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A new cryptic species of *Neanthes* (Annelida: Phyllodocida: Nereididae) from Singapore confused with *Neanthes glandicincta* Southern, 1921 and *Ceratonereis (Composetia) burmensis* (Monro, 1937)

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Abstract. A new cryptic species of *Neanthes* (Nereididae), *N. wilsonchani*, new species, is described from intertidal mudflats of eastern Singapore. The new species was confused with both *Ceratonereis* (*Composetia*) *burmensis* (Monro, 1937) and *Neanthes glandicincta* Southern, 1921, which were found to be conspecific with the latter name having priority. *Neanthes glandicincta* is newly recorded from Singapore, its reproductive forms (epitokes) are redescribed, and Singapore specimens are compared with topotype material from India. The new species can be distinguished from *N. glandicincta* by slight body colour differences and by having fewer pharyngeal paragnaths in Areas II (4–8 vs 7–21), III (11–28 vs 30–63) and IV (1–9 vs 7–20), and in the total number of paragnaths for all Areas (16–41 vs 70–113). No significant differences were found in the morphology of the epitokes between the two species. The two species have largely non-overlapping distributions in Singapore; the new species is restricted to Pleistocene coastal alluvium in eastern Singapore, while *N. glandicinta* occurs in western Singapore as well as in Malaysia and westward to India.

Key words. polychaete, new species, taxonomy, ragworm

INTRODUCTION

Two of the most commonly reported nereidid polychaetes (ragworms) in southern and eastern Asia are *Neanthes glandicincta* Southern, 1921 and *Ceratonereis* (*Composetia*) *burmensis* (Monro, 1937) (both names as currently listed in WoRMS, accessed August, 2014). However, as *Composetia* was elevated to full genus rank by Khlebovich (1996) and the decision followed by Bakken & Wilson (2005), we have used the combination *Composetia burmensis* from this point on in this paper. Both *Composetia burmensis* and *Neanthes glandicincta* have been reported widely in the region, including the Bay of Bengal, Andaman Sea and South China Sea (Wu et al., 1985; Muir & Maruf Hossain, 2014, and references therein). In Singapore, *C. burmensis* was first reported in April 2008 as the Pink Burmese Worm (Wild Singapore, 2008) and subsequently redescribed formally by Chan (2009). *Neanthes glandicincta* on the other hand has not been reported from Singapore previously, at least not in the taxonomic literature. Both species have also been reported widely throughout Southeast- and South Asia in the ecological literature (e.g., Bayen et al., 2005; Quadros et al., 2009); the two species were reported in the same ecological study in Quadros et al. (2009). Both species are atypical members of their respective nominative genera: *N. glandicincta* is reported to have very few (or no paragnaths) in the oral ring of the pharynx, atypical for *Neanthes* but more akin to *Ceratonereis* and *Composetia*, whilst *C. burmensis* has parapodia bearing three notopodial lobes, which resembles some *Neanthes* species. The possibility that the two species may have been conspecific was not considered previously, although Southern (1921) noted the similarity between his new species and *Nereis* (*Ceratonereis*), which at the time encompassed *Composetia* species.

In this study we collected and examined specimens fitting the descriptions of both species at several sites throughout Singapore. We analysed statistically the paragnath numbers between worms and established that there are two different species, having largely non-overlapping ranges. One species occurs in the west of the island and the other is restricted to the east. We compared the two different species with type or topotype material of both *Composetia burmensis* and *Neanthes glandicincta,* from Myanmar (Burma) and India respectively, and showed that the population in the west is conspecific with both. Monro's *Composetia burmensis* therefore becomes a junior synonym of the older named species, *Neanthes glandicincta.* A new species is described for the population in the east.

MATERIAL AND METHODS

All specimens, including sexually mature forms (epitokes), were collected from exposed mudflats in Singapore during low tide, as listed in the species descriptions. Additional

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specimen information including ecological and co-ordinate data and a corresponding 'ngs' code used in the statistical analysis is provided in Table 1. Specimens were fixed in 10% formalin solution and later transferred to 70% ethanol, or placed directly into 80% ethanol. Preserved specimens were examined using stereo (Nikon SMZ1500 or Olympus SZX16) and compound (Nikon Eclipse 80i, Olympus BX43) light microscopes, with Nomarski interference contrast in the case of the Eclipse 80i. For each specimen we measured body length, width (at the posterior prostomium and chaetiger 10, with and without parapodia), counted the number of chaetigers, and recorded morphometric data including the number of pharyngeal paragnaths and chaetae. Light microscope photographs were taken with an Olympus microscope-mounted camera DP21.

Macrophotographs of whole animals were captured with a Canon 5D digital camera and MPE-65 mm macro lens with flash or LED lighting (Schott KL2500).

Terminology for parapodial and chaetal features follows Bakken & Wilson (2005). Types and additional specimens have been deposited at the Museum & Art Gallery of the Northern Territory (NTM), Australia and Zoological Reference Collection (ZRC) of the Lee Kong Chian Natural History Museum, Singapore. Comparative specimens were sourced from the Natural History Museum (BMNH), London.

Species concept. In the absence of a phylogeny for most species of *Neanthes*, the definition of a species adopted here is the morphospecies concept as defined by Cronquist (1978), i.e., species are the smallest groups that are consistently and persistently distinct, and distinguishable by ordinary means. Our proposed species are therefore hypotheses falsifiable when independent data, for example morphological synapomorphies and DNA sequences, become available.

Statistical analyses. Initial examination of the worms indicated a sizeable variation in paragnath numbers. To test whether paragnath numbers were influenced by body size we used correlation analysis to explore the relationship between size (as measured by total body width at chaetiger 10) against paragnath numbers for each Area individually and combined. Specimens with a total body width less than ~1.5 mm were excluded from the statistical study because of the difficulty in dissecting the pharynx. To further explore paragnath variation and identify possible groupings indicated by the data, Principal Component Analysis (PCA) and Ward's hierarchical cluster analysis based on paragnath numbers were performed. For the dataset, we aimed to have a good representation of specimens across multiple localities from Singapore, and also included data from one topotype specimen of *N. glandicincta* from Calcutta, syntype specimens of *C. burmensis* from Burma, as well as from Southern's original description of *N. glandicincta*. Since the original description of *C. burmensis* (Monro, 1937) lacked paragnath information, syntype specimens from Burma were regarded as proxies. To ensure good resolution of data from each locality, at least five specimens were included from each locality where possible, while all specimens were included from localities with less than five specimens. Each statistical specimen was assigned an "ngs" code (see Table 1). Paragnath counts on either side of Areas II and IV appeared not to vary so for the purpose of the analyses, so paragnaths occurring on the left side of the body when viewed dorsally were used. First, a PCA (n = 85) was performed using paragnaths in all areas to identify potential specimen clusters and differentiating factors between the clusters. Subsequently, to improve the resolution for certain localities, the dataset was expanded to include six other specimens (ngs14, ngs15, ngs17, ngs24, ngs25, and ngs38) where complete maxillary ring data was available although oral ring data were undetermined. The specimens were next subjected to Ward's hierarchical cluster analysis based on a Euclidean distance matrix of the maxillary ring paragnaths (n = 91, transformed by subtraction of means) to define species groups within the specimens. All statistical analyses were performed using the R statistical programme (Oksanen et al., 2013; R Core Team, 2013).

RESULTS

PCA and cluster analyses. Results of PCA (n = 85) of paragnath counts in all areas were represented in a PC1/PC2 biplot (Fig. 1). Variations represented by PC1 accounted for 89% of total variation, implying that factors that contribute heavily to PC1 would be most significantly responsible for the distances amongst and spatial patterns of the specimens. Two clusters of specimens could be distinguished from the distribution along PC1 axis, the larger one located towards the negative scale. The PC1 coefficient values (see Table 2) suggested that the negative scale of PC1 was mainly affected by Area III paragnaths, and to a lesser extent by Areas I, II and IV. In other words, specimens in the larger cluster would have more paragnaths in the maxillary ring. Oral ring paragnaths (Areas V, VI, and VII–VIII) have zero or minimal influence in the distribution of the specimens between the clusters, given their negligible PC1 coefficient values. Further, distributions along axes of PC2 to PC5 were not useful for explaining any cluster differences because of their low PCA eigenvalues (Table 2).

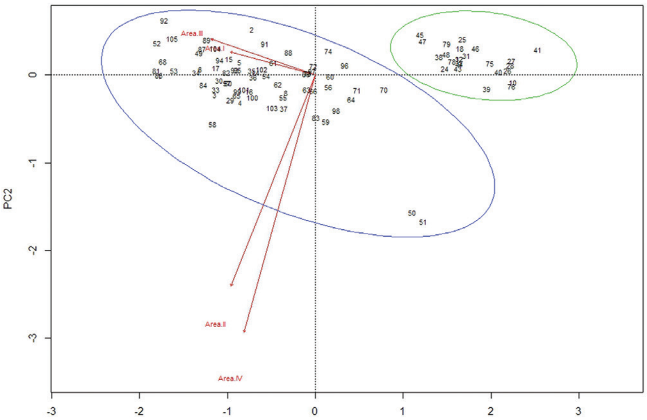

Fig. 1. Biplot of principal components of 85 *Neanthes* specimens based on all paragnath areas against the PC1 and PC2 axes. The specimens were later identified as belonging to two species groups, the blue circle indicating *N. glandicincta* specimens, and the green circle for *N. wilsonchani*, new species, specimens.

Table 1: List of registered study specimens together with the corresponding statistical code and ecological and geocoded data. *denotes the holotype specimen. ^ indicates that the specimen was not used in the PCA analysis but only in the cluster analysis.

Species	**Museum Catalogue Number/Reference**	**No. of specimen(s)**	**Statistical code**	**GPS**	**Tidal height (m)**
N. glandicincta	Southern 1921’s original description	26	ngs2	na	Less than 1.015
N. glandicincta	BMNH 1937.1.4.16–42	8	ngs64, ngs65, ngs66, ngs68, ngs70, ngs71, ngs72, ngs73	na	na
N. glandicincta	BMNH 1938.5.7.28	1	ngs74	na	na
N. glandicincta	SB 22/5 hede 2D.5(32)	4	ngs3, ngs4, ngs5, ngs6	na	na
N. glandicincta	ZRC.ANN.0039	7	ngs1, ngs33, ngs34, ngs35, ngs36, ngs37, ngs8	N01°26.729’ E103°43.674’ to N01°26.693’ E103°43.692’	1.5–1.1
N. glandicincta	ZRC.ANN.0040	1	ngs103	N01°27.139’ E103°46.580’ to N01°27.147’ E103°46.605’	0.55
N. glandicincta	ZRC.ANN.0041	8	ngs14^, ngs15^, ngs61, ngs,62, ngs63, ngs99, ngs100, ngs101	N01°18.516’ E103°45.062’ to N01°18.505’ E103°45.085’	0.6
N. glandicincta	ZRC.ANN.0042	1	ngs17^	N01°26.721’ E103°43.672’ to N01°26.695’ E103°43.667’	0.6–0.9
N. glandicincta	ZRC.ANN.0043	7	ngs29, ngs30, ngs91, ngs92, ngs93, ngs94, ngs95	N01°19.537’ E103°43.989’	0.8–1.3
N. glandicincta	ZRC.ANN.0044	1	ngs49	N01°25.448’ E103°51.621’ to N01°25.408’ E103°51.736’	0.5–1.7
N. glandicincta	ZRC.ANN.0045	2	ngs50, ngs51	N01°26.173’ E103°45.671’ to N01°26.189’ E103°45.690’	0.5–1
N. glandicincta	ZRC.ANN.0046	3	ngs52, ngs53, ngs54	N01°26.965’ E103°46.724’ to N01°26.969’ E103°43.696’	0.9–1.3
N. glandicincta	ZRC.ANN.0047	6	ngs55, ngs80, ngs81, ngs82, ngs83, ngs84	N01°26.609’ E103°44.196’ to N01°26.595’ E103°44.227’	1.25(?)
N. glandicincta	ZRC.ANN.0048	5	ngs56, ngs57, ngs58, ngs59, ngs60	N01°27.075’ E103°46.614’ to N01°27.104’ E103°46.612’	1.1
N. glandicincta	ZRC.ANN.0049	5	ngs85, ngs86, ngs87, ngs88, ngs89	N01°26.766’ E103°42.494’ to N01°26.788’ E103°42.481’	0.7–1.3

Table 1...continued

Species	Museum Catalogue Number/Reference	No. of specimen(s)	Statistical code	GPS	Tidal height (m)
N. glandicincta	ZRC.ANN.0050	2	ngs96, ngs98	N01º26.119’ E103º45.602’ to N01º26.135’ E103º45.627’	0.5–1.1
N. glandicincta	ZRC.ANN.0051	1	ngs97	N01º26.128’ E103º45.621’ to N01º26.099’ E103º45.623’	1.6
N. glandicincta	ZRC.ANN.0052	2	ngs104, ngs105	N01º25.147’ E103º55.762’	na
N. glandicincta	ZRC.ANN.0053	1	ngs102	N01º26.729’ E103º43.674’ to N01º26.693’ E103º43.692’	1.5–1.1
N. wilsonchani new species	ZRC.ANN.0028 *	1	ngs9	N01º24.347’ E103º58.273’ to N01º24.340’ E103º58.253’	1.1
N. wilsonchani new species	ZRC.ANN.0029	2	ngs10, ngs11	N01º24.347’ E103º58.273’ to N01º24.340’ E103º58.253’	1.1
N. wilsonchani new species	ZRC.ANN.0030	1	ngs12	N01º26.766’ E103º42.494’ to N01º26.788’ E103º42.481’	0.7–1.3
N. wilsonchani new species	ZRC.ANN.0031	1	ngs18	N01º23.407’ E103º59.446’ to N01º23.361’ E103º59.522’	0.4–1.1
N. wilsonchani new species	ZRC.ANN.0032	7	ngs41, ngs43, ngs44, ngs45, ngs46, ngs47, ngs48	N01º25.448’ E103º51.621’ to N01º25.408’ E103º51.736’	0.5–1.7
N. wilsonchani new species	ZRC.ANN.0033	2	ngs26, ngs27	N01º25.383’ E103º51.774’ to N01º25.409’ E103º51.768’	0.6–0.8
N. wilsonchani new species	NTM W25645	2	ngs24^, ngs25^	N01º25.383’ E103º51.774’ to N01º25.409’ E103º51.768’	0.6–0.8
N. wilsonchani new species	ZRC.ANN.0034	3	ngs28, ngs39, ngs40	N01º24.433’ E103º58.967’ to N01º24.431’ E103º58.995’	1.0–1.5
N. wilsonchani new species	ZRC.ANN.0035	3	ngs31, ngs32, ngs38^	N01º22.955’ E103º57.130’ to N01º22.949’ E103º57.154’	0.25
N. wilsonchani new species	ZRC.ANN.0036	2	ngs75, ngs76, ngs77	N01º23.396’ E103º59.468’ to N01º23.397’ E103º59.496’	0.45

Table 1...continued

Species	**Museum Catalogue Number/Reference**	**No. of specimen(s)**	**Statistical code**	**GPS**	**Tidal height (m)**
N. wilsonchani new species	ZRC.ANN.0037	1	ngs78	N01º22.952’ E103º57.905’ to N01º22.884’ E103º57.958’	0.7
N. wilsonchani new species	ZRC.ANN.0038	1	ngs79	N01º22.923’ E103º57.918’	0.6–1.2

Table 2. Principal components coefficients of the paragnath areas in 85 *Neanthes* specimens.

Variables (=Paragnath area)	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**
I	−2.5958	−0.2143	−1.4948	0.2412	−0.5271
II	−3.0865	2.1805	−0.3735	−0.8780	0.2562
III	−10.8751	−1.002	0.3959	−0.0024	0.0811
IV	−2.1516	2.1753	0.4386	0.8711	−0.3243
V	0	0	0	0	0
VI	0	0	0	0	0
VII–VIII	−0.3825	0.1119	−0.5654	0.6166	1.0295
Eigenvalue	259.3523	19.6390	5.6651	3.6643	2.8209
Variance proportion	0.8908	0.0675	0.0195	0.0126	0.0097
Cumulative variance proportion	0.8908	0.9582	0.9777	0.9903	1

Based on a Ward’s hierarchical cluster analysis (n = 91) using only maxillary ring paragnaths, we obtained two major groups in the dendogram (Fig. 2). The upper branch grouped together 27 specimens comprising lower paragnath counts in Areas II and III, and were hereby assigned as *N. wilsonchani,* new species. The lower branch grouped together specimens that had paragnath counts similar to *N. glandicincta* as described by Southern (1921) (ngs2), as well as the topotype from India (ngs74) and *C. burmensis* specimens from Burma (ngs64, ngs65, ngs66, ngs68, ngs70, ngs71, ngs72, ngs73). All specimens in this latter cluster are thus newly assigned or reassigned to *N. glandicincta*. The *N. glandincta* group was split into two subgroups, each comprising 32 specimens (Fig. 2). However, analysis of the ranges of paragnath counts in the two groups showed major overlap in the counts in Areas I, II, and IV (Fig. 3) and it was thus determined that these groups should be considered as one and the same species.

The groups of specimens identified in the dendrogram were consistent to the clusters formed in the PCA, thereby further supporting the earlier conclusion that maxillary ring paragnaths were the main differentiating factors between the species clusters. However, two specimens (ngs50 and ngs51) were determined to be anomalous because of the following observations. In the PCA, they were outliers from the main clusters (Fig. 1) and their positions in the cluster analysis varied. The cluster analysis of n = 85 specimens using paragnaths of all areas placed them in the *N. glandicincta* group (not shown), which contradicted the results of the analysis with n = 91 specimens using paragnaths of only the maxillary ring where they were placed with the *N. wilsonchani* new species (Fig. 2). Ngs50 and ngs51 have the following paragnath counts: I: 0, 0; II: 23, 23; III: 21, 19; IV: 22, 23, falling below the Area III range for *N. wilsonchani* new species, yet were similar to the *N. glandicincta* group for Areas II and IV. Specimens ngs96, ngs97 and ngs98 from the same locality as ngs50 and ngs51, i.e., Sungei Mandai, were closely grouped with type and topotype specimens of *C. burmensis* and *N. glandicincta* within the *N. glandicincta* group. The appearance of ngs50 and ngs51 is thus considered to be an anomaly, possibly indicating a mutation or hybridisation.

Omitting counts from outliers ngs50 and ngs51, the range of paragnath counts of *N. wilsonchani*, new species were distinctly lower especially in Areas II, III and IV (Fig. 4, 5). The resultant paragnath ranges for *N. glandicincta* based on our specimens (n = 64) are Areas I: 0–17 (1st quartile = 7, median = 9, 3rd quartile = 11); II: 7–21 (14, 16, 18,); III: 30–63 (41.75, 49, 53.25); IV: 7–20 (11, 13, 15), and for *N. wilsonchani*, new species (n = 25), are I: 0–4 (1, 2, 3); II: 4–8 (5, 6, 7); III: 11–28 (15, 21, 22); IV: 1–9 (5, 6, 7).

Although a slight overlap exists at the extremes of the ranges for Areas II (7–8) and IV (7–9), the range between

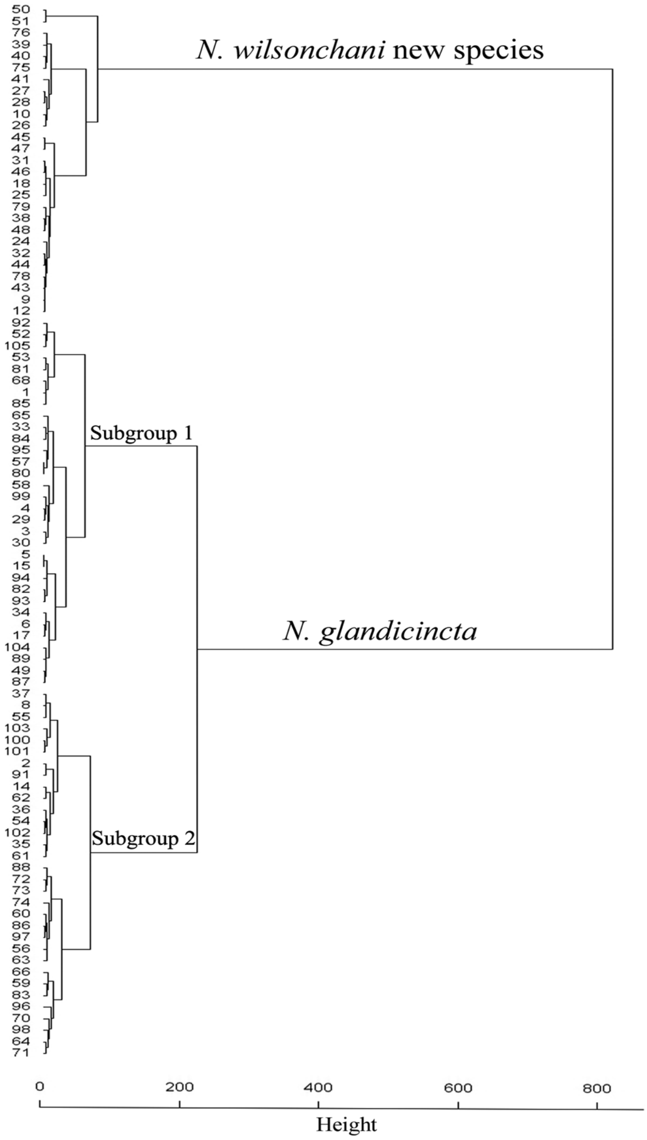

Fig. 2. Dendrogram generated by Ward's hierarchical cluster analysis of *Neanthes* specimens based on Euclidean distances between numbers of paragnath in Area I, II, III, and IV. Numbers at the end of each branch are ngs statistical codes (see Table 1 for corresponding specimens). Specimens in the top cluster are identified as *N. wilsonchani*, new species, and specimens at the bottom cluster belong to *N. glandicincta*, new species.

the first quartile and third quartile was sufficiently different to serve as diagnostic characters. For Area I, the range for *N. wilsonchani*, new species, overlaps entirely with the lower end (0–4) of the range for *N. glandicincta*, which has a much higher limit (up to 17). In conclusion, our study specimens appear to represent two different species of *Neanthes*, *N. glandicincta* (under which *C. burmensis* is synonymised), which have a higher number of paragnaths, as in the original description of Southern (1921), and a new species *N. wilsonchani* with a lower number of paragnaths in the maxillary ring.

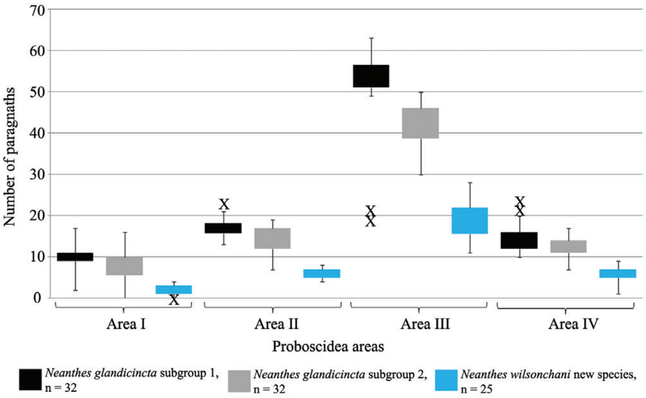

Fig. 3. Boxplot of the range of paragnath counts in Areas I, II, III and IV for subgroup 1 (n = 32) and subgroup 2 (n = 32) in the *N. glandicincta* group and the *N. wilsonchani* group (n = 25). The bars represent the range between the 1st and 3rd quartiles, while the line shows the extent of the minimum and maximum numbers of paragnaths. "x" represents paragnath counts of outliers ngs50 and ngs51.

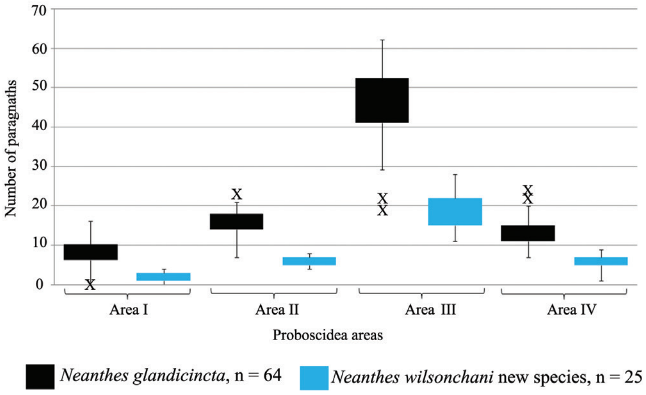

Fig. 4. Boxplot of the range of paragnath counts in Areas I, II, III and IV for the *N. glandicincta* group (n = 64) and the *N. wilsonchani* group (n = 25). The bars represent the range between the 1st and 3rd quartiles, while the line shows the extent of the minimum and maximum numbers of paragnaths. "x" represents paragnath counts of outliers ngs50 and ngs51.

Allometric correlations. Interestingly, the relationship between body size (as measured by its width at chaetiger 10) and total paragnath counts differed between the two species, and significantly, there was a clear separation between the two groups based on total paragnath numbers (Fig. 6). The correlation with body size was significant in *N. wilsonchani*, new species (r = 0.53, $P < 0.05$; n = 22), but not in *N. glandicincta* (r = 0, P = 0.995; n = 46). Analysed separately, counts in each paragnath Area showed no significant correlation with body width in *N. glandicincta*. In contrast, there were significant correlations between body size and the number of paragnaths in Areas II (r = 0.47, $P < 0.05$; n = 23) and III (r = 0.58, $P < 0.01$; n = 23) for *N. wilsonchani*, new species.

TAXONOMY

Nereididae Blainville, 1818

Neanthes Kinberg, 1865

Neanthes glandicincta (Southern, 1921)

(Figs. 7–9)

Nereis (*Nereis*) *glandicincta* Southern, 1921: 589–593, pl 23, fig. 9a–l, text–figs. 5a–e.

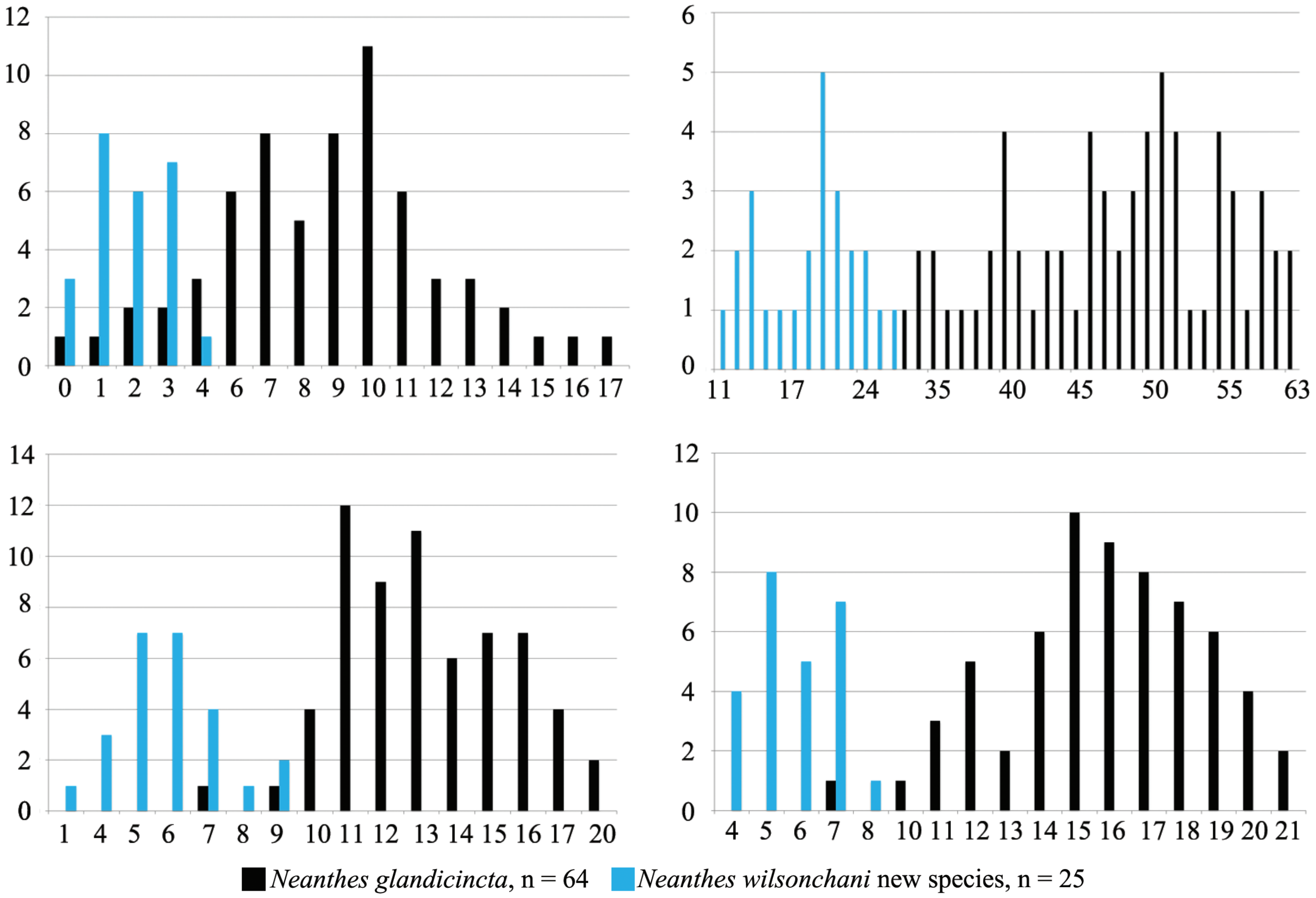

Fig. 5. Frequency charts of paragnath numbers in Areas I, II, III and IV of the maxillary ring for both *N. glandicincta* and *N. wilsonchani*, new species, based on specimens used in the Ward's hierarchical cluster analysis, omitting ngs50 and ngs51. The X-axes represent number of paragnaths in a specimen while the Y-axes represent frequency.

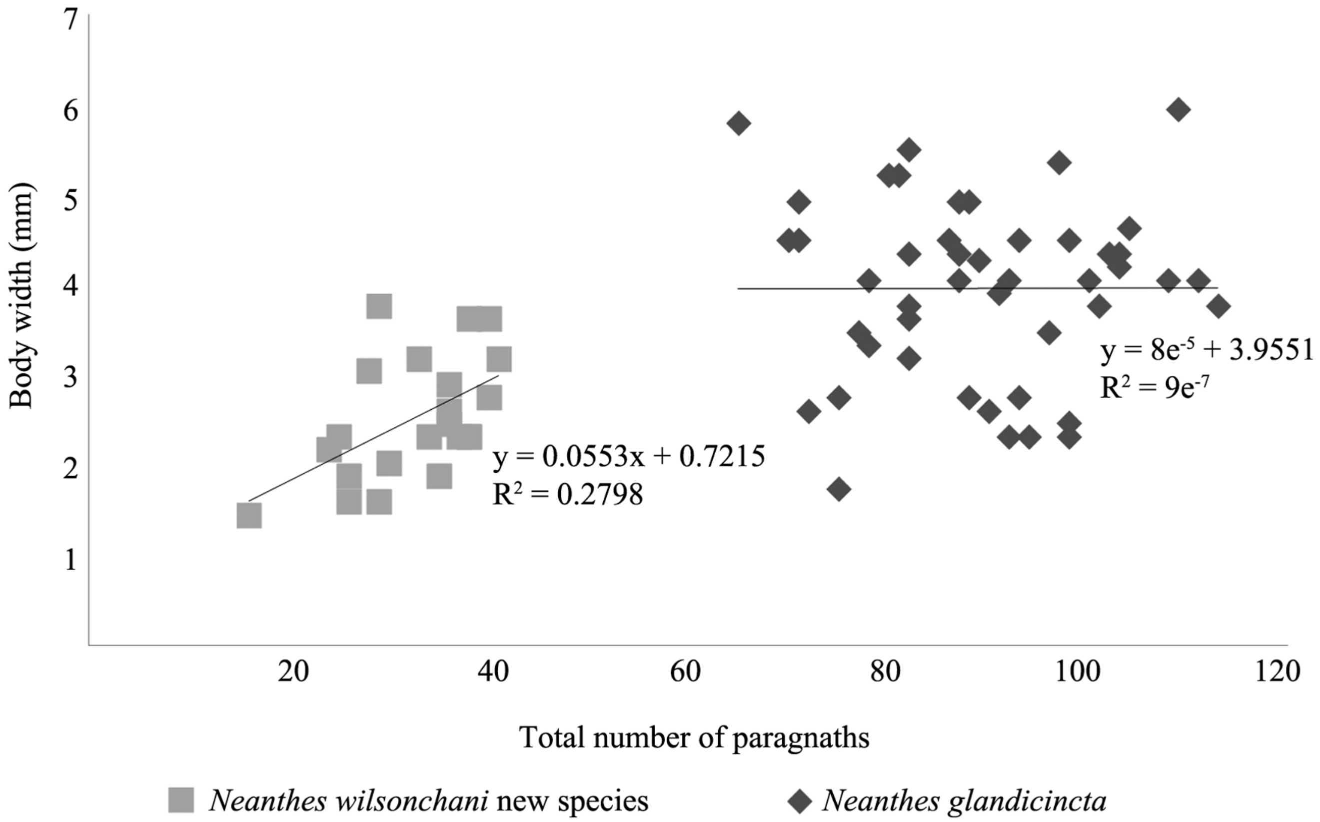

Fig. 6. Relationship between maximum body width and total paragnath number for *N. wilsonchani*, new species (left) and *N. glandicincta* (right).

Ceratonereis burmensis Monro, 1937: 532–536, fig. 1a–f; Ng et al. 2011, in part. New synonym.
Nereis (*Ceratonereis*) *burmensis* Fauvel, 1953: 196–197, fig. 97d–f.
Nereis glandicincta Fauvel, 1953: 181–182, fig. 91f–h.
Ceratonereis (*Composetia*) *burmensis* Hartmann-Schröder, 1985: 49 (list); Chan, 2009: 165–167, fig. 5a–r, in part.

Type locality. Chlika Lake, India.

Material examined. NON-TYPE: INDIA: 1 ex. BMNH 193.5.7.28, Water Lakes, Stn 2, Calcutta. SINGAPORE: 4 ex. SB 22/5 hede 2D.5(32), Sungei Buloh, coll. Reef Ecology Study Team, NUS, Year 2000; 7 ex. ZRC.ANN.0039, Sungei Buloh Besar, western bank, coll. CMBS team & volunteers, 2 December 2010; 1 ex. ZRC.ANN.0040, Sungei Cina, outer river mouth, coll. CMBS team & volunteers, 21 January 2012; 8 ex. ZRC.ANN.0041, Sungei Pandan, mid riverbed, coll. CMBS team & volunteers, 5 July 2011; 1 ex. ZRC.ANN.0042, Sungei Buloh Besar, along bridge near visitor centre, coll. CMBS team & volunteers, 18 August 2011; 7 ex. ZRC.ANN.0043, Sungei Jurong, upstream near gateway, coll. Helen Wong Pei San, Lee Yen-ling & Ng Heok Hee, 19 August 2011; 1 ex. ZRC.ANN.0044, Seletar, North shore of Yishun Ave 1, coll. Lee Yen-ling, Ng Heok Hee & Ong Joo Yong, 3 August 2011; 2 ex. ZRC.ANN.0045, Sungei Mandai, coll. CMBS team & volunteers, 24 November 2011; 3 ex. ZRC.ANN.0046, Sungei Cina, coll. CMBS team & volunteers, 26 January 2011; 6 ex. ZRC.ANN.0047, Kranji, beside nature trail, coll. CMBS team & volunteers, 15 January 2011; 5 ex. ZRC.ANN.0048, Sungei Cina, river mouth, coll. CMBS team & volunteers, 29 August 2011; 5 ex. ZRC.ANN.0049, Lim Chu Kang, coll. CMBS team & volunteers, 16 April 2011; 2 ex. ZRC.ANN.0050, Sungei Mandai, coll. CMBS team & volunteers, 10 April 2011; 1 ex. ZRC.ANN.0051, Sungei Mandai, feeder stream, coll. CMBS team & volunteers, 9 September 2011; 2 ex. ZRC.ANN.0052, Pulau Ubin, OBS Camp 1 mangrove, coll. Joelle Lai, 22 October 2012; 1 ex. ZRC.ANN.0053, Sungei Buloh Besar, western bank, coll. CMBS team & volunteers, 2 December 2010.

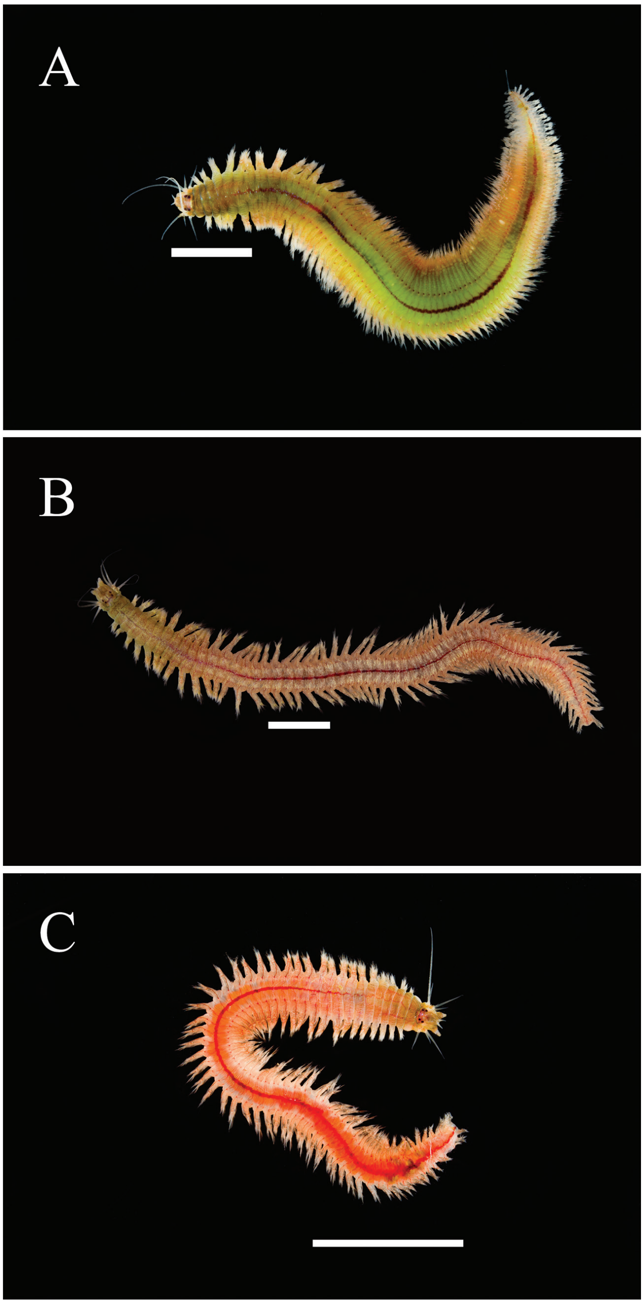

Fig. 7. Live specimens of *Neanthes glandicincta*, collected from Kranji on 24 Jan 2015. A. Dorsal view, female epitoke with green eggs; B. Dorsal view, early stage male epitoke, specimen incomplete posteriorly; C. Dorsal view, atokous specimens, incomplete posteriorly. Scale bars = 5 mm.

Comparative material examined. *Ceratonereis burmensis* Syntypes 27 specimens BMNH (1937.1.4.16–42), Maungmagan, Myanmar (formerly Burma), coll. GE Gates.

Diagnosis. *Neanthes* species having notopodia with 3 lobes/ligules (notopodial prechaetal lobe well developed), and lacking paragnaths on the oral ring of the pharynx (or if present, minute and few): viz. Area I: 0–17; Areas II: 7–21, III: 30–63; IV: 7–20; V: 0; VI: 0–1; VII–VIII: 0–8 (Table 3); total paragnath number 70–113; dusky brown pigment antero-dorsally in addition to a conspicuous row of dark glands on each segment and its parapodial.

Description of epitokous worms (n = 2 females and 4 males). Description based on ngs33, ngs36, ngs37, ngs96, ngs102 and ngs103. Body of epitokes filled with eggs/sperm, slightly more turgid than non-mature forms; no additional body pigmentation compared to atokous forms (Fig. 7A–C). Eyes slightly enlarged in both sexes compared to atokous forms. Males and females with basally swollen dorsal cirri (DC) (chaetigers 1 to 4–7 or swelling absent). Basally swollen ventral cirri (VC) present in males (chaetigers 1–4) but absent in females. Parapodia of unmodified anterior region (chaetigers 1 to 20–22) without additional lobes (Fig. 8A, B), thereafter parapodia modified bearing crenulate dorsal cirri (male only; restricted to mid-body; Fig. 8D) and in both sexes additional lamellae at dorsal base of DC, at dorsal and ventral bases of VC, and large postchaetal lamella on dorsal neuropodial lobe (Fig. 8C, D, E, F). Epitokal chaetae absent (female) or present (male) as ‘paddle’ chaetae in both notopodia and neuropodia; absence in female probably because specimens not fully mature. Fully mature females possess paddle chaetae, green coloured as result of eggs (Fig. 7A).

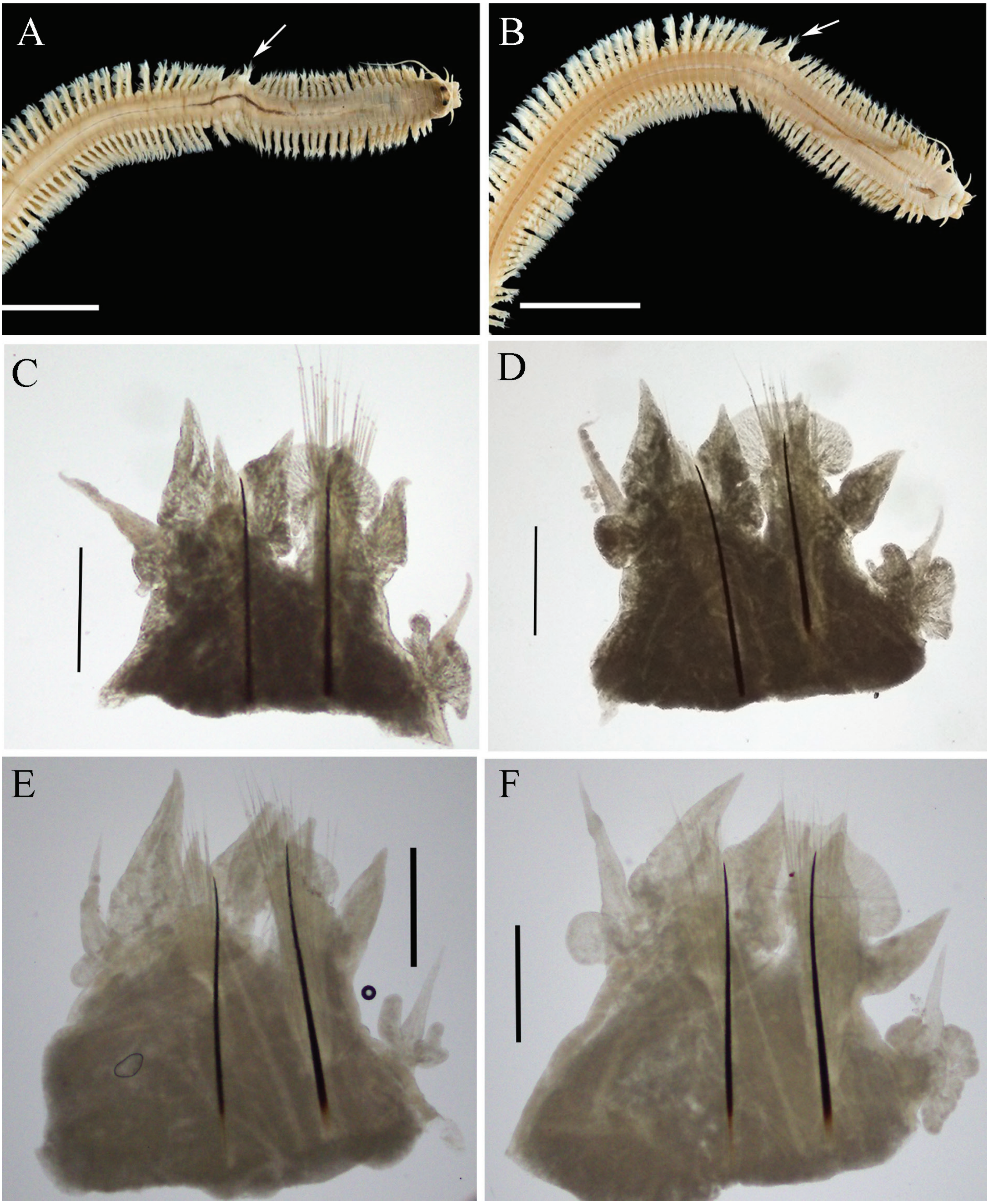

Fig. 8. Sexually mature epitokes of *N. glandicincta*. A–D. ngs102 (= ZRC.ANN.0053, male, E–F. ngs37 (part of ZRC.ANN.0039), female. A. Dorsal view, specimen incomplete posteriorly; B. ventral view, specimen incomplete posteriorly; C–F. modified parapodium, C. parapodium 25; D. parapodium 33; E. parapodium 25; F. parapodium 32. Scale bars: A, B, 5 mm; C, D, E, F: 0.5 mm. Arrows indicate start of first modified parapodia.

Distribution and habitat. Intertidal mudflats of northwestern and southwestern Singapore (Fig. 14). First record of the species in Singapore. Outside Singapore, the species is confirmed as occurring in Myanmar and India.

Remarks. The type material of *Nereis* (*Nereis*) *glandicincta* Southern, 1921 consists of 26 specimens from three localities near Calcutta (Salt lake near Barantolla; Dhappa and Garia) including one designated as a 'type' but no catalogue numbers are provided in the description. The types are probably in the Indian Museum, Calcutta, but were unavailable for loan. The specimen of *Nereis* (*Nereis*) *glandicincta* examined here (BMNH 1938.5.7.28 = ngs74) was collected from the same region (Calcutta), although the precise location of 'Water

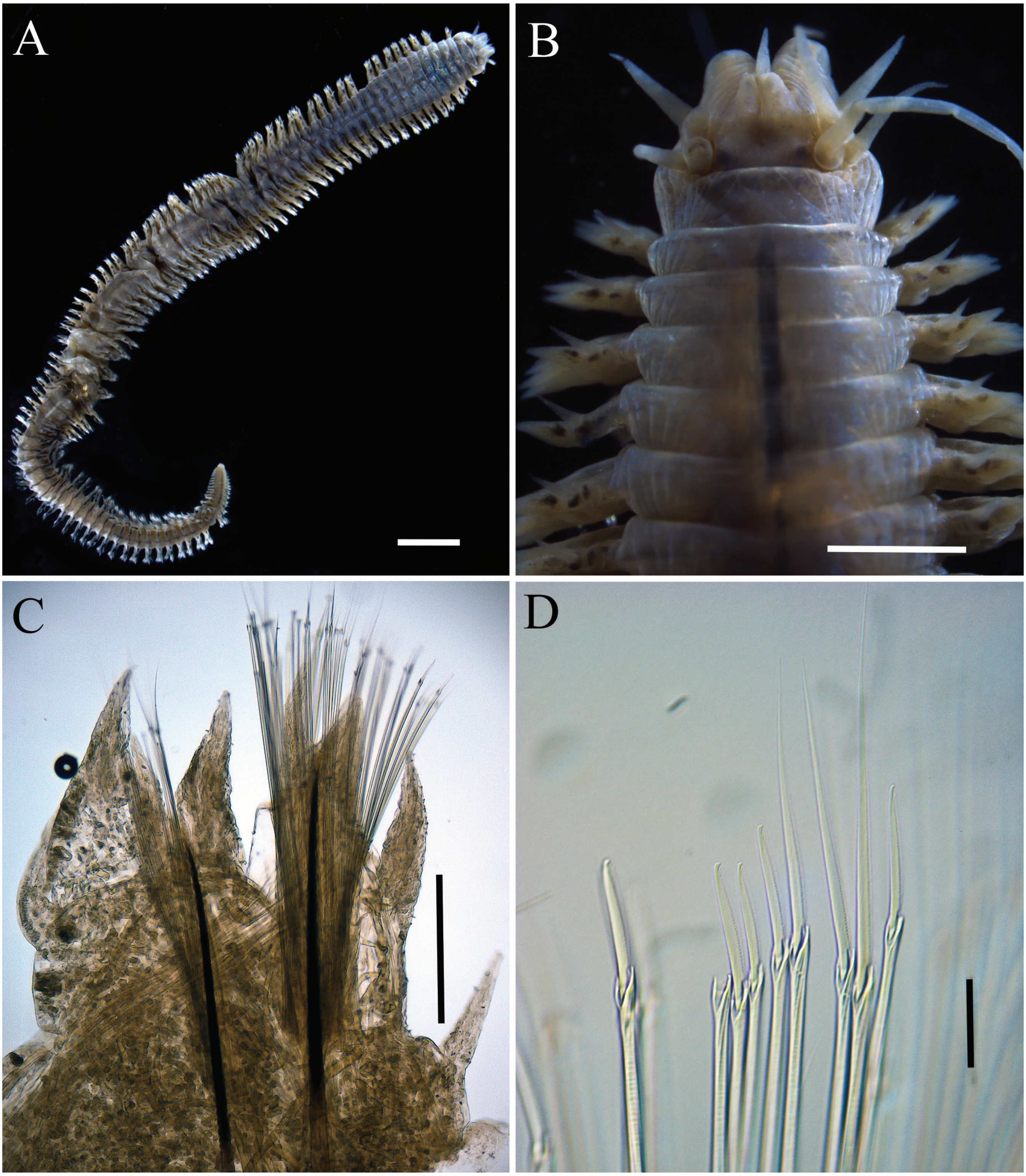

Fig. 9. Syntypes of *Ceratonereis burmensis* Monro, 1937, BMNH 1937.1.4.16–42. A, whole specimen, dorsal view; B. head end, dorsal view showing single antenna, the result of a malformation; C. parapodium of chaetiger 20, left side; D. long-bladed sesquigomph spinigers and sesquigomph falcigers in the subacicular neuropodium, chaetiger 20. Scale bars: A: 2.0 mm; B: 1.0 mm; C: 0.2 mm; D: 20 microns.

Lake' is unknown; this specimen groups together with ngs73 from Myanmar (syntype of *Composetia burmensis*) and ngs88 from Lim Chu Kang in the cluster dendrogram. Paragnath data from the original description by Southern also places the type specimen in the *Neanthes* group with higher paragnath counts, which is restricted to the western half of the island.

In addition to the morphometric data supporting synonymy of *Composetia burmensis* with *Neanthes glandicincta*, and conspecificity of the *N. glandicincta* group specimens, the general morphology of the specimens representing the two species is also very close. Although the topotype specimen of *N. glandicincta* is now faded, Southern (1921: 589) describes the pigmentation pattern as follows: "running transversely across the dorsal and ventral surface of each segment is a very conspicuous row of dark glands. The glands are continued into the feet, and are especially prominent in the dorsal ligule … there is usually a band of glands on the median dorsal area of the peristomium". This precise pigment pattern can still be seen in the syntypes of *Composetia burmensis* from Myanmar (Fig. 9A, B), further supporting the synonymy of the two species; it also occurs in the new species (below), supporting the idea that these forms represent a complex of similar species. Interestingly, the species name, *glandicincta*, refers to this arrangement of glands around the body. The parapodial and chaetal morphology of *C. burmensis* also is in close agreement with those of *N. glandicincta* (Fig. 9C, D cf. Figs. 11C, 12D).

Chan's (2009) specimens comprise both *N. glandicincta* and *N. wilsonchani*, new species (see below for discussion). All other records of *N. glandicincta* and *C. burmensis* in southern and eastern Asia require confirmation. It appears that at least one additional undescribed cryptic species of the *N. glandicincta* species group may be present in eastern Asia as evidenced by a form reported by Wu et al. (1985) whose non-epitokal specimens resemble closely the specimens described here, but differ in the form of the epitokal specimens, which have an unmodified anterior region of only 13–15 chaetigers (also different from the new species described below).

Neanthes wilsonchani, new species
(Figs. 10–13)

Ceratonereis (*Composetia*) *burmensis* Chan, 2009: 165–167, fig. 5a–r, in part.
Ceratonereis burmensis Ng et al., 2011: 426, Ragworms, in part.

Type locality. Pulau Ubin, Singapore.

Etymology. The new species is described after Wilson M.F. Chan who first noted its occurrence in the muddy shores of Singapore.

Material examined. All material from Singapore. HOLOTYPE: 1 ex. ZRC.ANN.0028, Pulau Ubin Southeast, near Sensory Trail, coll. CMBS team & volunteers, 12 February 2011. PARATYPES: 2 ex. ZRC.ANN.0029, Pulau Ubin Southeast, near Sensory Trail, coll. CMBS team & volunteers, 12 February 2011; 1 ex. ZRC.ANN.0030, Lim Chu Kang, coll. CMBS team & volunteers, 16 April 2011; 1 ex. ZRC.ANN.0031, Changi Creek, coll. Helen Wong Pei San, Lee Yen-ling & Ng Heok Hee, 7 July 2011; 7 ex. ZRC.ANN.0032, Seletar, North shore of Yishun Ave 1, coll. Lee Yen-ling, Ng Heok Hee & Ong Joo Yong, 3 August 2011; 2 ex. ZRC.ANN.0033, Seletar, North shore of Yishun Ave 1, coll. CMBS team & volunteers, 8 January 2012; 5 ex. NTM W25645, Seletar, North shore of Yishun Ave 1, coll. CMBS team & volunteers, 8 January 2012; 3 ex. ZRC.ANN.0034, Pulau Ubin Southeast, Kampong Melayu, near old site of mosque, coll. CMBS team & volunteers, 27 September 2011; 3 ex. ZRC.ANN.0035, Pasir Ris, right half of shore between Sungei Api-api and Sungei Tampines, coll. CMBS team & volunteers, 11 May 2012; 3 ex. ZRC.ANN.0036, Changi Creek, coll. CMBS team & volunteers, 12 April 2012; 1 ex. ZRC.ANN.0037, Sungei Loyang, river mouth at Pasir Ris Park side, coll. Lee Yen-ling & Ng Heok Hee, 27 April 2012; 1 ex. ZRC.ANN.0038, Sungei Loyang, river mouth at Pasir Ris Park side, coll. Helen Wong Pei San, Lee Yen-ling, Lim Sixian, Ng Heok Hee & (Rene) Ong Shue Ling, 25 May 2012.

Diagnosis. A *Neanthes* species having notopodia with 3 lobes/ligules (notopodial prechaetal lobe well developed), and lacking paragnaths on the oral ring of the pharynx (or if present minute and few), viz. Area I: 0–4; Areas II: 4–9, III: 11–18; IV: 1–9; V: 0; VI: 0–1; VII-VIII: 0–5 (Table 4); total paragnath number 16–41; a conspicuous row of dark glands on each segment and its parapodia.

Description (n=25). Type material ranged from 0.725–2.32 mm wide (chaetiger 10, without parapodia) and 1.45–3.77 mm wide (chaetiger 10, with parapodia). One complete specimen 112 chaetigers, 1.16/2.17 mm wide, 38.1 mm long. Preserved specimens have darkly pigmented glands running transversely in line across dorsal and ventral surface of each segment, continuing to parapodia, especially prominent in notopodial dorsal ligules; also band of glands on dorsal and ventral surfaces of peristomium, antero-lateral prostomium and inner palps. Pigmentation fades after a few years in ethanol.

Longest tentacular cirri (postero-dorsal) reaching chaetiger 1–9 (usually 5–8) (Fig. 10A, B); antennae paired, about 1/3 prostomium length extending to level with distal palpophore (occasionally single centrally positioned antenna, presumably representing an abnormality, eg. NTM W25645). Peristomium about equal in length to chaetiger 2, slightly longer in length than chaetiger 1 (Fig. 10C, D).

Paragnaths all conical, those in Areas II, IV larger and arising from raised epidermis; those in Areas I, III, VI smaller and positioned atop small papilla (= partially sclerotized papilla of Bakken et al., 2009). Paragnaths in Areas VII–VIII, when present are also small and atop large, low papillae (Fig. 10C, D). Paragnath counts as follows: I: 0–4 (mean 1.8); II: 4–8 (5.7); III: 11–28 (19.5); IV: 1–9 (5.8); V: 0; VI: 0–1; VII–VIII: 0–5.

Table 3. Count of paragnaths from 64 *Neanthes glandicincta* specimens. All specimens were used for the cluster analysis (n = 91). For PCA (n = 85), all except ngs14, ngs15, and ngs17 were included. "nd" indicates undetermined counts due to condition of specimen. “Pap” in Area VI refers to presence of papillae or non-sclerotinised paragnath. * refers to outlier specimens (see details under Statistical Analysis) and are not used in calculation of median and mean.

Category	**Area I**	**Area II**	**Area III**	**Area IV**	**Area V**	**Area VI**	**Area VII to VIII**
Median	8	15	46	13	0	1	0
Mean	8.66	15.81	48	13.25	0	1	1.10
Maximum	17	21	63	20	0	1	8
Minimum	0	7	30	7	0	1	0
Statistical Code							
ngs1	13	19, 21	60	16, 16	0	Pap: 1, 1	3
ngs2	10	10–13	50	10–12	0	1	7
ngs3	10	20, 20	52	15, 12	0	1, 1	0
ngs4	6	19, 19	49	16, 15	0	1, 1	0
ngs5	10	16, 17	50	11, 12	0	1, 1	0
ngs6	11	18, 16	55	13, 13	0	1, 1	0
ngs8	6	17, 18	43	13, 15	0	1, 1	2
ngs14	16	14, 17	46	14, 14	0	Pap: 1, 1	nd
ngs15	17	16, 16	50	11, 11	0	Pap: 1, 1	nd
ngs17	2	17, 14	55	13, 14	0	Pap: 1, 1	nd
ngs29	12	20, 20	49	15, 14	0	Pap: 1, 1	7
ngs30	10	18, 16	52	14, 5	0	Pap: 1, 1	6
ngs33	11	17, 17	52	17, 16	0	Pap: 1, 1	0
ngs34	13	17, 18	55	15, 14	0	Pap: 1, 1	1
ngs35	10	15, 16	48	13, 14	0	Pap: 1, 1	2
ngs36	11	18, 18	47	11, 11	0	Pap: 1, 1	1
ngs37	12	19, 21	41	14, 14	0	Pap: 1, 1	0
ngs49	11	16, 17	56	12, 14	0	Pap: 1, 1	3
ngs50*	0	23, 24	21	22, 20	0	Pap: 1, 1	0
ngs51*	0	23, 20	19	23, 16	0	Pap: 1, 1	0
ngs52	9	15, 14	63	14, 13	0	Pap: 1, 1	2
ngs53	13	20, 18	58	13, 12	0	Pap: 1, 1	0
ngs54	8	17, 17	46	11, 13	0	Pap: 1, 1	0
ngs55	6	19, 19	43	12, 11	0	Pap: 1, 1	0
ngs56	7	15, 16	37	11	0	Pap: 1, 1	0
ngs57	10	16, 18	51	16, 18	0	Pap: 1, 1	0
ngs58	10	21, 22	51	20, 15	0	Pap: 1, 1	6
ngs59	11	16, 17	35	17, 20	0	Pap: 1, 1	3
ngs60	0	14	39	10, 12	nd	nd	0
ngs61	7	14	46	11, 10	0	Pap: 1,1	0
ngs62	9	14, 15	44	15, 13	0	Pap: 1,1	0
ngs63	7	15, 15	40	13, 13	0	Pap: 1, 1	0
ngs64	4	15	34	12	0	Pap: 1, 1	0
ngs65	7	14	50	20	0	Pap: 1, 1	0
ng66	4	12	40	16	0	Pap: 1, 1	0
ngs 68	14	17	60	15	0	Pap: 1, 1	0
ngs70	4	11	30	12	0	Pap: 1, 1	0
ngs71	3	12	34	13	0	Pap: 1, 1	0
ngs72	8	12	40	11	0	Pap: 1, 1	0
ngs73	2	12	42	13	0	Pap: 1, 1	0
ngs74	10	12, 12	38	7, 7	0	1, 1	2
ngs80	9	16, 19	51	16, 14	0	Pap: 1, 1	0
ngs81	15	21, 23	60	13, 15	0	Pap: 1, 1	0
ngs82	7	18, 19	52	12, 13	0	Pap: 1, 1	0

Table 3...continued

Statistical Code	Area I	Area II	Area III	Area IV	Area V	Area VI	Area VII to VIII
ngs83	1	16, 15	39	17, 17	0	Pap: 1, 1	4
ngs84	11	17, 16	54	17, 17	0	Pap: 1, 1	3
ngs85	9	20, 19	61	15, 15	0	Pap: 1, 1	8
ngs86	6	15, 16	41	10, 14	0	Pap: 1, 1	0
ngs87	10	15, 15	56	12, 10	0	Pap: 1, 1	0
ngs88	9	11, 11	44	11, 11	0	Pap: 1, 1	0
ngs89	9	14, 18	56	11, 14	0	Pap: 1, 1	0
ngs91	8	11, 9	48	11, 11	0	Pap: 1, 1	0
ngs92	9	13, 14	63	11, 15	0	Pap: 1, 1	0
ngs93	7	17, 17	51	12, 14	0	Pap: 1, 1	0
ngs94	10	15, 15	53	13, 14	0	Pap: 1, 1	0
ngs95	7	13, 11	51	16, 22	0	Pap: 1, 1	0
ngs96	8	7, 14	36	14, 14	0	Pap: 1, 1	0
ngs97	7	15, 18	40	9, 10	0	Pap: 1, 1	0
ngs98	6	18, 18	35	12, 8	0	Pap: 1, 1	0
ngs99	10	18, 17	49	15, 14	0	Pap: 1, 1	0
ngs100	12	19, 22	46	14, 14	0	Pap: 1, 1	3
ngs101	14	19, 20	47	13, 12	0	Pap: 1, 1	5
ngs102	8	16, 15	47	11, 11	0	Pap: 1, 1	0
ngs103	3	18, 17	45	16, 15	0	Pap: 1, 1	0
ngs104	6	16, 19	55	10, 10	0	Pap: 1, 1	0
ngs105	9	15, 17	61	12, 12	0	Pap: 1, 1	1

Table 4. Count of paragnaths from 25 *Neanthes wilsonchani*, new species specimens. All specimens were used for the cluster analysis (n = 91). For PCA (n = 85), all except ngs24, ngs25, and ngs38 were included. "nd" indicates undetermined counts due to condition of specimen. “Pap” in Area VI refers to presence of papillae or non-sclerotinised paragnath.

Category	Area I	Area II	Area III	Area IV	Area V	Area VI	Area VII to VIII
Median	2	6	21	6	0	Pap: 1	0
Mean	1.8	5.7	19.48	5.76	0	Pap: 1	0.31
Maximum	4	8	28	9	0	Pap: 1	5
Minimum	0	4	11	1	0	Pap: 1	0
Statistical Code							
ngs9	2	6, 6	21	7, 7	0	Pap: 1, 1	2
ngs10	0	7, 6	13	6, 7	0	Pap: 1, 1	0
ngs12	3	6, 7	21	6, 6	0	Pap: 1, 1	0
ngs18	1	4, 7	22	6, 4	0	Pap: 1,0	0
ngs24	2	6, 6	23	9, 8	nd	nd	nd
ngs25	1	4, 5	22	4, 6	nd	nd	nd
ngs26	1	7, 6	14	4, 4	0	Pap: 1, 1	0
ngs27	1	5, 5	14	4, 4	0	Pap: 1, 1	0
ngs28	1	5, 5	14	5, 6	0	Pap: 1, 1	0
ngs31	4	5, 6	20	6, 6	0	Pap: 1, 1	5
ngs32	3	7, 9	21	5, 6	0	Pap: 1, 1	0
ngs38	3	7, 7	24	6, 6	0	Pap: 1, 1	nd
ngs39	2	8, 6	16	8, 6	0	Pap: 1, 1	0
ngs40	3	5, 5	15	7, 7	0	Pap: 1, 1	0
ngs41	0	4, 4	11	1, 1	0	Pap: 1, 1	0
ngs43	2	7, 8	21	7, 7	0	Pap: 1, 1	0
ngs44	2	7, 5	21	6, 5	0	Pap: 1, 1	0

Table 4...continued

Statistical Code	Area I	Area II	Area III	Area IV	Area V	Area VI	Area VII to VIII
ngs45	2	5, 7	28	5, 5	0	Pap: 1, 1	0
ngs46	0	4, 4	20	5, 7	0	Pap: 1, 1	0
ngs47	3	6, 5	27	5, 7	0	Pap: 1, 1	0
ngs48	3	7, 5	23	5, 5	0	Pap: 1, 1	0
ngs75	1	5, 7	17	6, 7	0	Pap: 1, 1	0
ngs76	1	5, 6	13	9, 7	0	Pap: 1, 1	0
ngs78	3	6, 6	22	7, 6	0	Pap: 1, 1	0
ngs79	1	5, 5	24	5, 5	0	Pap: 1, 1	0

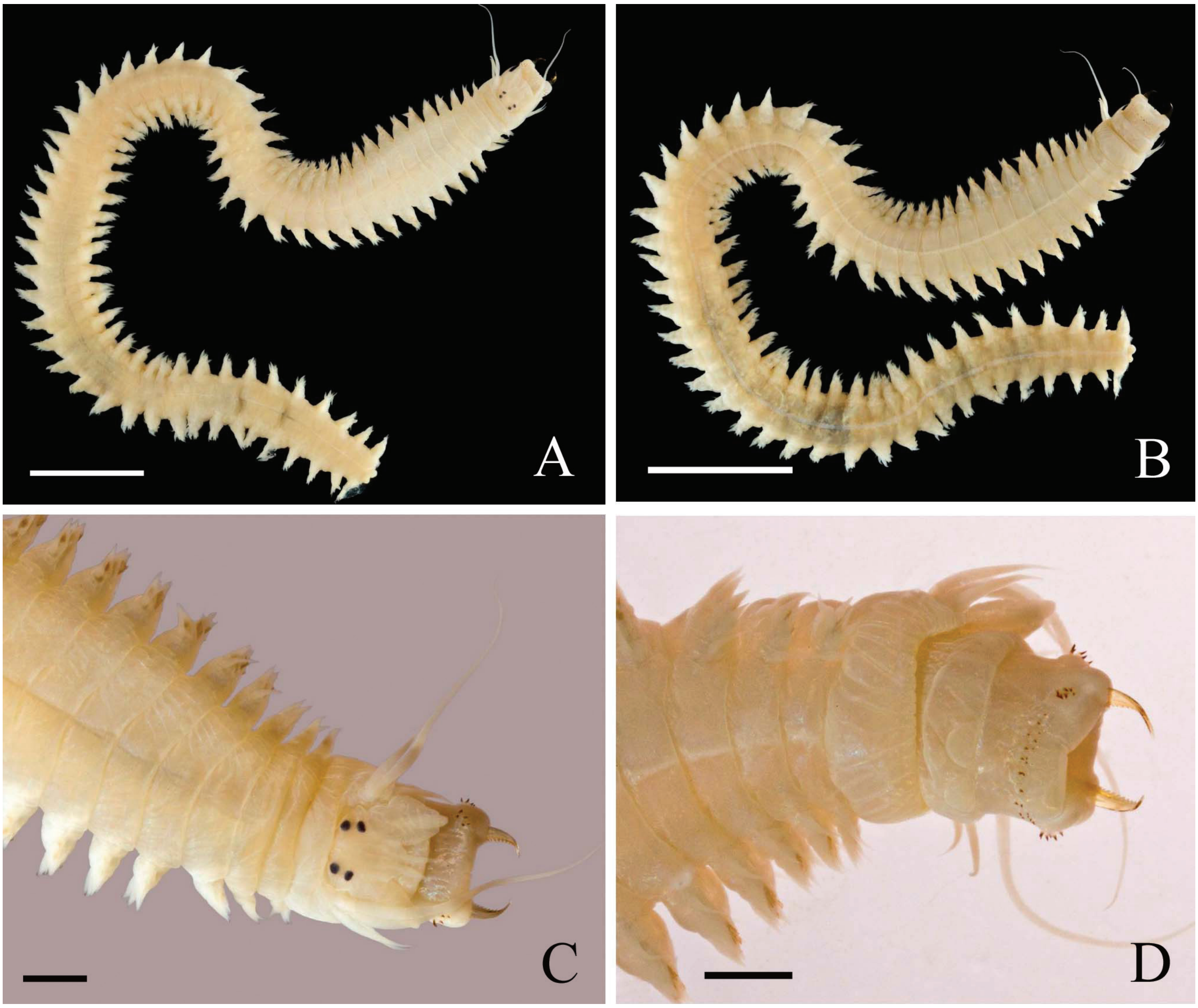

Fig. 10. A–D, *Neanthes wilsonchani*, new species. Holotype ZRC.ANN.0028. A. Entire specimen, dorsal view; B. entire specimen, ventral view; C. details of head end showing everted pharynx, dorsal view; D. details of head end showing everted pharynx, ventral view. Scale bars: A, B: 5 mm; C, D: 1 mm.

Parapodia well developed, with 3 notopodial and 4 neuropodial lobes and ligules throughout most of body (3 neuropodial lobes posteriorly); lobes/ligules distally pointed (Fig. 11A–D). Notopodial dorsal ligule (nodl) slightly larger than notopodial ventral ligule (novl) throughout; notopodial prechaetal lobe about 2/3 size of novl in anterior and posterior body, about 1/3 novl in mid-body. Neuropodial superior lobe (nesl), neuropodial postchaetal lobe (nepl) and neuropodial inferior lobe (neil) similar in size and shape anteriorly, by midbody reduced to an elongate papilla and absent by mid-posterior body. In posterior body only nopl and neil surrounding neurochaetae, similar in size to each other; neuropodial ventral ligule (nevl) present throughout, similar in size and shape to nodl; 2/3 size of nodl anteriorly reducing to ½ size of nodl posteriorly. DC arising at base of nodl throughout, 0.7–0.9 (rarely 1.5) length of nodl at chaetiger 10, 0.3–0.9 length of nodl at chaetiger 50, 0.5–1.0 length of nodl at chaetiger 90. VC arising at base of parapodia throughout, 0.3–0.8 length of nevl at chaetiger 10, 0.1–0.3 length of nevl at chaetiger 50, 0.3 length of nevl at chaetiger 90.

Chaetae present in both notopodia and neuropodia. Notochaetae are homogomph spinigers (Fig. 12A). Neurochaetae are long-bladed (Fig. 12B) and short-bladed (Fig. 12C) sesquigomph spinigers in supra-acicular fascicle; long-bladed sesquigomph spinigers and sesquigomph falcigers in subacicular fascicle (Fig. 12D). First four mentioned chaetal types present throughout body (Fig. 12E); sesquigomph falcigers start between chaetigers 16–25 and end between chaetigers 44–57 (see Table 5 for counts). Notoaciculae absent in the first two parapodia; thereafter both notoaciculae and neuroaciculae present.

Pygidial cirri arise ventro-laterally on the pygidium, extend forward over 8 chaetigers.

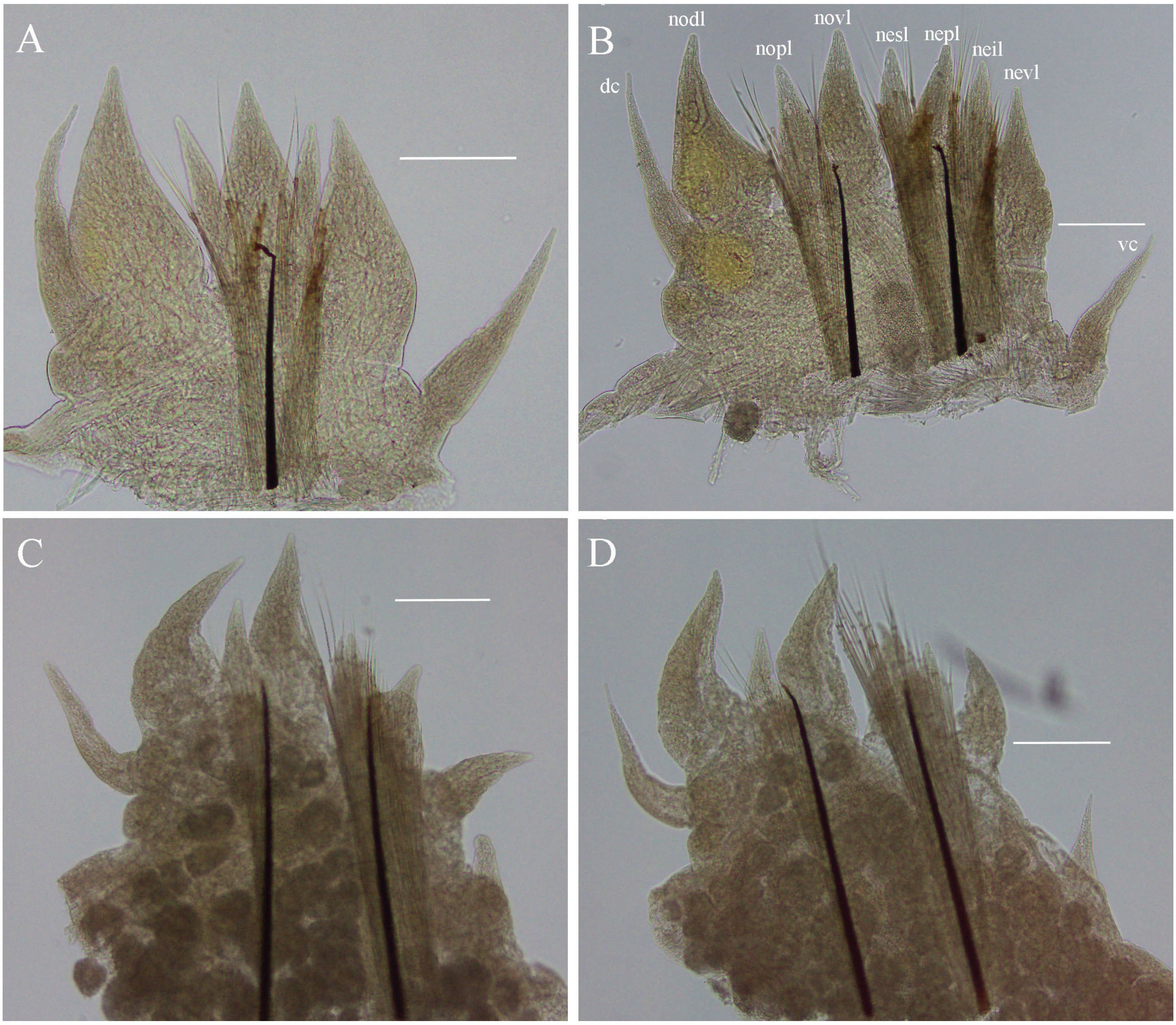

Fig. 11. A–D, Selected parapodia oriented with dorsal cirrus to left, *Neanthes wilsonchani* new species. Holotype ZRC.ANN.0028. A. Parapodium 2; B. parapodium 10; C. parapodium 30; D. parapodium 50. Scale bars = 200 microns. Abbreviations: dc = dorsal cirrus; nodl = notopodial dorsal ligule; nopl = notopodial prechaetal lobe; novl = notopodial ventral ligule; nesl = neuropodial superior lobe; nepl = neuropodial postchaetal lobe; neil = neuropodial inferior lobe; nevl = neuropodial ventral ligule; vl = ventral cirrus.

Table 5. Parapodial characters and chaetal numbers for *N. wilsonchani*, new species and *N. glandicincta*. ngs66 represents syntype material of *C. burmensis*. 'A' and 'P' indicate absence and presence respectively. Data that could not be determined because of mounting issues were indicated by 'NA'.

Chaetiger	Feature	***N. wilsonchani*, new species**							***N. glandicincta***					
		Overall	**ngs9**	**ngs18**	**ngs26**	**ngs27**	**ngs28**	**ngs48**	**Overall**	**ngs1**	**ngs52**	**ngs66**	**ngs96**	**ngs101**
2	Notopodial lobe	P	P	P	P	P	P	P	P	P	P	P	P	P
	Notopodial chaetae	A	A	A	A	A	A	A	A	A	A	A	A	A
	Neuropodial supra-sesquigomph spiniger, short blade	2–9	9	3	3	2	2	5	2–11	11	3	6	7	2
	Neuropodial supra-homogomph spiniger, long blade	2–18	8	18	8	2	4	6	8–12	10	12	12	8	8
	Neuropodial sub-sesquigomph spiniger	6–20	12	20	14	6	10	15	11–28	28	12	23	13	11
10	Notopodial homogomph spiniger	5–30	14	30	10	7	6	5	12–25	18	12	20	25	15
	Neuropodial supra-sesquigomph spiniger, short blade	2–10	10	10	5	2	2	4	5–13	13	10	6	9	5
	Neuropodial supra-homogomph spiniger, long blade	6–15	13	15	8	10	6	7	11–19	19	12	13	11	13
	Neuropodial sub-sesquigomph spiniger	10–25	18	25	18	11	13	10	20–29	27	25	29	23	20
30	Notopodial homogomph spiniger	6–13	12	NA	6	7	7	13	8–18	17	18	16	16	8
	Neuropodial supra-sesquigomph spiniger, short blade	0	0	0	0	0	0	0	0–4	0	2	4	4	0
	Neuropodial supra-homogomph spiniger, long blade	5–11	9	NA	8	5	11	8	6–13	12	13	9	12	6
	Neuropodial supra-sesquigomph falciger	0–6	6	NA	0	3	4	4	0–5	5	2	0	0	3
	Neuropodial sub-sesquigomph spiniger	3–5	6	NA	5	3	4	5	3–12	6	5	6	12	3
	Neuropodial sub-sesquigomph falciger	6–10	6	NA	6	10	6	10	11–16	16	13	15	12	11
50	Notopodial homogomph spiniger	3–14	9	14	8	3	7	10	5–16	14	16	12	12	5
	Neuropodial supra-sesquigomph spiniger, short blade	0–6	0	3	1	2	6	2	2–5	3	5	4	2 (or 4)	2
	Neuropodial supra-homogomph spiniger, long blade	6–12	11	11	6	7	9	12	5–10	10	5	8	10	5
	Neuropodial supra-sesquigomph falciger	0–1	0	0	0	0	0	1	0–3	3	0	0	2 (or 0)	0
	Neuropodial sub-sesquigomph spiniger	4–15	15	13	6	6	12	4	7–14	7	10	11	14	8
	Neuropodial sub-sesquigomph falciger	0–3	0	3	1	1	0	2	1–7	7	6	3	6	1
90	Notopodial homogomph spiniger	1–8	NA	8	NA	1	NA	5	6–7	0	7	6	6	NA
	Neuropodial supra-sesquigomph spiniger, short blade	0–1	NA	1	NA	0	NA	0	1–2	1	1	2	2	NA
	Neuropodial supra-homogomph spiniger, long blade	3–9	NA	9	NA	3	NA	9	4–7	6	7	5	4	NA
	Neuropodial sub-sesquigomph spiniger	7–12	NA	12	NA	7	NA	11	7–11	9	7	9	11	NA
	Neuropodial sub-sesquigomph falciger	0	NA	0	NA	0	NA	0	0	0	0	0	0	NA

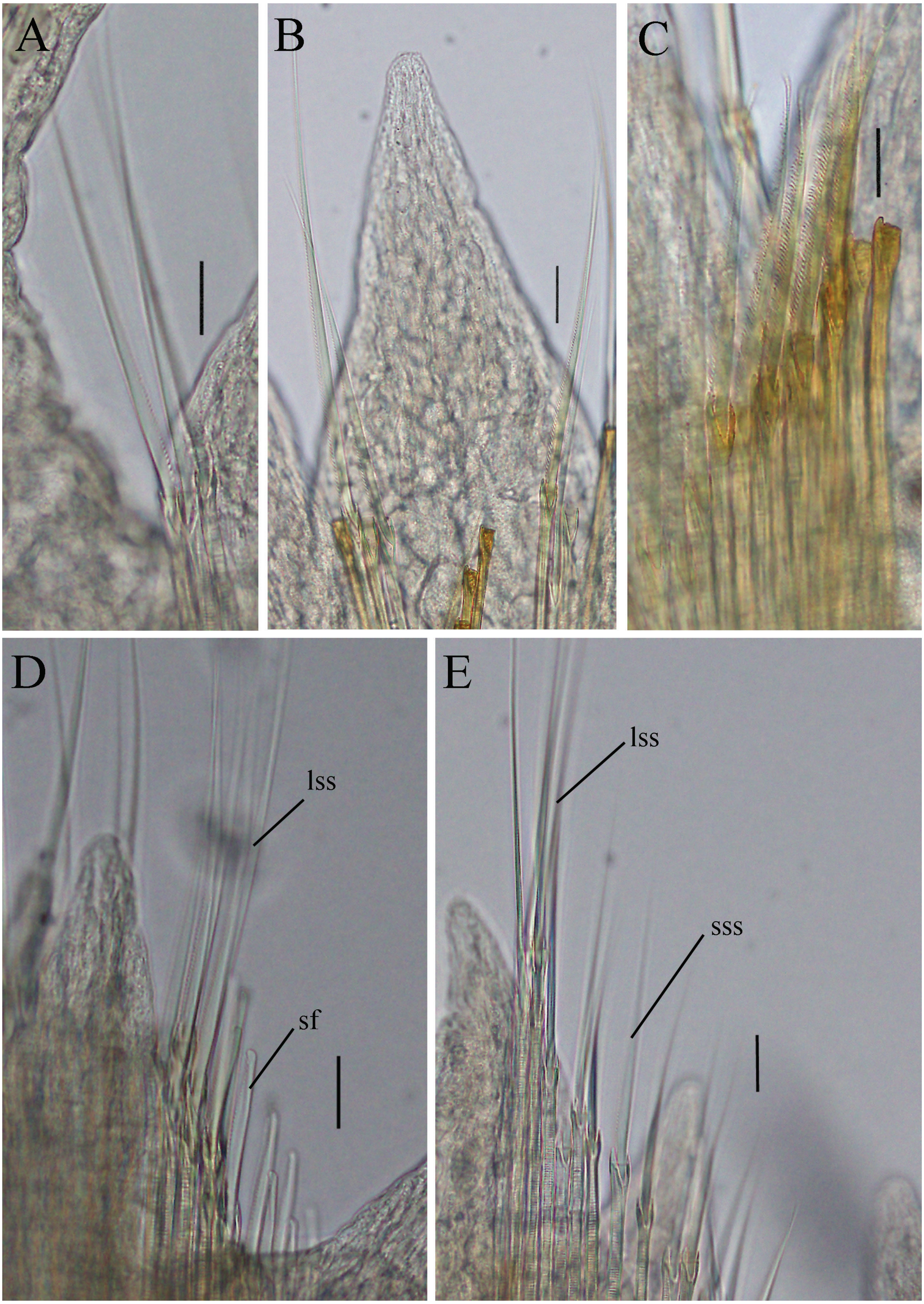

Fig. 12. A–E, Chaetal types in *Neanthes wilsonchani* new species. Holotype ZRC.ANN.0028. A. Homogomph spinigers, notopodium, chaetiger 60; B. long-bladed sesquigomph spinigers, supra-acicular neuropodium, chaetiger 2; C. short-bladed sesquigomph spinigers, supra-acicular neuropodium, chaetiger 10; D. long-bladed sesquigomph spinigers and sesquigomph falcigers, subacicular neuropodium, chaetiger 30; E. long-bladed sesquigomph spinigers, supra-acicular neuropodium, chaetiger 60. Abbreviations: lss = long-bladed sesquigomph spinigers; sf = sesquigomph falcigers; sss = short-bladed sesquigomph spinigers. Scale bars = 20 microns.

Description of epitokous worms (n = 1, male). Description based on ZRC.ANN.0037. 124 chaetigers, body width without chaetae 2.32 mm. Male with body slightly turgid as a result of sperm in coelom; no additional body pigmentation compared to atokous forms. Parapodia of unmodified anterior region (chaetigers 1–19) without additional lobes (Fig. 13A, B), thereafter parapodia modified bearing crenulate dorsal cirri (restricted to mid-body) and additional lamellae at dorsal base of DC, at dorsal and ventral bases of VC, and large postchaetal lamella on dorsal neuropodial lobe (Fig. 13C, D). Epitokal 'paddle' chaetae absent in both notopodia and neuropodia.

Remarks. The new species differs from *N. glandicincta* only in pigmentation pattern and paragnath numbers. Although both species have transverse pigmented glands across the dorsal and ventral surface, the latter also has dusky brown pigment on the dorsal surface of the prostomium, peristomium and anterior-most segments. The two species are most reliably distinguished on the basis of paragnath counts in Areas II, III and IV of the maxillary ring; the new species has 4–9 cones in Areas II (vs 7–21), 11–28 cones in III (vs 30–63) and 1–9 cones in IV (vs 7–20) and total paragnath counts (16–41 vs 70–130). A further possible difference between the new species and *N. glandicincta* may be the fewer short-bladed sesquigomph spingers in the supra-acicular position of the neuropodia, but this character shows large intra-specific variation in both species and the overlap between the two species is considerable (Table 5).

Comparison of the new species with other members of *Neanthes* is difficult because the genus is speciose and non-monophyletic (Bakken & Wilson, 2005). Nevertheless, these authors have suggested that species of *Neanthes* having a large notopodial prechaetal lobe may be monophyletic. The clade includes *N. bongcoi* Pillai, *N. cricognatha* Ehlers (part of the *N. acuminata* species group) and *N. succinea* (Leucart) together with *Alitta virens* (Sars). Bakken (2006) showed that *N. meggitti* Monro also has a large notopodial prechaetal lobe and therefore may also belong to this group. The present

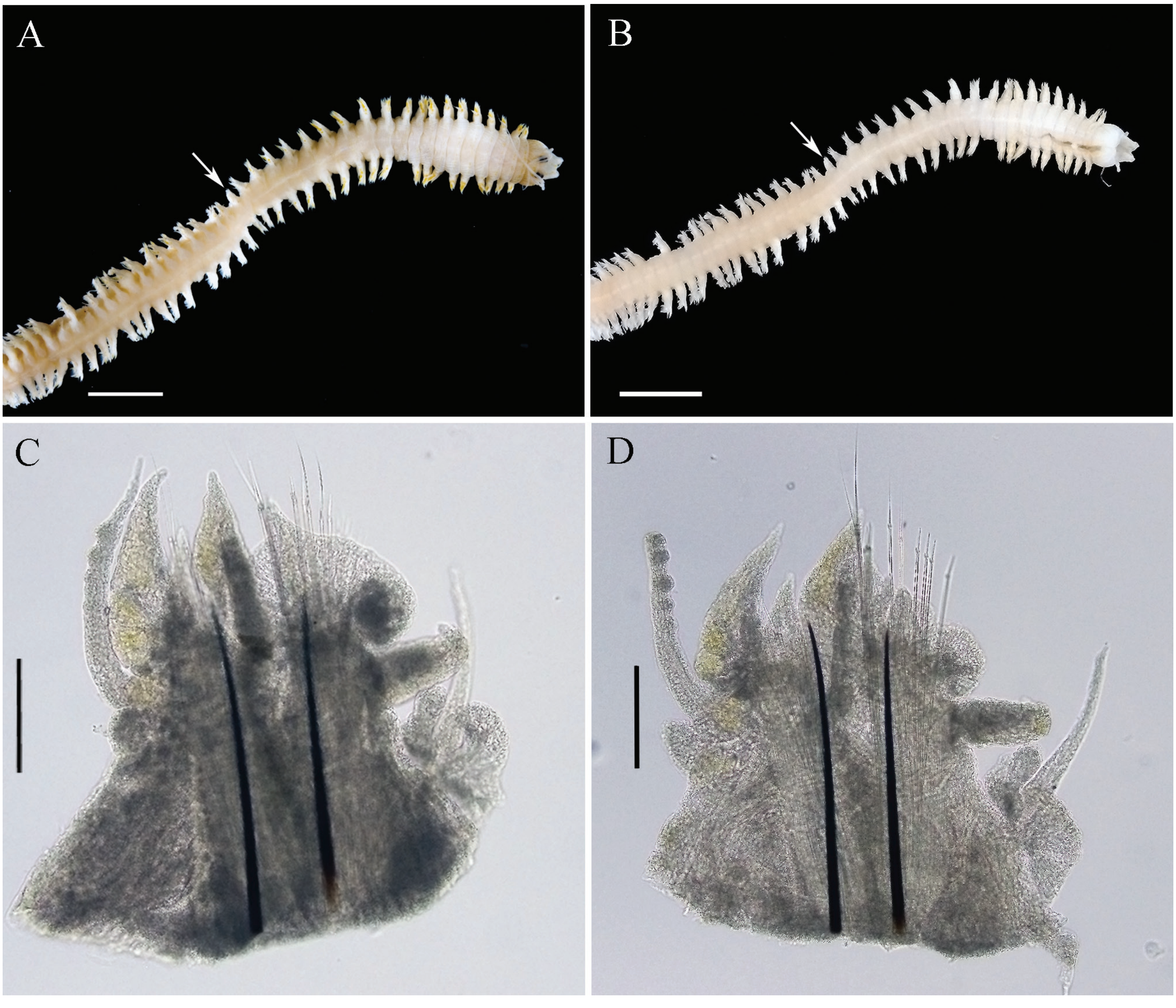

Fig. 13. Epitoke of *Neanthes wilsonchani*, new species. A–D, ZRC.ANN.0037, sexually mature male. A. Dorsal view, specimen incomplete posteriorly; B, ventral view, specimen incomplete posteriorly; C–D, modified parapodia. C, parapodium 25; D, parapodium 33. Scale bars: A, B: 2 mm; C, D: 200 microns. Arrows indicate start of first modified parapodia.

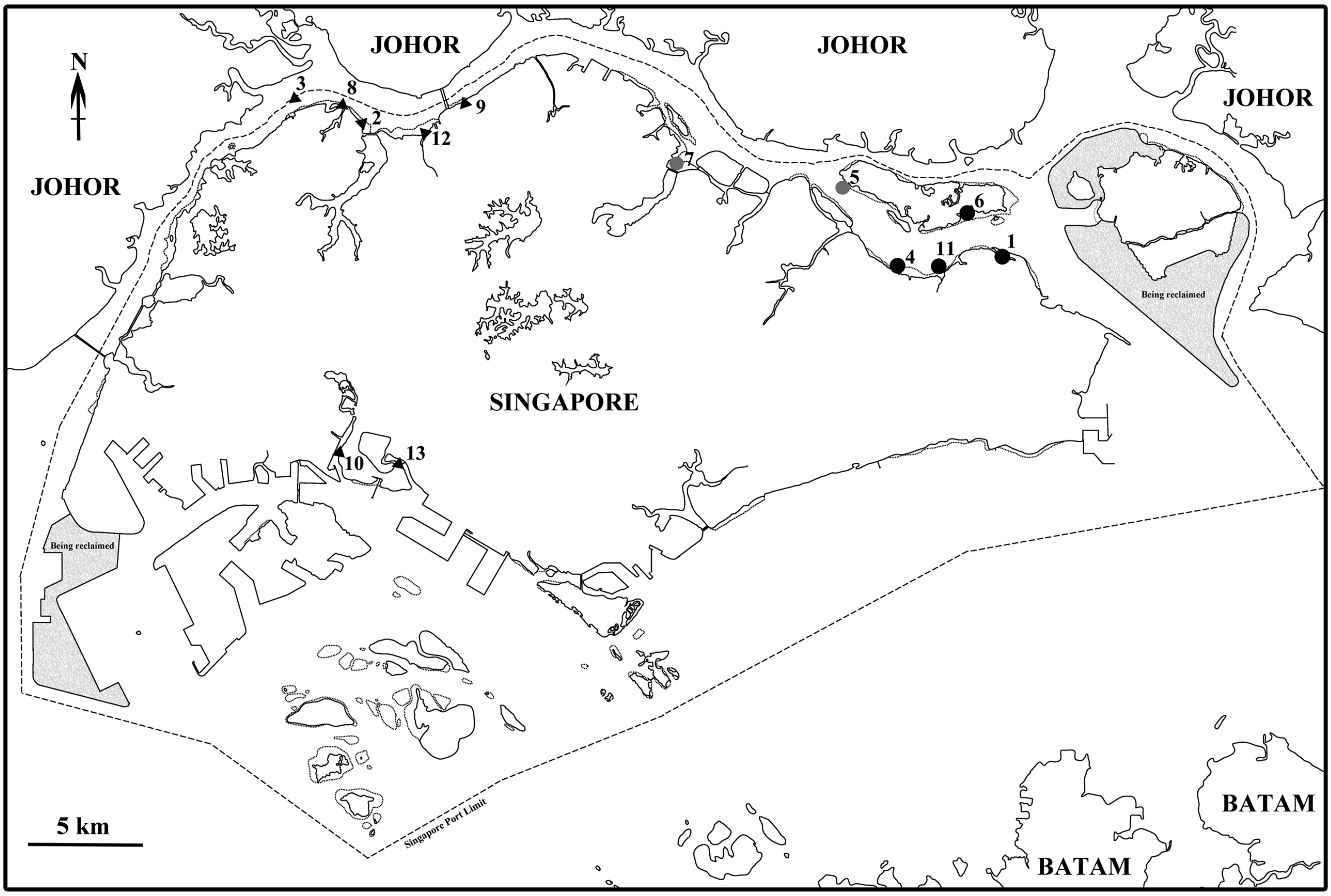

Fig. 14. Distribution map of *Neanthes glandicincta* and *N. wilsonchani* new species in Singapore. Localities are marked with filled shapes to represent occurrence of species: black triangles for *N. glandicincta*; black circles for *N. wilsonchani* new species; grey circles for *N. wilsonchani* new species with singular *N. glandicincta* records. 1. Changi Creek; 2. Kranji; 3. Lim Chu Kang; 4. Pasir Ris; 5. Pulau Ubin, OBS Camp 1 mangrove; 6. Pulau Ubin, southeast; 7. Seletar; 8. Sungei Buloh; 9. Sungei Cina; 10. Sungei Jurong; 11. Sungei Loyang; 12. Sungei Mandai; 13. Sungei Pandan.

new species differs from the other clade members having a large notopodial prechaetal lobe by the lack of substantial numbers paragnaths on the oral ring.

Chan (2009) is listed in the synonymy of both species accounts as 'in part' as his material appears to comprise a mix of the two species. A preliminary examination of the paragnath numbers however shows that his specimens are inconsistent with the ranges for AII and AIII for the two species established is this study. Possible explanations for this observation are that either the paragnath ranges *N. wilsonchani* have changed over last four years, or that there was a population of "intermediary" forms in the East and they were picked up by Chan, but not in our survey.

Distribution and habitat. Intertidal mudflats of eastern Singapore (Fig. 14).

DISCUSSION

Epitokal modifications. There are no significant differences in epitokal modification between the two species or between the sexes of each species. The observed differences appear to be related to the degree of maturity of the specimen. Increasing sexual maturity results in enlargement of eyes, appearance of paddle chaetae (both absent in early-stage epitokes) and greater development (basal swelling) of the dorsal and ventral cirri of the atokous region and lamellae of the epitokous region. Chan's (2009) reference to pronounced sexual dimorphism in live specimens of *Composetia burmensis* (= *Neanthes glandicinta* and *Neanthes wilsonchani* new species) appears to refer to the colour differences, which he noted is dark green in female epitokes, yellow in male epitokes; our observations of a female epitoke (Fig. 7A) agrees with those of Chan's.

Paragnath numbers and cryptic species. *Neanthes glandicincta* and its cryptic sibling, *N. wilsonchani*, new species, are common burrowing polychaetes of Singapore mudflats. They use the paragnaths on their eversible pharynx for both burrowing and feeding; the outer-most ones (oral ring) are used mainly for burrowing and the innermost ones (maxillary ring) are used for feeding (i.e., gripping food; Barnes & Head, 1977; Hateley et al., 1992). Our results show significant differences in the number of paragnaths in Areas II, III, and IV (maxillary ring) of the pharynx between *Neanthes glandicincta* and the new species *N. wilsonchani*. This result is congruent with the findings for other sympatric sibling nereidids, namely the *Hediste* species group in Japan (Sato & Nakashima, 2003), and the *Perinereis cultrifera* species group on Elba Island, Italy (Maltagliati et al., 2001). In both studies and ours, no significant difference was found in paragnath numbers of the oral ring; our study also showed a significant difference in total paragnath numbers (oral plus maxillary rings) between the two species, which was not analysed in the other studies. Differences in both total paragnath numbers and numbers on the oral ring have been associated with populations of widespread (cosmopolitan) species occupying different continents (Scaps et al., 2000; Breton et al., 2004).

Apart from small differences in paragnath numbers, cryptic nereidid species are often almost indistinguishable, at least for most of their life. Morphological differences typically appear at sexual maturity, and include body size, parapodial and chaetal morphology, reproductive behaviour, egg sizes, sperm morphology, larval development and allozymes (Maltagliati et al., 2001; Sato & Nakashima, 2003; Read, 2007; Glasby et. al., 2013). *Neanthes glandicincta* and *N. wilsonchani*, new species would therefore be expected to also show differences at sexual maturity, although none have been detected in the present study; confirmation of this must await a greater sample size of fully epitokous specimens of both species.

Hateley et al. (1992) and Sato & Nakashima (2003) have both demonstrated heritability of paragnath pattern, the latter authors only for maxillary paragnath numbers in Areas II, III. The most likely environmental factors influencing the number of paragnaths are thought to be diet and feeding mode (Hateley et al., 1992 and references therein; Sato & Nakashima, 2003). The latter authors observed a general reduction in paragnath numbers in the laboratory-bred specimens suggesting that diet, particularly food quality, may be a factor. It is possible therefore that the reduced paragnath numbers could be explained by present-day, less than optimal, feeding conditions in eastern Singapore – the implication being that *N. wilsonchani* is not a new species but simply a variant of *Neanthes glandicincta*. However, until it can be established that poor food quality can cause reduced paragnath numbers in natural populations, we prefer the present hypothesis of two separate cryptic species. The current, almost disjunct, distribution of the two species supports our contention.

Biogeogaphy. *Neanthes glandicincta* has a distribution range outside Singapore with a westward reach including the Indian shores. In Singapore, it has a wider distribution compared to *N. wilsonchani*, new species, occurring more in the northwestern and southern shores, while *N. wilsonchani* seems to be endemic to northeastern Singapore. Distributions of the two species in Singapore are largely exclusive of each other, excepting the occasional occurrence of *N. glandicincta* (ZRC.ANN.0044, Seletar and ZRC.ANN.0052, southwest Pulau Ubin) in the westernmost distribution of *N. wilsonchani*, new species. Remarkably, *N. glandicincta* is found to occupy both sides of the Johor-Singapore Causeway (Fig. 14) where the flow of traversing water is blocked. This phenomenon rules out the possibility that the Causeway, built in 1923, imposed a geographical barrier on the interaction between the two species. Geological studies of Singapore have recognised significant alluvium deposition during the Pleistocene era (circa 50,000 to 70,000 years ago) over eastern Singapore (Lee et al., 2009), an area that corresponds more or less with the distribution of *N. wilsonchani*, new species. We suggest therefore that *N. glandicincta* could have been the original species occupying a spatially-reduced Singapore. The emergence of *N. wilsonchani* as a new species in the east could be a result of sympatric speciation in tandem with the resultant change in sedimentary constitution during the alluvium deposition. The genetic isolation mechanism is unknown. The odd presence of *N. glandicincta* and "intermediary" forms *sensu* Chan (2009) at localities in east Singapore may be evidence of further, more recent, speciation within the *N. glandicincta* species group, perhaps in response to fluctuating environmental dynamics.

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