Forum

Male-biased selection of holotypes in parasite taxonomy: is it justified?

Robert Poulin[1,*], Bronwen Presswell[1] and Jerusha Bennett[1]

When a new parasite species is identified, a name-bearing specimen or holotype is designated as its reference standard. For most acanthocephalans and nematodes, the holotype is male, a bias which lacks scientific justification. We propose ways of redressing this imbalance and achieving fuller representation of each species in museum collections.

It's a male world

When running a Google image search for any sexually dimorphic species, such as guppies, birds of paradise, or elk, the top results are invariably dominated by photos of males. Everyone knows what a peacock looks like and thinks of it as representative of its species, *Pavo cristatus*, but fewer people even know what the peahen looks like. In the minds of most people, the typical appearance of a species amounts to that of the male. Yet, in dioecious species, that is, those with separate sexes, males and females have distinct morphologies, and there is no reason to view males as more representative of the species as a whole than females.

When a species is first discovered and formally named and described by taxonomists, a single specimen referred to as the 'holotype' must be identified (Box 1). The designation of a holotype is a formal requirement of the International Committee for Zoological Nomenclature, or ICZN[i], which sets the rules for the description and naming of new species. The holotype is meant to be a name-bearer for the species, a way of grounding the name of a new species in a concrete object; there is no requirement for the holotype to be typical or exemplary of the whole species [1,2]. However, for all practical purposes, this holotype becomes enshrined as the permanent representative for the species, the reference standard for the future. A recent analysis of name-bearing types of birds and mammals deposited in the world's largest natural history museums revealed that significantly more of them are male than female [3]. Here, we show that the male bias in holotype selection applies to parasite species as well. We explore the reasons behind this bias and argue that they have no scientific justification. Finally, we propose solutions aimed at redressing this male bias and achieving a more sex-balanced approach to the establishment of type specimens for parasite species with separate sexes.

The sex of parasite holotypes

The sex of holotypes is irrelevant for hermaphroditic taxa like cestodes and trematodes; however, a choice must be made in the case of dioecious species. Based on data from all species of nematodes and acanthocephalans described in eight leading journals between 2000 and 2021 inclusively [4], specimens of both sexes were available for the description and establishment of new species in about 90% of cases. In the vast majority of these species, that is, 89% of the time, a male specimen was chosen as the holotype (Figure 1). According to the information provided in the original publications, there are many species for which no female specimen has been deposited either as an allotype or among the paratypes, despite the availability of female specimens (Figure 1).

In natural populations of adult nematode and acanthocephalan parasites recovered from their vertebrate definitive hosts, sex ratios are usually female-biased, that is, more female individuals are found than male individuals [5]. Therefore, by choosing a holotype randomly among available specimens, one would expect taxonomists to pick females more frequently than males. The continued domination of males among holotypes of nematode and acanthocephalan species suggests active discrimination against female specimens in favour of males. This can only be explained as an unspoken but accepted rule, a tradition of bias that misrepresents reality and lacks scientific basis. Females are sometimes chosen instead of males as holotypes when male specimens are available (Figure 1), but this happened for only 41 species of acanthocephalans and nematodes combined, versus 797 species in which a male holotype was chosen.

In the remaining 10% of species described between 2000 and 2021, only specimens of one sex were available for description. More often than not, only females were recovered from all hosts examined, again because of the frequent female-biased sex ratios in natural infections [5]. In many nematode species from the genus *Philometra*, males have yet to be found and described. In all cases in which members of only one sex were available when the species was found and described, the holotype belongs to that sex, obviously. However, the traditional view that holotypes should be males is so deeply entrenched in the field that in one case, where only females were available, the authors chose not to designate a holotype at all but only a female allotype [6].

Species differentiation versus species description

Consistently using males as holotypes sets them up as the gold standard for the species: they define the species, with females representing secondary variations, or deviations from the archetype. And yet many biologists agree that conspecific

Box 1. Holotypes, paratypes, and allotypes

Upon the inception of a new dioecious species, a separate description of males and females is required, unless specimens of one sex cannot be obtained. In addition to its formal description, an (ideally) archetypal member of that species must be identified. This becomes the holotype: a single physical specimen explicitly designated as the name-bearing type specimen of a species, chosen by the taxonomists who formally described that species for the first time as the most representative and/or the best-preserved individual. The holotype is generally safely deposited in a museum, or any other institution that maintains an accessible research collection, to serve as the reference standard for future study.

For a dioecious species, this practice means that only one sex can be enshrined as the permanent representative of the species. The ICZN makes no recommendation regarding the sex of the holotype. If males and females look different, there are two ways of ensuring that both sexes are represented by type specimens. Firstly, an allotype can also be designated, that is, a specimen of the opposite sex to that of the holotype [10]. Secondly, additional specimens, known as paratypes, that were used to prepare the original species description can also be deposited in the same or a different museum, to act as insurance in case the holotype is lost or damaged. Members of the other sex can be included among the paratypes. However, neither of these practices is a requirement of the ICZN.

The sex, number, and museum accession numbers of holotypes, allotypes, and paratypes should be indicated clearly in published species descriptions, usually in a taxonomic summary section following the description itself.

males and females often differ as much from each other as individuals of different species [7]. In parasite taxa like nematodes and acanthocephalans, males and females generally differ in body size as well as in several key morphological traits other than those directly involved in reproduction (Figure 2). In short, they do not look the same.

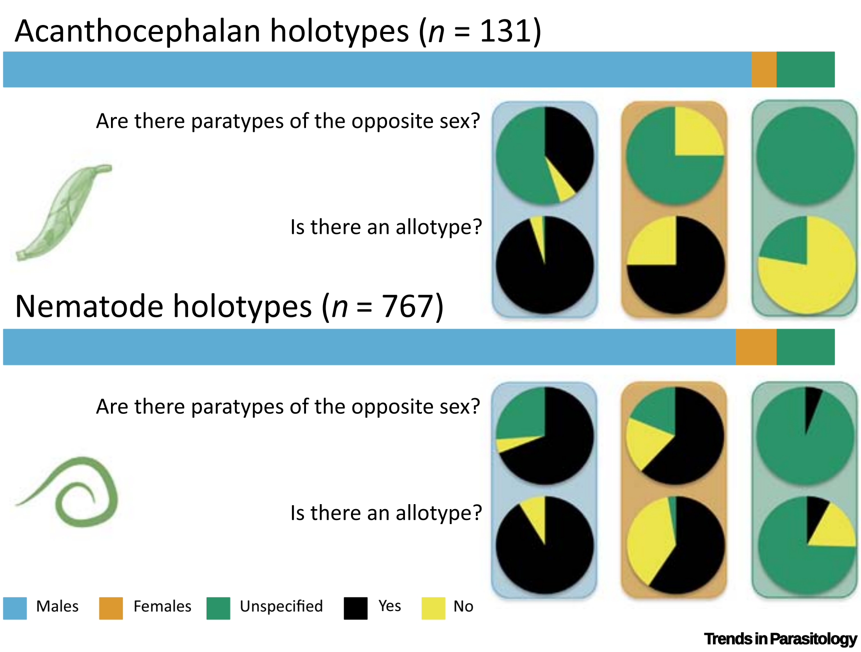

Figure 1. Sex of holotype for parasitic species of nematodes and acanthocephalans. Colours on the horizontal bars indicate the relative numbers of species whose holotype specimen is either male, female, or of unspecified sex. Pie charts summarise the proportions of species for which either an allotype or at least one paratype of the opposite sex has been deposited for future reference; these are shown separately based on whether the holotype is male, female, or unspecified. The data are based on information provided in the original species descriptions, for all parasite species described in the past two decades (2000–2021 inclusively) in eight leading journals, and for which specimens of both sexes were available at the time of description. The nematode data exclude hermaphrodite species (e.g., genera *Rhabdias* or *Serpentirhabdias*). See Table S1 in the supplemental information online for the full dataset. This figure contains elements created in BioRender.

In some taxa, one may justify using males as holotypes because male characters are better diagnostic features than female characters to distinguish among related species. Thus, having a male as the name-bearer for a species and available from a museum collection allows a point of reference for comparison whenever similar individuals of unknown taxonomic status are recovered. However, distinguishing among species is not the same as characterising species; male morphology may be more powerful for species discrimination, but a single male specimen is not sufficient to fully represent an entire species, and certainly not more representative of the species as a whole than a female. Species discrimination should be achieved using the existing descriptions of related species, as well as all material (holotypes, allotypes, paratypes; Box 1) available for comparison. The selection of type specimens should therefore not be limited to male specimens for the sole purpose of facilitating future species discrimination.

In addition to a bias toward male holotypes driven by their usefulness for species discrimination, some taxonomists have expressed a preference for male holotypes [8], but without providing any scientific justification. These kinds of arbitrary preferences have set the tone for traditions in holotype selection that have no practical grounding.

Equality of the sexes for new parasite species

Since males are not more representative of a species than females, and because there is no scientific justification for favouring males as holotypes, why is this still happening? More importantly, how can we eliminate this sex bias and achieve a fuller representation of new parasite species with type specimens?

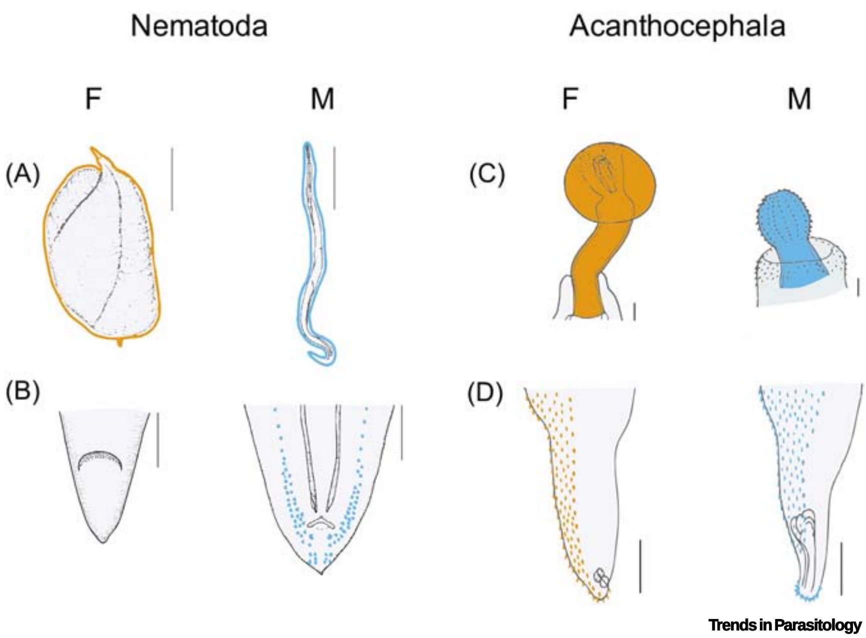

Figure 2. Females are morphologically distinct from males. Examples of morphological differences between female (F) and male (M) nematodes and acanthocephalans other than those involving reproductive organs, highlighted in colour. (A) Extreme sexual dimorphism in size and shape in *Tetrameres megaphasmidiata* (redrawn from [11]). (B) Elaborate arrangement of caudal papillae on the posterior end of the male but completely absent in the female of *Contracaecum mirounga* (redrawn from [12]). (C) Extreme swelling of the proboscis in the female but not the male of *Filicollis anatis* (redrawn from [13]). (D) Different distribution of ventral trunk spines on the posterior end of male and female *Corynosoma obtuscens*, and presence of large terminal spines in the male only (redrawn from [14]).

The ideal way forward, assuming male and female specimens are available when a new species is described, would be to adopt the practice of establishing two holotypes for each dioecious species, one male and one female. This is unlikely to ever be endorsed by the ICZN and might also cause an uproar in the taxonomist community, since breaking with tradition is always difficult. One alternative solution would be to choose the holotype randomly between a male or a female, and always assign an allotype of the other sex, thus providing a pair of type specimens that together more completely capture the variable morphology of a given species. The only situation in which establishing the holotype as the species representative without an allotype or paratypes of the opposite sex would be when no specimen of the other sex has been obtained. A second solution would be to complement the deposition of the holotype of either sex with high-resolution photographs (from light microscopy or scanning electron microscopy), publicly available through an online repository of taxonomic data associated with the institution where the type specimens are held, that fully capture the morphology of both sexes [9]. Digital types can never replace physical type specimens, but they can allow a fuller documentation of new species. These practices could easily be implemented, though at a modest extra cost to the authors of new species descriptions, simply by making them a requirement that could be enforced by reviewers and journal editors. Either of the aforementioned solutions would ensure that both sexes are properly represented in type material (physical or digital). However, only the first solution, that is, the random selection of the holotype among male and female specimens, will serve to redress the balance and stop perpetuating the male bias in type specimens for not just parasitic worms, but all dioecious species.

Finally, why does equal representation of both sexes among type specimens matter? Males and females of the same species are morphologically and physiologically different and are therefore likely to react differently to anthropogenic and natural pressures, and to exert different pressures on their hosts. Their combined characterisation and study are important for a full picture of biological diversity and its long-term preservation. Furthermore, awareness of deep-rooted, unjustified biases in science, such as the one identified here, allows us to rectify them and make the most out of the specimens and data we are collecting for future generations.

Acknowledgments

J.B. is supported by a University of Otago Doctoral Scholarship. We are grateful to two anonymous reviewers for constructive comments on an earlier version.

Declaration of interests

The authors declare no competing interests.

Supplemental information

Supplemental information associated with this article can be found online at https://doi.org/10.1016/j.pt.2022.08.003

Resources

[i]www.iczn.org/

[1]Department of Zoology, University of Otago, Dunedin, New Zealand

*Correspondence:
robert.poulin@otago.ac.nz (R. Poulin).
https://doi.org/10.1016/j.pt.2022.08.003

References

1. Bokulich, A. (2020) Understanding scientific types: holotypes, stratotypes, and measurement prototypes. *Biol. Philos.* 35, 54
2. Sluys, R. (2021) Attaching names to biological species: the use and value of type specimens in systematic zoology and natural history collections. *Biol. Theory* 16, 49–61
3. Cooper, N. *et al.* (2019) Sex biases in bird and mammal natural history collections. *Proc. R. Soc. B* 286, 20192025

4. Poulin, R. *et al.* (2022) What's in a name? Taxonomic and gender biases in the etymology of new species names. *Proc. R. Soc. B* 289, 20212708
5. Poulin, R. (1997) Population abundance and sex ratio in dioecious helminth parasites. *Oecologia* 111, 375–380
6. Caspeta-Mandujano, J.M. *et al.* (2009) A new philometrid species (Nematoda) from the freshwater fish *Cichlasoma istlanum* (Jordan and Snyder, 1899) (Cichlidae) in Mexico. *J. Parasitol.* 95, 403–406
7. Santora, T. (2020) Should ecologists treat male and female animals like 'different species'? *Sci. Amer.* https://www.scientificamerican.com/article/should-ecologists-treat-male-and-female-animals-like-different-species/
8. Riedel, A. *et al.* (2013) Integrative taxonomy on the fast track: towards more sustainability in biodiversity research. *Front. Zool.* 10, 15
9. Marshall, S.A. and Evenhuis, N.L. (2015) New species without dead bodies: a case for photo-based descriptions, illustrated by a striking new species of *Marleyimyia* Hesse (Diptera, Bombyliidae) from South Africa. *ZooKeys* 525, 117–127
10. Gloyd, L.K. (1982) The original definition and purpose of the term "allotype". *Syst. Zool.* 31, 334–336
11. Cremonte, F. *et al.* (2001) *Tetrameres* (*Tetrameres*) *megaphasmidiata* n. sp. (Nematoda: Tetrameridae), a parasite of the two-banded plover, *Charadrius falklandicus*, and white-rumped sandpiper, *Calidris fuscicollis*, from Patagonia, Argentina. *J. Parasitol.* 87, 148–151
12. Garbin, L.E. *et al.* (2019) Species of *Contracaecum* parasitizing the magellanic penguin *Spheniscus magellanicus* (Spheniscidae) from the Argentinean coast. *J. Parasitol.* 105, 222–231
13. McDonald, M.E. (1988) Key to Acanthocephala reported in waterfowl. *Res. Publ. US Fish Wildl. Service* 173, 1–45
14. Lisitsyna, O.I. *et al.* (2019) Morphological and molecular evidence for synonymy of *Corynosoma obtuscens* Lincicome, 1943 with *Corynosoma australe* Johnston, 1937 (Acanthocephala: Polymorphidae). *Syst. Parasitol.* 96, 95–110