

Supplemental Information

List of suction-related morphological characters

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List of cranial and mandibular characters

List of suction-related morphological characters

1. Blunt, wide rostrum

In odontocetes, blunt head shape contributes to creating a round oral aperture and limiting lateral (“notched”) gape [1–2]. Experimental data suggests that species with blunt head shapes generate greater negative pressures [1]. Blunt head shape is also related to “amblygnathy” (shortened, rounded jaws and rostra) [2]. In odontocetes, “amblygnathy” can be quantified by the mandibular bluntness index (MBI)—a dimensionless ratio of mandibular width:length. MBI strongly correlates with dental reduction in toothed whales [2].

Scoring reflects the degree to which the trait is manifested (3=strongly present/highly apparent, 2=somewhat present, 1=weakly present, 0=never present).

Examples:

Globicephala macrorhynchus (short-finned pilot whale): 3

Ziphius cavirostris (Cuvier’s beaked whale): 2

Tursiops truncatus (common bottlenose dolphin): 1

Stenella longirostris (long snouted spinner dolphin): 0

2. Reduced dentition

Suction-feeding taxa may use teeth to secure prey, but not to ingest prey via biting or seizing [2]. Reduced dentition may be interpreted in several ways, including reduction in number of teeth, size of erupted crown, complexity of crown, and “functionality” of the teeth for seizing prey (i.e., protruding above the mouth in beaked whales) [2–4].

Scoring reflects the degree to which the trait is manifested (3=strongly present/highly apparent, 2=somewhat present, 1=weakly present, 0=never present).

Examples:

Monodon monoceros (narwhal): 3

Delphinapterus leucas (beluga): 2

Phocoena phocoena (harbor porpoise): 1

Platanista gangetica (Ganges river dolphin): 0

3. Dental wear

During suction feeding, teeth can incur distinct patterns of wear via water flow, abrasion, and movements of the tongue [5]. The severity of tooth wear may also reflect the softness and/or thinness of the enamel, which in turn relates to the unimportance of the dentition in capturing prey [6].

Scoring reflects the degree to which the trait is manifested (2=strongly present/highly apparent, 1=somewhat present, 0=weakly or never present).

Examples:

Delphinapterus leucas (beluga): 2

Kogia breviceps (pygmy sperm whale): 1

Stenella longirostris (long snouted spinner dolphin): 0

4. Non-occluding teeth/jaws

Typical raptorial feeding may be inefficient if the teeth and jaws do not occlude. Teeth cannot occlude in extreme cases of dental reduction, such as the lack of erupted maxillary teeth (as in sperm whales and *Grampus*) [2]. Adult specimens with jaws that are congenitally curved—or broken and re-healed at angles precluding occlusion—suggest the unimportance of functional teeth and jaws for seizing prey [7].

Scoring reflects the degree to which the trait is manifested (3=strongly present/highly apparent, 2=somewhat present, 1=weakly present, 0=never present).

Examples:

Mesoplodon layardii (strap-toothed whale): 3

Kogia breviceps (pygmy sperm whale): 2

Delphinapterus leucas (beluga): 1

Stenella longirostris (long snouted spinner dolphin): 0

5. Robust tongue/hyoid

In odontocetes, intraoral suction is generated by rapid, piston-like depression and retraction of the tongue [8]. Extrinsic muscles involved in depressing and retracting the tongue originate on the hyoid skeleton. An enlarged hyoid skeleton, with robust thyrohyal and stylohyal elements, indicate ample attachment sites for prominent tongue muscles [8–10].

Scoring reflects the degree to which the trait is manifested (3=strongly present/highly apparent, 2=somewhat present, 1=weakly present).

Examples:

Physeter macrocephalus (giant sperm whale): 3

Globicephala macrorhynchus (short-finned pilot whale): 2

Tursiops truncatus (common bottlenose dolphin): 1

6. Specialized palate

Palates can be specialized in at least two ways for suction feeding. First, vaulted palates can hold a large tongue and ingested water (as well as prey) [3, 11–12]. Second, rough palatal surfaces—

such as cornified keratinous ridges in beaked whales—can hold slippery prey (e.g., cephalopods) in the absence of functional dentition for grasping [3].

Scoring reflects the degree to which the trait is manifested (3=strongly present/highly apparent, 1=somewhat present, 0=never present).

Examples:

Ziphius cavirostris (Cuvier's beaked whale): 3

Delphinapterus leucas (beluga): 1

Tursiops truncatus (common bottlenose dolphin): 0

7. **Weak jaw adductors**

Strong jaw-closing muscles (such as the temporalis muscle) are important for capturing prey via biting or seizing [13–14], but less so for suction ingestion. In fossils, muscle attachment sites (such as the temporal fossa) are useful osteological correlates for the size and importance of jaw adductors [14–15].

Scoring reflects the degree to which the trait is manifested (2=strongly present/highly apparent, 1=somewhat present, 0=never present).

Example:

Ziphius cavirostris (Cuvier's beaked whale): 2

Delphinapterus leucas (beluga): 1

Orcinus orca (killer whale): 0

8. **Long mandibular symphysis**

An elongated mandibular symphysis indicates an atypical oral cavity in which the tongue lies partially or entirely behind (rather than between) the tooth rows [7–8]. The extreme caudal position of the tongue in some suction feeders—such as *Physeter macrocephalus* (giant sperm whales)—suggests that prey are likely sucked directly into the oropharynx [7]. This also suggests that teeth (if present) are likely used for retaining prey, rather than prey prehension or transport [16].

Scoring reflects the degree to which the trait is manifested (3=strongly present/highly apparent, 2=somewhat present, 1=weakly present, 0=never present).

Example:

Physeter macrocephalus (giant sperm whale): 3

Ziphius cavirostris (Cuvier's beaked whale): 2

Delphinapterus leucas (beluga): 1

Phocoena phocoena (harbor porpoise): 0

9. Round mouth

A rounder oral aperture improves incurrent flow for suction ingestion, as opposed to a notched “Pac-Man” gape with open sides [1, 10]. Some suction feeders, such as belugas (*Delphinapterus leucas*), are capable of pursing the oral aperture into a circular shape [17]. In giant sperm whales (*Physeter macrocephalus*), the round aperture may be accomplished by the oropharyngeal isthmus [7]. Because a round oral aperture is usually dictated by soft-tissue orofacial morphology, this trait is likely undetectable in fossils.

Scoring reflects the degree to which the trait is manifested (3=strongly present/highly apparent, 2=somewhat present, 1=weakly present, 0=never present).

Example:

Kogia breviceps (pygmy sperm whale): 3

Mesoplodon layardii (strap toothed beaked whale): 2

Lagenorhynchus obscurus (dusky dolphin): 1

Stenella longirostris (long snouted spinner dolphin): 0

10. Throat grooves

Throat grooves allow for gular expansion to accommodate the influx of water during suction ingestion of water and prey [3].

Scoring reflects presence or absence (3=present, 0=absent).

Examples:

Ziphius cavirostris (Cuvier’s beaked whale): 3

Globicephala macrorhynchus (short-finned pilot whale): 0

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TABLE S1

Suction scores based on morphological characters A-J: A = Round mouth ($H(1) = 20.1$, $p < 0.001$), B = Throat grooves ($H(1) = 48.4$, $p < 0.001$), C = Blunt/wide rostrum ($H(1) = 9.10$, $p = 0.003$), D = Reduced dentition ($H(1) = 48.7$, $p < 0.001$), E = Dental wear ($H(1) = 47.3$, $p < 0.001$), F = Non-occluding teeth/jaws ($H = 54.0$, $p < 0.001$), G = Robust tongue/hyoid ($H(1) = 52.0$, $p < 0.001$), H = Specialized palate ($H(1) = 57.0$, $p < 0.001$), I = Weak jaw adductors ($H(1) = 54.3$, $p < 0.001$), J = Long mandibular symphysis ($H(1) = 31.6$, $p < 0.001$). Character sum, average, and standard deviation are reported for the entire suite of characters (soft tissue + osteology), as well as the osteological and dentition characters only.

| Species | Morphological characters | | | | | | | | | | Characters A-J | | | Characters C-J | | |
|------------------------------------|--------------------------|---|-------------------------|-----|-----|---|---|---|---|---|----------------|------|-------|----------------|-------|-------|
| | Soft Tissue | | Osteology and Dentition | | | | | | | | Sum | Avg. | SD | Sum | Avg. | SD |
| | A | B | C | D | E | F | G | H | I | J | | | | | | |
| <i>Aethalodelphis obliquidens</i> | 1 | 0 | 2 | 0.5 | 0 | 0 | 1 | 0 | 0 | 0 | 4.5 | 0.45 | 0.685 | 3.5 | 0.438 | 0.729 |
| <i>Aethalodelphis obscurus</i> | 1 | 0 | 2 | 0.5 | 0 | 0 | 1 | 0 | 0 | 0 | 4.5 | 0.45 | 0.685 | 3.5 | 0.438 | 0.729 |
| <i>Berardius arnuxii</i> | 1 | 3 | 1.5 | 3 | 1.5 | 3 | 3 | 3 | 2 | 2 | 23 | 2.3 | 0.789 | 19 | 2.375 | 0.694 |
| <i>Berardius bairdii</i> | 1 | 3 | 1.5 | 3 | 1.5 | 3 | 3 | 3 | 2 | 2 | 23 | 2.3 | 0.789 | 19 | 2.375 | 0.694 |
| <i>Cephalorhynchus australis</i> | 1 | 0 | 2 | 0.5 | 0 | 0 | 1 | 0 | 0 | 0 | 4.5 | 0.45 | 0.685 | 3.5 | 0.438 | 0.729 |
| <i>Cephalorhynchus commersonii</i> | 1 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 5 | 0.5 | 0.707 | 4 | 0.500 | 0.756 |
| <i>Cephalorhynchus cruciger</i> | 1 | 0 | 2 | 0.5 | 0 | 0 | 1 | 0 | 0 | 0 | 4.5 | 0.45 | 0.685 | 3.5 | 0.438 | 0.729 |
| <i>Cephalorhynchus eutropia</i> | 1 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 5 | 0.5 | 0.707 | 4 | 0.500 | 0.756 |
| <i>Cephalorhynchus heavisidii</i> | 1 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 5 | 0.5 | 0.707 | 4 | 0.500 | 0.756 |
| <i>Cephalorhynchus hectori</i> | 1 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 5 | 0.5 | 0.707 | 4 | 0.500 | 0.756 |
| <i>Delphinapterus leucas</i> | 3 | 0 | 3 | 2 | 2 | 1 | 3 | 1 | 1 | 1 | 17 | 1.7 | 1.059 | 14 | 1.750 | 0.886 |
| <i>Delphinus delphis</i> | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0.1 | 0.316 | 1 | 0.125 | 0.354 |
| <i>Feresa attenuata</i> | 2 | 0 | 3 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 8 | 0.8 | 1.135 | 6 | 0.750 | 1.165 |
| <i>Globicephala macrorhynchus</i> | 2 | 0 | 3 | 2 | 0 | 1 | 2 | 0 | 0 | 0 | 10 | 1 | 1.155 | 8 | 1.000 | 1.195 |
| <i>Globicephala melas</i> | 2 | 0 | 3 | 2 | 0 | 1 | 2 | 0 | 0 | 0 | 10 | 1 | 1.155 | 8 | 1.000 | 1.195 |
| <i>Grampus griseus</i> | 2 | 0 | 3 | 3 | 1 | 3 | 2 | 1 | 0 | 0 | 15 | 1.5 | 1.269 | 13 | 1.625 | 1.302 |
| <i>Hyperoodon ampullatus</i> | 2 | 3 | 2 | 3 | 1.5 | 3 | 3 | 3 | 2 | 2 | 24.5 | 2.45 | 0.599 | 19.5 | 2.438 | 0.623 |
| <i>Hyperoodon planifrons</i> | 2 | 3 | 2 | 3 | 1.5 | 3 | 3 | 3 | 2 | 2 | 24.5 | 2.45 | 0.599 | 19.5 | 2.438 | 0.623 |
| <i>Indopacetus pacificus</i> | 1 | 3 | 2 | 3 | 1.5 | 3 | 3 | 3 | 2 | 2 | 23.5 | 2.35 | 0.747 | 19.5 | 2.438 | 0.623 |
| <i>Inia geoffrensis</i> | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 4 | 0.4 | 0.966 | 4 | 0.500 | 1.069 |
| <i>Kogia breviceps</i> | 3 | 3 | 3 | 3 | 1 | 2 | 3 | 1 | 2 | 2 | 23 | 2.3 | 0.823 | 17 | 2.125 | 0.835 |
| <i>Kogia sima</i> | 3 | 3 | 3 | 3 | 1 | 2 | 3 | 1 | 2 | 2 | 23 | 2.3 | 0.823 | 17 | 2.125 | 0.835 |
| <i>Lagenodelphis hosei</i> | 1 | 0 | 2 | 0.5 | 0 | 0 | 1 | 0 | 0 | 0 | 4.5 | 0.45 | 0.685 | 3.5 | 0.438 | 0.729 |

| | | | | | | | | | | | | | | | | |
|-----------------------------------|-----|---|-----|-----|-----|---|---|---|---|---|------|------|-------|------|-------|-------|
| <i>Lagenorhynchus albirostris</i> | 1 | 0 | 2 | 0.5 | 0 | 0 | 1 | 0 | 0 | 0 | 4.5 | 0.45 | 0.685 | 3.5 | 0.438 | 0.729 |
| <i>Leucopleurus acutus</i> | 1 | 0 | 2 | 0.5 | 0 | 0 | 1 | 0 | 0 | 0 | 4.5 | 0.45 | 0.685 | 3.5 | 0.438 | 0.729 |
| <i>Lipotes vexillifer</i> | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 4 | 0.4 | 0.966 | 4 | 0.500 | 1.069 |
| <i>Lissodelphis borealis</i> | 0.5 | 0 | 1 | 0.5 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0.3 | 0.422 | 2.5 | 0.313 | 0.458 |
| <i>Lissodelphis peronii</i> | 0.5 | 0 | 1 | 0.5 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0.3 | 0.422 | 2.5 | 0.313 | 0.458 |
| <i>Mesoplodon bidens</i> | 1 | 3 | 1.5 | 3 | 1.5 | 3 | 3 | 3 | 2 | 2 | 23 | 2.3 | 0.789 | 19 | 2.375 | 0.694 |
| <i>Mesoplodon bowdoini</i> | 1.5 | 3 | 2 | 3 | 1.5 | 3 | 3 | 3 | 2 | 2 | 24 | 2.4 | 0.658 | 19.5 | 2.438 | 0.623 |
| <i>Mesoplodon carlhubbsi</i> | 1.5 | 3 | 2 | 3 | 1.5 | 3 | 3 | 3 | 2 | 2 | 24 | 2.4 | 0.658 | 19.5 | 2.438 | 0.623 |
| <i>Mesoplodon densirostris</i> | 2 | 3 | 2 | 3 | 1.5 | 3 | 3 | 3 | 2 | 2 | 24.5 | 2.45 | 0.599 | 19.5 | 2.438 | 0.623 |
| <i>Mesoplodon europaeus</i> | 1.5 | 3 | 2 | 3 | 1.5 | 3 | 3 | 3 | 2 | 2 | 24 | 2.4 | 0.658 | 19.5 | 2.438 | 0.623 |
| <i>Mesoplodon grayi</i> | 1 | 3 | 1 | 3 | 1.5 | 3 | 3 | 3 | 2 | 2 | 22.5 | 2.25 | 0.858 | 18.5 | 2.313 | 0.799 |
| <i>Mesoplodon hectori</i> | 1.5 | 3 | 2 | 3 | 1.5 | 3 | 3 | 3 | 2 | 2 | 24 | 2.4 | 0.658 | 19.5 | 2.438 | 0.623 |
| <i>Mesoplodon layardii</i> | 2 | 3 | 2 | 3 | 1 | 3 | 3 | 3 | 2 | 2 | 24 | 2.4 | 0.699 | 19 | 2.375 | 0.744 |
| <i>Mesoplodon mirus</i> | 1.5 | 3 | 2 | 3 | 1.5 | 3 | 3 | 3 | 2 | 2 | 24 | 2.4 | 0.658 | 19.5 | 2.438 | 0.623 |
| <i>Mesoplodon peruvianus</i> | 1.5 | 3 | 2 | 3 | 1.5 | 3 | 3 | 3 | 2 | 2 | 24 | 2.4 | 0.658 | 19.5 | 2.438 | 0.623 |
| <i>Mesoplodon stejnegeri</i> | 2 | 3 | 2 | 3 | 1.5 | 3 | 3 | 3 | 2 | 2 | 24.5 | 2.45 | 0.599 | 19.5 | 2.438 | 0.623 |
| <i>Monodon monoceros</i> | 3 | 0 | 3 | 3 | 2 | 3 | 3 | 1 | 1 | 1 | 20 | 2 | 1.155 | 17 | 2.125 | 0.991 |
| <i>Neophocaena phocaenoides</i> | 2 | 0 | 3 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 9 | 0.9 | 1.101 | 7 | 0.875 | 1.126 |
| <i>Orcaella brevirostris</i> | 2 | 0 | 3 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 11 | 1.1 | 1.101 | 9 | 1.125 | 1.126 |
| <i>Orcinus orca</i> | 0.5 | 0 | 2 | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 6.5 | 0.65 | 0.818 | 6 | 0.750 | 0.886 |
| <i>Peponocephala electra</i> | 2 | 0 | 2 | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 8 | 0.8 | 0.919 | 6 | 0.750 | 0.886 |
| <i>Phocoena dioptrica</i> | 2 | 0 | 2.5 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 8.5 | 0.85 | 1.001 | 6.5 | 0.813 | 0.998 |
| <i>Phocoena phocoena</i> | 2 | 0 | 2 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 8 | 0.8 | 0.919 | 6 | 0.750 | 0.886 |
| <i>Phocoena sinus</i> | 2 | 0 | 2 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 8 | 0.8 | 0.919 | 6 | 0.750 | 0.886 |
| <i>Phocoena spinnipinnis</i> | 2 | 0 | 2 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 8 | 0.8 | 0.919 | 6 | 0.750 | 0.886 |
| <i>Phocoenoides dalli</i> | 2 | 0 | 2.5 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 8.5 | 0.85 | 1.001 | 6.5 | 0.813 | 0.998 |
| <i>Physeter macrocephalus</i> | 3 | 3 | 2 | 3 | 2 | 3 | 3 | 1 | 1 | 3 | 24 | 2.4 | 0.843 | 18 | 2.250 | 0.886 |
| <i>Platanista gangetica</i> | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 4 | 0.4 | 0.966 | 4 | 0.500 | 1.069 |
| <i>Pontoporia blainvillei</i> | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 4 | 0.4 | 0.966 | 4 | 0.500 | 1.069 |
| <i>Pseudorca crassidens</i> | 2 | 0 | 2.5 | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 8.5 | 0.85 | 1.001 | 6.5 | 0.813 | 0.998 |
| <i>Sotalia fluviatilis</i> | 0 | 0 | 0.5 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1.5 | 0.15 | 0.337 | 1.5 | 0.188 | 0.372 |
| <i>Sotalia guianensis</i> | 0 | 0 | 0.5 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1.5 | 0.15 | 0.337 | 1.5 | 0.188 | 0.372 |
| <i>Sousa chinensis</i> | 0 | 0 | 1 | 0.5 | 0 | 0 | 1 | 0 | 0 | 0 | 2.5 | 0.25 | 0.425 | 2.5 | 0.313 | 0.458 |

| | | | | | | | | | | | | | | | | |
|------------------------------|---|---|-----|-----|---|---|---|---|---|---|------|------|-------|------|-------|-------|
| <i>Sousa plumbea</i> | 0 | 0 | 1 | 0.5 | 0 | 0 | 1 | 0 | 0 | 0 | 2.5 | 0.25 | 0.425 | 2.5 | 0.313 | 0.458 |
| <i>Sousa teuszii</i> | 0 | 0 | 1 | 0.5 | 0 | 0 | 1 | 0 | 0 | 0 | 2.5 | 0.25 | 0.425 | 2.5 | 0.313 | 0.458 |
| <i>Stenella attenuata</i> | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0.1 | 0.316 | 1 | 0.125 | 0.354 |
| <i>Stenella clymene</i> | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0.1 | 0.316 | 1 | 0.125 | 0.354 |
| <i>Stenella coeruleoalba</i> | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0.1 | 0.316 | 1 | 0.125 | 0.354 |
| <i>Stenella frontalis</i> | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0.1 | 0.316 | 1 | 0.125 | 0.354 |
| <i>Stenella longirostris</i> | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0.1 | 0.316 | 1 | 0.125 | 0.354 |
| <i>Steno bredanensis</i> | 1 | 0 | 1.5 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 5.5 | 0.55 | 0.599 | 4.5 | 0.563 | 0.623 |
| <i>Tasmacetus shepherdi</i> | 1 | 3 | 1 | 1 | 1 | 1 | 3 | 3 | 2 | 2 | 18 | 1.8 | 0.919 | 14 | 1.750 | 0.886 |
| <i>Tursiops aduncus</i> | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0.3 | 0.483 | 3 | 0.375 | 0.518 |
| <i>Tursiops truncatus</i> | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0.3 | 0.483 | 3 | 0.375 | 0.518 |
| <i>Ziphius cavirostris</i> | 2 | 3 | 2.5 | 3 | 2 | 3 | 3 | 3 | 2 | 2 | 25.5 | 2.55 | 0.497 | 20.5 | 2.563 | 0.496 |

TABLE S2

Phylogenetic signal in the suction-related character scores. The table lists Bloomberg's K and p -value for each morphological character, as well as the suction specialization index (SSI). Results for SSI are reported for both the index calculated from all 10 characters (soft tissue +osteology) and the adjusted index (osteology only). Larger K values indicate stronger phylogenetic signal; p -values indicate that the K values significantly differ from zero.

| Morphological character | Bloomberg's K | p-value |
|--------------------------------------|-----------------------------------|-----------------------------|
| Blunt, wide rostrum | 0.65403 | <0.001 |
| Reduced dentition | 1.37426 | <0.001 |
| Dental wear | 1.69405 | <0.001 |
| Non-occluding teeth/jaws | 1.88985 | <0.001 |
| Robust tongue/hyoid | 3.66575 | <0.001 |
| Specialized palate | 7.16255 | <0.001 |
| Weak jaw adductors | 8.88597 | <0.001 |
| Long mandibular symphysis | 13.3135 | <0.001 |
| Round mouth | 1.35863 | <0.001 |
| Throat grooves | 11.5185 | <0.001 |
| SSI (soft tissue + osteology) | 4.47371 | <0.001 |
| SSI (osteology only) | 4.47371 | <0.001 |

TABLE S3

Results of phylogenetic generalized least squares regression testing the correlation between morphology and prey capture method. The table reports the results of two linear models (Brownian motion, BM, Ordinary Least Squares, OLS) for each morphological character, as well as the suction specialization index (SSI). Results for SSI are reported for both the index calculated from all 10 characters (soft tissue +osteology) and the adjusted index (osteology only). Akaike criterion values (AIC), coefficients, standard errors of coefficient (SE), *t*-values, and *p*-values are listed.

| Morphological character | Model | AIC | Coefficient | SE | <i>t</i> -value | <i>p</i> -value |
|-------------------------------|-------|----------|-------------|--------|-----------------|------------------|
| Blunt, wide rostrum | BM | 125.1027 | 0.8977 | 0.3233 | 2.7767 | 0.0071 |
| | OLS | 176.4000 | 0.7729 | 0.2146 | 3.6024 | <0.001 |
| Reduced dentition | BM | 79.5226 | 1.6168 | 0.2312 | 6.9922 | <0.001 |
| | OLS | 96.9069 | 2.2125 | 0.1196 | 18.5007 | <0.001 |
| Dental wear | BM | 42.1662 | 0.3006 | 0.1757 | 1.7110 | 0.0918 |
| | OLS | 73.1214 | 1.2463 | 0.1004 | 12.4138 | <0.001 |
| Non-occluding teeth/jaws | BM | 56.9968 | 1.8022 | 0.1959 | 9.1981 | <0.001 |
| | OLS | 115.7153 | 2.4487 | 0.1373 | 17.8317 | <0.001 |
| Robust tongue/hyoid | BM | 0.8052 | 0.5692 | 0.1296 | 4.3912 | <0.001 |
| | OLS | 73.6874 | 1.6227 | 0.1008 | 16.0955 | <0.001 |
| Specialized palate | BM | -11.8839 | 0.7159 | 0.1181 | 6.0630 | <0.001 |
| | OLS | 142.2763 | 2.3077 | 0.1669 | 13.8233 | <0.001 |
| Weak jaw adductors | BM | -53.042 | 0.3596 | 0.0872 | 4.1221 | <0.001 |
| | OLS | 80.3658 | 1.6538 | 0.1059 | 15.6182 | <0.001 |
| Long mandibular symphysis | BM | 7.5833 | 0.0560 | 0.1362 | 0.4109 | 0.6825 |
| | OLS | 171.9322 | 1.4451 | 0.2076 | 6.9601 | <0.001 |
| Round mouth | BM | 74.4161 | 0.6736 | 0.2227 | 3.0245 | 0.0035 |
| | OLS | 159.2516 | 1.0485 | 0.1891 | 5.5438 | <0.001 |
| Throat grooves | BM | -0.2485 | 0.3699 | 0.1286 | 2.8759 | 0.0054 |
| | OLS | 156.3791 | 2.4231 | 0.1852 | 13.0848 | <0.001 |
| SSI (soft tissue + osteology) | BM | -27.5962 | 0.7361 | 0.1052 | 6.9983 | <0.001 |
| | OLS | 48.9132 | 1.7181 | 0.0840 | 20.4471 | <0.001 |
| SSI (osteology only) | BM | 2.7513 | 0.9202 | 0.1315 | 6.9983 | <0.001 |
| | OLS | 79.2607 | 2.1477 | 0.1050 | 20.4471 | <0.001 |

TABLE S4

Results of a principal component analysis on 25 cetacean skull characters. Characters and scorings are based on recent phylogenetic matrices by Viglino et al. (2021), Meekin et al. (2024), and Paolucci et al (2025). Principal components and their proportion of variance, standard deviation, and cumulative proportion are listed.

| Principal Component | Proportion of Variance | Standard Deviation | Cumulative Proportion |
|---------------------|------------------------|--------------------|-----------------------|
| PC1 | 18.39% | 2.14 | 18.39% |
| PC2 | 13.11% | 1.81 | 31.50% |
| PC3 | 12.08% | 1.74 | 43.58% |
| PC4 | 8.63% | 1.47 | 52.21% |
| PC5 | 7.34% | 1.35 | 59.55% |
| PC6 | 5.75% | 1.20 | 65.30% |
| PC7 | 4.98% | 1.12 | 70.28% |
| PC8 | 4.25% | 1.03 | 74.53% |
| PC9 | 4.21% | 1.03 | 78.75% |
| PC10 | 3.33% | 0.913 | 82.08% |
| PC11 | 2.78% | 0.834 | 84.86% |
| PC12 | 2.23% | 0.747 | 87.09% |
| PC13 | 2.21% | 0.743 | 89.30% |
| PC14 | 1.94% | 0.697 | 91.24% |
| PC15 | 1.77% | 0.665 | 93.01% |
| PC16 | 1.52% | 0.616 | 94.53% |
| PC17 | 1.36% | 0.583 | 95.89% |
| PC18 | 1.03% | 0.507 | 96.92% |
| PC19 | 0.89% | 0.472 | 97.81% |
| PC20 | 0.72% | 0.424 | 98.53% |
| PC21 | 0.54% | 0.367 | 99.06% |
| PC22 | 0.40% | 0.316 | 99.46% |
| PC23 | 0.34% | 0.293 | 99.81% |
| PC24 | 0.17% | 0.203 | 99.97% |
| PC25 | 0.03% | 0.0823 | 100.00% |

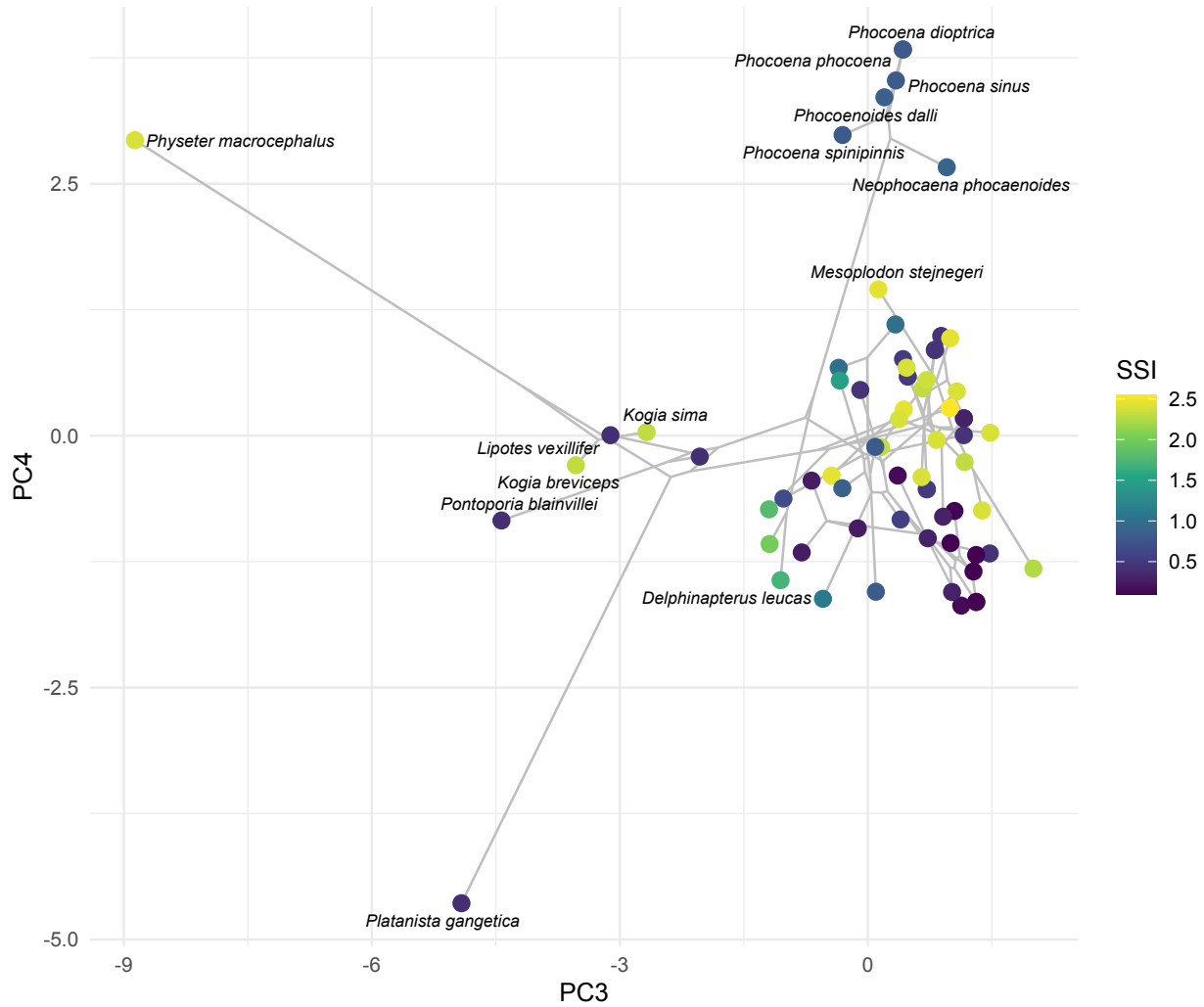


FIGURE S1

Resulting morphospace of the PCA on skull characters, with the suction specialization index (SSI) superimposed. PC3 (12.08% of variation) and PC4 (8.63% of variation) are plotted on the x- and y-axes, representing 20.71% of the total variation in the data. Color indicates SSI. Phylogeny was projected using a recent tree by Lloyd and Slater (2021).

List of Cranial and Mandibular Characters

Phylogenetic characters from Viglino et al. (2021) (via Meekin et al., 2024):

Rostrum

1. Length of rostrum as percent skull length: moderately long, 50–55% (0); long, 55–60% (1); very long, >60% (2); medium, 50–40% (3); very short, 40–35% (4).
2. Maxilla length as percent rostrum length: short, 89%, tips of maxillae to within 10% of rostrum tip (1); same as state 1 except lack of alveoli (2).
3. Lateral margin of rostrum anterior to maxillary flange: concave (0); straight (1); convex (2); absent (3).
4. Width of rostrum at antorbital notch as percent greatest width of maxillae at level of postorbital processes: wide >68% (0); medium, 68-45% (1); narrow, <45% (2).

Mandible

5. Length of mandibular symphysis as percent of mandible length: long, >20% (0); short, 69% of that distance (3).
6. Elevation of coronoid process: very high (0); moderate (1); low (2).

Orbit

7. Antorbital process of maxilla in dorsal view: triangular (0); robust and globose or rectilinear (1); absent (2).
8. Shape of postorbital process of frontal: robust, blunt descending posteriorly (0); pointed, attenuated, or acute triangular (1); triangular, trapezoidal, or an anteroposteriorly widened falciform (2); dorsoventrally long falciform (3).

Facial Region

9. Pneumatic maxillary crest overhanging medially: absent (0); present (1).
10. Premaxillae in dorsal view: separated anterior to bony nares, exposing mesethmoid (0);
joined premaxillae (or maxillae) closing at least posterior part of mesorostral groove (1).
11. Ratio of width of right premaxilla to width of left premaxilla in line with midpoint of
external nares: 0.90–1.19 (0); 1.20–1.50 (1); 1.50> (2).
12. Ratio of greatest width of premaxillae to greatest width of maxillae at level of postorbital
processes: ≥ 0.50 (0); 0.49–0.38 (1); 70% (2).
13. Supracranial basin: absent (0); present (1).

Vertex and Area Adjacent to the Nares

14. Vertex: absent (0); present (1); highly developed (2).
15. Cranial vertex skewed asymmetrically to left side: absent (0); present (1).
16. Nuchal crest: higher than frontals and/or nasals (0); at same level as frontals and/or nasals
(1); below frontals and/or nasals (2).

Temporal Fossae, Zygomatic Arch, and Occipitals

17. Parietals in dorsal view: contacting each other on the midline or separated by interparietal
(0); in skull roof but visible only as small triangular areas at edges of intertemporal
constriction, with supraoccipital overlapping and obscuring median portions (1);
completely absent in skull roof (2); visible only as triangular areas, dorsolateral to
supraoccipital, with non-overlapping supraoccipital separated from and contacting
parietals along irregular suture (3).
18. Sagittal crest for temporal muscle: present (0); absent (1).
19. Zygomatic process of squamosal: directed anterolaterally (0); directed anteriorly (1).
20. Postglenoid process of squamosal: not reduced (0); greatly reduced (1).

Anterior Basicranium

21. Palatine exposure: exposed ventrally (0); partially covered by pterygoid, which divides it into medial and lateral exposures (1); ventral surfaces completely covered by pterygoids (2).

Posterior Basicranium

22. Length of zygomatic process of squamosal as percent of greatest width of maxilla at postorbital process: $>31\%$ (0); $\leq 30\%$ (1).
23. Angle formed by basioccipital crests in ventral view: parallel with no angle formed (0); ca. $15\text{--}40^\circ$ (1); ca. $42\text{--}68^\circ$ (2); ca. $70\text{--}90^\circ$ (3); $>100^\circ$ (4).
24. Paroccipital process, skull in ventral view: posterior edge located well anterior to the posterior edge of condyle (0); posterior edge in transverse line with posterior edge of condyle (1).

Phylogenetic characters from Paolucci et al. (2025) :

25. Occipital shield (ordered): (0) convex and forming an angle of about 40° with the longitudinal axis of the rostrum; (1) as state 0 with an angle of about 60° ; (2) flat or concave forming an angle of about 90° ; (3) flat or concave forming an angle distinctly greater than 90° .