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SUPPLEMENTARY DATA

The evolution of feeding strategies in phocid seals (Pinnipedia, Phocidae)

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TABLES

TABLE S1. Specimen data for extant phocids included in the study.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Species | Accession No. | Sex | Specimen Age | Museum | Feeding Strategy\* |
| *Cystophora cristata* | 52336 | M  | Juvenile | LACM | Suction |
| *Cystophora cristata* | 188913 | M | Adult | NMNH | Suction |
| *Cystophora cristata* | 188914 | M | Adult | NMNH | Suction |
| *Cystophora cristata* | 188915 | M | Adult | NMNH | Suction |
| *Cystophora cristata* | 188917 | M | Adult | NMNH | Suction |
| *Cystophora cristata* | 188918 | F | Adult | NMNH | Suction |
| *Cystophora cristata* | 188927 | F | Adult | NMNH | Suction |
| *Cystophora cristata* | 188929 | M  | Adult | NMNH | Suction |
| *Cystophora cristata* | 188930 | F | Adult | NMNH | Suction |
| *Cystophora cristata* | 188938 | M  | Adult | NMNH | Suction |
| *Cystophora cristata* | 188943 | F | Adult | NMNH | Suction |
| *Cystophora cristata* | 188944 | M | Adult | NMNH | Suction |
| *Cystophora cristata* | 188956 | F | Adult | NMNH | Suction |
| *Cystophora cristata* | 188958 | F | Adult | NMNH | Suction |
| *Cystophora cristata* | 188970 | F | Adult | NMNH | Suction |
| *Cystophora cristata* | 572579 | M | Adult | NMNH | Suction |
| *Erignathus barbatus* | 22828 | - | Adult | LACM | Suction |
| *Erignathus barbatus* | 22829 | - | Adult | LACM | Suction |
| *Erignathus barbatus* | 52322 | - | Adult | LACM | Suction |
| *Erignathus barbatus* | 52335 | - | Juvenile | LACM | Suction |
| *Erignathus barbatus* | 52353 | - | Adult | LACM | Suction |
| *Erignathus barbatus* | 72574 | F | Adult | LACM | Suction |
| *Erignathus barbatus* | 72576 | F | Adult | LACM | Suction |
| *Erignathus barbatus* | 21466 | - | Adult | NMNH | Suction |
| *Erignathus barbatus* | 188827 | - | Adult | NMNH | Suction |
| *Erignathus barbatus* | 188835 | - | Adult | NMNH | Suction |
| *Erignathus barbatus* | 188837 | - | Adult | NMNH | Suction |
| *Erignathus barbatus* | 188838 | - | Adult | NMNH | Suction |
| *Erignathus barbatus* | 225796 | M | Adult | NMNH | Suction |
| *Erignathus barbatus* | 230952 | - | Adult | NMNH | Suction |
| *Erignathus barbatus* | 275058 | - | Adult | NMNH | Suction |
| *Erignathus barbatus* | 290656 | M | Adult | NMNH | Suction |
| *Halichoerus grypus* | 84079 | M  | Adult | LACM | Pierce |
| *Halichoerus grypus* | 86025 | F | Neonate | LACM | Pierce |
| *Halichoerus grypus* | 86045 | M  | Adult | LACM | Pierce |
| *Halichoerus grypus* | 4717 | - | Adult | NMNH | Pierce |

Table S1. (Continued)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *Halichoerus grypus* | 19837 | F | Adult | NMNH | Pierce |
| *Halichoerus grypus* | 31839 | M | Juvenile | NMNH | Pierce |
| *Halichoerus grypus* | 35291 | M | Adult | NMNH | Pierce |
| *Halichoerus grypus* | 38237 | F | Adult | NMNH | Pierce |
| *Halichoerus grypus* | 188839 | - | Juvenile | NMNH | Pierce |
| *Halichoerus grypus* | 446405 | - | Adult | NMNH | Pierce |
| *Halichoerus grypus* | 446406 | - | Adult | NMNH | Pierce |
| *Halichoerus grypus* | 446416 | - | Juvenile | NMNH | Pierce |
| *Halichoerus grypus* | 504211 | - | Juvenile | NMNH | Pierce |
| *Halichoerus grypus* | 504297 | - | Juvenile | NMNH | Pierce |
| *Halichoerus grypus* | 504481 | M  | Adult | NMNH | Pierce |
| *Halichoerus grypus* | 550367 | - | Adult | NMNH | Pierce |
| *Histriophoca fasciata* | 16484 | - | Adult | NMNH | Pierce |
| *Histriophoca fasciata* | 22950 | - | - | NMNH | Pierce |
| *Histriophoca fasciata* | 22995 | - | Adult | NMNH | Pierce |
| *Histriophoca fasciata* | 311771 | - | - | NMNH | Pierce |
| *Histriophoca fasciata* | 399449 | - | Adult | NMNH | Pierce |
| *Histriophoca fasciata* | 504959 | - | Adult | NMNH | Pierce |
| *Histriophoca fasciata* | 504960 | - | Adult | NMNH | Pierce |
| *Histriophoca fasciata* | 571367 | - | Adult | NMNH | Pierce |
| *Hydrurga leptonyx* | 30462 | - | Adult | LACM | Grip and tear |
| *Hydrurga leptonyx* | 15758 | - | Adult | NMNH | Grip and tear |
| *Hydrurga leptonyx* | 104557 | - | Adult | NMNH | Grip and tear |
| *Hydrurga leptonyx* | 269533 | F | Adult | NMNH | Grip and tear |
| *Hydrurga leptonyx* | 270315 | F | Adult | NMNH | Grip and tear |
| *Hydrurga leptonyx* | 270326 | M  | Adult | NMNH | Grip and tear |
| *Hydrurga leptonyx* | 275205 | F | Adult | NMNH | Grip and tear |
| *Hydrurga leptonyx* | 275208 | F | Adult | NMNH | Grip and tear |
| *Hydrurga leptonyx* | 396931 | - | Adult | NMNH | Grip and tear |
| *Hydrurga leptonyx* | 550358 | - | Adult | NMNH | Grip and tear |
| *Hydrurga leptonyx* | 550359 | - | Adult | NMNH | Grip and tear |
| *Hydrurga leptonyx* | 550360 | M  | Adult | NMNH | Grip and tear |
| *Hydrurga leptonyx* | 571676 | - | Adult | NMNH | Grip and tear |
| *Leptonychotes weddellii* | 269526 | F | Adult | NMNH | Pierce |
| *Leptonychotes weddellii* | 270318 | - | Juvenile | NMNH | Pierce |
| *Leptonychotes weddellii* | 270319 | M  | Adult | NMNH | Pierce |
| *Leptonychotes weddellii* | 395811 | - | Adult | NMNH | Pierce |
| *Leptonychotes weddellii* | 395812 | - | Adult | NMNH | Pierce |
| *Leptonychotes weddellii* | 395813 | - | Adult | NMNH | Pierce |
| *Leptonychotes weddellii* | 395814 | M  | Adult | NMNH | Pierce |
| *Leptonychotes weddellii* | 504871 | - | Adult | NMNH | Pierce |

TABLE S1. (Continued)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *Leptonychotes weddellii* | 550074 | F? | Juvenile | NMNH | Pierce |
| *Leptonychotes weddellii* | 550075 | F | Adult | NMNH | Pierce |
| *Leptonychotes weddellii* | 550076 | F | Juvenile | NMNH | Pierce |
| *Leptonychotes weddellii* | 550118 | - | Adult | NMNH | Pierce |
| *Lobodon carcinophaga* | 36586 | - | Adult | NMNH | Filter |
| *Lobodon carcinophaga* | 115285 | - | Adult | NMNH | Filter |
| *Lobodon carcinophaga* | 269532 | F | Adult | NMNH | Filter |
| *Lobodon carcinophaga* | 269722 | F | Adult | NMNH | Filter |
| *Lobodon carcinophaga* | 270324 | F | Adult | NMNH | Filter |
| *Lobodon carcinophaga* | 270325 | M | Juvenile | NMNH | Filter |
| *Lobodon carcinophaga* | 270385 | F | Adult | NMNH | Filter |
| *Lobodon carcinophaga* | 275204 | M | Juvenile | NMNH | Filter |
| *Lobodon carcinophaga* | 310693 | - | Adult | NMNH | Filter |
| *Lobodon carcinophaga* | 504741 | - | Adult | NMNH | Filter |
| *Lobodon carcinophaga* | 504742 | - | Juvenile | NMNH | Filter |
| *Lobodon carcinophaga* | 504743 | - | Adult | NMNH | Filter |
| *Lobodon carcinophaga* | 504744 | - | Adult | NMNH | Filter |
| *Lobodon carcinophaga* | 550077 | F | Adult | NMNH | Filter |
| *Lobodon carcinophaga* | 550078 | F | Adult | NMNH | Filter |
| *Lobodon carcinophaga* | 550080 | F | Adult | NMNH | Filter |
| *Lobodon carcinophaga* | 550083 | M  | Adult | NMNH | Filter |
| *Mirounga angustirostris* | 52369 | M  | Adult | LACM | Suction |
| *Mirounga angustirostris* | 52371 | M  | Adult | LACM | Suction |
| *Mirounga angustirostris* | 52427 | F | Juvenile | LACM | Suction |
| *Mirounga angustirostris* | 54394 | M  | Adult | LACM | Suction |
| *Mirounga angustirostris* | 54787 | M  | Adult | LACM | Suction |
| *Mirounga angustirostris* | 91324 | M  | Juvenile | LACM | Suction |
| *Mirounga angustirostris* | 91356 | M  | Juvenile | LACM | Suction |
| *Mirounga angustirostris* | 91357 | F | Juvenile | LACM | Suction |
| *Mirounga angustirostris* | 91358 | - | Juvenile | LACM | Suction |
| *Mirounga angustirostris* | 91360 | - | Juvenile | LACM | Suction |
| *Mirounga angustirostris* | 91361 | F | Juvenile | LACM | Suction |
| *Mirounga angustirostris* | 91362 | F | Juvenile | LACM | Suction |
| *Mirounga angustirostris* | 91364 | M  | Juvenile | LACM | Suction |
| *Mirounga angustirostris* | 91365 | M  | Juvenile | LACM | Suction |
| *Mirounga angustirostris* | 95715 | M  | Juvenile | LACM | Suction |
| *Mirounga angustirostris* | 97234 | F | Juvenile | LACM | Suction |
| *Mirounga angustirostris* | 97254 | F | Juvenile | LACM | Suction |
| *Mirounga angustirostris* | 97431 | M  | Juvenile | LACM | Suction |
| *Mirounga angustirostris* | JLong specimen | - | Juvenile | SDNHM | Suction |

TABLE S1. (Continued)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *Mirounga angustirostris* | 6747 | F | Juvenile | SDNHM | Suction |
| *Mirounga angustirostris* | 7296 | M  | Adult | SDNHM | Suction |
| *Mirounga angustirostris* | 20054 | M  | Adult | SDNHM | Suction |
| *Mirounga angustirostris* | 21255 | M  | Adult | SDNHM | Suction |
| *Mirounga angustirostris* | 21256 | F | Adult | SDNHM | Suction |
| *Mirounga angustirostris* | 22401 | F | Adult | SDNHM | Suction |
| *Mirounga angustirostris* | 22769 | F | Juvenile | SDNHM | Suction |
| *Mirounga angustirostris* | 22987 | F | Juvenile | SDNHM | Suction |
| *Mirounga angustirostris* | 23133 | M  | Adult | SDNHM | Suction |
| *Mirounga leonina* | 84245 | F | Adult | LACM | Suction |
| *Mirounga leonina* | 84290 | - | Adult | LACM | Suction |
| *Monachus monachus* | 23250 | M | Juvenile | NMNH | Pierce |
| *Monachus monachus* | 219059 | - | Adult | NMNH | Pierce |
| *Neomonachus schauinslandi* | 181250 | M  | Adult | NMNH | Pierce |
| *Neomonachus schauinslandi* | 243838 | M  | Adult | NMNH | Pierce |
| *Neomonachus schauinslandi* | 243839 | F | Adult | NMNH | Pierce |
| *Neomonachus schauinslandi* | 243840 | M  | Adult | NMNH | Pierce |
| *Neomonachus schauinslandi* | 243842 | F | Adult | NMNH | Pierce |
| *Neomonachus schauinslandi* | 243844 | M | Adult | NMNH | Pierce |
| *Neomonachus schauinslandi* | 243849 | F | Adult | NMNH | Pierce |
| *Neomonachus schauinslandi* | 334573 | - | Adult | NMNH | Pierce |
| *Neomonachus schauinslandi* | 395761 | - | Adult | NMNH | Pierce |
| *Neomonachus schauinslandi* | 395787 | - | Adult | NMNH | Pierce |
| *Neomonachus schauinslandi* | 395995 | - | Adult | NMNH | Pierce |
| *Neomonachus schauinslandi* | 504892 | M | Adult | NMNH | Pierce |
| *Neomonachus schauinslandi* | 504893 | - | Adult | NMNH | Pierce |
| *Neomonachus schauinslandi* | 18711 | - | Adult | SDNHM | Pierce |
| *Neomonachus schauinslandi* | 21252 | M  | Juvenile | SDNHM | Pierce |
| *Neomonachus tropicalis* | 22543 | M | Adult | NMNH | Pierce |
| *Neomonachus tropicalis* | 100354 | M | Adult | NMNH | Pierce |
| *Neomonachus tropicalis* | 100355 | F | Adult | NMNH | Pierce |
| *Neomonachus tropicalis* | 100356 | F | Adult | NMNH | Pierce |
| *Neomonachus tropicalis* | 100358 | M | Adult | NMNH | Pierce |
| *Neomonachus tropicalis* | 100361 | F | Adult | NMNH | Pierce |
| *Neomonachus tropicalis* | 100362 | F | Adult | NMNH | Pierce |
| *Neomonachus tropicalis* | 100363 | M  | Adult | NMNH | Pierce |
| *Neomonachus tropicalis* | 100372 | F | Adult | NMNH | Pierce |
| *Neomonachus tropicalis* | 100373 | F | Adult | NMNH | Pierce |
| *Neomonachus tropicalis* | 102525 | F | Adult | NMNH | Pierce |
| *Neomonachus tropicalis* | 102526 | F | Adult | NMNH | Pierce |
| *Neomonachus tropicalis* | 102532 | M | Adult | NMNH | Pierce |

TABLE S1. (Continued)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *Neomonachus tropicalis* | 102536 | F | Adult | NMNH | Pierce |
| *Neomonachus tropicalis* | 102537 | F | Adult | NMNH | Pierce |
| *Ommatophoca rossii* | 275206 | M  | Adult | NMNH | Pierce |
| *Ommatophoca rossii* | 270316 | F | Adult | NMNH | Pierce |
| *Ommatophoca rossii* | 302975 | - | Adult | NMNH | Pierce |
| *Ommatophoca rossii* | 339989 | - | Adult | NMNH | Pierce |
| *Ommatophoca rossii* | 270321 | M | Adult | NMNH | Pierce |
| *Pagophilus groenlandicus* | 881 | - | Adult | NMNH | Pierce |
| *Pagophilus groenlandicus* | 3503 | - | Adult | NMNH | Pierce |
| *Pagophilus groenlandicus* | 3505 | - | Adult | NMNH | Pierce |
| *Pagophilus groenlandicus* | 3517 | - | Adult | NMNH | Pierce |
| *Pagophilus groenlandicus* | 21535 | - | Adult | NMNH | Pierce |
| *Pagophilus groenlandicus* | 188759 | - | Adult | NMNH | Pierce |
| *Pagophilus groenlandicus* | 188767 | F | Adult | NMNH | Pierce |
| *Pagophilus groenlandicus* | 188770 | M | Adult | NMNH | Pierce |
| *Pagophilus groenlandicus* | 188773 | F | Adult | NMNH | Pierce |
| *Pagophilus groenlandicus* | 188775 | M | Adult | NMNH | Pierce |
| *Pagophilus groenlandicus* | 188787 | F | Adult | NMNH | Pierce |
| *Pagophilus groenlandicus* | 188789 | F | Adult | NMNH | Pierce |
| *Pagophilus groenlandicus* | 188790 | M | Adult | NMNH | Pierce |
| *Pagophilus groenlandicus* | 188791 | F | Adult | NMNH | Pierce |
| *Pagophilus groenlandicus* | 188816 | M | Adult | NMNH | Pierce |
| *Phoca largha* | 270974 | M | Adult | NMNH | Pierce |
| *Phoca vitulina* | 38230 | - | Adult | NMNH | Pierce |
| *Phoca vitulina* | 49911 | M | Adult | NMNH | Pierce |
| *Phoca vitulina* | 49911 | M | Adult | NMNH | Pierce |
| *Phoca vitulina* | 82820 | M | Adult | NMNH | Pierce |
| *Phoca vitulina* | 82821 | F | Adult | NMNH | Pierce |
| *Phoca vitulina* | 128065 | - | Adult | NMNH | Pierce |
| *Phoca vitulina* | 219868 | F | Adult | NMNH | Pierce |
| *Phoca vitulina* | 290654 | M | Adult | NMNH | Pierce |
| *Phoca vitulina* | 504298 | M | Adult | NMNH | Pierce |
| *Phoca vitulina* | 7513 | F | Juvenile | SDNHM | Pierce |
| *Phoca vitulina* | 7966 | F | Adult | SDNHM | Pierce |
| *Phoca vitulina* | 12516 | M  | Juvenile | SDNHM | Pierce |
| *Phoca vitulina* | 22824 | M  | Juvenile | SDNHM | Pierce |
| *Phoca vitulina* | 22985 | - | Adult | SDNHM | Pierce |
| *Phoca vitulina* | 23612 | M  | Adult | SDNHM | Pierce |
| *Pusa caspica* | 341615 | M  | Adult | NMNH | Pierce |
| *Pusa caspica* | 341616 | M  | Adult | NMNH | Pierce |
| *Pusa caspica* | 341617 | M | Adult | NMNH | Pierce |

TABLE S1. (Continued)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *Pusa hispida* | 3504 | - | Adult | NMNH | Pierce |
| *Pusa hispida* | 6566 | - | Adult | NMNH | Pierce |
| *Pusa hispida* | 6567 | - | Adult | NMNH | Pierce |
| *Pusa hispida* | 7102 | - | Adult | NMNH | Pierce |
| *Pusa hispida* | 106854 | F | Adult | NMNH | Pierce |
| *Pusa hispida* | 188820 | - | Adult | NMNH | Pierce |
| *Pusa hispida* | 219878 | - | Adult | NMNH | Pierce |
| *Pusa hispida* | 225757 | M | Adult | NMNH | Pierce |
| *Pusa hispida* | 225757 | M | Adult | NMNH | Pierce |
| *Pusa hispida* | 225766 | M | Adult | NMNH | Pierce |
| *Pusa hispida* | 225770 | M | Adult | NMNH | Pierce |
| *Pusa hispida* | 225781 | F | Adult | NMNH | Pierce |
| *Pusa hispida* | 230359 | F | Adult | NMNH | Pierce |
| *Pusa hispida* | 12213 | F | Juvenile | SDNHM | Pierce |
| *Pusa hispida* | 12214 | M  | Adult | SDNHM | Pierce |
| *Pusa sibirica* | 175690 | F | Adult | NMNH | Pierce |
| *Pusa sibirica* | 550028 | - | Adult | NMNH | Pierce |
| *Pusa sibirica* | 550034 | - | Adult | NMNH | Pierce |
| *Pusa sibirica* | 21557 | F | Adult | SDNHM | Pierce |
| *Pusa sibirica* | 22486 | F | Adult | SDNHM | Pierce |
| *Pusa sibirica* | 22767 | F | Juvenile | SDNHM | Pierce |
| \*Feeding strategy based on Kienle and Berta (2016) |   |   |   |

TABLE S2. Specimen data for fossil pinnipedimorphs included in the study.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Species | Accession No. | Sex | Museum | Sample |
| *Acrophoca longirostris* | 421632 | - | USNM | Cranium |
| *Allodesmus* sp. | 4320 | - | SDNHM | Mandible |
| *Allodesmus* cf. sp. nov | 10628-V | F | SDNHM | Cranium |
| *Allodesmus kernensis\** | 25227 | - | USNM | Cranium |
| *Allodesmus kernensis* | 116701 | - | SDNHM | Cranium |
| *Allodesmus kernensis* | 23249 | - | USNM | Cranium, mandible |
| *Desmatophoca brachycephala* | 335451 | - | USNM | Cranium |
| *Desmatophoca* sp. | 335694 | - | USNM | Mandible |
| *Homiphoca capensis* | SAM-PQ-30080 | - | USNM | Cranium |
| *Leptophoca proxima* | CMM-V-2021 | - | USNM | Cranium, mandible |
| *Leptophoca proxima* | 498752 | - | USNM | Mandible |
| *Piscophoca pacifica* | 360406 | - | USNM | Cranium, mandible |
| ‘*Pliophoca etrusca’* | 171221 | - | USNM | Mandible |
| *Pteronarctos goedertae* | 250320 | - | USNM | Cranium |
| *Pteronarctos goedertae* | 250323 | - | USNM | Cranium |

\*Formerly classified as *Allodesmus kelloggii* (see Boessenecker and Churchill, 2018)

TABLE S3. Positive and negative eigenvalues for the first six cranial principal components (PCs).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PC | % Variation | Character Change | Landmark | No. | PC Coefficient |
| PC1 | 21.5% | Skull length vs. width | Caudal suture of parietal and supraoccipital on dorsal midline (left)\* | x46 | -0.17 |
|  |  |  | Dorsal-most junction of jugal and squamosal (left) | y27 | -0.15 |
|  |  |  | Dorsal-most junction of jugal and squamosal (right) | y20 | -0.14 |
|  |  |  | Lateral-most tip of external auditory meatus | x32 | 0.18 |
|  |  |  | Dorsal- and caudal-most suture of jugal and maxilla | z22 | 0.18 |
|  |  |  | Dorsal junction of jugal and maxilla (right) | z26 | 0.18 |
|  |  |  | Caudal edge of last postcanine tooth (left) | x8 | 0.19 |
|  |  |  | Caudal-most projection of parietal and supraoccipital (left)\* | z44 | 0.22 |
|  |  |  | Junction of nasal, frontal, and maxilla | z19 | 0.22 |
|  |  |  | Dorsal junction of jugal and maxilla (left) | z25 | 0.22 |
|  |  |  | Lateral-most point of mastoid process (left) | x28 | 0.23 |
| PC2 | 16.6% | Skull width and shape rostrally vs. caudally | Lateral-most point of mastoid process (left) | y28 | -0.22 |
|  |  |  | Caudal-most projection of parietal and supraoccipital (left)\* | z44 | -0.17 |
|  |  |  | Caudal suture of parietal and supraoccipital on dorsal midline (left)\* | x46 | -0.16 |
|  |  |  | Dorsal junction of jugal and maxilla (right) | z26 | 0.17 |
|  |  |  | Dorsal- and caudal-most suture of jugal and maxilla | z22 | 0.17 |
|   |   |   | Dorsal junction of jugal and maxilla (left) | z25 | 0.19 |
| PC3 | 10.4% | Palate shape vs. parietal shape | Caudal-most point of palate midline | x3 | -0.30 |
|  |  |  | Junction of nasal, frontal, and maxilla\* | x19 | -0.25 |
|  |  |  | Caudal-most point of palate midline | z3 | -0.23 |
|  |  |  | Caudal-most point of palate midline | x3 | -0.18 |
|  |  |  | Dorsal- and caudal-most suture of jugal and maxilla | y22 | -0.17 |
|  |  |  | Caudal-most point of palate midline | z3 | -0.17 |

TABLE S3. (Continued)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | Dorsal junction of jugal and maxilla (left) | y25 | 0.18 |
|  |  |  | Rostral suture of parietal and frontal on dorsal midline (left)\* | x45 | 0.21 |
|  |  |  | Rostral-most suture of parietal and squamosal (left)\* | x41 | 0.22 |
| PC4 | 7.4% | Skull thickness vs. skull shape | Lateral-most point of mastoid process (left) | x28 | -0.19 |
|  |  |  | Caudal-most point of infraorbital foramen\* | x36 | -0.18 |
|  |  |  | Rostral suture of parietal and frontal on dorsal midline (left)\* | z45 | -0.18 |
|  |  |  | Caudal margin of occipital condyle | x2 | -0.17 |
|  |  |  | Lateral-most point of mastoid process (left) | z28 | 0.22 |
|  |  |  | Lateral-most tip of external auditory meatus | z32 | 0.22 |
|  |  |  | Junction of nasal, frontal, and maxilla\* | x19 | 0.23 |
|   |   |   | Rostral-most suture of parietal and squamosal (left)\* | y41 | 0.28 |
| PC5 | 6.0% | Palate width and length vs. parietal shape | Rostral-most suture of parietal and squamosal (left)\* | x41 | -0.27 |
|  |  |  | Caudal edge of last postcanine tooth (right) | x9 | -0.25 |
|  |  |  | Caudal edge of last postcanine tooth (left) | x8 | -0.22 |
|  |  |  | Caudal margin of occipital condyle | z2 | -0.21 |
|  |  |  | Caudal-most projection of parietal and supraoccipital (left)\* | y44 | -0.21 |
|  |  |  | Caudal-most point of palate midline | x3 | -0.20 |
|  |  |  | Medial-most point of auditory bulla at suture of basioccipital and basisphenoid | x33 | 0.17 |
|  |  |  | Rostral-most suture of parietal and squamosal (left)\* | y41 | 0.18 |
|  |  |  | Dorsal-most junction of jugal and squamosal (right) | x20 | 0.21 |
|  |  |  | Dorsal-most junction of jugal and squamosal (left) | x27 | 0.22 |
| PC6 | 5.08% | Skull width vs. orbit shape and position | Dorsal junction of jugal and maxilla (right) | x26 | -0.23 |
|  |  |  | Dorsal- and caudal-most suture of jugal and maxilla | x22 | -0.22 |

TABLE S3. (Continued)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | Dorsal junction of jugal and maxilla (left) | x25 | -0.20 |
|  |  |  | Dorsal-most junction of jugal and squamosal (right) | y20 | 0.21 |
|  |  |  | Caudal-most point of palate midline | x3 | 0.22 |
|  |  |  | Dorsal-most junction of jugal and squamosal (left) | y27 | 0.22 |
|   |   |   | Junction of nasal, frontal, and maxilla\* | x19 | 0.36 |

TABLE S4. Positive and negative eigenvalues for the first four mandible principal components (PCs).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PC | % Variation | Character Change | Landmark | No. | PC Coefficient |
| PC1 | 31.6% | Mandible length vs. thickness | Ventral edge of mandible underneath the tip of the coronoid process | z11 | -0.27 |
|  |  |  | Medial edge of mandibular symphysis caudal to the first incisor | x4 | -0.21 |
|  |  |  | Ventral edge of mandible underneath the canine | z5 | -0.20 |
|  |  |  | Lateral edge of canine midpoint | x3 | -0.18 |
|  |  |  | Ventral edge of mandible underneath the tip of the coronoid process | x11 | 0.24 |
|  |  |  | Lateral point at midline of M1 | x8 | 0.30 |
|  |  |  | Lateral and caudal edge of last postcanine | x6 | 0.31 |
|  |  |  | Caudal edge of last postcanine | x22 | 0.35 |
|  |  |  | Ventral edge of mandible underneath the last postcanine | x7 | 0.43 |
| PC2 | 19.6% | Mandible shape vs. coronoid process shape | Ventral edge of mandible underneath the canine | z5 | -0.41 |
|  |  |  | Caudal-most point of mandibular condyle | z2 | -0.22 |
|  |  |  | Caudal-most point of mandibular condyle | x2 | -0.19 |
|  |  |  | Ventral edge of mandible underneath the canine | y5 | 0.21 |
|  |  |  | Lateral point at midline of M1 | z8 | 0.23 |
|  |  |  | Lateral and caudal edge of last postcanine | z6 | 0.23 |
|  |  |  | Caudal edge of last postcanine | z22 | 0.25 |
|  |  |  | Rostral-most point of coronoid process | x13 | 0.27 |
|   |   |   | Rostral-most point on curving edge of coronoid process | x15 | 0.42 |
| PC3 | 9.9% | Mandible thickness vs. coronoid process size | Ventral edge of mandible underneath the last postcanine | z7 | -0.30 |
|  |  |  | Rostral-most point on curving edge of coronoid process | x15 | -0.25 |
|  |  |  | Ventral edge of mandible underneath the canine | y5 | -0.24 |
|  |  |  | Ventral edge of mandible underneath the tip of the coronoid process | z11 | -0.21 |

TABLE S4. (Continued)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | Ventral edge of mandible underneath the canine | z5 | -0.20 |
|  |  |  | Caudal-most point of mandibular condyle | y2 | -0.17 |
|  |  |  | Lateral edge of canine midpoint | z3 | 0.16 |
|  |  |  | Rostral-most point of coronoid process | x13 | 0.17 |
|  |  |  | Caudal-most point of coronoid process | x14 | 0.30 |
|  |  |  | Dorsal-most point of coronoid process | x12 | 0.32 |
| PC4 | 8.4% | Mandible thickness vs. coronoid process shape | Ventral edge of mandible underneath the tip of the coronoid process | z11 | -0.36 |
|  |  |  | Caudal edge of last postcanine | x22 | -0.22 |
|  |  |  | Ventral edge of mandible underneath the last postcanine | z7 | -0.19 |
|  |  |  | Lateral point at midline of M1 | x8 | -0.18 |
|  |  |  | Rostral-most point on curving edge of coronoid process | x15 | 0.18 |
|  |  |  | Dorsal-most point of coronoid process | z12 | 0.25 |
|  |  |  | Rostral-most point of coronoid process | z13 | 0.26 |
|   |   |   | Ventral edge of mandible underneath the tip of the coronoid process | x11 | 0.47 |

TABLE S5. Positive and negative coefficients for the three cranial canonical variates (CVs).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| CV | % Variation | Character Changes | Landmark | No. | CV Coefficient |
| CV1 | 67.7 | Skull length and depth | Dorsal junction of jugal and maxilla (left) | y25 | -266.63 |
|  |  |  | Suture of premaxilla and maxilla rostral to canine | y37 | -233.40 |
|  |  |  | Suture of maxilla and palatine (right) | z7 | -208.12 |
|  |  |  | Lateral-most point of mastoid process (left) | x28 | -185.15 |
|  |  |  | Caudal edge of last postcanine tooth (right) | y9 | -184.29 |
|  |  |  | Suture of maxilla and palatine (right) | x7 | -162.91 |
|  |  |  | Caudal edge of last postcanine tooth (right) | x9 | -162.45 |
|  |  |  | Dorsal junction of jugal and maxilla (left) | x25 | 165.60 |
|  |  |  | Dorsal junction of jugal and maxilla (left) | z25 | 171.88 |
|  |  |  | Caudal-most suture of palatine, pterygoid, and alisphenoid | y5 | 195.76 |
|  |  |  | Dorsal-most junction of jugal and squamosal (right) | y20 | 208.78 |
|  |  |  | Caudal edge of second postcanine tooth (left) | x11 | 232.22 |
|  |  |  | Rostral-most tip of rostrum | y1 | 244.13 |
|   |   |   | Rostral edge of canine along lingual palatine border (right) | y15 | 246.47 |
| CV2 | 23.2 | Rostral length and parietal shape | Caudal edge of last postcanine tooth (right) | x9 | -406.88 |
|  |  |  | Junction between L11 and L12 at palate midline | x13 | -393.64 |
|  |  |  | Rostral-most tip of rostrum | y1 | -302.66 |
|  |  |  | Lateral-most point of mastoid process (right) | y29 | -159.99 |
|  |  |  | Junction between L14 and L15 at palate midline | z16 | -158.39 |
|  |  |  | Caudal-most edge of first postcanine (left) | y17 | 174.21 |
|  |  |  | Suture of premaxilla and maxilla rostral to canine | y37 | 176.91 |
|  |  |  | Junction of nasal, frontal, and maxilla\* | x19 | 180.95 |
|  |  |  | Rostral edge of canine along lingual palatine border (right) | y15 | 189.01 |
|  |  |  | Caudal edge of last postcanine tooth (left) | y8 | 259.96 |
|   |   |   | Caudal edge of second postcanine tooth (left) | x11 | 316.89 |
| CV3 | 9.1 | Skull width and depth | Suture of maxilla and palatine (right) | z7 | -293.53 |

TABLE S5. (Continued)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | Caudal edge of second postcanine tooth (right) | y12 | -169.54 |
|  |  |  | Caudal edge of second postcanine tooth (left) | x11 | -165.11 |
|  |  |  | Rostral-most point of pterygoid at suture of pterygoid and palatine | y4 | -162.17 |
|  |  |  | Rostral edge of canine along lingual palatine border (right) | x15 | 166.46 |
|  |  |  | Caudal edge of last postcanine tooth (left) | y8 | 175.36 |
|  |  |  | Caudal-most edge of first postcanine (left) | x17 | 181.20 |
|   |   |   | Caudal-most suture of palatine, pterygoid, and alisphenoid | z5 | 212.17 |

TABLE S6. Procrustes distances between each feeding strategy in the cranial canonical variate analysis.

|  |  |  |  |
| --- | --- | --- | --- |
|   | Filter | Grip and tear | Pierce |
| Grip and tear | **0.105** | - | - |
| Pierce | **0.114** | **0.117** | - |
| Suction | **0.149** | **0.164** | **0.083** |
| Bolded numbers indicate p < 0.001 |  |

TABLE S7. Positive and negative coefficients for the two mandible canonical variates (CVs).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| CV | % Variation | Character Changes | Landmark | No. | CV Coefficient |
| CV1 | 69.3 | Mandible size and toothrow length | Ventral and lateral edge of canine | y17 | -62.99 |
|  |  |  | Ventral edge of mandible underneath the last postcanine | z7 | -57.7279 |
|  |  |  | Caudal-most point of coronoid process | y14 | -54.6347 |
|  |  |  | Lateral and caudal edge of last postcanine | x6 | -51.5041 |
|  |  |  | Lateral edge of canine midpoint | z3 | -42.1725 |
|  |  |  | Caudal-most point on curving edge of coronoid process | z16 | -41.2419 |
|  |  |  | Ventral edge of mandible underneath the tip of the coronoid process | z11 | -31.7447 |
|  |  |  | Lateral edge of canine midpoint | y3 | -31.0382 |
|  |  |  | Ventral edge of mandible underneath the canine | x5 | 30.0782 |
|  |  |  | Rostral-most point on curving edge of coronoid process | x15 | 32.3469 |
|  |  |  | Caudal-most point of mandibular condyle | y2 | 37.7421 |
|  |  |  | Rostral-most point on curving edge of coronoid process | z15 | 45.8972 |
|  |  |  | Ventral edge of mandible underneath the canine | z5 | 48.4986 |
|  |  |  | Dorsal-most tip of canine | z18 | 54.0809 |
|  |  |  | Rostral-most tip of mandible | y1 | 60.8958 |
|   |   |   | Dorsal-most tip of canine | x18 | 91.9645 |
| CV2 | 30.7 | Mandible depth and coronoid process shape | Ventral edge of mandible underneath the last postcanine | z7 | -58.8985 |
|  |  |  | Caudal-most point of mandibular condyle | x2 | -49.9903 |
|  |  |  | Lateral edge of canine midpoint | y3 | -43.9259 |
|  |  |  | Lateral point at midline of M1 | y8 | -37.3143 |
|  |  |  | Rostral-most tip of mandible | x1 | -36.4305 |
|  |  |  | Caudal-most point of coronoid process | z14 | -35.9112 |
|  |  |  | Ventral edge of mandible underneath the canine | x5 | -34.5623 |
|  |  |  | Ventral edge of mandible underneath the canine | z5 | -31.7527 |

TABLE S7. (Continued)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | Lateral edge of canine midpoint | z3 | -31.6091 |
|  |  |  | Dorsal-most point of coronoid process | z12 | -31.4565 |
|  |  |  | Lateral-most point of mandibular condyle | z9 | 34.6204 |
|  |  |  | Medial-most point of mandibular condyle | x10 | 42.5255 |
|  |  |  | Rostral-most tip of mandible | y1 | 46.9529 |
|  |  |  | Rostral-most point on curving edge of coronoid process | z15 | 48.3029 |
|  |  |  | Rostral-most tip of mandible | z1 | 52.7528 |
|  |  |  | Ventral edge of mandible underneath the canine | y5 | 55.0495 |
|   |   |   | Ventral and lateral edge of canine | x17 | 69.43 |

TABLE S8. Procrustes distances between each feeding strategy in the mandible canonical variate analysis.

|  |  |  |
| --- | --- | --- |
|   | Biting | Filter |
| Filter | **0.114** | - |
| Suction | **0.080** | **0.171** |
| Bolded numbers indicate p < 0.001 |

LITERATURE CITED

Boessenecker, R. W., and M. Churchill. 2018. The last of the desmatophocid seals: a new species of Allodesmus from the upper Miocene of Washington, USA, and a revision of the taxonomy of Desmatophocidae. Zoological Journal of the Linnean Society, <https://doi.org/10.1093/zoolinnean/zlx098>

Kienle, S. S., and A. Berta. 2016. The better to eat you with: the comparative feeding morphology of phocid seals (Pinnipedia, Phocidae). Journal of Anatomy 228:396–413.