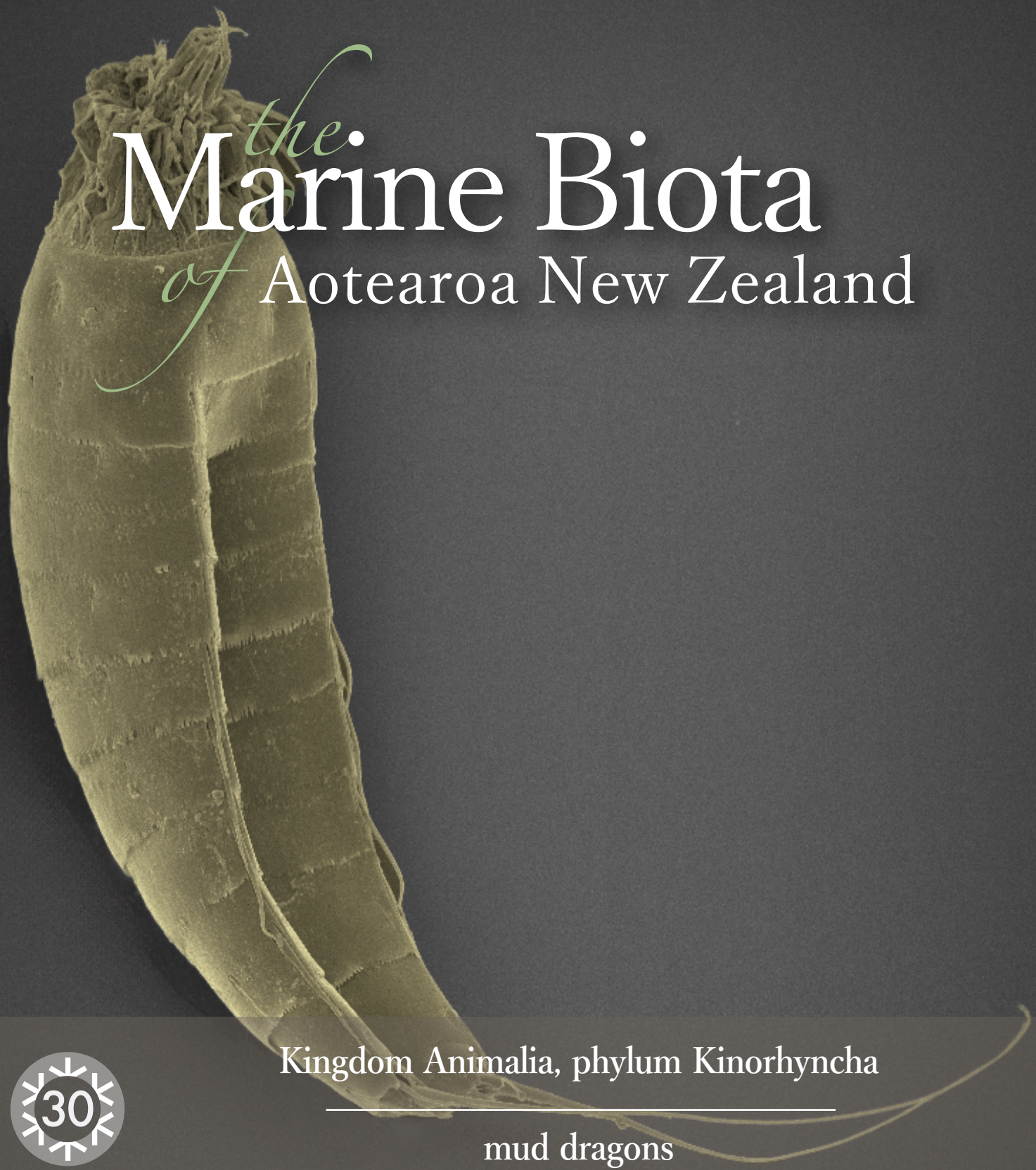
the Marine Biota of Aotearoa New Zealand



30

Kingdom Animalia, phylum Kinorhyncha

mud dragons

Katarzyna Grzelak & Martin V. Sørensen

CHAPTER 30

NIWA Biodiversity Memoir 136 2023

NIWA Taihoro Nukurangi

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Kingdom Animalia, phylum Kinorhyncha (mud dragons)

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Summary

The total number of kinorhynchs identified to species, from the Aotearoa New Zealand region, is 18, representing almost 5% of the global total for Kinorhyncha. The exploration and description of kinorhynchs from New Zealand waters was limited to three studies prior to the seminal review of Neuhaus *et al.* (2010):): (1) Coull & Wells (1981), who listed the first named record, *Echinoderes* cf. *coulli* Higgins, 1977; (2) Adrianov & Malakhov (1999), who described the first two (new) New Zealand species, *Echinoderes malakhovi* Adrianov, 1999 in Adrianov & Malakhov 1999, and *Pycnophyes newzealandiensis* Adrianov, 1999 in Adrianov & Malakhov 1999, from a Russian expedition to the western Pacific and New Zealand in the early 1990s; and (3) Neuhaus & Blasche (2006), who added the new genus *Fissuroderes* to the fauna with four new species of *Fissuroderes*. Neuhaus *et al.* (2010) listed a total of seven named species and 39 undescribed species. The recent study by Grzelak & Sørensen (2022) resulted in the discovery of 11 new species for the region (Fig. 30.2), and further research has revealed a further named species, five undescribed species (Table 30.1), and two species have been deleted from the record due to uncertainty (Table 30.2). It is expected that the discovery rate of new species and rate of new species description will increase during the next decade. A checklist of New Zealand extant kinorhynchs is provided.

Introduction

Kinorhynchs are exclusively marine, meiobenthic animals, with a body size ranging between 130 and 1000 µm long (Figs 30.1, 30.2). Kinorhynchs, also known as mud dragons, occur mostly in muddy or fine-grained sandy sediments, from shallow waters to hadal depths. Being part of the meiofauna – the most numerous metazoan community inhabiting marine sediments – they are essential for the functioning of marine ecosystems, are major components of numerous marine food webs, participate in the bioturbation of sediments, and contribute to the breakdown of organic matter and the release of the nutrients to the benthic system (Giere 2009). The phylum was discovered by Dujardin in 1841 at Saint-Malo, France (Dujardin 1851) and now, more than 180 years after their first discovery, the phylum accommodates more than 350 described species (Neuhaus 2022).

Anatomically, kinorhynch bodies can be divided into a head, a short neck, and a segmented trunk (Neuhaus 2013; Sørensen & Pardos 2020) (Fig. 30.1). The head is anatomically and functionally divided into two parts, a mouth cone, and an introvert (Fig. 30.1A). By contraction of longitudinal muscles connecting the head parts and the trunk, the head can be completely retracted into the trunk. The mouth cone is equipped with nine outer oral styles, whereas the introvert is equipped with up to eight rings of spinous scalids (Fig. 30.1A). The short neck region is formed by small plates, so-called placids (Fig. 30.1B). When the kinorhynch head is fully retracted into the trunk, the placids will act as a closing apparatus.

The trunk of an adult kinorhynch consists of eleven segments. Externally, the segmentation is expressed in cuticular differentiation, and internally in the muscular and nervous systems (Herranz *et al.* 2019, 2020, 2021). The individual segments can be composed of a closed cuticular ring, a plate that wraps around the trunk and articulates with itself midventrally or differentiated into a dorsal (= tergal) and one to three articulating ventral (= sternal) plates (Fig. 30.1B). The composition of the segments are often key characters when identifying families and genera (Sørensen & Pardos 2020). The segments may be equipped with different cuticular structures, such as spines, tubes, setae, and glandular cell outlets (Figs 30.1A, B). These structures are often important in species identification. The spines are usually the most prominent among these structures, and are typically found along the middorsal line, and lateroventrally, near the articulation of the dorsal and ventral plates. Many species, although not all, have pairs of prominent lateral terminal spines attached to the terminal segment, and occasionally an even longer midterminal spine (Figs 30.1A, C). The segmented trunk and the lateral terminal spines sometimes make the kinorhynch resemble a harpacticoid copepod, but they can easily be distinguished by the kinorhynch's completely different head and lack of legs.

All kinorhynchs are dioecious, and even though very little is known about their reproduction, it appears that it happens at a slow rate, where only a single egg is fertilised at a time (Kozloff 2007). The fertilised egg is laid in the sediment, subsequently hatching into

a juvenile. The juvenile resembles the adult, but has fewer segments, and typically more, and proportionally longer, spines. The juvenile develops towards adult morphology through six stages, switching between each stage by shedding its cuticle, and additional segments gradually added to the hind end. After six moults sexual maturity is reached, but moulting and slight changes in morphology might even occur among adults.

Kinorhynchs are protostomes and part of the diverse clade Ecdysozoa that also accommodates nematodes and arthropods. Their closest relatives are loriciferans (see Chapter 31 of this volume) and priapulids, and together they form the group Scalidophora. The three scalidophoran taxa share the presence of an eversible introvert with scalids.

Currently, phylum Kinorhyncha accommodates more than 350 described species globally, distributed among 32 genera (Neuhaus 2022). The classification currently follows the phylogenomic analysis of transcriptomes by Herranz *et al.* (2022), which is only a slightly emended classification proposed by Sørensen *et al.* (2015) that was based on combined phylogenetic analysis of morphology and two molecular markers. The phylum is divided into two classes, Cyclorhagida and Allomalorhagida. Cyclorhagida accommodates three orders: Xenosomata, Kentrorhagata, and Echinorhagata; the latter includes the highly diverse genus *Echinoderes* that accommodates more than one-third of all described kinorhynch species. The other class, Allomalorhagida, includes some smaller and relatively rare genera, such as the beach-dwelling *Franciscideres*, but also the reasonably diverse and common family Pycnophyidae. This family accommodates nearly another third of all known kinorhynch species.

Kinorhynchs are relatively easy to collect and explore. A chapter by Sørensen & Pardos (2020) in the recently published meiofauna guide of Schmidt-Rhaesa (2020), is a 'must-have' for everyone with an interest in marine meiofauna, as it describes how to collect, process, and observe kinorhynchs, and it also provides a dichotomous identification key to genus level. Identification of echinoderid kinorhynchs to species level is also possible with a virtual key designed for the DELTA freeware – DEscription Language for TAxonomy. The key is continuously updated; an introduction and user guide are provided by Yamasaki *et al.* (2020).

Table 30.1. Summary of extant Kinorhyncha diversity in the Aotearoa New Zealand region expressed as total numbers and percentage change. Data for 2010 are derived from Neuhaus *et al.* (2010: p. 471). OTU = Operational Taxonomic Unit.

	Kinorhyncha		% change
	2010	2023	
Total species diversity	46	61	33
Described extant species	7	18	157
Undescribed extant species (OTU)	39	43	10
Described endemic extant genera	0	0	0
Described endemic extant species	6	?	?

Status of New Zealand Kinorhyncha

The kinorhynch fauna of New Zealand is very poorly explored, with few studies conducted over the past decade. Published reports predating Neuhaus *et al.* (2010) include Adrianov & Malakhov (1999), who provided descriptions of the species *Echinoderes malakhovi* Adrianov, 1999 *in* Adrianov & Malakhov (1999), and *Pycnophyes newzealandiensis* Adrianov, 1999 *in* Adrianov & Malakhov (1999), from sandy sediments at 60 m water depth in the Bay of Plenty; and Neuhaus & Blasche (2006), who described the new genus *Fissuroderes*, which includes four novel New Zealand species. Two of the species, *F. papai* Neuhaus, 2006 *in* Neuhaus & Blasche (2006) and *F. rangi* Neuhaus, 2006 *in* Neuhaus & Blasche (2006), are from deep-sea mud on the Hikurangi Plateau and were found at 1849 to 3202 m water depth. Another deep-sea species, *F. novaezealandia* Neuhaus, 2006 *in* Neuhaus & Blasche (2006), was collected at 527 to 1468 m water depth, south of the Chatham Rise. The fourth species, *F. higginsi* Neuhaus, 2006 *in* Neuhaus & Blasche (2006), was also collected on the Chatham Rise, at 885 m water depth, but also in much shallower waters in the Firth of Thames. This species is also the only one that has subsequently been found outside of New Zealand; Sørensen *et al.* (2018) reported the species from 3675 m water depth off the coast of northern California, and Sánchez *et al.* (2019) also reported it from polymetallic nodules in the tropical East Pacific.

Neuhaus & Sørensen (2013) reported *Campyloderes vanhoeffeni* Zelinka, 1913, from the Hikurangi Plateau and the Chatham Rise. The species was originally reported in Neuhaus *et al.* (2010) as *Campyloderes* sp. indet. in Neuhaus *et al.* (2010), but because it

Table 30.2. Extant species deleted from the New Zealand record. Species cited in Neuhaus *et al.* (2010) that are no longer considered be valid for the New Zealand region, because they were added in error (as a historical mistake), or because their global taxonomic distribution or status has been updated. These are hereby deleted from the New Zealand record.

Taxon name in Neuhaus *et al.* (2010)	Comment & reference
Echinoderes cf. *coulli* Higgins, 1977 *in* Coull & Wells (1981)	Identity considered to be unlikely as this is an intertidal kinorhynch known from the east coast of the USA (Higgins 1977).
Kinorhynchus sp. indet. R.P. Higgins	Some, but not all species of *Kinorhynchus* were transferred to genus *Pycnophyes* by Sanchez *et al.* (2016). Some species of *Kinorhynchus* belong to other Pycnophyidae genera, such as *Cristaphyes*, *Higginsium* or *Leiocanthus*. We are unable to say to which genus *Kinorhynchus* sp. indet. R.P. Higgins belongs, and so hereby delete it from the New Zealand record.

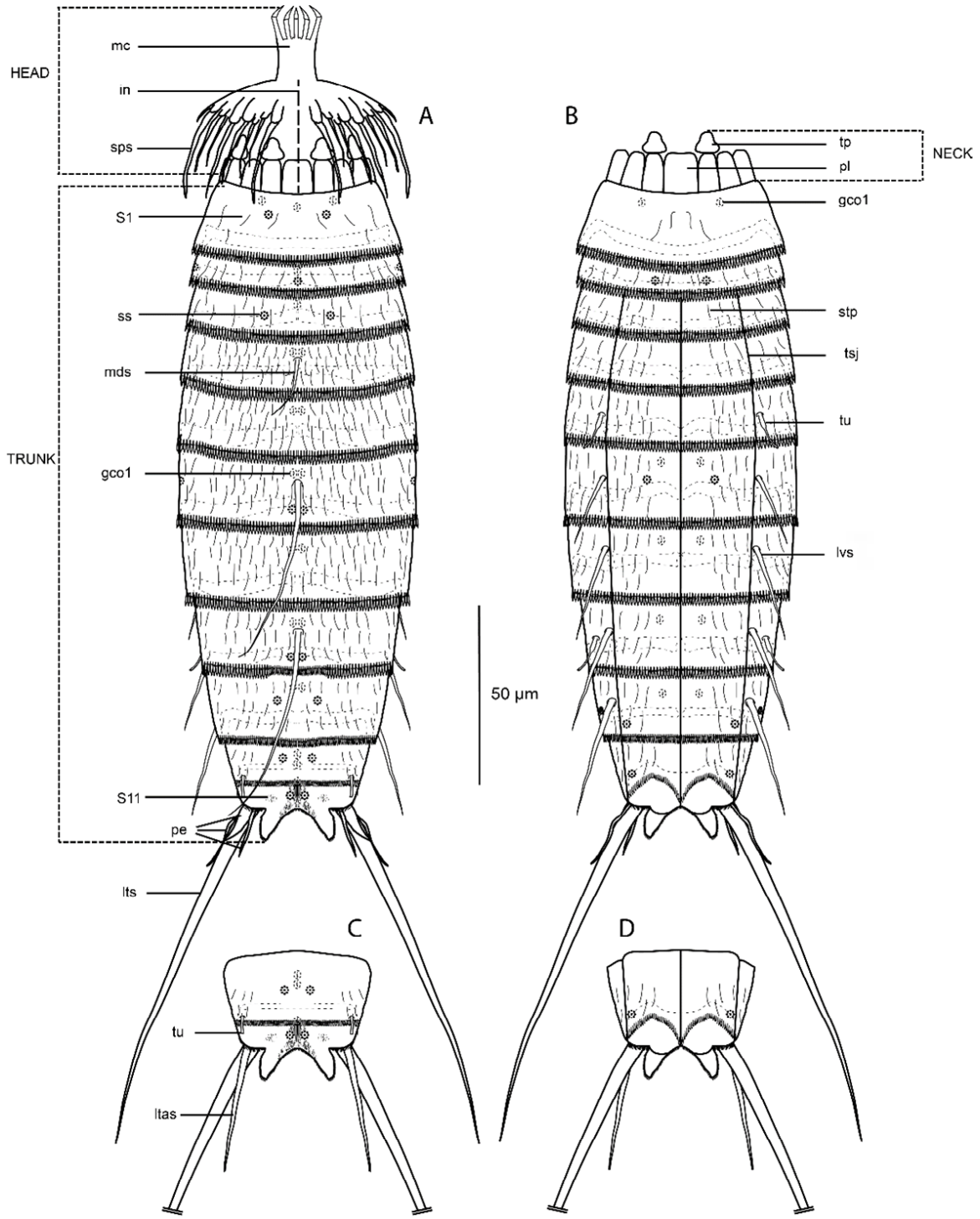

Figure 30.1. Line art illustrations showing general kinorhynch morphology exemplified with the genus *Echinoderes*. **A**. Male, dorsal view, **B.** Male, ventral view, **C.** Female, segments 10–11, dorsal view, **D.** Female, segments 10–11, ventral view. *Abbreviations*: *gco1* glandular cell outlet type 1; *in* introvert; *ltas* lateral terminal accessory spine; *lts* lateral terminal spine; *lvs* lateroventral spine; *mds* middorsal spine; *mc* mouth cone; *pe* penile spine; *pl* placid; *S* segment, followed by segment number; *sps* spinous scalid; *ss* sensory spot; *stp* sternal plate; *tp* trichoscalid plate; *tsj* tergosternal junction; *tu* tube.

appears that the genus accommodates only a single, cosmopolitan species, *C. vanhoeffeni*, or complex of pseudo-cryptic species, it is fair to consider the New Zealand specimens as part of this complex.

In addition, Neuhaus *et al.* (2010) cites Coull & Wells (1981) for finding *Echinoderes coulli* Higgins, 1977 from Pāuatahanui Bay near Wellington, recording it as *Echinoderes* cf. *coulli* Higgins, 1977 in Coull & Wells (1981), but this identity is very unlikely as it is an intertidal kinorhynch known from the east coast of the USA (Higgins 1977) (Table 30.2). It is also part of a larger complex of (mostly) intertidal and morphologically quite similar species. Representatives of this species complex (= the *E. coulli* species group)

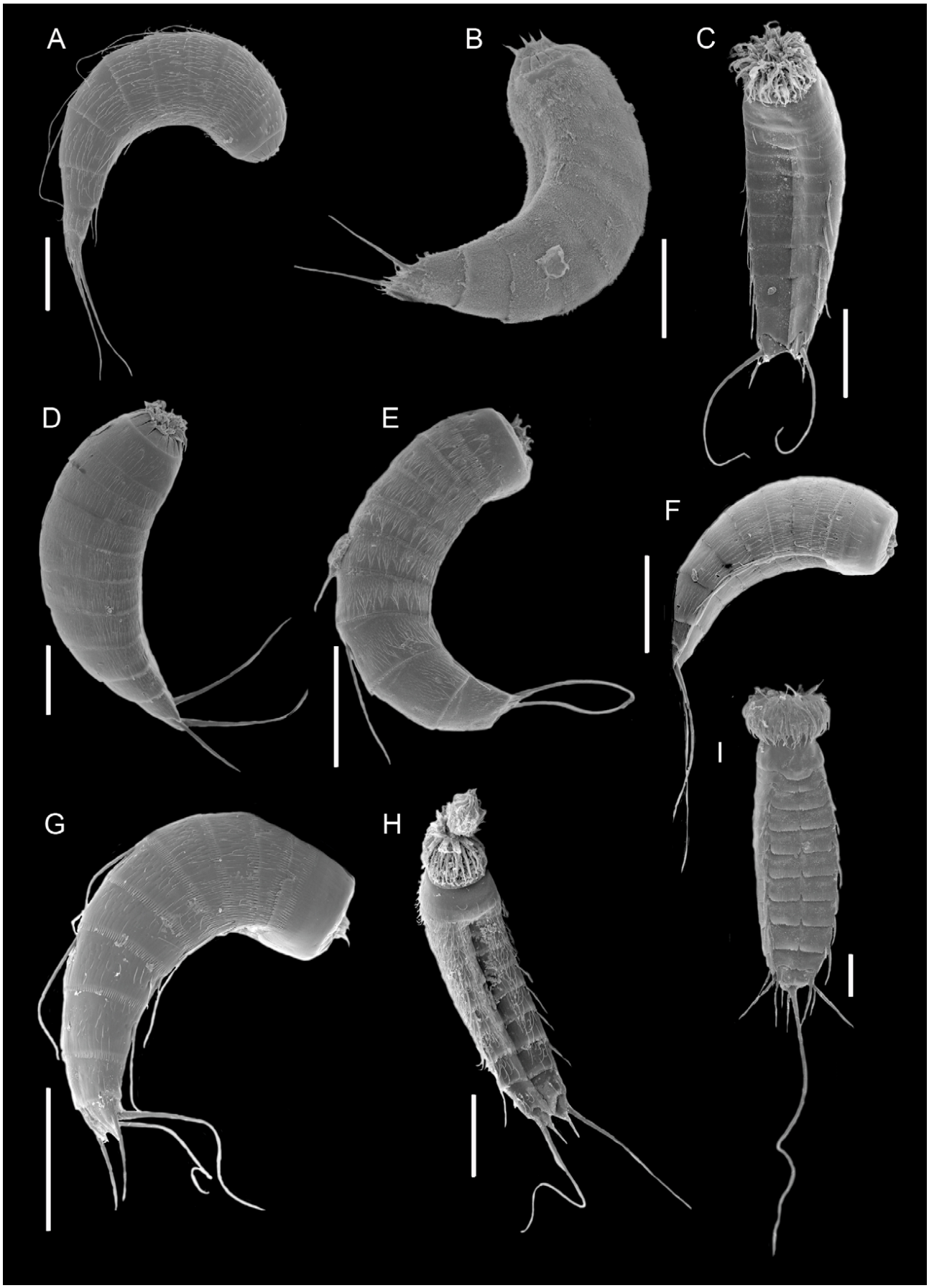

Figure 30.2. Scanning electron micrographs of selected kinorhynch species from New Zealand: **A.** *Echinoderes juliae* Sørensen, Rohal & Thistle, 2018; **B.** *Echinoderes blazeji* Grzelak & Sørensen, 2022; **C.** *Echinoderes dalzottoi* Grzelak & Sørensen, 2022; **D.** *Echinoderes landersi* Grzelak & Sørensen, 2022; **E.** *Echinoderes legolasi* Grzelak & Sørensen, 2022; **F.** *Echinoderes frodoi* Grzelak & Sørensen, 2022; **G.** *Echinoderes samwisei* Grzelak & Sørensen, 2022; **H.** *Echinoderes galadrielae* Grzelak & Sørensen, 2022; **I.** *Sphenoderes* sp. (NIWA 162661, TAN1004/130, Seamount 766). Scale = 50 µm. Images have been reproduced with permission from the authors.

can be found throughout the world, but each species has a much more restricted distribution (Randsø *et al.* 2019). Thus, it seems more likely that Coull & Wells (1981) recorded a new, yet undescribed, species of this species complex.

Recently, a new study of kinorhynchs from the Hikurangi Plateau, off the southeast coast of the North Island of New Zealand, was carried out by the authors of the present chapter. Sampling was conducted in 2010, at various water depths and habitats, including slope, canyon, and seamount sites (Rosli *et al.* 2016). A first comprehensive overview of the diversity of mud dragons, with an emphasis on species of *Echinoderes*, resulted from this work (Grzelak & Sørensen 2022). The study revealed fifteen species of *Echinoderes* from the Hikurangi Margin, of which only eleven could be identified with certainty: ten were described as new to science (Figs 30.2B–H), and the eleventh identified as *Echinoderes juliae* Sørensen, Rohal & Thistle, 2018. The remaining four species were tentatively identified as *Echinoderes* aff. *balerioni* Grzelak & Sørensen, 2019, *Echinoderes* aff. *lupherorum* Sørensen, Rohal & Thistle, 2018, *Echinoderes* aff. *unispinosus* Yamasaki, Neuhaus & George, 2018, and *Echinoderes* aff. *galadrielae* Grzelak & Sørensen, 2022 (or *E.* aff. *beringiensis* Adrianov & Maiorova, 2022). Because these identities remain uncertain, they have not been included in the checklist.

The most common among all species from the Hikurangi region was *Echinoderes gandalfi* Grzelak & Sørensen, 2022, which was found only in canyons. The second most common species, *E. juliae* (Fig. 30.2A), was found at several stations, including canyons, seamounts, and on the slope, between 670–1514 m. *Echinoderes juliae* is a deep-sea species originally found on the abyssal plain off Oregon and along the continental rise off California in the northeast Pacific at 2702–3679 m water depth (Sørensen *et al.* 2018). Recently *E. juliae* was also recorded in polymetallic nodules in the tropical eastern Pacific (Sánchez *et al.* 2019), and on the abyssal plains, east of the Atacama Trench, at 2560 m (Grzelak *et al.* 2021).

Other kinorhynchs that have been identified from Hikurangi Margin are: *Fissuroderes novaezealandia*; *F. higginsi* and an unidentified species of *Sphenoderes* (Fig. 30.2I). *Fissuroderes novaezealandia* was collected on the slope and in Campbell Canyon, from 728–1046 m water depth, a range similar to that found by Neuhaus and Blasche (2006) from the Chatman Rise. *Fissuroderes higginsi* showed a similar distribution regarding the depth range (from 690–1013 m), but interestingly, was not found at the same stations as *F. novaezelandia*. The former was present in Pahau Canyon and on a seamount. One final species belongs to the rare, species-poor genus *Sphenoderes*, with only four species described so far globally (Sørensen & Herranz 2022). Although the presence of this genus in New Zealand was previously mentioned by Neuhaus *et al.* (2010) (as *Sphenoderes* spp. indet. (7)), no information regarding its distribution, or a formal species description has been provided since then. We can confirm the presence of at least one species of *Sphenoderes*, which most likely represents a new species. Additional specimens were found on the slope at 690 m water depth, but their identity remains uncertain due to the low quality of the material, for which we were not able to confirm presence or absence of important morphological traits.

The other kinorhynchs collected after 2010 are from a survey taken in 2012 in the outer Bay of Plenty (Rosli *et al.* 2016). Specimens were collected from sediments at 697–1518 m water depth, including habitats such as submarine canyons and seamounts. This material was also passed to the authors of the present chapter, but its investigation is at a very preliminary initial stage. Nevertheless, even at this early juncture, we conclude that the kinorhynch fauna in this region is diverse, providing at least four additional new *Echinoderes* species for description. The presence of *Echinoderes aragorni* Grzelak & Sørensen, 2022 and *E. galadrielae*, from the Hikurangi Margin was also noted in the Bay of Plenty material, as well as *F. novaezealandia* and *F. higginsi*. The Bay of Plenty material also includes representatives of six other genera, namely: *Condyloderes*, *Campyloderes*, *Sphenoderes* and representatives of family Pycnophyidae: *Setaphyes*, *Cristaphyes* and *Krakenella*, suggesting that this region is more diverse than the Hikurangi Margin.

Knowledge about endemism of kinorhynchs is still limited. It is very difficult to determine which Kinorhyncha species are endemic, if any, as we still know very little about their geographic distribution. We can say, however, that all *Echinoderes* species described in Grzelak & Sørensen (2022), as well as *E. malakhovi*, *Pycnophyes newzealandiensis*, and *Fissuroderes novaezealandia, F. papai,* and *F. rangi*, have not been found elsewhere to date, whereas *Fissuroderes higginsi* has been recorded outside New Zealand several times.

Knowledge gaps, research progress and future priorities

Information on New Zealand kinorhynchs is still extremely limited; with the exception of Hikurangi Plateau, the kinorhynch fauna in all regions around New Zealand can be considered unexplored. Besides plateaus and deep-sea areas to the north, east and south, this includes all coastal areas. Kinorhynch abundances are usually highest in muddy sediments, but since they also may occur in sandy sediments, shell hash and among kelp and seaweed, many habitats are yet to be explored.

With the limited knowledge that is currently available, it is difficult to estimate the true kinorhynch biodiversity around New Zealand. However, it is likely that the coastal and shallow water habitats would host about 20 to 30 species, and if we expect to have about

the same number from deeper localities, the total estimated kinorhynch diversity for New Zealand would be somewhere between 50 to 100 species. Future studies should focus on such coastal habitats that potentially holds a diverse kinorhynch fauna, and the deeper waters in the north, east and south of New Zealand.

Acknowledgements

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Checklist of extant Kinorhyncha known from the New Zealand EEZ

The checklist is arranged according to the currently accepted systematics and classificatory scheme of Herranz *et al.* (2022) and Sørensen *et al.* (2015), employed by the World Kinorhyncha Database (https://www.marinespecies.org/kinorhyncha), accessed through World Register of Marine Species (WoRMS) (https://www.marinespecies.org/). More than two taxonomic authorities have been abbreviated to 'first author *et al.*' in the checklist. Numbers in parentheses after undescribed spp. indicate the number of species that are undescribed for that genus.

Phylum KINORHYNCHA
Class ALLOMALORHAGIDA
Order ALLOMALORHAGIDA INCERTAE SEDIS
Family PYCNOPHYIDAE
Cristaphyes sp. 1 (NIWA 158068, 158069) Sørensen & Grzelak, in prep.
Cristaphyes sp. 2 (NIWA 158814) Sørensen & Grzelak, in prep.
Cristaphyes sp. 3 (NIWA 162657)
Cristaphyes sp. 4 (NIWA 158800-158811) Sørensen & Grzelak, in prep.
Krakenella sp. (NIWA 162658)
Pycnophyes newzealandiensis Adrianov, 1999 *in* Adrianov & Malakhov 1999
Pycnophyes spp. indet. (3) R.P. Higgins *in* Neuhaus *et al.* 2010
Pycnophyes spp. indet. (2) B. Neuhaus *in* Neuhaus *et al.* 2010
Setaphyes sp. (NIWA 162659)

Class CYCLORHAGIDA
Order ECHINORHAGATA
Family ECHINODERIDAE
Echinoderes sp. nov. R.P. Higgins *in* Neuhaus *et al.* 2010
Echinoderes spp. indet. (6) R.P. Higgins *in* Neuhaus *et al.* 2010
Echinoderes spp. indet. (14) B. Neuhaus *in* Neuhaus *et al.* 2010
Echinoderes aragorni Grzelak & Sørensen, 2022
Echinoderes blazeji Grzelak & Sørensen, 2022
Echinoderes dalzottoi Grzelak & Sørensen, 2022
Echinoderes frodoi Grzelak & Sørensen, 2022
Echinoderes galadrielae Grzelak & Sørensen, 2022
Echinoderes gandalfi Grzelak & Sørensen, 2022
Echinoderes juliae Sørensen *et al.*, 2018
Echinoderes landersi Grzelak & Sørensen, 2022
Echinoderes leduci Grzelak & Sørensen, 2022
Echinoderes legolasi Grzelak & Sørensen, 2022
Echinoderes malakhovi Adrianov, 1999 *in* Adrianov & Malakhov 1999
Echinoderes samwisei Grzelak & Sørensen, 2022
Fissuroderes higginsi Neuhaus, 2006 *in* Neuhaus & Blasche 2006
Fissuroderes novaezealandia Neuhaus, 2006 *in* Neuhaus & Blasche 2006
Fissuroderes papai Neuhaus, 2006 *in* Neuhaus & Blasche 2006
Fissuroderes rangi Neuhaus, 2006 *in* Neuhaus & Blasche 2006

Order KENTRORHAGATA
Family CENTRODERIDAE
Centroderes sp. indet. R.P. Higgins *in* Neuhaus *et al.* 2010
Condyloderes? sp. indet. R.P. Higgins *in* Neuhaus *et al.* 2010
Condyloderes sp. indet. B. Neuhaus *in* Neuhaus *et al.* 2010
Condyloderes sp. (NIWA 162660)
Family SEMNODERIDAE
Antygomonas sp. indet. B. Paavo *in* Neuhaus *et al.* 2010
Sphenoderes spp. indet. (7) B. Neuhaus *in* Neuhaus *et al.* 2010
Sphenoderes sp. (NIWA 162661)

Order XENOSOMATA
Family CAMPYLODERIDAE
Campyloderes vanhoeffeni Zelinka, 1913
Campyloderes sp. B. Neuhaus *in* Neuhaus *et al.* 2010

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