CellPress

Trends in Parasitology

TrendsTalk

Trematodes 2024: the inaugural international meeting for trematode researchers

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Inspired by the various meetings held for other specific parasite lineages, two eminent scientists – Isabel Blasco-Costa (Natural History Museum of Geneva) and Scott Cutmore (Queensland Museum) – focused on the Trematoda, organised a comparable meeting for this group of parasites, the richest of the metazoan parasite lineages. Thus, the inaugural *Trematodes* meeting was held in September 2024, hosted at the Queensland Museum, Brisbane, Australia, featuring trematode taxonomy and systematics, evolution, life cycles, ecology, pathology and disease, and biogeography. In this *TrendsTalk*, we invited one of the organisers, Storm Martin, and the contingent of fellow early-career trematode enthusiasts in attendance, to outline the vision and future for the meeting series and to report and reflect on the science presented, ideas discussed, and the collective experience from this first meeting.

Storm B. Martin

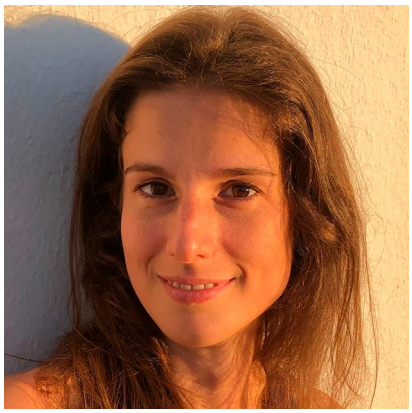
Anna Gonchar

Overview and reflections

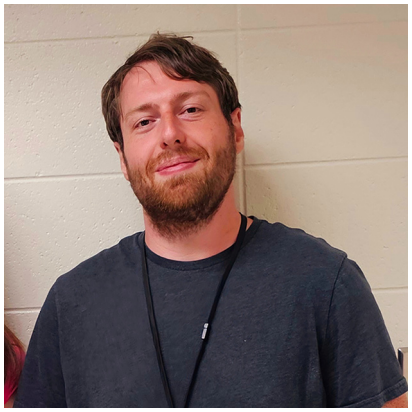
The purpose of *Trematodes 2024* was to bring researchers working on the Trematoda together to build a sense of community, strengthen global collaboration, and establish a precedent for the future of the conference series. The value and timeliness of a cohesive community was reiterated throughout the meeting, and was especially articulated in the first invited address, delivered by Tim Littlewood, Director of Science at the Natural History Museum, London, and himself a student of the Platyhelminthes. Tim argued that a unified collaborative effort can leverage individual strengths to amplify impact and effectively exploit opportunities at local through to global scales. Moreover, the time for such unity is now; our world is changing and we sit at the intersection of an increasingly interconnected and interdisciplinary scientific landscape, rapid advances in technological capabilities, and alarmingly urgent climate and biodiversity crises.

Measured against the above objectives, the meeting was a success. The conference was attended by more than 80 researchers, from institutions across 22 countries, and all inhabited continents. This attendance represents a sizeable proportion of the international research community working on the Trematoda, largely reflects where and by whom the work is currently being done, and included substantial diversity across specific expertise and perspectives, and career stage. The scientific programme included a welcome address, eight invited addresses, 58 submitted oral presentations, 25 poster presentations, and five workshops. The programme was structured into a single stream across four days, interrupted with a midweek excursion. This format made for a tight schedule with scarce opportunity for questions between presentations, although, in the context of a specialised and friendly meeting of modest scale, the opportunity for all participants to experience the entirety of the scientific programme was invaluable.

The importance of strong participation from early-career scientists was identified as a priority by the Organising Committee from the outset. The youngest invited speaker, Olena Kudlai (Nature Research Centre, Lithuania), was asked to share her scientific journey. She provided an inspiring recount highlighting the factors, decisions, and



Clarisse Louvard



Tyler J. Achatz

Marliese Truter

lessons learned that have shaped her impressive and adventurous career so far, and offered considered and well-received advice to early-career scientists in trematodology. Similarly, students were encouraged to submit abstracts for oral presentation, and the committee worked hard to raise sponsorship, all of which was directed towards 11 travel awards. More than half of the conference attendees were early-career scientists (students and researchers less than five years post-PhD). It is an encouraging indication for the future of trematode research that so many young scientists were involved, and the enthusiasm and aptitude they demonstrated was reciprocated by the approachability and interest exhibited by the established scientists in attendance. It was particularly special and encouraging to have Rod Bray, David Blair, Kazuo Ogawa, and Tom Cribb, all retired, actively engaging discussion with early-career scientists about their work.

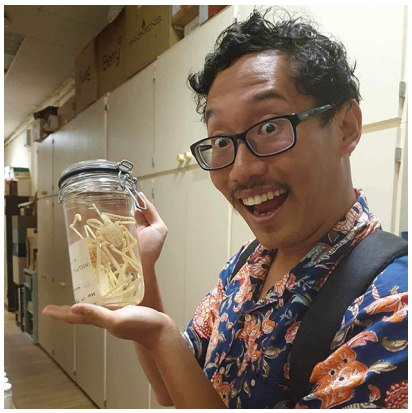
The conference also appears to have been a success measured against the atmosphere and engagement during the week, and the collective feedback received. The overwhelming sentiment expressed by attendees was of enthusiasm. The specialised programme was satisfyingly engaging, and each presentation and conversation was relevant, making for a constantly stimulating experience. Likewise, many researchers in the community met at *Trematodes 2024* for the first time, and this was the case even for some interactions between seasoned scientists. We think that the collective experience of all involved argues strongly for the value of a continued *Trematodes* conference series.

The workshops: discussions to galvanise the community

An important feature of the *Trematodes 2024* programme was the five workshop sessions, each a led discussion around a substantial current challenge, and thus opportunity, facing the international trematode research community. Consistent with the overarching objectives of the conference, the topics chosen for discussion in these workshops were issues for which progress might be substantially expedited through global collaborative initiatives. In each workshop, the session leaders articulated why and how the specific focal challenges impact and limit progress across the breadth of trematode research perspectives. Ultimately, global collaborative initiatives require strong and clear leadership, substantial strategic consideration and, of course, funding. These workshops stopped short of manifesting tangible collective commitments or projects within the sessions. Nevertheless, audience engagement and discussion were positive and constructive, and sparked further conversation and interest towards realising such projects. The purpose, discussion, and outcomes for each of these workshops is summarised below.

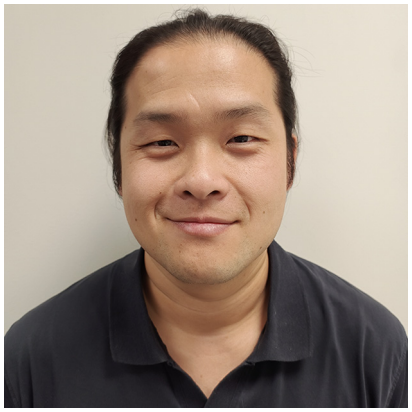
Workshop: genetic approaches

Dramatic progress has been made towards understanding the phylogeny and deep evolutionary trajectories of digeneans through reconstructions based on 28S and 18S rDNA. Taxon sampling for these markers is now impressively broad, yet important questions remain unanswered, and the uptake of advanced molecular approaches lags behind that for free-living taxa. Thus, the first workshop, led by Isabel Blasco-Costa (Natural History Museum of Geneva) and Tim Littlewood (Natural History Museum, London), sought to proactively discuss the various options for advanced molecular approaches available to the trematode research community and estimate our desires and needs in applying these technologies. Most attendees expressed little familiarity with advanced approaches beyond Sanger sequencing – for example, next-generation sequencing (NGS), metabarcoding, metagenomics, ultraconserved elements (UCEs), microsatellites, double digest restriction associated DNA (ddRAD) – but many apply molecular analyses to inform species identification, survey biodiversity, elucidate life cycles or examine



Russell Q.-Y. Yong

Georgii Kremnev



Nicholas Q.-X. Wee

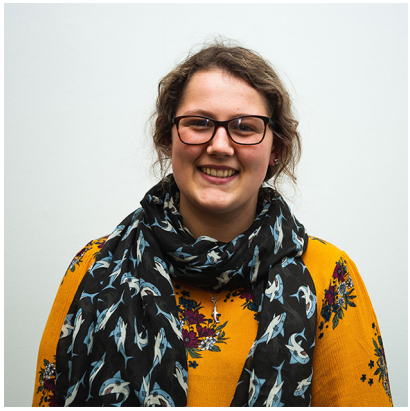
phylogeny, explaining the persistent use of simple and cost-effective molecular approaches. Nevertheless, the desire to apply advanced approaches to solve big-picture questions is strong in the community. The discussion emphasised the importance of collaboration to facilitate the leap into widespread application of advanced approaches, including within the community and across disciplines. The community must harmonise and democratise workflows and protocols, share samples, train researchers in NGS data processing, utilise existing platforms for sharing open data, and organise to pitch for funding to generate large datasets and answer big questions. It was exciting to realise that our community is beginning to explore applications for these technologies and appears poised to embrace them at scale.

Workshop: biogeography and distributions

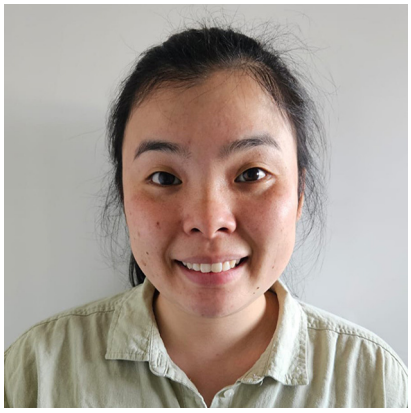
Gerardo Pérez-Ponce de León (National Autonomous University of Mexico) and Storm Martin (Murdoch University) led a discussion attempting to assess our capacity to inform trematode biogeography and understand distributions. The session outlined how our rudimentary understanding of distributions and biogeography simultaneously limits, and is limited by, our capacity for species identification, estimations of richness, and understanding of evolutionary histories. Most trematode species are known from single reports, and those few with substantial distribution data are usually based on morphological identification over the known range, and are therefore variously believable and require testing with molecular analyses. It is therefore clear that, for most trematode taxa, we remain far from being able to apply the formal biogeography approaches to explain causative processes shaping distributions that are achievable for some free-living faunas. Nevertheless, there is a trend for empirical, descriptive narrative approaches exploring biogeography for specific taxa in our literature. The discussion then turned to what is immediately achievable by the trematode research community: improving data for species distributions, calibrating our expectations for distributions across host groups, and devising targeted strategies to improve sequencing over geographic range and thus test reportedly wide species distributions. Our expectations for patterns of distributions remain hazy, and largely untested, and the first step is thus to pursue our current efforts to obtain a reliable description of distribution patterns with genetic sequencing over geographic range, considering the context of global ecosystem change. These are surmountable challenges, and now, with a connected community and broad accessibility of molecular sampling, is the time to address them.

Workshop: species recognition

This workshop, led by Tom Cribb (Queensland Museum) and Tyler Achatz (Middle Georgia State University), explored the value, utility, and limitations of current approaches to species delineation. It became clear that many of us encounter similar challenges relating to species identification, conflicting inference from morphological versus molecular data, and difficulties with species recognition over geographic and host range. The discussion considered useful examples, including contributions from the audience, which showed how individual pillars of evidence can be misleading when considered in isolation. Despite the limitations of morphology, host identity and geography, each remains important and informative in most cases, and the cases where they do fail are interesting. Likewise, there was general agreement that modern work requires a combination of genetic markers. It was convincingly argued that an integrative approach, combining consideration for morphology, host identity and ecology, and geography, together with molecular analyses, is best practice for recognising species. The discussion considered the value of individual expectations and pattern recognition derived through experience,



Jerusha Bennett



Berilin Duong

Maureen Duflot

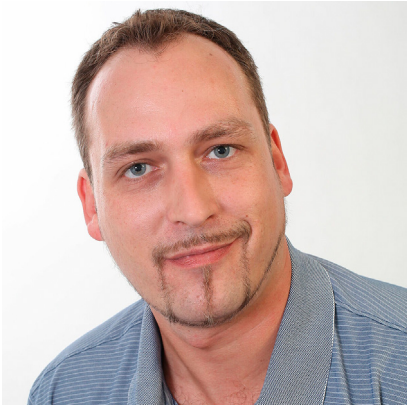
and emphasised recognition of the unavoidable inverse of experience, bias. Wisdom in species recognition requires consideration of all evidence, allowance for inferences to be shaped by experience, but openness to alternative explanations and awareness that our conclusions might prove inaccurate. The discussion also revealed that we are currently grappling with fine distinctions between intra- and interspecific variation, or between populations and species. Our capacity for species recognition has refined dramatically over time, yet there is still much investigation ahead of us, and these individual investigations range in outcome from the satisfying through the interesting, alarming, or humbling.

Workshop: best practices

This workshop, led by Scott Cutmore (Queensland Museum) and Vasyl Tkach (University of North Dakota), discussed best practices for the collection, preservation, handling, reporting, and characterisation of trematode specimens, for two purposes: (i) to work towards consensus and minimum standards as a community, and (ii) to provide opportunity to share and learn from our respective experience and wisdom. The discussion covered many specific details relating to all aspects of collection through to publication and beyond, with emphasis on methods resulting in quality specimens for both morphological and molecular analyses. The broader discussion included appreciation for the diversity of scenarios and study purposes that shape sampling, the importance of museums and collecting for the future, arrangements for effective teamwork in processing dissections, considerations for maximising output from the sacrificed host animal/s, the advantages of working with animal hospitals and rescue centres to procure fresh tetrapod hosts, the value in collaborating with other scientists including ecologists, physiologists, and other parasitologists, and responsible storage and deposition of unprocessed material. This session generated much discussion, interest, advice, and friendly and productive debate. Most importantly, it was evident our community is characterised by substantial collective experience and wisdom, flexibility, and openness for the betterment of our science, and a culture of friendly, supportive, and generous sharing of guidance and advice. Thus, for those new to science, venturing into new areas or seeking improvement for specific approaches, it would seem best practice to reach out for wisdom from within the community.

Workshop: information systems and a society

The overarching objective reiterated throughout the conference was a call for increased cohesiveness and collaboration as a global community. In the final workshop, Storm Martin (Murdoch University) presented the initial conception for two proposals to facilitate this objective: formation of an international society for trematode research, and development of a web information system to curate, share, and exploit trematode record data. Specifically, this latter proposal envisaged a modular and extendable relational database interfacing with existing systems and accessible and updateable via a web portal. The proposed basis of the system are the parasite-host-locality records from the primary literature which underpin many typical lines of investigation, and which are already largely but disjointly curated across various systems and personal databases. The proposed rationale for a society was increased cohesiveness of the research community, and stewardship of the continuing *Trematodes* conference series and any information systems or data repositories, whatever form these might take. These ideas were received with a mix of enthusiasm and hesitation. Though many were excited to explore and contribute to these possibilities, important foundational issues require consideration. The greatest trepidations related to the necessity for such a system, and resources for



Stefan Theisen

assured continuity. Ultimately, in our modern, interconnected era, it seems inevitable that improved solutions to sharing, curating, and exploiting dissection record data will manifest in some form. The community can likely expect these discussions and proposals to mature in the near future. These initiatives felt like the culmination of the conference and in many ways summarised why we were all in Brisbane that week.

Invited perspectives and contributed research: threads and themes

Whereas the workshop components sought to promote global collaboration, the programme of contributed research promoted familiarity among the community. The contributed abstracts were of an excellent standard, featured inspiring and stimulating content, were engagingly presented, and struck a natural balance between pure and applied research, and topics with broad, practical relevance and those of specific focus. We suspect that, for many in attendance, it was a revelation to see just how many of the ideas, frustrations, and desires are common across the community. Attendees represented a variety of backgrounds and paths through scientific enquiry which had led them to the Trematoda, yet the mutual understanding and reciprocal interest among attendees was high. Contributed research was complemented by eight invited speakers who delivered excellent and pertinent addresses which shaped the structural themes for the scientific programme. Here, this content is briefly summarised around these main, interconnected themes.

Regional faunas, histories, and challenges

The broad geographic representation at the conference was an excellent outcome and made for a truly international experience. Moreover, several presenters focused on, or took the opportunity to include, an overview of the fauna and history of research for their particular region. This was among the most enjoyable themes of the meeting, promoting improved awareness, interest, and understanding among the community. The invited address from Misako Urabe (University of Shiga Prefecture) detailed the fauna, geological history and trematode research history for a specific system, Lake Biwa, Japan. Lake Biwa includes an interesting and complex arrangement of old, new, and relic endemic faunas, and the extensive body of work from this system includes intriguing investigations into the biogeographical history of parasites relative to their hosts, as well as ecological interactions, including in relation to invasive host and parasite species.

Similarly, in his welcome address, Tom Cribb (Queensland Museum) delivered an entertaining and informative summary of the known and unknown trematode fauna found in Australia, and a history of the investigations into this fauna. Tom outlined that many of Australia's iconic mammals are disappointingly yet unsurprisingly trematode-poor, though others, including the platypus, make up the difference with suitably exciting yet poorly studied trematode parasites. Indeed, the paucity of investigation was made apparent for several groups of Australian tetrapods, as were the environmental challenges for trematode life cycles on this arid continent: despite the high richness of terrestrial snails, few host trematodes, and Australia has few freshwater fishes and systems relative to its landmass. Later in the week, Shokoofeh Shamsi (Charles Sturt University) showed that interesting richness could nevertheless be found in the arid continent's freshwater fishes, Di Barton (Charles Sturt University) made clear how poorly surveyed raptors are in Australia, and Storm Martin (Murdoch University) provided an early update from surveys of the fauna in marine fishes from neglected Western Australia.

South Africa was exceptionally well represented at the conference, and this was particularly impressive considering the scarce history of trematode research in South Africa.

Nico Smit (North-West University) outlined the recent turn in this trend and the exciting pace of current investigation in the country, and Russell Yong (North-West University) summarised the progress and exciting outlook for characterising the fauna found in marine fishes. Anja Vermaak (North-West University) provided a specific example of remarkable richness from a single, endemic fish species, including a possibly new aspidogastrean, and Marliese Truter (North-West University and South African Institute for Aquatic Biodiversity) summarised substantial richness and diversity of metacercariae from freshwater fishes in South Africa.

Many nations in the tropics have little local history or capacity for surveys of parasitic faunas, yet the greatest biodiversity occurs there. In this context, it was excellent to hear from researchers representing these regions. Anshu Chaudhary (Chaudhary Charan Singh University), Lenin De Silva (Murdoch University), Tilak Chandra Nath (Sylhet Agricultural University), Erick Arrashy Rudianto (Diponegoro University), and Bianca Nandyara (Federal University of Pará) each included perspectives of the varied local challenges, capacity and history of research, and appetite for collaboration from their respective super-diverse regions of India, Sri Lanka, Bangladesh, Indonesia, and Brazil.

Compared with these tropical regions faced with intimidating and largely unknown faunas in the Southern Hemisphere, some faunas in the Northern Hemisphere are far better known. Francisco Montero (University of Valencia) reported on the rich and well-studied digenean fauna in Mediterranean sparid fishes, and Anna Gonchar (Saint Petersburg University and Russian Academy of Sciences) and Georgii Kremnev (Russian Academy of Sciences) reviewed the fauna and history from the White Sea, where the trematodes are likely now substantially known, currently comprising 63 species from 18 families in the region. Nevertheless, there remains opportunities for substantial new surveys in the Northern Hemisphere: Anna Faltýnková (Mendel University in Brno) and Olena Kudlai (Nature Research Centre, Lithuania) summarised recent investigations into the freshwater trematode diversity from Iceland and Lithuania, respectively.

Trematodes in a changing world

Tim Littlewood (Natural History Museum, London) brought a rare and valuable perspective to the conference. In his invited address, Tim articulated the call for a unified and collaborative trematode research community within the theme of dramatic changes to ecosystems. Several contributed presentations included concepts relating to emerging parasitic disease and conservation. Pieter Johnson (University of Colorado) presented evidence for temporal and spatial emerging parasitic disease, with increased prevalence and intensity of infections of *Scaphanocephalus* spp. (Opisthorchiidae) metacercariae causing black spot syndrome in Caribbean coral reef fishes over the past century, and associated with anthropogenic disturbance at local scales. Similarly, Maureen Duflot (ANSES, France) presented the first detection of black spot syndrome caused by *Cryptocotyle* spp. (Heterophyidae) in commercial fishes from the English Channel and North Sea, and reported on increased risk of human clinostomiasis in France due to a diversifying diet increasingly including raw fish. Marta Valmaseda-Angulo (University of Valencia) investigated the potential for reciprocal amplification of a pathogenic blood fluke between maricultured tuna and wild bonito in the Mediterranean, Kristin Herrmann (Tarleton State University) reported concerning impacts to populations of freshwater mussels of conservation concern in Texas, and Jerusha Bennett (University of Otago) reported on unexplained outbreaks of *Copiatestes* spp. (Syncoeliidae) mesocercariae resulting in a bizarrely inadvertent yet alarming incidence of seabird mortality. Conversely, Petra Kundid (University of South Bohemia) reported on the surprisingly rich fauna found in

post-mining lakes in the Czech Republic and the exciting opportunities for research in these rewilded habitats.

Modern molecular approaches

Perhaps the most important and pressing theme for the meeting was the uptake of advanced molecular approaches. It is in this area where the pace of technological change is greatest and where we might achieve increased effectiveness and efficiency in maximising new opportunities as a community through some proactive discussion and consensus. Thus, in addition to the aforementioned workshop, this topic was also the focus for two of the invited talks, delivered by Neil Young (University of Melbourne) and Isabel Blasco-Costa (Natural History Museum of Geneva). Neil's address detailed inspiring examples of genomic and transcriptomic work applied to the Trematoda, demonstrating and explaining what was possible and likely coming for the field. Isabel explored trends in our literature for the past 10 years and argued that although we are good at repeating what we already know how to do (Sanger sequencing), we have already missed the opportunity for the application of early advanced approaches. Isabel challenged those of us thinking that more advanced approaches did not apply to our specific pattern of work, particularly taxonomists, with compellingly relevant examples. She advocated for genome-wide approaches versus expensive whole-genome approaches, and appealed to the early-career scientists to drive change in the community.

Indeed, several contributed presentations, many by students, demonstrated various applications for advanced molecular approaches, indicating that the trematode research community appears to be experiencing the early and exciting uptake of these approaches. Moreover, whereas the examples detailed by Neil focused on some of the most economically and medically significant trematode species, these contributed talks dealt with a variety of taxa across a range of economic significance.

Alfonso Diaz Suarez (Estonian University of Life Sciences) applied a metabarcoding approach to disentangle species identities among complex and morphologically conserved infracommunities of diplostomid metacercariae encysted in the eyes of fishes, Clarisse Louvard (North-West University) reported on a transcriptome for a digenean in a wild marine fish, Anshu Chaudhary (Chaudhary Charan Singh University) presented the first mitogenome from a clinostomid in India, Leslie Stout (University of Bordeaux) developed species-specific quantitative/digital PCR and environmental (e)DNA-type approaches to identify previously unknown life cycle stages and hosts, and detect infections and track phenology of intramolluscan generations; Simão Correia (University of Aveiro) investigated tissue-specific changes in gene expression profiles of cockles infected by sporocysts of *Bucephalus minutus* (Bucephalidae); and Mar Llaberia-Robledillo (University of Valencia) explored the complex population structures for two digeneans relative to the historical pattern of post-glacial lake colonisation by the European whitefish using ddRAD sequencing and *de novo* genome assemblies. Nathan Bott (RMIT, Australia) and representatives of his team, Melissa Carabott, Jemma Hudson, and Maree Widdicombe, presented a series of talks showcasing advanced molecular approaches applied to blood flukes (Aporocotylidae: *Cardicola* spp.) of economic significance in the ranched tuna fishery. Their work included obtaining the first full nuclear genomes, mitogenomes, and glycome for species of *Cardicola*, as well as the first comparison of transcriptomes from infected and uninfected tuna, and development of rapid diagnostic techniques via recombinase polymerase amplification (RPA) coupled with a lateral flow device. Finally, Stefan Theisen (University of Rostock) presented new

approaches in morphological study, including advanced digital visualisation via Confocal Laser Scanning Microscopy resulting in beautiful specimen images and animations.

The role of museums

Museums are critical sources of knowledge and specimens, and reiterating the essential role of these institutions in the modern scientific landscape was an important theme promoted by the Organising Committee. This was the focus of the invited address delivered by Sara Brant (Museum of Southwestern Biology, University of New Mexico). Sara expounded on the critical nature of lodging voucher specimens, including host tissue and data, and advocated the continued importance of museums, not just as repositories of specimens for taxonomic research, but also in support of other biological research. Sara highlighted a lack of 'museum culture' among non-taxonomist biologists, a de-valuing and lack of awareness of submitting voucher specimens in support of published work, leading to unverifiable science.

Tim Littlewood's (Natural History Museum, London) invited address also touched substantially on the role of museums. In particular, he described the importance of not just storing specimens but unlocking the value of collections by making them accessible through digitalisation. Likewise, Terry Miller, Head of Biodiversity and Geosciences at the Queensland Museum, and a student of the Trematoda himself, welcomed attendees to the venue and expressed similar goals to unlock the value of the local trematode collection. Jesus Hernández-Orts (Curator of Parasitic Worms and Protists, Natural History Museum, London) and Nick Wee (Collection Manager of Parasitology, Queensland Museum) followed these invited addresses with presentations summarising the history and current parasitological collections of their respective institutions, and detailed ongoing efforts to increase holdings, systemise databases, and improve access of these collections to researchers.

Breadth versus depth

Robert Poulin (University of Otago) delivered an excellent invited address examining the trade-off between breadth and depth of investigation for digenean taxa, arguing that we do breadth well but would benefit from more examples with greater depth, that is, model organisms for our fauna. Robert demonstrated the benefits of depth with a summary of the impressive and stimulating body of work on the microphallid *Maritrema novaezealandense* in New Zealand. Robert also articulated the logistical and biological factors that made this a suitable model organism.

This theme ran throughout the meeting and applied to all presentations, as all can be assessed in terms of the breadth versus depth of investigation. Here we summarise presentations by four attendees that echo Robert's call for greater depth. Across two fascinating talks, Ryan Hechinger (Scripps Institution of Oceanography) revealed novel insights into population dynamics of intramolluscan generations, with specific focus on the plasticity of soldier castes. Similarly, at the level of communities and infracommunities within molluscs, Miroslava Soldánová (Czech Academy of Sciences) summarised the multidisciplinary approach her team uses to gain insights into ecology, ecosystem functioning, species interactions, and epidemiology. Petra Kundid (University of South Bohemia) reported on investigations into complex interactions between trematodes, their hosts, and their environments, including detection of a significant mediation of the parasite impact on host snail population through predation of cercariae by mussels. Finally, Anna Gonchar (Saint Petersburg University and Russian Academy of Sciences) presented transmission

electron microscopy data for the miniscule miracidium of *Derogenes varicus* (Derogenidae) as part of common investigations into species delimitation, life cycles, and distributions for derogenids found in the White Sea.

Life cycles

The complex life cycle with multiple hosts and both sexual and asexually reproducing generations defines the digenean trematodes and is integral to their enormous success, diversity, and richness. In her invited address, Olena Kudlai (Nature Research Centre, Lithuania) recounted her pursuit of cercariae and metacercariae from freshwater systems around the world, and summarised the importance and advantages of working on these stages.

Life cycles remain incompletely known for most digenean species, even at the family level for several groups. Georgii Kremnev (Russian Academy of Sciences) presented an intriguing new first-intermediate host-switch hypothesis underlying evolution of the Brachycladiidae parasitic in marine mammals, and reported on the elucidation of life cycles and revised taxonomy for Holarctic renicolids parasitic in birds; Clarisse Louvard (North West University) hypothesised an elegant and unintuitive connection explaining transmission between seemingly disconnected intermediate and definitive hosts, and reported on novel efforts to elucidate life cycles for marine species in South Africa; Leslie Stout (University of Bordeaux) elucidated a life cycle using an eDNA-type approach; Sho Shirakashi (Kindai University) elucidated the life cycle for *Galactosomum* spp. (Heterophyidae) causing economically significant whirling disease in maricultured fishes; Kazuo Ogawa (Meguro Parasitological Museum) reported on the diversity and life cycles for blood flukes in maricultured fishes in Japan; Anna Gonchar (Saint Petersburg University and Russian Academy of Sciences) reported on the remarkably low specificity for the first intermediate hosts in the life cycle of *Microphallus pseudopygmaeus* (Microphallidae); Nico Smit (North-West University) recounted elucidation of the life cycle of his patronym *Neofibricola smiti* (Diplostomidae); and Tom Cribb (Queensland Museum, on behalf of Dan Huston, CSIRO, Australia) presented a new hypothesis to explain truncation of life cycles in digeneans infecting herbivorous fishes.

Finally, several talks dealt with surveys and identifications of larval stages: Tsukasa Waki (Toho University) reported on surveys from terrestrial snails in Japan, whereas Komal (Chaudhary Charan Singh University), and Marliese Truter (North-West University and South African Institute for Aquatic Biodiversity) and Willem Smit (University of Limpopo) reported on surveys from freshwater fishes in India and South Africa, respectively. Meanwhile, Pieter Johnson (University of Colorado) reported a sobering account of targeted attempts to detect the first intermediate host of *Scaphanocephalus* spp. causing black spot syndrome in Caribbean reef fishes.

Taxonomy and systematics, evolutionary history, distributions, and biogeography

Finally, taxonomy and systematics was an important theme throughout the meeting, represented by an assortment of presentations relating to various trematode taxa and associated host groups. Many of these presentations also touched on aspects of species recognition, evolutionary history, and distributions and biogeography, and it was reassuring to see that most presented work was based in integrated approaches.

Vasyl Tkach (University of North Dakota) delivered an invited address on the current state of knowledge related to the superfamily Diplostomoidea. This group has received extensive attention in recent years, partly due to its association with pathology in second

intermediate hosts. Whereas most studies have been limited to larval stages, hindering accurate identifications, Vasyl discussed a series of recent works that have begun to identify lineages previously known only from larvae and introduce significant taxonomic and systematic changes. Tyler Achatz (Middle Georgia State University) continued this thread with a presentation on the proterodiplostomids, an unusual diplostomoidean lineage. This project explored the diversity and coevolution of these digeneans with their crocodilian and other reptilian definitive hosts. Among other findings, the research revealed a strong coevolutionary relationship between host and parasite, dating back to before the breakup of supercontinents. Maggie Young (Middle Georgia State University) also reported on richness, taxonomy, and systematics of diplostomids, in kingfishers worldwide.

Several presentations focused on problematic taxonomy for digenean species of substantial zoonotic significance. David Blair (James Cook University) explained the complex taxonomic history of *Paragonimus westermani* (Paragonimidae), with genetic evidence showing that this species represents a complex which might never be fully resolved. Tilak Chandra Nath (Sylhet Agricultural University) provided a morphological and genetic characterisation of a zoonotic echinostomatid in Bangladesh, including a report on life cycle stages and the optimal conditions facilitating transmission in the country. Vania Agustina (Trisakti University) uncovered distinct intermediate fish hosts between human- and cat-infecting populations of the significant zoonotic *Opisthorchis viverrini* (Opisthorchiidae) species complex which appears to elegantly explain maintenance of the genetic structuring and suggests that the role of cats as reservoir hosts may be less important than previously recognised. Roman Kuchta (Czech Academy of Sciences, and Slovak Academy of Sciences) untangled the diversity and distributions of *Metagonimus* spp. (Heterophyida), concluding that reports of an East Asian species in Europe actually are representative of a distinct endemic species, and that a further distinct species is represented by reports in the Middle East.

Beyond zoonotic taxa, taxonomic works were presented across a variety of host groups. From tetrapods, Stephen Greiman (Georgia Southern University) shared preliminary data from parasite surveys of bats in Panama, where at least 13 species of digeneans were identified, including several new species; Di Barton (Charles Sturt University) reported several new records from Australia's iconic but under-surveyed wedge-tailed eagle; Piet King (Sefako Makgatho University) presented the first report of a species of the rare avian blood fluke genus *Macrobilharzia* (Schistosomatidae) infecting white-breasted cormorants in South Africa; Dylan Corner (Agri-Science Queensland) presented on advances in understanding richness, phylogeny and life cycles of marine turtle blood flukes; Lenin De Silva (Murdoch University) reported on trematodes from sea snakes in Sri Lanka; Gloria Animalesto (Museum Zoologicum Bogoriense) detected a putative new species of *Haematoloechus* (Haematoloechidae) through surveys of frogs in Indonesia; and Hirotaka Katahira (Azabu University) reported an intriguing discovery of a species of *Gorgoderina* (Gorgoderidae) in a relict population of Siberian salamanders in Hokkaido, whereas species of the genus are otherwise restricted to frogs on Honshu. Karin Tsuchida (Kyoto University) surveyed diversity and distributions of *Mesocoelium* spp. (Mesocoeliidae) in urodelan amphibians in Japan, and Bianca Nandyara (Federal University of Pará) grappled with historical collections to untangle variable morphology and a confusing history of reports for *Mesocoelium* spp. in Central and South America.

From freshwater fishes: Nehemiah Rindoria (University of Limpopo, Kisii University) presented the discovery of a putative new species of *Heterorchis*, an infrequently reported

plagiorchioidean group of uncertain familial classification and phylogenetic affinity, found in marbled lungfish in Kenya; Wilmien Luus-Powell (University of Limpopo) reported detection of a new cephalogonimidae in fishes of South Africa; Suhani (Meerut College) reported on a new pleurogenid from the zig-zag eel in India; and Gerardo Pérez-Ponce de León (National Autonomous University of Mexico) summarised a body of intriguing taxonomic and biogeographic work on morphologically deceptive allocreadiids in fishes of the Americas.

In marine fishes: Helen Armstrong (Murdoch University) and Erick Arrashy Rudianto (Diponegoro University) reported on investigations into the specific and generic identity of cryptogonimids in tropical snappers; Tori Wang (University of Queensland) investigated a morphologically difficult complex of gorgoderids in triggerfishes; Anja Vermaak and Linda van der Spuy (both North-West University) reported on taxonomic investigations into opecoelids in South Africa; Marta Valmaseda-Angulo (University of Valencia) examined the parasite fauna of a subtropical fish species that occasionally occurs in the Mediterranean Sea; Rei Hirasawa (Azabu University) used a molecular approach to examine richness and taxonomy of *Scaphanocephalus* spp. (Opisthorchiidae) metacercariae in Japan; Francisco Montero (University of Valencia, on behalf of Alejandro López-Verdejo, Stazione Zoologica Anton Dohrn) reported on a new gorgoderid from a stingray in Costa Rica; and Berilin Duong (University of Queensland) reported on the taxonomy as well as complex patterns of host usage and distribution for species of *Thulinia* (Hemiuroidea) in tropical Indo-West Pacific coral-reef fishes.

Recognition and prizes

The first international meeting for trematode research introduced a new honorific award, the Yamaguti medal for research excellence in the field of trematodology. Satyu Yamaguti was the most prolific taxonomist to work on the Trematoda, describing hundreds of species at a generally excellent standard for which the modern community remains most appreciative. A copy of the medallion is now on display at the Meguro Parasitological Museum, Japan. Fittingly, the first iteration of this award was presented to Rod Bray (Natural History Museum London). Rod has published hundreds of manuscripts dealing with the taxonomy, systematics, and functional morphology of trematodes from all around the world, co-edited and co-wrote several major texts, and has been a supportive and generous collaborator and mentor to many. Prizes were also awarded to early-career presenters. Faced with an intimidatingly excellent standard of contributions, the Organising Committee decided to award two best student presentations: to Marta Valmaseda-Angulo (University of Valencia) for her beautifully and engagingly presented investigation into shared blood fluke infections between wild and maricultured scombrid fishes, and Leslie Stout (University of Bordeaux) for her elegant development and application of a sophisticated species-specific molecular technique to identify infections and track phenology of intramolluscan infections. Best early-career presentation was awarded to Tyler Achatz (Middle Georgia State University) for his summary of an impressive and insightful body of work on diplostomids in crocodilians, and best student poster was awarded to Lenin De Silva (Murdoch University) who engaged passers-by with stimulating discussion concerning possible evolutionary narratives explaining the trematode fauna known from marine snakes.

Concluding remarks

It is perhaps surprising that an international meeting specific for research on the Trematoda has not occurred previously, especially considering the successful history of similar, specialised meetings for other parasite lineages. Regardless, the collective

experience of those in attendance demonstrates the appetite for such a meeting series and the eagerness for increased collaboration. Likewise, the consensus expressed through many contributed and invited presentations, as well as conversations during the week, is that now is the time to bring our community together. In summary, this meeting reaffirmed what many trematode researchers likely already knew to be true: that our community is collegiate, vibrant, and passionate, that the current state of research around the world is excellent and interesting, and that the future for students of the Trematoda is bright and exciting. Following the success of this meeting, the Organising Committee will proceed with the original proposal to establish the *Trematodes* conference series with a triennial fixture; *Trematodes 2027* will be held in Geneva.

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Declaration of interests

The authors declare no competing interests.

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