Small organisms create big problems for taxonomists

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The age of travelling naturalists such as Wallace, Darwin, and von Humboldt who explored newly discovered continents and islands and described their animal and plant biodiversity is now well and truly over. Understandably, the work of early explorers usually focused on the large and conspicuous organisms that they saw; as a result, we now have a good knowledge of the diversity of these large organisms, although a relatively small number of mammals, birds, and fish species continues to be described every year across the globe.

In an attempt to find more new and exotic species, biologists have more recently turned their attention to environments which until not long ago were inaccessible or difficult to sample, such as the polar regions and the deep sea. In these environments, undescribed species and higher taxa are abundant and the diversity is sometimes very high. However, less remote environments are also home to undiscovered biodiversity. Instead of standing on the bow of a ship scrutinising the horizon (à la Jacques Cousteau), we now need to crouch down, sift through unsightly piles of often smelly dirt and debris, and spend hours bent over a microscope. We need to pay more attention to the very small organisms right under our nose, and we need to think small.

Roundworms, or nematodes, are perhaps the best example of small, abundant, and highly diverse organisms about which we still know very little (Figure 1) – both their diversity and their role in ecosystems. It has been claimed that nematodes are the most numerous animals on the planet, leading the famous nematologist Nathan Cobb (1914, p. 472) to write:

> *…if all the matter in the universe except the nematodes were swept away, our world would still be dimly recognizable, and if, as disembodied spirits, we could then investigate it, we should find its mountains, hills, vales, rivers, lakes, and oceans represented by a film of nematodes. The location of towns would be decipherable, since for every massing of human beings there would be a corresponding massing of certain nematodes. Trees would still stand in ghostly rows representing our streets and highways. The location of the various plants and animals would still be decipherable, and, had we sufficient knowledge, in many cases even their species could be determined by an examination of their erstwhile nematode parasites.*

This image conjured by Cobb shows just how adaptable and widespread nematodes are; despite their simple body plan, which consists of a tube (a one-way gut) inside a tube (the outer body wall or cuticle), nematodes have adapted to an incredibly diverse range of ecological niches and environments ranging from ocean trenches, Antarctica, the deep subsurface biosphere of the Earth's crust, hot springs, and as parasites of animals and plants (e.g. Borgonie *et al*. 2011). Species have even been described from unlikely habitats such as beer mats and bottles of unpasteurised apple cider vinegar (e.g. the so-called 'vinegar eels' *Turbatrix aceti*, which have more recently also been noticed in kombucha cultures).

Despite their ubiquity, we still know relatively little about the diversity of nematodes in many parts of the globe. In New Zealand, the known diversity now stands at around 750 species, mainly from plant and vertebrate hosts and soils. The true total is likely to be several times that number (Yeates 2010), with over 1000 species estimated to be present in continental margin sediments alone (Leduc *et al*. 2012). Such is the gap in our knowledge of nematode taxonomy that it is possible to find new species in the vicinity of urban areas; a case in point is the recent discovery of several new intertidal nematode species just outside NIWA's Greta Point campus in Central Wellington (Leduc & Zhao 2016). This lack of knowledge of easily accessed habitats exists because the taxonomy of free-living marine nematodes in New Zealand has, until recently, been investigated only sporadically by visiting overseas experts (Gwyther & Leduc 2008). At present, there are very few specialists residing in New Zealand actively studying the diversity of small organisms, including highly diverse and widespread groups such as harpacticoid copepods, kinorynchs (mud dragons), and loriciferans (Figure 2).

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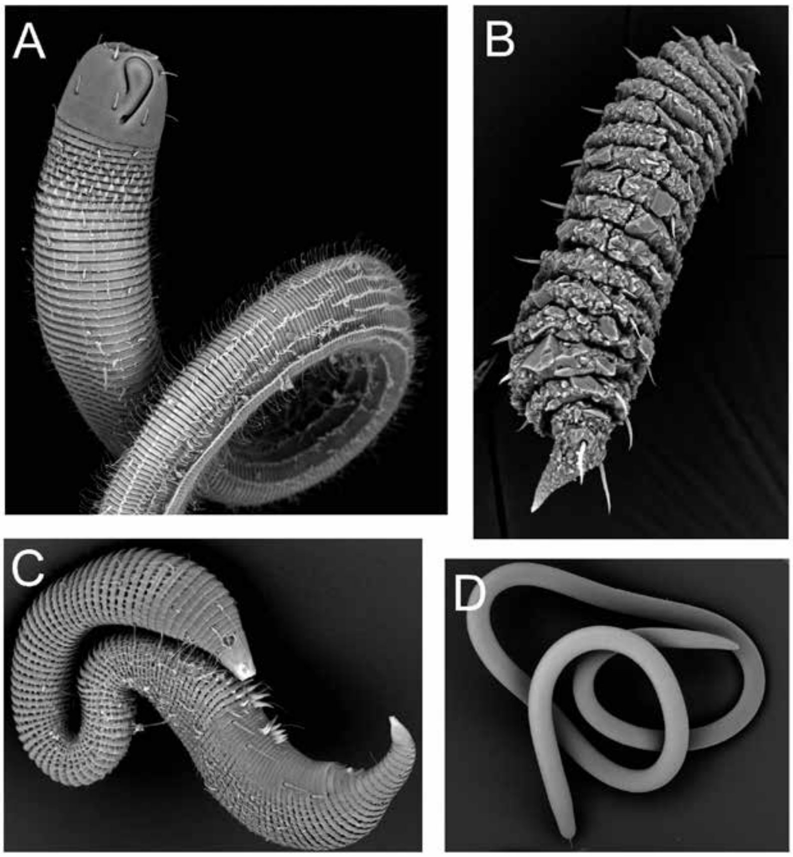

Figure 1. Examples of nematode morphology. A: *Desmodorella verscheldei* **from Hataitai beach, Wellington; B: an unidentified species of the genus** *Desmoscolex* **from Chatham Rise; C:** *Epsilonema rugatum* **from Hataitai Beach; D:** *Trophomera* **cf.** *marionensis***, a parasite of amphipods in the Kermadec Trench.**

Although the prospect of so much undiscovered biodiversity is exciting for taxonomists, the magnitude of the knowledge gap is daunting. How can we hope to describe and name the many thousands of tiny species that surround us and understand their roles in ecosystems, given the large amount of work involved in sampling, preserving, describing and publishing every new taxon, and the small number of taxonomists currently employed in New Zealand? There are no easy answers to this question. The ease with which new species can be discovered makes this country very attractive for visiting taxonomists from other parts of the globe, which are often more than happy to look at New Zealand material and contribute to the description of our native fauna. However, any serious attempt at addressing this taxonomic challenge will require developing the means to support our own resident experts over the long term. In addition to growing our pool of experts, we should be aiming to incorporate new technologies, some of which lend themselves particularly well to the study of small and numerous organisms. Environmental DNA (eDNA) metabarcoding provides a powerful tool to complement the morphological approach to taxonomy. This method, which is based on the bulk extraction of DNA sequences from water or sediment samples combined with high-throughput sequencing technologies, has already revealed unsuspectedly high levels of biodiversity in shallow and deep marine environments (Fonseca *et al*. 2010, Sinniger *et al*. 2016). The metabarcoding approach has the potential to expand our knowledge of the diversity of small organisms, but it is essential that it be integrated with morphology-based taxonomy in order to grow the taxon-linked sequence database against which bulk eDNA samples can be compared (Dell'Anno *et al*. 2015). Far from superseding so-called 'traditional' taxonomy, the emergence of new molecular technologies increases the need for morphology-base taxonomy for the foreseeable future. It is also clear that taxonomists need to incorporate molecular sequence data in their species descriptions whenever possible in order to maximise the uptake and integration of their science by the wider scientific community.

At this point, some of you may be wondering why we should go through all this trouble to describe and understand the diversity of tiny life forms which seem to have no obvious use; what does it matter that their diversity is high or low, that some species occur in some places but not others, or that we lose some species we never knew existed in the first place? These are legitimate questions to ask, which perhaps taxonomists could do a better job of answering – taxonomy, after all, is largely paid for by public funds. We value large species because we can see them and they therefore are part of our identity. Certain species are considered to be attractive, others useful, and some rather tasty.

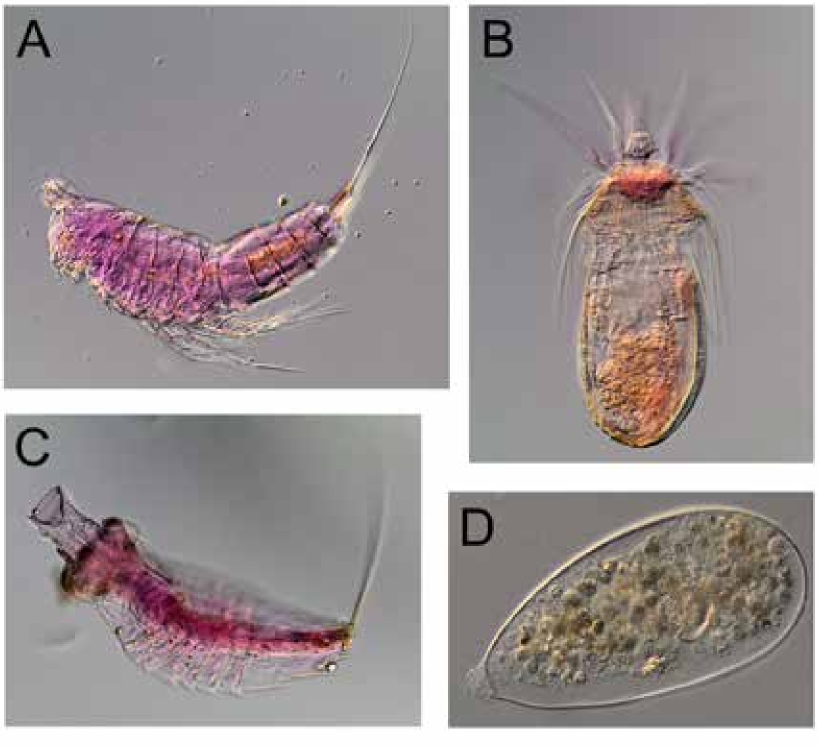

Figure 2. Examples of common, diverse, yet poorly known small organisms in New Zealand. A: Harpacticoid copepod, a highly diverse group of crustaceans; B: loriciferan, a phylum only discovered in the 1980s; C: kinorynch, or mud dragon, a group superficially similar to crustaceans but in fact a separate phylum; D: gromiid, a type of unicellular organism distantly related to the much better known foraminiferans.

On the other hand, small organisms such as parasitic nematodes have attracted a lot of attention because they result in financial loss from lost productivity. This is hardly an argument for conservation, although it has been shown that eradicating the parasites of charismatic host species may do more harm than good (Spencer & Zuk 2016). But what about free-living species living in aquatic sediments with which we don't seem to have any direct interactions? Although most of us are not aware of it, aquatic sediments provide many ecosystem services that benefit us in a very real way, including nutrient cycling, carbon sequestration, and absorption and detoxification of pollutants (Snelgrove *et al*. 2014). Ecological science has demonstrated that these services are largely driven by microscopic life forms such as bacteria, protists and small animals (e.g. Beaulieu 2002), and that maintaining the diversity of these organisms is essential to preserve the functional integrity of ecosystems (Balvanera *et al*. 2006, Isbell *et al*. 2011). Recent evidence also suggests that even coexisting cryptic nematode species (i.e. species which cannot be distinguished based on morphology alone) can have different ecological niches and thus different ecological roles and influence on ecosystem function (Derycke *et al*. 2016). Thus, better characterising the diversity of small organisms is something we need to do if we are to better understand not only how ecosystems work, but also how to protect them.

It is clear that taxonomists still have big problems to solve. There are, after all, plenty of blank spaces to fill on the map, and the age of exploration is not yet over, at least not for biologists interested in the smaller biota. New Zealand is still a great place to be for taxonomists, particularly if one is interested in describing and understanding the diversity of life that underpins the functioning of healthy ecosystems.

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