Conservation Assessment of *Keyacris scurra* (Rehn 1952) Key's Matchstick Grasshopper (Morabidae)

B Hope, B Law Version 1, May 2019
NSW Threatened Species Scientific Committee

***Keyacris scurra* (Rehn 1952) (family Morabidae), Key's Matchstick Grasshopper**

Photo: Michael Kearney

Distribution: Endemic to NSW/ ACT/ VIC (possibly extinct in VIC)
Current EPBC Act Status: Not listed
Current NSW TSC Act Status: Not listed
Proposed listing on NSW BC Act and EPBC Act: Endangered

Summary of Conservation Assessment
Keyacris scurra Key's Matchstick Grasshopper was found to be eligible for listing as Endangered B2ab(ii,iii,iv,v)c(iv). This species is endemic to NSW, the ACT and Victoria (although possibly now extinct in Victoria, Vic SAC 2018). The main reasons for this species being eligible are i) inferred restricted geographical range (AOO = 68 km^2), ii) severe fragmentation, iii) historical and inferred ongoing decline in abundance, habitat availability and quality and iv) ongoing threats (and poorly understood management requirements). This species was the focus of early chromosomal research (see Grodwohl 2017 for a summary) and unlike many insects, there was extensive survey work performed in the past that allows an historical assessment of the species' decline. At present only limited recent survey work has been performed, but this limited information indicates this species is now locally extinct at many known locations, indicative of decline.

Description and Taxonomy
Keyacris scurra (Rehn 1952) Key's Matchstick Grasshopper is a small (females ~25 mm, males ~18mm), slender, wingless grasshopper characterised by its slanted face, splayed hind femora and ensiform antennae. This species occurs in several colour forms, with brown being the most common (Farrow 2018). A full description is found in Rehn (1952) and Rentz (1991) also has information on this species. Within this species there are two parapatric chromosome races (15 chromosome and 17 chromosome), which are not distinguishable by external features (Key 1987). A similar-looking species which occurs in the same area are nymphs of *Acrida conica* (Giant Green Slantface), although *A. conica* develops wing buds which allow differentiation from *K. scurra* (R. Farrow *in. litt.* 15 Sept 2018). *Keyacris scurra* was originally described as *Moraba scurra* Rehn and was later transferred to the genus *Keyacris* Rehn (Key 1965). *Keyacris scurra* is in the subfamily Morabinae (Australian Faunal Directory 2018). The Morabinae is endemic to Australia and includes ~41 genera of flightless grasshoppers grouped into five tribes; many species are undescribed. *Keyacris* is in the tribe Keyacridini (Key 1976; Australian Faunal Directory 2018)..

Distribution and Abundance
Historical distribution
Keyacris scurra Key's Matchstick grasshopper was originally distributed from Victoria (Vic.) to Orange (NSW) across the wheat/sheep belt (White 1956, 1957, 1963; Rowell and Crawford 1995, 1999). This species is typically recorded in native grasslands in the following land-uses: cemeteries, along railway easements, travelling stock routes and more recently conservation reserves in the ACT. Disturbance appears to be an important determinant of site occupancy and it appears to be absent from sites that are disturbed during inappropriate times of the year (and interrupt the short non-overlapping lifecycle) or have been subjected to erratic management (e.g. periods of over and under grazing). More recently this species has been incidentally recorded within a wider range of habitats (R. Farrow *in litt.* 27 July 2018) than were previously thought to be suitable and further research is required to determine the importance of these locations to the distribution and conservation status of this species. It is also possible that given these newer records are in atypical habitats they may represent a similar but undescribed taxon. Another similar species, *K. marcida,* occurs to the west of *K. scurra* and is apparently parapatric. At three places in NSW thesethese species (*K. scurra* and the related *K. marcida*) occur within 14-16 km of each other (Key 1981).

Specimens
The Australian National Insect Collection (ANIC 2018) includes preserved (dry) specimens from most sites in historical surveys (White 1956, 1957, 1963) and the most recent specimen is from 1986 and the collection was accessed on 27 July 2018. Some locations noted in the ANIC collection are outside the distribution documented by White (1956, 1957, 1963). After 1986, ANIC has received an unknown number of specimens which are held in a wet collection, however this collection is yet to be catalogued and was not available for this review.

1950-1990 records
This species was recorded at approximately seventy-five sites in the 1950s and 1960s (for maps and lists see White 1956, 1957, 1963; Blackith and Blackith 1969; Rowell and Crawford 1995; 1999). Due to vague location descriptions the total number of known sites is uncertain, however at least 140 2x2 kilometre AOO squares appear to have been occupied in the 1950s, which is indicative of at least 140 populations. This estimate includesincludes records from the 1990-2000s (Rowell and Crawford 1995, 1999) and from 2008-2018 (detailed below) which are assumed to have also been presenting earlier decades?

1990-2000s records
Between the 1970s and 1990s there is a lack of records and published research on this species. In the mid-1990s surveys for this species were undertaken in the ACT (Rowell and Crawford 1995,1999). These surveys revealed three new sites, with the species confirmed to occur on seven known sites in the ACT. The species could not be located (and therefore may be locally extinct) at two known sites. Rowell and Crawford (1999) stated that by 1999 the species had also disappeared from 'Greenhills' Oval, Brindabella Road, Tidbinbilla Station and Condor Camp (paratype location). Of the seven confirmed ACT sites, five were on conservation reserves (Rowell and Crawford 1995). While it is possible for this species to evade detection during a single survey event (Rowell and Crawford 1999), lack of detection may indicate localised extinction or a very small population (which ultimately leads to a genetic bottleneck and reduced population viability). Butz (2004) reported this species as absent at Blundells Flat (ACT). Pullen (2000) listed the following occupied locations in the ACT: along the railway easement between 'Tralee' and Williamsdale [this is most likely the "Royalla" site studied extensively in the 1950's]; Captains Flat cemetery; on the lower slopes of Mount Jerrabomberra; and on the southern slopes of, Tuggeranong Hill in the Canberra suburb of Conder. Both Mount Jerrabomberra and Tuggeranong Hill are threatened by housing developments and the Mount Jerrabomberra population's habitat had apparently already been at least partly cleared in 2000 (Pullen 2000). Very little information is currently available about this species in NSW, although Jones (1993) who surveyed sites in the ACT and NSW (Southern Highlands), did not detect this species in NSW. Credible Bionet records of this species include sites within NSW on the Monaro Plain (e.g. Bredbo Cemetery (1997), Yaouk (2000) and Adaminaby (1997)), which is an area that this species was not reported from by White and other researchers, although the habitat is suitable and contiguous with other known sites.

Contemporary distribution

There are recent (2008-2018) credible records from seventeen (AOO = 68 km^2) well-dispersed, 2 km x 2 km AOO grid squares in NSW (nine, 2 km x 2 km grid squares) and ACT (eight, 2 km x 2 km grid squares). One major constraint in estimating AOO is that a number of the known locations (e.g. documented in White 1956, 1957) lack detailed descriptions, were mapped at coarse scale and were not able to be relocated by Rowell and Crawford (1995). A survey in September 2017 of twelve of White's (1956) listed sites located two single specimens at two nearby sites (Gundagai and Gundagai South Cemetery) and it was no longer found at sites which were previously studied intensively (e.g. Murrumbateman) (Hoffman and Kearney 2018). Hall Cemetery was surveyed in early 2019 and *Keyacris scurra* was present (Kearney *in litt.* Feb 2019). Changes in the management of cemeteries (e.g. mowing) may have contributed to the possible extinction in Victoria (Vic SAC 2018) and some NSW sites. Databases list recent records for a further three sites on (at least in part) conservation reserves in NSW and there are recent records from the ACT attributed to this species at Kambah, Tuggeranong Hills and Mulligans Flat (ALA Accessed March 2018). Kambah (ACT) and Mulligans Flat (ACT) were sites where Rowell and Crawford (1995) detected this species so these incidental records are likely to have been correctly identified. Tuggeranong Hills (ACT) is listed as a known site in Pullen (2000), which again adds credibility to this sighting. Mulvaney (2012) noted the presence of this species in the ACT at Gungahlin (National Transmission Authority land at Crace, Mulligans Flat NR and Crace NR), Hall cemetery (confirmed as present in 2019, Kearney *in litt.* Feb 2019) and possibly at the base of One Tree Hill (Kinlyside, at Moncrieff and to the north of Bonner). Recent credible photographic records (R. Farrow *in litt.* July 2018) at three known sites and at seven additional sites (in habitat previously thought to be unsuitable) raise the possibility that this species has a wider distribution than current information indicates. Conversely, while White (1963) recorded this species at four Victorian sites (Merton, Benalla, Beechworth and Wodonga) and there are ANIC specimens in the general vicinity of Bright, Corryong, Omeo and Hinnommunjie, there are no recent Victorian records and the species is possibly extinct in Victoria (Vic SAC 2018).

Ecology

Keyacris scurra Key's Matchstick Grasshopper is usually found in native grasslands but it has also been recorded in other vegetation associations containing a native grass understory (especially kangaroo grass *Themeda triandra)* and known food plants (particularly Asteraceae). Although it does not feed on *Themeda,* it may be important for providing protection from predators (White 1956). More recently, however, opportunistic sightings of *K. scurra* (as opposed to records from systematic surveys) have been reported in a wide range of vegetation types in south-east NSW (R. Farrow *in litt.* July 2018). These include wet sclerophyll forest, montane low forest, dry woodlands, heathland, and montane grasslands. In some reported locations there is an absence of *Themeda* and very few or no Asteraceae. Unlike many other grasshoppers (being flightless) this species does not disperse large distances which suggests these observations are indicative of resident populations (rather than dispersing individuals).

In captivity, Key's Matchstick Grasshopper feeds readily on *Helichrysum* spp. (White 1956). Later work found they consume a range of species, preferring smaller ephemeral plants to larger perennial species which are taken when small ephemerals are not available (Blackith and Blackith 1966). Both native and introduced species are consumed. Blackith and Blackith (1966) list the following plants as food sources (see original paper for preference category, taxonomy as published follows in brackets as does common name): *Aira caryophyllea* (Silver hairgrass), *Scirpus* sp. (sedges), *Wurmbea dioica* (Early Nancy), *Bulbine bulbosa* (Native Leek), *Calochilus paludosus* (Red Beard Orchid), *Rumex crispus* (Curled Dock), *Acetosella vulgaris*, (*Rumex acetosella*) (Sorrel), *Cerastium glomeratum* (Mouse-ear Chickweed), *Ranunculus lappaceus* (Common Buttercup), *Rosa rubiginosa* (Sweet Briar), *Acaena ovina* (Orchid), *Trifolium subterraneum* (Subterranean Clover), *Trifolium arvense* (Haresfoot Clover), *Poranthera microphylla*, *Stackhousia monogyna* (Creamy Candles), *Hibbertia sericea*, *Lavandula stoechas* (Lavender), *Salvia verbenaca* (Vervain), *Verbascum thapsus* (Great Mullein), *Sherardia arvensis* (Field Madder), *Galium tricornatum* (Rough Fruited Bedstraw), *Helichrysum apiculatum* (Common Everlasting), *Ozothamnus retusus* or *O. scaber (Helichrysum bilobum)*, *Podolepis jaceoides* (*Podolepis acuminate*) (Showy Copper-wire Daisy) and *Craspedia uniflora*.

Breeding
There is only one generation a year with no overlapping generations. Hatching from the egg takes place from December to January. Most males become adult by May, but females overwinter as nymphs and do not mature until the spring. Copulation has been observed in nature from September to the end of November. Fecundity is low; the maximum number of eggs obtained from a pair mating in captivity was 21 (White 1956) and eggs are laid in the soil (Rowell and Crawford 1995).

Threats
The principal threats to *Keyacris scurra* are: loss of habitat, small colony size, inappropriate disturbance (e.g. mowing, too frequent or poorly timed burning or over-grazing), lack of disturbance leading to regeneration of eucalypts or weed invasion, new burials (at cemetery sites), cultivation, pasture improvement, urban development and weed invasion and poor understanding on management requirements (Key 1981; Rowell and Crawford 1995; New 2011). Tall native grassland (usually *Themeda*) with native daisies (or other food sources) is the habitat that most historical records are associated with and such habitat has been widely grazed, cleared, modified and/or burned throughout its original range (Keith 2004). Native grassland remnants suitable for *K. scurra* have survived almost exclusively in local cemeteries (or railway easements) which have not been extensively grazed and which are not burned as part of hazard reduction burns or agricultural activities, although localised excavation and stockpiling of material occurs in active cemeteries. Some of the historical sites for this species are no longer active cemeteries. Cemeteries often occur on arable, long ungrazed land and are spared some of the impacts of surrounding arable lands that have long been targeted for agriculture (Prober 1996). Prober (1996) found that a lack of disturbance favoured *Poa sieberiana* over *Themeda triandra*, so appropriately timed disturbance may also benefit *Keyacris scurra* but the ideal frequency of this is unknown. Unless *Themeda* grasslands are subject to intermittent grazing by domestic stock or native animals and/or burning, *Themeda* develops a dense thatch that excludes other plants, potentially reducing food availability. Secondary *Themeda* grasslands, when fenced off from stock, are also subject to tree and shrub invasion that has, for example, destroyed the grassland habitat at Captains Flat cemetery and is a potential threat to this species (R Farrow *in litt.* July 2018).

Cemetery management, although site specific, often includes mowing grassy areas, and if sufficient habitat is not retained they are unable to support populations of *Keyacris scurra*. Modern management expectations of an intensively managed lawn aesthetic (without ornate gardens), which occurred after World War II may have exacerbated habitat loss in recent times (Clayden *et al.* 2018). The decline of this species in cemeteries may be more severe than elsewhere in the range, however long-term data is limited outside such environments.

Because of their very limited ability to migrate between islands of suitable habitat and (in some locations) persistence in very small habitat patches, a single poorly timed mowing or fire event can destroy a population. *Keyacris scurra* is a winter active species and control burns between autumn and spring may have an adverse impact because of its lack of mobility (R. Farrow *in litt*. July 2018). Reduced population size can also lead to inbreeding and consequent loss of genetic fitness in the species. White (1957) has estimated, on cytological grounds, that F1 hybrids between the races of *K. scurra* may suffer a reduction in fertility of up to 10% (Key 1981). It is possible that *K. scurra* could be reintroduced into areas of suitable habitat, provided source populations remain available (A. Hoffman, *in litt.* 2017 September 2017).

Rate of decline
Prior to 1950
White (1956) speculated that “the natural distribution of the species 130 years ago resembled a jigsaw puzzle from which a half or two-thirds of the pieces have been removed, but was to a large extent continuous except for the mountains”. By the 1950s White (1956) considered that the proportion of the total area occupied by this species had been reduced from about 40% (prior to 1820) to about 1%. Decline in the distribution of *Keyacris scurra* prior to the 1950’s was driven by the clearing of suitable habitat coupled with the grazing of native grasslands by exotic herbivores (and associated pasture improvement, see Reed 2014). These changes occurred over multiple decades, a long period relative to generation length of this

species (1 year). Assuming the estimated decline in the total area occupied occurred over 13 decades then the average 10 year rate of decline is approximately 28%.

Between 1950 and 2018

The estimated average decline over a 10 year period between 1950 and 2018 (as the generation length is one year, the 10 year period applies) is 30% in AOO and 26% in EOO (Table 1). These estimates assume the species originally occupied 160 2 km x 2 km grid squares as indicate by records from the literature, databases and researchers. Recent records in novel habitats were assumed to have been present but undetected at the time of those the 1950's baseline surveys (i.e. no colonisations of new sites since then). This assumption is based on the limited dispersal ability of this grasshopper and the heavily fragmented nature of the habitat. One major constraint in assessing persistence at known sites is the lack of detailed site descriptions and low resolution mapping of these sites. This resulted in many sites not being relocated by Rowell and Crawford (1995) (and hence the use of grid squares instead of discrete sites for this analysis). Attempts in 2018, as part of this review to geo-rectify earlier published maps (e.g. White 1956, 1957), resulted in up to a 3 km error when known sites (e.g. cemeteries) were compared with the predicted locations (in ArcMap 10.4 using ~20 control points at grid intersects). Note also that the estimation of decline over a 10 year period requires an assumption that clearing/ grazing/ burning occurred at a steady rate throughout the period 1950 to present, which is unlikely to be true. It is also possible and indeed likely that local extinctions are not random and if, for instance, are linked to drought, the decadal rate of decline would be much higher than the average rate during drought events.

Table 1 Decline in geographic range between 1960 and the present (58 years). A constant rate of decline is assumed.

	1960	**2018**	**Average % Change over 10 year period**
AOO ($km^{2)}$	540	52	-39.5%
EOO ($km^{2)}$	93,070	15,904	-30.0%

Assessment against IUCN Red List criteria

For this assessment is it considered that the survey of *Keyacris scurra* has been adequate and there is sufficient scientific evidence to support the listing outcome.

Criterion A Population Size reduction

Assessment Outcome: Vulnerable A2

Justification: Available evidence indicates this species is in decline and has declined historically (between 1950 and the present) at a rate exceeding 30% over a ten-year period based on the available records. This species is currently confirmed to occur within 17 AOO 2x2 km squares. Thirteen of the ~82 known sites have been resurveyed with positive records found at three sites. Local extinction is inferred at the remaining 10 sites. Extrapolation of these results suggest ~23% of all known sites might remain occupied. A reduction of geographic range based on available records has occurred, with available data indicating average rates of decline over a 10 year period of 39.5% (AOO) and 30% (EOO) (and therefore between 30-50% which is Vulnerable under this clause).

Criterion B Geographic range

Assessment Outcome: Endangered under Criterion B2ab(ii,iii,iv,v)c(iv)

Justification: The number of known sites currently (using records from 2008- 2018) occupied indicates that the AOO is 52 km^2 (based on a 2 km x2 km grid) and extent of occurrence EOO is 15,904 km^2. Based on all available records the AOO in the 1950s is estimated to have been 540 km^2 (below the threshold for Vulnerable). Due to likely declines in this species (inferred from localised extinctions) and considering the current known distribution, the most likely scenario is that the AOO is between 10 and 500 km^2 which corresponds to the Endangered category under this clause. Further survey will refine this estimate, however

the AOO is not considered likely to exceed the upper threshold for Vulnerable (2000 km^2) based on the availability of suitable habitat.

In addition to these thresholds, at least two of three other conditions must be met. These conditions are:

a) The population or habitat is observed or inferred to be severely fragmented or there is 1 (CR), ≤5 (EN) or ≤10 (VU) locations.

   Assessment Outcome: Severely fragmented (>10 locations)

   Justification: this species and its habitat is severely fragmented (over 50% of the AOO corresponds to locations with a very high risk of a single disturbance event leading to localised extinction). The number of confirmed populations detected within the last 10 years is >10. Known populations are isolated and this species has a limited dispersal ability. Therefore, there is very low likelihood of migration between isolated habitat patches.

b) Continuing decline observed, estimated, inferred or projected in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals

   Assessment Outcome: Continuing decline is inferred in all categories (i – v)

   Justification: There is evidence that the number of sites is reducing over time and that habitat quality is declining. This leads to a reduction in geographic range and total abundance. The lack of information on how to manage the habitat of *Keyacris scurra* means that even in conservation reserves habitat quality may be in decline. No population monitoring is occurring.

Extreme fluctuations.

   Assessment Outcome: Extreme fluctuations are likely to occur (R. Farrow *in litt.* June 2018)

   Justification: As a short-lived species, the population each year is dependent on the conditions in years' previous (although this species is not a prolific breeder like many grasshoppers that fluctuate over many orders of magnitude). It is therefore plausible that the number of mature individuals would be expected to vary within a range of 1-2 orders of magnitude between years. The geographic range does not fluctuate due to the very low vagility (mobility) of this species.

Criterion C Small population size and decline

Assessment Outcome: Data Deficient

Justification:

Ongoing decline has been established under Clause A and B.

There are no reliable current estimates of species abundance. Targeted surveys are required to confirm the total number of individuals. Recent records are all of individuals which is typical of incidental records. Two sites that were visited (Hoffman and Kearney 2018) for targeted surveys only resulted in the detection of a single individual. This may be indicative of low abundance at these sites but could equally reflect the fact that, it is a cryptic species and, like most Morabines, is probably more active at night when it ascends the vegetation to feed. Population density is difficult to measure or estimate in such species (Farrow *in litt.* July 2018).

Current population numbers are unknown, although population estimates in the 1950s (VIC, NSW, ACT) and in 1995 (ACT survey only based on seven sites and excludes NSW and VIC sites) are informative. White sampled 4,227 males (i.e. the total population including females was about 8,450) in 1955 (White 1956). In 1955/56 White (1963) sampled at least 7,830 males from 55 sites, with the minimum harvest at a site of three, the maximum recorded 1,377 and the average 142. White *et al.* (1963) sampled 6,085 males from 15 sites between 1958 and 1961 (most sites were visited once with "Wombat" visited twice 1958 and 1959). The White (1957) estimate included a figure from the "Wombat" site of 1,000 individuals, but the text notes this site could have contained 10,000 individuals (so this estimate and the estimates above are a

minimum). White *et al.* (1963) sampled a total of 11,142 males from eight intensively studied sites, probably selected for their large size, over the period 1955-1961 with most sites studied for up to four years. The total population in the 1950s vastly exceeded 10,000 mature individuals as these estimates do not include females.

Rowell and Crawford (1995) estimated that in seven sites in the ACT the population was >3,830 (of both sexes). The effective population size is also a consideration, Rowell and Crawford (1995) stated that "*K. scurra* now typically occurs as 'colonies', on the grounds that, in some of the larger units encountered, the genetically effective population size would have been smaller than the total number of individuals present, due to the low mobility of the species (e.g. the Wombat Cemetery colony with up to 10,000 individuals in 1956). He [White] regarded a colony of 1,000 as large, and considered that some of the smaller cemetery colonies, containing fewer than 50 individuals per generation, had persisted in isolation from other populations for well over 50 years by 1957."

At least one of two additional conditions must be met. These are:

C1. An observed, estimated or projected continuing decline of at least: 25% in 3 years or 1 generation (whichever is longer) (CE); 20% in 5 years or 2 generations (whichever is longer) (EN); or 10% in 10 years or 3 generations (whichever is longer) (VU).

Assessment Outcome: not applicable

Justification: See clause A above

C2. An observed, estimated, projected or inferred continuing decline in number of mature individuals.

Assessment Outcome: continuing decline inferred

Justification: See clause A above

In addition, at least 1 of the following 3 conditions:

a (i). Number of mature individuals in each subpopulation ≤50 (CR); ≤250 (EN) or ≤1000 (VU).

Assessment Outcome: Unknown

Justification: Historical estimates indicate that at a small proportion of known sites the population exceeded 1000. For instance, In the ACT, Rowell and Crawford (1995) found that there were "470 at Mulligans Flat (RC64,65) and 1330 at NTA/Gungahlin" (RC16)". Kambah Pool (RC41) contained a large population which was fragmented and dispersed over 14 ha containing 2 plant communities. In the 1950's three sites had more than 1000 individuals: Hall (1377), Royalla A (1325) and Wombat (1000). White *et al.* (1963) using data from 1955-1961 estimated that 6 sites had more than 1000 individuals each, these were: Tarago Swamp (1219), Wombat (2363), Hall (1377), Royalla (1682), Murrumbateman (1647, now apparently extinct, Hoffman and Kearney 2018) and Michelago (1811).

The only other known population estimate for an ACT site is that '2000 adults could occur under optimum conditions' at the Gibraltar Rocks Saddle site (K Key, in Greenslade 1991, unpublished). It is likely but unconfirmed that at least one population exceeding 1000 animals persists. Many of the populations are very small (<50) so factors such as bottle necking, genetic drift and isolation may lead to low genetic variability and the effective population size at these larger sites may therefore be considered to be below 1000 (although this requires further genetic research).

a (ii). percentage of mature individuals in one subpopulation is 90-100% (CR); 95-100% (EN) or 100% (VU)

Assessment Outcome: Unknown

Justification: Given most sites are very small and few are remaining, it is possible that one of the (presumed) extant larger populations contains >90% of the total population however without a comprehensive survey for this species this question cannot be answered.

b. Extreme fluctuations in the number of mature individuals

Assessment Outcome: Extreme fluctuations are likely to occur

Justification: See clause B (sub clause b) above.

Criterion D Very small or restricted population

Assessment Outcome: Data Deficient

Justification: There is no accurate population estimate. See Clause C for more details.

To be listed as Vulnerable under D, a species must meet at least one of the two following conditions:

D1. Population size estimated to number fewer than 1,000 mature individuals

Assessment Outcome: Data Deficient

Justification: There is no accurate population estimate. See Clause C for more details.

D2. Restricted area of occupancy (typically <20 km^2) or number of locations (typically <5) with a plausible future threat that could drive the taxon to CR or EX in a very short time.

Assessment Outcome: Data Deficient

Justification: There are >5 sites with current records and the AOO is 52km^2, both these estimates are expected to increase with further survey, although not dramatically.

Criterion E Quantitative Analysis

Assessment Outcome: Data Deficient

Justification: Population viability analysis not performed.

Conservation and Management Actions

Habitat loss, disturbance and modification

Prevent further loss of habitat.

Adaptive management of disturbance regime with monitoring to maintain grassland (or other suitable) habitat and ensure persistence at known sites and inform future management.

Invasive species

- Careful weed control at known sites with monitoring to measure impact. This may include measures to prevent native trees colonising grassland areas or maintaining grasslands at desirable densities.

Ex situ conservation

Captive breeding and release at new sites (or known sites where this species no longer occurs) is likely to be feasible

Stakeholder Management

- Inform land owners and managers of sites where there are known populations and consult with these groups regarding options for conservation management and protection of the species.

Survey and Monitoring priorities

- Habitat monitoring for increased habitat degradation or loss
- Regular surveys of species to determine whether there is a decline in the population
- Monitoring for recruitment.

Information and Research priorities

- Research on required management actions and actions with negative impacts. e.g. positive and negative impacts of fire, slashing or grazing in relation to intensity, type, size and timing.

References

Blackith RE, Blackith RM (1966) The food of morabine grasshoppers. *Australian Journal of Zoology* **14**, 877–894.

Blackith RE, Blackith RM (1969) Variation of Shape and of Discrete Anatomical Characters in the Morabine Grasshoppers. *Australian Journal of Zoology* **17**, 697–718.

Butz M (2004) Blundells Flat area, ACT: Management of natural and cultural heritage values - Background study for the Friends of ACT Arboreta.

Clayden A, Green T, Hockey J, Powell M (2018) Cutting the lawn - Natural burial and its contribution to the delivery of ecosystem services in urban cemeteries. *Urban Forestry and Urban Greening* **33,** 99–106. doi:10.1016/j.ufug.2017.08.012.

Farrow R (2018) `Insects of South-eastern Australia' (CSIRO: Victoria)

Grodwohl JB (2017) Natural Selection, Adaptive Topographies and the Problem of Statistical Inference: The *Moraba scurra* Controversy Under the Microscope. *Journal of the History of Biology* **50**, 753–796. doi:10.1007/s10739-016-9448-5.

Jones S (1993) Nature at the Grave's Edge. Remnant native flora and fauna in the cemeteries of the Australian Capital Territory and the southern tablelands of New South Wales. Final report to the Conservation Council of the South-East Region and Canberra.

Keith D (2004) `Ocean shores to desert dunes: the native vegetation of New South Wales and the ACT´. (NSW Department of Environment and Conservation: Sydney)

Key KHL (1965) Generic Assignment of the Species Hitherto Known as *Moraba scurra* Rehn (Orthoptera: Acridoidea). *Australian Journal of Entomology* **4**, 39.

Key KHL (1976) A generic and suprageneric classification of the Morabinae (Orthoptera: Eu- mastacidae), with description of the type species and a bibliography of the subfamily. *Australian Journal of Zoology, Supplementary Series* No. 37, 185 pp.

Key KHL (1981) The genus *Hastella* (Orthoptera: Eumastacidae: Morabinae). *Australian Journal of Zoology* **29**, 401–459.

Key KHL (1987) Speciation in the Australian morabine grasshoppers—taxonomy and ecology. In ´Genetic mechanisms of speciation in Insects´ (Ed. MJC White) pp. 43-56. (Springer: Dordrecht)

Mulvaney M (2012) The extent and significance of Gungahlin's Biodiversity Values, Conservation Planning and Research, Policy Division. Environment and Sustainable Development Directorate, Canberra.

New TR (2011) `in Considerable Variety´: Introducing the diversity of Australians insects. p158 (Springer, London)

Prober SM (1996) Conservation of the Grassy White Box Woodlands - Rangewide Floristic Variation and Implications For Reserve Design. *Australian Journal of Botany* **44**, 57–77. doi:10.1071/bt9960057.

Pullen K (2000) Key's matchstick Grasshopper. News of Friends of Grasslands. Page 4-5 November - December 2000.

Rehn JAG (1952) *Grasshoppers and Locusts (Acridoidea) of Australia*. Melbourne: CSIRO Vol. 1 326 pp. [138].

Rentz DCF (1991) Orthoptera in `Insects of Australia 2nd Edition' (CSIRO, Division of Entomology, Melbourne University Press), p387.

Reed KFM (2014) Perennial pasture grasses — an historical review of their introduction, use and development for southern Australia. *Crop & Pasture Science* **65**, 691–712.

Rowell A, Crawford I (1995) A survey of the morabine grasshopper *Keyacris scurra* (Rehn) in the ACT. Report to the Wildlife Research Unit, ACT Parks and Conservation Service. CSIRO, ACT.

Rowell A, Crawford I (1999) *Keyacris scurra*: grasshopper density and vegetation composition at selected sites in the A.C.T. region. Report to Wildlife Research and Monitoring, Environment ACT.

Victorian Flora and Fauna Guarantee - Scientific Advisory Committee (Vic SAC (2018). *Keyacris scurra* Rehn 1952 Match stick Grasshopper. Accessed 12 June 2018 https://www.environment.vic.gov.au/__data/assets/pdf_file/0026/92276/Matchstick-Grasshopper-final-rec.pdf

White MJD (1963) Cytogenetics of the grasshopper *Moraba scurra* - VIII. A complex spontaneous translocation. *Chromosoma* **14**, 140–145.

White MJB, Lewontin RC, Andrew LE (1963). Cytogenetics of the grasshopper *Moraba scurra*. vii geographic variation of adaptive properties of inversions. *Evolution* **17**, 147–162.

White MJD (1956) Adaptive Chromosomal Polymorphism in an Australian Grasshopper. *Evolution* **10**, 298–313.

White MJD (1957) Cytogenetics of the Grasshopper *Moraba scurra*. 2. Heterotic Systems and Their Interaction." *Australian Journal of Zoology.* **5**, 305–337.

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APPENDIX 1

Assessment against BC Act criteria

Clause 4.2 – Reduction in population size of species
(Equivalent to IUCN criterion A)
Assessment Outcome: Vulnerable under clause 4.2 1(c), 2(c)

(1) - The species has undergone or is likely to undergo within a time frame appropriate to the life cycle and habitat characteristics of the taxon:			
	(a)	~~for critically endangered species~~	~~a very large reduction in population size, or~~
	(b)	~~for endangered species~~	~~a large reduction in population size, or~~
	(c)	for vulnerable species	a moderate reduction in population size.
(2) - The determination of that criteria is to be based on any of the following:			
	~~(a)~~	~~direct observation,~~	
	~~(b)~~	~~an index of abundance appropriate to the taxon,~~	
	(c)	a decline in the geographic distribution or habitat quality,	
	~~(d)~~	~~the actual or potential levels of exploitation of the species,~~	
	~~(e)~~	~~the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.~~	

Clause 4.3 - Restricted geographic distribution of species and other conditions
(Equivalent to IUCN criterion B)
Assessment Outcome: Endangered under Clause 4.3 (b) (d) (e i, ii, iii & iv).

The geographic distribution of the species is:			
	~~(a)~~	~~for critically endangered species~~	~~very highly restricted, or~~
	(b)	for endangered species	highly restricted, or
	~~(c)~~	~~for vulnerable species~~	~~moderately restricted.~~
and at least 2 of the following 3 conditions apply:			
	(d)	the population or habitat of the species is severely fragmented or nearly all the mature individuals of the species occur within a small number of locations,	
	(e)	there is a projected or continuing decline in any of the following:	
		~~(i)~~	~~an index of abundance appropriate to the taxon,~~
		(ii)	the geographic distribution of the species,
		(iii)	habitat area, extent or quality,
		(iv)	the number of locations in which the species occurs or of populations of the species.
	~~(f)~~	~~extreme fluctuations occur in any of the following:~~	
		~~(i)~~	~~an index of abundance appropriate to the taxon,~~
		~~(ii)~~	~~the geographic distribution of the species,~~
		~~(iii)~~	~~the number of locations in which the species occur or of populations of the species.~~

Clause 4.4 - Low numbers of mature individuals of species and other conditions
(Equivalent to IUCN criterion Clause C)
Assessment Outcome: Data Deficient

The estimated total number of mature individuals of the species is:						
	(a)	for critically endangered species		very low, or		
	(b)	for endangered species		low, or		
	(c)	for vulnerable species		moderately low.		
and either of the following 2 conditions apply:						
	(d)	a continuing decline in the number of mature individuals that is (according to an index of abundance appropriate to the species):				
		(i)	for critically endangered species	very large, or		
		(ii)	for endangered species	large, or		
		(iii)	for vulnerable species	moderate,		
	(e)	both of the following apply:				
		(i)	a continuing decline in the number of mature individuals (according to an index of abundance appropriate to the species), and			
		(ii)	at least one of the following applies:			
			(A)	the number of individuals in each population of the species is:		
				(I)	for critically endangered species	extremely low, or
				(II)	for endangered species	very low, or
				(III)	for vulnerable species	low,
			(B)	all or nearly all mature individuals of the species occur within one population,		
			(C)	extreme fluctuations occur in an index of abundance appropriate to the species.		

Clause 4.5 - Low total numbers of mature individuals of species
(Equivalent to IUCN criterion D)
Assessment Outcome: Data Deficient

The total number of mature individuals of the species is:			
	(a)	for critically endangered species	extremely low, or
	(b)	for endangered species	very low, or
	(c)	for vulnerable species	low.

Clause 4.6 - Quantitative analysis of extinction probability
(Equivalent to IUCN criterion E)
Assessment Outcome: Data Deficient

The probability of extinction of the species is estimated to be:			
	(a)	for critically endangered species	extremely high, or
	(b)	for endangered species	very high, or
	(c)	for vulnerable species	high.

Clause 4.7 - Very highly restricted geographic distribution of species–vulnerable species
(Equivalent to IUCN criterion D2)
Assessment Outcome: Not met.

For vulnerable species,	the geographic distribution of the species or the number of locations of the species is very highly restricted such that the species is prone to the effects of human activities or stochastic events within a very short time period.