Original Article

Redescription of extinct New Zealand earthworm: *Tokea orthostichon* (Schmarda, 1861) (Annelida, Oligochaeta, Megadrilacea, Megascolecidae)

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Abstract. The first native earthworm formally described from Australasia, *Tokea orthostichon* (Schmarda, 1861), also has the distinction of now being classed extinct. Lingering doubts about its identity have been largely dismissed due to inspection of primary type (Vienna) and of other museum specimens (Hamburg, London) that have been erroneously claimed as such.

Key words: megadrile earthworms, conservation, extinction, invertebrates

Introduction

The first native earthworm formally described from Australasia, New Zealand's *Tokea orthostichon* (Schmarda, 1861), also has the distinction of now being classed extinct (Blakemore 2012). Lingering doubts about the identity of Schmarda's worm have been due to conflicting claims of museum type specimens (in Vienna, Hamburg and/or London). In 2016 the primary type from Vienna was kindly loaned to the author in Japan to confirm its identity. This report supports its extinction status as per IUCN's Redlist (Blakemore 2017).

Methods

The loaned Vienna type-specimen is described below with Discussion confined to Remarks.

Results

Synonymy and description:

Tokea orthostichon (Schmarda, 1861) (Figs. 1–6).

Hypogaeon orthostichon Schmarda, 1861: 12 (with text-fig. of seta), pl. 18, fig. 159; Beddard, 1891: 278; Benham, 1947: 350. [From Mt Wellington Auckland, not Tasmania (Blakemore 2000, 2012); type listed as in both Vienna and Hamburg (see below)].

Lumbricus orthostichon: Hutton, 1878: 317; Fletcher, 1886: 534.

Megascolides orthostichon: Beddard, 1892: 130; 1895: 496; Michaelsen, 1907: 161; Lee, 1959: 349; (non Lee, 1962: 175–176, figs. 11, 12 – see *T. maorica*); Blakemore, 2000a, b: 261–263, fig. 105; 2010; 2011; 2012: 121.

Notoscolex orthostichon: Michaelsen, 1900: 189; Ude, 1905: 83, 429; Michaelsen, 1917: 38–40, Pl. I, figs. 12–14 (but fig. 14, was also ascribed to *T. esculenta* type by Michaelsen, 1917: 48); Benham, 1947: 350.

Notoscolex (*Tokea*?) *orthostichon*: Benham, 1904a: 284; 1904b: 255.

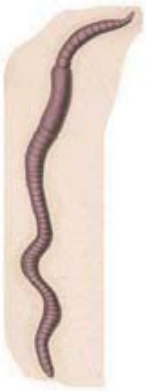

Fig. 105.
Megascolides orthostichon (Schmarda, 1861), from Schmarda (1861) Plate XVIII, fig. 159.

Fig. 1. Schmarda's original figure (from Blakemore 2000b; fig. 105; 2012: fig. 12).

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Fig. 2. Loaned type as received in Japan in 2016 (author's photo).

Fig. 3. Prostomium (author's photo 2016).

Fig. 4. Deteriorating clitellum and ventrum pinned at 12–13 (*ditto*).

Fig. 5. Distinctive male pores on 18 (*ditto*).

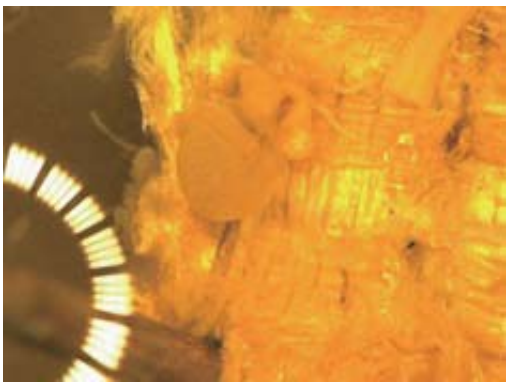

Fig. 6. Spermatheca in 8lhs in setal "a" line, with ventral nerve (*ditto*).

Tokea orthostichon: Blakemore, 2014: 148, fig. 13 (of Schmarda's text-fig. seta and Michaelsen's figs. 12–14 but fig. 14 is likely from *T. esculenta* type); Blakemore, 2017 .

Types and material inspected: Vienna Museum specimen, here affirmed as the lectotype: V.3948 registered as "*Notoscolex orthostichon (Schmar.) Neuseeland 1 Typus!*" with Schmarda's exterior label: "*K. [?] Universität Zool Vergl. Anat. Inst. Hypogaeon orthostichon S. 37 S[ch.?] N. Seeland*", and two labels inside the jar: "*Nr 37 Hypogaeon ortho. tischon [sic] N. Seeld.*" and "*Megascolides orthostichon (Schmarda) (Orig.!)*". A single, previously dissected and somewhat

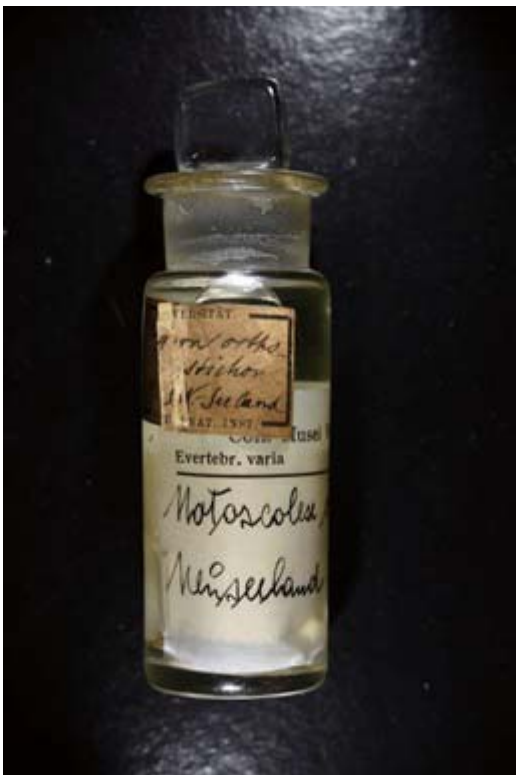

Fig. 7. Vienna type specimen as inspected above (photo: courtesy curator).

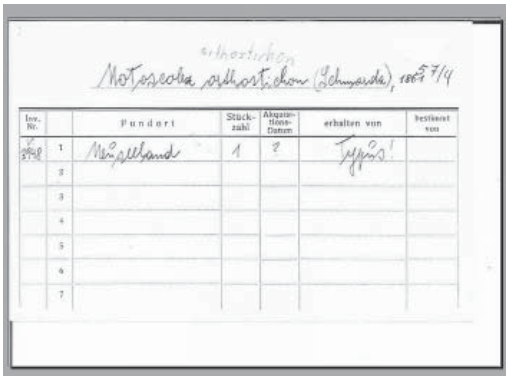

Fig. 8. Vienna type registration card (*ditto*).

damaged specimen with the cuticle, many internal organs, and the anterior digestive tract removed (by Beddard?) and missing. Specimen collected from Auckland in 1854 (from Glasby & Read, 1998: 349). Vienna Museum curator sent original photos (Figs. 7–8).

Beddard (1892) had inspected type material in the Vienna Museum, dissecting the specimen, and Beddard (1895: 496) later noted "*..I had only the type of Schmarda, which it was necessary to respect.*" Michaelsen (1917) said that when he was sent this same type it was unfortunately poorly preserved and was bent and damaged at 17/18 with many of the organs removed (likely by Beddard, as he did for some other types – such as for *Acanthodrilus dissimilis* Beddard, 1885: 825, fig. 3 – and not by Schmarda who did not describe its internal anatomy). This type was kindly sent to me in a plastic container half filled with "Ethylenglykol" by Dr. Helmut Sattmann head curator of Vienna Museum. My inspection (below) of the type found it to be severely damaged by previous dissection, strangely in the ventrum anterior from 1–17 (by Beddard) and dorsally after 17 thus it is almost broken in two at 17/18, and the posterior was also dissected ventrally (its orientation difficult to determine there as the setae are almost equidistant and dorsal pores absent although the position of the cut ventral nerve cord was a good reference). As the cuticle appeared to have been removed earlier, the clitellum in the type was almost detached when inspected in October, 2016 and disintegrated further during inspection when in Ethanol (70 %).

The type was also listed as Hamburg Museum: V.8615 (e.g., https://wvv.inhs.illinois.edu/people/mjwetzel/nomenoligo/nomenclatorspecierum/nomspec-o/ accessed 13th December, 2018) but their registration card says collector/donor were Deutsche Südpolarexpedion of 1901–1903 which cannot be correct as, from my information, New Zealand was not visited (Figs. 9–11). It is now certain that the holotype was actually returned to Vienna so the specimen in Hamburg is either a syntype (unlikely) or possibly a species such as *T.*

Fig. 9. Hamburg specimen V.8615 (non-type) (photo: courtesy curator).

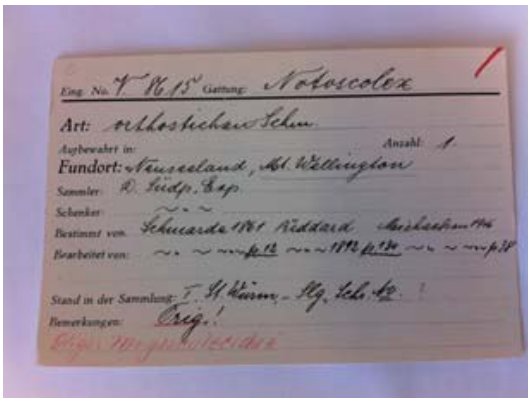

Fig. 10. Hamburg museum registration card (*ditto*).

Fig. 11. German South-polar expedition route (not to NZ).

esculenta or *T. decipiens* types of which were also described by Michaelsen (1917) (see Blakemore, 2014: 146–149, figs. 12–13). However, it is possible that the Vienna type's missing organs are in vials seen inside the Hamburg sample jar.

Regarding types, Coles (1981) had reported, firstly, that Beddard (1892) re-inspected Vienna Museum type specimens of *Hypogaeon orthostichon* [Coles said four specimens but this probably a mistake for *Hypogaeon heterostichon* for which Beddard (1892: 119) said three or four specimens were in the Vienna collection]; and secondly, that Beddard found *P. vitiensis* Beddard, 1892 [= *Pheretima* (*Pheretima*) *montana* Kinberg, 1867] had a specimen mislabeled as "*Hypogeon orthostichon Schm. Viti Ins.* [= Fiji]." Interestingly, this species was described by Beddard (1892: 131) immediately following *M. orthostichon*, perhaps accounting for the mislabelling. Since Beddard (1895: 496) mentions "*the type of SCHMARDA*" it may be taken that he designated the Vienna specimen as lectotype should there be any other syntypes, which now seems doubtful. Lee (1962), while apparently overlooking the key reference of Michaelsen (1917), described several specimens in NHM, London as *Megascolides orthostichon* but this in error as noted by Blakemore (2014: 146, fig. 12) who attributed them more properly to *Tokea maorica* Benham, 1905 (the author's research is ongoing whether these are part of its missing Otego type-series - Anusha Beer pers. comm.18th January, 2017).

Description: (From Schmarda, Beddard, Michaelsen, Blakemore 2012, 2014 and pers. obs. of Vienna holotype). Colour dark red in life; greyed in storage. Length 80 mm (Schmarda, Michaelsen; 180 mm was a lapsus by Beddard, 1895) by 2.5–4 mm; the type is coiled but measures about 75 mm unstretched and it further appears to be a posterior amputee as the last segments are blunt rather than tapered so the species may have been slightly longer (albeit Michaelsen recognized maganephridia in the last eleven segments as found in other congeners such as the *T. esculenta* type where they are in the last 20 segments). Segments 65 in type (agreeing with Schmarda's figure and according to Beddard, 1895 and Michaelsen, 1917 but Schmarda originally stated between 60–65). Prostomium "pointed" actually small, epilobous in type. Dorsal pores absent but possibly vestigial in a few posterior segments (pers. obs. from type). Setae 8 in equidistant rows in the anterior (Schmarda and as alluded to in the species' name; Beddard) which Michaelsen (1900: 189) assumed as a ratio of ab = bc = cd but later Michaelsen (1917) said posterior differed and was actually aa:ab:bc:cd:dd = 5:3:4:4:6. Moreover, in my inspection the type had ventral setae of at least 19–20 slightly off-line. Spermathecae contained in segment 8 & 9 [this according to Beddard but details of where they exited were omitted and Michaelsen (1917) made no comment whereas Lee (1959: 349) had "7/8/9" but this I think must have been his speculation]; my inspection of type shows them to be minute in 7/8/9 approximately in setal a lines. Clitellum annular ½13,14–17 rather than just 14–17 as Beddard says (but now mostly detached in type). Female pores seem to have not been noted by any author, nor could they be found on the type's disintegrated clitellum, possibly due to previous ventral dissection although its setae on 13–17 were mostly visible (i.e., midventral?). Male pores minute on 18 on small, darkened and flat circular pads each within a paler encompassing porophore only approximately in line with missing setae a since the setae in 19–20 seem to be offset slightly returning to series in 21 onwards (note that male pores were located by Beddard in the position of the ventralmost setae and by Michaelsen in the site of missing setae a). One porophore has a slight posterior extension exactly as Michaelsen (1917) described (due to a small, possibly parasitic, papilla – pers. obs.) thereby further confirming this specimen as the Vienna type. No GMs were found (but Michaelsen said damage to immediately posterior of segment 17 made its determination there uncertain).

Internal Anatomy: Pharyngeal salivary gland masses were noted in anterior but none of the septa remaining were particularly thickened (pers. obs. of type). The anterior digestive tract to segment 14 had been removed from the type but a gizzard was stated to be in 5 (by Beddard, the person likely responsible for removing most missing organs); no information is available on the calciferous glands, but they are absent from 14 and segments 15–16 are valvular to a wider, thin-walled intestine apparent in 17 (pers. obs.). Nephridia meroic with meganephridia in the last eleven segments (Michaelsen 1917). Remnants of vascular system in anterior comprise a single dorsal-blood-vessel in fragments and just one heart in 12 (thus not known if hearts in 13 were present or not). Testis and funnels are free and iridescent in 10 and 11 (pers. obs.). Seminal vesicles given as in 10–12 by Beddard but in the type I found remnants in 9rhs (small) and in parts in 10–12, thus in 9–12. Ovaries in 13 (still present as elongated sets of egg-strings); ovisacs in 14 (no longer clearly present) and oviducts not noted. Prostates no longer remain in type but are here classified as flattened quasi-tubular due to sketch and detailed description by Michaelsen (1917: figs. 12 and maybe 13) who found it with significant multiple

and minute side branches to the lumen, more so than in the *T. esculenta* type he also inspected. No trace of penial setae found. Neither a mid-ventral cushion internally in 18 (as in both *T. maorica* and *T. unipapillata*) nor paired glandular pads as in *T. neglecta* are present. Of the two pairs of spermathecae in 8 & 9, just one in 8lhs remains; each had a small, pyriform diverticulum with misdescription by Beddard noted and corrected by Michaelsen (1917: fig. 13) and also as photographed and sketched by current author again confirming Michaelsen's specimen as the selfsame Vienna holotype.

Ecology and Habitat: Schmarda found it in "black earth" and gut contents (pers. obs.) included charcoal grits (from a Maori midden or perhaps earlier burnt forestland?) and red-clay organic soil which combined with dark pigmentation suggests a topsoil habitat. Nothing else of its ecology is known. Benham (1904a: 284, b: 256) said Prof. Kirk informed him that "Mount Wellington is one of the small volcanic cones just out of Auckland. It is, now, under grass, and is in a fully cultivated district" (as it still is today being grazed by cattle) whereas in Schmarda's time (only 20 years after Auckland was established) there would as yet have been little cultivation since its use as a Maori pa (hill fortress).

Distribution: Maungarei / Mount Wellington which is youngest and largest volcanic scoria cone of the Auckland volcanic field, having been formed by an eruption around 10,000 years ago. The species is seemingly now extinct (Blakemore, 2011, 2012, 2014, 2017).

Remarks: *Tokea orthostichon* (Schmarda, 1861) synonymy as given above details available information with its similarities pondered by Benham (1904b: 256) and partly by Lee (1962: 176) who inexplicably thought his non-type specimens resembled *Tokea kirk*i Benham, 1904 although these were more properly attributed to *T. maorica* by Blakemore (2014) and as here confirmed from its type thus invalidating Lee's account.

The male pores of *Tokea orthostichon* type are now unequivocally shown to be separate and paired within two circular porophores, each surrounded by a lighter rim half a segment wide, looking exactly as interpreted from Michaelsen (1917: 39) and almost as figured by Benham (1904b: fig. 62–63) in the *Tokea* type: *T. esculenta*. This is a different configuration to the male field for either of the two *Tokea* species, *T. kirki* (paired in square porophores) and *T. maorica* (in common field), alluded to by Lee (1962) and revised by Blakemore (2014: figs. 11 vs. 12), and is different to *T. unipapillata* arrangement too. Previously unrecorded position of spermathecae was found in the type by the author (Oct., 2016) to be intersegmental in 7/8/9 in setal a lines, clearly differentiating this taxon from *T. kirki* and *T. rubra* (in 7/8/9 in b), *T. maorica* (posteriorly in 7 & 8) and *T. esculenta* (posteriorly in 6, 7 & 8). It seems *T. orthostichon* further lacks GMs often associated with internal glands as found in these other three species and in *T. unipapillata* and *T. neglecta* corresponding to the midventral or paired pads, respectively.

Lee's (1952) *T. rubra* is superficially similar to *T. orthostichon* in its male pores and lacking GMs and thus GM glands, but it has spermathecal pores in 7/8/9 in b; the spermathecal diverticulum is much smaller and it possibly also differs in its seminal vesicles in just 11 & 12 and intestine from segment 16.

Another species newly transferred to genus *Tokea* – as was intimated by Blakemore (2012, 2014) – is *Tokea raglani* (Lee, 1952) **comb. nov.** that has spermathecal pores in 7/8/9 in ab and GMs as mid-ventral, lenticular pads in 17/18 & 18/19. Note that Lee (1952) thought that *Anisochaeta antarctica* synonym *Spenceriella shakespeari* that is superficially similar except for perichaetine setae was locally derived from this species he had described as *Megascolides raglani*.

Benham (1904a: 255, 1904b: 284) had earlier suggested Schmarda's worm belongs in his genus *Tokea* and this genus reallocation is now fully endorsed. Past uncertainty of *Tokea orthostichon* generic placement is due to confusion with prostate categorization allowing default to *Megascolides* (with tubular prostates) or less likely to *Notoscolex* (with tubuloracemose-racemose prostates) rather than my current interpretation mainly from Benham (1904a, b) and Michaelsen (1917) as a 'quasi-tubular' derivation from strict tubular glands. Lack of information on absence of dorsal pores as prerequisite for *Tokea* has compounded this confusion until now (pers. obs.).

The type of *Tokea orthostichon* differs from both *T. maorica* and *T. unipapillata* in terms of spermathecal pores and male fields, but is comparable to *T. kirki*, *T. neglecta*, *T. raglani*, *T. reptans* and *T. viridis* especially with regards nature of spermathecal, male pores and genital markings as differentiated in the following table (Table 1).

From the monotypic descriptions it seems that distinctive characters of *T. orthostichon* are its unique combination of features in Table 1 plus its biometry of 80+ mm, 65+ segments and dark red colour; its spermathecae with spermathecal ampulla distinct from duct (rather than tapering) and with a short diverticulum and (from Michaelsen, 1917: fig. 12) possibly shorter ducts on its

Table 1. Characters Based on Original Descriptions and Inspections of Types (2016)

Spp	Sp pores	Clitellum	Gizzard	Ca glds	Seminal Vesicles	Genital Markings	Dorsal pores
Tokea orthostichon	7/8/9 in a	½13,14–17	5	(Not 14)	9,10–12	**None** found	None
T. esculenta	7,8,9 in a	½13–½18	5	No	9 & 12	16 & 17 pair	None?
T. kirki	7/8/9 in **b**	13–17	5	**14**	11–12	18 pair	None?
T. neglecta	7/8/9 in a	13,14–17,18	**6**	No	9 & 12	18 pair	None
T. raglani	7/8/9 **a/b**	13–18	5	No	9, 11 & 12	17/18, 18/19	None?
T. reptans	7/8/9 in a	14–17	**6**	10–**14**	9–12	18/19	None
T. rubra	7/8/9 in **b**	14–18	5	12–13	11 & 12	**None**	None?
T. viridis	7/8/9 in a	14–17	5	No	9–12	13/14, 18/19	None

Sp pores = spermathecal pores; Ca glds = Calciferous glands or oesophageal modifications.
Bolded characters distinguish taxa.

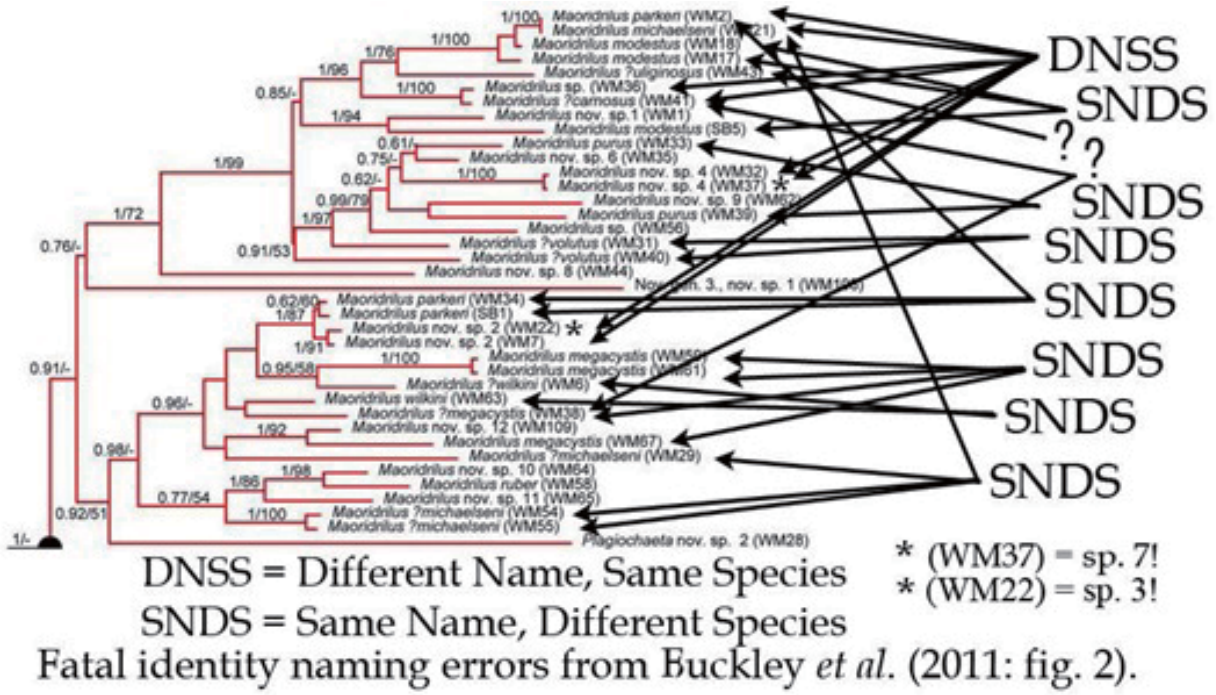

Fig. 12. Uncitable molecular survey with random names (cf. Blakemore 2010, 2011, 2012).

quasi-tubular prostates.

Tokea orthostichon (Schmarda, 1861) was not relocated at its type-locality during this author's survey in 2011, and neither is it known to have been reported on site or elsewhere for 150 years (Lee, 1959, 1962, 1985); some subsequent NZ earthworm surveys by novices did not consult proper taxonomic advice so are unhelpful as all their identities seem highly suspect (Fig. 12).

Schmarda's *Tokea orthostichon* thus qualifies under DoC NZTCS (Molloy *et al.* 2002) classification as 'Nationally Critical' or Extinct, and may now be tagged 'Extinct' under IUCN Red List Categories (Blakemore 2017). Although an abundant and diverse fauna was at Mt Wellington (Blakemore 2012), no native earthworms were located there thus it seems pastoral cultivation and agrichemical intensification particularly favours certain exotics and may account for overwhelming competitive exclusion and eventual extinction of native earthworms. Indeed, this rapid earthworm extinction was first noted by Smith (1894), by Lee (1961) and was confirmed by Blakemore (2018) on a broader scale under all but organic production.

Acknowledgements

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摘　要

ロバート J. ブレクモア , 2019. ニュージーランドから記録された絶滅ミミズ *Tokea orthostichon* (Schmarda, 1861)（環形動物門，貧毛綱，Megadriliacea 目，フトミミズ科）の再記載 . 神奈川県立博物館研究報告（自然科学）, (48): 61–68.［Blakemore, R. J., 2019. Redescription of extinct New Zealand earthworm: *Tokea orthostichon* (Schmarda, 1861) (Annelida, Oligochaeta, Megadrilacea, Megascolecidae). *Bull. Kanagawa prefect. Mus.* (*Nat. Sci.*), (48): 61–68.］

フトミミズ科のミミズ *Tokea orthositchon* (Schmarda, 1861) は、オーストララシア在来のミミズとして最も古く記載され、現在では絶滅種として位置づけられている。本種の同定に関しては、ハンブルク動物学博物館やロンドン自然史博物館に収蔵されている資料に基づく不確実な情報によって長い間混乱していたが、ウィーン自然史博物館に所蔵されているホロタイプ標本を解剖し、詳しく観察することで問題を解決することができた。

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