**Appendix 1**. List of characters and polarities based on the matrix proposed by Wang et al. (2018).

1. **Auditory bulla**. Polarity: 0, bulla relatively inflated; 1, bulla less inflated.
2. **Relationship of paroccipital process and mastoid process**. Polarity: 0, paroccipital process separated from mastoid process by an inflated bulla; 1, no connection between the paroccipital process and the bulla, a narrow shelf connecting paroccipital and mastoid processes; 2, no connection between the paroccipital process and the bulla, a very broad surface area between paroccipital and mastoid processes.
3. **Foramen on dorsal rim of foramen magnum**. Polarity: 0, absent; 1, present.
4. **Size of infraorbital canal**. Polarity: 0, small, clearly less than 1/3 of orbital width; 1, large, around or more than 1/3 of orbital width.
5. **Postorbital process of the frontal**. Polarity: 0, small and sharp tip; 1, developed tip; 2, reduced to a smooth surface.
6. **Postorbital region between postorbital process of frontal and postorbital constriction**. Polarity: 0, not lengthened (shorter or similar length compared to the width of the postorbital processes of the frontal); 1, lengthened (clearly longer than the width of the postorbital processes of the frontal).
7. **Antorbital fossa**. Polarity: 0, absent; 1, present.
8. **Antorbital rim location**. Polarity: 0, above the P3 or between P3/P4; 1, above the P2.
9. **Dorsal root of zygomatic arch**. Polarity: 0, not anteriorly located relative to the ventral root; 1, clearly anteriorly located relative to the ventral root.
10. **Palatine foramen location**. Polarity: 0, at P4 level; 1, at P3 level or between P3 and P4; 2, between P1 and P2 level.
11. **Inion is more anteriorly located than lambdoidal crest**. Polarity: 0, no; 1, yes.
12. **Posterior outline of the lambdoidal crest in dorsal view.** Polarity: 0, straight; 1, curved.
13. **Lateral expansion of the mastoid process.** Polarity: 0, narrow; 1, similar to width of the zygomatic arches.
14. **Ventral expansion of the mastoid process.** Polarity: 0, at the level or above the auditory meatus; 1, below the auditory meatus.
15. **Relationship between the tympanohyal-bulla articulation and the stylomastoid foramen.** Polarity: 0, located in a common depression; 1, separated by a bony bridge.
16. **Location of the postglenoid foramen.** Polarity: 0, below the auditory meatus; 1, anterior to the auditory meatus, above the bulla in dorsal view.
17. **Angular process**. Polarity: 0, long; 1, shortened.
18. **Masseter muscle attachment area expansion**. Polarity: 0, not expanded; 1, ventrally expanded to beyond ventral rim of masseteric fossa.
19. **P1**. Polarity: 0, not reduced; 1, reduced or absent.
20. **P4 metastylar blade length.** Polarity: 0, long; 1, short.
21. **P4 metastylar notch**. Polarity: 0, absent; 1, present.
22. **P4 protocone**. Polarity: 0, cuspidate; 1, shelf-like.
23. **P4 protocone position**. Polarity: 0, mesial to paracone; 1, lingual to paracone.
24. **P4 protocone shelf.** Polarity: 0, not expanded; 1, distally expanded.
25. **P4 protocone cuspules on the distal face.** Polarity: 0, absent; 1, present.
26. **P4 hypocone**. Polarity: 0, absent or weak hypoconal crest; 1, present, low crowned; 2, present, high crowned.
27. **P4 parastyle**. Polarity: 0, absent; 1, small; 2, large.
28. **M1 cingulum.** Polarity: 0, mesiolabial and distolingual; 1, mediolingual.
29. **M1 talon.** Polarity: 0, absent; 1, slightly enlarged; 2, distally expanded.
30. **Crenulation of M1**. Polarity: 0, absent; 1, present.
31. **M1 cuspule.** Polarity: 0, absent; 1, present, distal to metacone; 2, present, lingual to metacone.
32. **Distal accessory cusp on p4**. Polarity: 0, absent or weak; 1, distinctly developed.
33. **Distal metaconid ridge on m1**. Polarity: 0, absent; 1, present.
34. **Metastylid on m1**. Polarity: 0, absent; 1, present.
35. **Widening of m1 talonid**. Polarity: 0, not widened; 1, widened.
36. **Notch between m1 trigonid and talonid**. Polarity: 0, absent or shallow; 1, deep.
37. **Talonid of m1**. Polarity: 0, trenchant; 1, basined.
38. **Mandibular depth and width.** Polarity: 0, shallow and slim; 1, deep and slim; 2, deep and robust.
39. **Ventral margin of the mandible.** Polarity: 0, scaphoid; 1, straight.
40. **p4 distal cingulid.** Polarity: 0, absent, weak; 1, present and curve; 2, present and straight
41. **Height of p4 protoconid vs m1 protoconid.** Polarity: 0, p4 protoconid lower than m1 protoconid; 1, p4 protoconid as high as m1 protoconid; 2, p4 protoconid higher than m1 protoconid.
42. **m2 occlusal shape.** Polarity: 0, rounded; 1, mesiodistally compressed.
43. **Canines crenulation**. Polarity: 0, absent; 1, present.
44. **Number of mental foramina.** Polarity: 0, two of similar size; 1, two of different size; 2, three; 3, more than three.
45. **position of the first rostral mental foramina.** Polarity: 0, under the p2; 1, under the p3; 2, between p2 and c; 3, under the distal margin of c.
46. **P4 distolingual cingulum**. 0, absent; 1, low with no crest; 2, high crested extending to the hypocone crest.
47. **P4 distobuccal cingulum.** 0, weak/absent; 1, prominent.
48. **M1 metacone vs paracone.** 0, metacone much smaller than paracone; 1, metacone smaller than paracone; 2, metacone as big as paracone.

TableS1 - Loadings of the Principal Component Analysis (PCA) for upper teeth values in extant and fossil Lutrinae

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|   | PC1 | PC2 | PC3 | PC4 | PC5 | PC6 | PC7 | PC8 | PC9 |
| P2L | -0.24783 | 0.643022 | 0.225049 | -0.30382 | 0.342619 | 0.059276 | -0.47884 | 0.146263 | 0.102793 |
| P2W | -0.33058 | 0.389383 | -0.11564 | -0.15218 | -0.73459 | 0.096281 | 0.244653 | 0.221318 | -0.21175 |
| P3L | -0.36954 | 0.133277 | -0.20945 | -0.21641 | 0.476682 | -0.14638 | 0.697358 | -0.13737 | 0.03383 |
| P3W | -0.36504 | -0.15916 | -0.31275 | -0.23441 | -0.2028 | -0.30242 | -0.38334 | -0.63512 | 0.075773 |
| P4L | -0.33513 | 0.230331 | -0.1239 | 0.782877 | 0.083442 | 0.358669 | -0.04891 | -0.26148 | -0.00443 |
| P4W | -0.36528 | -0.26072 | -0.24628 | 0.147395 | -0.02452 | -0.16919 | -0.10796 | 0.566707 | 0.595128 |
| M1L | -0.3172 | -0.40114 | 0.341863 | -0.3114 | -0.02753 | 0.696999 | 0.0513 | -0.10607 | 0.155494 |
| M1Lext | -0.28359 | -0.05178 | 0.773121 | 0.224502 | -0.12712 | -0.47525 | 0.128309 | -0.09344 | 0.03948 |
| M1W | -0.36428 | -0.32739 | -0.06092 | 0.027587 | 0.22396 | -0.07341 | -0.21085 | 0.312834 | -0.74684 |

TableS2 - Loadings of the Principal Component Analysis (PCA) for lower teeth values in extant and fossil Lutrinae

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|   | PC1 | PC2 | PC3 | PC4 | PC5 | PC6 | PC7 | PC8 |
| p2L | -0.24628 | 0.671886 | -0.1003 | -0.2035 | -0.49218 | -0.33166 | 0.287238 | -0.04129 |
| p2W | -0.35754 | 0.290603 | -0.26621 | 0.735756 | 0.261309 | -0.14365 | -0.28605 | -0.06907 |
| p3L | -0.36159 | 0.308949 | 0.396475 | -0.2916 | 0.062388 | 0.48243 | -0.47481 | -0.26363 |
| p3W | -0.37873 | -0.21326 | 0.196729 | 0.385955 | -0.43683 | 0.481397 | 0.361656 | 0.264696 |
| p4L | -0.39317 | 0.036604 | 0.311039 | -0.20043 | 0.489553 | -0.26924 | 0.159246 | 0.607989 |
| p4W | -0.35802 | -0.36776 | 0.315212 | 0.029475 | 0.063153 | -0.37947 | 0.261106 | -0.64821 |
| m1L | -0.36922 | -0.10567 | -0.6889 | -0.32659 | 0.271789 | 0.320918 | 0.275299 | -0.13647 |
| m1W | -0.34386 | -0.41885 | -0.2291 | -0.18857 | -0.42101 | -0.29225 | -0.55687 | 0.213332 |