Research on the Camel Cricket *NOVOTETTIX naracoortensis* (Richards) (ORTHOPTERA : RHAPHIDOPDORIDAE) in the Naracoorte Karst System

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1. Introduction

The cave crickets located in the Naracoorte caves were first identified by Aola M. Richards, from specimens collected from Haystall Cave (5U-23), Corner Fence Cave (5U-24) and Smoke Cave (5U-42) by P. Atkins in 1962. In 1966, Richards classified and raised the Genus and Species for the cave cricket as follows:

Order	*Orthoptera*
Family	*Rhaphidophoridae*
Genus	*Novotettix*
Species	*naracoortensis*

As well as classifying *N. naracoortensis*, Richards (1966) made a number of observations relating to the Naracoorte cave crickets:

1. That "Alexandra Cave contains a colony of over 1500 *N. naracoortensis*, in contrast to the rather sparsely populated caves in south-eastern Australia".

2. That about two thirds of the insects were located on the walls 30 metres inside the entrance, and the remainder extended another 20 metres or more into the cave.

3. That the temperatures of Alexandra Cave and Victoria (Fossil) Caves were around 63° F (17° C) and that those caves were the warmest habitat so far recorded in Australasia.

4. That no crickets were found in those caves which were bat habitats and vice versa.

Other locations in Australia where members of the Rhaphidophorids are found include New South Wales, Victoria, Flinders Island in Bass Strait, Tasmania and the Nullarbor Plains in south-eastern Western Australia.

Rhaphidophorids are found world wide in New Zealand, South Africa, southern Europe, North and South America.

2. Study Area

This study was primarily undertaken to:

(a) Record the caves supporting populations of *N. naracoortensis*,

(b) Analyse cave cricket population variations,

(c) Record the seasonal population variations,

(d) Determine what effects human intrusion into the caves have on the cricket population.

Although some problems in the study areas were foreseen, many were not. Sorting through the many variables, classifying and prioritising them as they occurred, caused many delays.

3. Methodology of this Study

This paper is a report of the results of a survey conducted with the assistance of members of the South Australian caving organizations. The data was collected by many different people, but each observer was equipped with a standard recording sheet and information as to the definition and characteristics of a nymph, juvenile, male and female (Table 1).

Table 1: Simplified Guide for the Identification of Cave Crickets (*NOVOTETTIX naracoortensis*) when undertaking a Cave Census

Type	Body Length (mm)	Characteristics
Eggs	L <= 1.5	Will not be seen under normal circummstances as they are buried in small holes in the cave roof.
Nymph	L < 4	Newly hatched nymphs can be difficult to see; antennae fine and long and can exceed body length, identical to adults shape without showing sexual characteristics.
Juvenile	4 > L < 9	Abdomen filling out; hind legs larger than nymph's; antennae longer; sexual characteristics develop with each shedding of exoskeleton; possible six or seven stages of development (instars); last stages an be difficult to differentiate from adults.
Male	L > 9	Two small projections (cerci) from base of abdomen; hind legs long and spindly; antennae approximately five times the body length.
Female	L > 9	Long spur (ovipositor) projecting from base of abdomen; hind legs are shorter and thicker than the male's; antennae approximately five time the body length.

These characteristics were developed as a quick easy guide for a large number of inexperienced and unskilled people assisting in the study. It eliminated the need for teaching a complex list of taxonomical reference criteria.

A summary of the data, recording populations of *N. naracoortensis* collected from the caves visited is listed in Table 2. The data on cave cricket distribution, numbers and characteristics has been collected over a period of ten years. A total of 48 caves site were visited, 41 examined and 36 contained specimens of *N. naracoortensis*.

Table 2: Summary of Data from Caves with *N. naracoortensis*. (Mean Values)
41 Caves Entered, 36 Recorded Crickets

Cave Number	Cave Name	No. of Visits	No. of Nymph	No. of Juvenile	No. of Male	No. of Female	Total
U-1	Victoria Fossil	8	2.6	6.1	5.1	4.1	18.0
U-2	Bat	3	1.3	4.0	2.0	2.8	10.0
U-6	Blanche	3	0.0	0.0	2.3	1.3	3.7
U-7	Appledore	30	44.3	67.5	18.1	14.3	143.8
U-9	Blackberry	18	33.6	66.8	20.1	14.3	134.8
U-11	Stick	27	21.3	29.8	21.3	15.0	87.9
U-13	Cathedral	1	0.0	0.0	0.0	1.0	1.0
U-14	Brown Snake	2	0.0	0.0	0.5	1.0	1.5
U-15	Beekeepers	1	8.0	12.0	7.0	4.0	31.0
U-17	Robertson	6	0.0	0.8	3.8	1.3	6.0
U-22	Fox	4	6.5	13.3	12.3	9.0	41.0
U-24	Corner Fence	3	0.0	91.0	17.3	20.3	128.7
U-26	V.D.C.	3	0.0	30.3	12.0	8.0	50.3
U-31	Hoods	1	24.0	10.0	4.0	2.0	40.0
U-35	Specimen	7	0.0	0.0	0.1	0.1	0.3
U-38	Joanna Bat # 1	2	11.5	4.0	6.0	4.0	25.5
U-39	Joanna Bat # 2	2	13.0	7.5	27.5	20.0	68.0
U-42	Smoke	2	4.5	296.0	72.0	95.0	420.0
U-44	Little Victoria	16	25.6	38.8	19.3	10.6	94.2
U-46	Joanna Bat South	2	6.0	0.5	3.0	3.5	13.0
U-47	S 102	7	10.0	20.6	6.6	3.4	40.6
U-48	Anderite	6	6.8	16.8	25.0	15.7	63.3
U-50	Not Named	1	10.0	54.0	4.0	5.0	73.0
U-51	Not Named	1	16.0	33.0	22.0	20.0	91.0
U-58	Wombat	8	0.0	0.0	0.0	0.0	0.0
U-62	Saddle	1	0.0	86.0	69.0	28.0	183.0
U-63	Mosquito Creek	2	0.0	0.0	1.0	3.0	4.0
U-66	Rabbit	1	0.0	3.0	4.0	1.0	8.0
U-71	Not Named	1	0.0	6.0	4.0	2.0	12.0
U-81	Possum # 1	1	0.0	0.0	0.0	0.0	0.0
U-82	Possum # 2	1	0.0	0.0	0.0	0.0	0.0
U-89	Peppertree	1	0.0	0.0	0.0	0.0	0.0
U-90	Alexandra	9	8.2	8.9	13.1	10.6	40.7
U-98	Little Cathedral	1	0.0	0.0	0.0	0.0	0.0
U-102	Not Named	1	0.0	10.0	28.0	3.0	41.0
U-106	Stink Pot	2	287.0	188.0	22.5	14.5	512.0
U-108	Locks	2	9.0	8.5	18.5	8.0	44.0
U-125	Cable	13	107.8	187.3	57.3	30.4	338.9
U-127	Not Named	1	3.0	15.0	7.0	5.0	30.0

4. Behaviour and Morphology

The curved body shape of Rhaphidophorids gives the crickets the international common name of 'Camel' cricket. The body length varies between nine and eighteen millimetres with the female being longer. The dimensions of the rear femur and tubular also show sexual differences with the males having longer and slightly thinner legs than the female.

The female's ovipositor was not measured. The female's ovipositor has a long sturdy character and is as long or longer than the abdomen. Usually the ovipositor is a rusty colour which could indicate maturity or fecundity stage. Both the male and female's antennae are thin and long, reaching approximately four to five times the length of the body. A more taxonomical description of *N. naracoortensis* can be found in Richards (1966).

All Rhaphidorid crickets have well developed compound eyes. Communication within the human hearing range has not been noted although sounds have been detected within the ultra-sonic range attributed to cave crickets. By what means they produce and receive this form of sound has yet to be determined. Other crickets can produce sounds ranging from 15 to 32 kHz and 15 to 93 kHz, with grass hoppers from 13 to 75 kHz.

Although actual copulation between the male and female hasn't been observed, the cave crickets have been observed in the 'court-ship' behaviour and the position prior to copulation. The procedure of mating following the observed behaviour by Hubbell (1978) in Mammoth Cave in Kentucky, U.S.A.

Although the act of egg laying has not been positively identified, the females have been observed with their ovipositor inserted into the roof and upper walls apparently depositing their eggs in the small hole and cavities. Rhaphidophids overseas have been recorded depositing their eggs in the silt or mud on the cave floor and it may be due to the lack of suitable material on the Naracoorte cave floors that *N. naracoortensis* have utilized the roof area. Because of the omnivorous feeding habits of the crickets, probably only a single egg is deposited in each hole. The period of incubation is still unknown.

When hatched, nymphs are replicates of the adult form, without the sexual dimorphisms which appear about the fourth and fifth instar stages. They are difficult to locate as they hide and blend into the roof strata.

Caves which are located in areas with the surface dominated by exotic flora have either no cave crickets or only a very small number. For caves located in the Pinus radiata forests, there have been no observed cave cricket population in those caves.

Whereas *N. naracoortensis* are largely inactive during the daylight hours, they become active approximately one hour prior to sunset. Greatest activity occurring just after sunset when majority decend to the cave floor or exit the cave searching for food. The remainder of the night is alternated between rest and active periods with the crickets returning to the upper cave areas prior to dawn.

5. Observations on Feeding Habits

What the food preferences are outside has not been recorded. Due to the tenuous supply of food within the cave system, the cave crickets are feeders of opportunity, utilising a large range of food. This includes fresh and decaying vegetation, fungi, spores, moulds, faeces, dead vertebrate animals, and many forms of invertebrates - either dead or alive, including their own species.

The crickets have also been observed feeding on the carcasses of possums, snakes, frogs and other indescribable items. Adult *N. naracoortensis* have also been seen eating juvenile crickets. After shedding their exoskeleton during moulting the cricket consumes it while their new integument is hardening.

Numerous individuals have been observed with a leg missing, especially the hind leg. An observation in April 1994, recorded a male *N. naracoortensis* consuming its own rear legs (Simms, in press).

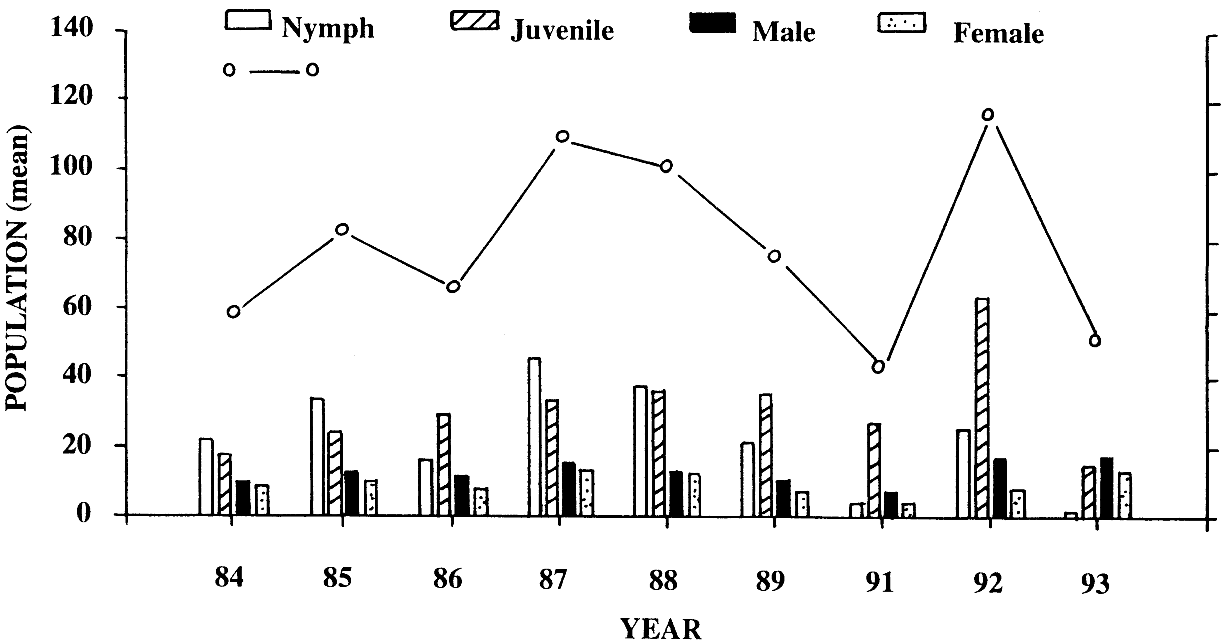
Feed lines have been used to determine if the cave crickets have preferable foods and would utilise food not usually associated with the cave environment. This experiment was conducted several times using different caves with no more than four food types being used at any given time. Food made available to the crickets included dry and moist rolled oats, milk soaked rolled oats, peanut paste, tomato, over-ripe banana, celery, lettuce, apple, bread, vegemite, sardines, cooked and fresh meat. It was found that the cave crickets generally ignored the tomato, celery, dry rolled oats, fresh meat and vegemite. The food was first detected by the antenna which would sweep the air sampling the odours present. On locating the food, the antenna would sweep over the food, possibly sampling the odours before selected food for consumption. The observations indicate that *N. naracoortensis* are primarily opportunist, omnivorous scavengers, consuming a wide range of food types.

6. Geographic Extent of Habitat and Population Relation

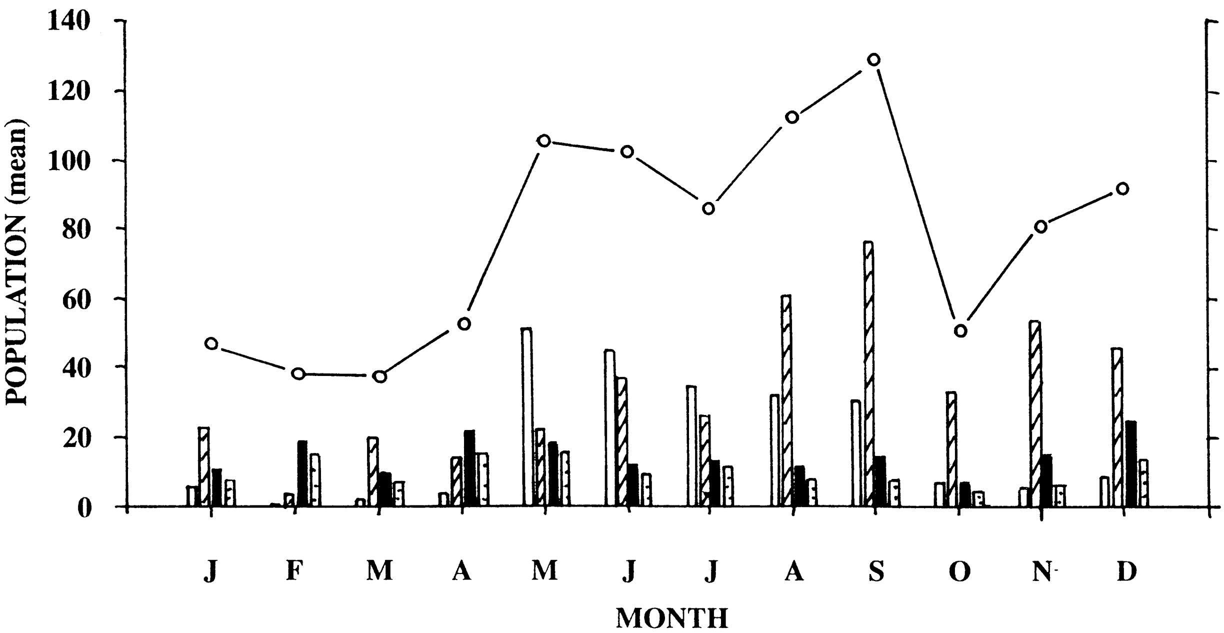
The research was confined to the Naracoorte Karst area which ranges from fifteen kilometres north of Naracoorte to twenty five kilometres south. It is evident that in the distribution of caves in which the crickets appear, no part of the Naracoorte Karst area would not be suitable as a habitat for *N. naracoortensis*. The controlling factor being the surface usage and vegetation. Caves located in fertilised pastures have low or no cricket populations. Also caves found within the pine forests haven't recorded any crickets (native insects are extremely rare in pine forests). Some caves with native vegetation surrounding the entrances have also recorded low or no cricket populations. The reason for this is unknown.

Table 3: Naracoorte Cave Cricket Research

Annual Mean for Years 1984 - 1993



Monthly Mean - All Caves 1984 - 1993



7. Seasonal Trends in Population Numbers

From the data collected, it is apparent that there is a seasonal population variation within the year. The lowest population numbers occur during February - March, peaking in August - September. Nymphs appear in large numbers at the end of April peaking during May. The juveniles numbers peak during August and September.

The adults show no dramatic fluctuation in population although peaks have been recorded in February, April and December, with low periods in January, March and October. The low recording in October is not dependable because of the low number of observations recorded for that month. The low number of observations in February may render that month's data unreliable. The adults appear to peak twice within the year; in April and December.

It is acknowledged that the number of *N. naracoortensis* observed would be below the actual numbers present, due to the inaccessible recesses, cracks and holes in which they rest.

The survival ratio of nymph/juveniles into adults is typical to that of most other insects with the over-all mean of 41% achieving the adult stage. For the 1984-89 period the ratio are 39.6% and the 1991-93 period 42.3%.

8. Trends in Population over time

The data collected on the N. naracoortens is population in the Naracoorte area allows for an analysis of trends in the numbers over the nine year period for some popular and well frequented caves.

There is an annual trend in the population with the nymph's major hatching occurring in April/May with the juvenile crickets maturing during the September/October period. The adult population appears reasonably stable for most of the year, with an increase in December followed by a decline during January/March.

A periodic peak and low population pattern has emerged over the study period. The cause has not yet been identified, but periodic aerial spraying of chemical on the adjacent pastures by the local property owners could have a contributing factor.

A natural decline in one cave has been noted due to a massive increase in lublinite appearing on the cave walls. Cave entrances with a predominance of lublinite have not recorded populations of the cave crickets.

9. Impact of Visitor Numbers on Populations Numbers

As indicated earlier, *N. naracoortensis* are sensitive to disturbance by humans. This is evident in the statistics when the caves are classified according to land tenure (National Parks or Private), and development for tourist/caver usage or restricted access.

Using six classifications for cave usage, an interesting pattern developed which shows a relationship for caves with high human usage and low cricket populations, against caves with low or nil human usage and high cricket populations. The caves with high tourist usage have small cricket populations while the caves located within natural native vegetation with restricted access recorded the highest population numbers.

When the total numbers of *N. naracoortensis* observed for all caves with each category are correlated, the implication of human impact on the cricket populations appears as a major factor.

The classifications are:

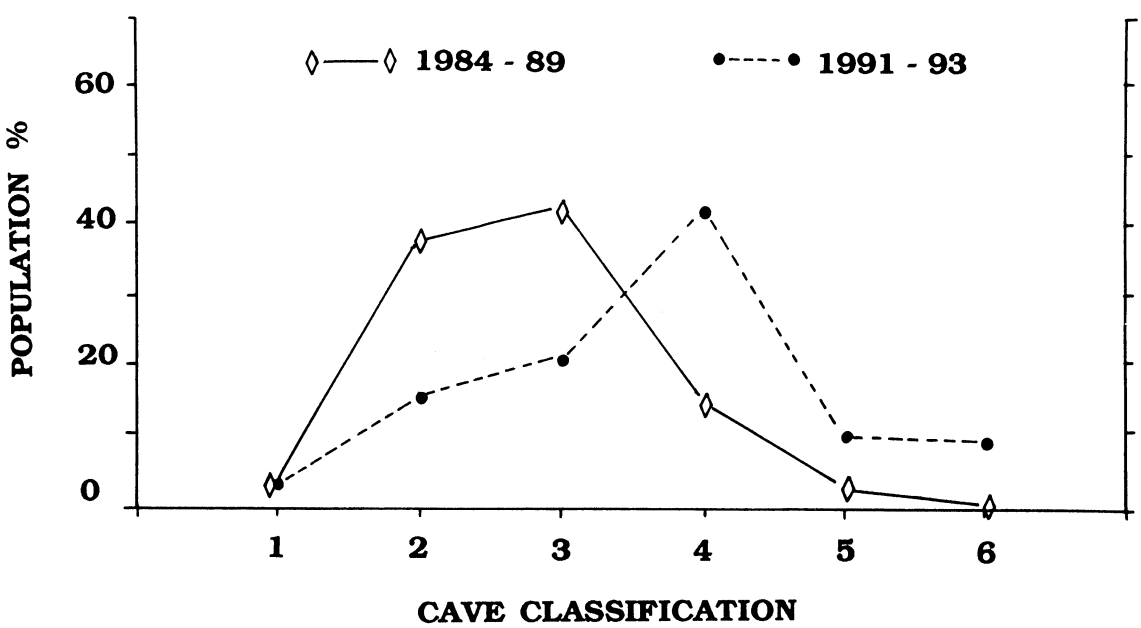
N.G.T. National Parks Guided Tours
N.W.T. National Parks Wild Guided Tours
N.W.U. National Parks Wild Unrestricted Access
N.W.R. National Parks Wild Restricted Access
P.W.U. Private Wild Unrestricted Access
P.W.R. Private Restricted Access

Cave cricket populations rated with cave classification range from the lowest number to the highest in the following order, as used by Table 4:

1. N.G.T. National Parks Guided Tours
2. N.W.T. National Parks Wild Guided Tours
3. P.W.U. Private Wild Unrestricted Access
4. N.W.U. National Parks Wild Unrestricted Access
5. P.W.R. Private Restricted Access
6. N.W.R. National Parks Wild Restricted Access

The impact caused by the number of people using the caves are not the only factor affecting the cave cricket populations, other factors include tourist facility improvements, washing and cleaning the formations, inflow of detritus material, other living cavernous forms, rainfall, humidity, temperature, usage of the surrounding surface, aerial pasture spraying, predators etc.

Table 4: Cave Usage Annual Variance, Cave Classification VS Cricket Population



Conclusion

In conclusion, it is apparent that *N. naracoortensis* has a wide distridution within the Naracoorte Karst system. Their population densities depends on a stable environment, being vulnerable to:

(a) Current pasture usage,

(b) Human interference to the biology of the caves,

(c) Volume and frequency of human visitation to an induvidual cave,

(d) Geolomorhpology within the cave entrance area..

The pattern of behavour shown by the camel crickets and the effects of human influences have on their environment mirrors in many ways what is happening world wide.

The balance for their survival in large numbers in Naracoorte and possibly for all cave crickets in Australia, appears for them to be able to access undisturbed caves located within natural vegetation.

References

Complete details were not available at the time of going to press.

Richards, 1966:

Hubbell, 1978:

Simms, in press: