

## Supplementary Information Files

### SI 1. Moa species and presence of tracheal rings

Moa taxon	Presence of tracheal rings	Ring type
<i>Dinornis robustus</i>	Present	Tracheal rings*
<i>Megalapteryx didinus</i>	Present	Tracheal rings and syringeal keel ring (NMNZ S. 028206, S. 023575)
<i>Anomalopteryx didiformis</i>	Present	Incomplete and complete tracheal rings, bronchosyringeal half-rings and syringeal keeled ring (NMNZ S. 024417)
<i>Euryapteryx curtus</i>	Present	Tracheal rings*
<i>Pachyornis australis</i>	Present	Tracheal rings*
Unidentified moa taxa	Present	Syringeal keeled rings (NMNZ S. 44754, more similar in shape to <i>Anomalopteryx didiformis</i> than <i>Megalapteryx didinus</i> ).

\*Presence or absence of keeled syringeal ring is not confirmed.

## SI 2. Syrinx, hyoid and larynx characters and character states

1. Syrinx Type (Livezey and Zusi 2007: 0738): Unordered
  0. Type bronchial; 2. Type tracheal; 3. Type tracheo-bronchial
2. Ossification of syrinx elements (Livezey and Zusi 2007: 0735): Ordered
  0. Ossification present; 2. Cartilaginous
3. Cart. bronchosyringaeles; number present: Ordered
  0. 0; 1. 1-4; 2. 5-8; 3. >8
4. Cart. bronchosyringaeles medial ridges bordering internal membranes (Griffiths 1994: 40): Ordered
  0. No fusion; 1. First and second bronchial rings fused; 2. Three or more bronchial rings fused
5. Modifications to shape of incomplete cart. bronchosyringaeles (Griffiths 1994: 34): Unordered
  0. Wider at medial ends; 1. Wider laterally with narrowed ends medially; 2. Uniform width
6. Asymmetry (Clarke *et al.* 2016: 6): Ordered
  0. Absent; 1. Present, minor; 2. Present, major

Note: Minor asymmetry occurs as a result of slight size or shape variation between the left and right sides of the syrinx. Major asymmetry when one side is considerably larger or of different shape to the other, includes single-sided presence of associated structures.
7. Cart. tracheosyringaeles incomplete dorsally: Unordered
  0. Absent; 1. Present
8. Cart. tracheosyringaeles width relative to cart. bronchosyringaeles (Clarke *et al.* 2016: 4): Unordered
  0. Tracheosyringal rings thinner in width; 1. Uniform width; 2. Bronchosyringal rings thinner in width
9. Cart. tracheosyringaeles directed downwards along the midline (Forbes 1881): Unordered
  0. One to two rings; 1. >2 rings; 2. None
10. Tympanum (Griffiths 1994: 20, 21; Livezey and Zusi 2007: 0736): Unordered
  0. Present; 1. Absent
11. Shape of tympanum, or caudal end of trachea if tympanum absent (Griffiths 1994: 26): Ordered
  0. Gradually widens caudally; 1. Almost cylindrical; 2. Cylindrical; 3. Mediolateral compression
12. Pessulus (Griffiths 1994: 15): Unordered
  0. Absent; 1. Present; 2. Dorsal proc. Pessuliform present

*Note- Absence of the pessulus results in Membrana tympaniformis connecting both bronchial tubes medially at the tracheal bifurcation*
13. Pessulus (Livezey and Zusi 2007: 0739): Ordered
  0. Cartilaginous; 1. Full or part ossification

14. Lateral intervals between cart. tracheosyringaeles and cart. bronchosyringaeles (Clarke *et al.* 2016: 3; Griffiths 1994: 36): Ordered

- 0. Wide lateral intervals between tracheal and bronchial rings; 1. Small interval between tracheal and bronchial rings; 2. No interval; overlap, or almost overlap, of tracheal and bronchial rings

15. Dorsal indentation of tracheosyringal rings: Unordered

- 0. Present; 1. Absent

16. Musculature (Gaunt 1983): Ordered

- 0. No intrinsic musculature; 1. 1 or 2 intrinsic muscle pairs; 2. 3 or more intrinsic muscle pairs

17. Basiurohyale (Tomlinson 2000): Ordered

- 0. Cartilaginous; 1. Part ossification; 2. Full ossification

18. Basihyale and urohyale (Livezey and Zusi 2007: 0758): Unordered

- 0. Synostosis, articular surfaces indiscernible; 1. Syndesmosis, articular surfaces discernible

19. Urohyale (Livezey and Zusi 2007): Unordered

- 0. Present; 1. Absent

*Note-* When absent, basihyal bone terminates just caudal to basihyal-ceratobranchial joint.

20. Urohyale shape (Tomlinson 2000): Unordered

- 0. Element with rounded caudal edge; 1. Element with angular caudal edge; 2. Urohyal absent

21. Basihyale rostral edge (Livezey and Zusi 2007; Tomlinson 2000): Ordered

- 1. Basihyoid rostral central concavity; 1. Basihyoid flattened rostral edge; 2. Basihyoid rostral edge convex

22. Ceratobranchiale (Tomlinson 2000): Unordered

- 0. Cartilaginous; 1. Ossified

23. Epibranchiale length relative to ceratobranchial (Livezey and Zusi 2007: 0763): Ordered

- 0. Epibranchials shorter than ceratobranchials; 1. Both comparable in length; 2. Epibranchials longer than ceratobranchials

24. Tongue shape, dorsal view (Erdogan and Iwasaki 2013): Unordered

- 0. Reduced triangular; 1. Reduced ovular; 2. Intermediate (Triangular) tongue corpus; 3. Elongated corpus

*Note-* Elongated corpus includes all elongated tongue types as described by Erdogan and Iwasaki (2013).

25. Tongue shape, frontal view: Unordered

- 0. Rounded tongue; 1. Dorso-ventral flattening

26. Papillae along margins of tongue corpus (Erdogan and Iwasaki 2013): Unordered

- 0. Absent; 1. Posterolateral corner of the tongue terminate with small lateral papillae; 2. Numerous lingual papillae along lateral margins
- 27. Paraglossum (Crole and Soley 2012b): Unordered
  - 0. Paired paraglossalia; 1. Single paraglossum
- 28. Paraglossum, when only single paraglossum (Tomlinson 2000): Unordered
  - 0. Rounded; 1. Triangular; 2. Triangular with caudal central concavity; 3. Elongate triangular
- 29. Cart. cricoidea (Zweers *et al.* 1981): Ordered
  - 0. Cartilaginous or rarely small ossification centres in older individuals; 1. Consistent part or full ossification of corpus; 2. Ossified corpus
- 30. Cart. cricoidea corpus, crista ventralis (McLelland 1989): Ordered
  - 0. Absent; 1. Only shallow ridge(s) present; 2. Prominent ridge(s) only part length of corpus; 3. Prominent ridge(s) full length of corpus
- 31. Cart. cricoidea corpus, proc. rostralis (Zweers *et al.* 1981): Ordered
  - 0. Prominent, flattened rostral process; 1. Prominent with angular rim; 2. Reduced, but present; 3. Absent, flattened cranial edge of corpus
- 32. Ala; cart. cricoidea dorsalis (Zweers *et al.* 1981): Unordered
  - 0. Wings fused, partly fused, or articulating with each other, closing cricoid ring dorsally; 1. Wings unfused, cricoid ring closed dorsally by procricoid articulation
- 33. Cart. cricoidea fusion with cart. tracheales (McLelland 1989): Unordered
  - 0. One or more tracheal rings part-fused with caudal end of cricoid; 1. No tracheal rings fused with cricoid
- 34. Cart. procricoidea (Zweers *et al.* 1981): Unordered
  - 0. Ossified; 1. Cartilaginous; 2. Absent
- 35. Cart. procricoidea corpus shape, dorsal view (Zweers *et al.* 1981): Unordered
  - 0. Cuboidal; 1. Triangular; 2. Circular; 3. Diamond; 4. Oval
- 36. Cart. procricoidea cauda, the ventral, ventro-caudad pointing tail (Zweers *et al.* 1981): Unordered
  - 0. Absent; 1. present
- 37. Cart. arytenoidea ossification (Zweers *et al.* 1981): Ordered
  - 0. Ossified; 1. Part ossified; 2. Cartilaginous
- 38. Cart. arytenoidea, proc. rostralis and caudalis (Zweers *et al.* 1981): Ordered
  - 0. Proc. caudalis and rostralis present; 1. Only proc. caudalis present; 2. Neither present
- 39. Cart. arytenoidea shape (McLelland 1989, p. 73): Unordered
  - 0. Rounded; 1. Flattened
- 40. Cart. arytenoidea and glottis lips (Crole and Soley 2012b): Unordered

- 0. Arytenoid cartilage supports glottis lips; 1. Arytenoid cartilage a separate structure to glottis lips
- 41. Laryngeal papillae, extending from elevated glottis lips (Crole and Soley 2012b): Ordered
  - 0. No papillae present; 1. 1-2 papillae; 2. 3-8 papillae; 3. > 8 papillae
- 42. Laryngeal papillae (Rodrigues *et al.* 2012): Ordered
  - 0. Extend only from lateral margins; 1. Extend from both lateral and caudal margins; 2. Extend only from caudal margins
- 43. Articulation of the maxillary process of the nasal with the maxilla: Unordered
  - 0. Absent; 1. Present

**SI 3. Character coding for 28 palaeognath and outgroup taxa**

Nothura_maculosa	211000020120?0101000110???132?1110??011???
Eudromia_elegans	21???00?01?0?0101000210???
Crypturellus	211020020120?0101000111???
Megalapteryx	20?0??1?1?011?1?00002110111?212?0???
Dinornis_robustus	20?0??1?1?011?1?00002110111?213?0???
Pachyornis_geranoides	20?0??1?1?011?1?00002110111?201?0???
Pachyornis_elephantopus	20?0??1?1?011?1?00002110111?201?0???
Pachyornis_australis	20?0??1?1?011?1?00002110111?201?0???
Anomalopteryx	20?0??1?1?011?1?00002110111?212?0???
Emeus_crassus	20?0??1?1?011?1?00002110111?222?0???
Euryapteryx_curtus	20?0??1?1?011?1?00002110111?211?0???
Casuarius_bennetti	???
Casuarius_casuarius	21?001101110?1000000110012110021113121110?1
Dromaius_novaehollandiae	21?0??1??100?1100000110012110010110021110?1
Dromaius_baudinianus	???
Apteryx_australis	212020101100?21110011101?0??03311??????121
Apteryx_owenii	212020101100?21010011101?1??03311??????121
Aepyornis	21???
Pterocnemia	???
Rhea_americana	20202002100110112?1211001111003001112100321
Struthio_camelus	211020120112?11000010100110?103011111000211
Lithornis	?1???
Grus_rubicunda	20?10?0?10?11?1?2101?1??????220?0?????????
Anhima_cornuta	???
Anseranas_semipalmata	20???0?2?0311????????????????220?1?????????
Leipoa_ocellata	????????????????2000210?????????????????
Gallus_gallus	20?121112001101?200101??????2?1110411010322
Chauna_torquata	20?0?0?2???