Distribution and Conservation Status of Tasmanian Native Earthworms

Dr Tim Kingston

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NEGP PROGRAM 9214

Dr Tim Kingston
Queen Victoria Museum
Launceston

What was the background to this project?

During the period 1986 to 1990, while employed by the Tasmanian Department of Primary Industries and Fisheries, the author was involved in a research project examining the benefits of exotic earthworms in Tasmanian pasture soils. Surveys of earthworms on farmland revealed that wherever pasture had been established for some years through cultivation and the addition of fertilizers and lime, introduced species of earthworms only were found. On more recently established low production pasture, mostly on poor soils, and also on very recently cleared land some native earthworms were found to have survived (Kingston and Temple-Smith 1989). That particular study, together with others reported in the literature, demonstrated that earthworms have the potential to improve soil structure following compaction and other physical degradation and that pasture production may be enhanced by significant amounts through introduction of earthworms to newly established pasture (Temple-Smith et al 1993). An earlier study by the author (Kingston 1989) had also shown that under adverse conditions, in this case irrigation, trampling by grazing animals can severely deplete earthworm populations. These results taken together suggest that earthworm population density in cultivated soils might have the potential to act as a biological indicator of soil health.

Some preliminary observations by the author during the above studies suggested that native earthworms were widespread, diverse and abundant in undisturbed soils under native vegetation, in some cases only a short distance outside a fence line separating pasture from bushland. Although introduced earthworm species were sometimes found in bushland, their occurrence was invariably associated with soil disturbance, whether severe, such as at log loading sites and fire dams, or minor, such as beside walking tracks. These observations begged exactly the same kind of questions for native earthworms in bushland, most particularly in relation to forestry activities in native forest, as those discussed above for farmland. In considering soil health under forestry or other anthropogenic changes in native vegetation, the spotlight falls largely on the survival of native earthworm species; although the extent of incursion by introduced species may have value as an additional measure of soil disturbance.

When dealing with native species, especially where there is partial or complete local clearance of native vegetation, there is the additional but vital consideration of the impact of this activity on the conservation status of earthworm species themselves. The likely severity of the impact on individual earthworm species will clearly be potentially greatest for species that are most limited in their geographical range as well as those confined to soils most highly prized for cultivation. Other pertinent questions in this context relate to the likely number of native earthworm species that have already been deleted by the extensive clearing of native vegetation that has occurred, and is still taking place in Tasmania; the value of bushland remnants for species' survival and the ability of native earthworms to recolonise and displace exotic species when native trees are replanted into former pasture.

Whether one's interest lies in earthworms as agents of soil remediation, as indicators of structural decline, or in the status of earthworm populations and species, there is a clear need to recognise the identity of the particular species, single or multiple, that are present in the location of interest. In 1990 the primary focus of the research of the author, now at the Queen Victoria Museum, migrated from exotic earthworms in farmland to native earthworms wherever they could be found. Specific studies of the impact of common forestry practices in Tasmanian forests were planned and some preliminary sampling conducted so that familiarity with the species could be attained. A search of the literature on Tasmanian native earthworms at that time revealed that the only recent paper dealing with the identity of Tasmanian native earthworms was a paper entitled "The Earthworms of Tasmania" by Australia's leading earthworm taxonomist, Professor Barrie Jamieson and published in 1974 (Jamieson 1974). This catalogue contains detailed descriptions and names of some 46 native earthworm species known from the State.

Attempts to identify the species in hand with the aid of this catalogue met, for the majority of species, with remarkably little success. Closer examination of the catalogue revealed that its contents were based upon collections made at a rather limited number of sites across Tasmania, that several sites were clustered around Hobart and two other localities and that collecting had been perfunctory rather than systematic at many of the sites.

Having become aware of the serious limitations in the quantity and geographical representation of the collections upon which Jamieson (1974) was founded, and the extent of the impediment to ecological studies that this represented, the author diverted his attention from the proposed studies of the responses of earthworms to disturbance, to rather more basic studies of earthworm diversity, distribution and taxonomy. Necessarily, the first step was to undertake a comprehensive collecting programme of native earthworms throughout the State, just such a programme was conducted by the author and funded by the National Estate Grants Program for the two years 1992/93 and 1993/94.

How much was known about Tasmanian native earthworms prior to this project?

Despite a promising start in the late eighteenth century, particularly by Baldwin Spencer who described 18 species in 1895, the study of Tasmanian native earthworms has been neglected ever since, as the maxim "out of sight, out of mind" appears to have largely prevailed during the twentieth century.

Since the time of Baldwin Spencer, very few additional specimens had found their way into permanent collections until the efforts of Professor V.V. Hickman and more especially Dr John Hickman at the University of Tasmania conducted sporadic collecting, initially for use in student practical classes, then to provide material for more focussed research by John Hickman, and eventually specifically to support taxonomic studies by Professor Barrie Jamieson at the University of Queensland. By the time Professor Jamieson was ready to publish his summary of the known Tasmanian earthworm species in 1972, he had available to him approximately 400 specimens from about 65 collection locations around Tasmania. A summary of these sites (Table 1) however reveals that many of them were concentrated in a few frequently collected areas, indeed a third of them (22) were from just "Hobart", "Mt Wellington" and "Tarraleah". Within this material Jamieson found representation of 8 previously described species and material that was the basis for the description of 26 new species. The remaining 12 species, reported for Tasmania in the early literature, were not found among the recent collections available to Jamieson, further reinforcing the emerging realisation that the group was as yet poorly sampled in the field.

Before his 1974 paper appeared in print, Professor Jamieson visited Tasmania on a brief collecting trip. With companion Mr Terry Walker, he drove from Launceston to the east coast via St Marys and St Helens to Hobart, from there to Queenstown via Bothwell and Lake St Clair and then to Somerset on the north coast via Zeehan, Rosebery and Tullah. They collected a further 400 specimens from 23 locations during this 5 day journey.

Following this collecting trip, Professor Jamieson conducted some initial sorting and identification of the material, but the emphasis of his work had by then developed in a different direction. Professor Jamieson donated his collections to the Queen Victoria Museum in 1991. The geographical origins of the specimens are summarised in Table 2.

Preserved collections made between 1974 and 1990 were again few, notable among them being those of the Lower Gordon Scientific survey conducted in 1976 and donated to the Queen Victoria Museum by Dr John Hickman in 1991 and some pitfall collections made by Dr Bob Green at Maggs Mountain (Arm River), during ecological studies in that area during the period 1975 to 1990.

Collections of earthworms under the author's program commenced in 1990. Firstly, Dr Bob Mesibov was contracted to conduct an intensive survey of an are of limited geographical extent close to Launceston. Mount Arthur, near Lilydale,

TABLE 1 Collections made between 1930 and 1972 and incorporated in Jamieson 1974

n	spp	date	locality	locality detail	lat. & long.		collectors
1	1	Feb 1892	Launceston		147-10	41-25	Simson, A
1	1	?Jan 1893	?				? Baldwin Spencer Collection
12	2	27-Jan-38	New Harbour		146-10	43-30	King, C.D.
1	1	19-Apr-38	Maydena	Kallista Ck	146-35	42-45	Rodway, Mrs
8	1	Nov 1938	Coxs Bight		146-15	43-30	King,C.D.
1	1	19-Jan-39	Maydena	Snowy Mountains	146-40	43-00	King, C.D.
3	1	16-Feb-39	Maydena	Russel River	146-40	42-45	King, C.D.
5	3	Jan 1940	Port Davey	Kelly's Beach	145-55	43-20	King, C.D.?
6	3	Feb 1941	Lake St Clair		146-10	42-05	(Kershaw?)
5	2	26-Jun-47	Risdon	Risdon	147-20	42-50	Hickman,V.V.
1	1	28-Jun-47	Mt Wellington		147-15	42-55	Hickman,V.V.
2	1	13-Sep-51	Mt Wellington		147-15	42-55	Hickman,V.V.
1	1	31-Mar-52	Mt Wellington		147-15	42-55	Radford, W.
1	1	26-Aug-53	Weldborough Pass	1.6 miles from eastern end of pass	147-55	41-10	Hickman, J.L.
1	1	26-Aug-53	St Helens	Launceston via Scotsdale, 94/96 mile posts	146-10	42-05	Hickman, J.L.
1	1	26-Aug-53	Lilydale	Mt Arthur	147-55	41-10	Hickman, J.L.
1	1	31-Aug-53	Lenah Valley	New Town creek	147-15	42-55	Hickman, J.L.
2	2	11-Sep-53	Hobart	Mt. Nelson, Sandy Bay	147-20	42-55	Hickman, J.L.
8	2	15-Sep-53	Lenah Valley	track along Newtown Ck	147-15	42-55	Hickman, J.L.
2	1	15-Sep-53	Hobart	Waterworks Road	147-20	42-50	Hickman, J.L.
2	1	31-Dec-53	Interview River	2 miles inland, south of Interview River	144-55	41-35	Jackson, R
2	1	30-Nov-53	Tarraleah		146-25	42-20	Hickman, V.V.
3	2	13-Jan-54	Mt Wellington		147-15	42-55	Hickman, J.L.
6	3	04-Mar-54	Mt. Wellington	Bett's Vale	147-15	42-55	Hickman, J.L.
1	1	04-Mar-54	Eagle Hawk Neck		147-55	43-00	Hickman, J.L.
2	1	16-Apr-54	Goulds Country	near Lottah	148-05	41-15	Hickman, J.L.
6	2	17-Apr-54	St Columba Falls		147-55	41-20	Hickman, J.L.
3	1	13-May-54	Eagle Hawk Neck		147-55	43-00	Hickman, J.L.

4	1	17-May-54	Burnie	Fern Glade, nr Emu River	41-05	145-55	Hickman, J.L.
8	2	22-May-54	Tarraleah	Lyell Highway	42-20	146-25	Hickman, J.L.
2	1	24-May-54	Bronte	Lyell Highway, 5 miles towards Hobart	42-15	146-35	Hickman, J.L.
1	1	24-May-54	Bronte	Marlborough Highway, 5 mls towards Hobart	42-15	146-35	Hickman, J.L.
2	2	24-May-54	Lyell Highway	Dee Bridge	42-15	146-35	Hickman, J.L.
8	2	26-May-54	Bronte	Marlborough Highway	42-10	146-30	Hickman, J.L.
16	2	26-May-54	Great Lake		41-55	146-45	Hickman, J.L.
39	4	27-May-54	Tarraleah	over pipeline	42-20	146-25	Hickman, J.L.
19	1	27-May-54	Tarraleah	Butlers Gorge Road	42-20	146-25	Hickman, J.L.
13	4	28-May-54	Hellyer Gorge		41-20	145-35	Hickman, J.L.
5	2	14-Aug-54	East Risdon		42-50	147-20	Hickman, J.L.
8	1	14-Aug-54	Eagle Hawk Neck		43-00	147-55	Hickman, J.L.
4	2	14-Aug-54	Hobart	Domain	42-50	147-20	Hickman, J.L.
5	1	17-Aug-54	Hobart	Water-works Road	42-50	147-20	Hickman, J.L.
31	2	18-Aug-54	Parattah		42-20	147-25	Hickman, J.L.
4	2	18-Aug-54	Tunnack		42-25	147-30	Hickman, J.L.
11	4	24-Aug-54	Table Cape		41-00	145-45	Hickman, J.L.
9	5	24-Aug-54	Burnie, N.W. Tas.	Fern Glade, Emu Road	41-05	145-55	Hickman, J.L.
4	2	25-Aug-54	Parrawe		41-20	145-35	Hickman, J.L.
9	1	13-Oct-54	Penguin	Ironcliff Road, Fern Dene	41-05	146-05	?
13	1	21-Jul-55	Florentine Valley		42-35	146-25	Gilbert, J.M.
3	2	27-Oct-55	Mt Wellington		42-55	147-15	Hickman, J.L.
11	3	08-Nov-55	Collinsvale		42.50	147-05	Hickman, J.L.
9	1	11-Nov-55	Geeveston	Arve Valley	43-05	146-50	Hickman, J.L.
4	1	13-Nov-55	Mt Wellington		42-55	147-15	Hickman, J.L.
9	1	Apr. 1956	Eagle Hawk Neck		43-00	147-55	Hickman, J.L.
35	3	24-Jun-57	Lenah Valley	New Town Falls	42-50	147-20	Hickman, J.L.
1	1	04-Aug-57	Tinderbox	Tinderbox	43-05	147-20	Hickman, J.L.
2	1	24-Sep-58	ANM Road	Styx River Bridge	42-50	146-35	Francombe, D.

2	1	Dec 1967	Port Davey	Melaleuca Inlet	43-20	145-55	Dartnall, A.J.
1	1	25-Feb-71	Lake Pedder	Maria Creek	42.55	146-10	Tyler, P.A.
2	1	13-Mar-71	Mt Arthur		41-15	147-20	Dartnall, A.J.
4	1	10-Apr-71	Bruny Island	Summit of Mt Mangana	43-25	147-15	Dartnall, A.J.
23	4	19-Aug-71	Mt. Wellington	Shoobridge Bend Track	42-55	147-15	Jamieson, B., & Bradbury, E.
1	1	19-Sep-71	Derby	nr Old Breiseis Mine dam	41-10	147-50	Kershaw, R.C.
5	3	15-Oct-71	Mt Arthur		41-15	147-20	Dartnall, A.J. & Kershaw, R.C.
5	1	?	"Hobart and Straham"		42-50	147-20	?
398	109		number of sites: 65 (Mt Wellington: 10, Hobart: 7, Tarraleah: 5)				

TABLE 2 Collections made by Professor Jamieson in 1972 and donated to QVM in 1991

n	spp	date	locality	locality detail	lat. & long.			
		9-Aug-72	Launceston, N. TAS	9 miles from Launceston on road to Scottsdale	41	27 S	147	10 E
14	2	9-Aug-72	Launceston, N. TAS	Mt Barrow near ruined stone hut	41	27 S	147	10 E
16	2	9-Aug-72	Launceston, N. TAS	Mt Barrow	41	27 S	147	10 E
55	2	9-Aug-72	Weldborough, N.E. TAS	Weldborough Pass	41	12 S	147	54 E
34	1	10-Aug-72	St Marys, E. TAS	Top of St Mary's Pass	41	35 S	148	12 E
14	1	10-Aug-72	St Helens, E. TAS	St Helens to Hobart Road, 2 mls from St Helens	41	20 S	148	14 E
5	1	10-Aug-72	Hobart, S.E. TAS	Foot of Mt Wellington	42	53 S	147	19 E
2	1	10-Aug-72	Hamilton, S.E. TAS	Miena Road				
0		10-Aug-72	Hamilton, S.E. TAS	8 miles from Hamilton along road to Bothwell	42	33 S	146	50 E
0		10-Aug-72	Bothwell, S.E.TAS	12 miles from Bothwell along road to Great Lake				
6	1	10-Aug-72	Liapootah, C.P. TAS	1 mile east of Liapootah	0	S	0	E
0		11-Aug-72	Lake St Clair, W. TAS	Banks of Lake St Clair	42	5 S	146	5 E
14	2	11-Aug-72	Queenstown, W. TAS	Lyell Highway, 4 miles West of Mt Arrowsmith	42	5 S	145	33 E
24	2	11-Aug-72	Queenstown, W. TAS	Mt Arrowsmith	42	5 S	145	33 E
4	2	12-Aug-72	Queenstown, W. TAS	Nelson Valley Ck on Lyell Hwy, 14 mls E of Queenstown	42	5 S	145	33 E
9	2	12-Aug-72	Queenstown, W. TAS	17 miles from Strahan along road to Queenstown	42	5 S	145	33 E
10	1	13-Aug-72	Queenstown, W. TAS	7 miles from Queenstown along road to Burnie	42	5 S	145	33 E
20	1	13-Aug-72	Zeehan, W. TAS	Murchison Highway, 4 miles N of Zeehan turnoff	41	54 S	145	21 E
19	1	13-Aug-72	Rosebery, W. TAS	Murchison Highway, 4 miles West of Rosebery	41	47 S	145	34 E
2	1	13-Aug-72	Rosebery, W. TAS	Mt Block on Murchison Highway	41	47 S	145	34 E
36	5	13-Aug-72	Tullah, N.W. TAS	Murchison Highway, 15 miles N. of Tullah	41	44 S	145	37 E
111	7	13-Aug-72	Waratah, N.W. TAS	Murchison Highway near Wandle River	41	27 S	145	32 E
4	1	13-Aug-72	Somerset, N.W. TAS	1 mile south of Somerset	41	3 S	145	50 E
399	**36**		**number of sites: 23**	**number of species: 19**				

was chosen on the basis that it supported a range of vegetation communities largely determined by altitude and aspect. Thirteen diverse sites were selected for study.

Two additional and significant opportunities to collect earthworms in remote locations arose in 1992 through the WEBS initiative of the Tasmanian Parks and Wildlife Service. This programme allowed myself and an assistant to spend a week based at each of Pelion Valley in February and at Melaleuca in March of that year. Earthworms were sampled at 14 localities within 10 km of the Pelion Rangers' Hut and at 10 localities within a 6 km radius of the airstrip at Melaleuca.

These and other directed and opportunistic collecting efforts during the two years preceding the National Estate-funded project allowed the accumulation of a further 950 specimens from 64 sites as summarised in Table 3.

In addition to these substantive collections, additional specimens arising from public enquiries and local surveys over the past four decades are shelved within the general collections of both the Queen Victoria Museum and the Tasmanian Museum. These specimens tend to be poorly preserved and poorly referenced, compared with the highly targetted collections assembled by the present author since 1990.

What was the aim of the project?

As stated in the grant application, the aim of the project was:

> "To increase the level of knowledge of Tasmanian native earthworms from the present low level to a point at which it will be possible to evaluate the National Estate significance of the fauna and to assess the conservation status of each species. A guide book of the distribution and habitat preference of each species will, for the first time, enable prediction of the impact of developments upon native earthworm species"

An additional implied aim was to attempt to reach a point at which it would be possible to conduct studies of the impact of forestry practices on earthworm populations and to assess their value as 'bio-indicators' of forest ecosystem health.

TABLE 3 Collections made by the author and associates 1990 - 1992

n	spp	date	locality	locality detail	grid ref.	alt.	collectors
41	9	23 -Aug- 90	Weldborough, N.E. TAS	Weldborough	EQ 744 351	680	Mesibov, R.
79	6	29 -Aug- 90	Weldborough, N.E. TAS	Weldborough	EQ 744 353	650	Mesibov, R.
38	6	7 -Sep- 90	Weldborough, N.E. TAS	Weldborough	EQ 745 353	660	Mesibov, R.
55	4	8 -Sep- 90	Waratah, N.W. TAS	Waratah	CQ 704 066	690	Mesibov, R.
41	7	19 -Sep- 90	Waratah, N.W. TAS	Waratah	CQ 702 064	680	Mesibov, R.
42	5	23 -Sep- 90	Waratah, N.W. TAS	Waratah	CQ 703 065	670	Mesibov, R.
4	1	-Sep- 90	Weldborough, N.E. TAS		EQ 756 395		Kingston, T.J. & Mesibov, R.
5	1	28 -Nov- 90	Mt. Arthur, N. TAS	Patersonia Rivulet	EQ 252 313	610	Mesibov, R.
24	4	6 -Dec- 90	Christmas Hills, N.W. TAS	Christmas Hills	CQ 309 667	60	Mesibov, R.
10	4	7 -Dec- 90	Christmas Hills, N.W. TAS		CQ 341 702	20	Mesibov, R.
5	1	10 -Dec- 90	Roger River, N.W. TAS		CQ 259 487	30	Mesibov, R.
14	3	16 -Dec- 90	Smithton, N.W. TAS	Big Eel Ck	CQ 180 303	190	Mesibov, R.
10	2	17 -Dec- 90	Trowutta Plateau, N.W. TAS		CQ 330 483	210	Mesibov, R.
12	2	18 -Dec- 90	Frankland River Bridge, N.W. TAS	Frankland River track	CQ 251 313	110	Mesibov, R.
1	1	20 -Dec- 90	Balfour, N.W. TAS	Frankland Plain	CQ 239 402	160	Mesibov, R.
12	2	28 -Dec- 90	Roger River West N.W. TAS	Montagu Swamp	CQ 287 547	30	Mesibov, R.
11	2	29 -Dec- 90	Mt. Hazelton, N.W. TAS	Mt Hazelton	CQ 266 189	650	Mesibov, R.
4	1	29 -Dec- 90	Mt. Frankland, N.W. TAS	Mt Frankland	CQ 269 262	310	Mesibov, R.
6	1	15 -Apr- 91	Triabunna, E. TAS	Buckland Military Area	EP 688 015	410	Mesibov, R.
3	1	16 -Apr- 91	Triabunna, E. TAS	Mitchelmore's Ck	EP 727 106	120	Mesibov, R.
3	1	17 -Apr- 91	Triabunna, E. TAS	Buckland Military Area	EN 696 961	150	Mesibov, R.
8	1	14 -May- 91	Mt. Arthur, N. TAS	Mt. Arthur site 1	EQ 253 320	650	Mesibov, R.
4	1	14 -May- 91	Mt. Arthur, N. TAS	Mt. Arthur site 2	EQ 255 327	550	Mesibov, R.
9	3	17 -May- 91	Mt. Arthur, N. TAS	Mt. Arthur site 3	EQ 255 317	630	Mesibov, R.
9	1	17 -May- 91	Mt. Arthur, N. TAS	Mt. Arthur site 4	EQ 251 308	660	Mesibov, R.
8	1	19 -May- 91	Mt. Arthur, N. TAS	Mt. Arthur site 5	EQ 224 325	520	Mesibov, R.

7	1	22 -May- 91	Mt. Arthur, N. TAS	Mt. Arthur site 6	EQ	234	305	1080	Mesibov, R.
19	3	22 -May- 91	Mt. Arthur, N. TAS	Mt. Arthur site 7	EQ	231	303	990	Mesibov, R.
2	1	18 -May- 91	Mt. Arthur, N. TAS	Mt. Arthur site 8	EQ	223	292	750	Mesibov, R.
32	4	18 -May- 91	Mt. Arthur, N. TAS	Mt. Arthur site 9	EQ	246	310	750	Mesibov, R.
50	3	21 -May- 91	Mt. Arthur, N. TAS	Mt. Arthur site 10	EQ	239	281	840	Mesibov, R.
6	3	18 -May- 91	Mt. Arthur, N. TAS	Mt. Arthur site 11	EQ	213	274	520	Mesibov, R.
1	1	21 -May- 91	Mt. Arthur, N. TAS	Mt. Arthur site 12	EQ	209	282	480	Mesibov, R.
2	1	11 -Aug- 91	Sideling Range, N.E. TAS						Kingston, T.J.
1	1	14 -Aug- 91	Cape Naturalist, N.E. TAS	Site 3					Kingston, T.J. & McGowan, L.F.
9	1	14 -Aug- 91	Cape Naturalist, N.E. TAS	Top Camp					Kingston, T.J. & McGowan, L.F.
4	1	15 -Aug- 91	Waterhouse, N.E. TAS	Little Waterhouse	EQ	516	751		Kingston, T.J.
5	3	27 -Aug- 91	Gog Range, N. TAS	Gog Range site 2	DQ	534	056		Kingston, T.J.
4	1	27 -Aug- 91	Gog Range, N. TAS	Gog Range site 1	DQ	543	058		Kingston, T.J.
2	1	13 -Dec- 91	Gog Range, N. TAS	Gog Range	DQ	548	059		Mesibov, R.
4	1	14 -Dec- 91	Mt. Barrow, N.E. TAS	Mt. Barrow	EQ	348	783	1295	Mesibov, R.
5	1	16 -Dec- 91	Gog Range, N. TAS	Gog Range	DQ	461	058	530	Mesibov, R.
3	1	16 -Jan- 92	Pioneer, N.E. TAS	Pioneer	EQ	782	512		Kingston, T.J. & Laffan, M.
27	4	10 -Feb- 92	Pelion Valley, W. TAS	Mt. Oakleigh	DP	208	705	985	Kingston, T.J. & M.E.
13	4	10 -Feb- 92	Pelion Valley, W. TAS	Mt. Oakleigh	DP	209	700	870	Kingston, T.J. & M.E.
20	6	10 -Feb- 92	Pelion Valley, W. TAS	Mt. Oakleigh	DP	209	702	895	Kingston, T.J. & M.E.
3	2	11 -Feb- 92	Pelion Valley, W. TAS	Pelion Gap track	DP	211	655	980	Kingston, T.J. & M.E.
12	3	11 -Feb- 92	Pelion Valley, W. TAS	Pelion Gap track	DP	213	653	1010	Kingston, T.J. & M.E.
9	3	11 -Feb- 92	Pelion Valley, W. TAS	Pelion Gap track	DP	217	649	1120	Kingston, T.J. & M.E.
2	1	12 -Feb- 92	Pelion Valley, W. TAS	buttongrass plain	DP	201	687	845	Kingston, T.J. & M.E.
15	5	12 -Feb- 92	Pelion Valley, W. TAS	nr Old Pelion Hut	DP	204	684	860	Kingston, T.J. & M.E.
11	5	12 -Feb- 92	Pelion Valley, W. TAS		DP	209	660	940	Kingston, T.J. & M.E.
23	5	13 -Feb- 92	Pelion Valley, W. TAS	Forth River, N.W. side	DP	173	674	725	Kingston, T.J. & M.E.
19	7	13 -Feb- 92	Pelion Valley, W. TAS	Forth River, S.E. side	DP	177	675	730	Kingston, T.J. & M.E.
3	1	13 -Feb- 92	Pelion Valley, W. TAS	Forth River, S.E. side	DP	180	678	760	Kingston, T.J. & M.E.
16	3	13 -Feb- 92	Pelion Valley, W. TAS	Forth River, S.E. side	DP	196	683	875	Kingston, T.J. & M.E.

19	5	14	-Feb- 92	Pelion Valley, W. TAS	Arm River track	DP	194	710	750	Kingston, T.J. & M.E.
10	2	1	-Mar- 92	Melaleuca area, S.W. TAS	nr Half-woody Hill	DM	339	909	15	Kingston, T.J. & McGowan, L.F.
9	1	3	-Mar- 92	Melaleuca area, S.W. TAS	Denny King's garden	DM	319	922	2	Kingston, T.J. & McGowan, L.F.
23	2	4	-Mar- 92	Melaleuca area, S.W. TAS	Celery Top Island	DM	309	977	8	Kingston, T.J. & McGowan, L.F.
11	2	4	-Mar- 92	Melaleuca area, S.W. TAS	edge of Melaleuca Lagoon	DM	321	921	1	Kingston, T.J. & McGowan, L.F.
28	3	5	-Mar- 92	Melaleuca area, S.W. TAS	South Coast Track	DM	328	904	10	Kingston, T.J. & McGowan, L.F.
61	6	5	-Mar- 92	Melaleuca area, S.W. TAS	Half-woody Hill	DM	338	889	80	Kingston, T.J. & McGowan, L.F.
3	1	23	-Apr- 92	Scottsdale, N.E. TAS	Scottsdale	EQ	434	432		Kingston, T.J.

TABLE 4 Collections made under the present study

n	spp	date	locality	locality detail	grid ref.			alt.	collectors
13	2	2-May-92	Retreat, N. TAS		EQ	144	481	135	Kingston, T.J. & D'orazio, R.
22	2	2-May-92	Retreat, N. TAS		EQ	156	473	130	Kingston, T.J. & D'orazio, R.
40	3	2-May-92	Retreat, N. TAS		EQ	160	451	160	Kingston, T.J. & D'orazio, R.
24	4	3-Jun-92	Springfield South, N.E. TAS	off East Diddleum Road	EQ	388	287	560	Kingston, T.J. & D'orazio, R.
15	2	9-Jun-92	Golconda, N. TAS		EQ	264	438	70	Kingston, T.J. & D'orazio, R.
34	3	9-Jun-92	Springfield, N.E. TAS	off Upper Brid Road	EQ	380	307	330	Kingston, T.J. & D'orazio, R.
5	3	9-Jun-92	Jetsonville, N.E. TAS		EQ	393	518	70	Kingston, T.J. & D'orazio, R.
8	1	15-Jun-92	Nabowla, N. TAS		EQ	263	383	260	Kingston, T.J. & D'orazio, R.
86	8	15-Jun-92	Sideling Range, N.E. TAS		EQ	344	353	530	Kingston, T.J. & D'orazio, R.
14	4	16-Jun-92	Mt. Barrow, N.E. TAS	Mt. Barrow site 1	EQ	317	223	500	Kingston, T.J. & D'orazio, R.
8	2	16-Jun-92	Mt. Barrow, N.E. TAS	Mt. Barrow site 2	EQ	353	212	750	Kingston, T.J. & D'orazio, R.
3	2	16-Jun-92	Mt. Barrow, N.E. TAS	Mt. Barrow site 3	EQ	354	193	1240	Kingston, T.J. & D'orazio, R.
26	6	16-Jun-92	Mt. Barrow, N.E. TAS	Mt. Barrow site 4	EQ	358	195	1020	Kingston, T.J. & D'orazio, R.
8	1	16-Jun-92	Mt. Barrow, N.E. TAS	Mt. Barrow site 5	EQ	358	202	895	Kingston, T.J. & D'orazio, R.
10	2	17-Jun-92	Merthyr Park, N. TAS		EQ	160	342	180	Kingston, T.J. & D'orazio, R.
15	2	17-Jun-92	Hollybank, N. TAS		EQ	179	270	300	Kingston, T.J. & D'orazio, R.
17	2	17-Jun-92	Lilydale Falls, N.E. TAS		EQ	179	355	180	Kingston, T.J. & D'orazio, R.
6	2	17-Jun-92	Prossers Forest, N. TAS		EQ	194	205	420	Kingston, T.J. & D'orazio, R.
23	5	22-Jun-92	Mt. Victoria, N.E. TAS	Mt. Victoria F.R. site 1	EQ	662	225	720	Kingston, T.J. & D'orazio, R.
51	3	22-Jun-92	Mt. Victoria, N.E. TAS	Mt. Victoria F.R. site 2	EQ	691	226	790	Kingston, T.J. & D'orazio, R.
25	5	22-Jun-92	Mt. Victoria, N.E. TAS	Mt. Victoria F.R. site 3	EQ	718	225	810	Kingston, T.J. & D'orazio, R.
30	8	23-Jun-92	Mathinna, E. TAS	Griffin F.R.	EQ	687	088		Kingston, T.J. & D'orazio, R.
73	9	23-Jun-92	Mathinna, E. TAS	Evercreech F.R.	EQ	812	162	350	Kingston, T.J. & D'orazio, R.
26	5	24-Jun-92	Mt. Maurice, N.E. TAS	Mt. Maurice site 1	EQ	503	263	940	D'orazio, R. & McGowan, L.F.
9	3	24-Jun-92	Mt. Maurice, N.E. TAS	Mt. Maurice site 2	EQ	505	262	910	D'orazio, R. & McGowan, L.F.
28	6	24-Jun-92	Mathinna Falls, N.E. TAS	Mathinna Falls Reserve	EQ	748	162	470	Kingston, T.J. & D'orazio, R.
21	3	25-Jun-92	Tombstone Creek F.R., N.E. TAS		EQ	577	163	640	D'orazio, R. & Cooper, M.
24	5	29-Jun-92	Dazzler Range, N. TAS	Kerrisons Road site 1	DQ	755	376	415	D'orazio, R. & Mitchell, A.

30	6	29 -Jun- 92	Dazzler Range, N. TAS	Kerrisons Road site 2	DQ	756	389	510	D'orazio, R. & Mitchell, A.
33	4	29 -Jun- 92	Dazzler Range, N. TAS	Horders Rd	DQ	764	349	330	D'orazio, R. & Mitchell, A.
13	4	29 -Jun- 92	Dazzler Range, N. TAS	Tattersalls Road	DQ	773	359	440	D'orazio, R. & Mitchell, A.
6	1	29 -Jun- 92	Dazzler Range, N. TAS	site 5	EQ	753	368	340	D'orazio, R. & Mitchell, A.
35	4	30 -Jun- 92	Dalgarth F.R., N. TAS	site 1	DQ	707	343	120	Kingston, T.J. & D'orazio, R.
45	3	30 -Jun- 92	Dalgarth F.R., N. TAS	site 2	DQ	722	325	0	Kingston, T.J. & D'orazio, R.
59	5	30 -Jun- 92	Dalgarth F.R., N. TAS	Wallaby Ck	DQ	734	329	0	Kingston, T.J. & D'orazio, R.
26	6	2 -Jul- 92	Fairy Glade S.R.. N. TAS		DP	766	883	740	D'orazio, R. & McGowan, L.F.
35	7	2 -Jul- 92	Liffey Falls, N. TAS		DP	763	827	920	D'orazio, R. & McGowan, L.F.
32	4	2 -Jul- 92	Liffey Falls, N. TAS		DP	813	845	520	D'orazio, R. & McGowan, L.F.
0	0	6 -Jul- 92	Cluan Tier, N. TAS	Wandilla Road	DP	805	946	425	D'orazio, R. & Mitchell, A.
5	2	6 -Jul- 92	Cluan Tier, N. TAS	Myrtle Ck Road	DP	872	878	520	D'orazio, R. & Mitchell, A.
23	5	7 -Jul- 92	Legerwood, N.E. TAS	Cuckoo Falls	EQ	516	343	415	D'orazio, R.
30	5	7 -Jul- 92	Legerwood, N.E. TAS	Hogarth Road	EQ	521	356	290	D'orazio, R.
17	1	7 -Jul- 92	Legerwood, N.E. TAS	Cuckoo Hill Road	EQ	543	338	455	D'orazio, R.
14	2	9 -Jul- 92	Liffey, N. TAS	Coalmine Ck	DP	833	848	510	D'orazio, R.
9	1	9 -Jul- 92	Drys Bluff, N. TAS		DP	867	837	450	D'orazio, R.
32	3	16 -Jul- 92	Blackwood Creek, N. TAS	Westons Rivulet	DP	895	758	375	D'orazio, R. & Cooper, M.
0	0	16 -Jul- 92	Caseyville, N. TAS	Abraham Ck	EP	38	636	360	D'orazio, R. & Cooper, M.
22	3	20 -Jul- 92	Pioneer, N.E. TAS	Royston Ck	EQ	828	493	215	D'orazio, R. & Cooper, M.
17	2	20 -Jul- 92	Pioneer, N.E. TAS	Old Chum Dam	EQ	883	539	110	D'orazio, R. & Cooper, M.
63	6	20 -Jul- 92	Mt. Cameron, N.E. TAS	Water Race Reserve	EQ	886	483	175	D'orazio, R. & Cooper, M.
23	3	21 -Jul- 92	Ringarooma, N.E. TAS	Mt. Paris Road	EQ	677	376	540	D'orazio, R. & Cooper, M.
29	4	21 -Jul- 92	Moorina, N.E. TAS	Frome Road	EQ	762	443	420	D'orazio, R. & Cooper, M.
31	3	21 -Jul- 92	Weldborough Pass, N.E. TAS	Myrtle F.R.	EQ	777	372	440	D'orazio, R. & Cooper, M.
72	6	21 -Jul- 92	Weldborough, N.E. TAS	Emu Road	EQ	781	408	540	D'orazio, R. & Cooper, M.
0	0	23 -Jul- 92	Launceston, N. TAS	Punchbowl Recreation Reserve	EQ	139	103	30	D'orazio, R. & Cooper, M.
6	1	23 -Jul- 92	Launceston, N. TAS	Carr Villa Floral Reserve	EQ	144	092		D'orazio, R. & Cooper, M.
10	1	27 -Jul- 92	Scamander, E. TAS	Scamander F.R.	FQ	015	123	100	D'orazio, R. & Cooper, M.

21	5	27 -Jul- 92	Toms Gully, E. TAS		FQ	900	218	320	D'orazio, R. & Cooper, M.
19	3	28 -Jul- 92	Peters Road, E. TAS		EQ	939	445	170	D'orazio, R. & Cooper, M.
26	4	28 -Jul- 92	Wild Pig Hill, E. TAS		EQ	962	489	160	D'orazio, R. & Cooper, M.
11	2	28 -Jul- 92	Badger Marsh, N.E. TAS		EQ	975	368	120	D'orazio, R. & Cooper, M.
33	4	29 -Jul- 92	Mt. Nicholas Road, E.TAS		EP	900	995	520	D'orazio, R. & Cooper, M.
41	5	29 -Jul- 92	Pyengana, N.E. TAS	Intake Bridge	EQ	781	260	360	D'orazio, R. & Cooper, M.
20	3	29 -Jul- 92	Trafalgar Flat, E. TAS		EQ	875	178	300	D'orazio, R. & Cooper, M.
7	1	3 -Aug- 92	Fingal, E. TAS	Valley Road	EP	875	895	500	D'orazio, R. & Cooper, M.
1	1	3 -Aug- 92	Mt. Puzzler F.R., E. TAS	Meadstone Falls Track	EP	892	791	480	D'orazio, R. & Cooper, M.
17	3	3 -Aug- 92	Fingal, E. TAS	Valley Road	EP	894	836	760	D'orazio, R. & Cooper, M.
3	2	3 -Aug- 92	Fingal, E. TAS	Valley Road	EP	985	875	500	D'orazio, R. & Cooper, M.
24	2	4 -Aug- 92	St Marys Pass S.R., E. TAS	Lower GermanTown Road	FP	002	989	220	D'orazio, R. & Cooper, M.
19	2	4 -Aug- 92	Irishtown, N.W. TAS	St Patricks Head S.R.	FP	026	988	430	D'orazio, R. & Cooper, M.
4	2	5 -Aug- 92	Hardings Falls F.R., E. TAS		EP	914	663	260	D'orazio, R. & Cooper, M.
35	4	5 -Aug- 92	Apsley Myrtle F.R., E. TAS		EP	932	719	450	D'orazio, R. & Cooper, M.
5	1	5 -Aug- 92	Bicheno, E. TAS	Swilly Marsh	EP	956	623	280	D'orazio, R. & Cooper, M.
21	2	5 -Aug- 92	Chain of lagoons, E. TAS	'E' Road, Piccaninny Ck bridge	FP	029	847	310	D'orazio, R. & Cooper, M.
25	3	10 -Aug- 92	Royal George, E. TAS	Meetus Falls	EP	731	552	600	D'orazio, R. & Cooper, M.
23	4	10 -Aug- 92	Lake Leake, E. TAS	Lost Falls F.R.	EP	746	447	470	D'orazio, R. & Cooper, M.
16	2	10 -Aug- 92	Royal George, E. TAS	West Swan River	EP	790	605	540	D'orazio, R. & Cooper, M.
38	5	11 -Aug- 92	Tooms Lakes, E. TAS	Tooms White Gum F.R.	EP	701	226	600	D'orazio, R. & Cooper, M.
25	5	11 -Aug- 92	Brookerana F.R., E. TAS		EP	709	193	590	D'orazio, R. & Cooper, M.
55	6	11 -Aug- 92	Tom Legges Tier, E. TAS	McKays Road	EP	728	302	600	D'orazio, R. & Cooper, M.
28	4	17 -Aug- 92	Colebrook, S.E. TAS	Coal River Gorge Nature Reserve	EN	325	965	310	D'orazio, R. & Cooper, M.
16	2	17 -Aug- 92	Colebrook, S.E. TAS	Spinning Gum F.R.	EN	393	950	460	D'orazio, R. & Cooper, M.
20	3	18 -Aug- 92	Dysart, Midlands, TAS	Barren Rock Falls F.R.	EN	208	867	350	D'orazio, R. & Cooper, M.
0	0	18 -Aug- 92	Bagdad, Midlands, TAS	Chauncy Vale Wildlife Sanctuary	EN	237	820	330	D'orazio, R. & Cooper, M.
3	1	19 -Aug- 92	Pipers Brook, N. TAS	Pipers Brook Road	EQ	152	537	100	D'orazio, R. & Cooper, M.
0	0	19 -Aug- 92	Waverley, Launceston, N. TAS	Distillary Ck Reserve	EQ	153	132	60	D'orazio, R. & Cooper, M.

17	1	19-Aug-92	Pipers Brook, N. TAS	State Forest, Bridport Highway	EQ	175	553	80	D'orazio, R. & Cooper, M.
25	3	24-Aug-92	Frankford, N. TAS	Mt. Careless State Forest	DQ	802	283	420	D'orazio, R. & Cooper, M.
9	2	24-Aug-92	Holwell, N. TAS	Holwell Gorge	DQ	804	304	300	D'orazio, R. & Cooper, M.
13	2	24-Aug-92	Four Springs, N. TAS	Four Springs Forest Park	DQ	863	199	180	D'orazio, R. & Cooper, M.
17	3	24-Aug-92	Notley Gorge, N. TAS		DQ	926	215	240	D'orazio, R. & Cooper, M.
26	4	25-Aug-92	Railton, N.W. TAS	Redwater Ck	DQ	487	195	200	D'orazio, R. & Cooper, M.
21	3	25-Aug-92	Railton, N.W. TAS	Henry Somerset Conservation Area	DQ	508	305	45	D'orazio, R. & Cooper, M.
44	4	25-Aug-92	Kimberley, N.W. TAS	Richland Hill	DQ	512	168	180	D'orazio, R. & Cooper, M.
34	4	26-Aug-92	Forth, N.W. TAS	Champion Nature Reserve	DQ	372	372	40	D'orazio, R. & Cooper, M.
6	2	26-Aug-92	Eugenana, N.W. TAS	Arboretum Nature Trail	DQ	414	357	50	D'orazio, R. & Cooper, M.
37	5	26-Aug-92	Paradise, N.W. TAS	Minnow Ck	DQ	447	086	260	D'orazio, R. & Cooper, M.
12	4	31-Aug-92	Forth Falls S.R., N.W. TAS	Lake Barrington Rd.	DQ	333	185	220	D'orazio, R. & Cooper, M.
15	4	31-Aug-92	Lower Wilmot, N.W. TAS	Ingram Ck, Wilmot Road	DQ	346	277	240	D'orazio, R. & Cooper, M.
29	2	31-Aug-92	Devonport, N.W. TAS	Bella - Macargee Falls	DQ	402	376	100	D'orazio, R. & Cooper, M.
10	1	1-Sep-92	Mole Creek, N. TAS	Baldocks Cave State Forest	DP	444	958	430	D'orazio, R.
7	2	1-Sep-92	Needles, N. TAS	Lobster Falls track	DQ	598	008	360	D'orazio, R.
11	2	2-Sep-92	Mole Creek, N. TAS	Croesus Cave S.R.	DP	352	966	300	D'orazio, R.
0	0	2-Sep-92	Mole Creek, N. TAS	King Solomons Cave S.R.	DP	371	997	440	D'orazio, R.
8	2	2-Sep-92	Mole Creek, N. TAS	Sensation Gorge Scenery Reserve	DP	442	992	290	D'orazio, R.
70	6	7-Sep-92	Tasman Peninsula, S.E. TAS	Pirates Road, Taranna	EN	711	476	70	Kingston, T.J. & D'orazio, R.
32	3	7-Sep-92	Tasman Peninsula, S.E. TAS	Pirates Road, Taranna	EN	723	338	105	Kingston, T.J. & D'orazio, R.
38	5	7-Sep-92	Tasman Peninsula, S.E. TAS	Hylands Road	EN	752	450	120	Kingston, T.J. & D'orazio, R.
28	4	7-Sep-92	Tasman Peninsula, S.E. TAS	Lizard Hill	EN	756	418	230	Kingston, T.J. & D'orazio, R.
25	4	8-Sep-92	Tasman Peninsula, S.E. TAS	Mt Arthur	EN	654	204	375	Kingston, T.J. & D'orazio, R.
28	5	8-Sep-92	Tasman Peninsula, S.E. TAS	Long Bay Ck, Fortescue Road	EN	708	269	20	Kingston, T.J. & D'orazio, R.
26	4	8-Sep-92	Tasman Peninsula, S.E. TAS	Balts Road	EN	723	301	140	Kingston, T.J. & D'orazio, R.
40	2	8-Sep-92	Tasman Peninsula, S.E. TAS	Cape Pillar Track, Fortescue Road	EN	761	228	70	Kingston, T.J. & D'orazio, R.
33	4	9-Sep-92	Tasman Peninsula, S.E. TAS	Badger Ck	EN	587	310	190	Kingston, T.J. & D'orazio, R.
53	5	9-Sep-92	Tasman Peninsula, S.E. TAS	Benjafields Ridge	EN	607	228	260	Kingston, T.J. & D'orazio, R.

39	5	9-Sep-92	Tasman Peninsula, S.E. TAS	Koonya State Forest	EN	647	269	315	Kingston, T.J. & D'orazio, R.
9	2	15-Sep-92	Mole Creek, N. TAS	Marakoopa Cave S.R.	DP	405	967	500	D'orazio, R.
28	3	15-Sep-92	Chudleigh, N. TAS	Westmorland Falls Track	DP	493	922	460	D'orazio, R.
5	3	16-Sep-92	Mole Creek, N. TAS	Martha Ck, Mersey Forest Road	DP	352	922	400	D'orazio, R.
40	5	16-Sep-92	Mole Creek, N. TAS	Urks Loop, Mersey Forest Road	DP	367	975	560	D'orazio, R.
6	2	16-Sep-92	Mole Creek, N. TAS	King Solomons Cave S.R.	DP	373	993	420	D'orazio, R.
25	4	28-Sep-92	Bruny Island, North, S.E. TAS	Gravel Reserve No. 0133	EN	290	287	60	D'orazio, R. & Cooper, M.
24	4	28-Sep-92	Bruny Island, North, S.E. TAS	McCrackens Ck, Missionary Road	EN	294	244	20	D'orazio, R. & Cooper, M.
1	1	28-Sep-92	Bruny Island, North, S.E. TAS	Bruny Island Neck Game Reserve	EN	306	134	10	D'orazio, R. & Cooper, M.
12	2	29-Sep-92	Bruny Island, South, S.E. TAS	Goulds Ck, Conley Road	EM	198	997	150	D'orazio, R. & Cooper, M.
13	2	29-Sep-92	Bruny Island, South, S.E. TAS	Clennetts Road	EM	219	931	75	D'orazio, R. & Cooper, M.
24	3	29-Sep-92	Bruny Island, South, S.E. TAS	Saintys Ck, Coolangatta Road	EM	222	981	365	D'orazio, R. & Cooper, M.
18	2	29-Sep-92	Bruny Island, South, S.E. TAS	Staffords Road	EM	233	905	145	D'orazio, R. & Cooper, M.
26	3	29-Sep-92	Bruny Island, South, S.E. TAS	South Bruny Range	EM	251	909	350	D'orazio, R. & Cooper, M.
39	2	29-Sep-92	Bruny Island, South, S.E. TAS	Captain Cook Ck	EM	258	952	175	D'orazio, R. & Cooper, M.
37	4	30-Sep-92	Bruny Island, South, S.E. TAS	La Billiardiere S.R.	EM	142	866	90	D'orazio, R. & Cooper, M.
40	4	30-Sep-92	Bruny Island, South, S.E. TAS	Resolution Road	EN	241	012	125	D'orazio, R. & Cooper, M.
5	1	5-Oct-92	Mole Creek, N. TAS	Arm River F.R.	DP	332	839	460	D'orazio, R. & Cooper, M.
29	4	5-Oct-92	Mole Creek, N. TAS	Lake MacKenzie Road site 1	DP	362	942	540	D'orazio, R. & Cooper, M.
15	4	5-Oct-92	Mole Creek, N. TAS	Lake MacKenzie Road site 2	DP	373	924	700	D'orazio, R. & Cooper, M.
27	4	5-Oct-92	Mole Creek, N. TAS	Snake Ck Road	DP	391	895	590	D'orazio, R. & Cooper, M.
10	2	5-Oct-92	Mole Creek, N. TAS	Devils Gullet S.R.	DP	443	876	1140	D'orazio, R. & Cooper, M.
10	1	6-Oct-92	Lake Rowallen, N. TAS	Mersey White Water F.R.	DP	351	808	445	D'orazio, R. & Cooper, M.
3	1	6-Oct-92	Lake Rowallen, N. TAS	Dublin Road	DP	363	802	650	D'orazio, R. & Cooper, M.
10	1	6-Oct-92	Lake Rowallen, N. TAS	Fish River Road	DP	365	749	720	D'orazio, R. & Cooper, M.
11	4	6-Oct-92	Lake Rowallen, N. TAS	Dublin Road site 1	DP	381	825	590	D'orazio, R. & Cooper, M.
6	1	6-Oct-92	Lake Rowallen, N. TAS	Dublin Road site 2	DP	385	833	575	D'orazio, R. & Cooper, M.
26	3	6-Oct-92	Lake Rowallen, N. TAS	Little Fisher River Road	DP	419	824	650	D'orazio, R. & Cooper, M.
44	4	12-Oct-92	Geeveston, S.E. TAS	Peppers Road	DN	857	252	260	D'orazio, R. & Cooper, M.

34	3	12 -Oct- 92	Geeveston, S.E. TAS	Lidgerwood Ck	DN	871	272	190	D'orazio, R. & Cooper, M.
45	5	12 -Oct- 92	Geeveston, S.E. TAS	Bermuda Road	DN	913	329	520	D'orazio, R. & Cooper, M.
40	6	12 -Oct- 92	Geeveston, S.E. TAS	Bermuda Hill	DN	918	320	520	D'orazio, R. & Cooper, M.
30	5	13 -Oct- 92	Geeveston, S.E. TAS	South Weld F.R..	DN	722	366	270	D'orazio, R. & Cooper, M.
48	7	13 -Oct- 92	Geeveston, S.E. TAS	South Weld Road.	DN	755	347	235	D'orazio, R. & Cooper, M.
33	4	13 -Oct- 92	Geeveston, S.E. TAS	Picton River	DN	762	213	90	D'orazio, R. & Cooper, M.
52	7	13 -Oct- 92	Geeveston, S.E. TAS	Tahune F.R.	DN	778	286	60	D'orazio, R. & Cooper, M.
47	3	13 -Oct- 92	Geeveston, S.E. TAS	Edwards Road	DN	834	262	150	D'orazio, R. & Cooper, M.
21	3	14 -Oct- 92	Geeveston, S.E. TAS	Hartz Mountain National Park	DN	809	171	700	D'orazio, R. & Cooper, M.
13	3	14 -Oct- 92	Geeveston, S.E. TAS	Hartz Road	DN	812	169	680	D'orazio, R. & Cooper, M.
17	2	14 -Oct- 92	Geeveston, S.E. TAS	Keoghs Ck	DN	828	218	180	D'orazio, R. & Cooper, M.
21	3	14 -Oct- 92	Geeveston, S.E. TAS	Harveys Ck	DN	854	186	520	D'orazio, R. & Cooper, M.
14	3	19 -Oct- 92	Dover, S.E. TAS	Esperance River Road	DN	899	082	140	D'orazio, R. & Cooper, M.
20	4	19 -Oct- 92	Dover, S.E. TAS	Hermons Road	DN	902	128	550	D'orazio, R. & Cooper, M.
24	3	19 -Oct- 92	Dover, S.E. TAS	Riawunna Road	DN	906	162	225	D'orazio, R. & Cooper, M.
26	2	19 -Oct- 92	Dover, S.E. TAS	Esperance F.R.	DN	928	590	75	D'orazio, R. & Cooper, M.
27	3	20 -Oct- 92	Dover, S.E. TAS	Hastings Caves S.R.	DM	878	955	85	D'orazio, R. & Cooper, M.
11	2	20 -Oct- 92	Dover, S.E. TAS	South Lune Road	DM	888	897	80	D'orazio, R. & Cooper, M.
11	2	20 -Oct- 92	Dover, S.E. TAS	Ckton Road	DM	890	952	70	D'orazio, R. & Cooper, M.
34	4	20 -Oct- 92	Dover, S.E. TAS	Ckton Rivulet	DM	922	983	110	D'orazio, R. & Cooper, M.
18	4	20 -Oct- 92	Dover, S.E. TAS	Ckton Road	DN	938	008	155	D'orazio, R. & Cooper, M.
43	8	21 -Oct- 92	Dover, S.E. TAS	Stubbs Link Road	DN	962	077	155	D'orazio, R. & Cooper, M.
26	3	21 -Oct- 92	Dover, S.E. TAS	Wobbly Ck bridge	DN	963	116	200	D'orazio, R. & Cooper, M.
33	5	21 -Oct- 92	Dover, S.E. TAS	Hopetoun F.R.	DN	971	051	190	D'orazio, R. & Cooper, M.
25	2	31 -Oct- 92	Flinders Island, N.E. TAS	West End Road, Leeka	ER	677	837		Kingston, T.J. & M.E.
5	1	31 -Oct- 92	Flinders Island, N.E. TAS	West End Road, Leeka	ER	705	825		Kingston, T.J. & M.E.
3	1	1 -Nov- 92	Flinders Island, N.E. TAS	Big River					Kingston, T.J. & M.E.
6	2	1 -Nov- 92	Flinders Island, N.E. TAS	Mt. Strzelecki					Kingston, T.J. & M.E.
56	4	2 -Nov- 92	Flinders Island, N.E. TAS	Strzelecki National Park	ER	908	480		Kingston, T.J. & M.E.

16	2	2-Nov-92	Flinders Island, N.E. TAS	Mt. Strzelecki	ER	925	485		Kingston, T.J. & M.E.
4	1	2-Nov-92	Flinders Island, N.E. TAS	Mt. Strzelecki					Kingston, T.J. & M.E.
30	3	3-Nov-92	Flinders Island, N.E. TAS	Mt. Strzelecki	ER	899	488		Kingston, T.J. & M.E.
5	2	3-Nov-92	Flinders Island, N.E. TAS	Mt. Strzelecki					Kingston, T.J. & M.E.
16	3	4-Nov-92	Flinders Island, N.E. TAS	Brougham Sugarloaf	ER	666	845		Kingston, T.J. & M.E.
11	2	4-Nov-92	Flinders Island, N.E. TAS	Walkers Lookout	ER	918	653	350	Kingston, T.J. & M.E.
31	3	4-Nov-92	Flinders Island, N.E. TAS	Walkers Lookout	ER	921	653	410	Kingston, T.J. & M.E.
22	2	4-Nov-92	Flinders Island, N.E. TAS	Middle Patriarch	FR	014	730	120	Kingston, T.J. & M.E.
12	2	5-Nov-92	Flinders Island, N.E. TAS	5 mile Road	ER	848	830		Kingston, T.J. & M.E.
35	4	16-Nov-92	Judbury, S.E. TAS	Denison Road	DN	802	416	160	D'orazio, R. & Cooper, M.
26	5	16-Nov-92	Judbury, S.E. TAS	Link Road	DN	820	427	140	D'orazio, R. & Cooper, M.
14	4	16-Nov-92	Judbury, S.E. TAS	Russell Road site 1	DN	779	501	360	D'orazio, R. & Cooper, M.
13	2	16-Nov-92	Judbury, S.E. TAS	Russell Road site 2	DN	820	479	400	D'orazio, R. & Cooper, M.
15	2	17-Nov-92	Mt. Wellington, S.E. TAS	Big Bend Trail	EN	173	518	1090	D'orazio, R. & Cooper, M.
22	4	17-Nov-92	Mt. Wellington, S.E. TAS	Huon Rd	EN	185	445	420	D'orazio, R. & Cooper, M.
18	6	17-Nov-92	Mt. Wellington, S.E. TAS	Pinnacle Rd	EN	192	512	1030	D'orazio, R. & Cooper, M.
16	2	17-Nov-92	Mt. Wellington, S.E. TAS	Badfords Track	EN	199	485	700	D'orazio, R. & Cooper, M.
12	3	18-Nov-92	Glenorchy, S.E. TAS	Humphreys Track	EN	192	547	250	D'orazio, R. & Cooper, M.
15	3	18-Nov-92	Glenorchy, S.E. TAS	Lena Valley Road	EN	198	532	390	D'orazio, R. & Cooper, M.
11	3	18-Nov-92	Glenorchy, S.E. TAS	Water Reserve & Wildlife Sanctuary	EN	202	532	320	D'orazio, R. & Cooper, M.
3	2	18-Nov-92	Glenorchy, S.E. TAS	Tolosa Road, Tolosa Park	EN	206	537	200	D'orazio, R. & Cooper, M.
24	3	23-Nov-92	Mt. Roland, N.W. TAS	Cethana Road	DQ	284	087	360	D'orazio, R. & Gittus, M.
5	1	23-Nov-92	Mt. Roland, N.W. TAS	Track off O'Neils Road.	DQ	329	072	420	D'orazio, R. & Gittus, M.
18	3	23-Nov-92	Mt. Roland, N.W. TAS	O'Neils Road	DQ	353	081	410	D'orazio, R. & Gittus, M.
27	3	23-Nov-92	Mt. Roland, N.W. TAS	Claude Road	DQ	381	126	235	D'orazio, R. & Gittus, M.
23	3	23-Nov-92	Mt. Roland, N.W. TAS	Currawong Road	DQ	406	115	390	D'orazio, R. & Gittus, M.
32	6	24-Nov-92	Mt. Roland, N.W. TAS	Cockatoo Road	DQ	304	051	640	D'orazio, R. & Gittus, M.
30	4	24-Nov-92	Mt. Roland, N.W. TAS	Olivers Road	DQ	344	021	715	D'orazio, R. & Gittus, M.
10	3	24-Nov-92	Mt. Roland, N.W. TAS	Liena Road	DQ	389	004	455	D'orazio, R. & Gittus, M.

39	4	24-Nov- 92	Mt. Roland, N.W. TAS	Belstone Road	DQ	429	078	300	D'orazio, R. & Gittus, M.
38	4	24-Nov- 92	Mt. Roland, N.W. TAS	Union Bridge Road	DQ	446	088	240	D'orazio, R. & Gittus, M.
34	4	25-Nov- 92	Nietta, N.W. TAS	Jean Brook Reserve	DQ	193	116	575	D'orazio, R. & Gittus, M.
11	2	25-Nov- 92	Lake Barrington, N.W. TAS	Billet Ck Nature Walk.	DQ	325	133	370	D'orazio, R. & Gittus, M.
16	2	25-Nov- 92	Lower Barrington, N.W. TAS	Lake Paloona Rd	DQ	373	298	75	D'orazio, R. & Gittus, M.
1	1	19 -Apr- 93	Yolla, N.W. TAS	Blackwell Road site 1	CQ	785	351	250	D'orazio, R. & Soccol, D.
10	3	19 -Apr- 93	Yolla, N.W. TAS	Blackwell Road site 2	CQ	790	352	250	D'orazio, R. & Soccol, D.
3	1	19 -Apr- 93	Calder, N.W. TAS	West Calder Road	CQ	839	517	110	D'orazio, R. & Soccol, D.
10	3	19 -Apr- 93	Calder, N.W. TAS	Oldina F.R.	CQ	876	595	70	D'orazio, R. & Soccol, D.
10	3	19 -Apr- 93	Calder, N.W. TAS	Tram Road Picnic Area	CQ	892	572	34	D'orazio, R. & Soccol, D.
27	5	20 -Apr- 93	Trowutta, N.W. TAS	Milkshake F.R.	CQ	462	483	160	D'orazio, R. & Soccol, D.
18	4	20 -Apr- 93	Trowutta, N.W. TAS	Tayatea Road	CQ	481	535	95	D'orazio, R. & Soccol, D.
27	3	20 -Apr- 93	Mawbanna, N.W. TAS	Dip Road	CQ	576	661	70	D'orazio, R. & Soccol, D.
22	5	20 -Apr- 93	Lileah, N.W. TAS	Daisies Road	CQ	624	545	120	D'orazio, R. & Soccol, D.
20	2	20 -Apr- 93	Mawbanna, N.W. TAS	Newhaven Road site 1	CQ	655	603	150	D'orazio, R. & Soccol, D.
6	1	20 -Apr- 93	Mawbanna, N.W. TAS	Newhaven Road site 2	CQ	692	614	200	D'orazio, R. & Soccol, D.
15	4	20 -Apr- 93	Mawbanna, N.W. TAS	Newhaven Road site 3	CQ	706	632	90	D'orazio, R. & Soccol, D.
30	4	21 -Apr- 93	Sisters Beach, N.W. TAS	Rocky Cape National Park site 1	CQ	792	684	30	D'orazio, R. & Soccol, D.
4	1	21 -Apr- 93	Sisters Beach, N.W. TAS	Rocky Cape National Park site 2	CQ	802	679	50	D'orazio, R. & Soccol, D.
0	0	17-May- 93	Smithton, N.W. TAS	Bass Highway	CQ	144	641	40	D'orazio, R. & Soccol, D.
22	5	17-May- 93	Roger River, N.W. TAS	Salmon River Road, Salmon River	CQ	199	534	50	D'orazio, R. & Soccol, D.
45	5	17-May- 93	Roger River, N.W. TAS	Roger River F.R.	CQ	331	524	50	D'orazio, R. & Soccol, D.
24	6	17-May- 93	Trowutta, N.W. TAS	Trowutta Caves S.R.	CQ	408	513	190	D'orazio, R. & Soccol, D.
18	5	18-May- 93	Balfour, N.W. TAS	Balfour Track F.R.	CQ	279	439	50	D'orazio, R. & Soccol, D.
32	4	18-May- 93	Roger River, N.W. TAS	Horton River, Sumac Road.	CQ	345	324	190	D'orazio, R. & Soccol, D.
16	2	18-May- 93	Roger River, N.W. TAS	Julius River F.R.	CQ	345	421	110	D'orazio, R. & Soccol, D.
18	3	18-May- 93	Roger River, N.W. TAS	Lake Chisholm F.R.	CQ	373	444	120	D'orazio, R. & Soccol, D.
12	2	18-May- 93	Roger River, N.W. TAS	Horton River	CQ	401	251	230	D'orazio, R. & Soccol, D.
21	2	18-May- 93	Roger River, N.W. TAS	Wes Beckett F.R.	CQ	433	386	180	D'orazio, R. & Soccol, D.

6	1	19 May- 93	Marrawah, N.W. TAS	West Point	CQ	024	566	30	D'orazio, R. & Soccol, D.
15	3	19 May- 93	Temma, N.W. TAS	Heemskirk Road	CQ	125	372	100	D'orazio, R. & Soccol, D.
34	4	19 May- 93	Marrawah, N.W. TAS	Dismal Swamp Reserve road	CQ	193	626	60	D'orazio, R. & Soccol, D.
15	2	19 May- 93	Temma, N.W. TAS	Blackwater Road	CQ	227	384	90	D'orazio, R. & Soccol, D.
1	1	31 May- 93	Waratah, N.W. TAS	Jasper Hill Track	CQ	605	058	210	D'orazio, R. & Soccol, D.
20	1	31 May- 93	Waratah, N.W. TAS	Mount Cleveland Road	CQ	618	109	210	D'orazio, R. & Soccol, D.
1	1	31 May- 93	Waratah, N.W. TAS	Wallaby Ck Road	CQ	721	054	685	D'orazio, R. & Soccol, D.
25	4	31 May- 93	Waratah, N.W. TAS	Belmont Road	CQ	769	174	390	D'orazio, R. & Soccol, D.
15	3	31 May- 93	Hellyer Gorge Reserve, N.W. TAS	Hellyer Gorge	CQ	836	294	310	D'orazio, R. & Soccol, D.
4	1	1 -Jun- 93	Tullah, N.W. TAS	Lower Pieman Road site 1	CP	577	814	230	D'orazio, R. & Soccol, D.
6	3	1 -Jun- 93	Tullah, N.W. TAS	Lower Pieman Road site 2	CP	592	809	200	D'orazio, R. & Soccol, D.
33	6	1 -Jun- 93	Tullah, N.W. TAS	Lower Pieman Road site 3	CP	623	809	170	D'orazio, R. & Soccol, D.
41	4	1 -Jun- 93	Tullah, N.W. TAS	Lower Pieman Road site 4	CP	643	814	170	D'orazio, R. & Soccol, D.
21	5	1 -Jun- 93	Tullah, N.W. TAS	Lower Pieman Road site 5	CP	703	785	160	D'orazio, R. & Soccol, D.
33	3	2 -Jun- 93	Corinna, W. TAS	Pieman River S.R.	CP	403	875	40	D'orazio, R. & Soccol, D.
37	3	2 -Jun- 93	Corinna, W. TAS	Little Hunter Ck	CP	445	910	200	D'orazio, R. & Soccol, D.
24	3	2 -Jun- 93	Corinna, W. TAS	Timbs Ck	CP	450	911	200	D'orazio, R. & Soccol, D.
25	5	15 -Jun- 93	Cradle Mountain, N.W. TAS	Southwell River Road	CP	970	989	610	D'orazio, R. & Soccol, D.
34	4	15 -Jun- 93	Cradle Mountain, N.W. TAS	Etchells Ck	DP	069	981	910	D'orazio, R. & Soccol, D.
15	4	15 -Jun- 93	Cradle Mountain, N.W. TAS	Dove River Road	DP	169	959	680	D'orazio, R. & Soccol, D.
27	9	16 -Jun- 93	Cradle Mountain, N.W. TAS	Murchison Highway S.R..	CP	901	976	680	D'orazio, R. & Soccol, D.
31	5	16 -Jun- 93	Cradle Mountain, N.W. TAS	Cradle Mountain road	CP	949	986	670	D'orazio, R. & Soccol, D.
14	1	16 -Jun- 93	Cradle Mountain, N.W. TAS	Beecroft Road	CQ	995	034	680	D'orazio, R. & Soccol, D.
4	2	26 -Jul- 93	Zeehan, W. TAS	Zeehan Highway	CP	675	598	160	D'orazio, R. & Soccol, D.
9	4	26 -Jul- 93	Zeehan, W. TAS	Anthony Road site 1	CP	771	505	380	D'orazio, R. & Soccol, D.
3	3	26 -Jul- 93	Zeehan, W. TAS	Anthony Road site 2	CP	839	609	530	D'orazio, R. & Soccol, D.
25	4	26 -Jul- 93	Zeehan, W. TAS	Anthony Road site 3	CP	854	671	580	D'orazio, R. & Soccol, D.
21	6	26 -Jul- 93	Zeehan, W. TAS	Anthony Road site 4	CP	861	731	400	D'orazio, R. & Soccol, D.
21	5	27 -Jul- 93	Zeehan, W. TAS	Granville Harbour	CP	379	689	40	D'orazio, R. & Soccol, D.

28	5	27 -Jul- 93	Zeehan, W. TAS	Heemskirk Road site 1	CP	523	689	170	D'orazio, R. & Soccol, D.
17	5	27 -Jul- 93	Zeehan, W. TAS	Heemskirk Road site 2	CP	568	669	185	D'orazio, R. & Soccol, D.
20	4	27 -Jul- 93	Zeehan, W. TAS	Heemskirk Road site 3	CP	601	634	210	D'orazio, R. & Soccol, D.
30	5	27 -Jul- 93	Zeehan, W. TAS	Henty Road site 1	CP	620	494	80	D'orazio, R. & Soccol, D.
1	1	27 -Jul- 93	Zeehan, W. TAS	Henty Road site 2	CP	630	585	140	D'orazio, R. & Soccol, D.
53	8	28 -Jul- 93	Zeehan, W. TAS	Henty Road site 3	CP	561	460	50	D'orazio, R. & Soccol, D.
10	3	27 -Jul- 93	Zeehan, W. TAS	Little Henty River	CP	641	549	140	D'orazio, R. & Soccol, D.
7	1	28 -Jul- 93	Zeehan, W. TAS	Trial Harbour Road site 1	CP	536	592	225	D'orazio, R. & Soccol, D.
52	8	28 -Jul- 93	Zeehan, W. TAS	Trial Harbour Road site 2	CP	593	616	220	D'orazio, R. & Soccol, D.
3	3	9 -Aug- 93	Queenstown, W. TAS	Lyell Highway site 1	CP	735	324	220	D'orazio, R. & Soccol, D.
42	6	9 -Aug- 93	Queenstown, W. TAS	Lyell Highway site 2	CP	748	336	340	D'orazio, R. & Soccol, D.
20	2	9 -Aug- 93	Queenstown, W. TAS	Lyell Highway site 3	CP	754	376	300	D'orazio, R. & Soccol, D.
37	4	9 -Aug- 93	Queenstown, W. TAS	Lake Margaret Rd	CP	795	456	360	D'orazio, R. & Soccol, D.
18	4	10 -Aug- 93	Queenstown, W. TAS	Kelly Basin Road site 1	CP	853	156	220	D'orazio, R. & Soccol, D.
34	8	10 -Aug- 93	Queenstown, W. TAS	Kelly Basin Road site 2	CP	860	213	200	D'orazio, R. & Soccol, D.
9	4	10 -Aug- 93	Queenstown, W. TAS	Kelly Basin Road site 3	CP	900	083	420	D'orazio, R. & Soccol, D.
25	7	10 -Aug- 93	Queenstown, W. TAS	King River	CP	787	315	35	D'orazio, R. & Soccol, D.
11	5	10 -Aug- 93	Queenstown, W. TAS	Mount Jukes Road site 1	CP	838	306	625	D'orazio, R. & Soccol, D.
14	5	10 -Aug- 93	Queenstown, W. TAS	Mount Jukes Road site 2	CP	857	255	260	D'orazio, R. & Soccol, D.
11	7	11 -Aug- 93	Queenstown, W. TAS	Lyell Highway	CP	895	406	235	D'orazio, R. & Soccol, D.
19	4	11 -Aug- 93	Queenstown, W. TAS	Nelson River	CP	954	377	330	D'orazio, R. & Soccol, D.
8	2	11 -Aug- 93	Derwent Bridge, Central Plateau, TAS	Collingwood River	DP	113	314	340	D'orazio, R. & Soccol, D.
5	3	11 -Aug- 93	Mt. Arrowsmith, W. TAS	Franklin River	DP	188	257	395	D'orazio, R. & Soccol, D.
2	1	11 -Aug- 93	Derwent Bridge, Central Plateau, TAS	Little Navare River	DP	303	295	820	D'orazio, R. & Soccol, D.
11	1	11 -Aug- 93	Miena, Central Plateau, TAS	Tods Corner	DP	821	559	1060	D'orazio, R. & Soccol, D.
20	4	11 -Oct- 93	Maydena, S.E. TAS	Styx Road site 1	DN	686	592	325	D'orazio, R. & Soccol, D.
38	8	11 -Oct- 93	Maydena, S.E. TAS	Styx Road site 2	DN	751	611	340	D'orazio, R. & Soccol, D.
33	4	11 -Oct- 93	Uxbridge, S.E. TAS	Styx Road site 3	DN	812	637	250	D'orazio, R. & Soccol, D.
21	7	11 -Oct- 93	Uxbridge, S.E. TAS	Styx Road site 4	DN	834	668	240	D'orazio, R. & Soccol, D.

24	4	11 -Oct- 93	Uxbridge, S.E. TAS	Plenty Valley Road	DN	885	549	470	D'orazio, R. & Soccol, D.
17	5	12 -Oct- 93	Mt. Wedge, S.W. TAS	Scotts Peak Road	DN	428	344	260	D'orazio, R. & Soccol, D.
23	6	12 -Oct- 93	Mt. Wedge, S.W. TAS	Scotts Peak Road	DN	482	413	320	D'orazio, R. & Soccol, D.
1	1	12 -Oct- 93	Mt. Wedge, S.W. TAS	Scotts Peak Road	DN	491	526	360	D'orazio, R. & Soccol, D.
15	3	12 -Oct- 93	Maydena, S.E. TAS	Scotts Peak Road	DN	496	575	570	D'orazio, R. & Soccol, D.
9	3	12 -Oct- 93	Maydena, S.E. TAS	Mueller Road	DN	532	598	540	D'orazio, R. & Soccol, D.
15	5	12 -Oct- 93	Maydena, S.E. TAS	Mueller Road	DN	584	606	520	D'orazio, R. & Soccol, D.
24	7	12 -Oct- 93	Maydena, S.E. TAS	Mueller Road	DN	625	610	520	D'orazio, R. & Soccol, D.
25	4	12 -Oct- 93	Maydena, S.E. TAS	Styx Road	DN	656	624	540	D'orazio, R. & Soccol, D.
9	2	13 -Oct- 93	Mt. Field National Park, S.E. TAS		DN	663	738	1070	D'orazio, R. & Soccol, D.
4	1	13 -Oct- 93	Mt. Field National Park, S.E. TAS		DN	694	746	990	D'orazio, R. & Soccol, D.
1	1	13 -Oct- 93	Mt. Field National Park, S.E. TAS		DN	733	743	620	D'orazio, R. & Soccol, D.
29	3	13 -Oct- 93	Mt. Field National Park, S.E. TAS		DN	751	744	280	D'orazio, R. & Soccol, D.
28	6	13 -Oct- 93	Mt. Field National Park, S.E. TAS		DN	764	747	200	D'orazio, R. & Soccol, D.
17	5	16 -Oct- 93	Birch Inlet, W. TAS	Birch Inlet	CN	753	878	10	Griffith, J. K. & Swiatkowski, P.
10	3	19 -Oct- 93	Avoca, E. TAS	Buffalo Brook	EP	488	788	360	Kingston, T.J. & D'orazio, R.
21	4	19 -Oct- 93	Avoca, E. TAS	Buffalo Brook	EP	492	791	320	Kingston, T.J. & D'orazio, R.
27	2	20 -Oct- 93	Epping Forest, N. TAS	Mount Joy Road	EP	185	724	160	Kingston, T.J. & D'orazio, R.
1	1	9 -Nov- 93	Avoca, E. TAS	Milford Road	EP	467	735	265	D'orazio, R.
5	3	9 -Nov- 93	Avoca, E. TAS	Milford Road	EP	477	744	390	D'orazio, R.
1	1	9 -Nov- 93	Avoca, E. TAS	Milford Road	EP	735	467	265	D'orazio, R.
11	1	23 -Nov- 93	Blackmans Lagoon, N.E. TAS	Blackmans lagoon	EQ	498	704	20	Kingston, T.J. & Griffith, J.
15	1	23 -Nov- 93	Waterhouse, N.E. TAS	Marys Puddle	EQ	535	784	20	Kingston, T.J. & Griffith, J.
14	3	11 -Jan- 94	Winnaleah, N.E. TAS	Banca Road	EQ	670	595	180	D'orazio, R. & Soccol, D.
8	3	11 -Jan- 94	Winnaleah, N.E. TAS	Banca Road	EQ	684	632	40	D'orazio, R. & Soccol, D.
12	2	11 -Jan- 94	Winnaleah, N.E. TAS	Banca Road	EQ	689	573	110	D'orazio, R. & Soccol, D.
13	2	11 -Jan- 94	Waterhouse, N.E. TAS	Waterhouse Road	EQ	724	693	20	D'orazio, R. & Soccol, D.
6	1	11 -Jan- 94	Waterhouse, N.E. TAS	Waterhouse Road	EQ	838	649	40	D'orazio, R. & Soccol, D.
17	3	11 -Jan- 94	Gladstone, N.E. TAS	Browns Bridge Rd	EQ	871	664	60	D'orazio, R. & Soccol, D.

3	1	12 -Jan- 94	Gladstone, N.E. TAS	Eddystone Road	EQ	970	636	40	D'orazio, R. & Soccol, D.
13	1	12 -Jan- 94	Gladstone, N.E. TAS	Eddystone Road	EQ	981	590	40	D'orazio, R. & Soccol, D.
5	1	12 -Jan- 94	Gladstone, N.E. TAS	Mt. William National Park	FQ	002	726	40	D'orazio, R. & Soccol, D.
2	1	12 -Jan- 94	Gladstone, N.E. TAS	Mt. William National Park	FQ	015	728	40	D'orazio, R. & Soccol, D.
7	2	12 -Jan- 94	Gladstone, N.E. TAS	Mt. William National Park	FQ	029	739	10	D'orazio, R. & Soccol, D.
12	2	12 -Jan- 94	Ansons Bay, N.E. TAS	Ansons River Reserve	FQ	034	541	40	D'orazio, R. & Soccol, D.
1	1	12 -Jan- 94	Ansons Bay, N.E. TAS	Eddystone Road	FQ	044	582	80	D'orazio, R. & Soccol, D.
3	1	12 -Jan- 94	Ansons Bay, N.E. TAS	Eddystone Road	FQ	098	598	40	D'orazio, R. & Soccol, D.
3	1	12 -Jan- 94	Ansons Bay, N.E. TAS	Eddystone Road	FQ	108	602	10	D'orazio, R. & Soccol, D.
3	2	19 -Jan- 94	Upper Castra, N.W. TAS	White Rock Road	DQ	216	234	470	D'orazio, R. & Soccol, D.
27	5	19 -Jan- 94	Upper Castra, N.W. TAS	Gaunts Road	DQ	228	213	485	D'orazio, R. & Soccol, D.
14	4	19 -Jan- 94	Upper Castra, N.W. TAS	Flints Road	DQ	228	224	480	D'orazio, R. & Soccol, D.
10	1	19 -Jan- 94	Upper Castra, N.W. TAS	Brambles Road	DQ	292	276	340	D'orazio, R. & Soccol, D.
22	3	19 -Jan- 94	Upper Castra, N.W. TAS	Chilcotts Road	DQ	304	274	285	D'orazio, R. & Soccol, D.
4	1	19 -Jan- 94	Upper Castra, N.W. TAS	Swamp Road	DQ	306	295	200	D'orazio, R. & Soccol, D.
4	1	19 -Jan- 94	Upper Castra, N.W. TAS	Chilcotts Road	DQ	316	266	240	D'orazio, R. & Soccol, D.
5	2	20 -Jan- 94	Ferndene, N.W. TAS	Ferndene	DQ	183	377	380	D'orazio, R. & Soccol, D.
13	5	20 -Jan- 94	Penguin, N.W. TAS	Penguin	DQ	188	445	75	D'orazio, R. & Soccol, D.
10	5	20 -Jan- 94	Penguin, N.W. TAS	Penguin	DQ	206	416	50	D'orazio, R. & Soccol, D.
1	1	20 -Jan- 94	Penguin, N.W. TAS	Penguin	DQ	208	458	160	D'orazio, R. & Soccol, D.
2	1	20 -Jan- 94	Penguin, N.W. TAS	Mt. Montgomery S.R.	DQ	212	451	130	D'orazio, R. & Soccol, D.
15	3	20 -Jan- 94	Penguin, N.W. TAS	Dial Road	DQ	216	432	145	D'orazio, R. & Soccol, D.

What were the outputs of the project?

A high quality comprehensive and representative collection of Tasmanian earthworms, sorted to 'morphospecies'

During the course of the NEGP funded study an additional 340 widely ranging sites were visited specifically to survey earthworms. All sites visited by the author and associates at the Queen Victoria Museum during the period 1990 to 1995 are shown on an outline map of Tasmania (Figure 1). Details for each of the additional 340 sites, including date, grid reference, altitude, the collectors and the number of both specimens and morphospecies retained, are given in Table 4.

Some statistics for the four collection categories previously summarised (Tables 1-4) are presented in Table 5. These include the mean number of specimens collected at sites, mean number of specimens per specimen lot (a specimen lot refers to all the specimens of a given morphospecies at a given site), the mean number of specimens per morphospecies and the mean number of morphospecies per site. (A morphospecies is a readily distinguishable variety that has not yet been subjected to the formal taxonomic process required to determine whether it is a truly distinct species.)
Comparison of the summary of collections by the present author (Tables 3 and 4) with those of previous collections (Tables 1 and 2) reveals that the present study was more extensive and intensive, resulting in a 10-fold increase in the number of specimens available for study and a 5-fold increase in the number of sites (Table 5). However, even these figures fail to tell the full story of the improved situation with respect to Tasmanian earthworm collections. Other respects in which the quality of the collections in the present study greatly surpass those of preceding ones include:

- Systematic planning of the sampling programme to ensure the most comprehensive coverage of Tasmania, including Flinders, Maria and Bruny Islands, and to avoid duplication of sampling (Figure 1).

- Application of extensive previous sampling experience led to the formation of an efficient 'search image' for earthworms, and to knowledge of where best to locate specimens and how to extract deep-burrowing species without damage.

- Strategic collecting, whereby specimens of the same species as already collected were discarded, and the discipline to move on to a new habitat in a timely fashion, prevented collections from being dominated by a large number of specimens of one or two common species. (Acknowledgement that this technique was employed requires that the proportions of species in the collections be taken as an approximate, rather than absolute, reflection of relative abundance of species in the field.)

Figure 1 Distribution of survey sites by the author and associates 1990-94

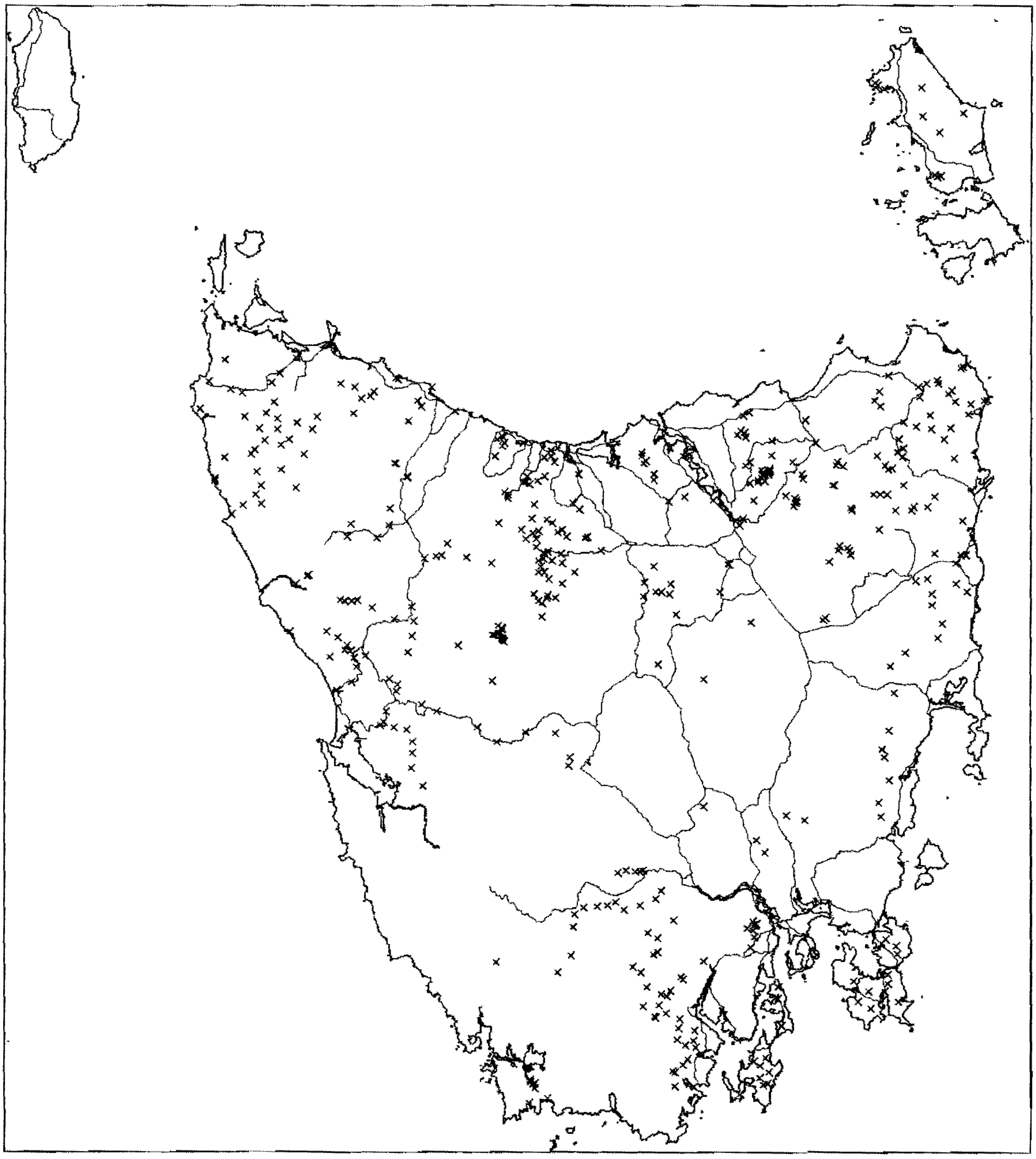


TABLE 5 Summary of statistics for earthworm collections since 1930

Notes: Includes specimens from targetted collecting of earthworms or ground invertebrates only

[1] A "specimen lot" comprises the specimens collected at a single locality that belong to the same species
[2] Species not re-collected since 1930 are excluded
[3] "Species" in this study refers to a morphospecies, ie a recognisably distinctive variety

collections	sites	specimens	specimen lots[1]	species	specimens / site	specimens / lot	specimens / species	species / site
Collections from 1930 - 1971 included in Jamieson (1974)[2]	63	396	107	34	6.3	3.7	11.6	1.7
Collection of Jamieson and Walker in 1972	23	399	36	19[3]	17.3	11.1	21.0	1.6
Collections by Kingston and associates at QVM 1990-92	64	951	170	56[3]	14.9	5.6	17.0	2.7
Collections under present study	340	6821	1089	213[3]	20.1	6.3	32.0	3.2
Combined studies	**490**	**8567**	**1402**					

- Standardisation of total sampling effort at each site at 2 man-hours throughout the survey, as well as of the techniques described above, ensured that the overall number of specimens and number of species collected at a site provided an accurate reflection of its true relative abundance and diversity. Such relative abundance between sites cannot be inferred for any previous studies of Tasmanian earthworms.

- The quality of georeferencing of the collections, although not obtained through GPS, was nevertheless accurate to within 100m in most cases and thus superior to previous studies. This was achieved through the consistent use of the 1:25 000 map series to identify geographic features and the survey vehicle odometer that was readable to 50m accuracy. In contrast, early collections were referenced (or retrospectively judged) either to the nearest 5 minutes (records in Jamieson 1974) or I minute (Jamieson and Walker collections) of latitude and longitude, representing a fixing accuracy of about 8km and 1.5km respectively. Greater accuracy clearly has benefits in that it allows uncommon species to be re-collected if necessary and the determination of distribution in relation to Reserve boundaries where a species is found to be rare. Such accurate determination of a sampling location has the added benefit that the altitude of the site can be determined from the map with a consistently high level of accuracy, information that will eventually have potential value in defining the ecological envelope occupied by each species.

- The best information available on the chemical fixing and preservation of earthworm specimens was extracted from the literature and used in the survey. Given that preservation is most efficiently conducted in the laboratory setting, the use of moist sphagnum moss in large, well aerated, plastic containers was adopted as a superior method for storage in the field and, in conjunction with a good quality insulated box or 'esky', for transport back to base. This system had a very significant advantage in that if a single damaged worm died and decomposed in the jar the resulting ordure was absorbed by the sphagnum and did not cause the death of the entire batch. 'Best practice' fixation of specimens was extended through a new technique, developed by the author, whereby specimens are anaesthetised in 10% ethanol and then suspended on a thread into the formalin fixation bath. This ensures that the specimens are preserved elongated, rather than coiled, and makes later microscopic examination and dissection a more tractable process. Few of the early collections were apparently fixed at all and many are now in poor condition as a consequence, whereas the author's collections would be expected to show negligible deterioration over decades.

The mean number of specimens collected from each site (6.3) was especially low for the 1938 to 1971 collections, reflecting the fact that many of the earlier collections were opportunistic rather than based on survey. This highlights the limitation of the collections upon which Jamieson (1974) was based. The mean figure of 20.1 specimens per site in the present study was achieved through spending 2 man-hours of effort at each site. The results suggest that this collecting effort would be a good benchmark for future earthworm surveys .

The number of morphospecies found at a site varied in the present study from zero to nine (Figure 2), with the great majority of sites (76%) returning from one to four. Nine were found at two sites in the NEGP study and at one site in 1990 by Bob Mesibov. Eight morphospecies were found at seven sites in the present study. The greatest number of (true) species found at a site in the early collecting was 5 by John Hickman at Fern Glade, Burnie (Table 1); while Jamieson and Walker collected more than 2 species from only 2 sites, including their maximum of 7 at one site near Waratah (Table 2). The mean of 3.2 morphospecies per site in this study (Table 5) is double the number of species of the early collectors. This is a result partly due to a greater search effort at each site and partly to the strategic collecting method, looking in all available micro-habitats at each site, together with perhaps a willingness to dig more deeply in the soil than less focused collectors. The majority of the sites at which no native morphospecies were recovered were instead populated by exotic species, notably the European Lumbricidae family. These were all sites that were on the margins of agricultural land or land that was incompletely cleared of native vegetation. They were sampled to check for persisting native species. Two groups of commonly occurring lumbricids, categorised as morphospecies 36 and 44, are included among the sketches and distribution maps in Volume 2. However, no records of species known to be introduced into Tasmania are included in the Tables and summary statistics.

The number of specimens per morphospecies varied greatly in the present study (Figure 3), from ten that were represented by just a single specimen each, to one, *Megascolex montisarthuri,* for which 698 specimens were gathered from 59 sites. The mean number, 32 specimens per site, was much higher in the present study than any of the previous ones, despite the far greater number of species and despite the discarding of multiple specimens of one or two abundant species at many sites. The reason for the high number is the relatively much higher intensity of the sampling; resulting in many morphospecies being collected at multiple sites.

A fourth statistic, the number of sites occupied by each morphospecies varied between one and 59 sites (Figure 4). 50 morphospecies were found only at a single site, while the most wide-ranging species (*Megascolex montisarthuri* again) was found at the maximum number of 59 sites.

A set of sketches of the external secondary sexual characters of about 212 morphospecies

All of the specimens collected were examined and, if not previously encountered, a sketch was drawn of the arrangement of the secondary sexual characters or "genital field". This arrangement, together with features such as size, colour of pigmentation and body proportions were used to sort specimens to the distinct categories referred to as 'morphospecies'. Copies of all of these

Figure 2 Frequency distribution of the number of earthworm morphospecies found at each site

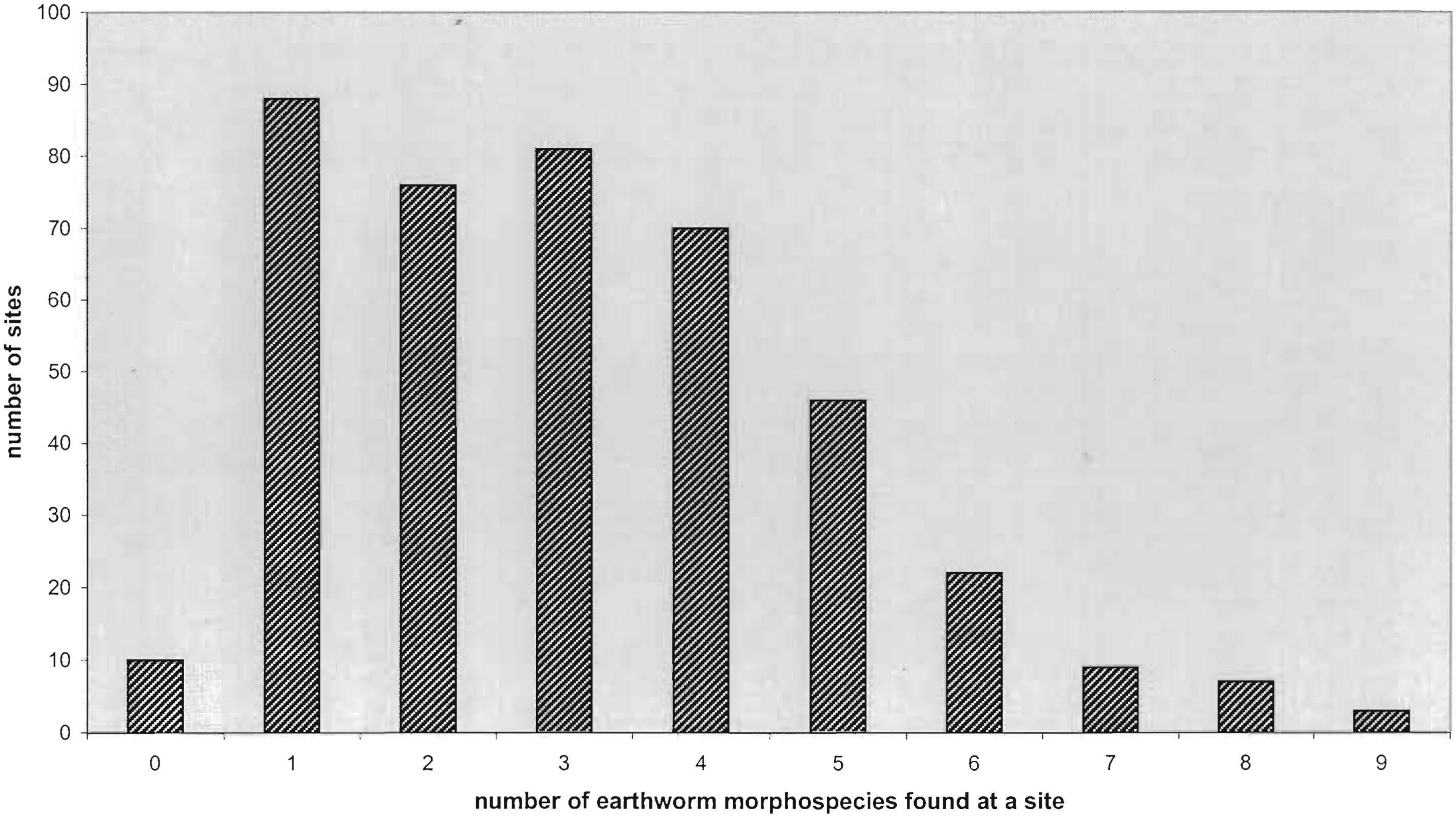


Figure 3 Frequency distribution of the number of specimens collected of each morphospecies

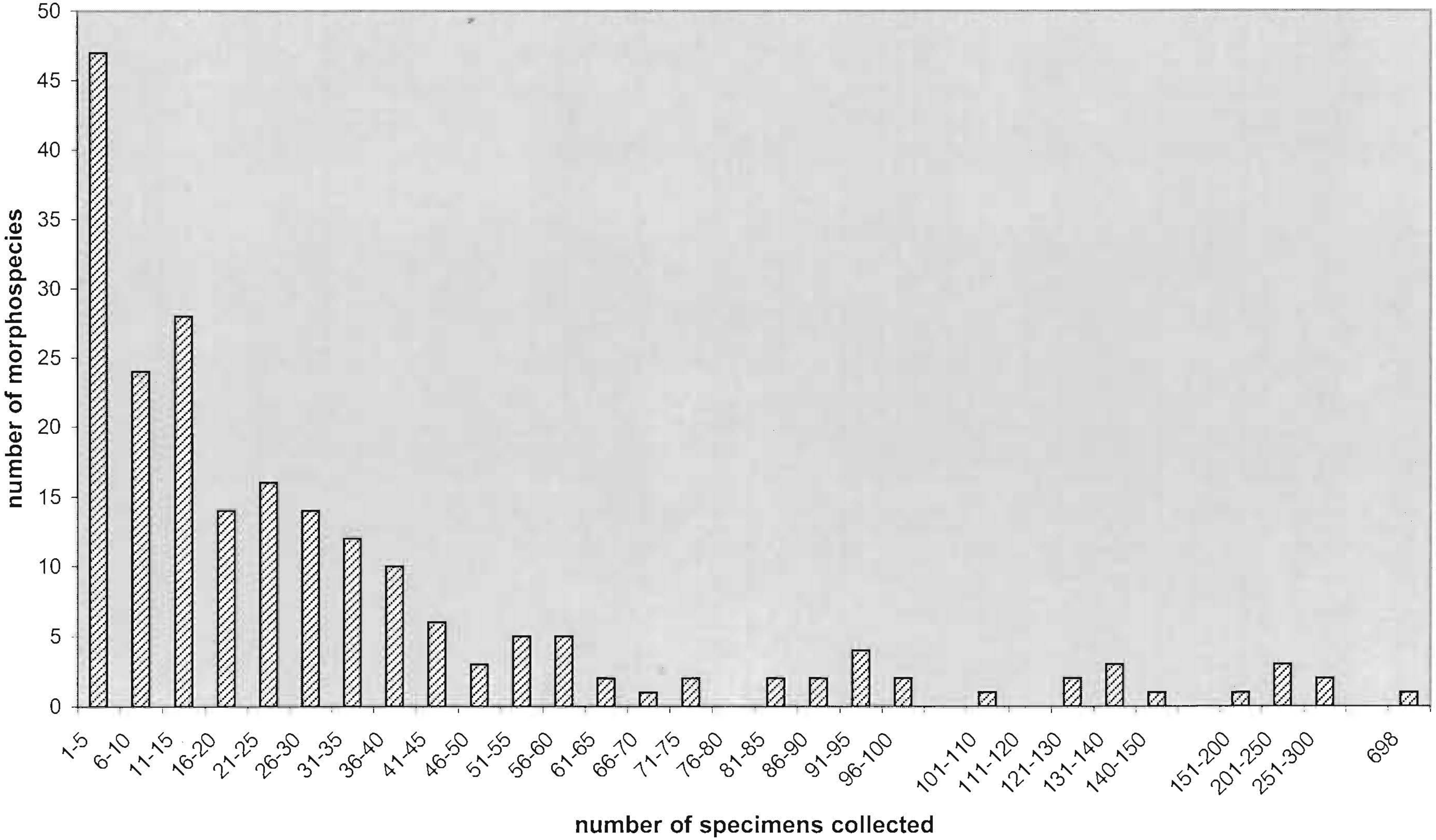
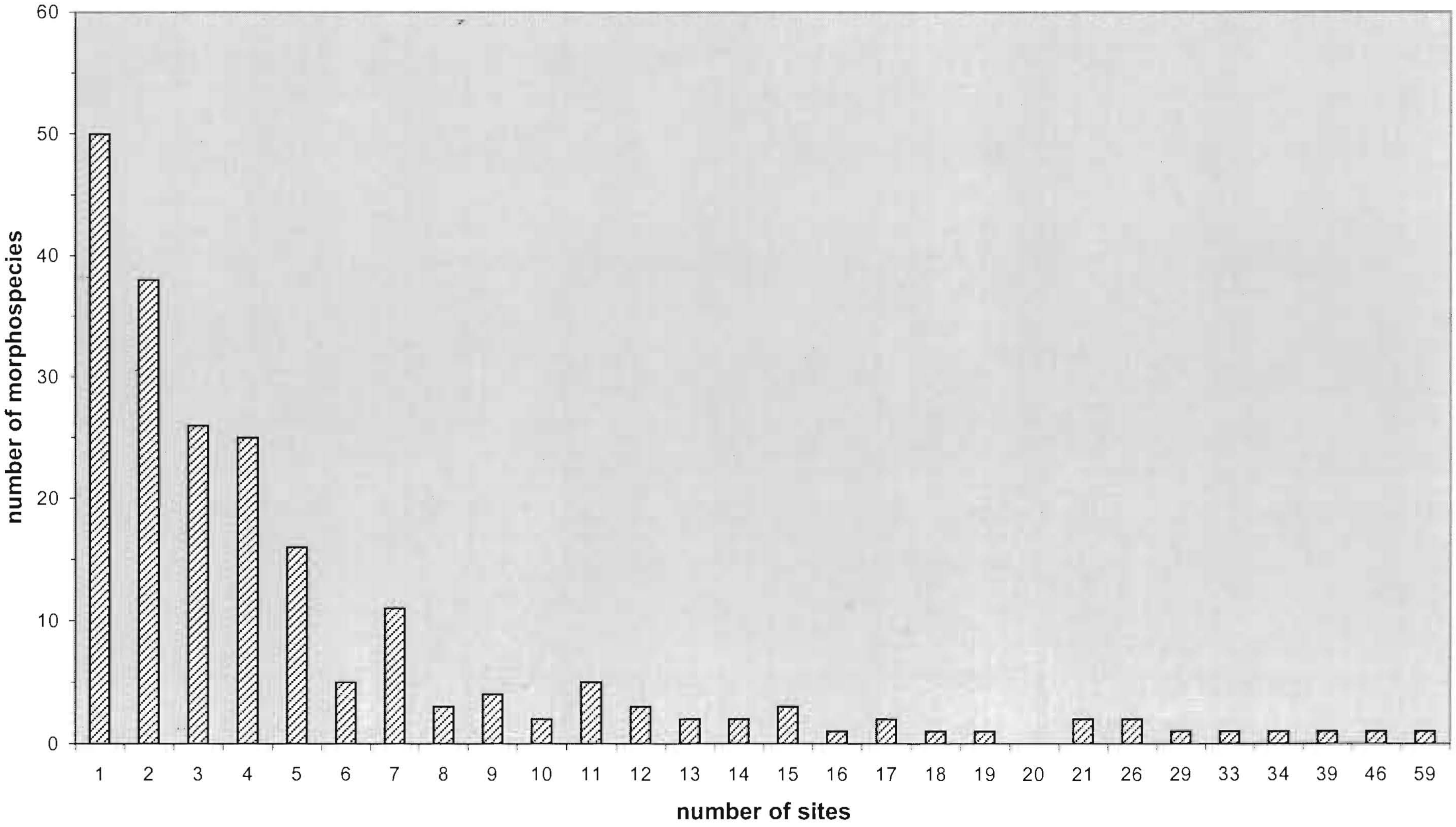


Figure 4 Frequency distribution of the number of sites at which morphospecies were found



sketches are included in Volume II of this report. Although these sketches proved invaluable in sorting specimens to morphospecies, these categories must be seen only as provisional ones requiring confirmation through dissection and description of internal organs.

Distribution maps for the defined morpho-species

Once all of the collected specimens had been sorted to morpho-species and the records collated, the distribution of each was plotted on an outline map of Tasmania using the computer software package IDRISI. A copy of the map for each morpho-species is included in Volume II of this report, alongside the sketch of the same morphospecies. These maps, once revised to take account of changes to morphospecies categories required by taxonomic study, will form the basis of a planned publication "Atlas of Tasmanian Earthworms".

Information on the relationship between earthworms and soil profile

During the course of the present study the author became aware that Mr Mike Laffan, a soil scientist working with Forestry Tasmania, was conducting research into soil profiles in northeast Tasmania. Mr Laffan's observations of the co-occurrence of deep-burrowing earthworms and soil profiles that exhibited much mixing of different sized particles had led him to the hypothesis that earthworms are important, certainly in maintaining, if not in actually forming these profiles. The opportunity was taken to synchronise our studies at some common sites and to attempt to examine quantitatively the relationship between soil profile type and earthworm species composition and abundance. Such a relationship was indeed demonstrated and documented by Laffan and Kingston (1997). A copy of this paper is appended to Volume I of this report.

A new estimate of the number of earthworm morphospecies present in Tasmania

As mentioned earlier in this report, the number of described species known from Tasmania prior to this study was 46. Of these, 26 were recognised among the collections made in the course of the present study. In addition to these named species a further 186 morphospecies were defined on the basis of external characters alone. The dissection and taxonomic study of these varieties was beyond the scope of the NEGP-funded component of the author's studies and thus there remains some uncertainty as to the actual number of species that will eventually be determined from these collections. Undoubtedly in some cases two or more morphospecies will be found to be merely variations of a single true species, equally probably some morphospecies will be found to separate out into two or more distinct species once internal morphology is examined. Currently however, the best possible estimate of the total number of 'species' of Tasmanian native earthworms is 232, made up of the following:

- Species previously recorded for the state as included in the catalogue of Jamieson (1974), but not collected in the present study. (approx. 20 taxa)

- Taxa previously recorded for the state and included in the list of Jamieson (1974), and collected again during the present study. (approximately 26 taxa)

- Taxa recorded for the first time during the present study (approximately 186 morphospecies)

The overall estimate for the number of morphospecies calculated from these figures will clearly depend upon how one deals with the 20 "uncollected' taxa of Jamieson (1974). Many of these were described from very few specimens, were only sparsely described and the specimens have not survived. Others have probably been collected in the present study but different preservation techniques may have resulted in apparent differences in external morphology. For these reasons, and to avoid exaggerating the total number of morphospecies, these 20 are assumed to be represented but undetected within the collections accumulated in the current study. On this basis the currently known number of morphospecies is 212.

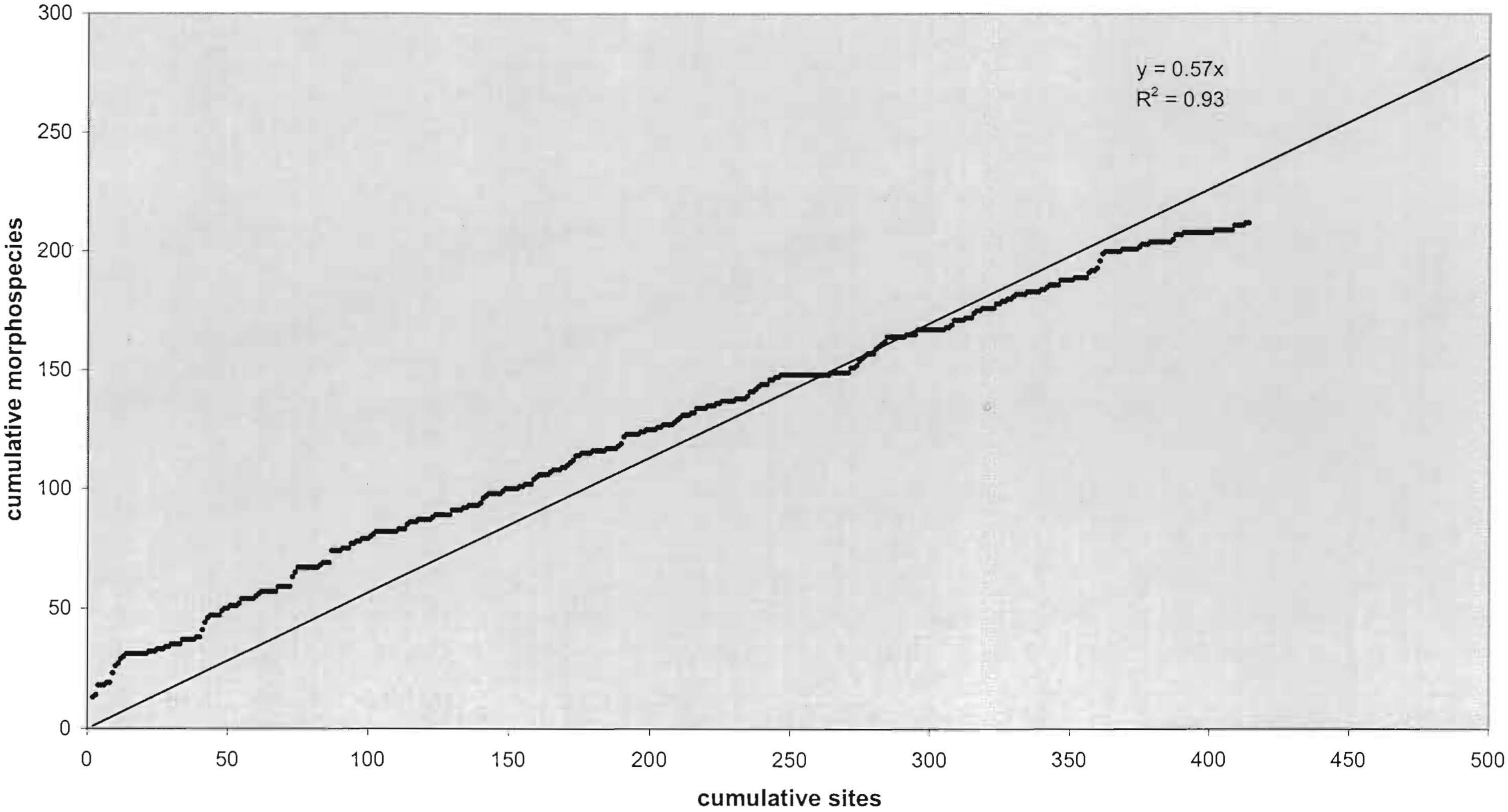
How many earthworm morphospecies are there in Tasmania?

As already noted the number of described species and new morphospecies combined has been increased during this study from 46 to 212. What proportion of the total number of morphospecies present in Tasmania is this figure likely to represent?

Although the field survey in this study was very extensive, and as comprehensive as it could have been with the resources available, there are clearly some inaccessible parts of Tasmania that were not sampled (Figure 1). Quite extensive gaps between samples exist particularly in the Central Plateau and Western parts of the State. Indeed, apart from the opportunities offered to collect at Pelion and Melaleuca, almost no other samples came from beyond the end of minor roads and forest tracks. Additionally, no sampling was carried out on King Island due to atypically early drying of the soil in spring 1994, when a visit to the Island had been planned.

There are a number of ways of examining the efficacy of the sampling programme. Perhaps the simplest is to consider how many new morphospecies were being found at sites visited late in the collecting period. A plot of the cumulative number of morphospecies collected, against the number of sites visited during the Museum surveys, commencing in August 1990 (Figure 5) reveals that the number of species was still increasing at a perceptible rate even at the end of the survey period. Linear correlation

Figure 5 Increasing number of morphospecies found with increasing number of sites sampled



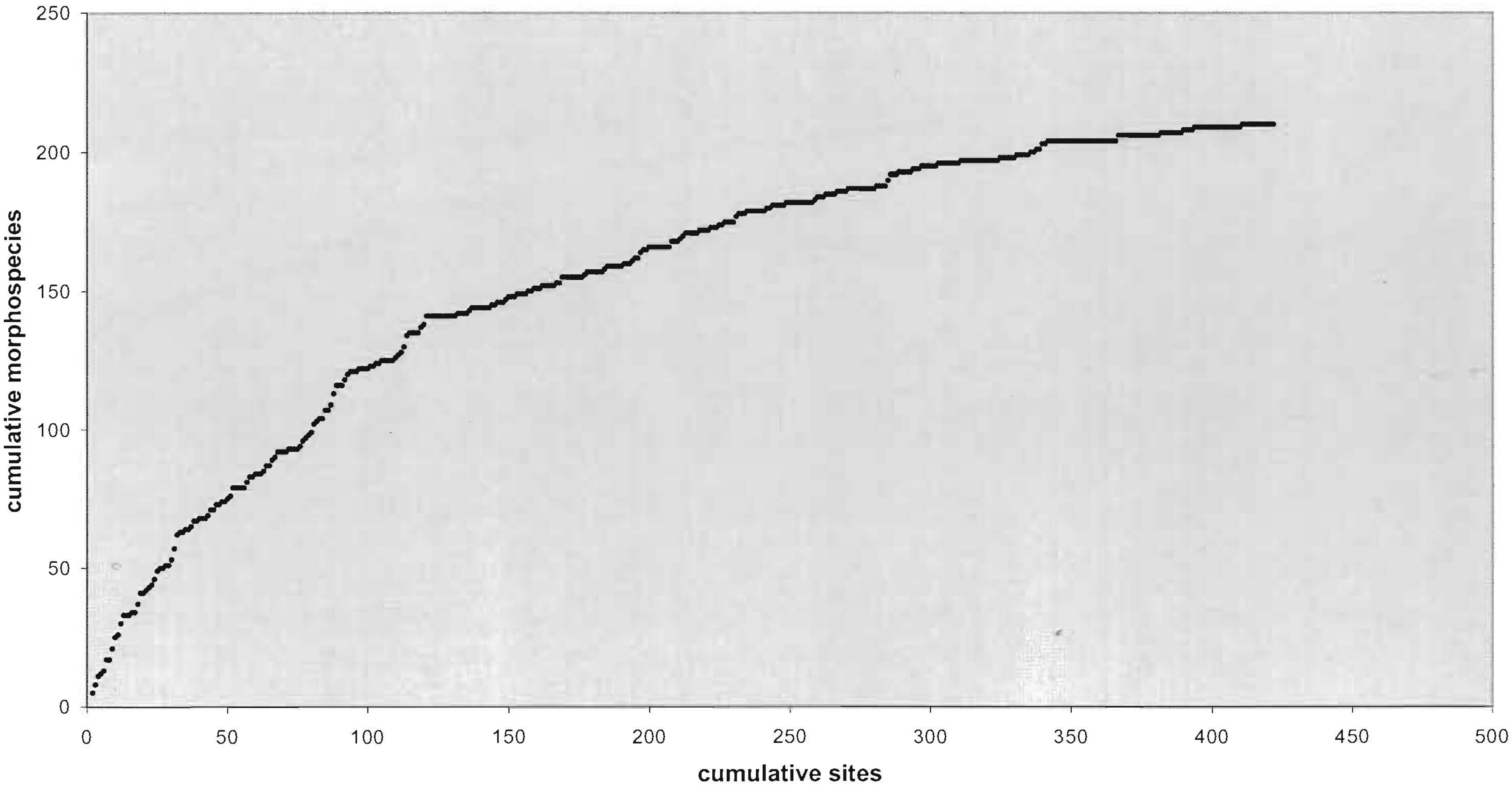
between cumulative species and cumulative sites gave a correlation coefficient of 0.93. A least squares best-fit linear plot through the graph's origin is shown for comparison. The data plot commences above the best fit line, a feature that is explained by the details of the first six sites in the sequence (Table 3). Three each of these sites were at Weldborough and three at Waratah, widely separated sites with no overlap of species. The mean number of species at these sites was 6.2, more than double the mean for all Museum surveyed sites. Once about 100 sites had been surveyed, the mean number of species collected per site starts to decline, until at about 270 sites it falls below the study average for the first time. After about 350 sites the rate of discovering new species has clearly dropped below the average, however, even in some of the last samples of the study new species were still being collected.

The above finding is perhaps not surprising considering that the survey program moved to unsurveyed regions of the State progressively week by week, the last sites were thus almost equally unrepresented in the collections as was the very first site surveyed. This finding perhaps tells us more about the extent of the distribution of species than it does about the number of them; clearly the fact that additional new morphospecies were found throughout the survey tells us that the range of many of them extends across relatively few consecutive sites. In attempting to use a projection of the relationship between cumulative species and cumulative sites to predict a total number of morphospecies for Tasmania one would clearly have to calculate the extent of unsampled areas of the State. King Island is one readily determined such area, as indeed are extensive remote parts of the central and western regions, equivalent to at least an additional 50 sites.

The calculated slope of the least squares line is 0.57 or, in words, a new morphospecies was identified on average at approximately every second site. In fact what tended to occur when moving into a new survey area was that several new morphospecies would be found at the first site in that area, followed by a rapid decline in the number of additional new morphospecies at subsequent sites within that area. Clearly this generalisation was also affected by the distance between the new area and the nearest previously sampled area. Towards the end of the survey the new areas increasingly lay between areas already sampled, and thus fewer new morphospecies were found. This is consistent with the observed drop of the data trace below the least squares line late in the survey.

An alternative way of examining the collecting data is to add site data in randomised rather than chronological order. This process differs from the above discussion in that it says nothing about unsurveyed areas but gives greater insight into the adequecy of the sampling effort within those areas actually sampled. The resulting graph of cumulative species collected (Figure 6) is clearly curvilinear, implying that a large number of additional sample sites within the same area as previously surveyed would return very few additional morphospecies. The curve appears to be levelling out at about 220 species. On this bais it is reasonable to assume that the predicted maximum number of morphospecies to be found in the area surveyed is of the order of 220.

Figure 6 Increasing number of morphospecies found with increasing sites (site order randomised)



To obtain the best possible estimate for the total number of morphospecies for Tasmania and its offshore islands, 10 additional ones should be allowed for King Island and an additional 20 for the estimated 50 equivalent sites in remote parts of Tasmania that remained unsurveyed. The best estimate possible is thus approximately 250 morphospecies.

How directly are morphospecies likely to translate into true species?

The use of external morphological characters alone to define earthworm varieties in the course of the survey proved to be a very valuable way of rapidly classifying the specimens. Given the large number of forms not found to correspond to any of the species in Jamieson 1974, there was really no choice but to employ this rapid, but admittedly provisional, method. There was an acknowledged expectation that upon dissection some morphospecies would, on the basis of differences in the structure of internal organs, be found to belong to two or more distinct species. Some of the defined morphospecies have distributions (see maps in Volume 2) that strongly hint that species might have been combined. Without wishing to delve too deeply here into the taxonomic work undertaken since the survey, in many cases formal taxonomic study has separated morphospecies in a way that does indeed 'explain' disjunct morphospecies distributions. Similarly some separate morphospecies would be expected to be found to be variations of a single species.

How widely distributed are the individual morphospecies?

Until such time as the translation of morphospecies categories into species is completed there is little point is examining the distributions of individual morphospecies in any detail, or in looking for general patterns. However, the frequency distribution of the number of sites occupied by each of the morphospecies (Figure 4) shows that even after sampling earthworms at over 400 sites across the State, 50 of them, perhaps 20% of the total, had nevertheless been found at only a single locality. Very few sites were situated more than 10 km from the nearest adjacent site which thus implies that these morphospecies had very restricted ranges, in many cases less than 10km in radius. Alternatively these morphospecies might be more widespread than it appears but are simply so uncommon that finding them involves a high degree of chance. Some of these may be associated with specific environmental conditions that are themselves patchy and uncommon, an association that was not recognised during the survey.

At the other extreme, only 10 morphospecies were recorded from more than 20 sites each, implying that very few species have truly extensive distributions. Again this is a picture that could change as the formal taxonomy proceeds if instances are found in which two or more morphospecies are found to be local variations of a single species. With respect to the taxonomic study completed to date this has not however been found to be a common occurrence.

What conclusions can be drawn concerning the conservation status of species

Any true species found at fewer than 4 distinct sites within Tasmania would require further, more detailed survey of its distribution and habitat requirements. 139 of the 212 morphospecies, or 65% currently fall into this category.

Species found at just one or two sites would require this work to be done as a matter of high priority. There are 88 morphospecies (42%) that fall into this group at present. Once confirmed through formal taxonomy, species that remain in this category will be the subject of further investigation and assessment of their distribution, abundance and the current and prospective level of threat to their survival. Where appropriate the species will be proposed for inclusion in the formal list of Tasmanian invertebrates under the State's *Threatened Species Protection Act 1995.*

What recommendations for future work emerge from this project?

The major recommendations for future work following on from this study include:

- Rigorous taxonomic study of all morphospecies defined in this study through examination of all specimens attributed to each morphospecies.

- Supplementary collecting, on an opportunistic basis, in those remote areas of Tasmania not yet able to be visited, as well as on King Island.

- Further more intensive survey in the areas surrounding each of the species that were recorded from only one or two sites, in order to better define the distribution of those species. This survey should also determine the habitat preference of these species to facilitate the next recommendation

- Each species found to be rare, or to occupy a restricted geographical range, should be assessed for listing under the *Threatened Species Protection Act 1995* and inclusion in the *Threatened fauna manual for production forests in Tasmania* (Jackson and Taylor, undated).

Postscript: a summary of progress 1994-1999

Since completion of earthworm survey under NEGP funding in 1994 significant additional funds from a variety of sources have been secured and deployed, mostly in support of taxonomic study of the specimens accumulated in the survey. These funds have included:

$61 000 from the Plomley Foundation to fund Dr Rob Blakemore to conduct taxonomic studies of the collections, jointly with the author, between 1996 and 1998.

$5 000 from the Tasmanian Parks and Wildlife Survey to fund a field survey and taxonomic studies of the earthworms around the shores of Lake Pedder in 199

$28 000 from the Tasmanian component of the Regional Forest Agreement process in support of Dr Blakemore's collaboration with the author on earthworm taxonomy.

$65 000 worth of support from the Australian Antarctic Division for studies of earthworms on Macquarie Island.

$33 000 from the Australian Biological Resources Study (ABRS) in support of earthworm taxonomy in 1999/2000

At the time of writing the taxonomic studies are continuing. Detailed descriptions of a total of approximately 180 species of Tasmanian earthworms have been completed, including both new species as well as augmented redescriptions of pre-existing species. One paper has been published (Blakemore and Kingston 1998, Appendix 2) while another has been accepted for publication, subject to only minor revision. By the time the funds listed above have been fully expended it is anticipated that all morphospecies distinguished during the current study will have been examined and all valid species described.

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Acknowledgements

The superb quality of the earthworm collection and associated database built up during this study is a reflection of the total commitment to the project made by the Project Officer Rob D'Orazio. Queen Victoria Museum Research Officer Ms Louise McGowan assisted the project with databasing of information as well as in the field. The project was greatly enhanced by involvement in fieldwork by Mark Cooper under the Commonwealth Government JOBSKILL programme and by a sequence of volunteers including Amanda Mitchell (4 days), Mark Gittus (3 days) and Daniel Soccol (25 days). The production of the maps was made possible through enthusiastic instruction in the use of IDRISI by Glyn Roberts of Howrah. Margot Kingston was selfless in her support of the project, frequently seeing family weekends excursions merge into collecting trips and her kitchen into an earthworm morgue.

Appendix 1 Laffan, M.D. and Kingston, T.J. (1997)

Aust. J. Soil Res., 1997, **35**, 1231–43

Earthworms in some Tasmanian forest soils in relation to bioturbation and soil texture profile

M. D. Laffan[A] *and T. J. Kingston*[B]

[A] Forestry Tasmania, Launceston. Present address: Forest Practices Board, PO Box 180, Kings Meadows, Tas. 7250, Australia.
[B] Queen Victoria Museum, Wellington Street, Launceston, Tas. 7250, Australia.

Abstract

Soil properties and earthworm population density were examined for 5 forest soils derived from Silurian–Devonian sandstones (Mathinna Beds) in north-eastern Tasmania. The soils occur along gradients of altitude, rainfall, and forest type; they include 2 with texture-contrast and 3 with gradational soil profile types. The density and biomass of the most abundant earthworm species *Megascolex montisarthuri*, and of all earthworm species combined, were found to be greater in gradational than in texture-contrast soils. A greater proportion of the earthworms in gradational soils than in texture-contrast soils was found to occur at soil depths exceeding 10 cm. The contrast was most pronounced between the 2 texture-contrast soils and the single gradational soil that occur under dry eucalypt forest. This paper explores the hypothesis that bioturbation of surface and subsurface layers by earthworms is an important mixing process that in gradational soils outweighs the counter tendency for soil particles to sort and thus form texture-contrast profiles.

Additional keywords: soil fauna.

Introduction

Soil mapping in north-eastern Tasmanian forests during 1990 by Laffan *et al.* (1995) differentiated a range of divergent soils formed on Silurian–Devonian sandstone (Mathinna Beds). Of particular interest were 5 soils, including 3 gradational and 2 duplex (texture-contrast) profile forms (Northcote 1979), occurring under dry eucalypt forests and wet forests. These soils comprise the Retreat, Wattley, Piper, Maweena, and Sideling soil profile classes characterised and mapped on the Pipers 1 : 100 000 scale topographic sheet (41° S, 147° E) (Laffan *et al.* 1995).

The major factors considered responsible for the development of texture-contrast soils have been reviewed by Chittleborough (1992); they include sedimentological layering, clay formation, clay weathering, clay illuviation and alluviation, and bioturbation. The author noted that bioturbation by soil fauna could cause homogenisation of profiles and thus prevent strong textural differentiation. Where the processes that tend to sort soil particles predominate over long periods, texture contrast profiles may result, whereas when sorting processes are negated by periodic or continuous soil mixing, gradational soils may be sustained. The roles of termites and ants in soil modification, including effects on soil texture profiles, have been reviewed by Lobry de Bruyn and Conacher (1990). Their review showed that there is evidence both for and against texture differentiation

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by ants and termites. Research into the role of earthworms in pedogenesis has been reviewed by Lee (1985). More recently, in a study in south-western Ivory Coast, Nooren *et al.* (1995) proposed that the selective erosion of surface worm casts by rain splash and overland flow was a significant contributor to the formation of sandy topsoils under forest. A similar process of winnowing of finer soil particles by water and wind erosion of faunal casts and mounds has been proposed as a global mechanism for the development of texture-contrast soils in materials that can be sorted (Paton *et al* 1995). Conversely, soil mixing by fauna that do not form casts or mounds on the soil surface can counteract the formation of texture-contrast profiles (Humphreys *et al.* 1996).

Field characterisation of the 5 Tasmanian forest soils suggested there may be marked differences in the levels of earthworm activity between soils; those with gradational profiles were observed to contain more subsurface earthworm burrows and casts than those with texture-contrast soils. Surface casts were not observed on any of these soils. Ant mounds occurred sporadically on the surface of the 3 soils under dry eucalypt forest, but there was no evidence that ant mounding was more prevalent on any one soil. Excavation of ant nests revealed that their galleries generally did not extend below the A1 horizon; ant activity is thus unlikely to have caused textural differentiation or mixing of subsurface horizons.

Examination of soil morphology and associated site characteristics led the authors to the hypothesis that differing levels of earthworm activity and hence bioturbation, in both surface and subsoil layers, could be a major causal factor in the development of either gradational or texture-contrast profiles. In order to seek support for this hypothesis, the densities of native earthworms, the major potential agents of faunal bioturbation present in these soils, were measured for the 5 soils and were analysed in relation to the 2 contrasting profile types.

Study sites

Parent material and topography

The parent materials of all 5 soils are Silurian–Devonian sandstone of the Mathinna Group of north-eastern Tasmania (Tasmania Department of Mines 1965). Retreat, Wattley, Piper, and Maweena soils occur on undulating (2°–6°) and rolling (6°–17°) slopes of hills at altitudes of 60–340 m. Parent materials of these soils are mainly strongly weathered. Sideling soils occur on rolling slopes of mountains at altitudes of 480–720 m; their parent materials are less weathered, reflecting the strong impress of periglacial and other colluvial slope processes during the Quaternary period.

Retreat soils are predominant on better drained sites, generally on crests and upper slopes of hills, whereas Wattley and Piper soils are more commonly found on less well drained sites such as lower hill slopes and drainage lines. However, Piper soils have been recognised on all segments of hilly landforms apart from narrow rocky ridge crests. In areas of low relief, Wattley soils often occur on lower lying slopes.

Climate and vegetation

Mean annual rainfall ranges from 800 to 1500 mm and the native vegetation varies from dry eucalypt forest to wet eucalypt forest and mixed forest of eucalypt

Table 1. Summary of site and profile data

Landform	Native vegetation/ mean annual rainfall	Texture profile	Drainage class	Soil classification: Australian[A]	PPF[B]	Soil Taxonomy[C]
			Retreat			
Midslopes, upperslopes, crests of hills	Shrubby dry eucalypt forest; 850–1000 mm	Loamy sands over clays	Moderately well drained	Bleached, brown kurosol	Dy5·41	Hapludult
			Wattley			
Lower slopes of hills, crests of low rises	Heathy dry eucalypt forest; 850–950 mm	Loamy sands over sandy clay loams and clays	Imperfectly drained	Bleached-Mottled, brown chromosol	Dy5·41	Hapludult
			Piper			
Lower slopes of hills, drainage lines	Sedgy dry eucalypt forest; 800–1000 mm	Fine sandy loams over sandy clay loams over sandy clays	Imperfectly drained	Acidic-Mottled, yellow dermosol	Gn3·91	Hapludult
			Maweena			
All facets of hillslopes	Wet eucalypt forest; 1000–1400 mm	Fine sandy loams over sandy clay loams and light medium clays	Moderately well drained	Acidic-Mottled, brown dermosol	Gn3·71	Hapludult
			Sideling			
Rolling mountain slopes	Mixed forest; 1200–1500 mm	Clay loams over light clays	Well drained	Acidic, brown dermosol	Gn4·31	Dystrochrept

[A]Isbell (1996).
[B]Principle Profile Form, Northcote (1979).
[C]Soil Survey Staff (1992).

canopy over a rainforest understorey. Details of soil and vegetation characteristics for each soil type are provided in Table 1. The groundcover occurring on Piper soils incorporates common to abundant sedges, indicating that surface and/or subsurface soils remain moist for more extended periods than is the case for the other soils.

Table 2. Bulk density and particle-size analysis for representative soils

Horizon	Depth (cm)	Bulk density (g/cm^3)	Sand[A] (%)	Silt[B] (%)	Clay[C] (%)
		Retreat			
A1	0–12	1·1	80	12	8
A2	13–24	1·3	84	12	4
A2e	24–35	1·6	88	8	4
B1t	35–41	1·6	56	20	24
B2t	41–83	1·5	24	16	60
		Wattley			
A1	0–18	1·2	82	12	6
A21e	18–30	1·5	84	12	4
A22e	30–36	1·7	84	12	4
B21t	36–56	1·4	63	12	25
B22t	56–87	1·5	48	12	40
B23g	87–95	n.d.	48	16	36
		Piper			
A1	0–13	1·2	70	16	14
B1t	13–29	1·6	60	16	24
B2t	29–87	1·5	44	16	40
B3gt	87–95	1·5	56	16	28
		Maweena			
A1	0–14	1·1	66	16	18
AB	14–26	1·4	59	20	21
B21t	26–36	1·8	56	20	24
B22t	36–58	1·6	60	20	20
B23t	58–80	1·6	60	16	24
		Sideling			
A1	0–9	0·8	32	40	28
B21	9–35	1·3	32	44	24
B22	35–70	1·1	28	48	24

n.d., not determined.
[A]2·0–0·02 mm.
[B]0·02–0·002 mm.
[C]<0·002 mm.

Soil properties

Soil physical and chemical properties for the 5 soils are given in Table 2 (bulk density and particle-size) and Table 3 (selected chemical characteristics). Retreat and Wattley soils (Fig. 1) are moderately well drained and imperfectly drained, respectively. Both soils have texture-contrast profiles characterised by dark grey sandy loam A1 horizons and bleached loamy sand or sand A2e horizons overlying yellowish brown, mottled clayey B2t horizons typically at a depth of about 30 cm in Retreat soils and 40 cm in Wattley soils. Earthworm burrows and casts are moderately abundant in A1 and A2 horizons, but little evidence of earthworm activity was recorded in underlying subsoils.

Table 3. Selected chemistry for representative soils

Horizon	Depth (cm)	pH (%)	Total N[A] (%)	OC[B] (%)	Total P[C] (μg/g)	Exch. Ca, Mg, K, Na[D] (cmol/kg)	ECEC[E] (cmol/kg)
				Retreat			
A1	0–13	4·7	0·12	1·1	55	3·84	5·0
A2	13–24	4·8	0·06	1·5	32	n.d.	n.d.
A2e	24–35	5·1	0·03	0·6	18	n.d.	n.d.
B1t	35–41	4·9	0·03	0·6	42	n.d.	n.d.
B2t	41–83	5·3	0·03	0·5	89	1·21	11·0
BC	83–95	5·4	n.d.	0·4	95	n.d.	n.d.
				Wattley			
A1	0–18	4·8	0·06	1·7	42	1·59	3·0
A21e	18–30	5·1	0·03	0·4	19	n.d.	n.d.
A22e	30–36	5·6	0·02	0·2	11	n.d.	n.d.
B21t	36–56	5·8	0·04	1·0	58	n.d.	n.d.
B22t	56–87	5·9	0·03	0·3	76	2·51	5·0
B23t	87–90+	5·9	0·02	0·2	74	n.d.	n.d.
				Piper			
A1	0–13	4·7	0·08	1·2	52	2·01	4·0
B1t	13–29	4·9	0·03	0·4	47	n.d.	n.d.
B2t	29–87	5·2	0·03	0·3	76	1·23	13·0
B3gt	87–90+	5·2	0·02	0·1	113	n.d.	n.d.
				Maweena			
A1	0–14	5·2	0·19	2·4	179	4·90	6·0
AB	14–26	4·9	0·06	0·9	104	n.d.	n.d.
B21t	26–36	4·9	0·05	0·5	92	n.d.	n.d.
B22t	36–58	4·8	0·04	0·5	142	1·84	9·0
B23t	58–80	4·8	0·05	0·6	202	n.d.	n.d.
				Sideling			
A1	0–9	4·2	0·37	5·6	359	1·59	7·0
B21	9–35	4·7	0·15	2·9	295	n.d.	n.d.
B22	35–70	4·9	0·12	1·9	310	0·37	3·0

n.d., not determined.
[A]Determined using Kjeldahl method (Rayment and Higginson 1992).
[B]Organic carbon, determined by Walkley and Black (1934) colorimetric method.
[C]Determined by perchloric acid digestion (Olsen and Sommers 1976).
[D]Total exchangeable Ca, Mg, K, Na determined using 1 M NH_4Cl at pH 7·0.
[E]Effective cation exchange capacity (exchangeable cations+exchangeable acidity).

Piper soils (Fig. 2) are also imperfectly drained, but they have gradational texture profiles characterised by dark grey sandy loam A1 horizons overlying olive brown sandy clay loam B1 horizons with distinct grey mottles and many prominent very dark grey infilled earthworm burrows and casts (Fig. 3). Deeper subsoil layers include yellowish brown and greyish fine sandy clays and clay loams with common or few earthworm burrows and casts to a depth of at least 70 cm. In many profiles, earthworm burrows and dark grey casts occur to depths below 90 cm.

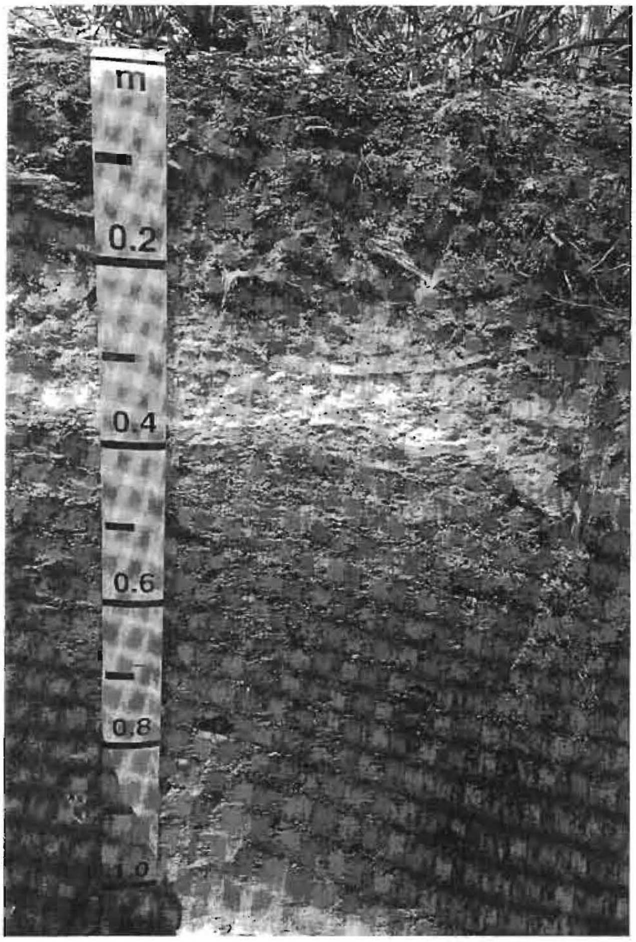

Fig. 1. Wattley soil profile to 1 m showing its texture-contrast character.

Maweena and Sideling soils are moderately well drained and well drained, respectively, and typically have gradational texture profiles, although some Sideling soils have uniform profiles. Maweena soils typically have dark brown sandy loam or sandy clay loam A1 horizons overlying yellowish brown clay loams and light clays with common distinct clay skins. Sideling soils are characterised by dark greyish brown clay loam A1 horizons overlying brown light clay or clay loam subsoils generally with common to many rock fragments. Humic litter layers often occur on the A1 horizons of both soils. Numerous earthworm burrows and casts occur to depths of at least 70 cm in both soils.

Earthworm populations

Extensive information on the native earthworms of north-eastern Tasmania has been gathered during the course of an ongoing survey commenced in 1992 (T. J. Kingston unpublished data). A minority of the earthworm species recovered have been identified by using species descriptions in Jamieson (1974); the collections were, however, found to contain several undescribed species.

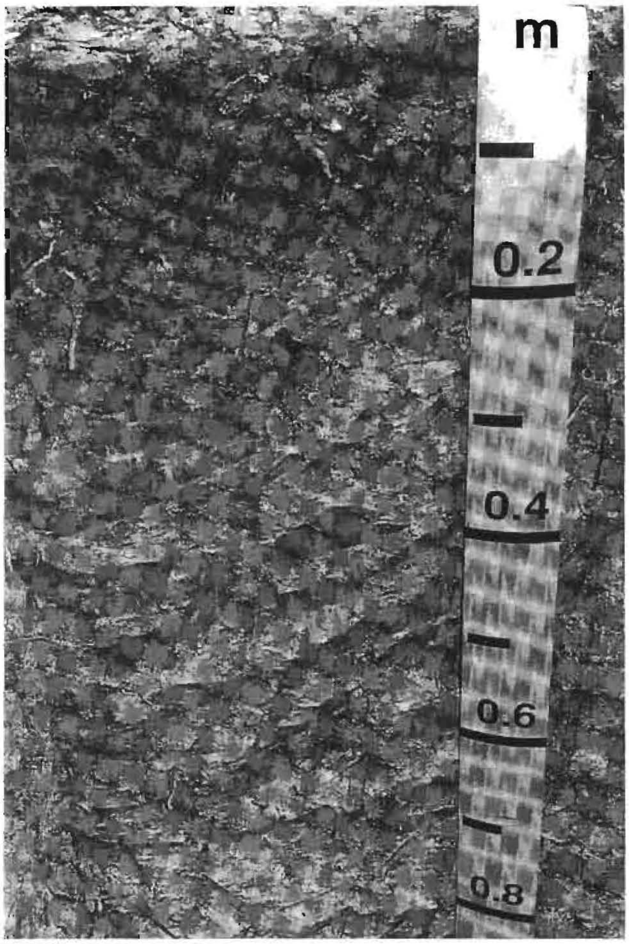

Fig. 2. Piper soil profile to 0·8 m showing its gradational character.

Earthworms found within the current study area include species belonging to the 3 main ecological types defined by Lee (1985). Earthworms belonging to the first category, those confined to the litter horizon, were present but are not considered in this study due to their absence from the mineral component of the soil profile. The second category, species that occupy the upper levels of the profile but do not form open burrows, was represented by 2 species: *Megascolex montisarthuri* and an undescribed species of *Vesiculodrilus*. During the earthworm survey, *M. montisarthuri* had been found to be widespread and abundant in north-eastern Tasmania (T. J. Kingston unpublished data). The same species was found to be the predominant one for all soils within the present study. During winter, when the soil is wet, members of this species were found to be active in the upper portion of the soil profile. In all 5 soils, the great majority of individuals were found in the upper 20 cm of the profile; however, in the gradational soils, but not in the texture-contrast soils, a minority of earthworms were encountered at depths to 40 cm. In summer, when the water content of the surface soil declines, the absence of *M. montisarthuri* individuals in the upper part of the profile has been noted; it appears that they burrow more deeply at this time

Fig. 3. Piper soil subsoil clod (from 40 to 50 cm depth) showing darkly coloured earthworm casts (scale bar 1 cm).

of year, presumably to avoid the desiccating conditions that prevail in the uppermost part of the profile. The second 'topsoil' species, *Vesiculodrilus* sp., was encountered relatively infrequently compared with *M. montisarthuri*; nothing is known of the ecology of this species. The third category of earthworm lifestyle, occupation of open burrows that extend deeply into the subsoil, is represented, in some parts only of the study area, by Tasmania's largest known earthworm species, *Pinguidrilus tasmanianus*. Mature individuals of this species achieve 40 cm in length, when extended. When present, members of the species occupy semi-permanent burrows that commonly reach a depth of 80 cm. Although the density of both earthworms and active burrows is always low, many unoccupied and infilled burrows were also detected. Detection was facilitated by the presence in the burrows of darker more highly organic soil translocated from the A1 horizons.

Methods

Field investigation of the earthworm populations of the 5 soils was conducted during the winter and spring of 1993. For each soil class, 3 representative but widely spaced (>1 km apart) localities were selected for the study of earthworm composition and density. At each site, a 100-m transect was laid out and 6 points were located randomly along its length. A $0 \cdot 25$-m^2 metal frame having 10-cm-high vertical sides was pushed into the ground at each point and the soil was excavated from within the quadrat in 2 depth intervals: 0–10 cm and >10 cm. Excavation continued until no further earthworms or burrows were evident; the depth at which this occurred varied between about 20 and 80 cm below the surface.

Soil excavated from each level was placed onto plastic sheeting, manually broken up, and sifted for earthworms and other soil fauna. All invertebrates found, including severed fragments, were preserved by placing them into 70% ethanol. In the laboratory, earthworms from each site were sorted to species, placed on absorbent paper to remove excess ethanol,

Table 4. Earthworm population densities (number/m^2), by soil class and depth

Within columns, means followed by the same letter are not significantly different at $P = 0{\cdot}05$

Soil	*Megascolex montisarthuri*			*Pinguidrilus tasmanianus*		*Vesiculodrilus* sp.		All species		Total
	0–10 cm	>10 cm	Combined	0–10 cm	>10 cm	0–10 cm	>10 cm	0–10 cm	>10 cm	Combined
Wattley	21·3b	1·1b	22·4bc	0	0	0	0	21·3c	1·1b	22·4c
Retreat	38·2b	1·3b	39·5bc	0	0	0	0	38·2bc	1·3b	39·5bc
Piper	55·1b	14·9a	70·0ab	0	0	2·2	0·2	57·3b	15·1a	72·4b
Maweena	97·1a	8·9ab	106·0a	0·2	0·2	4·9	0·9	102·2a	10·0ab	112·2a
Sideling	36·4b	14·4a	50·8bc	0	0·4	0	0	36·4bc	14·8a	51·3bc
Overall *P*	<0·01	<0·05	<0·05					<0·01	<0·05	<0·01

Table 5. Earthworm biomass (g/m^2), by soil class and depth

Within columns, means followed by the same letter are not significantly different at $P = 0{\cdot}05$

Soil	*Megascolex montisarthuri*			*Pinguidrilus tasmanianus*		*Vesiculodrilus* sp.		All species		Total
	0–10 cm	>10 cm	Combined	0–10 cm	>10 cm	0–10 cm	>10 cm	0–10 cm	>10 cm	Combined
Wattley	12·7c	1·3b	14·0c	0	0	0	0	12·7d	1·3b	14·0b
Retreat	19·9bc	0·9b	20·8bc	0	0	0	0	19·9cd	0·9b	20·8b
Piper	50·9a	20·8a	71·7a	0	0	4·4	0·5	55·3ab	21·3ab	76·6a
Maweena	62·9a	8·8ab	71·7a	0·9	2·5	9·1	2·0	72·8a	13·3ab	86·0a
Sideling	38·4ab	16·0a	54·4ab	0	18·7	0	0	38·4bc	34·7a	73·1a
Overall *P*	<0·01	<0·05	<0·01					<0·001	<0·05	<0·01

and weighed. Earthworms in each sample were counted; where there were severed pieces, only the 'heads' were scored.

Invertebrates other than earthworms, found mostly in the leaf litter layer, were collected from all sites. Collections included millipedes, centipedes, spiders, beetles, and the larvae of beetles, flies, and moths. Few of these were as large as an individual earthworm and none were found at depths below 25 cm. Together, these invertebrates were responsible for an insignificant proportion of total invertebrate biomass and hence of faunal activity in the soil. As with small litter-dwelling earthworms, these other invertebrates are not considered further in this paper.

Results

The mean densities of each of the 3 soil-dwelling earthworm species, according to soil class and the 2 depth intervals, are presented in Table 4 (earthworm density) and Table 5 (earthworm biomass). Three trends are apparent from these results. Firstly, for all soil classes, total earthworm biomass was 2·8 times greater at the surface (mean 39·8 g/m^2) than below a depth of 10 cm (mean 14·3 g/m^2). Secondly, for the 2 soil depths combined, total earthworm biomass for the gradational soils (78·6 g/m$^{2)}$) was 4·5 times greater than that for the texture-contrast soils (17·4 g/m^2). Thirdly, an overall dominance of the results by the one species, *M. montisarthuri* (86% of total earthworm biomass), is also apparent.

Earthworm density and biomass data were log-transformed, and both untransformed and transformed data were examined for normality, by calculation of the Shapiro–Wilks W statistic. For both density and biomass of *M. montisarthuri* and for the 3 earthworm species combined, log transformation of the data decreased the departure from normality to a non-significant level and thus log-transformed data were employed in all statistical analyses. For the 2 less-abundant species, the distributions of both untransformed and transformed data were far removed from normality and so parametric statistical techniques were unavailable for use in these cases.

The transformed data for *M. montisarthuri* and for all species combined were analysed according to soil profile type and soil depth, using 2-way analysis of variance. A third factor, soil profile type × soil depth interaction, was also included; the results of these analyses are given in Table 6.

Soil depth, soil profile type, and the interaction between these were all found to be significant factors in determining earthworm density and biomass in the samples. It is notable that the addition of data for the 2 less-common species to that of *M. montisarthuri* resulted in only minor changes in the values of the F-ratio. Examination of the coefficient of determination (R^2) revealed this to be consistently high at 0·83, whether earthworm density or biomass, or whether *M. montisarthuri* or combined species were considered.

Interpretation of the results for soil depth and soil profile type was straightforward; at the time of the study earthworm density and biomass were greater in the upper 10 cm of the soil profile than below this depth. Earthworm density and biomass were also higher in gradational soils than texture-contrast soils. The significant interaction between soil depth and soil profile type may be interpreted as a non-uniform effect of depth between the 2 soil profile types; a greater proportion of earthworm density and biomass was recovered from below 10 cm depth in gradational soils than in texture-contrast soils.

Table 6. Result of two-way ANOVA for *M. montisarthuri* and for all species combined

Factor	log(earthworm density)			log(earthworm biomass)		
	d.f.	*F*-ratio	*P*	d.f.	*F*-ratio	*P*
		Megascolex montisarthuri				
Depth	1	23·7	<0·0001	1	17·7	0·0003
Soil profile type	1	8·3	0·0079	1	17·8	0·0003
Soil profile type × depth	1	5·5	0·026	1	4·3	0·047
		All species				
Depth	1	23·6	<0·0001	1	17·2	0·0003
Soil profile type	1	8·8	0·0065	1	17·2	0·0003
Soil profile type × depth	1	5·6	0·025	1	5·6	0·026

While these results demonstrate the influence of soil profile type and soil depth on earthworm density and biomass, they do not distinguish between earthworm density and biomass in the 5 individual soil classes. In order to augment the results in relation to this aspect, univariate analysis of density and biomass by soil class was conducted for *M. montisarthuri* and for combined earthworm species, and comparisons were carried out between all soil pairs, using Student's *t*-test. The results, incorporated in Tables 4 and 5, provide insight into which of the 5 individual soil types made the greatest contribution to the results of the 2-way analysis based on the 2 profile types only.

Discussion

Earthworm density and biomass

The sampling methods employed produced estimates of the density and biomass of earthworms that varied in precision, according to species, as determined by calculation of the coefficient of variation (CV). Sampling was more precise for the abundant and widespread *M. montisarthuri* [CV(density) = 96%, CV(biomass) = 103%], while the size of the areas excavated was less efficient in its estimation of the large and locally occurring species, *P. tasmanianus* [CV(density) = 237%, CV(biomass) = 319%)]. The latter species was found only in Maweena and Sideling soils; in each case only 2 individuals were found in the soil excavated from 18 holes. These 4 earthworms imposed a considerable impact on the overall results for biomass, both in terms of the mean values for the sites at which they were found, and in terms of overall variability. For example, for the Sideling soil, inclusion of the 2 *P. tasmanianus* individuals increased the overall number of earthworms at this site by <1%, but increased the biomass by 34%. Simultaneously, the associated coefficient of variation increased from 23% to 52%. Future studies investigating the impact of large, deeply burrowing earthworms upon soil profile characteristics will need to overcome this problem through the (excessively labour-intensive) process of excavating holes of much larger surface area.

Earthworms and the soil texture profile

The results show that at the time of the study, in winter, when soil water content was high, there were clear differences between soils with texture-contrast and gradational profiles with respect to the density, biomass, and distribution by depth of earthworms. The proportions of total earthworm biomass extracted from each of the 2 soil depths vary considerably between soil classes. For the texture-contrast soils, the proportion of earthworm biomass found below 10 cm depth was 9% for Wattley and 4% for Retreat; in contrast, for the gradational soils the equivalent values were 28% (Piper), 16% (Maweena), and 47% (Sideling). It has already been acknowledged above that the earthworm biomass for the Sideling soil was enhanced by the presence of 2 *P. tasmanianus.* However, even if this species is ignored, the proportion found below 10 cm remains high at 29%. These differences (statistically significant between soil profile types) are consistent with the observation that the gradational soils all have numerous earthworm burrows and casts in their subsoils to depths of at least 70 cm, whereas relatively few burrows and casts were found in subsurface horizons (A2e) and subsoils of texture-contrast soils. The results of the earthworm study, together with profile morphology, strongly suggest that bioturbation by earthworms may be a major factor in the development of gradational texture profiles. Of particular interest are the differences in earthworm biomass and depth of activity of the (texture-contrast) Retreat and Wattley soils as opposed to the (gradational) Piper soil. These soils have similar parent material and climate and all support dry eucalypt forests of similar species composition. The soils are assumed to be of similar age. Variation in the water status of the upper part of the profiles appears to be the main soil feature affecting earthworm populations and distribution, especially since other properties such as bulk density and organic carbon concentrations are relatively uniform (Tables 2 and 3). We infer that upper subsoils of Piper soils remain moist for longer periods and thus provide a habitat for earthworms which is more favourable than the drier subsurface layers in Retreat and Wattley soils. Of course earthworm density and biomass are more likely to have decreased during the formation of the A2e horizons (because of increasing sand content and droughtiness) than to have been stable throughout the development of these subsurface layers. However, we surmise that earthworm biomass would have been relatively low in these soils prior to development of distinct A2e horizons.

Examination of the various processes able to influence the development of texture-contrast profiles (Chittleborough 1992) indicates that bioturbation is the most obvious factor which is significantly different between the 3 soils. The impacts of the other factors are difficult to ascertain but it is unlikely that they are different between the soils examined in this study. There is no evidence of sedimentological layering or any lack of uniformity across the soil classes with respect to physical processes, such as forest windthrow, which can cause substantial mixing of surface and subsurface soil layers and thus counteract the development of texture-contrast profiles. Indeed, windthrow would be expected to be more prevalent in Retreat and Wattley soils because of shallower effective rooting depth. The occurrence of distinct clay skins in all 3 soils is taken as evidence of clay illuviation, but we are unable to comment on possible differences in rates of clay translocation.

The greater density and biomass of earthworms in both topsoils and upper subsoils of Piper soils compared with Retreat and Wattley soils is assumed to represent evidence of faunal bioturbation. We suggest that bioturbation by earthworms in the upper layers of Piper soils is a major factor responsible for the development of gradational texture profiles. The continual mixing of the mineral soil fraction between surface and subsoil layers counteracts processes such as clay translocation which favour the development of texture-contrast profiles. Conversely, in Retreat and Wattley soils, the absence of earthworm bioturbation in surface and subsurface layers permits the texture-contrast condition to prevail.

Although the results of this study have revealed a distinct relationship between soil profile type and the biomass of earthworms present, it is acknowledged that evidence of causation is circumstantial. The data presented in this study do, however, support the global bioturbation model proposed by Humphreys *et al.* (1996) to explain the development and maintenance of texture-contrast and gradational or uniform-textured soils.

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Appendix 2 Blakemore, R.J. and Kingston, T.J. (1997)

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1

Opisthogastric earthworms (Megascolecidae: Oligochaeta) and allied forms in north-western Tasmania

R. J. BLAKEMORE and T. J. KINGSTON

Queen Victoria Museum, Wellington St, Launceston, Tasmania, 7250

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A new genus *Nexogaster* is established for a Tasmanian megascolecid earthworm, *Nexogaster sexies* sp. nov., that has an oesophageal gizzard and intestinal gizzards, the opisthogastric condition, that in this species are moniliform. The only previously known opisthogastric species from Australia, *Hickmaniella opisthogaster*, is also from Tasmania but has a single intestinal gizzard; this species is redescribed. A new species, *Hickmaniella gogi*, is bithecal but otherwise similar to the type-species. *Nexogaster* differs from *Hickmaniella* in being lumbricine and having prostates that are racemose, rather than tubuloracemose (although both forms are an apomorphy of tubular prostates). Sympatric species are newly described that have close morphological similarities: one, *Anisochaeta simpsonorum*, is comparable with *Hickmaniella*, and two others, *Notoscolex pilus* and *Megascolides maestus*, not only resemble one another but are also similar to *Nexogaster*. A major morphological difference is that *M. maestus* has tubular prostates; this combined with its other primitive character states, such as lumbricine setae, give an indication of a possible precursor to the other species. Extensive generic reviews and redefinitions have been required to accommodate the new species.

KEYWORDS: *Anisochaeta*, *Cryptodrilus*, *Hickmaniella*, *Megascolex*, *Megascolides*, *Nexogaster*, *Notoscolex*, Tasmanian earthworms.

Introduction

Hickmaniella was believed by Jamieson (1974) to be unique among the known Australian Megascolecidae in possessing an intestinal gizzard, the 'opisthogastric' condition. Since 1991, a programme designed to sample native earthworms comprehensively throughout Tasmania for the first time has been undertaken by the second author. The material accumulated from some 600 localities has been examined by the authors and found to contain approximately 250 varieties, including several opisthogastric forms and their allies some of which are the subjects of this paper. Before these species can be described it is necessary to critically review several genera, especially those in which these species fit best. Following the taxonomic principle of priority, this review considers several 'classical' genera that have been variously synonymized. The fate of type-species is of particular concern, as the species is the basic element of morphological taxonomy.

Materials and methods

Segments are counted in Arabic numerals, intersegments designated by a slash (e.g. 1/2), variations shown by a comma and range by a dash (e.g. 3,4–5). Setae, counted from the ventral-most on each side, have lower case letters (a, b, c, d) and ranges are shown without a space (e.g. ab); setal lines refer to longitudinal setal series. New material is lodged in the Queen Victoria Museum, Launceston and has a QVM registration number (beginning QVM:14:), in the National Earthworm Collection of the CSIRO Division of Entomology, Canberra (prefixed ANIC:), and in the Tasmanian Museum, Hobart (TM:). The Natural History Museum, London is abbreviated BM. For material examined, H refers to holotype and P to paratype. Specimens were anaesthetized with dilute ethanol before being fixed in 10% formalin and preserved in 80% ethanol. Dissections and camera lucida drawings were by the principal author; in the figures all scale bars are 1 mm.

As part of the process of determining to which genera the new species described in this paper should be allocated it became necessary to review and revise the diagnoses of six genera. For most of the individual species, allocation to genus was based upon the outcome of several generic reviews; for this reason the generic reviews are presented first followed by species' descriptions.

Systematics, generic diagnoses

Hickmaniella Jamieson, 1974. Emend.

Hickmaniella Jamieson, 1974: 300.

Diagnosis

Setae numerous per segment. Male pores from tubuloracemose prostates paired on 18. An oesophageal gizzard in 5 and an intestinal gizzard in 19–20. Nephridia meroic (with *ca.* three to six tubules per side), avesiculate, not tufted anteriorly. Spermathecae one or two pairs, spermathecal diverticula clavate often with several internal chambers (i.e. multiloculate but not sessile). Calciferous glands, typhlosole and intestinal caeca absent. Penial setae present.

Type-species. Hickmaniella opisthogaster Jamieson, 1974.

Distribution

North/north-western Tasmania.

Remarks

The generic definition is emended following re-examination of the type-species which has an intestinal gizzard in 19 and 20 (cf. 19 or 20, Jamieson) and to accommodate a new species having only one pair of spermathecae. Intestinal gizzards, while rare in the Megascolecidae, are found in several other families: in the Palaearctic, the Hormogastridae have oesophageal gizzards and a rudimentary intestinal gizzard, the Lumbricidae have only an intestinal gizzard while the Criodrilidae have oesophageal and intestinal thickenings; Neotropical Glossoscolecidae have a gizzard in 6 and intestinal dilation in the region of 16; the African Eudrilidae have an oesophageal gizzard (in 5) but rarely have intestinal gizzards (Sims, 1980). These last two families have closest links with the Megascolecidae, although the intestinal gizzards may have been acquired independently (Jamieson, 1974).

Hickmaniella may be derived from *Anisochaeta* Beddard, 1890 via its apomorphic acquisition of an intestinal gizzard. Especially some new species of the latter genus currently being described by the authors (see below) are superficially similar. Alternatively, it may be viewed as a derivation of a *Notoscolex*-like precursor that has undergone transition from 8 setae per segment (the plesiomorphic lumbricine state) to more numerous setae (perichaetine state).

Anisochaeta Beddard, 1890

(Synonyms: *Trichaeta*, ?*Spenceriella*, ?*Gemascolex*)

Megascolex (part) Templeton, 1844: 89; Beddard, 1890: 56; 1895: 381; Michaelsen, 1900: 212–216; 1907: 163; Stephenson, 1930: 837; Jamieson, 1974: 318–319.
Perichaeta (part), Schmarda, 1861: 13; Beddard, 1890: 56.
Anisochaeta Beddard, 1890: 56.
Trichaeta Spencer, 1900: 30–31.
Spenceriella (part? including type-species) Michaelsen, 1907: 160–161; Jamieson, 1972a.
Gemascolex (part?) Edmonds and Jamieson, 1973: 23–24.

Diagnosis

Setae >8 per segment, at least in the hind-body. Male pores from tubuloracemose or racemose prostates paired on 18. An oesophageal gizzard in 5 (or 6). Nephridia meroic, at least in the fore-body, avesiculate, often tufted in the anterior. Spermathecae one or more pairs (sometimes unpaired?), with one or more extramural diverticula. Calciferous glands and typhlosole present or absent; intestinal caeca and gizzards absent. Penial setae present or absent.

Type-species. *Perichaeta coxii* Fletcher, 1886: 565–659; Fletcher, 1889: 1554.

Distribution

Australia (according to Beddard, 1890), New Zealand (Lee, 1959).

Remarks

Australian species that would formerly have been placed in *Megascolex* (or in *Spenceriella/Gemascolex*) are allocated to the resurrected genus *Anisochaeta* as defined above. Beddard (1890) established *Anisochaeta* for three species from New South Wales, *Perichaeta attenuata* Fletcher, 1889, *P. enormis* Fletcher, 1889 and *P. coxii* Fletcher, 1886 (the type-species by prior description), distinguished thus:

> 'Setae 8 in number per segment anteriorly, afterwards increasing up to 30 [i.e. perichaetine]; nephridia diffuse [i.e. meroic]; atria lobate [i.e. prostates tubuloracemose or racemose].'

This definition differed from Beddard's characterization of *Megascolex* principally in the transition of setae from 8 anteriorly to more numerous posteriorly. Later, Beddard (1895) transferred *Anisochaeta* to *Megascolex* where it has remained subsumed to this time.

A monotypic *Trichaeta* was established by Spencer (1900) for *Trichaeta australis* from Victoria, a species that has 12 setae per segment arranged in pairs, meronephridia (tufted anteriorly) and racemose prostates. This genus was subsequently subsumed in *Megascolex* (e.g. by Michaelsen, 1907; Stephenson, 1930).

Michaelsen (1907) defined *Spenceriella* with *Diporochaeta notabilis* Spencer, 1900 from Victoria as type-species, as he believed it differed from *Megascolex* principally through having plesiomorphic tubular prostates (as described by Spencer). Jamieson (1972a) (while conceding that 'the exact form [was] uncertain owing to partial fragmentation') concluded that the prostates were racemose (or 'racemose though elongate', Jamieson, 1971: 492) in a poorly preserved specimen that he designated a neotype of *Diporochaeta notabilis* (despite its noteworthy difference in arrangement of genital markings?). This observation rendered '*Spenceriella* indistinguishable from *Megascolex* as defined by Michaelsen (1907)'. Jamieson (1972a) omitted to define *Megascolex* but he saw no reason to consider *D. notabilis* to be congeneric with the type-species of *Megascolex* and therefore maintained both genera. However, if the justifiable view (e.g. held by Michaelsen, 1907: 160; Stephenson, 1930: 836) that an increase in setae in any part of the body beyond the plesiomorphic 8 per segment is the dividing line, then on the basis of its setal pattern and non-tubular prostates, *D. notabilis* conforms with previous definitions, not only of *Megascolex* but of both *Trichaeta* and *Anisochaeta* also. Since *Anisochaeta* is the priority genus, *Spenceriella* s. Jamieson as well as *Trichaeta* are, necessarily, synonymized in this genus upon separation from *Megascolex* s. str.

The type-species of *Megascolex*, *M. caeruleus* Templeton, 1844 from Sri Lanka, lacks extramural spermathecal diverticula and on this character alone can be separated from all known Australian megascolecids. It is therefore proposed to thus restrict *Megascolex* and to transfer pertinent Australian species to *Anisochaeta*. Many Australian species that formerly would have been included in *Megascolex* sensu lato have been variously allocated to *Spenceriella sensu* Jamieson, 1972a, to *Gemascolex* Edmonds and Jamieson, 1973 (which differs from *Spenceriella* principally by having genital markings, where present, intersegmentally) or to *Propheretima* Jamieson, 1995. This last genus was stated by Jamieson (1995: 590) to differ from *Spenceriella* by a combination of characters: presence of setae between the male pores, restriction of the clitellum to segments 14–16 and, typically, a single female pore. However, Jamieson (1972a), in his redescription of *D. notabilis* has the clitellum 'poorly developed, annular, on 14–16' and in his figure (Jamieson, 1972a: fig. 1D) appears to show a seta between the male pores. Moreover, at least one species included in *Spenceriella* s. Jamieson, *S. conondalei* Jamieson, 1995, has a single female pore, an erstwhile diagnostic characteristic of both *Propheretima* and *Gemascolex*. Full review of these genera is beyond the scope of the present study, but *Anisochaeta* as defined above probably forms a polyphyletic group (Stephenson, 1930: 712) and many included species may therefore eventually be transferred to other genera, including possibly several new ones.

Nexogaster gen. nov.

Diagnosis

Setae 8 per segment. Dorsal pores present. Male pores from racemose prostates paired on 18. An oesophageal gizzard in 5 and moniliform intestinal gizzards in the region of 22–27. Nephridia meroic, avesiculate, not tufted anteriorly. Spermathecae two pairs, spermathecal diverticula single, clavate. Calciferous glands and caeca absent, typhlosole present. Penial setae present.

Type-species. Nexogaster sexies sp. nov. (see below)

Distribution

North-western Tasmania.

Remarks

Nexogaster is distinguished from all known megascolecids by the possession of an oesophageal gizzard in segment 5 and moniliform intestinal gizzards in 22,23–26,27. The monotypic genus *Pleionogaster* Michaelsen, 1892 from the

Philippines (and doubtfully from Moluccas), while having intestinal gizzards in 26–28,29, differs principally by being perichaetine, vesiculate meroic and having an oesophageal gizzard in segment 8 (Easton, 1979). Its similarity in other respects supports a close relationship between Australian and Oriental megascolecids. Multiple intestinal gizzards are also found in the primitive and distantly-related, Oriental family Moniligastridae. Phylogenetic affinities of the present genus are unlikely to be close to those of *Hickmaniella* (q.v.) because taxonomic differences, such as the lumbricine setae, racemose prostates and typhlosole, suggest that their intestinal gizzards represent homoplastic rather than homologous development. Conversely, two new species (of *Notoscolex* and *Megascolides*) are described below which bear superficial similarity to *Nexogaster sexies* and may be indicative of its antecedents. For reasons that become apparent below, before *Notoscolex* and *Megascolides* can be considered it is necessary to reaffirm *Cryptodrilus*.

Cryptodrilus Fletcher, 1886
(Synonym: *Trinephrus*)

Cryptodrilus Fletcher, 1886: 570.
Cryptodrilus (part) + *Trinephrus*; Beddard, 1895: 483.
Notoscolex (part) + *Trinephrus*; Michaelsen, 1900: 185.
Notoscolex (part); Michaelsen, 1907: 162; Stephenson, 1930: 836–837; Gates, 1959: 254; Jamieson, 1972b: 518.
Cryptodrilus; Jamieson, 1972c: 154–155.
Cryptodrilus (part); Jamieson, 1974: 266.

Diagnosis

Setae 8 per segment. Dorsal pores present or absent. Male pores from tubuloracemose or racemose prostates paired on 18. An oesophageal gizzard in 5. Nephridia vesiculate meroic, with multiple bladders in at least some segments of body. Spermathecae two (or three) pairs, with one or more clavate diverticula. Extramural calciferous glands and caeca absent, typhlosole absent or present. Penial setae present or absent.

Type-species. *Cryptodrilus rusticus* Fletcher, 1886: 570–573.

Distribution

New South Wales, Victoria, Tasmania.

Remarks

The type species, *Cryptodrilus rusticus*, has vesiculate meronephridia (i.e. several nephridia per segment with terminal bladders), tubuloracemose prostates and two (opposed) or three spermathecal diverticula. Other congeneric species have the more usual single diverticulum. The attainment of nephridial bladders serves to separate *Cryptodrilus* from the prior Australian genus *Notoscolex* Fletcher, 1886 which in addition typically has racemose prostates and extramural calciferous glands.

The genus *Trinephrus* (with *Cryptodrilus fastigatus* Fletcher, 1889 as type-species) was erected by Beddard (1895) for those cryptodrilids with three pairs of nephridia per segment. Simultaneously and incorrectly Beddard placed *Notoscolex*, a prior genus, as a junior synonym in *Cryptodrilus*. While correcting and reversing this lapse, Michaelsen (1900) included the type-species of *Cryptodrilus* in *Notoscolex* and placed some Tasmanian cryptodrilids, viz. *Cryptodrilus officeri*, *C. polynephricus* and *Megascolides simsoni*, all of Spencer (1895), in *Trinephrus*. Later, Michaelsen (1907) transferred *Trinephrus* into the synonymy of *Notoscolex*. Whereas Jamieson (1972b: 518) included *C. rusticus* (but not *C. fastigatus*, cf. Jamieson, 1973: 235) in *Notoscolex*, Jamieson (1972c) restored *Cryptodrilus* (keeping *Trinephrus* as its junior synonym) for vesiculate meroic species after demonstrating multiple nephridial bladders in syntypes of both *C. rusticus* and *C. fastigatus*. Subsequently, Jamieson (1974: 266) expanded the diagnosis of *Cryptodrilus*, ignoring variations in nephridia from vesiculate to avesiculate (and presence or absence of preseptal funnels) and ignoring prostate form from tubular to racemose, so that it subsumed those characters that define both *Notoscolex* and *Megascolides*. This action is here reversed as conformity to types requires that species with plesiomorphic tubular prostates, never part of the original descriptions of *Cryptodrilus*, are excluded and only vesiculate meroic species are allowed. *Cryptodrilus* is diagnosed above and *Notoscolex* and *Megascolides* are restored and redefined below.

Notoscolex Fletcher, 1886

(Synonyms: *Tokea*, *Pseudonotoscolex*, ?*Oreoscolex*).

Notoscolex Fletcher, 1886: 546.
Notoscolex + *Megascolides* (part); Michaelsen, 1900: 187.
Notoscolex (part); Stephenson, 1930: 836.
Notoscolex; Michaelsen, 1907: 160–162; Lee, 1959: 317; Gates, 1959: 254; Jamieson, 1973: 236, 239.
Tokea Benham, 1904: 240.
Pseudonotoscolex Jamieson, 1971: 496.
Oreoscolex (part? excluding type-species); Jamieson, 1973: 215–252; 1974: 302–303.

Diagnosis

Setae 8 per segment. Dorsal pores present or absent. Male pores from racemose (or tubuloracemose?) prostates paired on 18. An oesophageal gizzard in 5 or 6. Nephridia meroic, at least in the fore-body, avesiculate, sometimes tufted. Spermathecae two or three pairs (or unpaired?), with multiloculate sessile (or one or more clavate) diverticula. Typhlosole typically absent; extramural calciferous glands typically present; intestinal caeca absent. Penial setae typically present.

Type-species. *Notoscolex camdenensis* Fletcher, 1886: 546–551, Pl. VII, figs 1–5.

Distribution

New South Wales, Victoria, Tasmania, Western Australia, southern Queensland, (New Zealand, ?South India, Sri Lanka).

Remarks

For *Notoscolex*, the 'classical' definition of Michaelsen (1900, 1907) and Stephenson (1930) (as perpetuated by Lee, 1959 and Gates, 1960) is retained for Australian species, after removal of vesiculate species to *Cryptodrilus* (q.v.). Although Jamieson (1973: 239) suggested that *Notoscolex* should be restricted to species with extramural calciferous glands in 14–16 (?and/or 9–13 as in *N. montiskosciuskoi* Jamieson, 1973), no significance was attached to the fact that the type-species has multiloculate spermathecal diverticula, often a generic character. It is possible that only those species with multioculate diverticula truly belong in *Notoscolex*.

In 1973, Jamieson erected the monotypic genus *Oreoscolex* for his *Oreoscolex imparicystis*, a species lacking calciferous glands but possessing these diagnostic features: lumbricine setae, avesiculate meronephridia, racemose prostates and unpaired, bidiverticulate spermathecae. An expanded diagnosis of *Oreoscolex* by Jamieson (1974: 302) permitted presence or absence of calciferous glands, racemose or tubuloracemose prostates, and uniloculate or multiloculate spermathecal diverticula. This re-definition was so expansive that it allowed synonymy with *Notoscolex*, a prior genus (and also with *Pseudonotoscolex*?). This impacts especially upon two of the eight Tasmanian species that Jamieson (1974) included under *Oreoscolex*: *Notoscolex leai* Michaelsen, 1910 and *N. sexthecatus* (Jamieson, 1974), as well as *Cryptodrilus ? albertisii* (Cognetti, 1910), *Notoscolex officeri* (Spencer, 1895) and *N. simsoni* (Spencer, 1895), as the states of the caudal nephridia in these species — pivotal for designation in Jamieson's scheme — were inconclusive. *Oreoscolex* is herein considered a junior synonym of *Notoscolex*, although an alternative view could allow its retention as a monotypic genus holding only the type-species, *O. imparicystis*, with its unpaired spermathecal pores. Two *Notoscolex* species have recently been described by Jamieson (1995), one as *Cryptodrilus bunyaensis* from southern Queensland, the other as *Oreoscolex retrocystis* (represented by a posterior amputee, aclitellate holotype that is possibly the '*Notoscolex* sp. from Galston Gorge' as adjudged in Jamieson, 1972c).

Jamieson (1971) erected the monotypic *Pseudonotoscolex* (a genus similar to *Notoscolex*) for his *P. pallinupensis* from Western Australia, a species represented by a posterior-amputee holotype. Later, Jamieson (1981: 907) raised the possibility of absorbing *Pseudonotoscolex* in *Cryptodrilus*, a move not permissible for an avesiculate species although its characteristics comply with the diagnosis of *Notoscolex* above. *Pseudonotoscolex* is therefore synonymized under *Notoscolex*.

Benham's New Zealand genus *Tokea* was synonymized under *Notoscolex* in Stephenson (1930: 837) (cf. Lee, 1959: 259), but it appears that some included species having tubular prostates actually belong in *Megascolides*.

Megascolides McCoy, 1878. Emend
(Synonyms: *Austrohoplochaetella*, *Pseudocryptodrilus*)

Megascolides McCoy, 1878: 21.
Cryptodrilus (part); Beddard, 1895: 497.
Megascolides; Michaelsen, 1900: 182; 1907: 160–161.
Megascolides + *Notoscolex* (part); Stephenson, 1930: 835.
Megascolides; Lee, 1959: 284–285.
Austrohoplochaetella Jamieson, 1971: 490.
Pseudocryptodrilus Jamieson, 1972c: 172.

Diagnosis

Setae 8 per segment. Clitellum typically developed over at least four segments. Male pores from tubular prostates paired on 18. An oesophageal gizzard in 5 or 6 (or 7). Nephridia meroic, at least in the fore-body, avesiculate or vesiculate, sometimes tufted anteriorly. Spermathecae one or more pairs, each with a clavate diverticulum. Typhlosole and calciferous glands present or absent; intestinal caeca absent. Penial setae present or absent.

Type-species. *Megascolides australis* McCoy, 1878.

Distribution

Victoria, New South Wales, Tasmania, Western Australia, (New Zealand, ?North America).

Remarks

The Victorian type-species, *Megascolides australis*, has numerous meronephridia per segment whereas other species included in the genus have fewer tubules and some appear transitional from holonephridia to meronephridia. In the present scheme, the rationale is that any nephridial forms intermediate between holonephridia and meronephridia (with the exception of tufted pharyngeal holonephridia) are classed as apomorphic meroic derivations. This pragmatic approach is consistent with Michaelsen and with Stephenson (1930: 830) who stated: 'From *Plutellus* is derived *Megascolides*, in which the nephridia are breaking up or have broken up; this apparently does not always take place in the same way. In one group of forms there are three or four nephridia on each side of each segment, all about the same size, while in other cases there is one large one and a number of quite small ones; however, all stages of the process are included in this genus, so long as the prostates and setae retain their original condition.' The generic definition above is emended only to note that both vesiculate and avesiculate nephridial forms are included since Jamieson (1972c; 1973) found multiple bladders in *Megascolides tenuis* (Fletcher, 1889). Incidentally, Michaelsen (1907: 161) had already transferred this New South Wales species to this genus (cf. Jamieson). *Megascolides* is distinguished from *Notoscolex* and *Cryptodrilus* by its possession of plesiomorphic tubular prostates.

Jamieson (1971) erected the monotypic genus *Austrohoplochaetella* for his species *A. kendricki* from Western Australia, its diagnosis differing from that of *Megascolides* principally because it exhibited transition from meronephridia to 'a pair of single stomate megameronephridia' caudally. Jamieson (1972c) proposed the monotypic genus *Pseudocryptodrilus* for *Megascolides diaphanus* Spencer, 1900 from Victoria which has a similar transition, but this time from meronephridia to 'a pair of stomate exonephric holonephridia' caudally. Both of these nephridial states, if indeed they differ, were preallowed in *Megascolides* by Michaelsen (1907: 160, 'wenigstens im Vorderkörper mikronephridisch'—at least in the fore-body meroic), as he described *Megascolides nokanenaensis* from Western Australia having just such nephridial transition. This is perhaps why Jamieson (1981: 907) stated that *Austrohoplochaetella* is probably a junior synonym of *Megascolides*, a view supported here. If this is the case, there is little justification for retaining *Pseudocryptodrilus* and it is therefore similarly synonymized.

Two Tasmanian species were placed in *Megascolides* by Spencer (1895), but neither belonged as *Notoscolex simsoni* (Spencer, 1895) has non-tubular prostates and *Vesiculodrilus? bassanus* (Spencer, 1895) was described with (vesiculate?) holonephridia.

Systematics, species descriptions

Hickmaniella gogi sp. nov.
(Fig. 1)

Material examined

HOLOTYPE (H) QVM:14:3328, Gog Range, N. Tasmania, 41°29'S 146°27'E, 27 August 1991, T. J. Kingston (mature, dissected and figured).

PARATYPES (P1) ANIC:RB.96.11.1, same details as H (mature, dissected); (P2) ANIC:RB.96.11.1, same details as H (immature); (P3) QVM:14:3319, same details as H (immature, dissected).

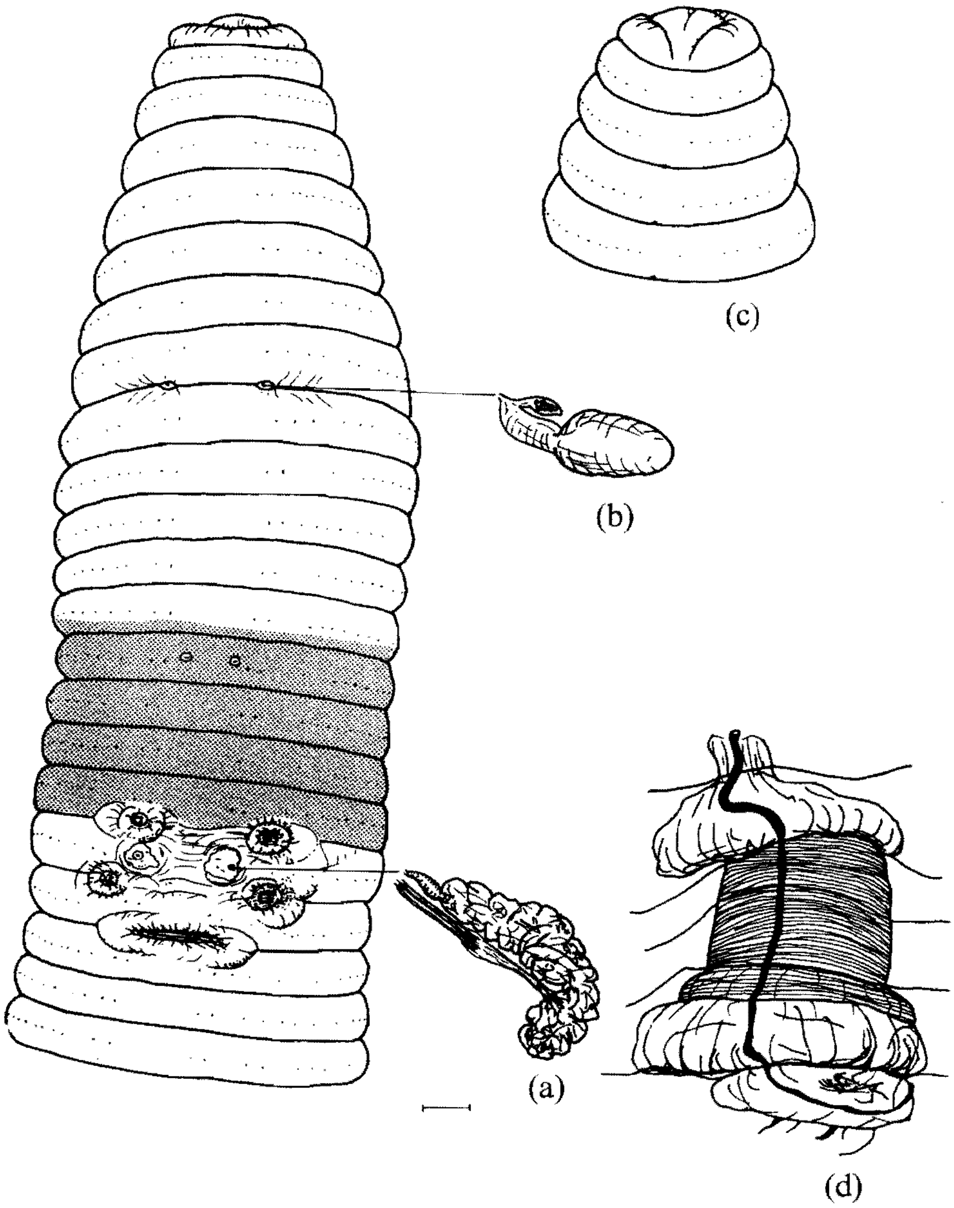

FIG. 1. *Hickmaniella gogi* sp. nov., holotype: (a) prostate and penial setae; (b) spermatheca; (c) prostomium; (d) intestinal gizzards in 19–20($\frac{1}{2}$21).

(P4) TM:K1523, Little Fisher River, Lake Rowallan, N.W. Tasmania, 41°42′S 146°18′E, 6 October 1992, R. D. D'Orazio and M. Cooper (mature, dissected and figured); (P5–9) QVM:14:0416, details same as P4 (five matures, one aclitellate).

(P10–14) QVM:14:0417, Dublin Creek, Lake Rowallan, N.W. Tasmania, 41°42′S 146°15′E, 6 October, 1992, R. D. D'Orazio and M. Cooper (five specimens: two clitellate, one aclitellate, two immature).

(P15) QVM:14:3532, Pelion Gap, N.W. Tasmania, 41°52'S 146°03'E, 31 January, 1992, D. Baker (mature, dissected).

(P16–18) ANIC:RB.96.11.3, Snake Creek Road, Mole Creek, N.W. Tasmania, 41°37'S 146°16'E, 5 October, 1992, R. D. D'Orazio and M. Cooper (one mature and two sub-adults, one dissected); (P19–21) QVM:14:0970, same details P16–18 (one mature and two sub-adults).

(P22–23) TM:K1524–1525, O'Neils Road, Gowrie Park, N.W. Tasmania, 41°26'S 146°14'E, 23 November 1992, R. D. D'Orazio and M. Gittus (one mature and one sub-adult, dissected); (P24–25) QVM:14:0679, same details P22–23 (two sub-adults).

External features

Body stout hardly tapering to tail, first segment compressed. Length mm: (H) 75, (P1) 70, (P4) 60. Width: *ca* 7 mm. Segments: (H) 98, (P1) 97, (P2) 91, (P3) 70, (P4) 103. Colour: unpigmented in alcohol, clitellum buff. Prostomium: tapering epilobous, faintly furrowed dorsally. Clitellum: weak in $\frac{1}{2}$13,14–17 (H, P1) or tumid in $\frac{1}{2}$13,14–17,$\frac{1}{2}$18 (most other matures). Dorsal pores: rudimentary in 2/3, open from 3/4. Nephropores: not found. Setae: numerous, 40–48 per segment, ventral couples ab in regular rows, other rows sinuous; dorsal setal gap *ca* $\frac{1}{2}$aa. Spermathecal pores: paired in 8/9 in a or ab lines within tumid area. Female pores: widely paired on 14. Male pores: paired on 18 on flat, irregular pads with two or three penial setae protruding. Genital markings: median troughs in bb in 10/11 (P10–12) or 13/14 and/or 16/17 (P1, P4–P9, P16–22); two pairs of ill-defined hollow disks joined by median troughs in 17/18 and 18/19 wider apart than the male pores (H, P1 and all other matures); elongate, depressed pads in bb in 19/20 same width as male pores (H, P1 and all matures except P10–15, P22).

Internal anatomy

Septa: 7/8–12/13 thickened, 9/10/11/12 peripherally adpressed in H (as pericardiac testis-sacs?). Gizzards: muscular but compressible oesophageal gizzard in 5; large muscular intestinal gizzard in 19–20 and perhaps part of 21 also modified; externally with lateral bands of muscle fibres, internally with longitudinal striations, wall *ca* 0·5 mm thick (thicker than that of oesophageal gizzard). Oesophagus: not especially dilated. Nephridia: avesiculate meroic, five or six tubules per side equatorially connected by mesentery; larger anteriorly but not tufted; funnels not found. Vascularization: dorsal blood vessel single; hearts 10–12 with connectives to supra-oesophageal vessel in 7–14. Spermathecae: one pair in 9; ampulla saccular (smooth in H, P1; irregular in outline in some other matures) on thick duct bearing small clavate diverticulum with numerous iridescent chambers internally. Male organs: holandric, iridescent testes in mucus in 10 and 11; small racemose seminal vesicles in 9 and 12. Ovaries: compact in 13. Prostates: tubuloracemose in 18, gland folded over itself; overlain by long penial setal sheaths and tendons. Intestine: from 18, dilated and thin-walled on either side of gizzard in 18 and in 21, spiralling from 22; typhlosole absent; gut contains soil with numerous quartz grits and sand.

Remarks

The definition of *Hickmaniella* has been emended to accommodate this bithecate species. Specific differences that further separate *Hickmaniella gogi* from *H. opisthogaster* are position of first dorsal pore and the form and arrangement of the genital markings. The genus *Hickmaniella* is perichaetine with tubuloracemose prostates, an intestinal gizzard in 19–20 and lacks a typhlosole (on these characters it differs from *Nexogaster* gen. nov. described below).

Distribution and habitat

Gog Range, Lake Rowallan, Pelion Gap, Mt. Roland and Mole Creek in north/north-western Tasmania.

Hickmaniella opisthogaster Jamieson, 1974
(Fig. 2)

Hickmaniella opisthogaster Jamieson, 1974: 301–302, Fig. 18A (p. 270), 32C, D (p. 325), Pl. 64–66.

Material examined

HOLOTYPE: (H) TM:K360, Parrawe, 41°18′S 145°35′E, 25 August, 1954, J. L. Hickman (mature, dissected). PARATYPES: (P1) BM:1973.2.34, same details as H (mature, dissected); (P2) TM:K361, same details as H (immature, here dissected to confirm intestinal gizzard).

Specimens. QVM:14:1619, Stephens Rivulet, Balfour Track Forest Reserve, N.W. Tasmania, 41° 08′S 144° 57′E, 18 May 1993, R. D. D'Orazio and D. E. Soccol (mature, dissected and figured, plus an immature).

QVM:14:1616, Bond Tier South, Dismal Swamp, N.W. Tasmania, 40°58′S 144°51′E, 19 May 1993, R. D. D'Orazio and D. E. Soccol (five specimens, one immature); ANIC:RB.96.11.4, same details, (six matures, one dissected);

QVM:14:3329–3330, Dismal Swamp, N.W. Tasmania, 40°59′S 144°51′E, 8 September 1987, T. J. Kingston (two matures, one dissected).

QVM:14:1260, Tram Road Picnic Area, Calder, N.W. Tasmania, 41°02′S 145°41′E, 19 April 1993, R. D. D'Orazio and D. E. Soccol (seven specimens).

QVM:14:1080, Hellyer Gorge Reserve, N.W. Tasmania, 41°17′S 145°37′E, 31 May 1993, R. D. D'Orazio and D. E. Soccol (one mature and one immature).

QVM:14:1074; Belmont Road, Waratah, N.W. Tasmania, 41°23′S 145°32′E, 31 May 1993, R. D. D'Orazio and D. E. Soccol (three matures).

QVM:14:562, West Calder Road, Calder, N.W. Tasmania, 41°05′S 145°37′E, 19 April 1993, R. D. D'Orazio and D. E. Soccol (one specimen).

QVM:14:1613, Trowutta Caves State Reserve, Smithton, N.W. Tasmania, 41°04′S 145°06′E, 17 May 1993, R. D. D'Orazio and D. E. Soccol (one mature, dissected).

QVM:14:3277, Walking Track off Bass Highway, near Dismal Swamp, 40°57′S 144°49′E, 24 June 1993, T. J. Kingston, J. Buckerfield, R. J. Blakemore (two matures); ANIC:RB.96.11.5, same details (two matures, one dissected).

QVM:14:3554, Fern Glade Reserve, Burnie, N.W. Tasmania, 41°05′S 145°55′E, 3 December 1996, R. J. Blakemore and T. J. Kingston (three matures, one dissected).
Type material not examined. (P3–4) AM: W5322–5323, Table Cape, 40°57′S 145°43′E, 24 August 1954, J. L. Hickman.

External features

Body short and robust, first segment compressed. Lengths mm: 45–70. Width: *ca* 5–5·5 mm. Segments: 80–90. Colour: unpigmented, clitellum buff. Prostomium: epilobous, weakly furrowed to appear tanylobous. Clitellum: ½13–½17 (often appears saddle-shaped when markings impinge). Dorsal pores: from 4/5 (rudimentary in 3/4

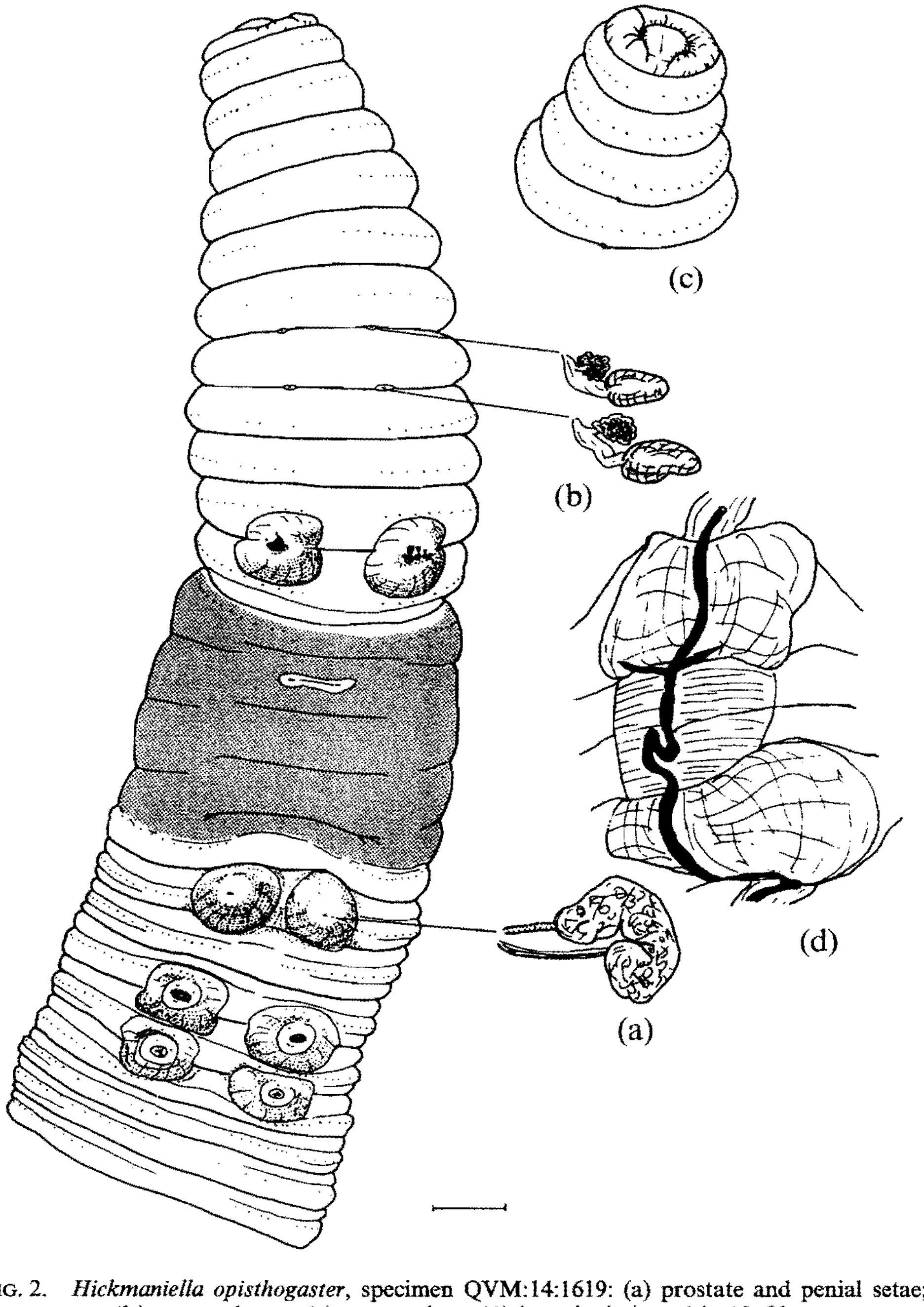

FIG. 2. *Hickmaniella opisthogaster*, specimen QVM:14:1619: (a) prostate and penial setae; (b) spermathecae; (c) prostomium; (d) intestinal gizzard in 19–20.

in some specimens). Nephropores: not found. Setae: 40–50 per segment; ventral gap wide, dorsal gap less so. Spermathecal pores: in 7/8/9 in a or ab lines. Female pores: paired on 14. Male pores: paired on 18 on prominent mounds, just wider than setal gap. Genital markings: large, paired (or analogue) glandular mounds in 11/12 and, variously, in 10/11, 14/15–16/17 and 19/20–22/23, slightly wider than male and spermathecal pores.

Internal anatomy

Septa: 6/7–12/13 thickening. Ventral nerve cord large. Gizzards: large spherical but weakly muscular oesophageal gizzard in 5; intestinal gizzard large and muscular in 19–20. Oesophagus: not especially dilated. Nephridia: avesiculate meroic, three or four per side equatorially as small, convoluted masses; not tufted anteriorly; funnels not found. Vascularization: hearts 10–12; supra-oesophageal vessel moderately developed in 7–13, large in 14–17. Spermathecae: two pairs in 8 and 9; saccular ampulla on short duct, diverticulum clavate with numerous internal chambers (sometimes rosette-like but not sessile). Male organs: holandric, testes and funnels in 10 and 11, iridescent and invested in mucus; racemose seminal vesicles in 9 and 12. Ovaries: in 13. Prostates: tubuloracemose, folded once in 18; long penial setae present. Intestine: from 18, dilated and thin-walled atria on either side of gizzard in 18 and 21 (the anterior crop-like dilation often impinges on gizzard in 19; that in 21 sometimes extends into segment 22 also), intestine spirals from 22; typhlosole absent; gut contains soil.

Remarks

This account confirms and considerably augments the type description. Morphological features recorded by the current study are the compressed first segment, epilobous prostomium, lack of pigmentation, lesser extent of the clitellum, variations in the distribution of genital markings, the large ventral nerve cord and the intestinal gizzard in 19 and 20 (rather than 19 or 20 according to Jamieson, 1974) with intestinal dilations on either side in 18 and 21. The distributional range is also expanded.

Distribution and habitat

North-western Tasmania from a north-south line from Burnie-Waratah, westwards to Balfour and Marrawah, including Parrawe, Hellyer Gorge, Wynyard, Smithton. Found mainly in wet sclerophyll and rainforest soils.

Anisochaeta simpsonorum sp. nov.
(Figs 3, 4)

Material examined

HOLOTYPE: (H) QVM:14:3275, Dismal Swamp Nature Reserve, N.W. Tasmania, 40°59′S 144°51′E, 8 September 1987, T. J. Kingston (mature, posterior amputee, dissected and figured).

PARATYPES: (P1) ANIC:RB.96.11.6, Walking Track off Bass Highway, near Dismal Swamp, 40°57′S 144°49′E, 24 June 1993, T. J. Kingston, J. Buckerfield, R. J. Blakemore (mature, posterior amputee, dissected and figured).

(P2–4) TM:K1526–1528, Belmont Rd., Waratah, N.W. Tasmania, 41°23′S 145°32′E, 31 May 1993, R. D. D'Orazio and D. E. Soccol (3 matures, P2 dissected and figured); (P5–P8) ANIC:RB.96.11.7, same details (4 matures); (P9–11) QVM:14:1075, same details, (three matures, P11 dissected, plus three unregistered juveniles).

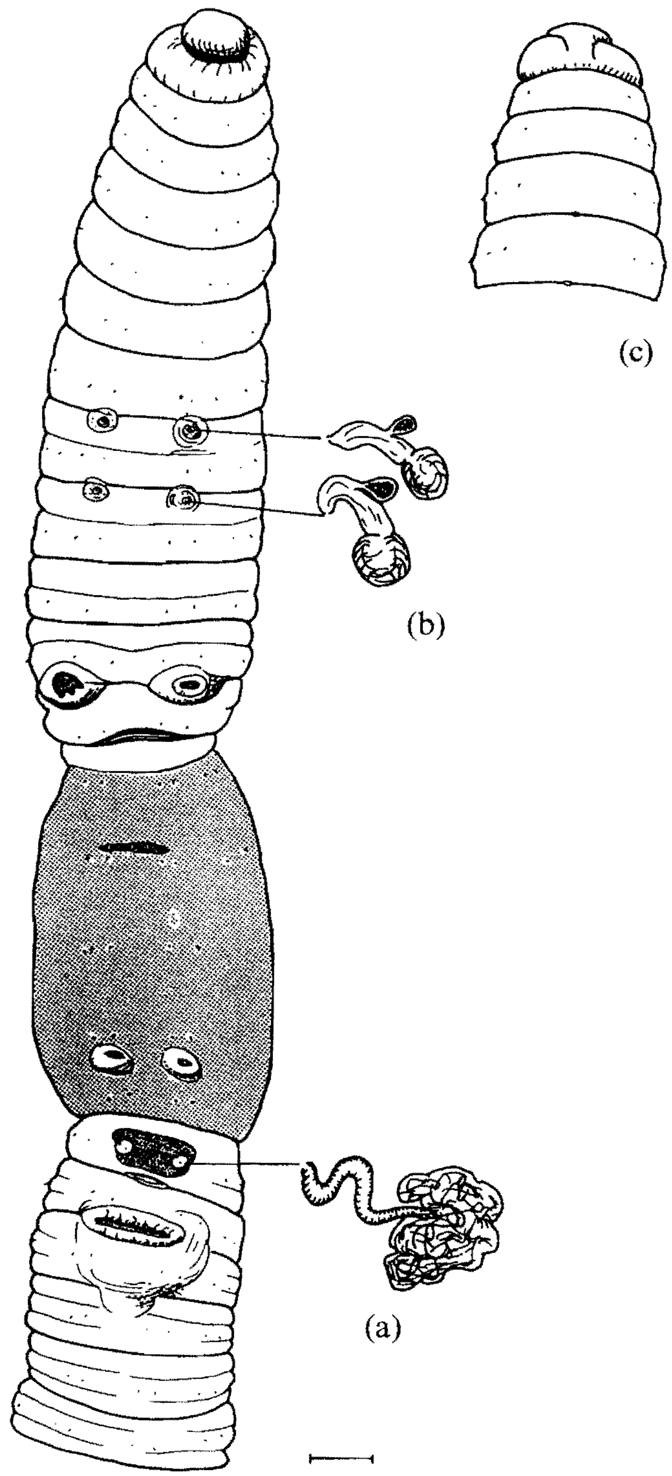

FIG. 3. *Anisochaeta simpsonorum* sp. nov., holotype: (a) racemose prostate; (b) spermathecae; (c) prostomium.

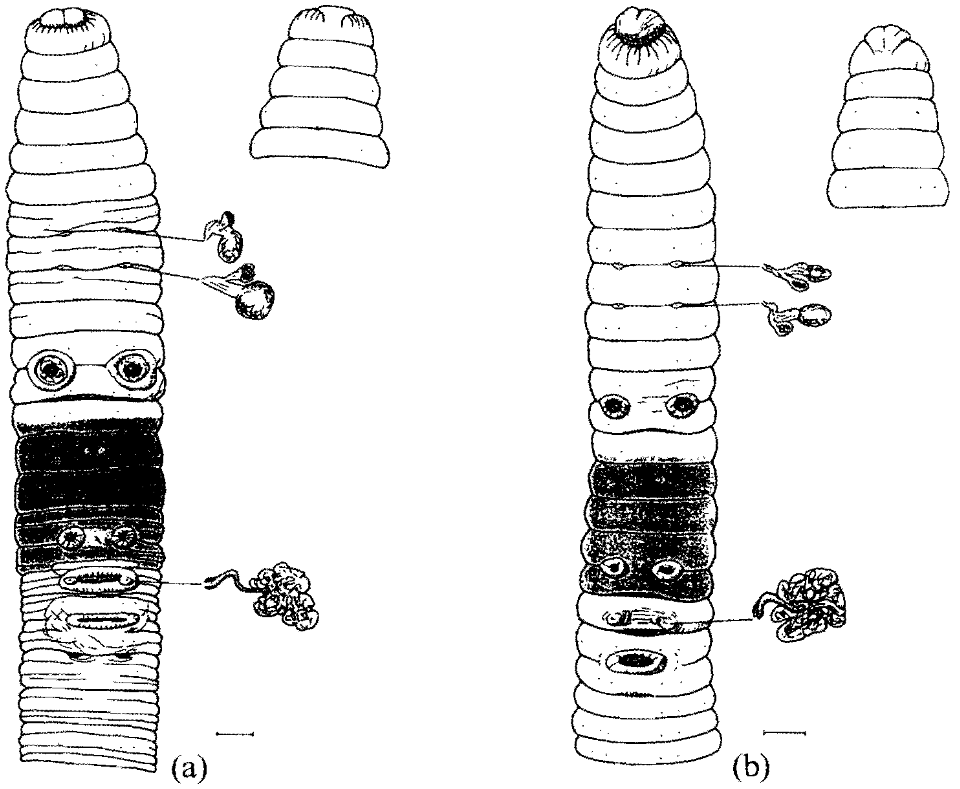

FIG. 4. *Anisochaeta simpsonorum* sp. nov., variations in spermathecae and markings: (a) P1; (b) P2.

(P12) QVM:14:3529, 'Killara' property, Marrawah, N.W. Tasmania, 41°01'S 144°44'E, 7 September 1987, T. J. Kingston (mature).

(P13) QVM:14:3530, Wombat Hill near Waratah, N.W. Tasmania, 41°29'S 145°27'E, 22 September 1990, R. Mesibov (mature, posterior amputee, dissected).

(P14–16) ANIC:RB.96.12.3–5, 1.5 Km along forest track in Crown land east of 'Killara' property, Marrawah, 41°01'S 144°44'E, 4 December 1996, R. J. Blakemore and T. J. Kingston (three matures, one dissected); (P17–19) TM:K1535–1537, same details, (three matures, one dissected); (P20) QVM:14:3572, same details (one mature, dissected; sample also contains nine sub-adult and immature specimens that superficially agree).

(P21) QVM:14:3052, Corinna Rd., N.W. Tasmania, 41°36'S 145°08'E, 2 June 1993, R. D. D'Orazio and D. E. Soccol (mature, dissected—separated off 14:1052 which contained 18 specimens).

(P22) QVM:14:1048, Pieman River, Corinna, N.W. Tasmania, 41°39'S 145°05'E, 2 June 1993, R. D. D'Orazio and D. E. Soccol (mature, dissected).

External features

Lengths mm: range 60–115; (P2–3) 93, (P5–12) 80–90, (P14–20) 60–80, (P21–22) 90–115, (H and P1 are 50 + and 55 + mm, respectively). Segments: (P2) 136, (P3) 140 (P21) 124, (P22) 114. Colour: pale, unpigmented or with a yellow tinge, clitellum orange/buff. Prostomium: open epilobous. Clitellum: ½13–17. Dorsal pores: from 4/5. Setae: 12 throughout in mostly regular rows except for some irregularities in cd lines posteriorly. Nephropores: not seen. Spermathecal pores: paired in 7/8–8/9 near a setal lines. Female pores: paired anteriomedial to setae a. Male pores: paired near a setal lines on small raised papillae within rimmed, mid-ventral tumid area. Genital markings: paired pads centred in b lines and extending slightly beyond ab lines in 11/12; (12/13 infolded ventrally in several specimens); smaller pads paired (or analogue) in ab lines in 16/17, sometimes absent; elongate trough in bb or aa in 19/20 surrounded by tumid area extending to setal arcs of 19–20; paired or single darkened patches in aa in 20/21. Markings are consistently in 11/12 and 19/20, however, P10–13 and P21–22 have aberrant markings: in P10 and P12 they are asymmetrical (in some of 11/12/13, 16/17 and 18/19/20/21), while P11, P13, P21–22 have elongate troughs in bb in 11/12 (and in aa in 16/17 in P11, P21–22) and in aa in 19/20 (P11, P13, P21–22).

Internal anatomy

Septa: thin in anterior, 9/10–12/13,13/14 only slightly thickened. Gizzard: in 5, muscular and barrel-shaped with anterior flange, displaced posteriorly. Oesophagus: dilated and internally lamellate in 10–16, especially 15–16, but not calciferous. Nephridia: avesiculate meroic, ca two or three small clusters of tubules per side becoming laterally connected bands in midbody; not tufted anteriorly; funnels not found. Vascularization: dorsal blood vessel single; hearts in 10–12; supra-oesophageal vessel in 9–13. Spermathecae: two pairs in 8 and 9; ampulla saccular on longer duct with clavate diverticulum from middle of duct (iridescent bulb sometimes has irregular outline). Male organs: holandric, iridescent testes and funnels in mucus in 10 and 11; seminal vesicles paired (sometimes rudimentary), saccular in 9 and racemose in 12. Ovaries: large in 13; small ovisacs paired in 14. Prostates: in 18, racemose, bilobed but appear as rosettes; ducts sinuous, wide at base; penial setae not found. Intestine: origin 18 (appears to be 17 in some specimens where septum 17/18 deflected anteriorly); darker and more dilated from 19; deep typhlosole developing from 20; intestinal gizzards absent; gut contains soil, some organic matter and quartz grits.

Remarks

This species is morphologically similar to parts of an *Anisochaeta montisarthuri* (Jamieson, 1974) species-complex at present under investigation in this laboratory. Differences include the numbers of setae, the positions of the genital markings, spermathecal and male pores, and the presence of seminal vesicles in 9.

Distribution and habitat

North-western Tasmania, in rainforest or wet sclerophyll forest soils. Samples from the Bass Highway, Belmont Rd and Dismal Swamp sites also contained specimens of *Hickmaniella opisthogaster*, a species having similar genital markings in 11/12.

Nexogaster sexies gen. et sp. nov.
(Fig. 5)

Material examined

HOLOTYPE (H) QVM:14:3320, 'Killara' property, Marrawah, N.W. Tasmania, 41°01'S 144°44'E, 7 September 1987, T. J. Kingston (mature, dissected and figured).

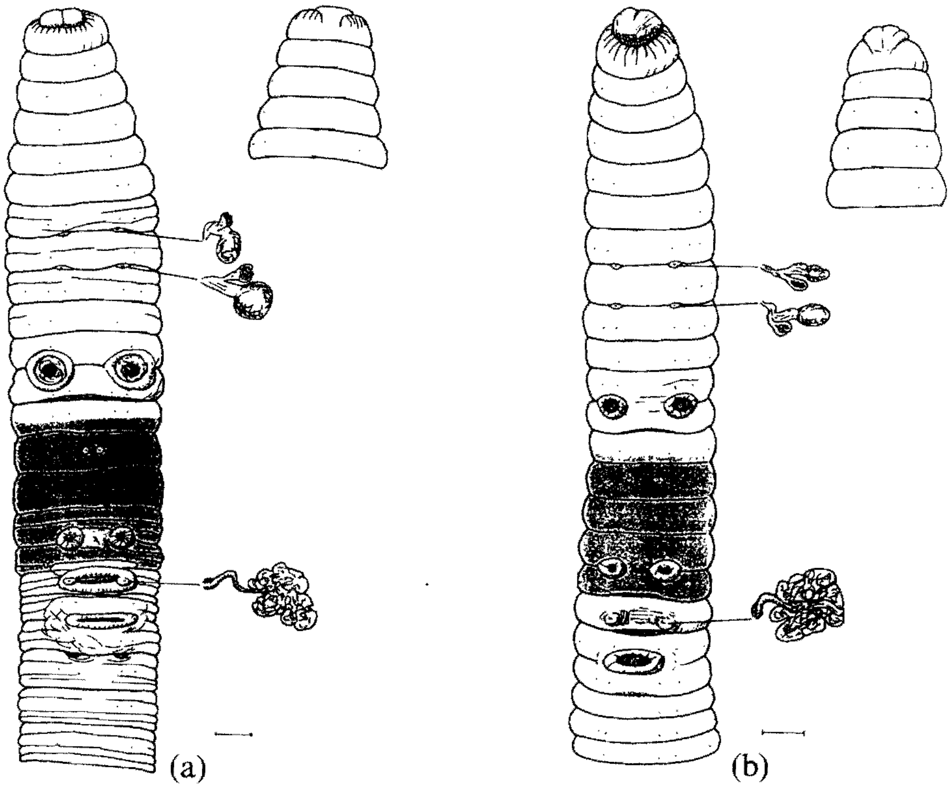

FIG. 4. *Anisochaeta simpsonorum* sp. nov., variations in spermathecae and markings: (a) P1; (b) P2.

(P12) QVM:14:3529, 'Killara' property, Marrawah, N.W. Tasmania, 41°01'S 144°44'E, 7 September 1987, T. J. Kingston (mature).

(P13) QVM:14:3530, Wombat Hill near Waratah, N.W. Tasmania, 41°29'S 145°27'E, 22 September 1990, R. Mesibov (mature, posterior amputee, dissected).

(P14–16) ANIC:RB.96.12.3–5, 1.5 Km along forest track in Crown land east of 'Killara' property, Marrawah, 41°01'S 144°44'E, 4 December 1996, R. J. Blakemore and T. J. Kingston (three matures, one dissected); (P17–19) TM:K1535–1537, same details, (three matures, one dissected); (P20) QVM:14:3572, same details (one mature, dissected; sample also contains nine sub-adult and immature specimens that superficially agree).

(P21) QVM:14:3052, Corinna Rd., N.W. Tasmania, 41°36'S 145°08'E, 2 June 1993, R. D. D'Orazio and D. E. Soccol (mature, dissected—separated off 14:1052 which contained 18 specimens).

(P22) QVM:14:1048, Pieman River, Corinna, N.W. Tasmania, 41°39'S 145°05'E, 2 June 1993, R. D. D'Orazio and D. E. Soccol (mature, dissected).

External features

Lengths mm: range 60–115; (P2–3) 93, (P5–12) 80–90, (P14–20) 60–80, (P21–22) 90–115, (H and P1 are 50 + and 55 + mm, respectively). Segments: (P2) 136, (P3) 140 (P21) 124, (P22) 114. Colour: pale, unpigmented or with a yellow tinge, clitellum orange/buff. Prostomium: open epilobous. Clitellum: ½13–17. Dorsal pores: from 4/5. Setae: 12 throughout in mostly regular rows except for some irregularities in cd lines posteriorly. Nephropores: not seen. Spermathecal pores: paired in 7/8–8/9 near a setal lines. Female pores: paired anteriomedial to setae a. Male pores: paired near a setal lines on small raised papillae within rimmed, mid-ventral tumid area. Genital markings: paired pads centred in b lines and extending slightly beyond ab lines in 11/12; (12/13 infolded ventrally in several specimens); smaller pads paired (or analogue) in ab lines in 16/17, sometimes absent; elongate trough in bb or aa in 19/20 surrounded by tumid area extending to setal arcs of 19–20; paired or single darkened patches in aa in 20/21. Markings are consistently in 11/12 and 19/20, however, P10–13 and P21–22 have aberrant markings: in P10 and P12 they are asymmetrical (in some of 11/12/13, 16/17 and 18/19/20/21), while P11, P13, P21–22 have elongate troughs in bb in 11/12 (and in aa in 16/17 in P11, P21–22) and in aa in 19/20 (P11, P13, P21–22).

Internal anatomy

Septa: thin in anterior, 9/10–12/13,13/14 only slightly thickened. Gizzard: in 5, muscular and barrel-shaped with anterior flange, displaced posteriorly. Oesophagus: dilated and internally lamellate in 10–16, especially 15–16, but not calciferous. Nephridia: avesiculate meroic, ca two or three small clusters of tubules per side becoming laterally connected bands in midbody; not tufted anteriorly; funnels not found. Vascularization: dorsal blood vessel single; hearts in 10–12; supra-oesophageal vessel in 9–13. Spermathecae: two pairs in 8 and 9; ampulla saccular on longer duct with clavate diverticulum from middle of duct (iridescent bulb sometimes has irregular outline). Male organs: holandric, iridescent testes and funnels in mucus in 10 and 11; seminal vesicles paired (sometimes rudimentary), saccular in 9 and racemose in 12. Ovaries: large in 13; small ovisacs paired in 14. Prostates: in 18, racemose, bilobed but appear as rosettes; ducts sinuous, wide at base; penial setae not found. Intestine: origin 18 (appears to be 17 in some specimens where septum 17/18 deflected anteriorly); darker and more dilated from 19; deep typhlosole developing from 20; intestinal gizzards absent; gut contains soil, some organic matter and quartz grits.

Remarks

This species is morphologically similar to parts of an *Anisochaeta montisarthuri* (Jamieson, 1974) species-complex at present under investigation in this laboratory. Differences include the numbers of setae, the positions of the genital markings, spermathecal and male pores, and the presence of seminal vesicles in 9.

Distribution and habitat

North-western Tasmania, in rainforest or wet sclerophyll forest soils. Samples from the Bass Highway, Belmont Rd and Dismal Swamp sites also contained specimens of *Hickmaniella opisthogaster*, a species having similar genital markings in 11/12.

Nexogaster sexies gen. et sp. nov.
(Fig. 5)

Material examined

HOLOTYPE (H) QVM:14:3320, 'Killara' property, Marrawah, N.W. Tasmania, 41°01'S 144°44'E, 7 September 1987, T. J. Kingston (mature, dissected and figured).

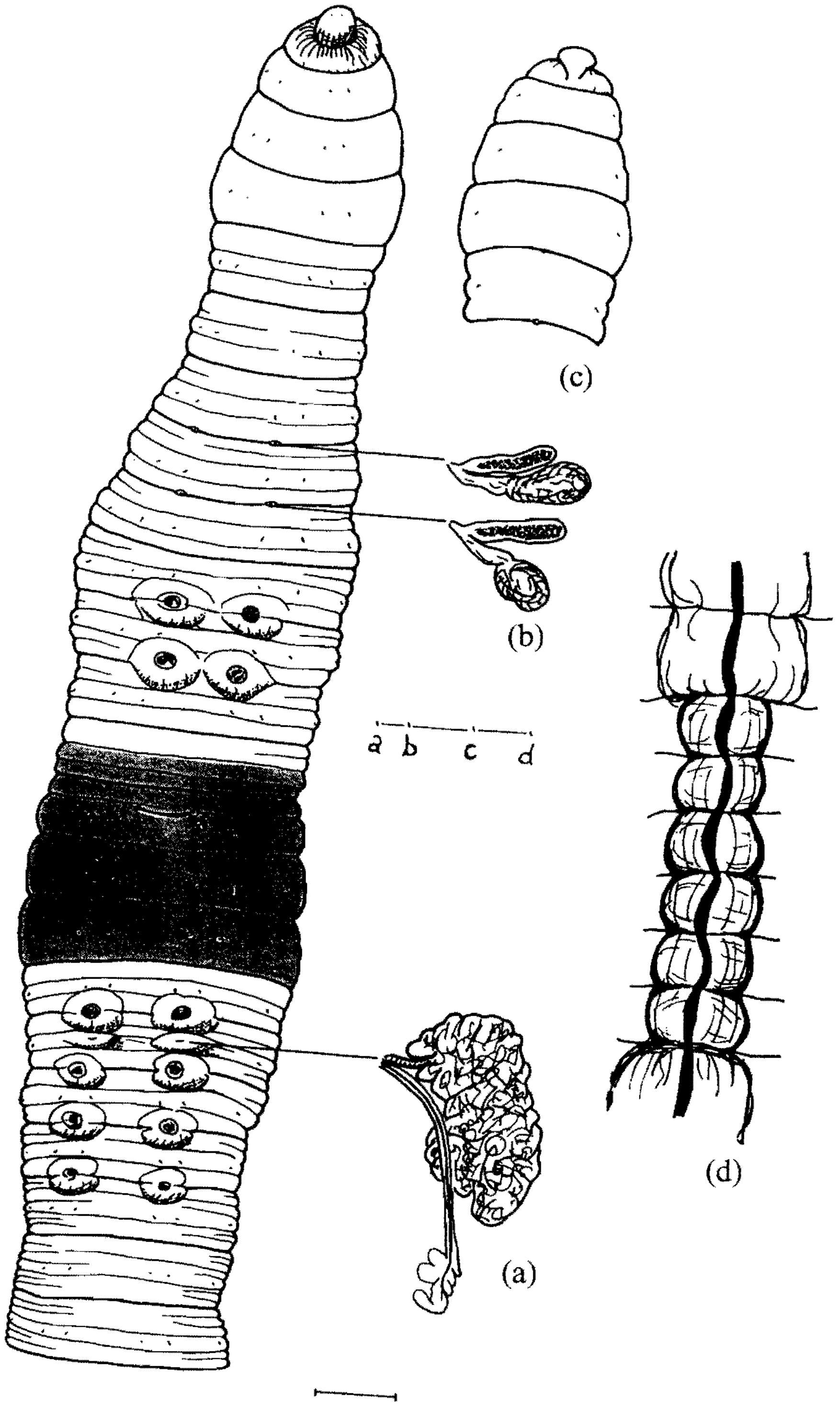

FIG. 5. *Nexogaster sexies* sp. nov., holotype: (a) racemose prostate and penial setae; (b) spermathecae; (c) prostomium; (d) intestinal gizzards in 22–27.

PARATYPES: (P1) ANIC:RB.96.11.9, same details as H (mature, dissected); (P2) TM:K1529, same details as H (mature); (P3) ANIC:RB.96.11.10, same details as H (mature, aclitellate); (P4), QVM:14:3324, same details as H (a mature specimen, dissected).

(P5) QVM:14:3571, New Paddock at 'Killara', 24 June 1993, T. J. Kingston, R. J. Blakemore, J. Buckerfield, S. Pilkington (a mature specimen); (P6) ANIC:RB.96.12.2, same details as P5 (mature, dissected); (P7), TM:K1534, same details as P5 (mature).

External features

Body slender, often dorso-ventrally flattened, first segment not reduced. Length mm: range 60–90; (P6–7) 90, (H, P2 and P5) 80, (P1) 75, (P3) 65, (P4) 60. Width: *ca* 3·3 mm. Segments: (H) 132, (P1) 128. Colour: unpigmented in alcohol, small yellow dots laterally near c setae; clitellum buff. Prostomium: open epilobous. Clitellum: ½13–16,½17. Dorsal pores: small in 4/5, larger from 5/6. Nephropores: not found. Setae: eight in regular rows (except in some specimens setae are slightly irregular at the caudal extremity and, seen in H, occasional odd or duplicated seta added); P1 has several dark speckles of unknown origin ventrally on 18 and 19. Spermathecal pores: 7/8–8/9 in a lines. Female pores: paired. Male pores: paired on small mounds in ab. Genital markings: large, paired sucker-like discs in 10/11 and sometimes also in 11/12 (in H, P3, P6, P7) centred in a lines; similar disks in 17/18 and some of 18/19–20/21 in ab (markings absent from 18/19 in P1, P4 and P7; absent from 20/21 in P2, P5 and P7); i.e., consistently occurring only in 10/11, 17/18 and 19/20.

Internal anatomy

Gizzards: muscular oesophageal gizzard in 5; intestinal gizzards smooth, muscular and moniliform in 22–27 (in H and P1) or 23–27 (P4) or 22–26 (P6), i.e. five or six of. Oesophagus: slightly dilated but not calciferous in 14–15,16. Nephridia: avesiculate meroic, clusters of four or five tubules per side centred around bc and easily broken up on dissection; larger in clitellar region, becoming smaller after this; not tufted anteriorly; funnels not found. Vascularization: hearts 10–12; supra-oesophageal vessel 9–12. Spermathecae: two pairs in 8 and 9; saccular ampulla with large, wholly iridescent, clavate diverticulum on duct ectally. Male organs: holandric, iridescent testes in 10 and 11; racemose seminal vesicles paired in 9 and 12. Ovaries: large in 13. Prostates: racemose in 17–19,20; long, curving penial setae present. Intestine: from 18, dilated and thin-walled in 18–21,22; intestinal gizzards 22,23–26,27, moderately deep typhlosole after intestinal gizzards from 28; gut contains organic matter or dark soil and many quartz grits.

Remarks

Hickmaniella (q.v.) was the only previously known Australian megascolecid to have an oesophageal and an intestinal gizzard. From this genus *Nexogaster* differs by being lumbricine and by having racemose rather than tubuloracemose prostates, clavate spermathecal diverticula without multiple internal chambers, a typhlosole, and 5–6 intestinal gizzards in series rather than a single intestinal gizzard. Despite literally one or two aberrant setae occurring on the tail in the holotype (at least?), these are not sustained and consequently the lumbricine state is retained.

The name *Nexogaster sexies* alludes to the connected intestinal gizzards repeated about 6 times.

Distribution and habitat

Marrawah, on a farm property. Specimens were collected following cultivation of indigenous swampy heath vegetation and after sowing to pasture. This narrowly distributed species may thus be endangered by agriculture.

Notoscolex pilus sp. nov.
(Figs 6, 7)

Material examined

HOLOTYPE: (H) QVM:14:3325, Dismal Swamp Nature Reserve, N.W. Tasmania, 40°59′S 144°51′E, 8 September 1987, T. J. Kingston (mature, dissected and figured).

PARATYPES: (P1) ANIC:RB.96.11.8, same collection data as H (mature, dissected).

(P2) TM:K1530, Belmont Rd, Waratah, N.W. Tasmania, 41°23′S 145°32′E, 31 May 1993, R. D. D'Orazio and D. E. Soccol (mature, dissected); (P3) QVM:14:3326, same details (mature); (P4) QVM:14:3566, same details (weakly clitellate mature, possibly a posterior regenerate, dissected; plus an unregistered immature that superficially agrees).

(P5) QVM:14:2524, Wombat Hill near Waratah, N.W. Tasmania, 41°29′S 145°27′E, 22 September 1990, R. Mesibov (mature, dissected; (P6) ANIC:RB.96.11.14, same details (mature); (P7) ANIC:RB.96.11.15, same details (mature, dissected); (P8) TM:K1533, same details (mature); (P9), same details (mature, dissected); (P10), QVM:14:3567, same details (mature); (P11), QVM:14:3568, same details (sub-adult); (P12) QVM:14:3569, same details (sub-adult).

(P13), QVM:14:0111, Frog Flats, Pelion Valley, N.W. Tasmania, 41°48′S 146°02′E, 13 February 1992, T. J. and M. E. Kingston (mature, dissected and figured).

(P14) QVM:14:0124, near Old Pelion Hut, Pelion Valley, N.W. Tasmania, 41°48′S 146°03′E, 12 February 1992, T. J. and M. E. Kingston (mature).

External features

Lengths mm: range 30–55; (H, P1, P13–14) 30, (P2–3) 55, (P5–10) 38–45. Width: 1·8 mm. Segments: (H and P13) 84, (P1) 95, (P2) 98, (P5) 94. Colour: unpigmented or with yellow tinge in alcohol; clitellum yellowish. Prostomium: open epilobous (faint ventral cleft on peristomium in some specimens). Clitellum: $\frac{1}{2}$13–16,$\frac{1}{2}$17. Dorsal pores: small in 4/5, larger from 5/6. Nephropores: not found. Setae: eight throughout in regular series (sometimes slightly irregular in tail). Spermathecal pores: 7/8–8/9 in a lines. Female pores: paired. Male pores: paired on small mounds in ab; upward curving tips of long penial setae protrude. Genital markings: faint paired discs posterior to spermathecal pores in 8 and 9 (H, P5–12—these Wombat Hill specimens, except P6, P10–11, have additional markings in either 7 or 10); large mid-ventral pad with median eye-like marking in 10 (P4) or 13 (P5, P8–9, P12) or in 17 (H, P1, P12) or paired in 17/18 in b lines (P2–P12) or a lines (P13–14 from Pelion Valley); some specimens possibly have weak paired markings in b lines in 18/19; paired eye-like markings within tumid pads in ab in 19/20 (P3,

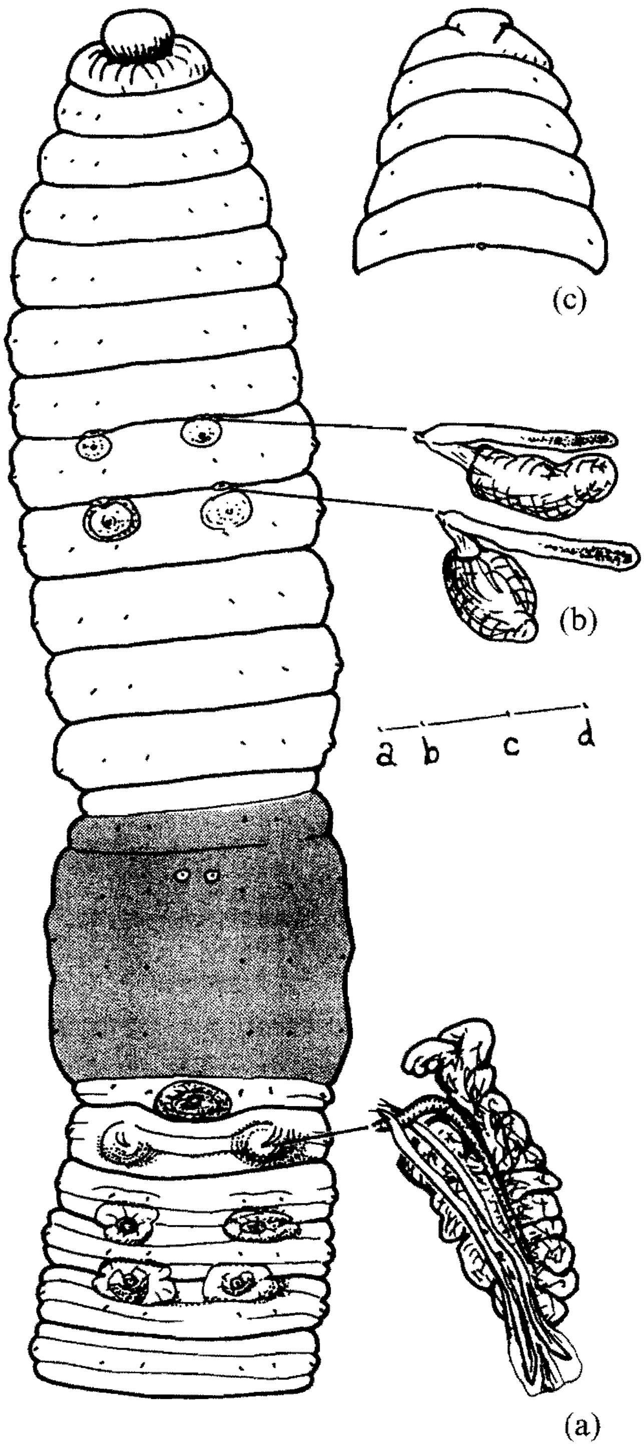

FIG. 6. *Notoscolex pilus* sp. nov., holotype: (a) tubuloracemose prostate with external duct and penial setae; (b) spermathecae; (c) prostomium.

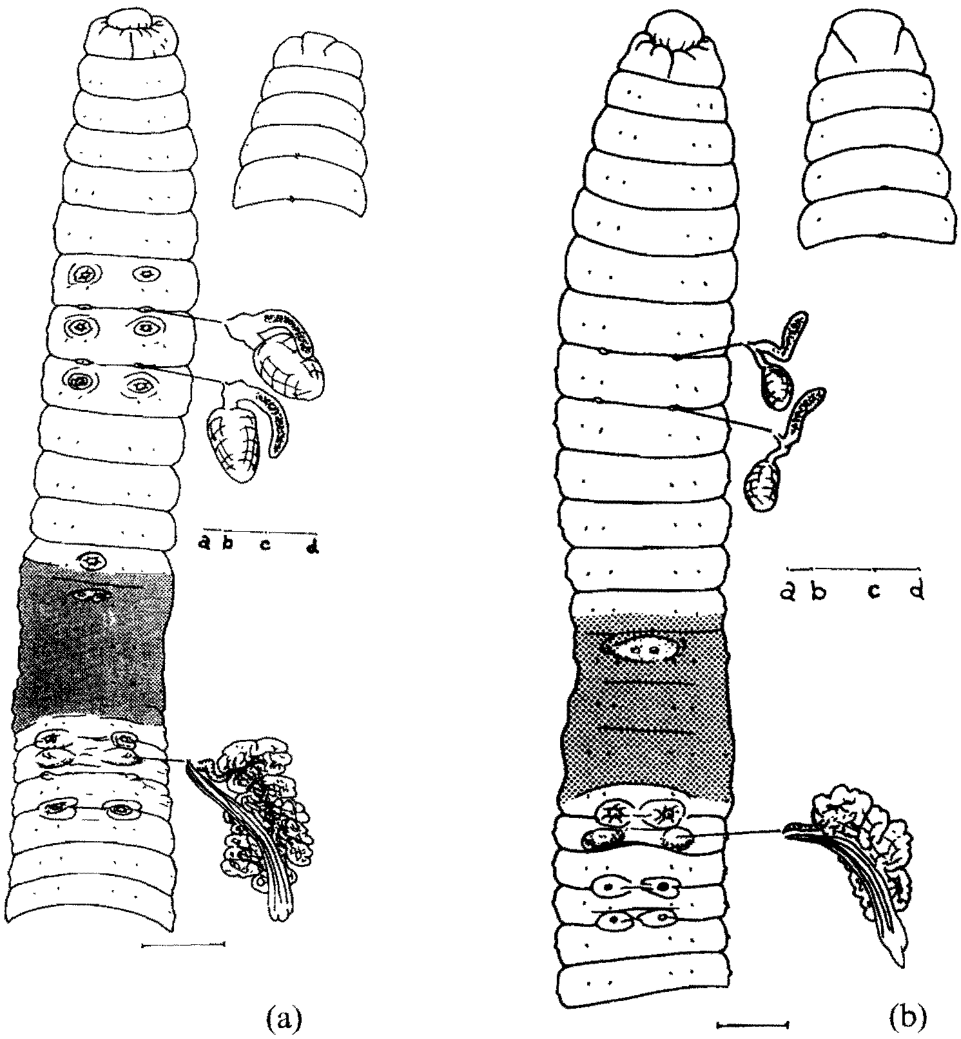

FIG. 7. *Notoscolex pilus* sp. nov., variations in genital markings: (a) P5; (b) P13.

P5–7, P11–12) and 20/21 (H, P2, P8–10 and P13–14 although markings are more ventral in these latter two specimens) and 21/22 (P1).

Internal anatomy

Septa: thin. Gizzard: muscular in 5 (but displaced to 6). Oesophagus: white, dilated and lamellate in 14 and 15 forming annular calciferous glands. Nephridia: avesiculate meroic, two per side in *ca.* b and d lines, intertwined but separable with care in fore-body, (appearing as holonephridia in hind-body); not tufted anteriorly. Vascularization: hearts 10–12; supra-oesophageal vessel weak in 9–12. Spermathecae: two pairs in 8 and 9; elongate ampulla on short duct with long, digitiform diverticulum ectally (iridescent). Male organs: holandric, iridescent testes in 10 and 11 in seminal mucus; racemose seminal vesicles in 9 and 12. Ovaries: large in 13; ovisacs absent. Prostates: tubuloracemose (or flattened racemose?) in 18–20,21; duct external to the glandular part for most of its length (H and P1) and (in P1 only) bilobed; long, curving penial setae sheathed in 18–23. Intestine: from 17 but septum 16/17 often displaced forwards; intestinal gizzards absent; typhlosole absent but low dorsal ridge sometimes present; gut contains gritty, yellow soil.

Remarks

Notwithstanding the possibility that only species with multiloculate spermathecal diverticula (and extramural calciferous glands) are truly congeneric with the type-species of *Notoscolex*, the present species is tentatively placed in this genus. *Notoscolex* species known from the north-west region that possess two pairs of spermathecae are *N. simsoni*, *N. irregularis* (Spencer, 1895) and *N. bidiverticulatus* (Jamieson, 1974), all differ from *N. pilus* (based on reinspection of types and on new material), not least in the distribution of genital markings. Similar quadrithecal species from south-eastern Tasmania are *N. campestris* (Spencer, 1895), *N. leai* Michaelsen, 1910 and *N. wellingtonensis* (Spencer, 1895), however these species have multiloculate spermathecal diverticula (and often a deep typhlosole).

Some variations in the arrangements of genital markings appear in different populations of *N. pilus* as described above (cf. those from Wombat Hill and Pelion Valley). Specimens from these populations nevertheless conform on all other morphological characters.

The shape of the spermathecae, prostates and penial setae in *Notoscolex pilus* are reminiscent of *Nexogaster sexies*; this latter species differs in the distribution of its anterior genital markings, larger size, racemose prostates, in having a deep typhlosole and, most significantly, in having intestinal gizzards. *Notoscolex pilus* may represent a species having common descent with *Nexogaster sexies* from a precursor that was perhaps not unlike *Megascolides maestus* (below).

Distribution and habitat

From Dismal Swamp Nature Reserve, Waratah and Pelion Valley in north-west/ central Tasmania.

Megascolides maestus sp. nov.
(Fig. 8)

Material examined

Holotype: (H) QVM:14:3327, Dismal Swamp Nature Reserve, N.W. Tasmania, 40°59′S 144°51′E, 8 September 1987, T. J. Kingston (complete mature, dissected and figured).

Paratypes: (P1) ANIC:RB.96.12.1, Dismal Swamp, approximately 400 m along eastern reserve track, 3 December 1996, R. J. Blakemore and T. J. Kingston (complete mature, dissected); (P2) TM:K1531, same details as P1 (mature in two halves, dissected).

(P3) QVM:14:3570, Dismal Swamp, gully west of turn off beside Bass Highway, 40°58′S 144°51′E, 3 December 1996, R. J. Blakemore and T. J. Kingston (mature, caudal tip missing).

External features

Lengths mm: *ca* 35. Width: 1·6 mm. Segments: (H) 99, (P1) 105, (P2) 102. Colour: unpigmented, small yellow dots near setae c on anterior segments; clitellum

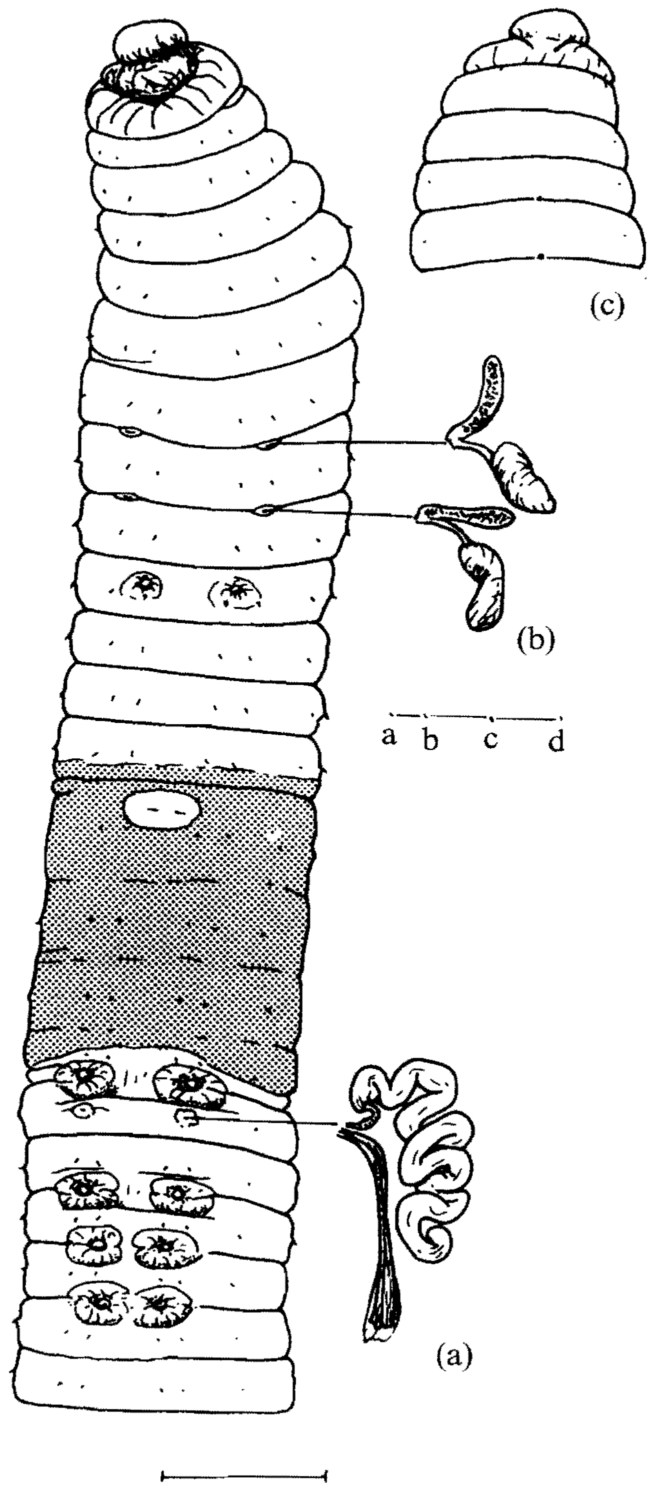

FIG. 8. *Megascolides maestus* sp. nov., holotype: (a) tubular prostate and penial setae; (b) spermathecae; (c) prostomium.

pale yellow. Prostomium: open epilobous. Clitellum: ½13–½17,17. Dorsal pores: small in 4/5, larger from 5/6. Nephropores: not found. Setae: eight throughout in regular series. Spermathecal pores: 7/8–8/9 in b lines. Female pores: paired in 14. Male pores: superficial in ab on 18. Genital markings: paired discs anterior to a setae on 10; pairs of discs in ab obscuring median intersegmental furrow in 17/18, and slightly narrower in 19/20–21/22 (three pairs in H; the last pair not developed in P1; only the first pair in P2–3 plus analogue on right in 20/21 in P2).

Internal anatomy

Septa: thin. Gizzard: compact muscular in 5 (displaced to appear in 6). Oesophagus: narrow except for white dilated annulations (calciferous glands?) in 14 and 15. Nephridia: avesiculate meroic; two per side approximately in b and d lines, intertwined and appearing as holonephridia but separable with care; not tufted. Vascularization: hearts 10–12; supra-oesophageal vessel seen in 9–12. Spermathecae: two pairs in 8 and 9; elongate saccular ampulla on thin duct with long and iridescent, digitiform diverticulum ectally. Male organs: holandric, iridescent testes in 10 and 11 in mucus; racemose seminal vesicles in 9 and 12. Ovaries: in 13; ovisacs absent. Prostates: tubular, coiled in 18–20, duct short; long penial setae in 18–23. Intestine: from 17 (septum 16/17 anteriorly displaced); gizzards absent although intestinal wall slightly thickened in 18–23; typhlosole absent; gut contains yellow soil, woody particles and some quartz grits.

Remarks

Superficially *Megascolides maestus* is similar to the sympatric *Notoscolex pilus*; major morphological differences are its plesiomorphic tubular prostates and, at the specific level, its characteristic markings in 10 and spermathecal pores in b, rather than a, setal lines. The occurrence of both these species in the same sample as specimens of *Hickmaniella opisthogaster* is of interest as this latter species may be derived from ancestral stock similar to *M. maestus* that has acquired tubuloracemose prostates (as in *Notoscolex pilus*) and, additionally, perichaetine setae and an intestinal gizzard. *Nexogaster sexies* has undergone a different transition, attaining racemose prostates while retaining lumbricine setae and developing moniliform intestinal gizzards that must bestow an advantage, perhaps acting as 'grinding mills' using ingested quartz grits for more thorough comminution of its food. It is perhaps also significant that both *M. maestus* and *N. pilus* have calciferous gland-like modifications of the oesophagus whereas neither *Hickmaniella* spp. nor *Nexogaster sexies* has.

The only previously described *Megascolides* from Tasmania is *Megascolides acanthodriloides* (Jamieson, 1974) which, amongst other differences, lacks calciferous glands. The distinctive male genital field of *M. acanthodriloides* was stated by Jamieson (1974) to distinguish this species from *M. diaphanus* from Victoria but also to demonstrate a 'special relationship' with *Notoscolex bidiverticulatus* from Tasmania with which it has an almost identical genital field (as does *Woodwardiella acanthodriloides* Jamieson, 1971, figs. 2(a) and 4(b)). The occurrence of *Megascolides* in Victoria, New South Wales and Western Australia (see generic definition above) serves to link the Tasmanian fauna with those of both the eastern and the south-western subregions of Australia.

Distribution and habitat

Dismal Swamp Nature Reserve, sympatric with *Hickmaniella opisthogaster*, *Anisochaeta simpsonorum* and *Notoscolex pilus* and some other new endemic species, currently in the process of being described, as well as exotic lumbricids.

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