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MOBS 1.0: A database of interspecific variation in Marine Organismal Body Sizes

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Abstract

Motivation: Body size is a fundamental trait influencing an organism's life history, ecology, physiology, and evolutionary dynamics. While extensive body-size databases exist for terrestrial vertebrates, equivalent datasets for marine animals are lacking, even though they include a much larger number of species. This data gap hinders comparative and macroecological analyses that rely on body-size data to uncover evolutionary and ecological patterns and processes in marine ecosystems. The Marine Organismal Body Size (MOBS) Database aims to address this deficit by providing standardized body-size data for marine animals, enabling deeper investigations into marine biodiversity and informing conservation and ecological theory.

Main types of variables contained: The MOBS Database includes maximum linear dimensions of marine animals, specifically height, length, width, and diameter. Additional fields include species taxonomy (linked to AphiaIDs in the World Register of Marine Species), notes about measurements, and data sources.

Spatial location and grain: The dataset is global in scope, encompassing marine species across all oceanic regions, but does not itself contain geographic data. Integrations with databases like the Ocean Biodiversity Information System (OBIS) can yield spatially resolved analyses.

Time period and grain: Modern, extant species.

Major taxa and level of measurement: MOBS focuses on marine animals (kingdom Animalia), covering 30 marine phyla. The database currently contains data for 85,204 species (40.4% of valid marine animal species in WoRMS), with seven phyla surpassing 75% coverage. Measurements are reported at the species level, with some records including multiple observations to account for intraspecific variation.

Software format: The MOBS Database is available in csv format and is hosted on GitHub for public access (https://github.com/crmcclain/MOBS_OPEN).

Introduction

Body size directly or indirectly impacts an organism's life history, physiology, ecology, and behavior (Calder 1984, Smith and Lyons 2005, Bonner 2007). For example, larger organisms often have different reproductive strategies, metabolic rates, and ecological roles relative to smaller ones with comparable body plans (Brown et al. 1993, Brown et al. 2004). Therefore, much attention has been paid to measuring organismal size, as it allows researchers to deduce many aspects of an organism's basic biology, including its dietary preferences, habitat choices, competitive interactions, and energy needs (McNab 1963, Cohen et al. 2003, Brown et al. 2004, Millien 2004, Costa 2009, Reuman et al. 2013). The ubiquity of body-size data across numerous species has made it a valuable trait for comparative analyses and meta-analyses (Hillebrand and Azovsky 2001, DeLong et al. 2010, Harmon et al. 2010, Thornton and Fletcher Jr 2014, Heim et al. 2017, Bloom et al. 2018), enabling detailed examinations of patterns and trends across diverse ecological, geographical, and evolutionary scales. Thus, the ease of measuring body size not only simplifies data collection but also unlocks valuable information about an organism's role within an ecosystem.

The wealth of body-size data for vertebrates, and particularly for terrestrial vertebrates, has enabled a vast array of analyses that are not currently possible for marine animal, which are nearly all outside the vertebrate clade. Many of the substantial findings for vertebrates on body size date back three decades. For example, the comprehensive Masses of Mammals Database (Smith et al. 2003), revealed that evolutionary pressures strongly favor larger body masses in herbivores, while omnivores typically have body masses intermediate between those of herbivores and carnivores (Price and Hopkins 2015). In addition, diversification to occupy ecological niches played a pivotal role in the evolution of giant mammals; however, environmental temperature and available land area imposed constraints on the maximum attainable size (Smith et al. 2010). Similar to mammals, a comprehensive database of avian sizes has been available since 2007 (Dunning Jr 2007), with extensive datasets dating back to 1994 (Blackburn and Gaston 1994), which have also greatly enhanced research endeavors in this field. For example, these data reveal that the body-mass distribution among all living bird species exhibits a significant right-skew, and this skew is an inherent characteristic of the distribution, not an outcome of biased sampling. In birds, the level of threat faced by endangered species might also be associated with body mass; larger birds tend to be more vulnerable to extinction than smaller species (Gaston and Blackburn 1995). More recent work illustrates a substantial inverse association between bird body-mass ratio in competitive species pairs and competitive strength, with competitive strength intensifying as the body masses of the birds became more similar (Leyequién et al. 2007). In addition, the availability of FishBase has allowed for the discovery that the body-size, measured as length, distribution of fishes is not as conserved over different oceanic regions (Fisher et al. 2010) when compared to the distribution of mammalian sizes across continents (Smith et al. 2004). Additionally, fish species tend to converge toward a modal size with increasing depth (Priede et al. 2006), indicating that the largest and smallest fish species are primarily found in shallow waters, a trend that aligns with more limited gastropod datasets (McClain et al. 2006). Recent work has also shown that extinction risk in marine ray-finned fishes (class Actinopterygii) is also strongly sized biased, with larger fishes at greatest risk primarily due to commercial over-harvest (Bak et al. 2023). However, when we extend our focus beyond fishes, our comprehension of the evolutionary and ecological aspects of body size in the ocean falls short compared to our knowledge of terrestrial vertebrates.

The absence of an extensive body-size database hinders our ability to investigate fundamental questions about body size and its role in shaping marine biodiversity. For instance, we lack knowledge about the size distribution of existing marine animals, particularly marine invertebrates. While at the oceanic and regional scales, body sizes of marine animals exhibit left-skewed (Roy et al. 2000, Roy and Martien 2001), right-skewed (Fisher et al. 2010), and normal (Kirchner et al. 1980) distributions on a log scale, the deficiency in sampling across various phyla raises concerns about potential sampling biases, spatial-scale dependence, and generality of findings across taxa. Notwithstanding the extensive body of research dedicated to understanding the ecological significance of body size, it remains a disconcerting reality that our knowledge of body sizes for most marine organisms is conspicuously inadequate. The paucity of comprehensive studies on body-size distributions across diverse marine taxa impedes our capacity to attain a comprehensive understanding of marine ecosystems. It prevents marine biologists from participating in broader scientific dialogue about the ecology and evolution of body size. It substantially restricts our ability to anticipate and address the repercussions of environmental alterations on these ecosystems, encompassing the far-reaching consequences of climate change, overexploitation, and habitat degradation.

Body size is often considered one of the easiest traits to measure, rarely requiring highly technical equipment, procedures, or specialized expertise (Brown 1995). Whether through direct visual estimation, measurements of linear dimensions such as length or height, or precise weighing, body size provides a relatively uncomplicated and dependable means of comparing and categorizing organisms across a wide variety of body types and ecologies (Brown 1995). The accessibility of body size as a trait, typically not requiring any specialized equipment, facilitate swift data acquisition across a diverse array of species, rendering body size an invaluable tool in nearly every facet of animal research, including population monitoring and conservation, community interactions and niche dynamics, macroevolutionary constraints and diversification, and ecosystem processes (Hillebrand and Azovsky 2001, DeLong et al. 2010, Harmon et al. 2010, Thornton and Fletcher Jr 2014, Heim et al. 2017, Bloom et al. 2018).

Presently, the World Register of Marine Species (WoRMS) encompasses 210,911 valid marine animal species, and our objective is to obtain standardized body size measurements for 75% of these species at the family level. Here, we provide release 1.0 of the Marine Organismal Body Size (MOBS) Database with body-size data comprising 170,214 total observations for 85,204 species as a key initial step towards this long-term objective.

Methods

We have collected size data for valid species within WoRMS. We have based our standardized taxonomy, which incorporates unique species identifiers (AphiaID), synonymized names, and taxonomy, on the WoRMS structure. The operational measure of body size used in MOBS is linear dimension (cm) for a species, which includes attributes like height, length, width, and diameter. We choose linear dimension for this dataset as it is the most-reported measure of size in the literature for marine invertebrates, which represent the overwhelming majority of marine animals. While mass, rather than length, scales more directly with energetics and metabolic rate, linear measurements scale with mass in higher taxa and thus also correlate with the metabolic rate and other mass-related traits at high taxonomic levels (Trites and Pauly 1998, Benke et al. 1999, Gaspar et al. 2001, Seebacher 2001, Méthot et al. 2012, Rosati et al. 2012, Santini et al. 2018). While mass is undoubtedly a useful and frequently used trait, we believe there is strong precedent for the utility of linear dimensions in macroecological and evolutionary studies, especially when mass data are unavailable or inconsistent across large, diverse datasets. Previous studies have demonstrated how linear size measures can yield meaningful insights into body size evolution, ecological scaling relationships, and trait-based comparisons across taxa (e.g. Kirchner et al. 1980, Sookias et al. 2012, Velasco et al. 2020). MOBS, and the linear measurements within, were inspired by the practical challenges of data availability as well as the demonstrated value of such measures in these important studies.

In the MOBS database, measurements reflect the largest reported size(s) for a species, as documented in sources. These values are not calculated here; rather, they are extracted from taxonomic descriptions, online databases, and species accounts, which typically report the largest observed individual. For example, taxonomic descriptions frequently provide measurements of holotypes and paratypes, which are often the largest known specimens of a species.

Because different sources may report different 'maximum' sizes for the same species, MOBS includes multiple records when available. This inclusive approach allows users to assess variation in reported maxima. While our dataset enables the calculation of a mean size for species with multiple entries, this mean would reflect the average of the maximum reported values rather than an intraspecific mean body size analogous to what could be calculated based on a standing population. Given our focus on broad taxonomic coverage for applications to macroecological and macroevolutionary studies, where differences among species vastly exceed differences within species, we prioritize maximum reported size as it is widely available across taxa and commonly used in ecological and evolutionary studies.

For many species in the MOBS database, particularly those that grow indeterminately, age data are unavailable, which limits our ability to directly account for the relationship between age and size. However, by using the largest reported size for each species, we infer that these are likely individuals near their maximum size, typically reached at or near their maximum age. While we cannot fully incorporate age for indeterminately growing species, it is important to note that growth rates generally slow as individuals age, even for species that continue to grow throughout their life. This slowdown in growth is observed in a range of marine organisms (Sebens 1987), which suggests that the largest individuals in our dataset are likely to be at or near their maximum age for many species. Given that size data are typically log transformed prior to analysis, this slowdown in linear growth with age means that differences among individuals within a species are unlikely to have major impacts on the results of broad macroecological or macroevolutionary analyses.

Whenever feasible, we collect all these linear measurements for a species, provided they originate from the same individual. Our data collection process is structured to efficiently compile as much data as possible for MOBS, with particular emphasis on taxonomic coverage, which is currently the most important knowledge limitation. We begin with online databases, which provide broad coverage, then move to published taxonomic compilations and primary literature, and finally incorporate museum datasets when necessary. The emphasis on this order reflects practicality: databases and compilations allow for rapid aggregation of large datasets with greater taxonomic breadth, while literature and museum records require more targeted searches. Our use of 'museum specimens' refers primarily to datasets provided by museums, where holotypes and paratypes have been measured and recorded by taxonomists.

We check for possible data entry errors in existing online databases by comparing the size measurements available to original sources. This effort is made to prevent replicating data entry errors. Thus, each row of MOBS includes an AphiaID (linking it to the species name and taxonomy in WoRMS), length (cm), width/diameter (cm), height (cm), a note field to indicate other information about the measurement, he reference for the size data, and biological unit denoting whether the measurement is a zooid, polyp, colony, or solitary. Although capturing intraspecific variation in size is not a primary goal of MOBS, some species have multiple measurements if a species is found in multiple previous databases or taxonomic treatments (46/3% of species currently in MOBS have more than one measurement, 28.8% have two measurements).

We have set a 75% coverage threshold as a practical benchmark based on insights from previous research and our understanding of how body size distributions stabilize with increasing species representation. While not derived from a formal statistical analysis, this threshold reflects a point where additional species are unlikely to substantially alter the overall distribution. While 75% serves as a minimum benchmark, our aim is to exceed this threshold, particularly in well-studied groups like Mollusca. Our approach is to focus on one phylum at a time, and once we achieve 75% completion for that phylum, we will release the updated data to a public repository on GitHub (https://github.com/crmcclain/MOBS_OPEN).

The GitHub repository contains a CSV file, also included as an appendix to this publication, representing the dataset as of 11/22/24 with the current WoRMs taxonomy. Additionally, we will continue to provide updated datasets on GitHub, allowing users to reconcile them with WoRMS for the most current taxonomy. A README file on GitHub provides instructions on the necessary R code and packages for this process. Regardless of the dataset version used, we strongly recommend reconciling with WoRMS, as invertebrate taxonomy— even at higher taxonomic levels—is continually revised with new research.

In our database, we aim to center our efforts on the Animal. This choice excludes a significant portion of marine biodiversity found within the Archaea, Bacteria, Protozoa, Chromista, and Plantae (Teske and Sørensen 2008, Caron et al. 2012, Culley 2013, Forster et al. 2016, Leray and Knowlton 2016, Snelgrove 2016, Yilmaz et al. 2016, Keeling and Del Campo 2017, DeLong 2021), and we are also fully aware of the necessity to address these important groups in future phases of MOBS. Nevertheless, these additional groups present additional challenges in terms of acquiring size data and compiling comprehensive species lists, and even in defining “species”. Therefore, we have initially chosen to prioritize the kingdom Animalia, as it represents the "low-hanging fruit" with greater accessibility, allowing us to make substantial progress while laying the groundwork for future endeavors involving other kingdoms.

Results and Discussion

Using the 210,911 valid extant animal species in the World Register of Marine Species, MOBS now contains size data for 85,204 species (170,214 total observations), which is 40.3% of the current total species count. Out of 30 marine animal phyla, 14 have less than 10% of species with recorded size measurements available whereas just nine phyla surpass the 50% mark (**Fig. 1**). The current release has size data for seven phyla surpassing the 75% threshold: Brachiopoda, Chaetognatha, Chordata, Ctenophora, Mollusca, Phoronida, and Tardigrada (**Fig. 1**). The distribution of maximum linear dimensions, taken as the largest reported linear measurement for each species, among the 85,204 species in MOBS is negatively skewed (-0.12), but we interpret this finding to reflect the fact that databases incorporated into MOBS so far largely focus on larger-bodied taxa along with the fact that MOBS collection efforts have yet to include some of the more speciose meiofaunal taxa (e.g. Nematoda; **Fig. 2**).

Integrating the current version of MOBS with occurrence records from the Ocean Biodiversity Information System (OBIS) highlights data gaps in both databases (**Fig. 3**). For some taxa, such as Nemertea and Platyhelminthes, significant portions of species lack both body size and geographic data. In other cases, such as Porifera, substantial geographic data exists for species that still need body-size information. Conversely, for taxa like Mollusca, there is an abundance of body-size data but limited geographic data.

The MOBS Database has already yielded two publications (McClain et al. 2024b, McClain et al. 2024a). The first study (McClain et al. 2024a) used a preliminary MOBS dataset and examined maximum size measurements across 27,271 marine species, finding that while multiple estimates exist due to intraspecific variation, their impact on macroecological patterns is minimal. Differences in size distributions between estimates were subtle, and the rank order of species sizes remained robust (mean correlation = 0.98) among random draws for each species. This minimal variation supports the use of maximum size compilations in macroecology and macroevolution analyses, despite rare cases of large ranges in reported maximum sizes, due to either natural variation or error, in a few species. In our second study (McClain et al. 2024b), we analyzed over 62,000 marine species and found an inverse correlation between species' size and the timing of their formal description, with smaller species being described more recently. This taxonomic bias, consistent across taxa and habitats, underscores the importance of completing marine inventories, especially for smaller, potentially vulnerable species.

A potential limitation of this dataset is the use of maximum linear body dimensions rather than direct estimates of body mass. While body mass is often preferred in ecological and physiological studies due to its stronger mechanistic links to metabolic rate and energy use (Brown et al. 2004), it is not always available—particularly many marine invertebrates. In contrast, maximum body length, width, and diameter is more commonly reported in taxonomic and ecological literature, and can often be obtained with greater consistency across a broad diversity of species. For many invertebrate groups, especially those with rigid or conserved body shapes (e.g., echinoderms, crustaceans), linear dimensions scale relatively predictably with body volume or mass, making them reasonable proxies when mass data are lacking. However, this substitution becomes less reliable when comparing taxa with divergent body shapes or morphologies (e.g., gelatinous vs. rigid-bodied animals), where two organisms with similar lengths may differ in mass by orders of magnitude. Two possible solutions exist to deal with this scenario. One approach is to apply known length–mass scaling relationships, which are available for many marine taxa, though often lacking for smaller or understudied groups. We plan that future MOBS releases will include a dataset of known length-mass relationships for marine organisms. Another option is to estimate body shape using biovolume equations tailored to different morphologies—for example, modeling polychaetes as cylinders based on length and diameter, or gastropods as stacked cones. For many species in the MOBS dataset, measurements include not only length but also width—and in some cases, height—allowing for direct biovolume calculations. Within morphologically similar clades, missing dimensions (e.g., width or height) can be imputed using data from related species, enabling biovolume estimates even when some measurements are unavailable. Users of the database should therefore apply caution when making cross-taxa comparisons involving organisms of markedly different morphologies and consider applying shape-correcting allometric conversions when possible. Nonetheless, for many macroecological, macroevolutionary, and trait-based applications where large-scale patterns are of interest, maximum linear size remains a valuable and pragmatic alternative to body mass (e.g. Kirchner et al. 1980, Sookias et al. 2012, Velasco et al. 2020).

Assembly and compilation of biodiversity data across large geographical scales started during the 18th century. Observations by Alexander von Humboldt around 1799, such as his statement that "the nearer we approach the tropics, the greater the increase in the variety of structure, grace of form, and mixture of colors," laid foundational insights into spatial patterns of biodiversity (Hawkins 2001). Alongside seminal works by Darwin (1859) and Wallace (1878), these observations formed the basis of our understanding of biodiversity changes across space and time, including taxonomic, functional, and phylogenetic diversity (Magurran and McGill 2011). Despite three centuries of research, gaps remain in our knowledge of species traits—a deficit known as the “Raunkiæran shortfall” (Hortal et al. 2015, Gonçalves-Souza et al. 2023). Named after the Danish botanist Christen Raunkiær, who proposed a system for classifying plant life forms based on their adaptations to environmental conditions, the "Raunkiæran shortfall" is one of the seven data shortfalls of biodiversity knowledge (Hortal et al. 2015). The MOBS database seeks to address this by compiling body size data for at least 75% of described marine animals, thus providing a roadmap to fill existing gaps in species trait knowledge.

We believe that MOBS will greatly enhance our understanding of marine biodiversity and the role of body size in shaping marine ecosystems. By coordinating efforts and establishing a centralized repository for body size data (maximum length, width, height, and mass, as available for each species), we can overcome the current limitations posed by non-standardized measurements and a lack of size measurements for many taxa. The utility of a complete marine body-size database will undoubtedly open a multitude of research questions and remove a barrier to many research efforts. Moreover, MOBS has the potential to contribute to theoretical frameworks in ecology and evolution, improve our understanding of marine biodiversity, and inform conservation strategies by highlighting the importance of body size in marine species' survival and adaptation.

Figures

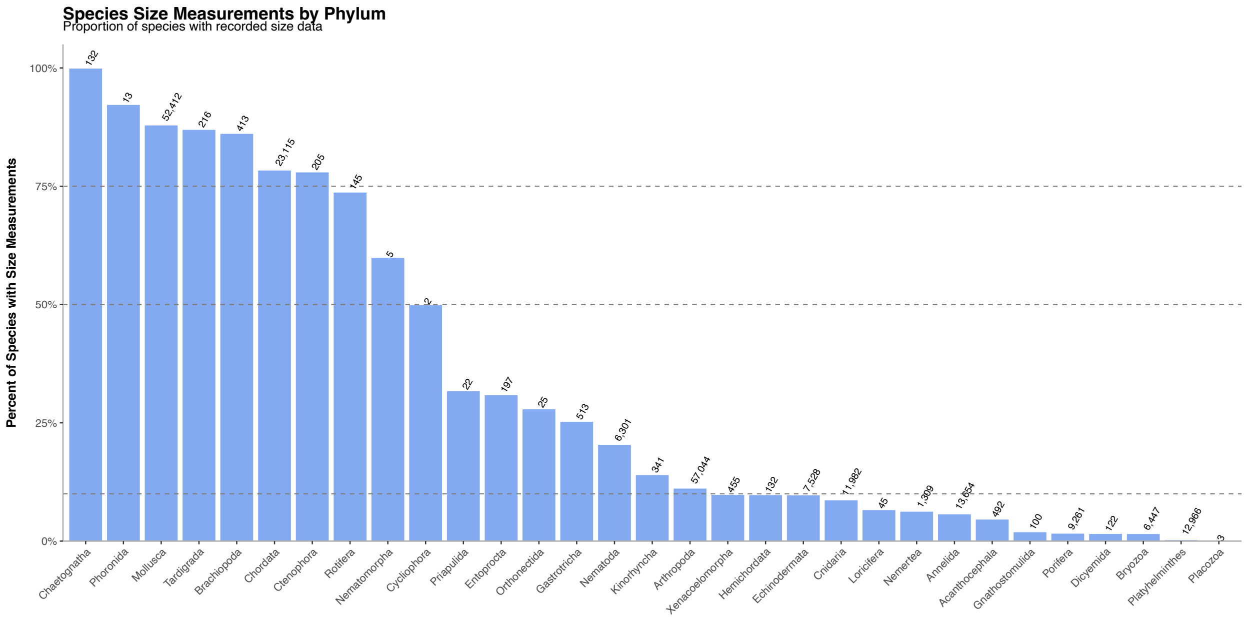

Figure 1: Bar chart of the percentage of species with size measurements in the Marine Organismal Size Database (MOBS) by phylum. Numbers above bars are the current number of described species in the World Register of Marine Species (WoRMS). Lines indicate 50% and 75% coverage levels.

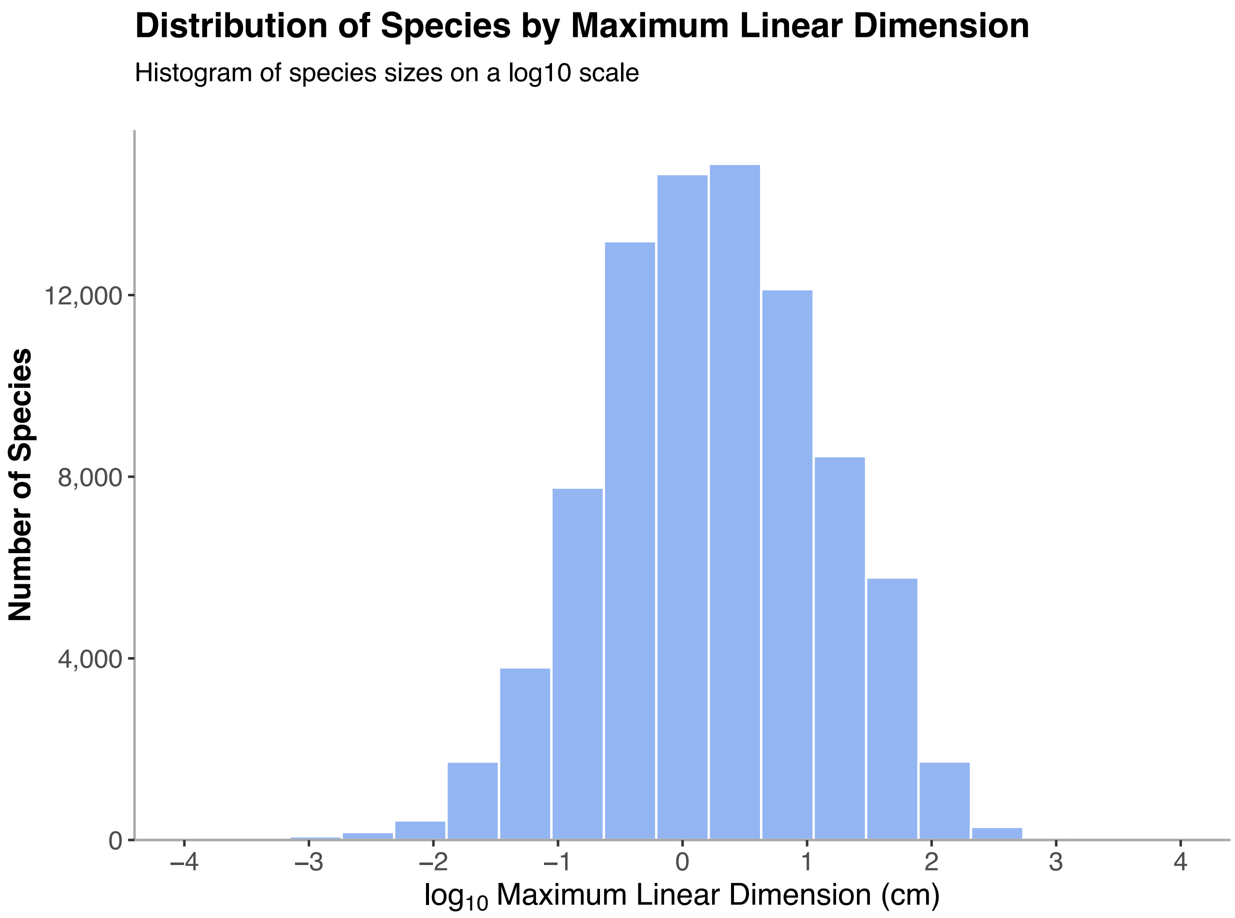

Figure 2: Distribution of maximum linear dimension for all species in the Marine Organismal Size Database (MOBS).

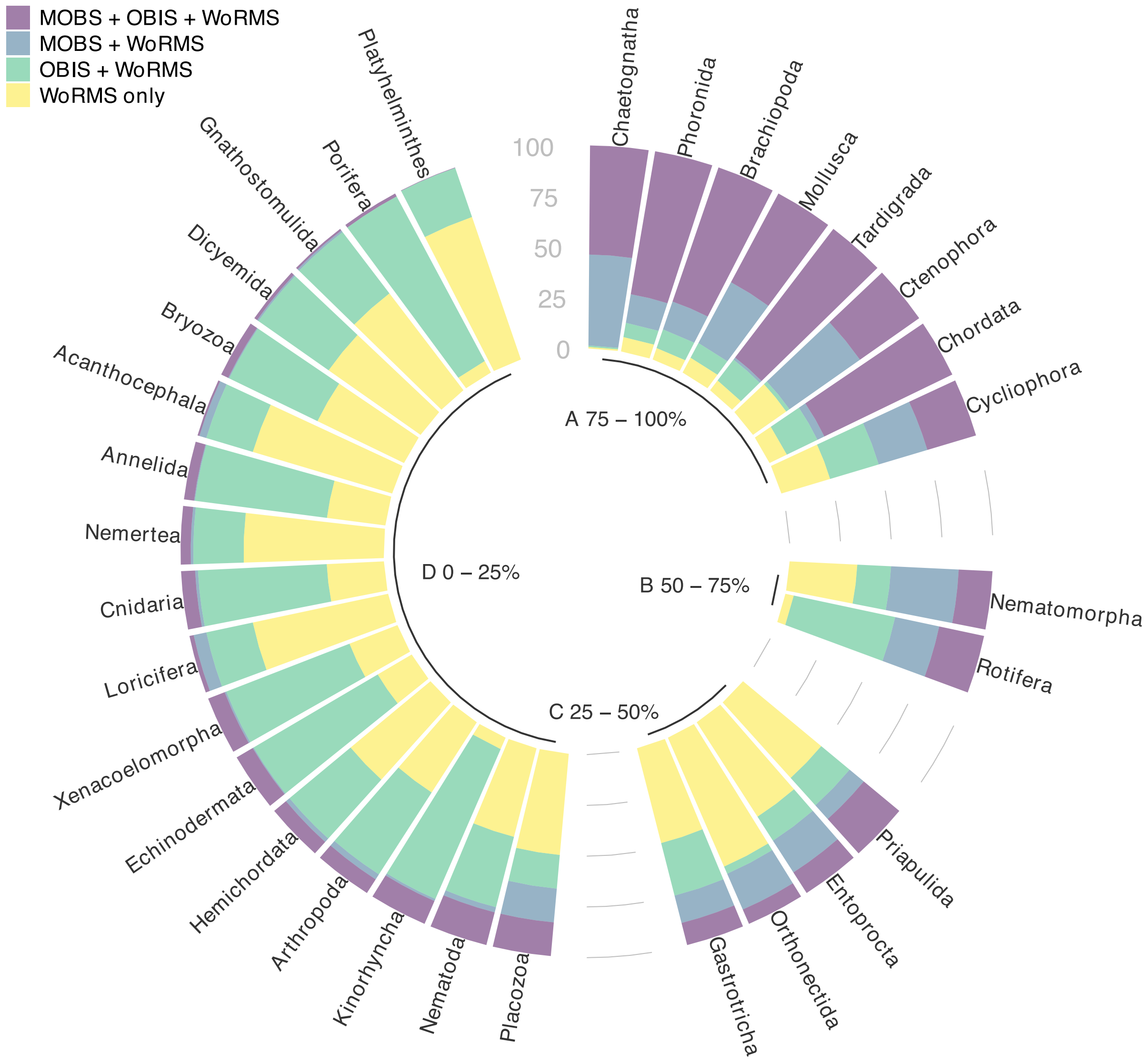

Figure 3: Stacked bar chart by phylum of the percentage of species with data in both MOBS and OBIS (MOBS + OBIS + WoRMS), species with size data only in MOBS (MOBS + WoRMS), species with geographic data only in OBIS (OBIS + WoRMS), and those species known form WoRMS but found neither in MOBS or OBIS (WoRMS Only). Note that the combined percentage of MOBS + OBIS + WoRMS and MOBS + OBIS represent the total percentage of species with size data.

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