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

Ben Hope, Brad Law, Version 3, Nov 2021
NSW Threatened Species Scientific Committee

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

Photo: Michael Kearney

Distribution: Endemic to NSW/ ACT/ VIC
Current EPBC Act Status: Not listed
Current NSW BC Act Status: Endangered
Current VIC Flora and Fauna Guarantee Act status: Threatened
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. The main reasons for this species being eligible are i) inferred restricted geographical range (AOO = 124 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 which along with recent surveys of known sites, allows an historical assessment of the species' decline. This species is now locally extinct at many previously known locations.

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). Additionally, *A. conica* lacks a triangular gap between the base of the head and the thorax, which is present on all matchstick grasshoppers (M. Kearney *in litt.* Dec 2019). Species from the genera *Achurimima*, *Heidi and Vandiemenlla* are also similar in appearance to *Keyacris* and the collection of specimens from novel locations allows the presence of this species to be unambiguously determined. Another similar species, *K. marcida,* occurs to the west of *K. scurra* and is apparently parapatric. At three places in NSW these species (*K. scurra* and the related *K. marcida*) occur within 14-16 km of each other (Key 1981). *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).

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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) although in recent times the range has contracted. This species is typically recorded in native grasslands, secondary native grasslands or areas that contain the native grass *Themeda* with appropriate disturbance regimes. These disturbance regimes are more typically found in the following land-uses which are characterised by infrequent disturbance: 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) (Rowell and Crawford 1995,1999; New 2019).

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 (e.g. in the general vicinity of Bright, Corryong, Omeo and Hinnommunjie) are outside the distribution documented by White (1956, 1957, 1963) and this species has recently (2019) been recorded in the Omeo area (VIC) following targeted surveys (M Kearney *in litt.* Dec 2019). 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 200 2x2 kilometre AOO squares appear to have been occupied in the 1950s, which is indicative of at least 200 populations, given collection sites were typically not connected by suitable habitat (fragmented) and the spacing of sites rendered movement by individuals between sites improbable. This estimate includes records from the 1990-2000s (Rowell and Crawford 1995, 1999) and from 2009-2019 (detailed below), noting that colonisation of new habitat during this period is unlikely. White (1963) recorded this species at four Victorian sites (Merton, Benalla, Beechworth and Wodonga) and there are records in the ANIC collection in the general vicinity of Bright, Corryong, Omeo and Hinnommunjie.

1990-2000s records
Between the 1970s and 1990s there is a lack of records and published research on *K. scurra* as this species was not being actively investigated. 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). In cases where habitat has been totally removed, localised extinctions are unambiguous. Butz (2004) reported this species as absent at Blundells Flat (ACT), a site with historical records. 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

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Jerrabomberra population's habitat had apparently already been at least partly cleared in 2000 (Pullen 2000). Very little information is available about this species in NSW in the 1990-2000 period, 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 although no habitat remains in 2019, M Kearney *in litt.* Dec 2019), 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. These Bionet records were attributed to Rainer Rehwinkel who in surveys over a 20 year period in grasslands and grassy woodlands in south east NSW, found populations of this species at less than 10 sites, during c. 7500 site visits during that time (G Robertson *in litt.* June 2019).

Contemporary distribution

There are recent (2009-2019) credible records from 31 (AOO = 124 km^2) well-dispersed (the EOO is 32,809 km^2), 2 km x 2 km AOO grid squares in NSW (15, 2 km x 2 km grid squares) ACT (10, grid squares) and VIC (6, grid squares). M. Kearney and A. Hoffman between 2017 and 2019 performed a targeted survey of known sites and found that most historical sites were easy to locate (e.g. cemeteries) and for other sites where they were not able to accurately locate, suitable habitat was not present within a large radius of the site, and the conclusion in these cases was that local extinction had occurred (Kearney in litt. Dec 2019). These recent surveys found *K. scurra* at a total of 23 sites which are summarised in the remainder of this paragraph. These surveys resulted in the detection of *K. scurra* at 11 of 62 known sites (sites documented by White or others in the 1950s and 1960s). At all known sites (except Murrumbateman), where they were not detected, suitable habitat (tall *Themeda* grass) was completely absent, hence localised extinction in these cases is highly probable. This represents a rate of decline over a ten-year period of 25.4% (using an exponential rate of decline from 1950 as the start point and 2019 as the end point with the number of sites used as a coarse index of abundance). Changes in the management of cemeteries (e.g. mowing) may have contributed to the extinction at some NSW sites. At Murrumbateman suitable habitat remained in 2019, however no *K. scurra* were found after five site visits. A further 30 sites with apparently suitable habitat (i.e. some *Themeda* that was more than 5-10 cm tall, and food plants present) were surveyed. These sites were either recommended by a botanist with knowledge of remnant *Themeda* grasslands or were Travelling Stock Route reserves within the historical distribution of this species. *Keyacris scurra* was detected at 12 of the 30 sites targeted.

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).

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).

In captivity, Key's Matchstick Grasshopper feeds readily on *Helichrysum* spp. (White 1956). Later work found they consume a wide 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

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(see original paper for preference category, current 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. The generation length is therefore one year. Hatching from the egg takes place from December to January and eggs are buried in the soil (Rowell and Crawford 1995). 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). Rowell and Crawford (1995) performed surveys between August and November and this period was chosen to coincide with the presence of mature males and mature/maturing females.

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 active cemetery sites), cultivation, pasture improvement, urban development, insecticides, climate change, 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 or timing 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, degraded 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, the non overlapping short life cycle and (in some locations) persistence in very small habitat patches, a single poorly timed mowing or

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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).

Climate change could plausibly affect phenology of emergence, hence food availability, susceptibility to wildfires and breeding success, as well as affecting those processes through other mechanisms, for example increased frequency and severity of droughts. Insecticides (e.g. as used for Plague Locust) may impact this species.

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: Data deficient

Justification: Available evidence indicates this species is currently in decline and has declined historically with declines starting when European clearing and grazing occurred. The rate of recent decline (last 10 years) cannot be accurately enumerated due to the long period of time between comprehensive surveys and limitation with the available data. The available decline data from 1960 until present are described below, but were not used to assess status using Criterion A.

The clearest evidence of decline is measured by localised extinctions (when surveyed in 2019 as reported by M Kearney *in litt.* Dec 2019; Kearney *et al.* 2021) at study sites used by White in the 1950s and 1960s and others which has resulted in a reduction of geographic range over time. The 2019 surveys resulted in the detection of *K. scurra* at 11 of 62 known sites (sites documented by White or others in the 1950s and 1960s), and at all sites (except Murrumbateman, which was survey 5 times without a positive detection) where they were not detected, suitable habitat (tall *Themeda* grass) was completely absent, hence localised extinction in these cases is highly probable. This represents a mean decadal rate (the period of time specified by IUCN 2019 for a species with a generation length of one year) of decline of 25.4% (using an exponential rate of decline and using 1960 as the start point and 2019 as the end point with the number of sites used as a coarse index of abundance). The period used for this estimate is 1960 to 2019, however the IUCN (2019) method requires assessment over a ten-year period (or three generation, whichever is longer) so the rate of decline is expressed as average decadal rates of decline (generation length is one year). This decline estimate relies on using localised extinctions to measure decline. As there is evidence that both the abundance at known sites and geographic range is also declining the true rate of decline in abundance could feasibly be higher as not all populations were the same size and some extant population may now be considerably smaller, however this possible has not been included in these estimates. For instance, Wombat Cemetery may have once contained 10,000 animals (according to White 1957) and recent surveys did not detect this species on the site and no habitat remained on the cemetery itself (M Kearney *in litt.* Dec 2019). The timing of the Wombat Cemetery extinction event is unknown, however due to the lifecycle of this species a single disturbance event that disrupts the lifecycle could results in local extinction of an isolated population. Given the threats (e.g. mowing), some local declines in abundance may have occurred and these estimates therefore represent the lower bound of estimated decline in the number of mature individuals as both the number of sites and the abundance with it site is likely to be declining.

The decline in AOO was also considered (see Tables 1a,b,c below). and based on available records the AOO has apparently contracted at a rate of 27.1% per ten-year period between 1960 and 2019 although the apparent rate of decline has slowed down over time with a 9.1% rate of decline in the period 1995 to 2019 and at a higher rate of 39% between 1960 and 1995. The surveys conducted in 1995 were focussed

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on sites in the ACT and as such were not a complete survey across the range, in contrast to the 1950-60 period or 2019 which were geographically comprehensive. The apparent slowing of the rate of decline after 1995 may therefore be an artefact of the way the data were collected. Declines are unlikely to have been uniform and the period of time between geographically comprehensive surveys conducted in the 1960s and 2019, is much longer than the assessment period (the last ten years). It is feasible that the rate of decline has fluctuated over time with periods of stability followed by episodic and irreversible decline. An additional bias is that any site found in 2019 was also assumed to have been occupied in 1995 and 1960 further compounding temporal survey bias.

Table 1 (a,b,c) Decline in geographic range between 1960, 1995 and 2019 and the AOO and EOO for each time period. A constant exponential rate of decline is used and the rate is calculated over a 10-year period following IUCN guidelines. *indicates probable underestimate due to uneven survey effort over time (survey intensity was high in 1950/1960s, moderate but restricted to the ACT in 1995 and high again in 2019. In the intervening periods there was almost no survey performed). The 1960 estimates assume the species occupied 800 2 km x 2 km grid squares as indicated by records from the literature, databases and researchers. All available records were used in the baseline period, this included recent records which were assumed to have been present but undetected in the 1950-1960s baseline period. This assumption is based on the limited dispersal ability of this grasshopper and the heavily fragmented nature of the habitat. This approach creates a bias where more survey effort was expended to establish the baseline, however when viewed in conjunction with resurveys of known sites (in 2019 *K. scurra* was found to be locally extinct at 51 of 62 known sites) it is clear the species is declining. Note also that the estimation of decline over decadal periods requires an assumption that clearing/ grazing/ burning occurred at a steady rate throughout the period 1950 to present, which is unlikely to be true in practice. 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 these drought events or at other times when threats were more active.

Table 1a

	1960	**1995**	**Average % Change over 10 year period**
AOO ($km^{2)}$	800	156	-39.0%
EOO ($km^{2)}$	98,922	41,912	-21.8%

Table 1b 1960 to 2019

	1960	**2019**	**Average % Change over 10 year period**
AOO ($km^{2)}$	800	124	-27.1%
EOO ($km^{2)}$	98,922	32,809	-17.1%

Table 1c 1995 to 2019

	1995	**2019**	**Average % Change over 10 year period**
AOO ($km^{2)}$	156	124	-9.1%*
EOO ($km^{2)}$	41,912	32,809	-9.7%*

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Declines 1820 to 1950

Historic declines are not assessed under this clause, but have presented here to provide a longer-term context. The rate of decline from 1820 to 1950 was estimated by White (1956) to be equivalent to around 25% per ten-year period (using an exponential rate of decline calculated over a ten year period as per IUCN recommendations), however this was a very coarse estimate and as such is of limited utility. 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 landscape occupied by this species had been reduced from about 40% total landscape cover (prior to 1820) to about 1% of the landscape. 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 the short 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 (as the generation length is one year) exponential rate of decline from 40% landscape cover to 1% landscape cover was approximately 25% (although this is a very coarse estimate). However, if this rate of decline continued from 1950 it would have resulted in the total extinction of the species by about 1980, which did not occur as the remaining refugia (e.g. cemeteries) were not exposed to the same threats present in the wider landscape.

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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 2009- 2019) occupied indicates that the AOO is 124 km^2 (based on a 2 km x 2 km grid) and extent of occurrence EOO is 32,809 km^2. Based on all available records the AOO in the 1950s is estimated to have been 800 km^2 (below the threshold for Vulnerable). In 1995 the AOO was estimated to have been 156km^2. Further survey will refine this estimate, however the AOO is not considered likely to exceed the upper threshold for Endangered (500 km^2) based on the availability of suitable habitat. Surveys in 2019 covered a large proportion of the known sites and also surveyed other suitable sites across the range of this species and the AOO for the 2009-2019 period is considered to be an accurate representation of the true distribution. Additionally, surveys by White and others were relatively intense (compared to other invertebrates) in the 1950s and 1960s. In recent times other surveyors were aware of this species and surveying suitable habitat, but the species was recorded infrequently, for instance Friends of Grasslands (G Robertson *in litt.* June 2019) reported the following "FOG member, Rainer Rehwinkel, working with the NSW environment departments (NPWS, DECC, OEH, etc.) in surveys over a 20 year period in grasslands and grassy woodlands in south east NSW, found populations of this species at less than 10 sites, during c. 7500 site visits during that time. Those data are in the Grassy Ecosystems Database (GEDB), which is lodged in NSW Bionet and the Atlas of Living Australia". The Friends of Grasslands submission also noted that "Alison Rowell agrees that local sightings are rare now compared to the 1990s".

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, typically small, vulnerable to extinction from a single poorly timed disturbance event 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.

Extreme fluctuations.

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

Justification: As a short-lived species with non-overlapping generations, 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.

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Criterion C Small population size and decline

Assessment Outcome: Near Threatened

Justification: Ongoing decline has been established under Clause A and B and extreme fluctuations occur. A comprehensive population estimate has not been undertaken in recent times. Recent surveys have detected a total of 376 animals (of any sex) which forms the lower bound of the population estimate (although this is considered to be an underestimate). It is not possible under this clause for a Critically Endangered outcome (as the population exceeds 250), and under Clause B this species is already considered Endangered based on distribution so while the data are uncertain, further work to refine the abundance estimate will not lead to an increased threat status under this clause.

Population density is difficult to measure or estimate in such species (Farrow *in litt.* July 2018). It is a cryptic species and, like most Morabines, is probably more active at night when it ascends the vegetation to feed. More intense surveys in known sites are likely to increase this population estimate, plausibly to above the threshold for endangered (2,500) or vulnerable (10,000). It is also very likely that further surveys will increase the number of total populations as recent targeted surveys have detected this species at 12 out of 30 new survey sites (survey result from M Kearney *in litt.* 2019) and it is expected new sites will continue to be found. It should be noted that targeted surveys looking for new sites have been undertaken in the best quality habitat which is limited in supply and the discovery of new sites is not expected to continue at the same rate with further survey. Historical estimates (see below) indicate that a single site could contain over 10,000 animals (with sites often containing 1000s of animals) and the life history strategy (r-selected) used by most invertebrates favours a relatively high abundance, with considerable year to year variation, however it is the lower end of these variations that should be considered under this clause. Recent declines due to threats may also mean that the abundances recorded historically may no longer be applicable, however there are a few large sites on conservations reserves that are expected to yield high numbers of this species based on the size of the reserves and the amount of available habitat.

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, across multiple sites, destructively sampled 4,227 males (i.e. the total population including females was at least 8,450) in 1955 (White 1956). In 1955/56 White (1963) destructively 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) destructively 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. White also found 1,647 animals present at Murrumbateman (this site was studied intensively) and this species now appear to be extinct at this location. 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) and this is only a subset of known sites. 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). [note: The Wombat Cemetery no longer contains habitat although there is roadside habitat adjacent that appears suitable, however this species was not found in this location in 2019 (M Kearney *in litt.* 2019).] 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:

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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: sub-clause met for Endangered (although as C above is only Near threatened this is not applicable)

Justification: The AOO rate of reduction between 1960 and 1995 was calculated using available records at 20.8% for a 5 year period (using the RAMAS program). The rate of decline appears to have slowed down however in the absence of other data and due to the uneven survey effort over time this estimate is very approximate. Also 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: Recent surveys have detected a total of 376 animals across 23 sites (of any sex) with 100 detected at one site, however these surveys were not designed to estimate total population and are therefore minimum estimates. 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 removed (and the total population was larger by an unknown amount as only males were removed): 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) and the population outside of optimal conditions is not known. 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: clause not met

Justification: There are 31 AOO squares currently occupied. Given the spacing of these records there are assumed to be at least 31 sub-populations. It is unlikely that a single sub-population would contain more than 90% of all mature individuals.

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.

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Criterion D Very small or restricted population
Assessment Outcome: Least concern
Justification: Population suspected to exceed 1000, although 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: Least concern

Justification: There is no accurate population estimate, however present information indicates at least 376 animals are known to exist and it assumed the total population exceeds 1000 when individuals present but not detected at surveys sites and individuals at sites not yet surveyed are included (although the upper bound of the population estimate has not been established). The ability to recover from drought is not understood. Further surveys following drought are required to increase certainty of population estimates. 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: Sub clause not met

Justification: There are >5 locations with current records and the AOO greatly exceeds 20 km^2.

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.
- Avoid/minimise mowing and slashing of vegetation at cemeteries and other habitat remnants. Where these management actions are required provide land managers with information on how to minimise impacts.
- 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 given that non-natives are palatable to this species and may provide a food resource. 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.

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Survey and Monitoring priorities

- Habitat monitoring for increased habitat degradation or loss
- Regular, range-wide surveys of the species to determine whether there is a decline in the population and estimate the number of mature individuals
- Monitoring for recruitment.
- Research on species detectability (repeat surveys)
- Targeted survey for new populations

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.
- Improved knowledge on basic life history, phenology, sensitivity to climate, drought response, population recovery rates (from drought or disturbance), maximum and minimum population sizes at known sites (to document fluctuation sizes and assess long-term population trends).

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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: Data deficient 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.~~	

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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.~~		

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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.~~

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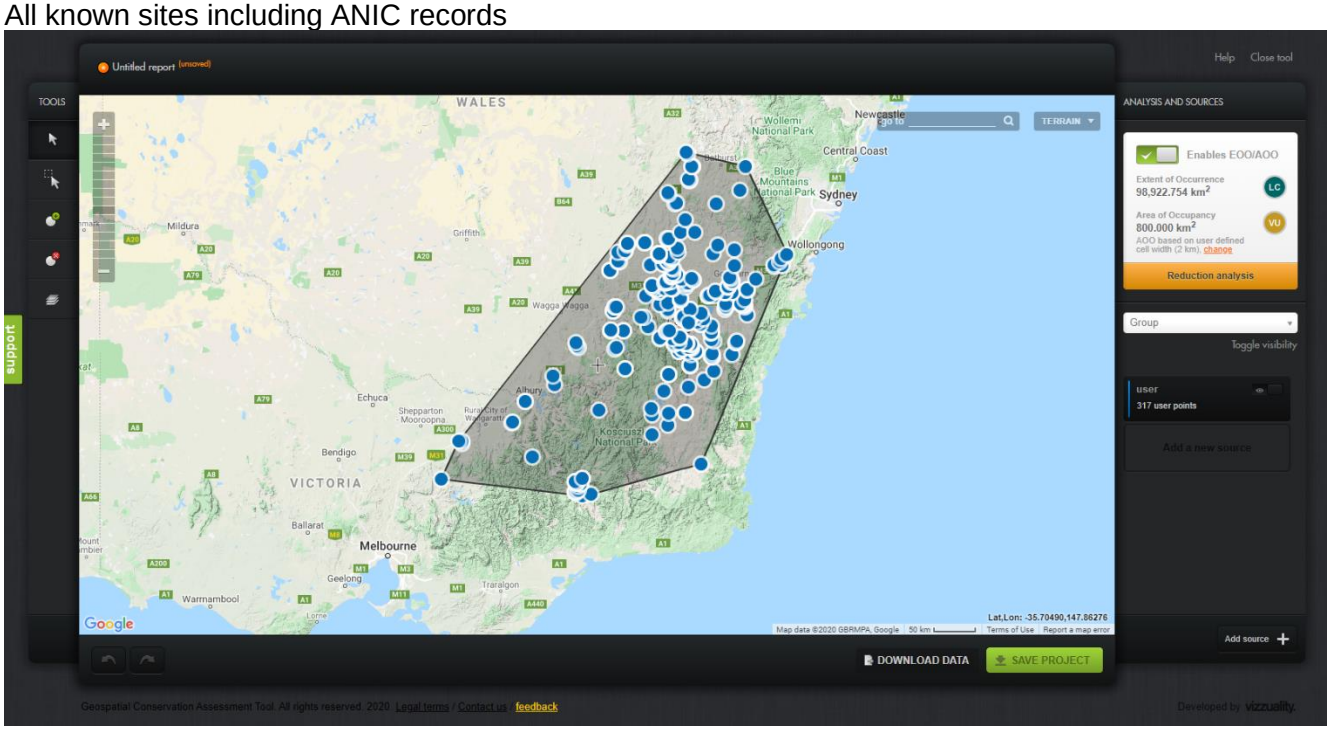
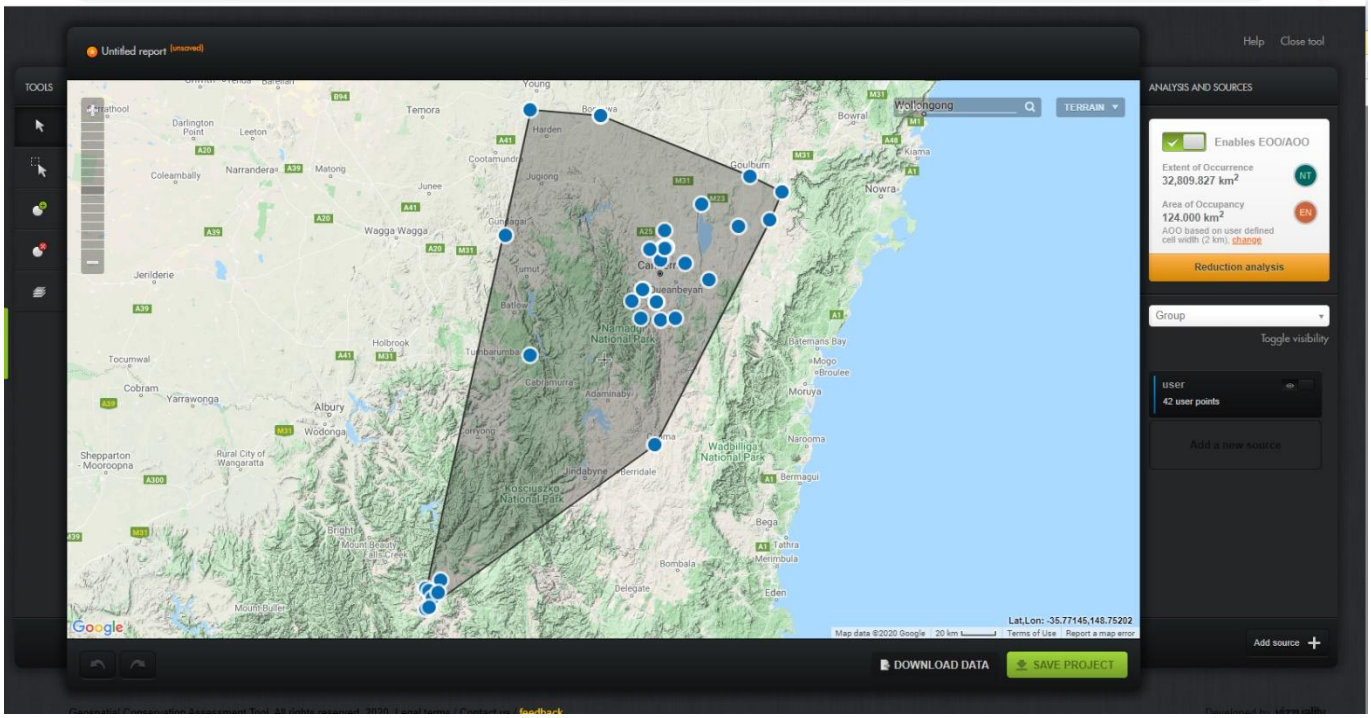
Appendix 2 Location and source for *K. scurra* records (tables and maps)

All known sites including ANIC records



Recent records (2009 to present)



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