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Museum Victoria Science Reports Nos 2-5



Studies of The Giant Gippsland Earthworm, *Megascolides australis*, in South Gippsland, Victoria, Australia

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January 2002

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Museum Victoria Science Reports 2: 1–10.

ISBN 0 7311 7243 4 (print); 0 7311 7256 6 (on-line)

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Museum Victoria Science Reports 5: 1–10.

ISBN 0 7311 7246 9 (print); 0 7311 7259 0 (on-line)

Cover design: Luisa Laino (Museum Victoria)

Front cover illustrations from Loch, South Gippsland, from top to bottom: 1 *Megascolides australis* egg cocoons. 2 an adult *M. australis*. 3 Hills of South Gippsland where *M. australis* occurs. Photos: Alan Yen and Bill Green.

The Giant Gippsland Earthworm, *Megascolides australis*, population at Loch Hill, South Gippsland : distribution and preliminary biological and soil studies

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Abstract

Van Praagh, B.D., Hinkley, S.D. and Sargeant, I. J. 2002. The Giant Gippsland Earthworm, *Megascolides australis*, population at Loch Hill, South Gippsland : distribution and preliminary biological and soil studies. *Museum Victoria Science Reports 2*: 1–10.

A preliminary study of the distribution, soils and biology of the Giant Gippsland Earthworm at Loch Hill was conducted between September and November 2001. This population occurs in the vicinity of proposed roadworks for the South Gippsland Highway between Loch and Bena.

The earthworm population at Loch Hill was found to have a relatively restricted distribution, confined to an area of approximately 2500m², extending south-east of the tree fern, across the face of the hill to just past the seepage channel. The population extends downslope to just above the tributary of Allsop Creek but is absent from the valley floor. Soil investigations reveal that this area corresponds to a section of the hill with very pronounced terracettes, indicating that the land surface is wetter than the surrounding area.

Worms appeared to be widespread within their area of distribution. Six quadrats were examined for worm density from which a total of 23 worms were recorded. Worm density within this area was very high ranging from 4.1 to 17.9 worms per m³ with an average of 8.5 worms per m³ calculated. This indicates a very high density of worms at Loch Hill.

A range of age classes were found with adult, subadult and juvenile worms recorded. The largest worm found weighed 250g. No breeding adults were found despite sampling occurring within the known breeding season.

If road works proceed in the area occupied by the Giant Gippsland Earthworm population at Loch Hill, the entire earthworm habitat at the site would be lost. The impacts of road works at the site on the species are discussed and include directly killing individuals and injury of earthworms during soil excavation, compacting the soil and altering the soil habitat in particular drainage and moisture regimes at the site.

The only mitigation measure available is to attempt to 'rescue' the existing population before and during roadworks and endeavour to protect or restore any earthworm habitat near by that may escape the direct impacts of the roadworks. Research opportunities resulting from this situation and their benefits to the long term survival and conservation of this species are discussed.

1. DISTRIBUTION AND PRELIMINARY BIOLOGICAL STUDIES AT LOCH HILL

Background

Museum Victoria was contracted by Vic Roads in October 2000 to investigate the potential impact on the Giant Gippsland Earthworm, *Megascolides australis*, of road and bridge construction works on the South Gippsland Highway around Loch and Bena (Van Praagh and Hinkley 2000a, b, c, 2001). During these surveys, a population of *M. australis* was located at Loch Hill (Van Praagh and Hinkley 2000b). Further surveys were conducted at this site in July 2001 after roadworks associated with bore testing and soil excavation occurred within the vicinity of the earthworm population (Van Praagh and Hinkley 2001). This work revealed that the area supported a large population of the species, which was more widespread at the site than previously thought. Assessment of the site after the disturbance indicated that the works resulted in the destruction of some earthworm habitat and individual earthworms, though exact numbers were difficult to estimate.

Museum Victoria was further contracted (August 2001) to provide advice on what mitigation measures (if any) may be effective for protection of the remaining population of *M.*

australis at Loch Hill. The objectives of the project are:

- Identification of the specific area inhabited by the earthworm colony by determining the AMG co-ordinates for boundary corners (using GPS).
- Estimation of the depth occupied by worms.
- Evaluation of the density per m³ of worms in the area.
- Assessment of the potential impacts that the roadworks could have on the colony.
- Identification of measures that could be implemented to prevent or minimise the potential impacts on *M. australis*.
- Assessment of soils where *M. australis* occurs.

Methods

Distribution. The distribution of *M. australis* at Loch Hill was obtained by surveying the site in and around the vicinity of the known locations. This involved digging and looking for signs of the worms' presence. Quadrats of approximately 50 cm x 50 cm were dug to examine the soil for Giant Gippsland Earthworm burrows. Burrows are easily identified and, if wet, represent burrows that are actively being utilised by the

worms. If the ground is wet, presence of the worms can also be established by banging the ground with a spade and listening for gurgles, the sound that is made when the worms retreat down their burrows.

Sampling began just east of the lone tree fern and continued east across the hillside until no more worms were located. Sampling extended downslope to the creek at the bottom of Loch Hill. Areas above the road cutting were also surveyed.

Density and population structure. Information regarding earthworm density and population structure was obtained by extensive digging of large quadrats to obtain individual specimens. Quadrats were located in areas where active earthworms were detected from the distribution survey such as those with wet burrows or where gurgles were heard. Once the soil was exposed, the site was searched for wet burrows. Wet burrows were then followed carefully until the worm was found and part of its body exposed. Once exposed, the entire worm was slowly dug out of the burrow, using a trowel. Individual worms were then measured and weighed and their reproductive status recorded. It is difficult to obtain an accurate estimate of worm size due to the worms' ability to expand and contract. A contracted worm can more than double its length when relaxed. Weight possibly gives a better comparative estimate of size, although this may vary according to amounts of soil consumed and that voided during capture. Depth of the worms was also recorded by measuring the depth in the soil when the worm was first observed. Worm density was estimated by calculating the number of worms located in a given area of soil dug.

Worms were classified into juveniles, subadult and adults based on the number and position of clitella banding (Van Praagh 1994). These small, light coloured bands occur on the ventral surface of the worm between segments xvii and xix. Juvenile worms have no external banding, subadults one or two and adults have three bands on segments xvii, xviii and xix. This information could only be obtained from worms that were fully dug up, or at least had their anterior segments exposed far enough so the clitella banding could be examined.

Unfortunately, even when great care is taken, individual worms can be killed or damaged through the excavation process. As the worms are very fragile, even bruising can result in death. Any worms injured or killed were fixed in formalin and preserved in 70% alcohol and retained in Museum Victoria collections for further research. Worms were relaxed in a mixture of 10% Magnesium sulphate and Magnesium chloride added to water, fixed in 10% formalin and stored in 70% alcohol. All uninjured worms were released at site of capture.

Not all worms sighted could be dug up. If worms were found very deep in the soil or where a large number of worms were found together, only the number and depth of the worms found was recorded as the risk of injury to other worms was considered to outweigh the successful capture and release of a worm.

Worm density is expressed per m^3 of soil. To take into account the hillslope when digging a quadrat, the average of the highest and lowest depth of the quadrat dug is used for the calculation. The estimation of the number of worms at Loch can also be given per m^2 , assuming that most worms are in the top 1m of soil.

Mean densities were converted to logarithms to calculate

the 95% confidence limits. Log transformations are used on small sample sizes where the sample is not randomly distributed over an area (Elliot 1977) as is the case with the Giant Gippsland Earthworm at Loch Hill.

Soil. A soil scientist, Ian Sargeant, an expert in soils of the South Gippsland region, was engaged to provide advice on soils at the study site where the worms occur at Loch Hill.

The distribution of the Giant Gippsland Earthworm at the study site is recorded on a map and the AMG/Lat Long coordinates provided.

Field trips were carried out on 12 September, 10 and 17 October, 13 and 28 November 2001.

Results

Distribution of *M. australis* at Loch Hill. The location and habitat characteristics of worm sites are given in table 1. Worms were located about 30 m SE of tree fern (site 1) ($38^{\circ} 22' 741 145^{\circ} 43' 591$) and continued down to just above the creek bank at the bottom of Loch Hill ($38^{\circ} 22' 742 145^{\circ} 43' 545$) (Plate 1a & 1b) Their distribution followed a band eastward across the hill to sampling point 14, close to the obvious drainage channel running downslope ($38^{\circ} 22' 742 145^{\circ} 43' 563$). This channel appeared to be fed by an underground spring evident in the cut face above the road (Plate 2). This coincides with the observed distribution of burrows in the cutting above the roadside, which appeared to diminish on the east side of the turn circle ($38^{\circ} 22' 714 145^{\circ} 43' 591$) (see Plate 2). Burrows appeared to be absent from the creek bank itself, although they were found close by into the hillslope (eg site 11). They were also absent from the area above the road cutting. Therefore the worms were confined to a fairly specific area of the hill. The area occupied by worms was approximately $2500 m^2$. Within this area, worms were patchy but appeared to be quite dense in parts. Live worms were observed during this survey and gurgles were heard.

Biology and Density. Six quadrats were dug at Loch Hill to examine the density of earthworms and estimate their depth in the soil (Table 2). Three of these sites (site 1, 2 and 3) occurred just below the road cutting which was covered in fallen soil (Plate 3) and the remaining study sites occurred in undisturbed pasture toward the bottom of Loch Hill, about 10 m above the creek bank (site 4, 5 and 6) (Plate 4).

A large area of pasture below the road cutting was covered by soil from the excavation above. The pre-existing pasture was evident approximately 20-30 cm below the new soil line. Worms were located in this area and burrows were evident above the old pasture line, indicating that they had successfully burrowed into the new soil. A total of 9 worms were found from these three sites (see table 2). This included 4 juveniles, 1 subadult, 1 adult and 3 unknowns (worms not completely dug out).

A total of 14 worms were recorded from the three sites located toward the bottom of Loch Hill. These sites had a high density of burrows and worms (Plate 5 and 6). In particular, site 6 where such a large number of worms were encountered while digging, that it was very difficult to pursue many of the worms without damaging others. At one point, 5 worms were exposed at one time (Plate 7a and 7b).

At this site, one small juvenile worm was recorded which appeared to be fairly recently hatched. Two empty egg

cocoons were found, one of which appeared to be quite a recent hatchling and therefore may have been the one from which the juvenile worm had emerged. No unhatched egg cocoons were located during sampling. No breeding adults were found (ie adults with swollen clitella). Worms were found at a mean depth of 39.3 ± 16.6 cm.

Worms ranged in size from 25 cm to around 80 cm with weights ranging from 18 g for a newly hatched juvenile up to 250 g for an adult.

Overall Density. The number of worms found ranged from 1 to 9 with the mean density per m^3 ranging from 4.1 to 17.9. The high figure of 17.9 arises due to the small volume of soil dug to record the single individual found. The mean number of worms at the site is $8.5 m^{-2}$ with a 95% CL = 5 -14.5 m^{-2} . The area estimated to be occupied by worms at Loch Hill is 50 x 50 m (=2500 m^2). Using the average density of worms (8.5), the total number of worms at Loch Hill is estimated to be 21,250 with 95% C. L limits of 12,500 –36,250 worms.

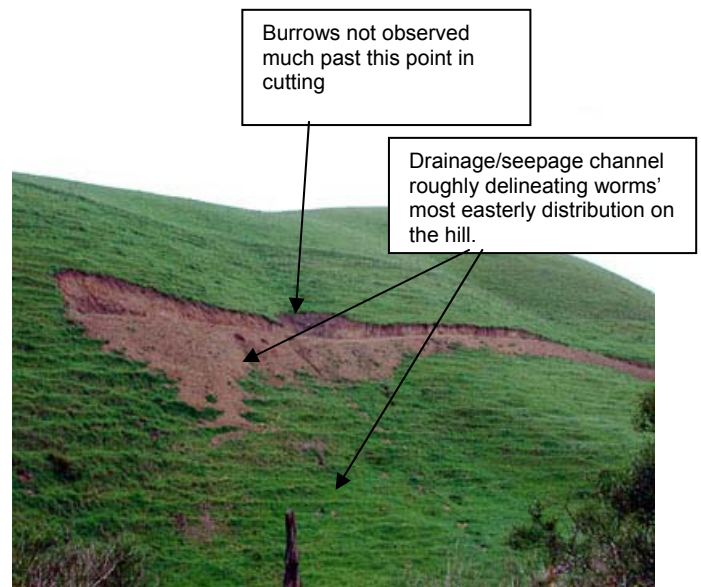
Plate 1a. Distribution of the Giant Gippsland Earthworm at Loch Hill



Plate 1b. Distribution of the Giant Gippsland Earthworm at Loch Hill



Plate 2. Distribution of Giant Gippsland Earthworms and seepage point at Loch Hill.



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Table 1. Distribution of Giant Gippsland Earthworm at Loch Hill

Distribution Point	Lat Long		Worm burrow density
1.	38° 22' 741" 145° 43' 548"	About 30m South of tree fern	Worm burrows and fresh cast
2.		2.5 m south of site 2.	
3.	38° 22' 732" 145° 43' 550"	1.5 m downslope from Site 2	High density of burrows
4.	38° 22' 742" 145° 43' 544"		Burrows and young GGE worm at 15 cm depth
5.	38° 22' 740" 145° 43' 540"		A few burrows (low density)
6.	38° 22' 729" 145° 43' 540"		A few burrows
7.	38° 22' 742" 145° 43' 540"	About 2m from creek bank at bottom of hillslope/steep bank.	Gurgle, wet burrow and a juvenile GGE
8.	38° 22' 739" 145° 43' 548"	About 10 m from creek in steep part of hillslope above bend in the stream.	Medium density burrows.
9.	38° 22' 737" 145° 43' 554"		1 adult worm at 10cm depth. High density of burrows
10.		Just below site 9.	High density of burrows
11.	38° 22' 740" 145° 43' 551"	Very steep section of hill about 4 m above creek. About 4 m below site 9.	Gurgle, very high density of burrows. Adult worm
12.	38° 22' 737" 145° 43' 558"	Just under level of soil excavation spill (from west).	Very high density of burrows. Close to surface. Wet burrows and gurgles.
13.	38° 22' 737" 145° 43' 560"	Middle of hillslope almost level with tree fern	Gurgles and burrows close to surface.
14.	38° 22' 272" 145° 43' 575"	21 m below road, just past turn cutting	Gurgle and large adult, about 20 cm depth.

Table 2. Number, depth and density of *M. australis* recorded at study sites at Loch Hill. Unknown indicates that a worm was observed but not completely dug out so that its age class could not be determined. ? indicates that weight was not recorded. Immature indicates either juvenile or subadult worm.

Date	Site	Lat long	No of worms	*Age class and weight of known worms	No of egg cocoons	Ave depth of worms (cm) (range)	Area dug m ³	Ave density of worms per m ³
10 Oct 01	1	38° 22' 720" 145° 43' 570"	1	Juvenile (95 g)	0	20	0.8 x0.35x0.2 =0.056	17.9
10 Oct 01	2	38° 22' 722" 145° 43' 563"	5	3 Unknown, 1 subadult, 1 adult	0	55.8 (50-68)	1.20 x1.10x 0.50 (ave depth 0.58) = 0.8	6.5
17 Oct 01	3	38° 22' 725" 145° 43' 567"	3	3 juveniles (18g, 33g, ?)	0	25 (20-35)	1.20x1.50x0.55(ave depth 32.8)=0.47	5.1
17 Oct 01	4	38° 22' 763" 145° 43' 55	2	1 adult (150g), 1 unknown	0	59 (54-64)	1.13x 0.90x 0.90 (ave depth 0.47) .	4.1
13 Nov 01	5	38° 22' 739" 145° 43' 548"	3	1 immature, 1 adult, 1 juvenile (50 g)	1(hatched)	28 (10-50)	110x90x60 (ave depth 0.35)=0.34	8.7
28 Nov 01	6	38° 22' 725" 145° 43' 567"	8-10 (9)	2 Juveniles (30 g, ?), 4 adults (215g, 250g, 220g, ?) and 4 unknowns.	2 (hatched) @ 25 and 15 cm	35 (15-55)	150x150x80 (ave depth 0.45)	8.9
			23			39.3±16.6	Average density of worms	8.5 ± 5.0

Plate 3. Location of study sites 1, 2 and 3 at Loch Hill

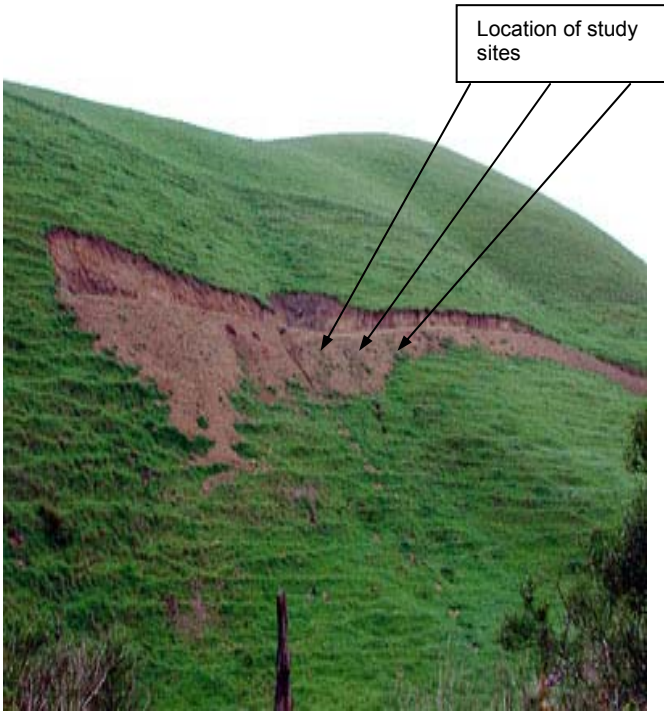


Plate 5. Section of soil showing high density of burrows found at site 6.



Plate 4. Location of study sites 4, 5 and 6 at Loch Hill

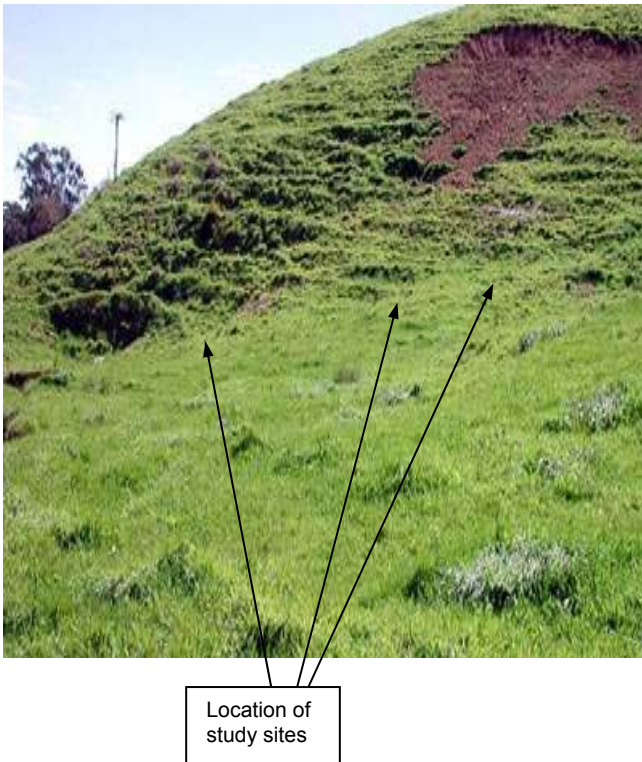


Plate 6. Area dug at site 6 where approximately 9 worms were found.



Plate 7a and b. Site 6 showing high numbers of earthworms exposed during excavation

7a



7b



2. SOME PRELIMINARY COMMENTS ON THE SOILS ASSOCIATED WITH THE EARTHWORM POPULATION AT LOCH, VICTORIA

Introduction

This is a preliminary report relating to observations on a population of Giant Gippsland Earthworms near Loch, Victoria. The extent of this population is quite small, being confined to a wedge shaped area extending some 30 m downslope from a cutting into a hill constructed to gain access to a bore test site (Van Praagh and Hinkley, 2001). The widest lateral extent of the earthworm population is found on the lower slopes adjoining a westerly flowing creek running approximately parallel to the road. The earthworms are not found in the valley floor, nor are they found on the adjoining slopes.

Geology

The underlying rocks in the area are Lower Cretaceous sediments of the Strzelecki Group, predominantly sandy silty clay with feldspathic sandstone and mudstone rock fragments (Douglas, 1979).

Soils

The soils throughout Gippsland have been described by Sargeant (1995) at a scale of 1:100 000. Here the soils are mapped as the Strzelecki map unit. At this scale no detail regarding slope and aspect is described for this area. In general the soils of this unit tend to be more clayey and deeper on the southern and south-eastern slopes, and without lime additions they are generally moderately to strongly acidic. In general, decomposing rock is found between 0.8 and 1.5m from the surface.

At this site the track exposure showed that the depth to intact rock was about 0.8 to 1.0 m. A small section immediately to the west of a seepage line appeared to be deeper, and the author gained the impression that some downslope soil creep had occurred.

Geomorphology

The overall landscape consists of maturely dissected, hilly, cleared terrain with relatively youthful valleys. Many of the steeper hillslopes show a regular rippled surface appearance with miniature terraces extending across the slope, usually at right angles to the direction of maximum slope (Plate 1, Van Praagh and Hinkley, 2001). Such ripples, which are often called terracettes, are generally less than 0.5m wide and deep. The appearance of terracettes is often accentuated by the movement of sheep and cattle. Since terracettes may or may not occur on similar topography at

similar stocking rates, and may also occur on lightly grazed land, it is usually considered that terracettes are a form of landscape instability and not poor land management.

Carson (1967) related the presence of terracettes to slope, depth of soil, irregularities in the underlying rock mantle and the nature of the vegetation. Where the soil mantle was deeper than a critical depth for the degree of slope, landslips, rather than terracettes were common.

In his review on slope stability in the Strzelecki Ranges, Brumley (1983) listed the various factors causing slope movement. In summary, these were:

- Steep slopes*
- Deep weathering and residual soil development
- The presence of expansive clay minerals (at this site it is montmorillonite)*
- Seasonal volume changes in plastic clay soils which lower cohesion by developing fissures and assisting water to penetrate the soil profile*
- Progressive release of stored residual and overburden stress during weathering and erosion
- Structural weakness in the Cretaceous rocks*
- Seismicity
- Intense rainfall leading to an increase in soil moisture content and groundwater level*

The factors denoted * are present at this site.

At the site where the earthworms were found, the terracettes were very pronounced and the average slope was between 35 and 40 degrees. No slope measurements were taken elsewhere, but the general impression was gained that the area where earthworms were located had greater micro-relief due to the presence of terracettes than the surrounding area. This is taken to indicate that the land surface is wetter than the surrounding area and may be subject to "soil creep" or accelerated terracette formation. Landscape instability has occurred in this valley in the past, with the author recalling two landslips in the past 20 years on the southern flank of this valley.

Hydrology

The soils where the earthworms were found was quite moist and free water was noted in many of the active burrows. As mentioned earlier, there was a zone of seepage directly above the earthworm population which would have maintained the water content of the soil for extensive periods of time prior to the construction of the cutting. As noted by Van Praagh and Hinkley (2001), water balance within burrows is important for worm movement and respiration. Burrows occupied by the species are very wet and usually have some free-flow of water in them. These water conditions were apparent at this site. During wetter periods of the year, the area appears to be on the point of landscape instability, but no landslides have occurred yet.

3. DISCUSSION - IMPACTS, MITIGATION MEASURES AND FUTURE RESEARCH

Preliminary surveys at Loch Hill reveal the earthworm population to have a relatively restricted distribution, confined to an area of approximately 2500m², extending south-east of the tree fern, across the face of the hill to just past the seepage channel. The population extends downslope to just above the tributary of Allsop Creek but is absent from the valley floor. According to the soil investigations, this area corresponds to a section of the hill with very pronounced terracettes, indicating that the land surface is wetter than the surrounding area. The presence of running water down the cut face of the hillslope, generally below the soil surface but exposed during soil excavations, supports this.

Worm density within this area was very high ranging from 4.1 to 17.9 worms per m³ with an average of 8.5 worms per m³ calculated. This is a higher density than that recorded nearby for Loch where an average of 2.25 worms per m³ was found (Van Praagh 1994). However, the Loch study occurred over 3 years and included all seasons. Worms are often not found in January and February, which can bring the average number of worms down considerably. The overall worm density for the site is extremely high and estimated at between 12,500 and 36,250 worms. These figures are based on the hypothesis that the worm is found over the entire 2500 m² area. However, it is known that worm distribution is patchy and therefore, further sampling within the worms range would yield zero figures where no worms would be found and this would bring the density estimates down. While these figures are very high and can only be regarded as rough estimates, the high densities encountered at individual sites and the fact that the worms were relatively widespread within the area they occupied, indicates that the area supports very high numbers of earthworms.

Worms were at a slightly more shallow depth at Loch Hill (mean 39.3 cm) compared with that found at Loch where the mean depth was 48 cm.

Population structure data was quite difficult to obtain due to the low sample size and difficulty in obtaining whole (entire) specimens without injury. Four juveniles and one subadult worm were found at study sites 1, 2 and 3. This represents a relatively high number of immature earthworms which is in contrast to other studies that have found that the Giant Gippsland Earthworm populations generally consist predominantly of adult earthworms with a ratio of at least 3 adults to one immature earthworm (Van Praagh 1992, 94). However, it is difficult to determine the significance of this as the sample size is so small and many worms could not be dug out entirely to determine their size class.

Breeding adults are evident by a swollen clitellum that occurs over nine segments between segments xiii to xxi (Van Praagh 1996). No breeding adults were found, which is surprising given that sampling took place within the known breeding season (primarily September–December). Studies have found that adult worms need to be at least 180 g with the average weight of 255 g before breeding can occur (Van Praagh 1996). At least three adult worms found had weights over this threshold (215, 220 and 250g) although only one was close to the average weight of clitellate worms. However, it is thought that adults may not necessarily breed every year and may only do so under favourable conditions. Precisely what those favourable conditions are remains unknown. For

example, at Loch, the number of clitellate (breeding) adults varied yearly with only one clitellate adult found in 1988, compared with nine and four in 1989 and 1990 respectively (Van Praagh 1994). The relatively prolonged cool weather in the 2001 spring and summer season may have an effect on the breeding of the species and it would be interesting to note whether breeding is indeed delayed until the warmer weather begins.

Aside from the direct injury to the earthworms during soil excavation for geotechnical investigation, it is difficult to determine the long-term effects, (if any) of the disturbance. The first three quadrats were dug in the area that had approximately 20-30 cm cover of fallen soil over the pasture surface. A relatively high density of active earthworms were found in these quadrats and a high burrow density was noted. As new burrows were evident in the disturbed soil lying over the top of the pasture, the worms appear to have coped with the initial disturbance quite well. The rotting pasture grass, located within the soil profile would provide a food source until new grass established. New grass was already present over the site by late November. The Giant Gippsland Earthworm is a long-lived species and population turnover is slow. Detrimental impacts may not be evident for some time and therefore long term studies are required to measure any changes within the population.

Further field work at the site pre-roadworks to obtain further baseline information on the population is required. A larger sample size would yield more robust data on the densities and population structure of the earthworm at this site.

Impacts

There is no doubt that if road works proceed within the area occupied by worms at Loch Hill, the majority of the earthworm population at the site will be destroyed. The life cycle of the species including long life span, low reproductive and recruitment rates, and low dispersal ability make the fragmented populations, as a whole highly vulnerable to catastrophic events (Van Praagh 1992, McCarthy *et al.* 1994). Mathematical modelling of life characteristics of Giant Gippsland Earthworm populations by McCarthy *et al.* (1994) suggests that removal of even very low numbers of earthworms can significantly impact on the survival of local populations and result in extinction of that population over time.

The impacts of road works at the site on the species are discussed in Van Praagh and Hinkley 2001c. These include directly killing individuals and injury of earthworms during soil excavation, compacting the soil and altering the soil habitat, in particular drainage and moisture regimes at the site. Individuals do not recover if injured and have no capacity to regenerate. Studies at this site indicated worms were found at an average depth of 39.3 cm. Egg cocoons are found within 40 cm of the soil surface with an average depth of around 23 cm (Van Praagh 1994). Thus worms would be particularly vulnerable to direct injury. Depth of excavation for road works will be down to the rock, which would include the entire area occupied by the worms.

Probably the most detrimental impact on the earthworms aside from any direct physical damage to worms during excavation would be the alteration in the soil moisture regimes to the surrounding areas of the site. Soil moisture and

proximity to water are extremely important in governing the distribution of *M. australis* (Van Praagh 1992, 1994). This is particularly evident in the restricted distribution of the species at Loch Hill. The distribution of *M. australis* at Loch Hill is confined to an area of increased soil moisture fed by underground springs (see section on soils of the site). The worm does not occur at other parts of Loch Hill, especially to the east of the hill, as the level of soil moisture is much lower. Any changes in soil hydrology or water table may impact upon those individuals surviving downhill of the road works. Water balance within burrows is important for worm movement and respiration. For example, burrows occupied by the species are very wet and usually have some free-flow of water in them. Compaction caused by heavy machinery affects burrow structure and the worm's ability to make new burrows.

Mitigation Measures

Measures such as conducting the roadworks in summer when the worms are generally deeper in the soil would have little effect in preserving the population as the scale of the work involved is so large and the long-term effects to the site significant eg. Major habitat destruction, damage to individual worms during site excavation, compaction, physical presence of a road, altered drainage patterns and moisture regimes.

The species was found to occupy an area of approximately 2500 m². This entire earthworm habitat would be lost during this section of the realignment of the South Gippsland Highway. Therefore, the only mitigation measure available is to attempt to 'rescue' the existing population before and during roadworks and endeavour to protect or restore any earthworm habitat near by that may escape the direct impacts of the roadworks.

Rescuing the earthworm population would involve translocation of some earthworms and egg cocoons to areas of suitable habitat close by and/or attempt to create suitable earthworm habitat in which to release translocated individuals. While the precise habitat parameters for the species are unknown, the most obvious factor of importance is soil moisture. No such work has previously been carried out and the success of such an exercise is unknown. Egg cocoons may present the best chance for the worms' translocation.

The fact the worms appeared to readily burrow into disturbed soil lying over the pasture gives some hope that there may be avenues of translocation of adults worth exploring. The fate of released worms after excavation is unknown. One of the adults recorded was released back down an existing burrow where it soon disappeared. Other earthworms seemed to remain at the mouth of the burrow without attempting to move away. These worms were always covered with soil. However, unless they made new burrows quite quickly or moved into existing burrows, they would be at great risk of desiccation.

Proposed Future Research for Mitigation

While it is unfortunate that a section of the proposed realignment of the South Gippsland Highway will most probably result in the destruction of the population of Giant Gippsland Earthworms at Loch Hill, it is thought that the research opportunities resulting from this situation will benefit the long term survival of this species. The benefits that may arise from research on the population at the site may serve as a model to

develop conservation guidelines for the species in the future. With the expansion of urbanisation and development of areas within the known range of the Giant Gippsland Earthworm, populations of the earthworm will continue to be threatened by similar disturbances throughout its range.

At present there is little information on the impacts and survival of the species after road works. The proposed research would involve investigation of the impacts of road-works on any individuals that remain at the site, and more importantly, investigate the success of translocation of the species to near by sites. The collection of damaged specimens would also provide important material to examine the genetic variability of the population, which may be important in the translocation of the species.

Research of this kind would be challenging and would indeed need to be innovative and experimental. To be of any value, it would also need to be long term, with at least a five year plan that would include before, during and after monitoring.

Aims of research

- To investigate the impacts of road works on the Giant Gippsland Earthworm
- To investigate the feasibility of translocating either individuals, egg capsules or both from the site to (i) areas close by that do not already support populations of the worm and (ii) to near by sites that already support GGE populations
- To investigate the genetics of the population of worms at Loch Hill
- To examine restoration of habitat for the Giant Gippsland Earthworm including hydrology
- Develop mitigation guidelines for the future conservation of the species

It is very likely that this situation will arise in the future as road works and other forms of soil disturbance continue to occur throughout the South Gippsland region. It is hoped that lessons learnt from the proposed research at Loch will benefit other populations of Giant Gippsland Earthworms that encounter similar forms of disturbance.

Acknowledgements

This work was funded by Vic Roads. Help of Vic Roads staff, in particular Graham Embry is much appreciated. Giant Gippsland Earthworms were collected under Research Permit to Dr A. Yen under Wildlife Act (1975) and Flora and Fauna Guarantee Act (1988) No. 10001109

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Survey of the Giant Gippsland Earthworm, *Megascolides australis* in areas potentially affected by a realignment of the South Gippsland Highway – Bena to Korumburra

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Abstract

Van Praagh, B.D., and Hinkley, S.D. 2002. Survey of the Giant Gippsland Earthworm, *Megascolides australis*, in areas potentially affected by a realignment of the South Gippsland Highway – Bena to Korumburra. *Museum Victoria Science Reports* 3: 1–5.

A survey for the Giant Gippsland Earthworm, *Megascolides australis*, was conducted in an area between Bena and Korumburra, which is the subject of a planning study into possible improvements to the South Gippsland Highway. Assessment of any impacts of road construction on *M. australis* and opportunities for mitigation are discussed.

Giant Gippsland Earthworm populations were recorded in two areas along the proposed route for the realignment of the South Gippsland Highway. Both sites were located on the north side of the highway in Victoria Rail Track land. The first site encompassed an area approximately 200 m long within which eight earthworm sites were located. A juvenile earthworm and three egg cocoons were also recorded within this area. The Narracan Burrowing Crayfish, *Engaeus phyllocercus*, a listed species of burrowing cray also appeared to occur within a creek/soak at this site. The second area was very localised and while one adult Giant Gippsland Earthworm was located, no evidence of any other Gippsland worms was found.

Recommendations for protecting the populations of Giant Earthworms at site one includes carrying out possible improvements to the South Gippsland Highway on the south side of the existing highway for approximately 400 m in the vicinity of the designated earthworm habitat, leaving the north side where the earthworms occur intact.

Introduction

Museum Victoria was contracted by Vic Roads in October 2001 to provide advice on whether the Giant Gippsland Earthworm, *Megascolides australis* will be impacted by potential road works along the South Gippsland Highway between Bena and Korumburra. The Giant Gippsland Earthworm is listed as threatened under Victoria's *Flora and Fauna Guarantee Act (1988)* and the Commonwealth's *Environment Protection and Biodiversity Conservation Act (1999)*. The species has been recorded within the Bena – Korumburra region (Smith and Peterson 1982, Van Praagh 1992, 1994).

Objectives. The aim of the study is to conduct a survey for the Giant Gippsland Earthworm in potential road project sites between Bena and Korumburra, South Gippsland. In addition, to provide advice on whether the Giant Gippsland Earthworm will be affected by road improvements and report on what actions can be undertaken to mitigate any affects on the species.

Project Outline. The specific tasks required of this study are:

- Provide advice on the presence of the Giant Gippsland Earthworm in the bands of interest based on active searches;
- Give locations of where the Giant Gippsland Earthworm is encountered in AMG/Lat, Long coordinates;

- Provide an objective assessment of the potential impacts of the road realignment on any Giant Gippsland Earthworms recorded during the survey;
- Describe any opportunities to avoid or mitigate these potential impacts through design or management;
- Provision of an assessment of the likely resultant level of impacts if mitigation measures are adopted.

Giant Gippsland Earthworm

Significance of the Giant Gippsland Earthworm. The Giant Gippsland Earthworm, one of the largest earthworms in the world, has International, Commonwealth and State conservation significance. It is listed as Vulnerable by the International Union for the Conservation of invertebrates (IUCN) (Wells *et al.* 1983) as well as under the Commonwealth Endangered Species Act. In Victoria it is listed as Vulnerable (CNR 1995) and Threatened (Flora and Fauna Guarantee Scientific Advisory Committee 1991). The species has also been listed on the register of the National Estate (Coy 1991) and is protected under Victoria's *Flora and Fauna Guarantee Act (1988)*.

Distribution. The species is endemic to a relatively small area of approximately 40,000 ha of the Bass River Valley in South Gippsland, in a triangle roughly bounded by Loch, Korumburra and Warragul. The species can have a very localised distribution and is very patchy within its range. Sightings are regarded as uncommon and usually confined to within 40 m of stream banks, in particular smaller tributaries of the Bass River, soaks, and wet

south facing hills.

Biology. Much of the biology of *M. australis* remains unknown, reflecting the difficulty in sampling a long lived and fragile subterranean animal. *M. australis* is an hermaphrodite with two individuals required for fertilisation. Breeding activity is evident by a large, swollen clitellum and occurs predominantly in spring and summer (Van Praagh 1996). Large amber coloured egg cocoons ranging in size from 5 to 9 cm are laid in chambers branching from the adult burrow at an average depth of 22 cm (Van Praagh 1994). Only one embryo is found in each egg cocoon, which is thought to take over 12 months to incubate. Although the life span of the species is unknown, field and laboratory studies suggest that it is very long lived, possibly taking up to 5 years to reach reproductive maturity. Field studies show the population consists predominantly of adults at all times of the year (Van Praagh 1994). This suggests a slow growth rate and population turnover, with a low rate of recruitment.

The worms live in complex, permanent burrows that extend to around 1 to 1.5 m in depth. Worms appear to remain underground, feeding on the root material and organic matter ingested in the soil. Occupied burrows are always wet, even in summer, probably aiding the worm in movement and gas exchange. Worms can be locally abundant with a mean density of 2 per m³ with up to 10 worms per m³ recorded (Van Praagh 1992, 1994).

Threats to the Species. The Giant Gippsland Earthworm is one of the few species of native earthworms that has persisted in areas converted from native bush to pasture by surviving in pockets of suitable habitat where the affects of cultivation have been less severe (Van Praagh 1994, 1997).

The worm is a subsoil species, lives in a complex burrow system and rarely comes above the surface of the soil. Although the worm is somewhat buffered from environmental stress due to its depth in the soil profile, it exhibits particular life history characteristics which make it vulnerable. For example, the worm is long lived, has a slow growth rate, produces few young and has a poor dispersal ability (Van Praagh 1992, 1994, 1997). These characteristics mean that populations have little ability to recover from any damage since population turnover is so slow. Individuals are extremely fragile and even slight bruising or damage may result in death. The major threats to the species include disturbances to its soil habitat (physical and chemical), soil erosion, compaction, vegetation clearance and, in particular, changes to the water table and altered drainage patterns.

Study Area. South Gippsland Highway – Realignment Bena to Korumburra between 111.5km and 115.2km.

The study area comprises an area of approximately 3.7 km east of Bena consisting primarily of pasture in roadside and railway reserve, and private property.

Methodology

To establish the presence of the Giant Gippsland Earthworm along the routes of the proposed road improvements, a survey of the site was undertaken. This involved:

Identification of suitable habitat. The entire length of the route of the proposed road realignment was assessed to

identify areas of suitable earthworm habitat. While precise habitat parameters for the species are unknown, several factors that characterise suitable habitat have been identified (Smith and Peterson 1982, Van Praagh 1994). These include proximity to water, soil moisture and soil type. The earthworm is usually associated with creek banks, in particular smaller tributaries of the Bass River, soaks or wet south facing slopes but is generally absent from areas where there is a high level of waterlogging and compaction. Areas of higher underground water content or seepages can often be observed due to greener patches of pasture often presenting as soaks and areas that have pronounced terracettes (Van Praagh *et al.* 2002). These areas were targeted for earthworm sampling.

Detailed surveying of areas of suitable earthworm habitat. Sites identified as suitable habitat within or near the bands of interest were surveyed to establish the presence of the earthworms. The most reliable way of locating the earthworm is by digging and looking for earthworm burrows. This involves digging quadrats of approximately 50 cm x 50 cm to examine the soil for burrows. A wet burrow indicates that the burrow is actively being utilised by a worm. Earthworms can also be detected by a gurgling sound that is made when worms retreat down their wet burrows. Thus presence of the worms can also be established by banging the ground with a spade and listening for gurgles, particularly if the ground is wet.

All records of the Giant Gippsland Earthworm were recorded using AMG coordinates within 5 m of the site.

A field survey for the Giant Gippsland Earthworm was conducted on 16 and 22 of January 2002.

Limitations of study. Due to the large survey area involved, sites of suitable habitat were targeted for sampling. While every effort was made to identify these sites, it is possible that some sites were missed during the survey. For example, *M. australis* sometimes occurs on roadsides where the identification of suitable habitat may not be obvious. It was not possible to sample every section of roadside within the proposed area of road realignment due to time constraints and, in some cases, inaccessibility. However, eroded roadside embankments were examined for burrows where possible.

Results

Small amounts of suitable earthworm habitat were identified along the band of interest realignment between Bena and Korumburra. Most of these sites were on the north side of the South Gippsland Highway in the railway reserve. Very little suitable habitat was identified on the south side of the highway, possibly because these areas were north facing and therefore not as wet. There was only one creek transecting the study area and it occurred on the south side of the highway. Several sites along this creek bank were sampled and although the soil looked relatively suitable, no signs of the earthworm were found.

The Giant Gippsland Earthworm was recorded at two sites within the study area, both on the north side of the South Gippsland Highway in Victoria Rail Track land (Fig 1). Site 1 encompassed an area of approximately 200 m starting east of Bena at 38° 25' 200" 145° 47' 190" and continuing to 38° 25' 274" 145° 47' 308" (towards Korumburra). Worm burrows

were located at 8 sites within this area (Table 1 - sites 1a to 1h). Egg cocoons were found at three of these sites (1b, 1c and 1g) and one juvenile earthworm was found at another (1d). Gurgles were heard at another 3 of the 8 sites. All of the sites except one, showed evidence that worms currently occupied them. This area consisted of pasture and scattered fruit trees (Plate 1a, b).

The last site within the 200 metre area occurred on a large roadside embankment under tall pine trees (*Pinus radiata*). Burrows were confined to the outer edges on the top of the embankment. Further inspection of this embankment from above did not reveal any signs of recent worm activity and it is likely the burrows are old and are no longer occupied by earthworms. A large gully with a small creek within it occurred to the north of this site. A small number of yabby

burrows were recorded within the bank and flood bed of this creek. While a specimen of the yabby occupying the burrows could not be obtained, it is likely that they represented burrows of the Narracan Burrowing Crayfish (*Engaeus phyllocercus*).

The second site occurred at 38° 25' 565" 145° 47' 861" in Victoria Rail Track land adjacent to a private property access road which continued under a railway bridge (see Fig 1). The site occurred on the edge of a drainage channel or creek, arising from a culvert further up hill towards the railway track. A clump of trees consisting of eucalypts, wattles (Blackwoods and Silver Wattles) and a fruit tree occurred at the site. A very large adult worm was found at a depth of about 10 cm. No other signs of Giant Gippsland Earthworms were found at this site and distribution appeared to be limited to this single site. This site was rather unusual in that it was very rocky.

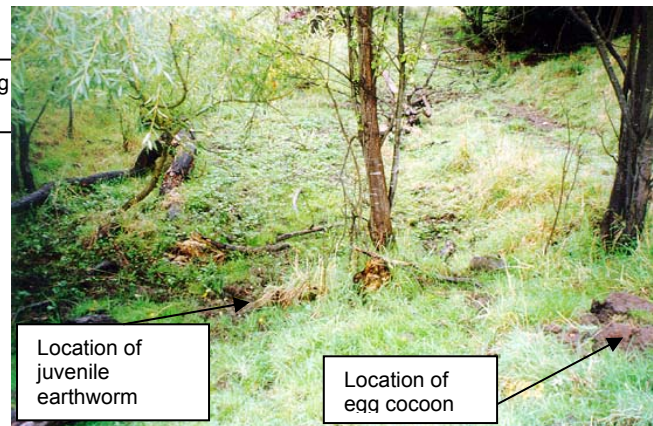
Table 1 Location of Giant Gippsland Earthworm sites from Bena to Korumburra

Site	Lat	Long	Land	GGE Distribution	GGE Activity*	GGE Activity	Habitat
1a	38° 25'	145° 47'	Vic Rail	Found for about 20 m west of	Medium –	None detected	Pasture in front of slope up to rail way track.
1b	38° 25'	145° 47'	“	Found on embankment of hole across to small gully and gentle slope leading to highway	Medium	Egg cocoon and gurgles	Pasture, dock, scattered trees (<i>Prunus</i>) and Hazel derris.
1c	38° 25'	145° 47'	“	Found around top edge of gully/soak near cattle track	Medium	Egg Cocoon (cm)	Pasture
1d	38° 25'	145° 47'	“	Found at side edge of small soak, a couple of metres from egg cocoon (1c) found.	Medium	Juvenile worm	Pasture, dock and scattered fruit trees (<i>Prunus</i>). Pugging at bottom of gully Highway.
1e	38° 25'	145° 47'	“	Gentle slope		Gurgles	Pasture
1f			“	Gentle slope, 8 m east of site		Gurgles	Pasture
1g	38° 25'	145° 47'	“	Confined to corner of block, adjacent to large pines	Medium	Egg Cocoon and gurgles	Pasture with old dead tree above site
1h	38° 25'	145° 47'	“	Top of steep roadside embankment, under large Pines	Medium-	No signs of activity.	Embankment with pine
2	38° 25'	145° 47'	“	Confined to a single locality of creek/ drainage channel.	Low	Large adult (10cm depth)	Creek drainage channel bordered by pasture with clump of trees including large eucalypts, Blackwood and Silver Wattles.

Plate 1a. Location of a Giant Gippsland Earthworm egg cocoon – site 1b



Plate 1b. Location of juvenile Giant Gippsland Earthworm and egg cocoon – site 1c and d



Discussion

Implications of road construction. Possible improvements to the South Gippsland Highway from Bena to Korumburra could involve major physical disturbance to the soil resulting from large scale soil excavation, removal of rock and soil by machine extraction, compaction and altered soil hydrology.

Potential impacts on *M. australis*. The impacts of major earthworks such as road making within known *M. australis* habitat are discussed by Van Praagh and Hinkley (2000 a,b,c and 2001). These include directly killing or injuring earthworms during soil excavation, and indirectly by compacting the soil and altering the soil habitat in particular drainage and moisture regimes. Soil moisture levels are very important in governing earthworm distribution and water balance within burrows is important for worm movement and respiration.

Individuals do not recover if injured and appear to have no capacity to regenerate. The species generally occurs within the top 1m to 1.5 m of soil and egg cocoons are found in the top 40 cm (Van Praagh 1992). Depth of excavation for road works can include the entire area occupied by the worms.

Impact of proposed road realignment on *M. australis*. One relatively large population of *M. australis* would be affected by the proposed realignment (Table 1 site 1a-1h). The most significant aspect of this population was the number of egg cocoons recorded in addition to a juvenile worm, indicating a healthy, breeding population. Egg cocoons are normally quite difficult to find, as the breeding rate for *M. australis* is so low (0.36 cocoons per adult) (Van Praagh 1994). Young worms were not visible in at least 2 of the eggs found, indicating that they were recently laid. The other was too damaged by digging to make any observations. Lots of gurgles also indicated that an active population occurred within the area. The worms were patchily distributed over the 200 metres although it is apparent that the last site under the large pines no longer supports a Giant Earthworm population. However, the stream in the gully behind this area possibly supports the Narracan Burrowing Crayfish *Engaeus phyllocercus*. This species is listed under Victoria's *Flora and Fauna Guarantee Act* (1988). It is restricted to the Eastern Strzelecki Ranges and occurs from Strzelecki-Ferndale in the west to the Little Morwell River at

Darlimurla in the south east. Land For Wildlife Atlas records show the species has been collected as far west as Korumburra, Loch and Warragul although there has been little survey work in this area for the species (Van Praagh and Hinkley 1999).

Road construction through the site 1 area where an active earthworm population occurs would most likely result in the elimination of these local populations by direct effects of road works. Indirect effects such as altered soil hydrology would probably destroy any remaining worms. The life cycle of the species including long life span, low reproductive and recruitment rates, and low dispersal ability make the fragmented populations, as a whole highly vulnerable to catastrophic events (Van Praagh 1992, McCarthy *et al.* 1994).

As only one worm was found at site 2 and distribution appears very limited, the site is not regarded as significant. No evidence of any other Giant Gippsland Earthworms at this site was found.

Impact minimisation. The only guaranteed way of protecting the earthworm colonies at site 1 is to avoid road improvement works on the north side of this 200 m section of the South Gippsland Highway. If possible, any highway improvements should be constructed on the south side commencing at least 100 m west of the start of the earthworm habitat and continue approximately 100 m east of the last locality point, leaving the north section intact.

Recommendations

- 1 South Gippsland Highway improvements should be made on the south side of the existing highway for at least 400 m starting at approximately 100 m west of 38° 25' 00" 145° 47' 190" and continuing for at least 100 m past 38° 25' 274" 145° 47' 308"
- 2 Leave at least a 100 m east and west of the designated earthworm habitat (as described above) as a buffer area for the earthworms.
- 3 Limit any activities close to the buffer zone that may effect the hydrology within the designated earthworm habitat.
- 4 Avoid any disturbance in the Vic Track railway land on the north side of the highway within this designated Giant Gippsland Earthworm area.
- 5 Avoid any disturbance of the small creek /soak in the gully

behind the pines at the overpass (38° 25' 274 145° 47' 308") to preserve the probable population of *Engaeus phyllocercus*. In particular, the natural hydrology of the area must be maintained.

- 6 Notify Museum Victoria of any Giant Gippsland Earthworms unearthed / exposed during construction. Record the number and location of all Giant Gippsland Earthworms unearthed / exposed.
- 7 All unharmed Giant Gippsland Earthworms unearthed / exposed during construction must be promptly relocated to a nearby area which will not be impacted upon by the works. Worms shall be placed in a shallow hole and covered with loose moist soil.

Acknowledgements

This work was funded by Vic Roads. Help of Vic Roads staff, in particular Graham Embry is much appreciated. Wildlife Act 1975 and National Parks Act 1975 Research Permit No. 10001631 to Dr A. Yen.

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Survey of the Giant Gippsland Earthworm, *Megascolides australis* in areas potentially affected by a realignment of the South Gippsland Highway – Korumburra to Leongatha

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Abstract

Van Praagh, B.D., and Hinkley, S.D. 2002. Survey of the Giant Gippsland Earthworm, *Megascolides australis*, in areas potentially affected by a realignment of the South Gippsland Highway – Korumburra to Leongatha. *Museum Victoria Science Reports* 4: 1–4.

The Giant Gippsland Earthworm was not recorded in any of the sites examined within the proposed area of the South Gippsland Highway realignment from Korumburra to Leongatha. No specific mitigation measures are required in relation to the Giant Gippsland Earthworm.

Introduction

Museum Victoria was contracted by Vic Roads in October 2001 to provide advice on whether the Giant Gippsland Earthworm, *Megascolides australis* will be impacted by potential road works along the South Gippsland Highway between Korumburra and Leongatha. The Giant Gippsland Earthworm is listed as threatened under Victoria's *Flora and Fauna Guarantee Act* (1988). The species has been recorded within the Korumburra region (Smith and Peterson 1982, Van Praagh 1992, 1994).

Objectives. The aim of the project is to conduct a survey for the Giant Gippsland Earthworm in potential road project sites between Korumburra and Leongatha, South Gippsland. In addition, to provide advice on whether the Giant Gippsland Earthworm will be affected by road improvements and report on what actions can be undertaken to mitigate any affects on the species.

Project Outline. The specific tasks required of this project are:

- Provide advice on the presence of the Giant Gippsland Earthworm in the bands of interest based on active searches;
- Give locations of where the Giant Gippsland Earthworm is encountered in AMG coordinates;
- Provide an objective assessment of the potential impacts of the road realignment on any Giant Gippsland Earthworms recorded during the survey;
- Describe any opportunities to avoid or mitigate these potential impacts through design or management;
- Provision of an assessment of the likely resultant level of impacts if mitigation measures are adopted.

Giant Gippsland Earthworm

Significance of the Giant Gippsland Earthworm. The Giant Gippsland Earthworm, one of the largest earthworms in the world, has International, Commonwealth and State

conservation significance. It is listed as Vulnerable by the International Union for the Conservation of Invertebrates (IUCN) (Wells *et al.* 1983) as well as under the Commonwealth Endangered Species Act. In Victoria it is listed as Vulnerable (CNR 1995) and Threatened (Flora and Fauna Guarantee Scientific Advisory Committee 1991). The species has also been listed on the register of the National Estate (Coy 1991) and is protected under Victoria's *Flora and Fauna Guarantee Act* (1988).

Distribution. The species is endemic to a relatively small area of approximately 40,000 ha of the Bass River Valley in South Gippsland, in a triangle roughly bounded by Loch, Korumburra and Warragul (Smith and Peterson 1982). The species can have a very localised distribution and is very patchy within its range. Sightings are regarded as uncommon and usually confined to within 40 m of stream banks, in particular smaller tributaries of the Bass River, soaks, and wet south facing hills.

Biology. Much of the biology of *M. australis* remains unknown, partly reflecting the difficulty in sampling a long lived and fragile subterranean animal. *M. australis* is an hermaphrodite with two individuals required for fertilisation. Breeding activity is evident by a large, swollen clitellum and occurs predominantly in spring and summer (Van Praagh 1996). Large amber coloured egg cocoons ranging in size from 5 to 9 cm are laid in chambers branching from the adult burrow at an average depth of 22 cm (Van Praagh 1994). Only one embryo is found in each egg cocoon, which is thought to take over 12 months to incubate. Although the life span of the species is unknown, field and laboratory studies suggest that it is very long lived, possibly taking up to 5 years to reach reproductive maturity. Field studies show the population consists predominantly of adults at all times of the year (Van Praagh 1994). This suggests a slow growth rate and population turnover, with a low rate of recruitment.

The worms live in complex, permanent burrows that extend to around 1 to 1.5 m in depth. Worms appear to remain underground, feeding on the root material and organic matter ingested in the soil. Occupied burrows are always wet, even in

summer, probably aiding the worm in movement and respiration. Worms can be locally abundant with a mean density of 2 per m³ with up to 10 worms per m³ recorded (Van Praagh 1992, 1994).

Threats to the Species. The Giant Gippsland Earthworm is one of the few species of native earthworms that has persisted in areas converted from native bush to pasture by surviving in pockets of suitable habitat where the affects of cultivation have been less severe (Van Praagh 1994, 1997).

The worm is a subsoil species, lives in a complex burrow system and rarely comes above the surface of the soil. Although the worm is somewhat buffered from environmental stress due to its depth in the soil profile, it exhibits particular life history characteristics which make it vulnerable. For example, the worm is long lived, has a slow growth rate, produces few young and has a poor dispersal ability (Van Praagh 1992, 1994, 1997). These characteristics mean that populations have little ability to recover from any damage since population turnover is so slow. Individuals are extremely fragile and even slight bruising or damage may result in death. The major threats to the species include disturbances to its soil habitat (physical and chemical), soil erosion, compaction, and, in particular, changes to the water table and altered drainage patterns.

Study Area

South Gippsland Highway – Realignment Korumburra to Leongatha between 117.4km and 130.0km.

The study area comprises an area of approximately 12.6 km east of Korumburra to the township of Leongatha consisting primarily of pasture in Crown land and freehold land.

Methodology

To establish the presence of the Giant Gippsland Earthworm along the routes of the proposed road improvements, a survey of the site was undertaken. This involved:

Identification of suitable habitat. The entire length of the route of the proposed road realignment was assessed to identify areas of suitable earthworm habitat. While precise habitat parameters for the species are unknown, several factors that characterise suitable habitat have been identified (Smith and Peterson 1982, Van Praagh 1994). These include proximity to water, soil moisture and soil type. The earthworm is usually associated with creek banks, in particular smaller tributaries of the Bass River, soaks or wet south facing slopes but is generally absent from areas where there is a high level of waterlogging and compaction. Areas of higher underground water content or seepages can often be observed due to greener patches of pasture often presenting as soaks and areas that have pronounced terracettes (Van Praagh *et al.* 2001). These areas were targeted for earthworm sampling.

Detailed surveying of suitable earthworm habitat. Sites identified as suitable habitat within or near the bands of interest were surveyed to establish the presence of the earthworms. The most reliable way of locating the earthworm is by digging and looking for earthworm burrows. This involves digging quadrats of approximately 50 cm x 50 cm to examine the soil for burrows. A wet burrow indicates that the

burrow is actively being utilised by a worm. Earthworms can also be detected by a gurgling sound that is made when worms retreat down their wet burrows. Thus presence of the worms can also be established by banging the ground with a spade and listening for gurgles, particularly if the ground is wet.

All records of the Giant Gippsland Earthworm were recorded using AMG/Lat, Long coordinates.

A field survey for the Giant Gippsland Earthworm was conducted over several days in January and February 2002.

Limitations of study. Due to the large survey area involved, sites of suitable habitat were targeted for sampling. While every effort was made to identify these sites, it is possible that some sites were missed during the survey.

Results

The Giant Gippsland Earthworm was not recorded in any of the sites examined within the proposed area of highway realignment from Korumburra to Leongatha.

Discussion

The NRE Wildlife Atlas database and records by Van Praagh (1994) indicate that the township of Korumburra represents the most south-easterly known distribution of the Giant Gippsland Earthworm (Figure 1). The closest known records to the study area are from the Korumburra Golf Course and Caravan Park, about 1 km north east of the township. Thus it would be expected that the closer to Leongatha, the less likely suitable earthworm habitat would be found. It is therefore not surprising that no sightings of *M. australis* were made during the current survey, although the area just east of Korumburra represents potential habitat.

It is not certain whether the study area represents unsuitable habitat for the species or whether other factors such as limited dispersal ability and geographical barriers prevent the worms from moving outside their known range. It is certainly obvious that about 6- 7km east of Korumburra, the vegetation changes from predominantly Blue Gums to Messmates and Stringy Barks. According to Sargeant (pers. comm. 2002) this change in vegetation is accompanied by a change in soil profile. Soils past this point tend to have a more marked transition between the topsoil and the subsoil and the topography is more subdued. Also the sandier Tertiary sediments cut in towards Leongatha. A similar change in soil characteristics marks the western boundary of the worm distribution (just west of the Bass River). Many species of earthworms have difficulty tolerating the more sandy soil. Soil texture has been found to be an important factor in governing distribution of many earthworm species (McKenzie and Dyne 1991) and soil analyses by Van Praagh (1994) indicated that *M. australis* was absent in soils with a high coarse sand content. *M. australis* appears to be mainly confined to hilly areas where Blue Gums dominate the landscape.

A previous study by (Van Praagh *et al.* 2002) noted a possible relationship between the prevalence of landslips in the south to south –easterly facing slopes of the hilly country and the associated presence of surplus subsoil water and Giant Gippsland Earthworm distribution. The flatter topography east of Korumburra may not yield enough surplus subsoil water to create the conditions for *M. australis* to survive.

Implications of road construction. Possible improvements to the South Gippsland Highway from Korumburra to Leongatha could involve major physical disturbance to the soil resulting from large scale soil excavation, removal of rock and soil by machine extraction, compaction and altered soil hydrology.

Potential Impacts on *M. australis*. None

Mitigation Measures. No mitigation measures in relation to the Giant Gippsland Earthworm are required.

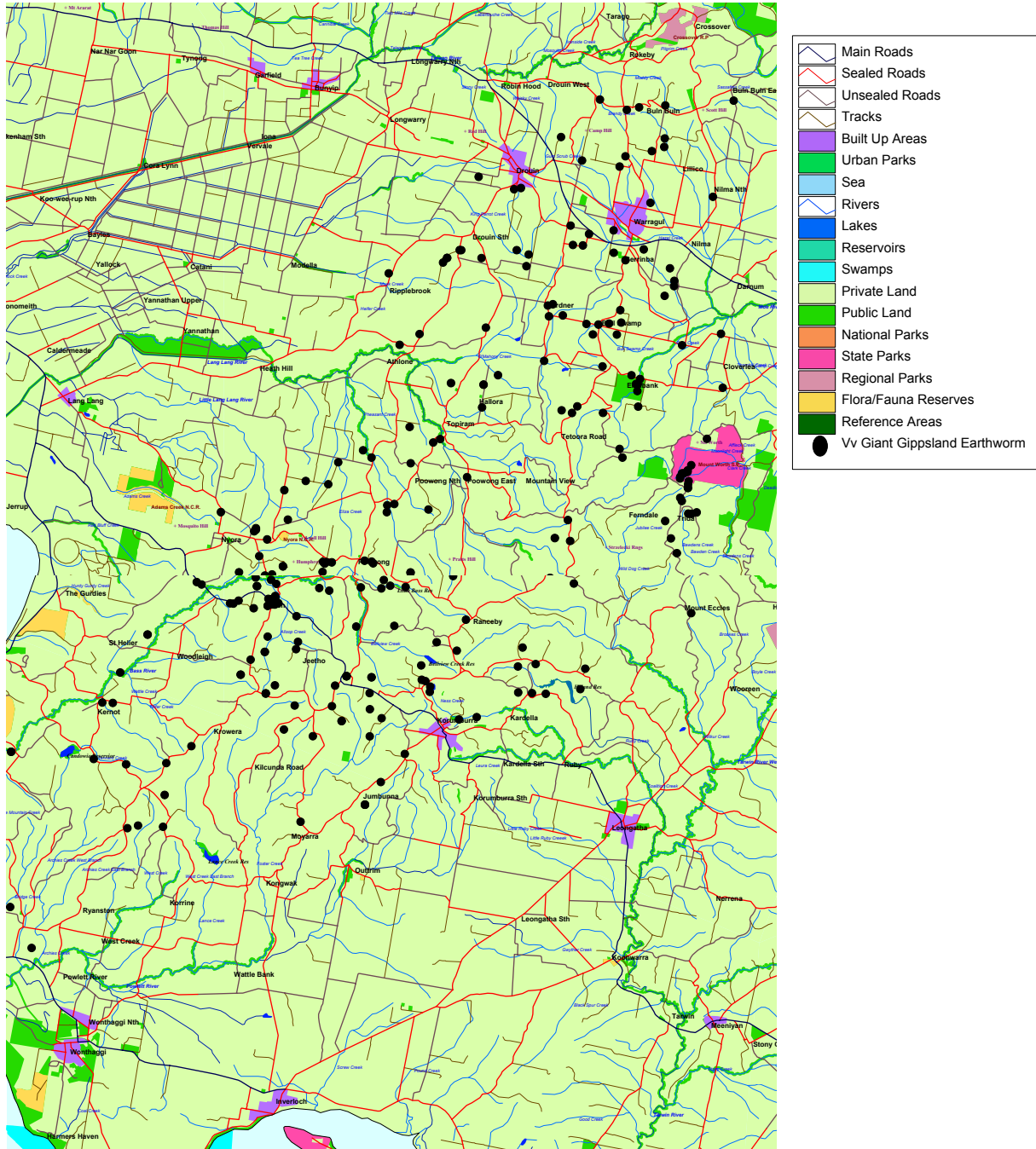
Recommendations. Major recommendations regarding protection of the Giant Gippsland Earthworm within the area specified as potential areas for roadworks between Korumburra and Leongatha are not required. However, while every effort was made to sample the specified area for populations of the Giant Gippsland Earthworm, it is always possible that a population may have been missed. In the event that this situation arises the following is recommended:

- 1 Notify Museum Victoria of any Giant Gippsland Earthworms unearthed / exposed during construction. Record the number and location of all Giant Gippsland Earthworms unearthed / exposed.
- 2 All unharmed Giant Gippsland Earthworms unearthed / exposed during construction should be promptly relocated to a nearby area which will not be impacted upon by the works. Worms shall be placed in a shallow hole and covered with loose moist soil.

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Figure 1. Victorian Wildlife Atlas showing distribution of Giant Gippsland Earthworm. (From Department of Natural Resources and Environment). Note not all records verified.



Further studies on the Giant Gippsland Earthworm (*Megascolides australis*) population at Loch Hill, South Gippsland, Victoria.

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Abstract

Van Praagh, B.D., and Hinkley, S.D. 2002. Further studies on the Giant Gippsland Earthworm (*Megascolides australis*) population at Loch Hill, South Gippsland, Victoria. *Museum Victoria Science Reports* 5: 1–12.

As part of ongoing investigations into the Giant Gippsland Earthworm population at Loch Hill, a site occurring within the vicinity of proposed roadworks for the South Gippsland Highway, further investigations into earthworm density and population structure were conducted over a four month period from February to June 2002. Preliminary investigations into release methods for worms and possible release sites for translocation near Loch Hill were also made.

Introduction

Museum Victoria was contracted by Vic Roads in October 2000 to investigate the potential impact on the Giant Gippsland Earthworm, *Megascolides australis*, of road and bridge construction works on the South Gippsland Highway around Loch and Bena (Van Praagh and Hinkley 2000a, b & c, 2001). During these surveys, a population of *M. australis* was located at Loch Hill (Van Praagh and Hinkley 2000b) (Appendix 2).

A preliminary study of the distribution, soils and biology of the Giant Gippsland Earthworm at Loch Hill was conducted between September and November 2001. A large earthworm population was found to occur over an area of approximately 2500m². Worms appeared to be widespread within their area of distribution. Worm density within this area was very high ranging from 4.1 to 17.9 worms per m³ with an average of 8.5 worms per m³ calculated. This indicates a very high density of worms at Loch Hill. Due to the limited sample size and extended cooler weather conditions, further monitoring of the site was considered beneficial before roadworks begin to obtain more baseline information about the population including breeding, density and population structure.

Museum Victoria was further contracted (February 2002) to continue monitoring the population at Loch Hill for approximately five months (Feb to June 2002) to obtain more information about the population at Loch Hill. Objectives of the project were to to obtain more information on:

- Population structure.
- Breeding.
- Density.

Further objectives were to conduct preliminary investigations into:

- Capture and release methods for individual worms.
- Potential translocation sites at Loch Hill.
- Specific veterinary aspects of worm management (see Appendix 1).

Methods

Worm Density and Population Structure. Field work was conducted approximately every three weeks from February 13

to June 5th. Information regarding earthworm density and population structure was obtained by extensive digging of large quadrats to obtain individual specimens. Quadrats were randomly located within the area of known earthworm distribution at Loch Hill in an attempt to determine more accurate information on earthworm density and distribution within the total area occupied by worms. However, sampling was somewhat biased towards accessibility. Once the soil was exposed, the site was searched for wet burrows. Wet burrows were then followed carefully until the worm was found and part of its body exposed. Once exposed, the entire worm was slowly dug out of the burrow, using a shovel and trowel. Individual worms were then measured and weighed and their reproductive status recorded. It is difficult to obtain an accurate estimate of worm size due to the worms' ability to expand and contract. Weight possibly gives a better comparative estimate of size, although this may vary according to amounts of soil consumed and that voided during capture. Depth of the worms was also recorded by measuring the depth in the soil when the worm was first observed. Worm density was estimated by calculating the number of worms located in a given area of soil dug.

Worms were classified into juveniles, subadult and adults based on the number and position of clitella banding (Van Praagh 1994). These small, light coloured bands occur on the ventral surface of the worm between segments xvii and xix. Juvenile worms have no external banding, subadults one or two and adults have three bands on segments xvii, xviii and xix. This information could only be obtained from worms that were fully dug up, or at least had their anterior segments exposed far enough so the clitella banding could be examined.

Unfortunately, even when great care is taken, individual worms can be killed or damaged through the excavation process. As the worms are very fragile, even bruising can result in death. Any worms injured or killed were fixed in formalin and preserved in 70% alcohol and retained in Museum Victoria collections for further research. Worms were relaxed in a mixture of 10% Magnesium sulphate and Magnesium chloride added to water, fixed in 10% formalin and stored in 70% alcohol. All uninjured worms were released at site of capture.

Not all worms sighted could be dug up. If worms were found very deep in the soil or where a large number of worms were found together, only the number and depth of the worms found was recorded as the risk of injury to other worms was considered to outweigh the successful capture and release of a worm.

Collected egg cocoons were taken back to the laboratory and kept in a container with moist soil from Loch Hill at a temperature of 16°C. The embryos were then observed under a microscope using optic lighting to determine the size of the worm.

Worm density is expressed per m³ of soil. To take into account the hillslope when digging a quadrat, the average of the highest and lowest depth of the quadrat dug is used for the calculation. The estimation of the number of worms at Loch can also be given per m², assuming that most worms are in the top 1m of soil.

Mean densities were converted to logarithms to calculate the 95% confidence limits. Log transformations are used on small sample sizes where the sample is not randomly distributed over an area (Elliot 1977) as is the case with the Giant Gippsland Earthworm at Loch Hill. The confidence limits indicate that if one went back to sample the site, the mean density would fall between the confidence limit range given 95 % of the time.

Samples of Giant Gippsland Earthworm were also taken on one occasion for some trial genetic analyses by Dr Dave Runciman.

Methods for release of worms. Two methods were explored: release of worms into existing burrows, and creation of burrows using metal rod.

In the first method, uninjured worms were gently placed, anterior first into existing burrows of appropriate size. Sticks or a metal rod was used to check that the burrows were not blocked or did not end abruptly. However, this was often difficult to establish as the burrows were not straight. Worms were guided into burrows as far as possible. This was usually only a few centimetres. The posterior section of the worm was supported by either a hand made ledge below the burrow on which the worm body could rest or with a build up of soil. The exposed section of the worm was gently buried with loose soil as far as possible to reduce the likelihood of desiccation and exposure to predators. The soil and burrow into which the worm was placed was dampened with tap water.

Artificial burrows were made using a thin metal rod, 1 cm in diameter hammered into the exposed soil face of a trench using a rubber mallet.

Possible future release sites at Loch Hill for translocated worms. During the translocation of worms and/ or egg cocoons at Loch Hill, it is proposed that at least one or more receptor sites should be located at Loch Hill in areas that will not be directly impacted by the road works. These sites may include i) areas near by that do not already support populations of the worm, preferably adjacent to existing sites and ii) restored habitat at Loch Hill.

A preliminary search for sites adjacent to known worm habitat was undertaken to determine suitable receptor sites for translocated worms. The boundaries of known Giant Gippsland Earthworm distribution around the bottom of Loch Hill were surveyed to determine where the worms "perched

out". Small quadrats were dug to examine the soil for Giant Gippsland Earthworm burrows. Burrows are easily identified and, if wet, represent burrows that are actively being utilised by the worms. If the ground is wet, presence of the worms can also be established by banging the ground with a spade and listening for gurgles, the sound that is made when the worms retreat down their wet burrows. Large quadrats were dug at some sites to obtain an indication of worm density.

Results

Biology and Density. Eight quadrats were dug at Loch Hill over four months to further examine the density of earthworms and estimate their depth in the soil profile (Table 1a-1c). These sites were randomly located within the area of known worm distribution. All quadrats had Giant Gippsland Earthworm burrows and worms were recorded in all but one quadrat. A total of 20 Giant Gippsland Earthworm were recorded comprising 6 adults, 2 subadults/adults, 5 juveniles, and 7 worms of unknown size class.

Four egg cocoons were collected, including one hatched cocoon. One of the egg cocoons was accidentally chopped so the developmental stage of the embryo could not be ascertained. The two other egg cocoons were taken back to the laboratory where their progress is being monitored. If they hatch successfully, they will be released back at Loch Hill during the translocation phase of the project. The first egg cocoon collected on February 13th appeared to be fairly recently laid. The cocoon itself was relatively hard and opaque and it was difficult to observe the embryo inside. It was obviously very small at this point and thought to possibly be dead. The cocoon was examined several weeks later with a similar result. However, 3.5 months later, the cocoon was examined and the young worm was observed easily through the more transparent cocoon. It was found to have grown considerably and was around 3.5 times the length of the egg cocoon and around 16 cm in length (Plate 1). The second cocoon collected on June 5th contained an embryo of approximately 8cm in length (Plate 2). At present it is not possible to correlate embryo size with the age of the developing worm as this data is very difficult to collect and relies on the collection of freshly laid egg cocoons. Also development time varies according to temperature, with higher temperatures speeding up development. As these cocoons are being kept at 16°C, the temperature is higher than that of the soil (around 10°C) and therefore accelerated growth would be expected. Estimates of growth of cocoons from fertilisation to hatching is around 12 months at 12°C (Van Praagh 1994).

No breeding adults were found (ie adults with swollen clitella).

Worms were found at a mean depth of 37cm.

The number of worms found ranged from 0 to 9 with the mean density per m³ ranging from 1.4 to 28.5 (Table 1b). The mean density recorded from the second sampling season was 7.3, a similar density to that recorded from the first sampling season (8.5 see table 1a). The mean density from both seasons combined is 7.9 per m³.

A total of 43 worms were found from both study periods with all developmental classes recorded (Table 1a-c).

Release of worms into existing burrows. Several worms were released into existing burrows. One such released adult worm was followed up two weeks after release. It had died and

was in a similar position to that which it was left in, with little progress into the burrow. A relatively recently hatched juvenile worm was successfully released into a small burrow (Plate 2a-d). Whilst the long term survival of this worm isn't known, its quick disappearance down a burrow is promising.

Although released worms were not severely injured, there is still stress involved in the capture process, often resulting in small abrasions and 'pressure' on the body (Plate 3).

Creation of burrows using metal rod. This method proved to be unsuccessful due to difficulties in hammering in the rod far enough and being able to remove it from the soil

Future sites for translocation of Giant Gippsland Earthworm around Loch Hill

Two sites that may serve as potential Giant Gippsland Earthworm translocation sites were discovered during this study.

Site 1 was located in the next major hillslope gully just to the east of Loch Hill in the property owned by Christina and Gerry Norbergen. A small patch of Giant Gippsland Earthworms were found virtually at the head of the gully. This area was terraced and very moist. Worms were restricted to a small area of 5-10 m wide by approximately 15 to 20 long. They were not found in the surrounding hillside area. Burrows were quite dense in the top section of this area with a juvenile worm located indicating a breeding population occurred at the site. Burrows then became less dense toward the lower end of the occupied area

Site 2 was located at the bottom of the hillslope at Loch Hill, to the west of the tree fern. It occurred on the border of the established worm distribution and had a very low density of burrows. Burrows disappeared further west.

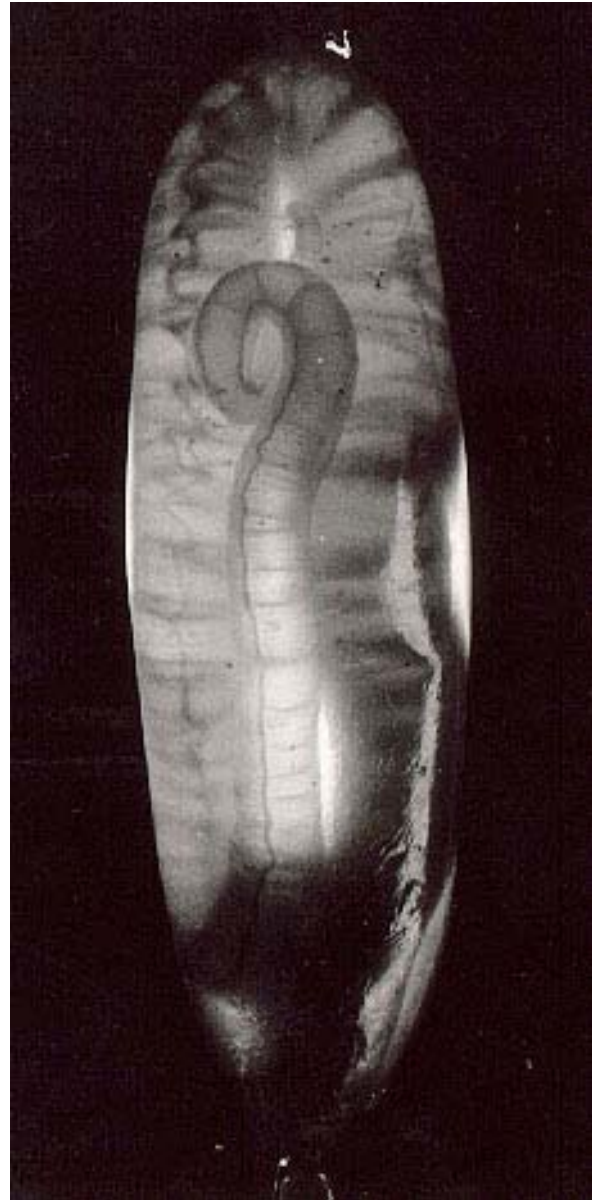


Plate 1 Developing embryo as viewed inside egg cocoon

Table 1a Number, depth and density of *M. australis* recorded at study sites at Loch Hill from October to end of November (previous study). “Unknown” indicates that a worm was observed but not completely dug out so that its age class could not be determined; ? indicates that weight was not recorded. Immature indicates either juvenile or subadult worm.

Date	Site	Lat long	No of worms	*Age class and weight of known worms	No and depth of egg cocoons	Ave depth of worms (cm) (range)	Area dug m ³ Ave depth = the average of the highest and lowest depth of the quadrat taking into account hillslope	Ave density of worms per m ³ (95% C.L)
10 Oct 01	1	38° 22' 720" 145° 43' 570"	1	Juvenile (95 g)	0	20	0.8 x0.35x0.2 =0.056	17.9
10 Oct 01	2	38° 22' 722" 145° 43' 563"	5	3 Unknown, 1 subadult, 1 adult	0	55.8 (50-68)	1.20 x1.10x 0.50 (ave depth 0.58) = 0.8	6.5
17 Oct 01	3	38° 22' 725" 145° 43' 567"	3	3 juveniles (18g, 33g, ?)	0	25 (20-35)	1.20x1.50x0.55(ave depth 0.33) =0.59	5.1
17 Oct 01	4	38° 22' 763" 145° 43' 55	2	1 adult (150g), 1 unknown	0	59 (54-64)	1.13x 0.90x 0.90 (ave depth 0.47) = 0.48.	4.1
13 Nov 01	5	38° 22' 739" 145° 43' 548"	3	1 immature, 1 adult, 1 juvenile (50 g)	1(hatched)	28 (10-50)	110x90x60 (ave depth 0.35)=0.34	8.7
28 Nov 01	6	38° 22' 725" 145° 43' 567"	8-10 (9)	2 Juveniles (30 g, ?), 4 adults (215g, 250g, 220g, ?) and 4 unknowns.	2 (hatched) @ 25 and 15 cm	35 (15-55)	1.5x1.5x 0.80 (ave depth 0.45) =1.01	8.9
			23		3	39.3±16.6	Average density of worms	8.5 (4.9-14.6)

Table 1b Number, depth and density of *M. australis* recorded at study sites at Loch Hill from February until May (present study). “Unknown” indicates that a worm was observed but not completely dug out so that its age class could not be determined; ? indicates that weight was not recorded. Immature indicates either juvenile or subadult worm.

Date	Site	Lat long	No of worms	*Age class and weight of known worms	No and depth (cm) of egg cocoons	Ave depth of worms (cm) (range) ±S.D	Area dug m ³ Ave depth = the average of the highest and lowest depth of the quadrat taking into account hillslope	Ave density of worms per m ³ (95% C.L)
13 Feb 02	1	38 25 365 145 47 556	0	-	0	-	0.90 x1.20 x 0.80 (average depth 0.60) =0.6	0
13 Feb 02	2	38 22 734 145 43 559	3	2 adults (125g, ?) 1 unknown	1 * (15cm) taken back to lab	44(40-47)	1.45x 0.95x55 (ave depth 0.50) =0.69	4.3
13 March 02	3	38 22 734 145 43 570	1	1 adult (g?) Possible post clitellate	0	50	1.5x1.05 x 0.80 (ave depth 0.45) = 0.7	1.4
13 March 02	4	38 22 733 145 43 566	2	2 adults 155g, 170g)	0	37.5 (35-40)	1.0x 0.9x.8 (ave depth 0.50) =0.45	4.4
03 April 02	5	38 22 737 145 43 558	1	1 subadult/adult 155 g 2-3 bands present	3 (1 empty, 1 damaged, 1 undamaged) (35, 26, 24 cm depth respectively)	45	1.28x0.6x 0.7(ave depth 42.5) =0.33	3.0
23 April 02	6	38 22 741 145 43 538 (edge of worm distribution)	1	1 Subadult/adult 125 2-3 bands present	0	40	1.13 x.85x.50 (ave 0.30) =0.28	3.5
23 April 02	3	38 22 737 145 43 545	3	1 juvenile (30g), 2 unknown	0	26.6(10-55)	0.8 x 0.90 x 0.52 (ave 0.31) =0.22	13.6
22 May 02	8	Near above site	9	4 juveniles (52, ?), 1 adult (140 g), 4 unknowns	0	38.3 (20-50)	1.0 x 0.8x 0.6 (ave 0.35) =0.28	28.5
Total			20		4	36.9±15.4		7.3 (3.1-17.2)

Table 1c. Total number, average depth and density of *M. australis* recorded at study sites at Loch Hill from both studies combined

Total No of worms	*Age class					No of egg cocoons	Ave depth of worms (cm) (±S.D.)	Ave density of worms per m ³
	Juv	Sub-adult	Immature	Adult	Unknown			
43	11	3 ?	1	13	15	7	38.3±15.6	7.9 (4.8-12.9)



Plate 2a. Juvenile worm prior to release into existing burrow.



Plate 2b. Juvenile worm moving into existing burrow.



Plate 2c. Juvenile worm moving into existing burrow.



Plate 2d. Juvenile worm moving into existing burrow.



Plate 2e. Juvenile worm moving into existing burrow. The process was completed over a 5-10 minute period.



Plate 3. An adult worm showing physical stress of capture. Generally caused by worm wedging itself into burrow so that it cannot be pulled out of its burrow.

Discussion

Biology and Density. The Giant Gippsland Earthworm was found to be widely distributed over its known range at Loch Hill. All but one of the randomly located quadrats supported worms and all quadrats contained burrows. The suggestion of very high worm densities at Loch Hill as indicated in the first study was supported by the results in this study. The overall density of 7.9 worms per m³ remains higher than the previous average density of 2.25 worms per m³ recorded from other studies (Van Praagh 1992, 96). Generally worm density drops off markedly during the summer months when it can be very difficult to locate worms. However, at Loch Hill, worms were easily found over the summer period. This may be due to the mild weather conditions this year and the absence of prolonged periods of hot weather over summer. It could also indicate that the site is wet throughout the summer. Worms were found at similar depth to the initial study at an average depth of 37.2 cm.

All age classes (juvenile, subadults and adults) were recorded at the site. In particular, a large number of juvenile worms and several egg cocoons. This indicates the presence of a healthy, breeding population of earthworms. Worms with swollen clitella, indicative of breeding were not recorded in the last survey, which was thought surprising given that sampling occurred during the breeding season (Sept to Feb). It was thought that the prolonged cooler weather conditions encountered in spring and summer 2001 may have delayed breeding. However, no breeding worms were found in the latest survey. Studies have found that adult worms need to be at least 180 g with an average weight of 255 g before breeding can occur (Van Praagh 1996). The largest adult recorded in the present study was only 170g, well below the average adult weight and known breeding threshold as determined from studies at a nearby creek bank at Loch (Van Praagh 1994). Studies at this site, where sampling occurred fortnightly over a three year period, found the average adult weight was around 210 g with the largest worm weighing 380g. The average weight of adults from the first and second survey at Loch Hill was 208 and 147g respectively with the overall average weight from both surveys being 178g (n=8). The largest adult found weighed 250 g. Therefore average adult weight was lower than that found from other studies. It may simply be a sampling bias in that they were deeper down in the soil and therefore not completely dug out for weighing. Other possibilities include low sample size, the high densities recorded may cause competition resulting in smaller worms or that the quality of the habitat is not as good as that found elsewhere.

Release Methods. Both release methods met with varying degrees of success. Releasing worms into established burrows is a possibility though it is difficult following up the success of this method without killing or injuring the worm. Also the identity of the released worm is difficult to establish until appropriate marking techniques are developed. One of the difficulties with releasing worms may be that the method of extraction, rather than the release itself, causes the most problems for the worms. It is very difficult to extract worms by hand, regardless of how careful one is, without causing some physical stress to the worm. Thus it is not known whether the death of worms after release results from the injuries caused by capture or occurs because the release method was inadequate and the worm could not proceed down the burrow for some

reason. If worms were extracted without injury, they may have a better chance of survival using this method.

One method of extraction suggested for the trial in translocation involves using machinery to move large blocks of soil supporting worms into pre-dug holes or removing worms individually from soil blocks and releasing into burrows. While some worms on the edges of these blocks are vulnerable to injury, it is possible that those in the centre of the block may remain unharmed.

Given the apparent success of releasing a juvenile worm (although its survival after being released was not monitored) it appears likely that young worms and egg cocoons represent the best chance of successful translocation. This may be partly because it is easier to extract young worms out of the soil without injury because of their small size.

The creation of artificial burrows was unsuccessful due to the difficulties of hammering the steel rod into the ground far enough and then removing it. The use of a screw auger may be more beneficial as it would be more adaptable for the purpose of creating holes. However, Giant Gippsland Earthworm burrows are not entirely vertical or horizontal but rather form a connected network of burrows radiating in different directions (Kretzschmar and Aries 1992).

Translocation Sites. At this stage it is unknown whether the most appropriate translocation sites should already support worms. If sites do not support Giant Gippsland Earthworm then it is likely that the habitat is unsuitable for the species and therefore may not sustain released worms. A possibility may be to attempt to manipulate this sort of habitat to suit worms. However, at this point the feasibility of this is unknown. This will be the subject of some pre-translocation investigations. The two sites found in this study represent sites that have a small population or are on the edge of the worms' distribution. Site one has a very discrete, small population of worms. This site may be able to be extended somewhat to support translocated worms and since the existing population is small, the new worms may be easier to distinguish. However there may be some accessibility problems for this site given that it occurs high up on a very steep hillslope. Site two exists on the eastern border of worm distribution at Loch Hill. It is not known whether this is because the site represents marginal habitat or simply because the worms have not dispersed that far yet.

Loch Hill supports an extensive Giant Gippsland Earthworm population with very high densities recorded. All age classes occur at the site with a relatively high number of juvenile worms noted. This, along with the collection of several developing and hatched egg cocoons, indicates a healthy breeding population, although no breeding adults were found. Adult earthworms were overall somewhat smaller than that recorded from similar studies. This may be a result of small sample size or because the high densities are causing competition amongst the population. Another possibility is that the habitat at Loch Hill is not as conducive to the development of larger sizes as the creek bank site where previous studies have occurred. Time consuming and damaging techniques of hand collection result in small sample sizes so that only limited interpretation of population structure can be made. Further information on a scale never before possible will be obtained during the translocation phase of the project at Loch Hill. The use of machinery and the movement of large amounts of soil

will allow many more individual earthworms to be examined allowing more solid data to be collected. This information, together with the results of the translocation of specimens, will aid in our understanding of the species and its conservation.

Acknowledgements

This work was funded by Vic Roads. Help of Vic Roads staff, in particular Graham Embry and David Gellion is much appreciated. Giant Gippsland Earthworms were collected under Research Permit to Dr. A. Yen under Wildlife Act (1975) and Flora and Fauna Guarantee Act (1988) No. 10001631

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Appendix 1 – Giant Gippsland Earthworm Project – Preliminary investigations into veterinary aspects of worm management

By Dr. David Middleton. (Healesville Sanctuary's Wild Animal Clinic)

Background

As a result of decisions taken at the initial planning meeting on May 1st, 2002 at Loch, Victoria, undertakings to investigate specific veterinary aspects of worm management were made. The provisional estimate document, 13/5/02, listed 11 components allocated to three distinct parts – Basic Health Care Techniques, Immediate management objectives and Laboratory based investigations (Appendix 2). Five of the eight components of Parts One and Two were initiated with some encouraging and useful information emerging.

These aspects included reviewing the anatomy of the species, identifying clinical parameters useful for assessing health status, trialing various sedatives, examining a range of tissues histo-pathologically (especially the skin and its response to injury), establishing a small colony in captivity for the development of health monitoring protocols and the design and implementation of methods for identifying individuals visually. In response to these objectives a field trip was conducted on 22 May 2002. Two sub-adult worms were retrieved for clinic based trials of sedatives, anaesthetics and euthanasia agents. These specimens provided the basis for anatomical, haematological and histological studies.

Items investigated (component numbers are consistent with the provisional estimates document)

Anatomy. The anatomy of Giant Gippsland Earthworm has been described in reasonable detail in Baldwin Spencer, (1888) to be supplied. However clinical anatomical descriptions are lacking. We investigated various accessible blood sampling points, coelomic fluid sampling points and administration sites for various agents.

Health parameters. The components of the blood have been described in Jones et al. (1994) and Stephenson (1930). But the response to injury, to metabolic disturbance and to infection does not seem to have been investigated in detail. We have conducted preliminary haematological investigations and submitted blood films and digital images to a specialist clinical pathologist for more accurate identification of cells and their functions. We have also sampled quantities of a clear serous fluid which resembles lymph. The identity of this fluid remains uncertain as the exact site of origin within the worm is not known. It may be a transudate of gut origin and it may have some relationship to the pale fluid reported to be expressed through the dorsal pores as a lubricant for subterranean motion (Spencer 1888). It is possible that this fluid may be valuable in health monitoring.

Histopathological investigations. A range of tissues were submitted for histopathological investigation. Although no specific abnormalities were reported, a more detailed account of the structure of tissues of particular interest (skin for example) has not yet been received. We intend to assemble a library of normal tissue sections for future reference.

Sedation, anaesthesia and euthanasia methods. Various substances were trialled as sedatives under both field and laboratory conditions and four routes of administration were used (topical, intra-coelomic, intra-muscular and intra-venous). These trials were preliminary as only 3 worms were used and a number of substances administered in series. This meant that individual worms received more than one substance and observations about single drug effects could not be made in most cases. Some initial response to diazepam was noted in the field however this was not repeatable with any reliability. Isoflurane, ketamine, zolazepam/tiletamine mixture, lignocaine, bupivacaine, medetomidine, suxamethonium chloride, midazolam and pentobarbitone were all tested in a preliminary manner. No substances were considered appropriate for sedation or euthanasia. Following advice from invertebrate specialists in UK (Cooper, 2001), further trials will include electrolyte solutions, carbon di-oxide, tricaine and benzocaine topically. Whilst direct access to the circulation of the worm was possible using fine needles (30g) this was not reliable enough to guarantee IV administration. Further work on access sites is required. Euthanasia methods are not easy to evaluate because of the difficulty in establishing the point of death. Further research is required in this area.

Marking and identification. These aspects have not been investigated to date. Plans to trial a number of mechanisms including dermal dyes and implants are planned for the future.

Thermal imaging trials. These have not been conducted. An introduction to the technology is to take place at Healesville in the near future to ascertain its applicability to worm research.

Provision of materials for genetic investigations. A genetics representative was present during the field trial and samples of various kinds were collected for analysis.

Establishment of a laboratory colony. Two specimens were retrieved for euthanasia and investigation. No immediate plans exist for the establishment of captive colony. It is recommended that this goes ahead in the near future however. Specialist invertebrate staff are available at Healesville to oversee the construction of a facility and provide day to day husbandry.

Summary of progress and future directions

If the Giant Gippsland Earthworm colony at Loch Hill is impacted by road construction, further investigations are required on all aspects outlined. Specifically, more recently recommended agents of anesthesia need to be trialled and a captive colony established at Healesville Sanctuary's Wild Animal Clinic to support further studies including health monitoring and response to injury and infection.

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Appendix 2 – Giant Gippsland Earthworm Project Provisional Estimates for Health Investigations

By Dr. David Middleton (Healesville Sanctuary's Wild Animal Clinic)

Introduction

Healesville Sanctuary's Wild Animal Clinic (AWH) provides veterinary services for the health, welfare and conservation of Australian wildlife. AWH is currently engaged in a number of endangered and threatened species recovery projects including those for Orange Bellied Parrots, Helmeted Honeyeaters, Eastern Barred Bandicoots, Tiger Quolls and Eastern Quolls. AWH also provides professional services in support of wildlife management objectives such as koala and kangaroo fertility control, flying fox translocation, mortality and disease investigations, bird of prey rehabilitation and wildlife rescue.

Our veterinarians are involved in research at many levels including original investigations, training of investigators, capture and restraint techniques, health monitoring and welfare advice. They also provide support for various government and university entities such as ethics committees, steering committees, technical advisory bodies and panels established for such tasks as the drafting of codes of practice for wildlife. The AWH is accessible 365 days a year for assisting veterinarians and other professional and technical individuals to solve problems associated with wildlife from the individual animal level through populations to issues relevant to the survival of the species.

Healesville Sanctuary is uniquely equipped to interpret and summarise conservation projects and present them to the visiting public. In this way, our organization is able to generate community support and interest for various programs which seek to provide long term security for wildlife and wildlife

habitat. Our mission is to encourage enduring relationships between people, wildlife and the environment.

Giant Earthworm Project – Basic Health Care Techniques

Review of current knowledge of earthworm health and survival including consideration of environmental factors influencing health.

Collection and analysis of basic health parameters.

Histopathological investigation of normal and abnormal tissues with a view to characterizing the response to injury and infection.

Giant Earthworm Project – Basic Support of immediate management objectives

Investigation of appropriate sedation and euthanasia methods.

Investigation of marking and identification techniques.

Trialing of survey and monitoring techniques involving specialized thermal imaging.

Provision of appropriate tissues/fluids for genetic investigation.

Establishment of artificially maintained colony at Healesville Sanctuary.

Giant Earthworm Project – Laboratory based investigations on artificially maintained worms

Refinement of husbandry and maintenance protocols.

Trialing of management techniques relevant to field management.

Design and construction of public display.