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Palaeontology

A really big fossil whale

J. G. M. Thewissen & David A. Waugh

A newly discovered fossil of an extinct whale from Peru indicates that the animal's skeleton was unexpectedly enormous. This finding challenges our understanding of body-size evolution. **See p.824**

Whales, dolphins and porpoises belong to a group called cetaceans, which includes the largest known animals to have ever lived on Earth. Until now it had been assumed that the blue whale (*Balaenoptera musculus*) holds the record for the largest body size. However, on page 824, Bianucci *et al.*[1] challenge that assumption in their presentation of fossil evidence from a 39-million-year-old whale found in Peru. This whale, a member of the basilosaurid group (a family of extinct cetaceans), not only had an extremely large body size, but also had an exceptionally heavy skeleton relative to its body mass. Discoveries of such extreme body forms are an opportunity to re-evaluate our understanding of animal evolution — it seems that we are only dimly aware of how astonishing whale form and function can be.

Vertebrate palaeontologists by necessity focus most of their attention on bone, and the bones of this newly discovered species termed *Perucetus colossus* are extremely unusual. The cross-section of a mammalian bone commonly looks like a baguette in terms of having a hard and solid crust (compact bone) that surrounds a spongy interior (trabecular bone). The proportions of crust and interior vary according to the animal's need. Hippopotamuses, for example, need to walk fully submerged on riverbeds, so their bones have a lot of compact bone that makes their skeletons heavy. Bones that are made up of a lot of compact bone are also common in slow-moving marine mammals such as manatees and bowhead whales (*Balaena mysticetus*).

But most whales are different — they are predators of fast-moving prey and have relatively light skeletons compared with other mammals of the same size (see Fig. 4 of ref. 1). *Perucetus colossus* is on the hippo end of the scale, with bones mostly or solely made of compact bone. This suggests it was not chasing fast prey, and the authors propose that it led an alternative lifestyle, that of a scavenger.

The discovery of *P. colossus* also invites us to think about how life-history strategies evolved. As the authors point out, gigantism characterizes whales that are active swimmers in the open ocean, but *P. colossus* was an exception to that as an extremely large whale that was unlikely to be a fast swimmer. Vertebrates that live underwater but are not bottom dwellers are usually more or less neutrally buoyant, which means that the weight of heavy tissues (such as bones) is balanced by that of light tissues (such as fat), although there can be wide variation in absolute mass between species and between individuals of the same species.

Although *P. colossus*' skeleton is incomplete, consisting of several vertebrae, ribs and pelvic bones, it had a lot of heavy bone and therefore it must have had a lot of lighter tissues, too. This is a fundamental difference compared with animals living on land for which all tissues contribute to weight that needs to be supported by body parts such as limbs. By contrast, in water, heavier tissues can be offset by lighter tissues to acquire neutral buoyancy, and total mass is less important.

What type of life-history strategy might *P. colossus* have had? Cetaceans, unlike most mammals, keep growing long past

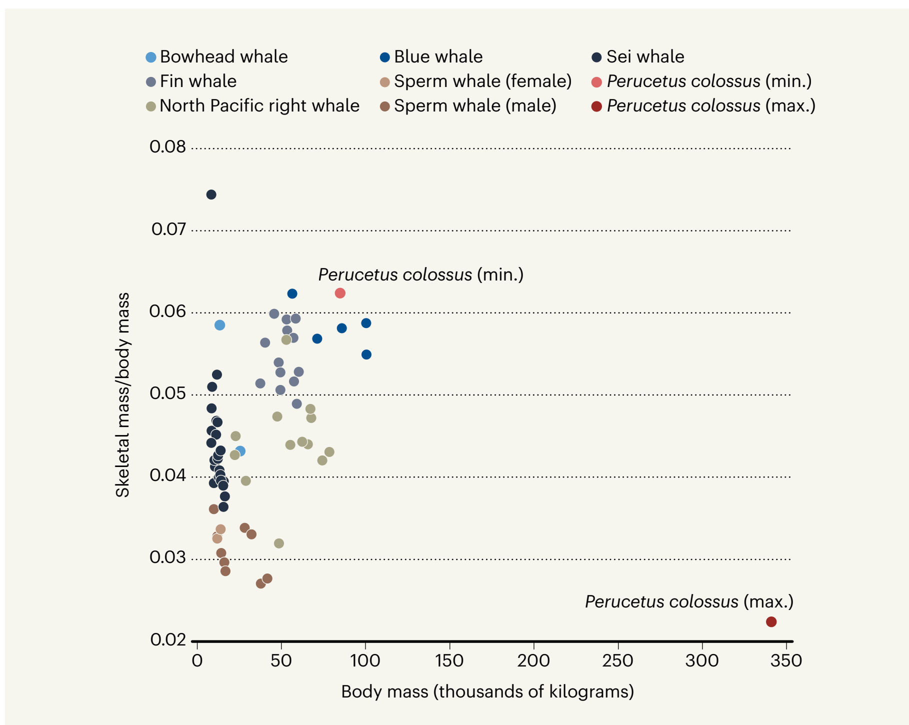

Figure 1 | The body mass and skeletal mass of individual whales. Whales grow for most of their lives, therefore individuals of a given species with a heavier body mass can typically be assumed to be older and for sperm whales (*Physeter macrocephalus*), males are heavier than the females. Bianucci *et al.*[1] discovered fossils of an extinct whale species that they named *Perucetus colossus*, and estimated its body mass and skeletal mass (minimum and maximum estimates are plotted). *Perucetus colossus* had a large body mass and an exceptionally heavy skeleton as revealed by the proportion of its total body mass that is attributed to bone (skeletal mass to body mass). Examining the proportion of body mass that is attributed to bone can shed light on a whale's lifestyle. Blue whales (*Balaenoptera musculus*) and fin whales (*Balaenoptera physalus*) are fast swimmers and published data[3–5] indicates that they maintain the same relative skeletal mass to body mass over their lifetime. By contrast, sei whales (*Balaenoptera borealis*)[5] and bowhead whales (*Balaena mysticetus*)[6–8] decrease their relative skeletal mass as they age. This is the type of lifestyle predicted for *P. colossus*. Bowheads, sei whales and North Pacific right whales (*Eubalaena japonica*)[9,10] might reduce blubber and bone in tandem as they age. Data shown are from refs 1, 3–10.

sexual maturity[2]. This unusual pattern of near-indeterminate growth was probably present in *P. colossus*, too. The discovered specimen might have been sexually mature, but it was surely still growing as evidenced by the unfused end sections of the vertebrae (structures called epiphyses).

In the case of indeterminate growth, individuals that are heavier also tend to be older. For blue whales, fin whales (*Balaenoptera physalus*) and sperm whales (*Physeter macrocephalus*), published data[3–5] indicate that the proportion of body mass attributed to skeletal bone mass does not change greatly with age (Fig. 1). For these species, this suggests that buoyancy is controlled similarly across age groups. Blue and fin whales are fast and sustained swimmers that might migrate long distances, and their body composition and form are optimized for that lifestyle, which is strikingly different from the one proposed for *P. colossus*.

The life history of *P. colossus* might be more similar to that of two other whales (Fig. 1). Published data[5] shows that sei whales (*Balaenoptera borealis*) show a decrease in bone contribution to body mass with increasing size (and thus probably with age). Evidence available for the bowhead whale[6–8] is consistent with the trend found for sei whales.

Bowheads have a different buoyancy-control system from that of blue, fin and sperm whales. Bowheads have lots of blubber (fat underneath the skin that is used for energy storage, insulation and streamlining) and high bone mass in their first year of life when they are nursed. However, both decrease over the next few years as the whales lose body weight because of inefficient feeding, which is due to their small baleen rack (the organ in their mouth that strains water for food)[6]. However, buoyancy remains constant for bowheads during their lifespan because the amount of blubber and bone are reduced in tandem[6].

A similar mechanism might also occur for right whales (of the genus *Eubalaena*) and sei whales. The large amount and high density of bone in *P. colossus* implies that the species must have had a lot of low-density tissues that combined to increase its total body weight.

P. colossus is a major discovery but the limitations of the fossil should be acknowledged. Many parts of the skeleton, such as the skull, for instance, remain undiscovered. We have few clues as to how old the individual was when it died and can only make inferences about its life history. Ribs of *P. colossus* show bands that indicate periodic, perhaps seasonal, growth and lack signs of remodelling, which is unusual for mammals.

If *P. colossus* had a life-history strategy similar to that of sei and bowhead whales, was this a young individual that carried copious and buoyant body fat, and its skeleton provided weight for ballast? Could this fossil be a testament to the origin of blubber? That hypothesis is consistent with the fossil's age of around 39 million years old, from a time when Earth and the oceans were cooling and insulating blubber might have been an advantage. It is too early to tell, but such considerations demonstrate that the importance of this fossil goes beyond the documentation of a previously unknown life form.

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Ecology

Assessing the values of nature for policymaking

Giulia Sajeva

Understanding the diverse ways in which the natural world provides value aids informed policy decisions. The generation of a detailed catalogue of this diversity, and ways to assess values, paves the way to a more sustainable future. **See p.813**

What is the value of nature? Every aspect of human life and socioeconomic development benefits from nature and biodiversity, yet – or maybe precisely because of this – there is no definitive response to this question. On page 813, Pascual *et al.*[1] propose a common classification 'language' (typology) to deal with the variety of the values provided by nature, and the diversity of ways in which people's lives, principles and behaviours are influenced by their perception of nature.

For some, the search for the value or values of nature might seem a trivial or an impossible enterprise. However, assessment of the different perceptions that people have of nature's values is essential, given that policymakers must address the protection of ecosystems and the sustainable use of natural resources. To avoid what they call a values crisis, Pascual and colleagues provide policymakers with useful, clear and important information that might help to better integrate these diverse evaluations into decision-making procedures.

This study builds on the work of IPBES (the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services), an independent intergovernmental body founded in 2012 with the aim of reinforcing the dialogue between policymakers and science to promote the conservation and sustainable use of biodiversity, human well-being and sustainable development. Pascual et al. process the key results of IPBES's 2022 report[2] (hereafter referred to as the Values Assessment). Thanks to the work of more than 100 specialist researchers and 200 contributing authors, and drawing on the analysis of more than 50,000 selected documents – including scientific publications, policy reports and information from Indigenous and local-knowledge sources on the perceived value of nature in different contexts and according to a variety of world views – the Values Assessment represents a key milestone in efforts to influence political and economic decisions that are being taken to address the current environmental crisis.

However, the need arose for this Values Assessment to be 'translated' in a more concise and systematized way, and Pascual and colleagues' study addresses this need. To do so in the most effective way, the authors also rely on infographics that incorporate a great amount of information while remaining beautiful and straightforward.

Pascual *et al.* discuss the current gaps[3] in the processes and methodologies used for nature's valuations. In particular, they propose that values be categorized into a typology with four layers (namely: world views; broad values; specific values; and value indicators).

This approach helps to identify which values are most often excluded from decision-making processes[4]. It also highlights the need to pay