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Two new free-living nematode species (Comesomatidae) from the continental slope of New Zealand, with keys and notes on distribution

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Abstract

Two new free-living marine nematode species of the family Comesomatidae are described from the continental slope of New Zealand, and their distributions at 32 sites are investigated in relation to environmental factors. *Vasostoma aurata* **n. sp.** is characterised by a distinctly set-off head, amphideal fovea with 4.5 turns, conspicuous chords consisting of two bands fusing at body extremities, with outline of cell bodies usually golden-coloured, and relatively short spicules. *Setosabatieria conicauda* **n. sp.** is characterised by an amphid with 4.25–4.5 turns, the presence of only 1–3 sub-cephalic setae per file, several clusters of intracellular inclusions, sometimes brown-coloured, in the intestinal wall, and a conical tail. Keys to all known species of *Setosabatieria* and *Vasostoma* are provided. Both species were mostly restricted to subsurface (1–5cm depth) sediments. The abundance of *V. aurata* **n. sp.** and *S. conicauda* **n. sp.** was significantly correlated with food quantity and quality, but the patterns differed between species. The effect of food-related factors may be directly linked to interspecific differences in food requirements, or mediated by biogeochemical processes (i.e., tolerance of sub-surface oxygen and sulphide concentrations). No significant correlations were found between sediment granulometry and abundances, despite the wide range of sediment grain-sizes (6–93% silt and clay) at the sampling sites.

Key words: biosystematics, dichotomous keys, Chatham Rise, Challenger Plateau, *Vasostoma aurata* **n. sp.**, *Setosabatieria conicauda* **n. sp.**, chloroplastic pigment concentration, sediment granulometry

Introduction

Deep-sea nematode communities exhibit high alpha diversity compared to shallow water communities (e.g., Lambshead & Boucher 2003). The number of free-living nematode species reported from the deep sea (< 700), however, is limited compared to the total number of free-living marine nematode species described to date (4000–5000) (Miljutin *et al*. 2010). Vast areas of the deep sea floor have not been studied due to logistical difficulties associated with deep-sea sampling and the scarcity of taxonomic expertise. The deep-sea nematode fauna in the south-western Pacific region, in particular, is very poorly known, with only eight species records to date (Miljutin *et al*. 2010). Two of these records were made within the New Zealand Exclusive Economic Zone (EEZ) based on material collected during the *Galathea* expedition in 1951 (Wieser 1956). The two species, *Thoracostoma bruuni* Wieser 1956 and *Synonchoides galatheae* (Wieser 1956) Platonova 1970 were described from the eastern Tasman Sea (595 m water depth) and the southern Kermadec Trench (4510–4570 m water depth).

Nematode specimens are usually identified only to genus or putative species in deep-sea ecological studies. Consequently, very little information is available about the distribution of nematode species. About one hundred species are known to have a wide (> 1000 m) depth range; *Desmolorenzenia desmoscolecoides* Timm 1970, for example, has been found from depths of 460 to 6200 m and has the greatest depth range recorded so far for nematodes (Miljutin *et al*. 2010). Many species have been recorded from more than one ocean basin and may have cosmopolitan distributions (Miljutin *et al*. 2010). Thus, the evidence available to date suggests that some deep-sea nematode species have wide bathymetric and/or geographic ranges, but little is known about the potential influence of environmental factors (e.g., sediment granulometry, food availability) on their distribution. A better knowledge

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of species-environment relationships would help improve our understanding of the ecological factors influencing deep-sea community structure and diversity, and could help predict future changes in response to changing environmental conditions, or human activities such as deep-sea mining (Miljutin *et al*. 2011).

The present study describes new species belonging to the genera *Vasostoma* Wieser 1954 and *Setosabatieria* Platt 1985 from the continental slope of New Zealand. Species-environment relationships are investigated by estimating abundances of these species at 32 stations spanning a wide range of environmental conditions (240–3100 m water depth, 6–93% silt and clay content, 10–100% $CaCO_3$, and high to low chloroplastic pigment content).

Methods

Sampling and laboratory methods

The present study focussed on two main bathymetric features of the New Zealand EEZ, Challenger Plateau and Chatham Rise. Challenger Plateau encompasses water depths ranging from ca. 400 to 3000 m in an area of generally low biological productivity to the northwest of the South Island, New Zealand (Murphy *et al*. 2001) (Figure 1). Chatham Rise is a submarine ridge that extends eastwards from the South Island of New Zealand, over water depths ranging from ca. 250 to 3000 m. The rise lies beneath the Subtropical Front (STF), a region associated with heightened primary productivity (Bradford-Grieve *et al*. 1997; Murphy *et al*. 2001). Elevated macro-and meiofaunal biomass on the upper southern slope and crest of the rise is probably due to the proximity of the STF (Probert & McKnight 1993; Nodder *et al*. 2003; Grove *et al*. 2006; Nodder *et al*. 2007).

Samples for studying the effect of environmental parameters on the distribution of nematode species were collected along a transect at 178º30′E across the Chatham Rise (nine stations, 350–3100 m water depth) in austral spring (September–October) 2001 during National Institute of Water and Atmospheric Research (NIWA) cruise TAN0116 (Figure 1). Twenty-three additional stations between 240 and 1300 m water depths on Chatham Rise and Challenger Plateau were sampled in austral autumn-early winter (March–April and May–June) 2007 (NIWA cruises TAN0705 and TAN0707, respectively). Nematode specimens for species descriptions were obtained from a single site (the type locality) on the southern flank of Chatham Rise (Site 10, TAN0705, 1240 m water depth; 44º29.1′S, 177º8.6′E).

Sediment samples were collected using an Ocean Instruments MC-800A multicorer (MUC; core internal diameter = 9.52 cm). One to three replicates (i.e., samples from different MUC deployments) per site were obtained for faunal analyses. Four additional pseudo-replicates (for a total of three cores from each of two deployments) were analysed from the type locality (Leduc *et al*. 2010a). Each sample consisted of one subcore of internal diameter 26 mm taken to a depth of 5 cm. Samples from the type locality were split into 0–1 and 1–5 cm sediment depth fractions to characterise the vertical distribution of *Vasostoma aurata* **n. sp.** and *Setosabatieria conicauda* **n. sp.** in the sediments. Samples were fixed in 10% formalin and stained with Rose Bengal. Samples were subsequently rinsed on a 1 mm sieve to remove large particles and on a 45 µm sieve to retain nematodes. Nematodes were extracted from the remaining sediments by Ludox flotation and transferred to pure glycerol (Somerfield & Warwick 1996). Extracted samples were mounted onto slides and nematode abundance was determined by scanning slides at 100× magnification (Leduc *et al*. 2010b). Between 110 and 150 randomly chosen nematodes (or all individuals if fewer were present in the sample) were observed at 1000× magnification and *V. aurata* **n. sp.** and *S. conicauda* **n. sp.** individuals were counted. The abundance of these species at each site was estimated by multiplying the proportion of each species by total nematode abundance.

Species descriptions were made from glycerol mounts using differential interference contrast microscopy and drawings were made with the aid of a camera lucida. All measurements are in µm, and all curved structures are measured along the arc. Type specimens are held in the National Nematode Collection of New Zealand (NNCNZ), Landcare Research New Zealand Ltd, Auckland, and in the NIWA Invertebrate Collection (NIC), Wellington. Anterior sense organs are defined as follows: papillae (<1 µm long), setiform papillae (1–2 µm), and setae (>2 µm) (Leduc & Wharton 2008). Abbreviations in the text are as follows: a, body length/maximum body diameter; abd, anal body diameter; b, body length/oesophagus length; c, body length/tail length; cbd, corresponding body diameter; %V, vulva distance from anterior end of body × 100/total body length.

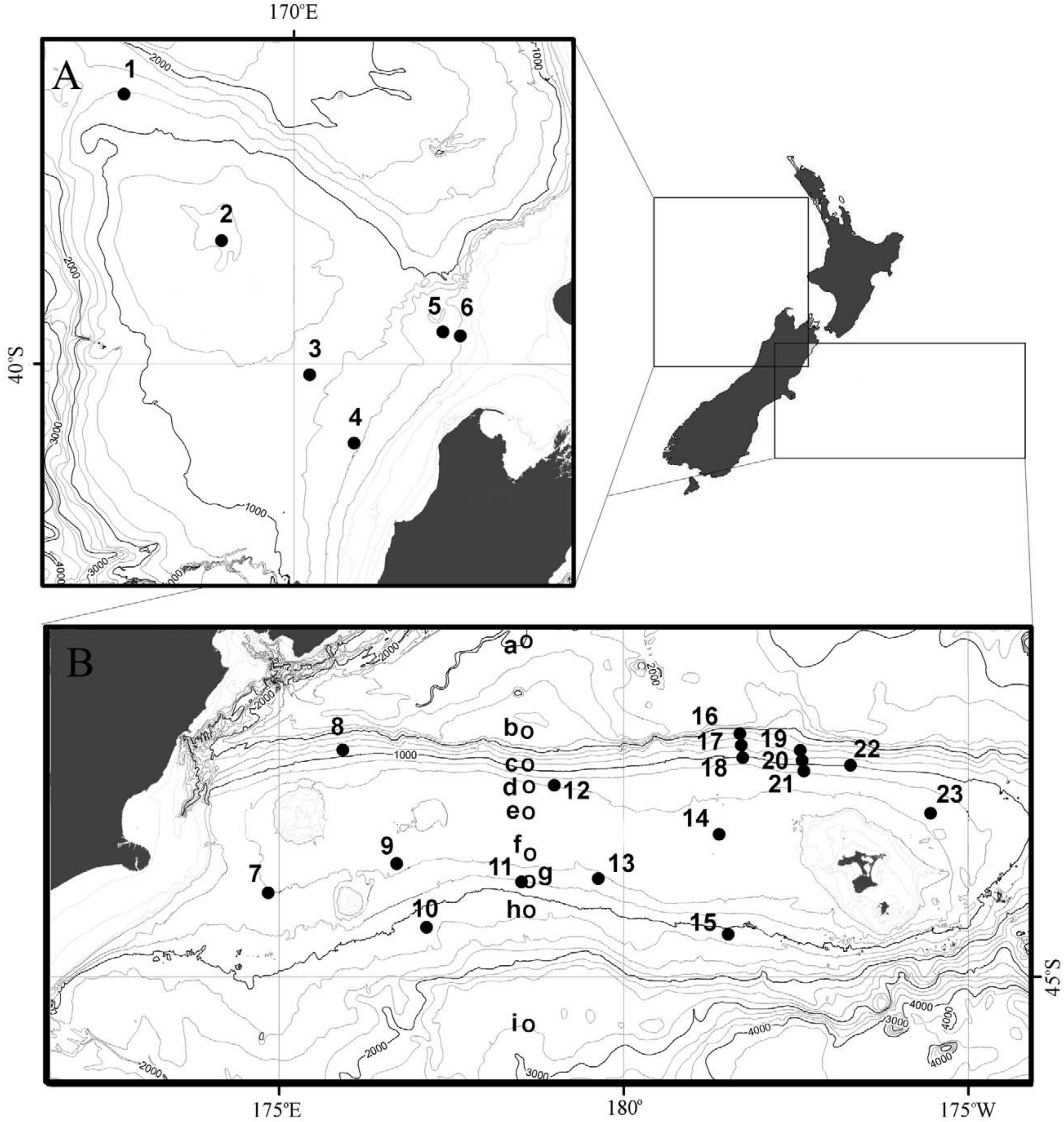

FIGURE 1. Map of New Zealand showing bathymetric contours and study sites on (A) Challenger Plateau (top left panel) and (B) Chatham Rise (bottom panel), including sites sampled in 2001 (empty circles) and 2007 (filled circles). Site 10 is the type locality.

Physical and biogeochemical sediment parameters at each site were measured for the surface (0–5 mm) sediment layer from one or two cores of the same MUC deployment. These parameters were: %silt/clay (proportion of silt and clay particles relative to total particles), %TOM (total organic matter content), %H$_2$0 (water content), %CaCO$_3$ (carbonate content), chloroplastic pigments (sum of chlorophyll *a* and phaeopigments, µg g^{-1} DW$_{\text{sediment}}$,), and %chl *a* (proportion of chlorophyll *a* relative to chloroplastic pigments). Only surface sediment data were used because subsurface sediment data were lacking for several sites; analysis of available data, however, showed that surface and subsurface sediment characteristics (e.g., %silt/clay, chloroplastic pigments, %chl *a*) were significantly correlated (linear regression, $R^2 = 0.45–0.94$, $p < 0.05$). Chloroplastic pigments provide a measure for the amount of photosynthetically derived sediment organic matter (SOM), whereas %chl *a* provides a measure of the lability or freshness of photosynthetically-derived SOM (Ingels *et al*. 2009). Methods for the determination of environmental parameters are presented in Nodder *et al*. (2003) and Grove *et al*. (2006).

Data analysis

Abundance data are often characterised by a high occurence of zeros that can lead to the violation of assumptions for parametric methods such as traditional regression analyses (e.g., Lewin *et al*. 2010). The DistLM routine in PERMANOVA+ is a semi-parametric, permutation-based method that allows the modelling of species-environment relationships without the assumption of normally distributed data (Anderson *et al*. 2008). The influence of environmental parameters on the abundance of *V. aurata* **n. sp.** and *S. conicauda* **n. sp.** was investigated using the DistLM routine using the following predictor variables: water depth, chloroplastic pigments, %chl *a*, %TOM, %silt/clay, %$CaCO_3$, and %H_20. Similarity matrices were built using euclidean distance of log(x+1)-transformed species abundance data. *P*-values for individual predictor variables were obtained using 9999 permutations of raw data, except for water depth and %chl *a* data which were log(x+1)-transformed to reduce skewness. The relationship between environmental parameters and the abundance of a species may not always be linear, and may show, for example, a peak at intermediate values. Quadratic relationships were therefore also modelled in DistLM, which was achieved by performing regressions on first- and second-order terms in sets (Anderson *et al*. 2008). The fit of linear and quadratic relationships was compared using adjusted R^2 values (Quinn & Keough 2009). Whilst absence data may provide useful information about species-environment interactions (i.e., "true" zeros that reflect the absence of a species due to ecological processes or chance), they can also reflect methodological shortcomings (i.e., "false" zeros that record the species as absent when it is in fact present) (Martin *et al*. 2005). Regression analyses were therefore performed with and without absence data to help take into account the potential effect of false zeros.

Systematics

Family Comesomatidae Filipjev 1918

Subfamily Dorylaimopsinae De Coninck 1965

***Diagnosis* (from Jensen 1979):** Cuticle usually differentiated laterally. Cephalic sense organs in three distinctly separated crowns. Buccal cavity strongly cuticularised; anterior portion shallow, sometimes with small pointed projections at border with vestibulum; posterior portion dilated, cylindrical or conical, with strongly cuticularised walls and three thornlike projections at the border between the two portions. Spicules sometimes differentiated proximally, medially or distally. Gubernacular apophyses usually directed caudally, occasionally dorsocaudally.

Genus *Vasostoma* Wieser 1954

***Diagnosis* (modified from Wieser 1954 and Jensen 1979):** Cuticle undifferentiated laterally. Outer labial papillae immediately anterior to cephalic setae. Posterior portion of buccal cavity cylindrical to conical, provided with three small acute projections at border with anterior portion. Spicules bent. Gubernacular apophyses directed dorsocaudally.

Vasostoma aurata n. sp. (Fig. 2–4, Table 1)

Material examined. **Holotype** Male, collected 6 April 2007, Chatham Rise (1240 m water depth), 44º29.1′S, 177º8.6′E. Characteristics of surface sediment layer (0–5 mm): mostly silt/clay (82.9%), with very fine sand (10.2%), and fine sand (8.4%); calcium carbonate content: 38.4%; total organic matter content: 1.91%; chloroplastic pigment concentration: 3501 ng/gDWsediment (NNCNZ 272).

Paratypes Two males, three females, one J4 juvenile, same data as holotype (NNCNZ 2653-8); three males, three females, same data as holotype (NIWA 71586-7).

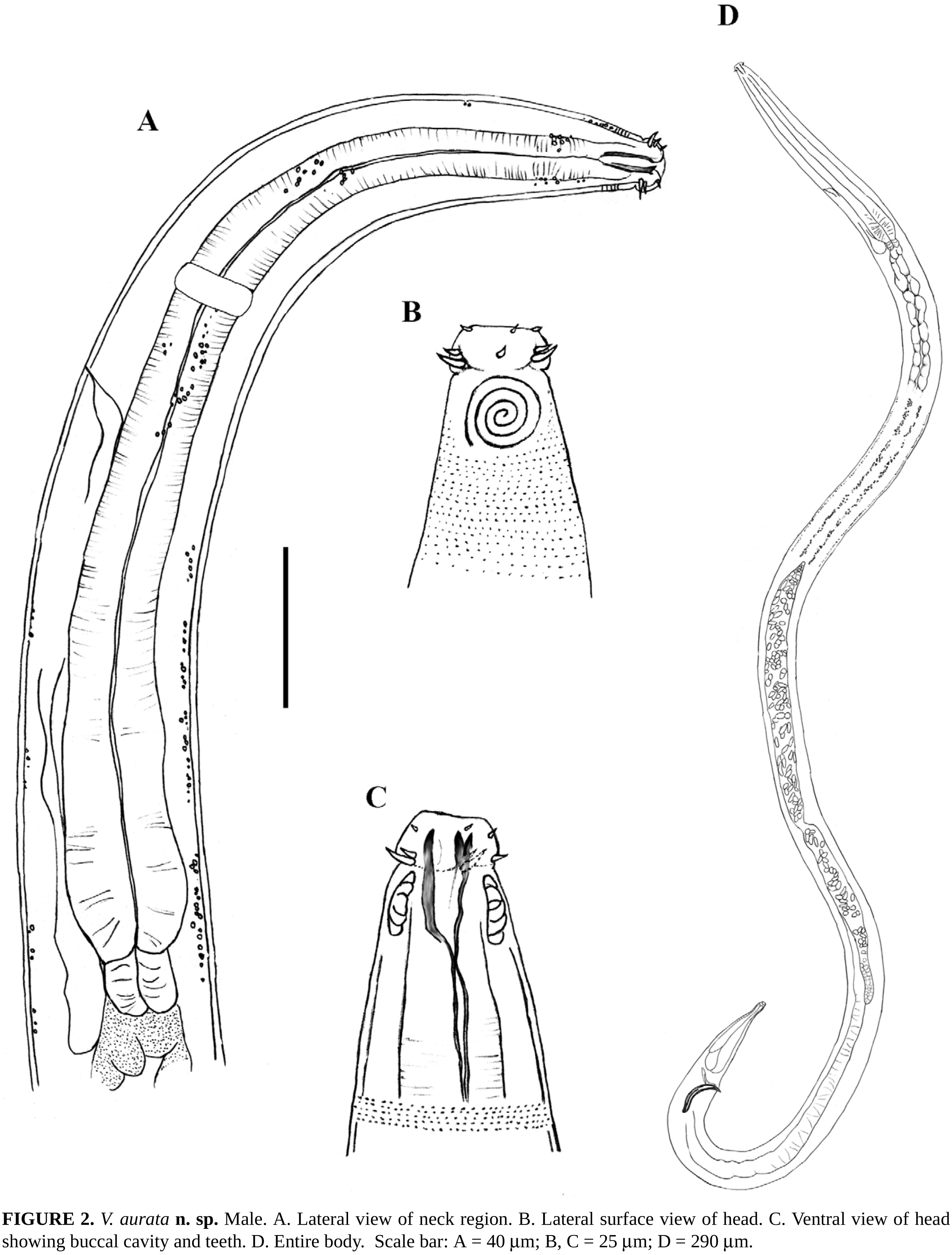

FIGURE 2. *V. aurata* **n. sp.** Male. A. Lateral view of neck region. B. Lateral surface view of head. C. Ventral view of head showing buccal cavity and teeth. D. Entire body. Scale bar: A = 40 µm; B, C = 25 µm; D = 290 µm.

Description. *Males* Body cylindrical, medium-sized, tapering towards both extremities. Cuticle with transverse rows of dots, no lateral differentiation. No somatic setae except on tail. Lateral, dorsal, and ventral chords conspicuous in most specimens, consisting of two bands of irregular cell bodies, <1–4 µm in size, with outline often golden-coloured, fusing into single band near anterior and posterior ends of body (Figure 4). Head distinctly set-off by constriction immediately posterior to cephalic setae. Six inner labial papillae, six outer setiform outer labial papillae, and four cephalic setae, the latter two very close to each other. Anteror portion of buccal cavity cup-shaped. Posterior portion of buccal cavity cylindrical to conical, cuticularised, 13 µm deep, with three cuticularised projections (teeth) at border with anterior portion. Amphid spiral, 4.5 turns. Pharynx gradually swelling, not forming true bulb. Cardia short. Nerve ring near one third of pharynx length from anterior. Cellular body of ventral gland at level of cardia, excretory pore near middle of pharynx.

TABLE 1. Morphometrics (µm) of *V. aurata* **n. sp.** and *S. conicauda* **n. sp.** including mean values (range). (a, body length/maximum body diameter; abd, anal body diameter; b, body length/oesophagus length; c, body length/tail length; cbd, corresponding body diameter; %V, vulva distance from anterior end of body × 100/total body length.)

Species	***Vasostoma aurata* n. sp.**				***Setosabatieria conicauda* n. sp.**		
	Males		**Females**	**J4**	**Males**		**Females**
	Holotype	**Paratypes**	**Paratypes**	**Paratype**	**Holotype**	**Paratypes**	**Paratypes**
n	-	5	6	1	-	4	5
L	2057	2134 (2017–2252)	2292 (2052–2432)	1040	1094	1257 (1148–164)	1555 (1360–1807)
a	41	45 (42–48)	41 (39–45)	35	27	28 (25–30)	26 (23–28)
b	7	7	7 (7–8)	5	6	7 (6–8)	8 (7–10)
c	14	16 (15–16)	16 (15–19)	12	18	16 (15–18)	19 (16–21)
%V	-	-	51 (48–54)	-	-	-	48 (44–50)
Head diam.	16	16 (15–16)	17 (15–18)	12	16	17 (16–17)	18 (17–19)
Mouth diam.	5	4 (4–5)	5 (4–5)	4	3	4 (3–4)	4
Length of sub-cephalic setae	-	-	-	-	6	6 (5–7)	6 (6–7)
Length of cephalic setae	4	4 (3–4)	4 (3–4)	3	7	7 (6–8)	7 (6–8)
Amphid height	10	11 (10–12)	9 (8–9)	7	13	13 (12–13)	11 (10–11)
Amphid width	10	10 (9–11)	9 (8–10)	7	12	12 (11–12)	11
Amphid width/cbd (%)	63	65 (56–73)	53 (50–55)	58	75	68 (65–75)	57 (55–58)
Amphid from anterior end	6	7 (6–8)	7 (6–7)	7	8	7 (6–8)	8 (8–9)
Nerve ring from anterior end	115	122 (115–130)	105 (92–113)	89	114	104 (96–108)	114 (110–116)
Nerve ring cbd	38	38 (37–39)	40 (38–41)	26	34	36 (34–38)	38 (35–39)
Excretory pore from anterior end	158	156 (156–157)	157	115	126	130 (126–133)	132 (130–134)
Pharynx length	285	307 (300–314)	305 (274–342)	199	174	178 (166–190)	196 (183–219)
Pharynx cbd	48	46 (45–47)	51 (48–54)	31	38	40 (36–43)	46 (43–52)
Pharyngeal bulb diam.	31	30 (29–31)	35 (32–36)	21	24	26 (25–26)	31 (27–35)
Max. body diam.	50	48 (47–50)	54 (51–56)	30	40	46 (40–52)	61 (54–78)
Spicule length	73	67 (64–69)	-	-	59	55 (51–58)	-
Gubernacular apophyses length	23	23 (21–24)	-	-	11	12 (11–13)	-
Anal body diam.	44	43 (42–44)	45 (42–47)	25	33	36 (33–39)	40 (35–48)
Tail length	148	137 (135–143)	145 (109–163)	84	61	79 (71–93)	81 (69–90)
Tail length/abd	3.4	3.2 (3.1–3.4)	3.2 (2.3–3.5)	3.4	1.8	2.1 (1.9–2.4)	2.0 (1.8–2.4)
Vulva from anterior end	-	-	1130 (1039–1225)	-	-	-	734 (675–830)
Vulval body diam.	-	-	54 (51–56)	-	-	-	61 (54–77)

Reproductive system diorchic, opposed, outstretched. Anterior testis to left of intestine, posterior testis to right of intestine. Spicules paired, equal, curved, 1.4–1.5 abd long, proximal end slightly enlarged, central lamella well developed. Gubernaculum with pair of straight caudal apophyses. Cloacal gland cells surround posterior portion of spicules and gubernaculum. Up to seven tubular pre-cloacal supplements, often difficult to distinguish, one pre-cloacal seta. Tail conico-cylindrical, with several short caudal setae and three short terminal setae. Three large caudal glands.

Females Similar to males, but with slightly larger maximum body diameter, amphid smaller, 3.5 turns. Reproductive system didelphic, opposed, outstretched. Anterior ovary to left of intestine, posterior ovary either to right or left of intestine. Vulva slightly post median. Granular vaginal glands present, vagina uterina surrounded by constrictor muscle.

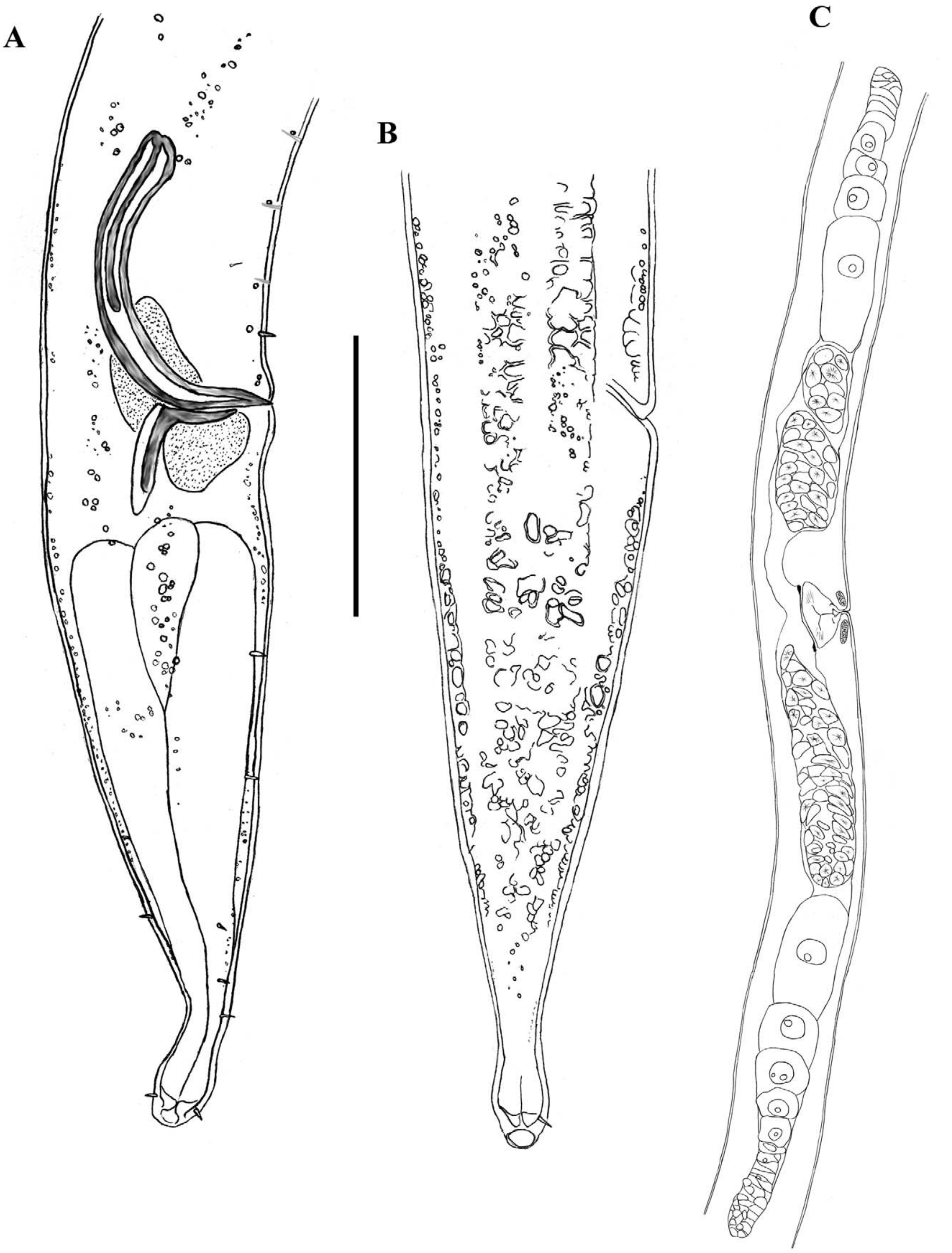

FIGURE 3 *V. aurata* **n. sp.** A. Male posterior body region showing copulatory apparatus B. Female posterior body region showing chords. C. Mid-region of female body showing vulva and genital branches. Scale bar: A, B = 50 µm; C = 145 µm.

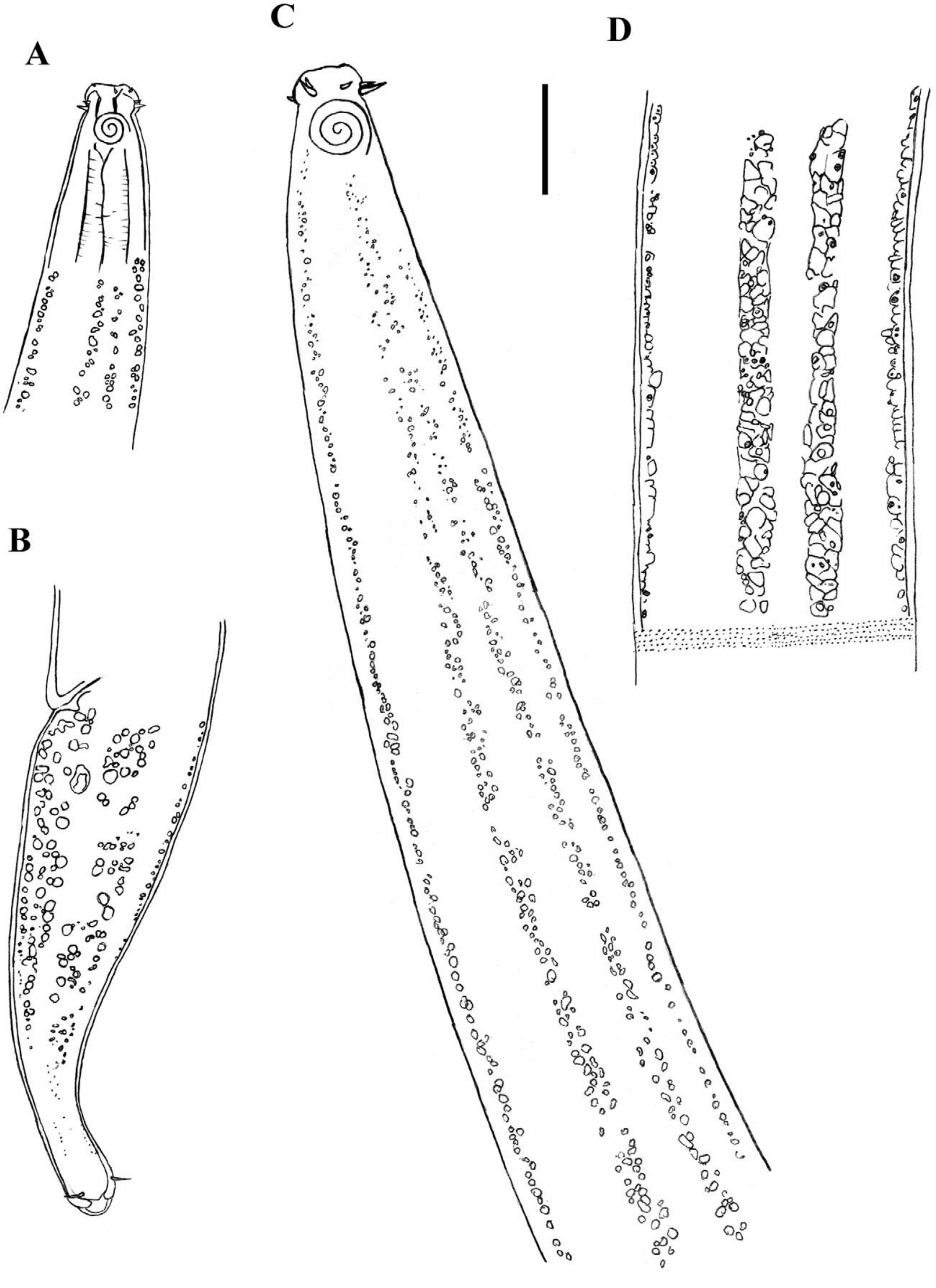

FIGURE 4. *V. aurata* **n. sp.** A. Lateral view of juvenile anterior body region. B. Lateral view of juvenile posterior body region showing chords. C. Lateral view of female anterior body region showing amphid and chords. D. Female mid-body region showing chords. Scale bars: A, B, C, D = 25 µm.

Fourth stage juveniles Similar to adults but smaller body size, smaller amphid with 4.25 turns. Lateral chords conspicuous.

Diagnosis and relationships. *V. aurata* **n. sp.** is characterised by a distinctly set-off head, amphid with 4.5 turns, conspicuous chords consisting of two bands of irregular, often golden-coloured cell bodies, short spicules, and faint tubular supplements.

V. aurata **n. sp.** is similar to the type species *V. spiratum* Wieser 1954, but can be distinguished from the latter by its greater body length (2017–2432 vs 1370–1850 µm), higher a values (41–47 vs 26–36), higher c values (14–19 vs 9–13), shorter tail (2.3–3.5 vs 4 abd), presence of conspicuous chords, and the presence of faint tubular supplements (as opposed to 11 well-developed supplements in *V. spiratum*).

Etymology. The specific name ("gilded with gold") refers to the intricate golden patterns of the chords.

Discussion. *V. aurata* **n. sp.** specimens from the type locality were found exclusively in subsurface (1–5 cm) sediments. A study of the nematode community at the type locality found that *V. aurata* **n. sp.** (referred to as *Vasostoma* sp. A therein) was the fourth most common species at that site, and accounted for 3.6% of total nematode abundance (Leduc *et al*. 2010a).

Key to all known species of *Vasostoma*

1	Spicules < 2 abd long	2
-	Spicules > 2 abd long	3
2	Body length > 2000 µm, conspicuous chords consisting of two bands fusing at body extremities, with outline of cell bodies usually golden-coloured	*V. aurata* **n. sp.** (New Zealand)
-	Body length < 2000 µm, chords not conspicuous	*V. spiratum* Wieser 1954 (Chile)
3	Spicules with joints	*V. articulata* Huang & Wu 2010 (Yellow Sea)
-	Spicules without joints	*V. longispicula* Huang & Wu 2010 (Yellow Sea)

Subfamily Sabatieriinae Filipjev 1934

***Diagnosis* (from Jensen 1979):** Cephalic sense organs in three separate crowns, second and third crowns close together. Buccal cavity weakly cuticularised; anterior portion globular to cup-shaped, sometimes very small; posterior portion never strongly cuticularised and never cylindrical or conical. Spicules bent, usually enlarged proximally. Gubernacular apophyses usually directed dorsocaudally and paired.

Genus *Setosabatieria* Platt 1985

***Diagnosis* (from Platt 1985):** Cuticle not punctated. Two latero-dorsal and two latero-ventral longitudinal rows of sub-cephalic setae.

***Setosabatieria conicauda* n. sp.** (Fig. 5–6, Table 1)

Material examined. Holotype Male, collected 6 April 2007, Chatham Rise (1240 m water depth), 44º29.1′S, 177º8.6′E. Characteristics of surface sediment layer (0–5 mm): mostly silt/clay (82.9%), with very fine sand (10.2%), and fine sand (8.4%); calcium carbonate content: 38.4%; total organic matter content: 1.91%; chloroplastic pigment concentration: 3501 $\text{ng/gDW}_{\text{sediment}}$ (NNCNZ 273).

Paratypes Two males, two females, same data as holotype (NNCNZ 2659-62); two males, three females, same data as holotype (NIWA 71585).

Description. *Males* Body cylindrical, medium-sized, tapering towards both extremities. Cuticle with faint annulations visible throughout body, most visible at anterior and posterior extremities. Sparse somatic setae. Head slightly set-off by constriction at level of amphid. Six minute inner labial papillae, six outer setiform papillae, and four cephalic setae in three distinct crowns. Buccal cavity cup-shaped. Amphid spiral, 4.25–4.5 turns. Two latero-dorsal and two latero-ventral longitudinal rows of 1–3 sub-cephalic setae, typically 2–3 per file. Pharynx with small bulb, cardia short. Nerve ring situated posterior to middle of pharynx, anterior to excretory pore. Cellular body of ventral gland medium-sized, situated posterior to pharynx. Intestine wall containing several clusters of round intracellular inclusions, 3–10 µm in diameter and distinct from surrounding tissue, sometimes with brown colouration (Figure 6C).

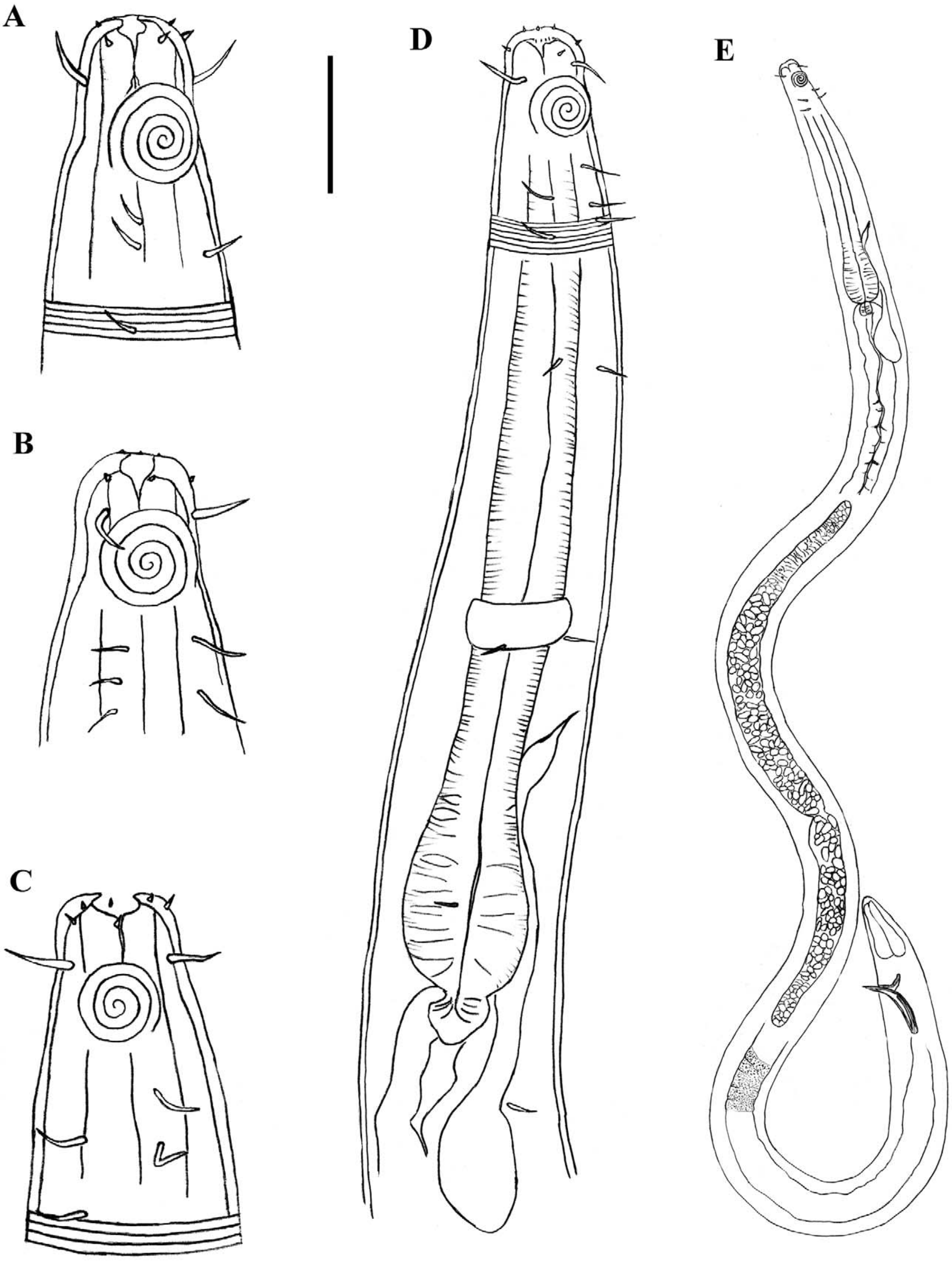

FIGURE 5. *S. conicauda* **n. sp.** A. Lateral view of male head. B. Lateral view of male head. C. Lateral view of female head. D. Lateral view of male anterior body region. E. Entire male. Scale bar: A, B, C = 20 µm; D = 30 µm, E = 100 µm.

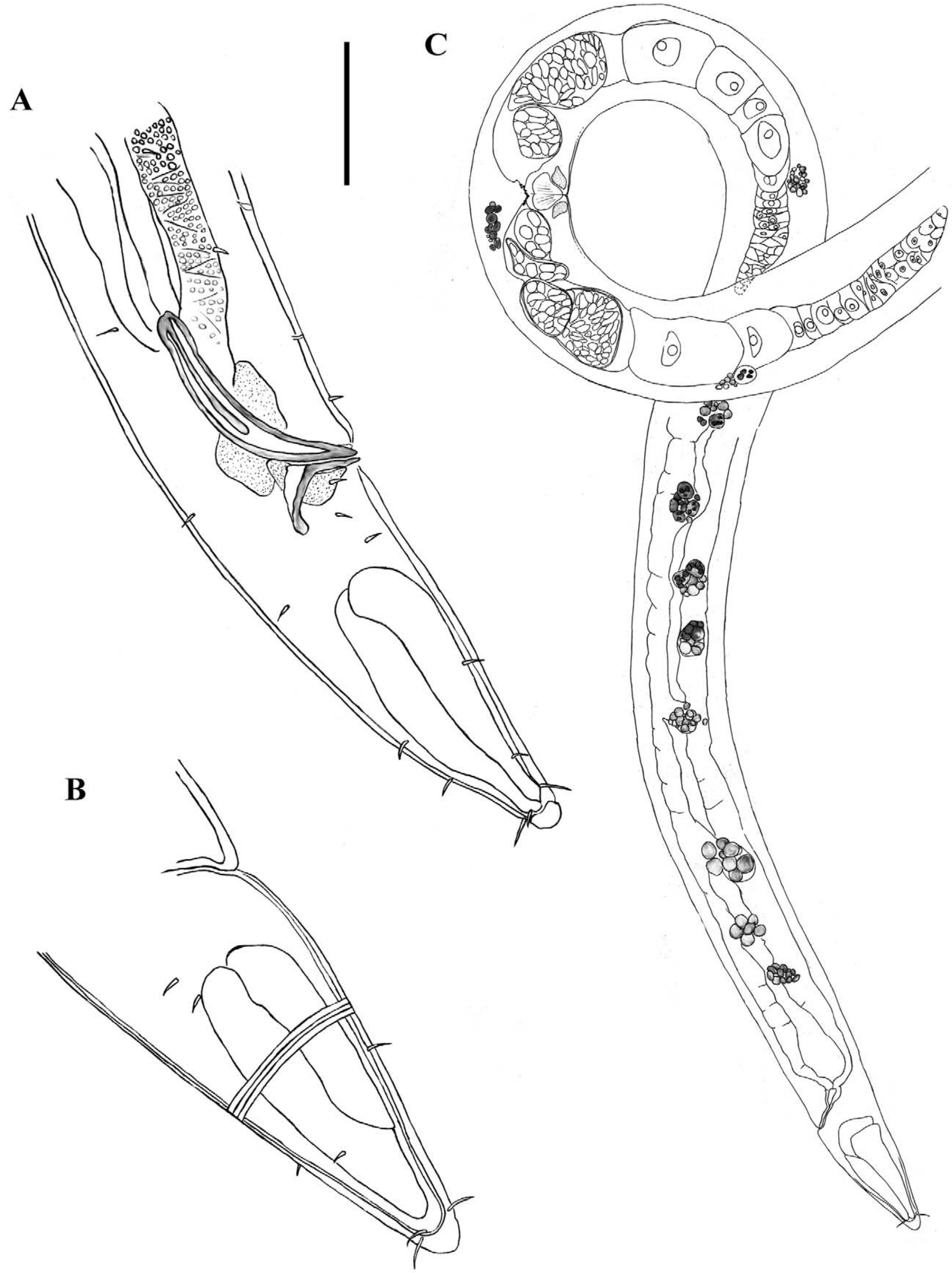

FIGURE 6. *S. conicauda* **n. sp.** A. Male posterior body region showing copulatory apparatus. B. Female posterior body region. C. Female mid-body and posterior body regions showing vulva, genital branches, and intracellular inclusions in gut wall. Scale bar: A, B = 30 µm; C = 100 µm.

Reproductive system diorchic, opposed, outstretched. Anterior testis to left of intestine, posterior testis to left or right of intestine. Spicules paired, equal, slightly curved, with well-developed central lamella in proximal portion. Gubernaculum with pair of dorso-caudal apophyses, bent ventrally in distal portion. Cloacal gland cells surround posterior portion of spicules and gubernaculum. Seven to nine small tubular supplements, often difficult to observe. One small pre-cloacal seta. Tail conical with several short caudal setae and three longer terminal setae. Three large caudal glands.

Females Similar to males, but slightly wider body and smaller amphid. Reproductive system didelphic, opposed, outstretched, with branches either to the right or left of intestine, but always on opposite sides. Vulva slightly post median. Cuticular vagina vera and vagina uterina surrounded by constrictor muscle. Vaginal glands present.

Diagnosis and relationships. *S. conicauda* **n. sp.** is characterised by amphid with 4.25–4.5 turns, the presence of only 1–3 sub-cephalic setae per file, and a conical tail. The latter trait distinguishes *S. conicauda* **n. sp.** from all other species of the genus, which possess conico-cylindrical tails.

Etymology. The specific name refers to the conical shape of the tail, which is the main distinguishing characteristic of this species.

Discussion. Most (> 90%) *S. conicauda* **n. sp.** specimens were found in subsurface (1–5 cm) sediments. *S. conicauda* **n. sp.** accounted for 1.6% of total nematode abundance at the type locality (Leduc *et al*. 2010a, referred to as *Setosabatieria* A therein).

It has been suggested that dark intracellular inclusions in intestinal cells, similar to those observed in *S. conicauda* **n. sp.**, play a role in sulphur detoxification (Jennings & Colam 1970). These inclusions have been observed in several nematode taxa living in sulphidic muds, including the closely related genus *Sabatieria* (Nicholas et al. 1987). There is still much debate, however, about the potential adaptive value of these structures to life in high sulphide conditions (Thiermann et al. 1994).

Key to all known species of *Setosabatieria*

1	Tail conico-cylindrical	2
-	Tail conical	*S. conicauda* **n. sp.** (New Zealand)
2	Arcuate or curved spicules	3
-	L-shaped spicules with median hollow region	*S. australis* Leduc & Gwyther 2008 (New Zealand)
3	Spicules with central cuticularised strip	4
-	Spicules without central cuticularised strip	5
4	Leaf-like extensions of the cuticle lateral to cloaca; 11–16 precloacal supplements	*S. hilarula* (De Man 1922) Platt 1985 (North Sea, English Channel, Mediterranean, Northwest Atlantic, Southeast Atlantic, Bay of Bengal)
-	Leaf-like projections absent; 9 precloacal supplements	*S. jingjingae* Guo & Warwick 2001 (Bohai Sea)
5	Amphideal fovea with more than 3 turns	6
-	Amphideal fovea with 2.5 turns; gubernaculum with triangular apophysis	*S. triangularis* Riera et al. 2006 (Canary Islands)
6	Amphideal fovea with 4.25 turns; 3–4 sub-cephalic setae per file	*S. fibulata* (Wieser 1954) Platt 1985 (Chile)
-	Amphideal fovea with 3.5 turns; 6–8 sub-cephalic setae per file	*S. coomansi* Huang & Zhang 2006 (Yellow Sea)

Species-environment relationships

Vasostoma aurata **n. sp.** and *Setosabatieria conicauda* **n. sp.** were recorded from a total of 13 and 11 sites, respectively (Table 2). All records were from the Chatham Rise, except for a single *V. aurata* **n. sp.** specimen from site 1 on the Challenger Plateau. *V. aurata* **n. sp.** and *S. conicauda* **n. sp.** co-occurred at sites 8, 10, 12, d, and e. When present, mean abundance of *V. aurata* **n. sp.** and *S. conicauda* **n. sp.** ranged from 5 to 60 individuals (ind.) 10 cm^{-2} and from 2 to 148 ind. 10 cm^{-2}, respectively.

There was a significant, but weak, negative linear relationship between %chl *a* and abundance of *V. aurata* **n. sp.** (R^2_{adj} = 0.15, P = 0.019, Table 3). A stronger, quadratic relationship was found between chloroplastic pigments and *V. aurata* **n. sp.** abundance (R^2_{adj} = 0.28, P = 0.003). No significant relationships were found between any of the environmental factors and the abundance of *V. aurata* **n. sp.** when absence data were excluded from the analysis. There was a significant, positive linear relationship between chloroplastic pigments and the abundance of *S. coni-*

cauda **n. sp.** both with and without absence data (R^2_{adj} = 0.23–0.45, $P < 0.05$). Exclusion of absence data also revealed negative relationships between %chl *a*, water depth and the abundance of *S. conicauda* **n. sp.** (R^2_{adj} = 0.40–0.48, $P < 0.05$). Significant quadratic relationships were also found for %chl *a* and chloroplastic pigments, but they exhibited lower R^2_{adj} relative to the corresponding linear relationships.

TABLE 2. Distribution of *V. aurata* **n. sp.** and *S. conicauda* **n. sp.** at the Challenger plateau and Chatham Rise sites, and range of environmental conditions at these sites. See Figure 1 for location of sites.

	***V. aurata* n. sp.**	***S. conicauda* n. sp**
Sites	1,8, 10-14, 18, 22, 23, c-e	7, 8, 10, 12, 16, a, b, d-f, h
Water depth (m)	350–1238	350–3100
Chloroplastic pigments (ng/gDW$_{sediment}$)	1114–6279	1074–8350
%chl a	<0.1–2.1	<0.1–13.9
%TOM	1.8–7.5	1.4–6.3
%silt/clay	5.8–95.3	5.8–96.6
%$CaCO_3$	13.1–86.1	13.1–100
%H_2O	37–60	37–63

The results of DistLM analyses suggest that the abundance of *V. aurata* **n. sp.** and *S. conicauda* **n. sp.** peaked at intermediate and high chloroplastic pigment concentrations, respectively, which may indicate differences in habitat preference related to food availability. Differences in the shape and size of mouth cavities between these species (e.g., cylindrical cavity with teeth in *V. aurata* **n. sp.** and small, cup-shaped cavity in *S. conicauda* **n. sp.**) also point towards dissimilarities in their feeding habits. The relationships we observed could, however, be related to the indirect effect of food input on sediment biogeochemistry (Soetaert *et al.* 2002). Tolerance of low oxygen and high sulphide levels in sediments subject to high food input is highly variable between species (e.g., Steyaert *et al.* 2007). *S. conicauda* **n. sp.** may tolerate these suboptimal conditions better than *V. aurata* **n. sp.**, which could explain its apparent preference for areas characterised by elevated chloroplastic pigment concentrations. Dark intracellular inclusions, which may be involved in sulphide detoxification (Jennings & Colam 1970), were only observed in the intestine of *S. conicauda* **n. sp.** specimens.

The abundance of both species showed a linear decrease with %chl *a*, suggesting a preference for food of relatively low quality. Whether these species prefer feeding on older and more refractory organic matter, however, remains unclear, and other processes could explain the trend we observed. For example, because population growth is expected to lag behind the initial input of fresh organic matter to the seafloor, greater abundances may be more likely to occur in sediments with older organic matter with relatively low %chl *a*.

No relationship was found between the physical and chemical characteristics of the sediments (i.e., %silt/clay, %$CaCO_3$, %H_2O) and the abundance of *V. aurata* **n. sp.** and *S. conicauda* **n. sp.** This finding is somewhat unexpected given the strong relationship usually found between sediment granulometry and nematode community structure in shallow habitats (Heip et al. 1985), and the wide range of sediment grain sizes sampled in the present study (6–93% silt/clay). Some studies, however, have shown that the influence of sediment granulometry on nematode distribution is sometimes restricted to surface sediments (Steyaert et al. 2003; Leduc *et al.* 2010b). Low oxygen and high sulphide concentrations in subsurface sediments (where *V. aurata* **n. sp.** and *S. conicauda* **n. sp.** are most abundant) subject to elevated organic matter input may have an overriding effect on subsurface nematode communities by restricting the distribution of some species (Steyaert *et al.* 2003). This process is likely to occur on the Chatham Rise, particularly at sites situated in proximity to the highly productive STF (e.g., Grove *et al.* 2006). Although no data are available on oxygen or sulphide concentrations in subsurface sediments of the Chatham Rise, the presence of glauconite over large areas of the rise is indicative of pervasive low oxygen conditions associated with high organic matter input (Cullen 1967; Glasby & Summerhayes 1975). In light of these findings, future studies on the effect of sediment granulometry on nematode communities should consider surface and subsurface sediments separately.

The findings of the present study suggest that food-related factors may influence the distribution of two nematode species on the continental slope of New Zealand. The trends described in the present study, however, are relatively weak, and based on a limited number of samples. Further research is required to better quantify the potential influence of environmental factors on the distribution of deep-sea nematode species.

TABLE 3. DistLM results showing linear and quadratic (hump-shaped) relationships between environmental parameters and the abundance of *V. aurata* **n. sp.** and *S. conicauda* **n. sp.** with and without absence data. Numbers in bold show significant relationships ($P < 0.05$). Positive and negative linear relationships are shown by **+** and **–** symbols, respectively following R^2_{adj} values.

	Predictor	**Linear**		**Quadratic**	
		P	R^2_{adj}	***P***	R^2_{adj}
Vasostoma aurata **n. sp.**					
with absence data	Water depth	0.648	<0.01	0.220	0.043
	Chloroplastic pigments	0.060	0.082	**0.003**	**0.276**
	%chl a	**0.019**	**0.150 (-)**	0.051	0.130
	%TOM	0.693	0.047	0.937	<0.01
	%silt/clay	0.606	<0.01	0.864	<0.01
	%$CaCO_3$	0.493	<0.01	0.669	<0.01
	%H_20	0.554	<0.01	0.594	<0.01
without absence data	Water depth	0.916	<0.01	0.223	0.096
	Chloroplastic pigments	0.883	<0.01	0.159	0.173
	%chl a	0.444	<0.01	0.675	<0.01
	%TOM	0.974	<0.01	0.968	<0.01
	%silt/clay	0.072	0.194	0.181	0.420
	%$CaCO_3$	0.098	0.162	0.085	0.289
	%H_20	0.684	<0.01	0.862	<0.01
Setosabatieria conicauda **n. sp.**					
with absence data	Water depth	0.706	0.029	0.907	0.065
	Chloroplastic pigments	**0.006**	**0.225 (+)**	**0.024**	**0.207**
	%chl a	0.092	0.070	0.069	0.137
	%TOM	0.745	0.032	0.796	0.066
	%silt/clay	0.241	0.013	0.368	0.003
	%$CaCO_3$	0.475	0.015	0.675	0.039
	%H_20	0.282	0.005	0.526	<0.01
without absence data	Water depth	**0.026**	**0.397 (-)**	**0.046**	**0.415**
	Chloroplastic pigments	**0.016**	**0.453 (+)**	**0.047**	**0.423**
	%chl a	**0.015**	**0.483 (-)**	**0.042**	**0.415**
	%TOM	0.656	<0.01	0.684	<0.01
	%silt/clay	0.234	0.064	0.371	0.018
	%$CaCO_3$	0.389	<0.01	0.671	<0.01
	%H_20	0.149	0.133	0.074	0.334

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