**APPENDIX 1**

 *Morphological character descriptions*

1. Premaxilla, rostral tip: straight (0); hooked (1); strongly down-turned (as in flamingos) (2).

2. Nares, length: extends for more than half length of beak (0); less than half length of beak (1).

3. Large, paired fenestrae perforate occipital region of skull dorsolateral to foramen magnum: absent (0); present (1).

4. Skull, shape in caudal view: dorsal face rounded (0); dorsal face very flat, giving skull a square appearance (1). See Bocheński (1994: figure 7D).

5. Ossified median raphe extends crista nuchalis saggitalis caudally, forming a wedge-shaped eminence: absent (0); present (1). This raphe serves as an attachment site of *m. adductor mandibulae* (Zusi and Storer 1969).

6. Vomer, rostral end expanded mediolaterally forming small, spoon-like tip: absent (0); present (1).

7.Tuberculum basilare: flat or modestly projected (0); strong projection contribute to lateral walls bounding lamina parasphenoidalis (1).

8. Mandible, extensive pneumatization: absent (0); present (1).

9. Mandible, processus retroarticularis elongate and mediolaterally compressed: absent (0); present (1).

10. Mandible, shape of fossa caudalis in posterior view: dorsoventrally narrow, rectangle in outline (0); trapezoidal in outline (1); open pneumatic chamber (2). Bocheński (1994) recognized 4 states for this character in grebe. Here, we combine states B, C, and D from that study into a single state (1).

11. Mandible, shape of fossa caudalis: oriented caudally, not visible in dorsal view (0); oriented caudodorsally, visible in dorsal view (1).

12. Axis, strong lateral flanges project from processus ventralis: absent (0); present (1).

13. Posterior cervical vertebrae bear chevron-like processes: absent (0); present (1). The distinctive morphology of the cervical vertebrae in *Aechmophorus* was noted by Storer (1960).

14. Presacral vertebrae, number: twenty-two or less (0); twenty-three (1); twenty-four (2); twenty-five (3), twenty-six (4); twenty-seven or more (5). Sanders (1967) observed significant intraspecific variation in the number of presacral vertebrae in some grebes. We combine our own observations with those of Sanders (1967), resulting in polymorphic codings for several species. Ordered.

15. Sternum, labri externi: separated by a notch at midline (0); meet at midline, forming a continuous ridge (1). Murray (1967) described this character and observed the derived state of this character in the fossil grebe *Pliolymbus baryosteus*.

16. Sternum, labrum externum: level with labrum internum at midline (0); projected cranial to labrum internum at midline (1). This character was scored non-comparable for taxa in which the labri externi do not meet at midline.

17. Sternum, trabecula lateralis: narrow (0); mediolaterally wide throughout length (1).

18. Sternum, margo caudalis, notch at midline: absent (0); present (1).

19. Furcula, apophysis furculae: absent or present as a minute tubercle (0); strong, blade-like projection (1); two tubercles present, each slightly lateral of midline (2); low, mediolaterally wide projection with slight tubercles at lateral ends (3).

20. Coracoid, processus procoracoideus: absent (0); present (1).

21. Coracoid, processus lateralis: placed near the facies articularis sternalis and triangular (0); displaced towards omal end and forming a weak flange (1); displaced towards omal end and forming a strong, triangular expansion (2).

22. Coracoid, facies articularis sternalis extends over significant portion of ventral surface: absent (0); present (1).

23. Ulna, tuberculum carpale: distally placed, forms a small incisura tuberculi carpalis (0); proximally displaced, creating larger incisura tuberculi carpalis (1).

24. Pelvis, proportions: wide (0); mediolaterally compressed (1); extremely mediolaterally compressed (2). See Fjeldså (2004: figure 4.2).

25. Ischium, caudal extent: equal to or shorter than ilium (0); projects moderately beyond ilium (1); projects far beyond ilium (2). Ordered.

26. Proportions of hindlimb: femur much shorter than tarsometatarsus (0); femur and tarsometatarsus subequal in length (1).

27. Hypertrophied patella: absent (0); present (1).

28. Tibiotarsus, proximal projection of cnemial crests: short, length of cnemial crests much less than 10% of the total length of tibiotarsus (0); elongated, length of cnemial crests between 10% and 15% of the total length of tibiotarsus (1); extremely elongated, length of cnemial crests greater than 15% of the total length of tibiotarsus. Ordered.

29. Tibiotarsus, anterior projection of distal condyles: subequal (0); condylus lateralis projects farther (1).

30. Tibiotarsus, distal notch in rim of condylus medialis: absent (0); present (1).

31. Tibiotarsus, distal notch in rim of condylus lateralis: absent (0); present (1).

32. Tarsometatarsus, canal for tendon of m. flexor perforatus digiti II: absent (0); present (1). We code *P. major* (0/1) for this character based on reports of variation in this species (Olson 1995).

33. Tarsometatarsus, canal for tendon of m. flexor perforatus digiti II: centrally located, directly plantar to canal for tendon of m. flexor digitorum longus (0); laterally displaced relative to level of canal for tendon of m. flexor digitorum longus (1). This character is scored non-comparable for taxa lacking the canal.

34. Tarsometatarsus, shaft: slender with strong mediolateral compression (0); stout (1).

35. Cervical epaxial musculature: ossification of tendons absent or sparse (0); large bundles formed by intratendinous ossifications flank cervical vertebrae (1). As noted Storer (2000), these ossifications are sometimes discarded in preparation.

36. M. extensor longus digiti III, distal head: absent (0); present (1). Scorings are based on the work of Sanders (1967).

37. Rostrum, wide black ring around bill in breeding adult: absent (0); present (1).

38. Rima oris (gape), bright yellow area of bare skin forming 'grin patch': absent (0); present (1).

39. Feathers of forehead, distal barbs fused into shaft; absent (0); present (1). Scorings are based on the work of Storer and Muller (2000).

40. Feathers of head, median crest: absent (0); forming a median occipital crest (1); forming a small, helmet-like crest (2).

41. Feathers of regio auricularis ('ear feathers'): undifferentiated from adjacent feathers (0); form a fan of plumes (1); arranged as a broad ruff (2); white elongate feathers arranged throughout plumage on side of head (these feather give the head a 'frosty' appearance in *Poliocephalus*)(3); all feathers long and narrow (4). Modified from character 16 of Fjeldså (2004).

42. Colouration pattern on dorsal surface of wing: no white panel present (0); tips of remiges secundariae white (1); white wing panel formed by remiges secundariae (2); white wing stripe formed by colouration of remiges primariae and remiges secundariae (3). Modified from character 26 of Fjeldså (2004).

43. White triangular panel on dorsal surface of patagium: absent (0); present (1).

44. Rectrices: well-developed, forming distinct tail (0); reduced to loose tufts, forming short and indistinct tail (1).

45. Pedal digits: webbed over most of length (0); lobed (1).

46. Hatchling plumage extensively striped: absent (0); present (1).

47. Hatchling plumage, buff or reddish colouration: absent (0); present over most of corona, occiput and nucha (head and neck) (1); restricted to a bar across occiput (2). Codings for most taxa were taken from Fjeldså (2004: plate 8 and text).

48. Corona (crown) bare in downy young: absent (0); present (1). Codings after Storer (1967).

49. Corona (crown) with patch of red feathers in downy young: absent (0); present (1). Codings after Storer (1967).

**APPENDIX 2**

 *Morphological character matrix*

A = 0/1, B = 1/2, C = 1/3, D = 2/3, E = 3/4, F = 4/5, G = 2/3/4, non-comparable = -.

Taxon 10 20 30

*Phoenicopterus chilensis* 2 1 1 0 0 0 0 1 1 1 1 0 0 1 1 0 0 0 1 1 0 0 0 0 0 0 0 0 0 1

*Phoenicopterus ruber* 2 1 1 0 0 0 0 1 1 1 0 0 0 1 1 0 0 0 1 1 0 0 0 0 0 0 0 0 0 1

*Aechmophorus clarkii* 0 1 0 1 1 0 1 0 0 1 1 1 1 5 0 - 1 1 2 0 2 1 0 2 1 0 1 2 1 1

*Aechmophorus occidentalis* 0 1 0 1 1 0 1 0 0 1 1 1 1 5 0 - 1 1 2 0 2 1 1 2 1 0 1 2 1 1

*Limnodytes dominicus* 0 0 0 0 0 0 0 0 0 ? 0 0 0 B 1 0 0 1 1 0 1 1 0 1 2 0 1 1 0 1

*Podiceps auritus* 0 0 0 0 0 0 0 0 0 1 1 0 0 E 0 - 0 1 1 0 1 1 0 2 0 0 1 2 A 1

*Podiceps cristatus* 0 0 0 0 0 0 0 0 0 1 1 0 0 F 1 1 0 1 1 0 2 1 1 2 0 0 1 2 0 1

*Podiceps grisegena* 0 0 0 0 0 A 0 0 0 1 1 0 0 E 0 - 0 1 3 0 2 1 1 2 0 0 1 2 1 1

*Podiceps major* 0 1 0 A 0 0 0 0 0 1 1 0 0 F 0 - 0 1 C 0 2 1 1 2 0 0 1 1 0 0

*Podiceps nigricollis* 0 0 0 0 0 0 0 0 0 0 1 0 0 G 0 - 0 1 1 0 B 1 0 1 0 0 1 2 0 1

*Podiceps occipitalis* 0 0 0 0 0 0 0 0 0 0 1 0 0 D 0 - 0 1 A 0 1 1 ? 1 2 0 1 1 0 1

*Podilymbus gigas* 1 0 0 0 0 1 0 0 0 1 1 0 0 D 1 1 0 1 0 0 1 1 ? 2 0 1 1 ? 0 0

*Podilymbus podiceps* 1 0 0 0 0 1 0 0 0 1 1 0 0 B 1 1 0 1 0 0 1 1 0 2 0 1 1 1 0 0

*Poliocephalus poliocephalus* 0 0 0 0 0 0 0 0 0 1 0 0 0 2 1 ? 0 1 0 0 1 1 0 1 2 0 1 B 0 A

*Rollandia microptera* 0 0 1 0 0 0 0 0 0 1 A 0 0 D 0 - 0 1 0 0 1 1 0 1 0 0 1 1 0 A

*Rollandia rolland* 0 0 1 0 0 0 0 0 0 1 A 0 0 D 0 - 0 1 0 0 2 1 0 1 0 0 1 1 0 A

*Tachybaptus ruficollis* 0 0 0 0 0 0 0 0 0 1 0 0 0 2 1 0 0 1 B 0 0 1 0 1 2 0 1 1 0 0

*Tachybaptus novaehollandiae* 0 0 0 0 0 1 0 0 0 1 0 0 0 1 1 0 0 1 1 0 2 1 0 1 2 0 1 1 0 0

*Thiornis sociata* ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? 0 1 ? 0 1 1 0 ? 2 0 1 1 ? 0

Truckee Fossil Species A? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? 0 1 1 0 1 1 ? 1 ? 0 1 1 0 1

Truckee Fossil Species B ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? 1 ? 0 1 1 ? ?

Taxon 40 49

*Phoenicopterus chilensis* 0 0 - 0 0 ? 0 0 0 0 0 0 0 0 0 0 0 0 0

*Phoenicopterus ruber* A 0 - 0 0 ? 0 0 0 0 0 0 0 0 0 0 0 0 0

*Aechmophorus clarkii* 1 0 - 0 1 ? 0 0 0 0 0 1 0 1 1 0 0 1 0

*Aechmophorus occidentalis* 1 0 - 0 1 1 0 0 0 0 0 1 0 1 1 0 0 1 0

*Limnodytes dominicus*  0 0 - 0 0 1 0 0 0 0 0 3 0 1 1 1 0 0 1

*Podiceps auritus*  A 0 - 0 0 ? 0 0 0 0 2 2 A 1 1 1 0 1 0

*Podiceps cristatus*  0 0 - 0 0 ? 0 0 0 0 2 2 1 1 1 1 0 1 0

*Podiceps grisegena*  0 0 - 0 0 1 0 0 0 0 0 2 1 1 1 1 0 1 0

*Podiceps major*  0 A - 0 0 1 0 0 0 2 0 3 0 1 1 1 0 1 0

*Podiceps nigricollis*  0 0 - 0 0 ? 0 0 0 1 1 2 0 1 1 1 0 1 0

*Podiceps occipitalis*  0 0 - 0 0 1 0 0 0 1 1 2 0 1 1 1 0 1 0

*Poliocephalus poliocephalus* 0 0 - 0 0 1 0 0 0 0 3 3 0 1 1 1 1 0 1

*Podilymbus gigas*  ? 1 1 1 0 0 1 0 1 0 0 1 0 1 1 1 2 0 1

*Podilymbus podiceps*  0 1 1 1 0 0 1 0 1 0 0 1 0 1 1 1 2 0 1

*Rollandia microptera*  0 1 0 0 0 1 0 0 0 0 4 2 0 1 1 1 1 0 0

*Rollandia rolland*  0 1 0 0 0 1 0 0 0 0 4 2 0 1 1 1 1 0 0

*Tachybaptus ruficollis*  0 1 0 0 0 1 0 1 0 0 0 1 0 1 1 1 1 0 1

*Tachybaptus novaehollandiae* 0 1 0 0 0 ? 0 1 0 0 0 3 0 1 1 1 1 0 1

*Thiornis sociata*  ? ? ? 0 ? ? ? ? ? ? ? ? ? ? ? ? ? ? ?

Truckee Fossil Species A0 ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ?

Truckee Fossil Species B ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ?

**APPENDIX 3**

*Specimens examined for morphological character coding*

|  |  |
| --- | --- |
| Taxon | Specimens |
| *Aechmophorus clarkii* | AMNH 20027; NCSM 19442; USNM 560542 |
| *Aechmophorus occidentalis* | AMNH 18666; NCSM 4168, 4169; USNM 560552, 569547 |
| *Limnodytes dominicus* | USNM 343476, 347811 |
| *Podiceps auritus* | AMNH 23137; NCSM 16156, 16157, 18842; USNM 344943, 347813, 610498, 622496 |
| *Podiceps cristatus*  | AMNH 25241; USNM 503553, 560592 |
| *Podiceps grisegena* | AMNH 3878; NCSM 16163; USNM 271892, 612747, 612759 |
| *Podiceps major* | AMNH 5044; USNM 227344, 49117, 59896, 614513 |
| *Podiceps nigricollis* | AMNH 19791; USNM 560607, 561078 |
| *Podiceps occipitalis* | USNM 227487, 227545 |
| *Podilymbus gigas* | USNM 343470, 343471 |
| *Podilymbus podiceps* | AMNH 10506; NCSM 10255, 17617, 18617; USNM 500858 |
| *Poliocephalus poliocephalus* | AMNH 11460; USNM 121237 |
| *Rollandia rolland* | USNM 614509, 614512 |
| *Rollandia micropterum* | USNM 345660 |
| *Tachybaptus novaehollandiae* | USNM 561519, 561520 |
| *Tachybaptus ruficollis* | AMNH 24767; USNM 292001, 292009 |
| *Thiornis sociata* | USNM 477226 (cast of holotype) |