Morphometric classification of kangaroo bones reveals paleoecological change in northwest Australia during the terminal Pleistocene

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Supplementary Note. Pes bone shape variation between macropod species

\textit{Large macropods}

The main separation among astragali of large macropods is along Principal Component (PC) 2. This is driven by the breadth of the navicular facet, followed by differences in the proportions of the talocalcaneal facets on the plantar surface of the astragalus (Fig. S1). The astragali of agile wallaby, common wallaroo and the northern nail-tail wallaby exhibit a broad navicular facet, a shallow and narrow medial talocalcaneal facet and a short lateral talocalcaneal facet. In contrast red and grey kangaroo astragali have a deep and broad medial talocalcaneal facet and a longer lateral talocalcaneal facet.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{FigureS1.png}
\caption{Proportional shape change between astragali of large macropods. Arrows indicate the direction of measurement change between taxa.}
\end{figure}
Calcanea of agile wallaby and northern nail-tail wallaby are separated from the other large macropods along PC1 by a more deeply stepped calcaneocuboid articulation and a broader sustentaculum tali for passage of the flexor digitorum longus (Fig. S2). Grey and red kangaroos and the wallaroos have a broader tuber calcanei and a longer lateral calcaneotalar facet. Red and grey kangaroos are separated from the wallaroos along PC2 by a more deeply stepped calcaneocuboid articulation and more slender tuber calcanei.

Supplementary Figure S2. Shape variation between calcanea of large macropods.
Fourth metatarsal shape of large macropods overlaps substantially, although some difference can be observed along PC1 associated with metatarsal length and robusticity of the metatarsal shaft. Red and grey kangaroos have longer, more mediolaterally slender metatarsals, while wallaroos, agile wallabies and northern nail-tail wallabies have shorter, more robust metatarsals (Fig. S3).

Medium macropods
The medium sized rock-wallaby astragali are separated from spectacled hare-wallabies and the nail-tail wallabies along PC1 by a longer lateral talocalcaneal facet and a broad navicular facet (Fig. S4). The astragali of spectacled hare-wallabies and nail-tail wallabies have a deeper medial talocalcaneal facet and broader trochlear crests than rock-wallabies. While astragali of both species of nail-tail wallaby are similar in shape to spectacled hare-wallabies the former are substantially larger in size.
Medium sized rock-wallaby calcanea are separated from spectacled hare-wallabies and nail-tail wallabies along PC1 by a longer lateral calcaneotalar facet and a broader tuber calcanei (Fig. S5). In contrast, spectacled hare-wallabies and nail-tail wallabies have more deeply stepped calcaneocuboid articulation and a deeper medial sustentaculum tali.

Supplementary Figure S5. Shape variation between calcanea of medium macropods. Arrows indicate direction of measurement change between genera.

Rock-wallabies are differentiated from spectacled hare-wallabies along PC1 by comparatively short and mediolaterally broad fourth metatarsals (Fig. S6). Metatarsal shape of the two species nail-tail wallabies does not overlap in the main variation of the PCA. Northern nail-tail wallabies exhibit more slender metatarsals than brindled nail-tail wallabies which are very similar in shape to those of rock-wallabies but have a dorsoventrally taller shaft.

Supplementary Figure S6. Shape variation between fourth metatarsals of medium macropods. Arrows indicate direction of measurement change between genera.
**Small macropods**

The astragali of bettongs have a narrower lateral talocalcaneal facet, broader medial talocalcaneal facet and broader navicular facet than rufous and spectacled hare-wallabies (Fig. S7). Banded hare-wallaby astragali are intermediate in shape between the bettongs and other hare-wallabies in the main variation of the PCA and share similar features with both. Astragali of juvenile small macropods tend to score negatively along PC2 which is strongly associated with a longer talar neck.

![Supplementary Figure S7. Shape variation between astragali of small macropods. Arrows indicate direction of measurement change between genera.](image)

Bettong calcanea are separated from the other small macropods along PC1 by a narrow tuber calcanei, and broad dorsolateral calcaneocuboid articulation and broad medial calcaneotalar facet (Fig. S8). Conversely hare-wallabies and the Nabarlek have a broad tuber calcanei, a narrow medial calcaneotalar facet and long medial process on the sustentaculum tali. The shape of hare-wallaby calcanea vary from the Nabarlek along PC2 with the latter exhibiting a longer lateral calcaneotalar facet and shorter calcaneocuboid step.

![Supplementary Figure S8. Shape variation between calcanea of small macropods. Arrows indicate direction of measurement change between genera.](image)
Bettong and banded-hare wallaby fourth metatarsal shape overlaps entirely in the main variation of the PCA and are visually very similar in shape (Fig. S9). Rufous hare-wallaby metatarsals can be differentiated from other small macropods by their longer and more slender shape. Narbalek metatarsals are intermediate in shape to the rufous hare-wallaby and bettongs. Although proportionally similar, the proximal end of bettong fourth metatarsals is distinctive, exhibiting a ‘L’ shaped articulation while other small macropods have a more triangular proximal articulation (Fig. S9).

Supplementary Figure S9 Shape variation between fourth metatarsals of small macropods. Arrows indicate direction of measurement change between genera.
Supplementary Figure S10. Archaeological specimens from Boodie Cave examined in this study. (Top) astragali superior (L) and inferior views (R); (Middle) calcanea superior (L) and medial (R) views; (Bottom) fourth metatarsals superior (L) and lateral (R) views.
Supplementary Figure S11. Left macropod astragalus showing measurements used in this study. (A) superior view, (B) inferior view, (C) medial view.
Supplementary Figure S12. Right macropod calcaneus, showing measurements used in this study. (A) superior view, (B) inferior view, (C) medial view, (D) anterior view.
Supplementary Figure S13. Left macropod fourth metatarsal showing measurements used in this study. (A) superior view, (B) medial view.
Supplementary Figure S14. Loadings for linear discriminant 1 on three macropod pes bones. **top** large macropod astragali (left), calcanea (middle) & fourth metatarsals (right); **middle** medium macropod astragali (left), calcanea (middle) & fourth metatarsals (right); **bottom** small macropod astragali (left), calcanea (middle) & fourth metatarsals (right)
| Taxa                                      | Astragali | Calcanea | Metatarsal IV |
|-------------------------------------------|-----------|----------|---------------|
| Agile wallaby (*Notamacropus agilis*)     | 13        | 13       | 9             |
| Antilopine wallaroo (*Osphranter antilopinus*) | 6         | 5        | 5             |
| Banded hare-wallaby (*Lagostrophus fasciatus*) | 12        | 10       | 6             |
| Black-flanked rock-wallaby (*Petrogale lateralis*) | 17       | 16       | 14            |
| Black wallaroo (*Osphranter bernardus*)  | 5         | 5        | 4             |
| Bridled nail-tail wallaby (*Onychogalea fraenata*) | 12        | 13       | 7             |
| Brushtail bettong (*Bettongia penicillata*) | 14        | 14       | 10            |
| Burrowing bettong (*Bettongia lesueur*)    | 10        | 8        | 5             |
| Common Wallaroo/Euro (*Osphranter robustus*) | 19        | 19       | 17            |
| Nabarlek (*Petrogale concinna*)           | 3         | 3        | 3             |
| Northern nail-tail wallaby (*Onychogalea unguifera*) | 10       | 11       | 7             |
| Red kangaroo (*Osphranter rufus*)         | 16        | 14       | 14            |
| Rothschild’s rock-wallaby (*Petrogale rothschildi*) | 5         | 5        | 2             |
| Rufous hare-wallaby (*Lagorcheses hirsutus*) | 18        | 17       | 14            |
| Short-eared rock-wallaby (*Petrogale brachyotis*) | 3         | 3        | 3             |
| Spectacled hare-wallaby (*Lagorcheses conspicillatus*) | 11       | 13       | 10            |
| Western grey kangaroo (*Macropus fuliginosus*) | 10        | 11       | 12            |
| **Total**                                 | **184**   | **180**  | **142**       |
Supplementary Table S2. Archaeological specimens from Boodie Cave examined in this study. (SQ) Excavation square, (XU) Excavation Unit, (SU) Stratigraphic Unit.

| Specimen ID | SQ   | XU   | SU | Skeletal element | Body Side |
|-------------|------|------|----|------------------|-----------|
| BC041       | F101 | 400  | 1  | calcaneus        | L         |
| BC003       | G101 | 533  | 2  | fourth metatarsal| L         |
| BC026       | G101 | 534  | 3  | fourth metatarsal| L         |
| BC001       | G101 | 535  | 3  | fourth metatarsal| L         |
| BC024       | G101 | 535  | 3  | fourth metatarsal| L         |
| BC022       | G101 | 536  | 3  | fourth metatarsal| R         |
| BC217       | B111 | 306  | 3  | fourth metatarsal| R         |
| BC337       | A106 | 29   | 3  | astragalus       | L         |
| BC261       | A107 | 13   | 3  | calcaneus        | L         |
| BC331       | A106 | 33   | 3  | calcaneus        | R         |
| BC062       | E101 | 606  | 4  | astragalus       | R         |
| BC059       | E101 | 606  | 4  | calcaneus        | R         |
| BC142       | G100 | 509  | 4/5| astragalus       | R         |
| BC047       | F101 | 408  | 5  | calcaneus        | R         |
| BC048       | F101 | 408  | 5  | astragalus       | L         |
| BC046       | F101 | 408  | 5  | calcaneus        | L         |
| BC004       | G101 | 538  | 5  | astragalus       | R         |
| BC211       | A103 | 249  | 5  | astragalus       | L         |
| BC212       | A103 | 249  | 5  | astragalus       | L         |
| BC044       | F101 | 409  | 5  | astragalus       | R         |
| BC085       | E101 | 610  | 5  | calcaneus        | R         |
| BC170       | A103 | 255  | 5  | astragalus       | L         |
| BC042       | F101 | 415  | 6  | astragalus       | R         |
| BC224       | A102 | 227  | 6  | astragalus       | R         |
| BC293       | A102 | 264  | 7  | astragalus       | L         |
| BC294       | A102 | 264  | 7  | astragalus       | L         |
Supplementary Table S3. Description of measurements taken on macropod astragali. (* ) Denotes measurements included after redundancy analysis.

| Measurement | Description |
|-------------|-------------|
| B_nf *      | Mediolateral breadth of navicular facet |
| H_nf        | Dorsoventral height of navicular facet |
| L_tn *      | Anteroposterior length of talar neck |
| L_mtc       | Anteroposterior length medial trochlear crest |
| L_ltc       | Anteroposterior length of lateral trochlear crest |
| B_atc *     | Mediolateral breadth of trochlear crests (anteriorly) |
| B_ptc       | Mediolateral breadth of trochlear crests (posteriorly) |
| B_t         | Greatest mediolateral breadth of the astragalus |
| B_mTaCa *   | Greatest mediolateral breadth of medial talocalcaneal facet, measured perpendicular to direction of joint movement. |
| H_mTaCa *   | Greatest dorsoventral height of anterior surface of the medial talocalcaneal facet, measured parallel to direction of joint movement. |
| B_lTaCa *   | Greatest mediolateral breadth of lateral talocalcaneal facet, measured at the maximum curvature of the facet. |
| L_lTaCa *   | Anteroposterior length of the lateral talocalcaneal facet, measured at the point of maximum curvature of the anterior and posterior margins of the facet. |
**Supplementary Table S4. Description of measurements taken on macropod calcanea.**

(*) Denotes measurements included after redundancy analysis.

| Measurement | Description |
|-------------|-------------|
| L_{dlCaCu} * | Anteroposterior length of the dorsolateral calcaneocuboid facet. |
| B_{dlCaCu} * | Greatest mediolateral breadth of the dorsolateral calcaneocuboid facet. |
| H_{dlCaCu} | Greatest dorsoventral height of the dorsolateral calcaneocuboid facet. |
| B_{dmCaCu} | Greatest mediolateral breadth of the dorsomedial calcaneocuboid facet. |
| H_{dmCaCu} | Greatest dorsoventral height of the dorsomedial calcaneocuboid facet. |
| B_{CaCu} | Breadth of calcaneocuboid articulation |
| H_{CaCu} | Height of calcaneocuboid articulation |
| L_{tcd} | Length of calcaneus from dorsolateral calcaneocuboid facet to epiphysis suture |
| H_{tce} | Height of epiphysis |
| B_{tce} | Breadth of epiphysis |
| L_{rps} | Anteroposterior length of the rugrose plantar surface, measured on the lateral side, parallel to tuber calcanei. |
| B_{ms} * | Mediolateral breadth of the tuber calcanei, measured at the midpoint of the rugrose plantar surface. |
| H_{ms} * | Dorsoventral height of the tuber calcanei, measured at the same point as the B_{ms}. |
| B_{ch} | Greatest mediolateral breadth of the sustentaculum tali |
| B_{fdl} * | Greatest breadth of the medial projection of the sustentaculum tali beyond the wall of the tuber calcanei, forming a sulcus for the passage of the flexor digitorum longus. |
| L_{st} * | Greatest anteroposterior length of the semi-circular crest of the medial sustentaculum tali. |
| H_{st} * | Greatest dorsoventral height of the medial sustentaculum tali, measured from the top of the medial calcaneotalar facet to the underside of the semi-circular crest of the medial sustentaculum tali. |
| L_{mCaTa} | Anteroposterior length of medial calcaneotalar facet, including the site of attachment for the ligamentum cervicis tali. |
| B_{mCaTa} * | Mediolateral breadth of the medial calcaneotalar facet. |
| L_{lCaTa} * | Anteroposterior length of the lateral calcaneotalar facet. |
| B_{lCaTa} | Mediolateral breadth of the lateral calcaneotalar facet. |
| B_{CLAJ} | Breadth of the continuous lower ankle joint |
| B_{CaFi} | Breadth of calcaneofibular articulation |
| H_{CaFi} | Height of calcaneofibular articulation, measured perpendicular to B_{CaFi} |
Supplementary Table S5. Description of measurements taken on macropod fourth metatarsals.

(*) Denotes measurements included after redundancy analysis.

| Measurement | Description                                                      |
|-------------|------------------------------------------------------------------|
| GL *        | Greatest anteroposterior length of metatarsal.                   |
| B_p *       | Greatest mediolateral breadth of proximal end of the metatarsal. |
| H_p *       | Greatest dorsoventral height of proximal end of the metatarsal.  |
| B_ms *      | Mediolateral breadth of the shaft at half the length of the metatarsal. |
| H_ms *      | Dorsoventral height of the shaft at the same point as B_ms.     |
| B_d *       | Greatest mediolateral breadth of the distal epiphysis of the metatarsal. |
| H_d *       | Greatest dorsoventral height of the distal epiphysis of the metatarsal. |
Supplementary Table S6. Mean standard deviation of repeat measurements proportional to repeat measurement mean ($s / \bar{x}$) and intraclass correlation coefficients (ICC3) for each measurement ($r$). All intraclass correlations are significant at <0.001.

| Variable | Large Macropods | Medium Macropods | Small Macropods |
|----------|-----------------|-----------------|-----------------|
|          | $s / \bar{x}$   | $r$             | $s / \bar{x}$   | $r$             | $s / \bar{x}$   | $r$             |
| **Astragali** |                 |                 |                 |
| B_nf     | 0.017           | 0.991           | 0.022           | 0.975           | 0.023           | 0.960           |
| H_nf     | 0.007           | 0.998           | 0.007           | 0.996           | 0.012           | 0.967           |
| L tn     | 0.028           | 0.974           | 0.042           | 0.929           | 0.045           | 0.895           |
| L_mtc    | 0.005           | 0.999           | 0.011           | 0.987           | 0.011           | 0.986           |
| L_htc    | 0.111           | 0.994           | 0.014           | 0.986           | 0.018           | 0.963           |
| B_atc    | 0.011           | 0.996           | 0.016           | 0.983           | 0.017           | 0.946           |
| B_ptc    | 0.012           | 0.992           | 0.020           | 0.965           | 0.018           | 0.947           |
| B t      | 0.005           | 0.999           | 0.005           | 0.997           | 0.005           | 0.992           |
| B_mTaCa  | 0.015           | 0.998           | 0.023           | 0.956           | 0.026           | 0.950           |
| H_mTaCa  | 0.021           | 0.971           | 0.031           | 0.948           | 0.027           | 0.915           |
| B_JTaCa  | 0.015           | 0.990           | 0.026           | 0.965           | 0.03           | 0.936           |
| L_lTaCa  | 0.014           | 0.993           | 0.024           | 0.976           | 0.022           | 0.958           |
| **Calcanea** |                 |                 |                 |
| L_dlCaCu | 0.032           | 0.970           | 0.041           | 0.960           | 0.034           | 0.893           |
| B_dlCaCu | 0.016           | 0.989           | 0.019           | 0.969           | 0.018           | 0.962           |
| H_dlCaCu | 0.016           | 0.993           | 0.024           | 0.975           | 0.024           | 0.980           |
| B_dmCaCu | 0.009           | 0.996           | 0.019           | 0.981           | 0.020           | 0.961           |
| H_dmCaCu | 0.013           | 0.996           | 0.021           | 0.984           | 0.029           | 0.891           |
| B_CaCu   | 0.006           | 0.998           | 0.009           | 0.995           | 0.006           | 0.984           |
| H_CaCu   | 0.008           | 0.998           | 0.011           | 0.992           | 0.010           | 0.962           |
| L_tcd    | 0.004           | 0.999           | 0.007           | 0.996           | 0.007           | 0.994           |
| H_tce    | 0.007           | 0.998           | 0.015           | 0.982           | 0.013           | 0.978           |
| B_tce    | 0.005           | 0.999           | 0.008           | 0.992           | 0.010           | 0.988           |
| L_rps    | 0.004           | 0.999           | 0.006           | 0.997           | 0.009           | 0.996           |
| B_ms     | 0.009           | 0.998           | 0.017           | 0.986           | 0.032           | 0.953           |
| H_ms     | 0.007           | 0.999           | 0.012           | 0.993           | 0.012           | 0.970           |
| B_ch     | 0.007           | 0.996           | 0.007           | 0.995           | 0.010           | 0.982           |
| B_fhdl   | 0.016           | 0.989           | 0.023           | 0.982           | 0.024           | 0.959           |
| L_st     | 0.009           | 0.997           | 0.015           | 0.986           | 0.021           | 0.969           |
| H_st     | 0.011           | 0.994           | 0.015           | 0.994           | 0.015           | 0.972           |
| L_mCaTa  | 0.012           | 0.993           | 0.015           | 0.984           | 0.016           | 0.959           |
| B_mCaTa  | 0.016           | 0.989           | 0.022           | 0.962           | 0.028           | 0.910           |
| L_ICaTa  | 0.016           | 0.994           | 0.028           | 0.969           | 0.028           | 0.891           |
| B_ICaTa  | 0.017           | 0.991           | 0.022           | 0.975           | 0.034           | 0.873           |
| B_CLAJ   | 0.007           | 0.997           | 0.010           | 0.992           | 0.012           | 0.945           |
| H_CaFi   | 0.020           | 0.986           | 0.028           | 0.960           | 0.039           | 0.857           |
| B_CaFi   | 0.018           | 0.992           | 0.034           | 0.960           | 0.029           | 0.903           |
| **Fourth Metatarsal** |                 |                 |                 |
| GL       | 0.001           | 1.000           | 0.001           | 1.000           | 0.001           | 1.000           |
| Bp       | 0.005           | 0.999           | 0.007           | 0.996           | 0.009           | 0.970           |
| Dp       | 0.006           | 0.998           | 0.008           | 0.996           | 0.008           | 0.973           |
| B_ms     | 0.009           | 0.995           | 0.007           | 0.997           | 0.009           | 0.983           |
| H_ms     | 0.015           | 0.990           | 0.012           | 0.994           | 0.012           | 0.965           |
| Bd       | 0.005           | 0.999           | 0.004           | 0.999           | 0.002           | 0.998           |
| Dd       | 0.005           | 0.999           | 0.009           | 0.995           | 0.009           | 0.979           |
Supplementary Table S7. Multivariate analysis of variance on large macropod pes bone shape.

Principal component scores comprising 95% of total shape variation were used as a proxy for bone shape. Groups with < n-2 observations (where n is the number of principal components) were not tested. Bold indicates a significant p-value (<0.01).

| Taxa                        | MANOVA                      | df1 | df2 | F     | p     |
|-----------------------------|-----------------------------|-----|-----|-------|-------|
| **Astragali**               |                             |     |     |       |       |
| All large macropods         | Shape ~ Age                 | 5   | 62  | 9.376 | <0.001|
| Agile wallaby               | Shape ~ Size                | 5   | 7   | 0.965 | 0.498 |
|                             | Shape ~ Age                 | 5   | 7   | 5.994 | 0.018 |
|                             | Shape ~ Sex                 | 5   | 5   | 0.570 | 0.724 |
| **Osphrander species**      | Shape ~ Age                 | 5   | 32  | 4.154 | 0.005 |
| Common wallaroo             | Shape ~ Island vs Mainland Subspecies | 5 | 13 | 1.992 | 0.147 |
|                             | Shape ~ Size                | 5   | 13  | 2.573 | 0.079 |
|                             | Shape ~ Age                 | 5   | 9   | 2.178 | 0.146 |
| Red kangaroo                | Shape ~ Size                | 5   | 10  | 2.482 | 0.104 |
|                             | Shape ~ Age                 | 5   | 7   | 0.549 | 0.736 |
|                             | Shape ~ Sex                 | 5   | 5   | 0.662 | 0.669 |
| Western grey kangaroo       | Shape ~ Size                | 5   | 4   | 3.242 | 0.139 |
|                             | Shape ~ Age                 | 5   | 4   | 3.885 | 0.106 |
| **Calcanea**                |                             |     |     |       |       |
| All large macropods         | Shape ~ Age                 | 6   | 61  | 9.459 | <0.001|
| Agile wallaby               | Shape ~ Size                | 6   | 6   | 2.327 | 0.164 |
|                             | Shape ~ Age                 | 6   | 6   | 7.002 | 0.016 |
|                             | Shape ~ Sex                 | 6   | 4   | 1.500 | 0.362 |
| **Osphrander species**      | Shape ~ Age                 | 6   | 29  | 6.235 | <0.001|
| Common wallaroo             | Shape ~ Subspecies (Island vs Mainland) | 6 | 12 | 3.468 | 0.032 |
|                             | Shape ~ Size                | 6   | 12  | 3.988 | 0.02  |
|                             | Shape ~ Age                 | 6   | 9   | 1.015 | 0.472 |
| Red kangaroo                | Shape ~ Size                | 6   | 7   | 2.793 | 0.103 |
|                             | Shape ~ Age                 | 6   | 3   | 1.571 | 0.382 |
|                             | Shape ~ Sex                 | 6   | 3   | 0.467 | 0.804 |
| Western grey kangaroo       | Shape ~ Size                | 6   | 4   | 6.144 | 0.05  |
|                             | Shape ~ Age                 | 6   | 3   | 2.652 | 0.227 |
| **Fourth metatarsals**      |                             |     |     |       |       |
| All large macropods         | Shape ~ Age                 | 5   | 52  | 7.463 | <0.001|
| Agile wallaby               | Shape ~ Size                | 5   | 3   | 7.707 | 0.062 |
|                             | Shape ~ Age                 | 5   | 3   | 0.576 | 0.725 |
|                             | Shape ~ Sex                 | 5   | 3   | 2.348 | 0.257 |
| **Osphrander species**      | Shape ~ Age                 | 5   | 26  | 5.388 | 0.002 |
| Common wallaroo             | Shape ~ Subspecies (Island vs Mainland) | 5 | 11 | 7.255 | 0.003 |
|                             | Shape ~ Size                | 5   | 11  | 7     | 0.04  |
|                             | Shape ~ Age                 | 5   | 9   | 0.375 | 0.854 |
| Red kangaroo                | Shape ~ Size                | 5   | 8   | 1.86  | 0.207 |
|                             | Shape ~ Age                 | 5   | 2   | 40.804| 0.024 |
|                             | Shape ~ Sex                 | 5   | 4   | 5.665 | 0.059 |
| Western grey kangaroo       | Shape ~ Size                | 5   | 6   | 0.992 | 0.493 |
|                             | Shape ~ Age                 | 5   | 5   | 1.747 | 0.278 |
|                             | Shape ~ Sex                 | 5   | 1   | 6.074 | 0.298 |
Supplementary Table S8. Multivariate analysis of variance on medium macropod pes bone shape.

Principal component scores comprising 95% of total shape variation were used as a proxy for bone shape. Groups with < n-2 observations (where n is the number of principal components) were not tested. Bold indicates significant p-value (<0.01).

| Taxa                          | MANOVA          | df1 | df2 | F      | p    |
|-------------------------------|-----------------|-----|-----|--------|------|
| **Astragali**                 |                 |     |     |        |      |
| All medium macropods          | Shape ~ Age     | 5   | 34  | 2.155  | 0.082|
| Onychogalea species           | Shape ~ Age     | 5   | 7   | 1.641  | 0.266|
| Bridled nail-tail wallaby     | Shape ~ Size    | 5   | 6   | 1.076  | 0.457|
| Northern nail-tail wallaby    | Shape ~ Size    | 5   | 4   | 1.866  | 0.283|
|                               | Shape ~ Age     | 5   | 1   | 2.308  | 0.461|
|                               | Shape ~ Sex     | 5   | 1   | 1.407  | 0.562|
| **Petrogale species**         |                 |     |     |        |      |
| Bridled nail-tail wallaby     | Shape ~ Age     | 5   | 14  | 1.122  | 0.393|
| Northern nail-tail wallaby    | Shape ~ Size    | 5   | 6   | 1.076  | 0.457|
|                               | Shape ~ Age     | 5   | 1   | 2.308  | 0.461|
|                               | Shape ~ Sex     | 5   | 1   | 1.407  | 0.562|
| Black-flanked rock-wallaby    | Shape ~ Size    | 5   | 11  | 3.553  | 0.037|
| Spectacled hare-wallaby       | Shape ~ Size    | 5   | 5   | 4.81   | 0.055|
|                               | Shape ~ Age     | 5   | 1   | 2.607  | 0.437|
| **Calcanea**                  |                 |     |     |        |      |
| All medium macropods          | Shape ~ Age     | 6   | 37  | 3.609  | 0.006|
| Onychogalea species           | Shape ~ Age     | 6   | 8   | 2.952  | 0.08 |
| Bridled nail-tail wallaby     | Shape ~ Size    | 6   | 6   | 1.489  | 0.32 |
| Northern nail-tail wallaby    | Shape ~ Size    | 6   | 4   | 1.617  | 0.334|
|                               | Shape ~ Age     | 6   | 2   | 2.517  | 0.311|
|                               | Shape ~ Sex     | 6   | 1   | 9.898  | 0.239|
| Petrogale species             |                 |     |     |        |      |
| Black-flanked rock-wallaby    | Shape ~ Size    | 6   | 9   | 0.394  | 0.866|
| Spectacled hare-wallaby       | Shape ~ Size    | 6   | 6   | 2.538  | 0.141|
|                               | Shape ~ Age     | 6   | 2   | 0.135  | 0.976|
| **Fourth metatarsals**        |                 |     |     |        |      |
| All medium macropods          | Shape ~ Age     | 5   | 26  | 1.246  | 0.317|
| Onychogalea species           | Shape ~ Age     | 5   | 2   | 1.974  | 0.37 |
| Bridled nail-tail wallaby     | Shape ~ Size    | 5   | 1   | 1284.631 | 0.021|
| Northern nail-tail wallaby    | Shape ~ Size    | 5   | 1   | 1351.283 | 0.021|
| Petrogale species             | Shape ~ Age     | 5   | 12  | 2.19   | 0.123|
| Black-flanked rock-wallaby    | Shape ~ Size    | 5   | 8   | 2.178  | 0.157|
| Spectacled hare-wallaby       | Shape ~ Size    | 5   | 4   | 0.635  | 0.688|
Supplementary Table S9. Multivariate analysis of variance on small macropod pes bone shape.

Principal component scores comprising 95% of total shape variation were used as a proxy for bone shape. Groups with < n-2 observations (where n is the number of principal components) were not tested. Bold indicates significant p-value (<0.01).

| Taxa                          | MANOVA                                | df1 | df2 | F    | p     |
|-------------------------------|---------------------------------------|-----|-----|------|-------|
| **Astragali**                 |                                       |     |     |      |       |
| All small macropods           | Shape ~ Age                            | 6   | 56  | 2.188| 0.058 |
| Banded hare-wallaby           | Shape ~ Size                           | 6   | 5   | 0.764| 0.628 |
| Bettonia species              | Shape ~ Age                            | 6   | 16  | 0.691| 0.66  |
| Brush-tailed bettong          | Shape ~ Age                            | 6   | 7   | 3.216| 0.076 |
|                               | Shape ~ Size                           | 6   | 7   | 0.702| 0.659 |
|                               | Shape ~ Sex                            | 6   | 4   | 0.94 | 0.55  |
| Burrowing bettong             | Shape ~ Size                           | 6   | 3   | 5.493| 0.095 |
|                               | Shape ~ Age                            | 6   | 2   | 0.251| 0.921 |
| Lagorches species             | Shape ~ Age                            | 6   | 18  | 1.37 | 0.279 |
| **Rufous hare-wallaby**       | Shape ~ Island vs Mainland Subspecies  | 6   | 11  | 21.982| <0.001|
|                               | Shape ~ Size                           | 6   | 11  | 1.989| 0.153 |
|                               | Shape ~ Age                            | 6   | 11  | 1.437| 0.285 |
|                               | Shape ~ Sex                            | 6   | 5   | 1.136| 0.454 |
| **Calcanea**                  |                                       |     |     |      |       |
| All small macropods           | Shape ~ Age                            | 6   | 44  | 1.638| 0.159 |
| Banded hare-wallaby           | Shape ~ Size                           | 6   | 3   | 6.918| 0.071 |
|                               | Shape ~ Age                            | 6   | 3   | 0.864| 0.60  |
| Bettonia species              | Shape ~ Age                            | 6   | 14  | 0.815| 0.576 |
| Brush-tailed bettong          | Shape ~ Size                           | 6   | 7   | 0.455| 0.822 |
|                               | Shape ~ Age                            | 6   | 7   | 0.601| 0.724 |
|                               | Shape ~ Sex                            | 6   | 4   | 1.066| 0.498 |
| Burrowing bettong             | Shape ~ Size                           | 6   | 1   | 15.644| 0.191 |
| **Rufous hare-wallaby**       | Shape ~ Subspecies (Island vs Mainland)| 6   | 10  | 5.580| 0.009 |
|                               | Shape ~ Size                           | 6   | 10  | 1.035| 0.457 |
|                               | Shape ~ Age                            | 6   | 10  | 1.999| 0.159 |
|                               | Shape ~ Sex                            | 6   | 5   | 1.899| 0.249 |
| **Fourth metatarsals**        |                                       |     |     |      |       |
| All small macropods           | Shape ~ Age                            | 5   | 32  | 3.896| 0.007 |
| Brush-tailed bettong          | Shape ~ Size                           | 5   | 4   | 0.293| 0.894 |
|                               | Shape ~ Sex                            | 5   | 2   | 1.556| 0.435 |
| **Rufous hare-wallaby**       | Shape ~ Sub-Species (Island vs Mainland)| 5   | 8   | 2.852| 0.091 |
|                               | Shape ~ Size                           | 5   | 8   | 1.573| 0.271 |
|                               | Shape ~ Age                            | 5   | 8   | 0.663| 0.662 |
|                               | Shape ~ Sex                            | 5   | 5   | 2.212| 0.202 |