl had been drawn <1cm below the ground surface by a contractile root but there was no overt sign of a developing corm on any of these seedlings (Figure 2).

IMMATURE PLANTS

Most immature plants had 1–3(4) small (mostly <10 cm long), simple, narrowly elliptic or narrowly ovate to lanceolate leaves. Occasional plants had much broader laminas. No reproductive structures were observed on plants with such leaves. The corms of the four immature plants we excavated (Table 2) were compound structures ~1cm in diameter and situated 3–4(5) cm below the ground surface. The uppermost segment, the developing, new corm was a conical, white body with leaves arising from its apex. New, white, adventitious roots had emerged around its base (Figures 3a &3b), some of which exhibited transverse ribbing, indicating that they were contractile. Below that, there was a light-brown, barrel-shaped body with redundant (shrivelled, brown) roots. Presumably, this was the organ that had developed the previous year and supported the initial emergence of the new season's growth. It would also have sustained the plant through the preceding dry-season's dormancy period. Below that, there was usually a darker, shrivelled, conical structure, the remnant of an even older corm. These were clearly immature plants undergoing (at least) their third growth episode.

MATURE PLANTS

Besides the presence of reproductive organs, mature plants were readily distinguished from immature ones by their larger (>10 and < 40+ cm) leaves. The shape of the leaf lamina of mature plants exhibited extensive polymorphism, although the leaves on any one plant were similar. Lamina shapes in mature plants varied from narrowly linear to tri-lobed or hastate. Lobes of tri-lobed and hastate leaves were commonly narrowly linear to narrowly lanceolate. The lateral lobes varied in length from being much reduced to sub-equal to approximately equal to the central lobe. On occasional plants, leaf lobes were very broad, approaching orbicular (the

Figure 3b. Enlargement of the corm of the plant in Figure 3a. Note the three sections corresponding with corms developed sequentially over three growing episodes.

Figure3a. An immature *Typhonium* sp. Kununurra plant. Compare the lamina shape with those of a mature plant in Figure 4.

phrase-name 'type' is of this form). The primary lobes of all tri-lobed forms commonly but not invariably had diminutive to sub-equal, symmetrical or asymmetrical, secondary lobes.

The corms of the reproductively-mature plants that we excavated were 5–6 cm below ground level and 2–3(4) cm in diameter. As with immature plants, the remains of previous year's corms were present below the current one. In one case (ANS 2240) the corm was dividing. Although the incipient, 'sister corms' were still conjoined, each had given rise to separate leaf clusters from apical meristems and each unit carried two seed-bearing peduncles showing that they were both reproductively competent. Moreover, a small (<1 cm) 'daughter corm' was developing in an axillary leaf scar on the shoulder of one unit. It had, as yet, grown neither its own roots nor leaves.

DISCUSSION

Climatic effects

At Kununurra, January, February and early March 2013 were exceptionally dry. In January, the airport received 137 mm rain (mean 201 mm) and no rain was recorded there in February (mean 215 mm) or early March when the study was undertaken. It was also an exceptionally hot period; Kununurra airport recorded 25 days with temperatures at or above the long-term means of 35.9°C and 35°C respectively for January and February, including five days during the last week of January and the first week of February when it exceeded 40°C. The highest temperature during that period was 43.1°C (Australian Bureau of Meteorology).

Typically, in January and February, 'black soil plains'

Figure 4. A mature plant with narrow, lobed, leaf laminas.

of the east Kimberley are saturated and surface water is present in most gilgais but, in early March 2013, we found no areas of black soil with free surface water. In the vicinity of Kununurra and near the mouth of the Keep River (which was the wettest site we visited), black soils were damp but not saturated. At all other locations, they were dry and crumbly to a depth of at least 10 cm.

Evidently, areas near Kununurra town site and the mouth of the Keep River had received localised rainfall later than other areas we visited. Near Kununurra, it had been sufficient to induce and sustain vegetative growth and limited flowering by some plants. (We observed fruiting plants but no fresh flowers.) However, at other sites we visited, the species was either absent or, if it was present, soil moisture levels had been too low to break dormancy or to sustain growth. It appears that *T*. sp. Kununurra is probably absent from the Keep River site (although it is now known from other parts of the Ord River's ancestral floodplain within the Northern Territory

(John Kirby personal communication). It was not possible to determine whether it was absent or merely dormant at any of the other 'new' sites we searched but our survey did show that, in the Ord Stage 2 buffer zone, there is relatively little habitat similar to that from which it is known.

Development and population structure

Observations on the plants that were excavated and on plants examined *in situ* provide an insight into the life history of the species, which is comparable, in many ways, to that described by Banerji (1947) for *Typhonium trilobatum* Schott from India. Banerji's (1947) account of *T. trilobatum* is the only developmental study of another *Typhonium* species of which we are aware. It should be noted here that, in the view of Cusimano *et al*. (2010), who studied genetic evidence of the phylogeny of the genus, Australian *Typhonium* spp. and those from Asia belong to different clades and the Australian species may warrant generic recognition. Be that as it may, the clades are closely related and, in the following discussion the similarities and differences in the life-histories of *T*. sp. Kununurra and *T. trilobatum* are compared.

Both species are cormous with the primary ('mother') corm shedding leaves and roots as it enters a period of dry season dormancy. With the onset of the next wet season, both species develop replacement corms from the apex of the 'mother corm'. New roots grow from the base of the newly developing corm. Leaves and (in mature plants) reproductive structures grow from the apex of the new corm. In *T. trilobatum*, seed always germinates in the season it is formed. We have shown that same-season germination occurs in (and may be the normal mode in) *T*. sp. Kununurra. Although loss of seed viability over the dry season is suspected it was not demonstrated in *T*. sp. Kununurra.

In both species (as in other monocotyledons) a portion of the cotyledon remains partially enclosed within the testa after germination. One would expect a corm to develop in the same year that seed germinates so energy can be sequestered for survival through the next dry season and provide energy for initial vegetative growth in the following wet season. We did not observe this in the seedlings we found but noted the position at which it would develop, at the junction of the plumule and radical, had been drawn below the ground surface by a contractile root. Contractile roots were also reported for *T. trilobatum* by Banerji (1947).

In *T*. sp. Kununurra, plants go through an extended juvenile stage during which each growth episode produces one to four juvenile leaves from the top of the new-season's developing corm. The duration of this stage is not known but the presence of two generations of older corms in addition to the current season's developing corm on immature plants that we excavated; suggest it can be protracted, lasting through at least three growth episodes. Assuming there is normally one growth episode per wet season, the seedling stage can last at least three years and possibly considerably longer, particularly if abnormally dry years prolong progress to maturity. Be that as it may, the predominance of immature plants in all subpopulations (a situation not recognised by many previous observers, e.g. in reports cited by Kirby (2015)) indicates a protracted maturation process. Moreover, the relative abundance of immature plants in all subpopulations we observed suggests a very high juvenile mortality rate.

The preponderance of immature plants in 2013 is consistent with our previous experience and photographs show a similar but unrecognised situation in previous surveys of many subpopulations (e.g. the frontispiece in Byrne 2013). However, it has been noted that, in years with average to above-average wet-season rainfall, the ratio of mature to juvenile plants is higher than in years with below-average wet season rainfall (John Kirby, personal communication). Although Kirby's observations are not quantified, the difference was clear enough to suggest that mature plants, with more substantial energy reserves in their larger corms, may be able to sustain dormancy through low rainfall years whereas immature plants may be compelled to break dormancy or die because their small corms are incapable of sustaining them for more than one year and/or to provide the energy required for early vegetative growth after two years. The fate of immature plants at sites where the species had been noted in previous years, but not by us in 2013, is unknown but it can be predicted that mortality was high in younger plants with smaller corms and perhaps lower in older plants with larger corms. If this is so, increasing temperatures associated with climate change may be a significant threatening process.

Once they reach maturity, *T*. sp. Kununurra can reproduce vegetatively by division of the corm to produce 'sister' corms and/or by developing secondary ('daughter') corms from axillary buds on the 'mother' corm. This is apparently common in *T. trilobatum* (Banerji 1947, Li *et al*. 2010). Indeed, in that species, Banerji (1947 p. 208) reports that 'a large number of axillary buds develop on the mother corm' and 'In the next season, these buds develop into separate plants, while the mother corm shrivels and disintegrates'. This would account for Banjeri's (1947) observation of 'many (*T. trilobatum*) plants in close association'. In *T*. sp. Kununurra, development of axillary daughter corms was observed; in the dry year, 2013, it was infrequent but unquantified observations by John Kirby (personal communication) in a subsequent year of abundant, early rainfall suggest it may be common in *Typhonium* sp. Kununurra when conditions are suitable. The division of a primary corm was observed only once in our, admittedly limited, excavations of the corms of *T*. sp. Kununurra. Less frequent vegetative reproduction in *T*. sp. Kununurra may explain why the dense aggregations of *T. trilobatum* plants reported by Banjeri (1947) in India and observed in north-western Thailand (personal observation), have not been observed *T*. sp. Kununurra.

CONCLUSION

In 2013, populations of *T*. sp. Kununurra were overwhelmingly dominated by immature plants. The immature stage is protracted and the ratio of mature to immature plants suggested high levels of mortality during this phase. Consequently climate change may become a significant threatening process if temperatures were to increase and/or effective rainfall was to decrease near Kununurra. Vegetative reproduction is possible, but probably slower in *T*. sp. Kununurra than in *T. trilobatum*. The demographic structure of sub-populations warrants considerably more research (particularly in relation to rainfall and the prospects of climate change) than we were able to accomplish in the short time available to us. However, the proportion of immature plants as well as prevailing climatic conditions should be taken into account in any surveys undertaken to assess the conservation status of the species in the future.

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