

# A REVISION OF THE ANATOMY OF THE TRIASSIC PTEROSAUR *AUSTRIADRACO DALLA VECCHIAI* AND OF ITS DIAGNOSIS

FABIO MARCO DALLA VECCHIA

## Supplementary information

### **Humerus/tibia (tibiotarsus) and wing phalanx 1/tibia (tibiotarsus) length ratios of *Rhamphorhynchus muensteri* and *Dorygnathus banthensis***

The humerus/tibia (tibiotarsus) length (h/ti) and wing phalanx 1/tibia (tibiotarsus) length (wph1/ti) ratios of *Rhamphorhynchus muensteri* (sensu Bennett 1995) specimens from the Upper Jurassic 'Solnhofen limestones' of southern Germany are based on the measurement data taken from Wellnhofer (1975b: tabs after p. 186). That of *Rhamphorhynchus muensteri* represents the largest pterosaur sample available for statistical analyses. The skull lengths, when available, are also reported in the list below as a proxy for body size; when the skull is not preserved, the humerus or the wing phalanx 1 is reported as a proxy for body size, according to the ratio.

Wellnhofer (1975b) distinguished five species (*R. longicaudus*, *R. intermedius*, *R. muensteri*, *R. gemmingi* and *R. longiceps*), which Bennett (1995) considered as three size classes (small, medium and large-size classes) representing growth stages of a single species, *R. muensteri*.

Wellnhofer (1975b) reported the lengths of the tibiae in his tables; it is plausible that these measurements correspond to the actual lengths of the tibiae in immature specimens (see Wellnhofer 1975a: fig. 17), whereas they refer to those of the tibiotarsi in more mature individuals with the astragalus and calcaneum fused to the tibia. Therefore, h/ti and wph1/ti ratios are systematically higher in *Rhamphorhynchus muensteri* (sensu Bennett 1995) individuals with unfused proximal tarsals, which plausibly include all the smaller ones (small-size class of Bennett 1995) than in larger individuals with fused proximal tarsals (see Wellnhofer 1975a, b and Bennett 1995). Unfortunately, information about the fusion of the proximal tarsals within the medium-size class is vague (Bennett 1995: 573). The decrease of the ratio values with the increase of the skull length within the medium-size class (Fig. 1) could be due to the increase of the length of the tibia caused by the fusion of the astragalus and calcaneum. However, ratio values increase again in the large-size class (Fig. 1).

The humerus/tibia (tibiotarsus) length ratio has been calculated in 49 specimens with the skull length ranging 34-160 mm. The ratio ranges 0.76-1.20 (the extreme values are emphasized in red bold in the list below), but only one individual has a ratio of 1.20 and only another one has a ratio over 1.05. If we consider only comparatively large specimens (arbitrarily considered as those with the skull length  $\geq 90$  mm), the h/ti ratio has a similar range (0.78-1.05) as that of the whole sample inclusive of smaller specimens.

#### *Rhamphorhynchus longicaudus*

Skull: 34 mm	<b>h/ti: 1.05</b>	
Skull: 35 mm	h/ti: 0.99	
Skull: 35 mm	h/ti: 1.03	
Skull: 36 mm	h/ti: 1.04	
Skull: 39 mm	h/ti: 0.97	
Skull: 40 mm	h/ti: 1.06	
Skull: 41 mm	h/ti: 1.00	
Skull: 41 mm	h/ti: 1.00	
Skull: -	h/ti: 1.00	h: 14 mm
Skull: -	h/ti: 0.97	h: 14.5 mm

Skull: - h/ti: 1.07 h: 14.6 mm  
Skull: - h/ti: 1.07 h: 15.5 mm

*Rhamphorhynchus cf. longicaudus*

Skull: - h/ti: 1.16 h: 14.5 mm  
Skull: - h/ti: 1.04 h: 13.5 mm

*Rhamphorhynchus intermedius*

Skull: 50 mm h/ti: 1.03  
Skull: 54.3 mm h/ti: 0.99  
Skull: 57 mm h/ti: **1.20**  
Skull: 65 mm h/ti: 1.09

*Rhamphorhynchus muensteri*

Skull: 78.7 mm h/ti: 0.85  
Skull: 90 mm h/ti: 0.83  
Skull: 90 mm h/ti: 0.85  
Skull: 90 mm h/ti: 0.93  
Skull: 92 mm h/ti: 0.91  
Skull: 94 mm h/ti: 0.90  
Skull: 95 mm h/ti: 0.83  
Skull: 97 mm h/ti: 0.85  
Skull: 98.5 mm h/ti: 0.82  
Skull: 99 mm h/ti: 0.82  
Skull: 101.5 mm h/ti: 0.81  
Skull: 103 mm h/ti: 0.78  
Skull: 103.5 mm h/ti: 0.81  
Skull: 104 mm h/ti: 0.79  
Skull: 110 mm h/ti: 0.81  
Skull: 112 mm h/ti: 0.83  
Skull: 112.5 mm h/ti: 0.78  
Skull: 160 mm h/ti: 0.82  
Skull: - h/ti: **0.76** h: 32 mm  
Skull: - h/ti: 0.92 h: 33 mm  
Skull: - h/ti: 0.83 h: 44 mm

*Rhamphorhynchus gemmingi*

Skull: 116 mm h/ti: 0.81  
Skull: 123.3 mm h/ti: 0.94  
Skull: 125 mm h/ti: 0.98  
Skull: - h/ti: 0.93 h: 36 mm

*Rhamphorhynchus cf. gemmingi*

Skull: 87 mm h/ti: 0.86

*Rhamphorhynchus longiceps*

Skull: 95 mm h/ti: **1.05**  
Skull: 150 mm h/ti: 1.01

*Rhamphorhynchus cf. longiceps*

Skull: 78.5 mm h/ti: 0.91

*Rhamphorhynchus* sp.

Skull: 87 mm      h/ti: 0.89  
Skull: -            h/ti: 0.86    h: 37 mm

The wing phalanx1/tibia (tibiotarsus) length ratio has been calculated in 46 specimens with skull length ranging 34-160 mm. The ratio ranges 2.08-2.68 (extreme values are emphasized in bold red in the list below). If we consider only the larger specimens (arbitrarily considered as those with skull length  $\geq 90$  mm), the ratio has a similar range (2.08-2.62).

*Rhamphorhynchus longicaudus*

Skull: 34 mm      wph1/ti: 2.48  
Skull: 35 mm      wph1/ti: 2.27  
Skull: 35 mm      wph1/ti: 2.15  
Skull: 36 mm      wph1/ti: 2.29  
Skull: 39 mm      wph1/ti: 2.13  
Skull: 40 mm      wph1/ti: 2.39  
Skull: 41 mm      wph1/ti: 2.32  
Skull: 41 mm      wph1/ti: 2.38

*Rhamphorhynchus intermedius*

Skull: 50 mm      wph1/ti: **2.68**  
Skull: 54.3 mm    wph1/ti: 2.44  
Skull: 55.5 mm    wph1/ti: 2.40  
Skull: 57 mm      wph1/ti: 2.40

*Rhamphorhynchus muensteri*

Skull: 90 mm      wph1/ti: 2.30  
Skull: 90 mm      wph1/ti: 2.37  
Skull: 90 mm      wph1/ti: 2.62  
Skull: 92 mm      wph1/ti: 2.47  
Skull: 94 mm      wph1/ti: 2.47  
Skull: 95 mm      wph1/ti: 2.16  
Skull: 97 mm      wph1/ti: 2.37  
Skull: 98.5 mm    wph1/ti: 2.30  
Skull: 99 mm      wph1/ti: 2.16  
Skull: 101.5 mm    wph1/ti: **2.08**  
Skull: 103 mm      wph1/ti: 2.36  
Skull: 103.5 mm    wph1/ti: 2.19  
Skull: 104 mm      wph1/ti: 2.18  
Skull: 105 mm      wph1/ti: 2.10  
Skull: 106 mm      wph1/ti: 2.24  
Skull: 110 mm      wph1/ti: 2.33  
Skull: 112 mm      wph1/ti: 2.17  
Skull: 112.5 mm    wph1/ti: 2.30  
Skull: **160 mm**    wph1/ti: 2.49  
Skull: -            wph1/ti: 2.54    wph1: 91 mm  
Skull: -            wph1/ti: 2.20    wph1: 92.5 mm  
Skull: -            wph1/ti: 2.31    wph1: 113 mm  
Skull: -            wph1/ti: 2.20    wph1: 117 mm

*Rhamphorhynchus gemmingi*

Skull: 116 mm      wph1/ti: 2.21  
Skull: 123.3 mm    wph1/ti: 2.50  
Skull: 125 mm      wph1/ti: 2.57  
Skull: -            wph1/ti: 2.58      wph1 99.5 mm

*Rhamphorhynchus cf. gemmingi*

Skull: 87 mm      wph1/ti: 2.43

*Rhamphorhynchus longiceps*

Skull: 95 mm      wph1/ti: 2.38  
Skull: 150 mm     wph1/ti: 2.33

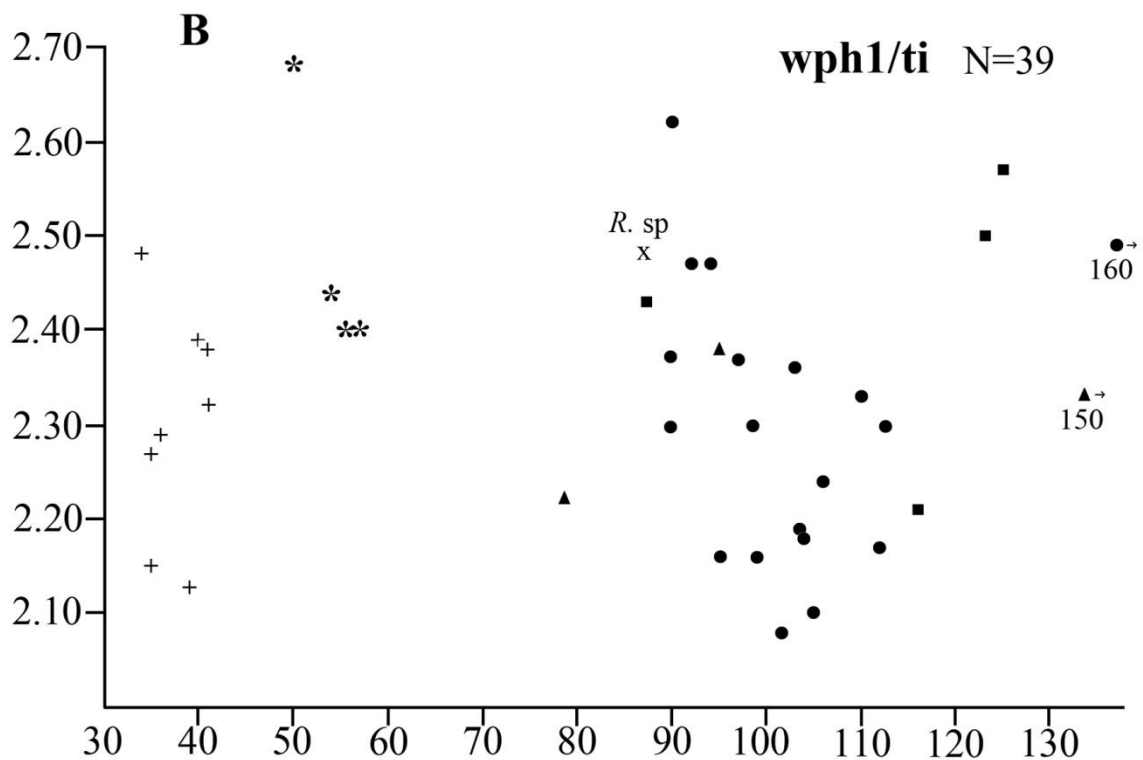
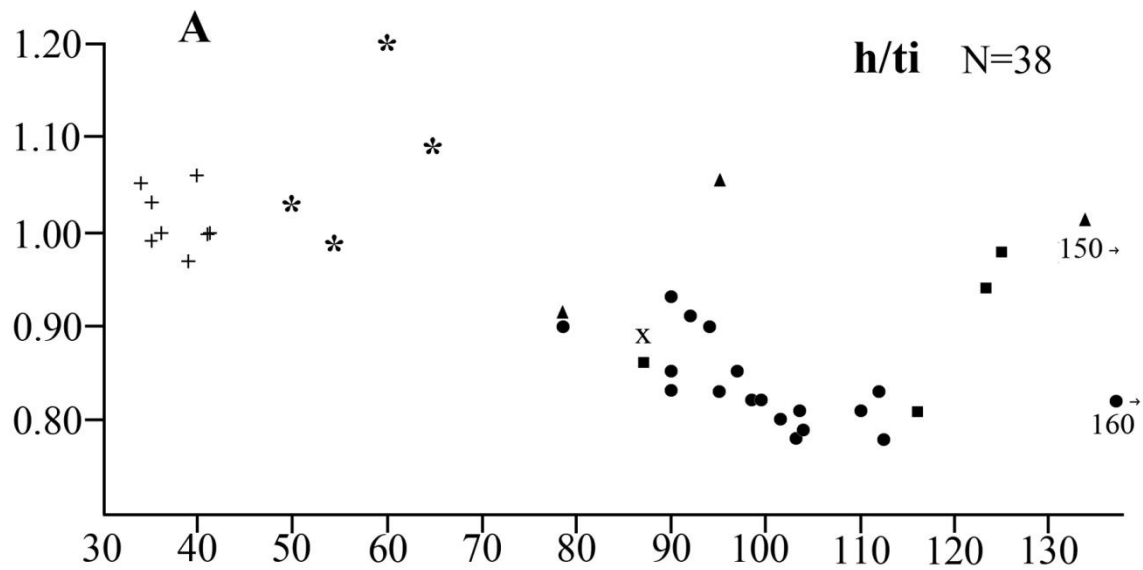
*Rhamphorhynchus cf. longiceps*

Skull: 78.5 mm    wph1/ti: 2.22

*Rhamphorhynchus sp.*

Skull: 87 mm      wph1/ti: 2.48  
Skull: -            wph1/ti: 2.13      wph1: 89.5 mm  
Skull: -            wph1/ti: 2.30      wph1: 99 mm

The ratios have been plotted against the skull length to show their distribution with respect to the body size (SI Fig. 1). The ratios of *Rhamphorhynchus cf. gemmingi* and *Rhamphorhynchus cf. longiceps* specimens are plotted as *Rhamphorhynchus gemmingi* and *Rhamphorhynchus longiceps*, respectively.



+ *R. longicaudus* \* *R. intermedius* • *R. muensteri* ■ *R. gemmingi* ▲ *R. longiceps*

SI Fig. 1 - The humerus/tibia (tibiotarsus) length (h/ti, A) and wing phalanx 1/tibia (tibiotarsus) length (wph1/ti, B) ratios vs. skull length (x-axis, in millimetres) of *Rhamphorhynchus muensteri* (sensu Bennett 1995) specimens based on the measurement data of Wellnhofer (1975b) and reported in the text. The original species definitions by Wellnhofer (1975b) are retained as further information. The value marked with X refers to a specimen identified as *Rhamphorhynchus* sp. by Wellnhofer (1975b). The skull length (in mm) is reported near the plot of two specimens falling outside the plotting area.

That of *Dorygnathus banthensis* from the Lower Jurassic Posidonienschiefer of southern Germany represents the second largest non-pterodactyloid pterosaur sample available for statistical analyses. The humerus/tibia (tibiotarsus) length (h/ti) and wing phalanx 1/tibia (tibiotarsus) length (wph1/ti) ratios of *Dorygnathus banthensis* specimens are based on the measurements reported by Padian (2008a: tab. 1). The estimated wing span, when available, is reported as a proxy for the body size; when the wing span is not listed in the data set, the humerus or the wing phalanx 1 is reported as a proxy for body size, according to the ratio. When the same specimen has the right and left skeletal elements that differ in length, the mean has been used for calculating the ratio, if the difference is one centimetre or less. Information about the fusion-unfusion of the astragalus and calcaneum to tibia is not available for this taxon. The small specimen BSP 1938 I 49 (wingspan 890 mm) has tarsals that are not fused to the tibia (Dalla Vecchia 2018: fig. 1B), but it is unclear whether the measurement taken by Padian (2008a) includes them or not.

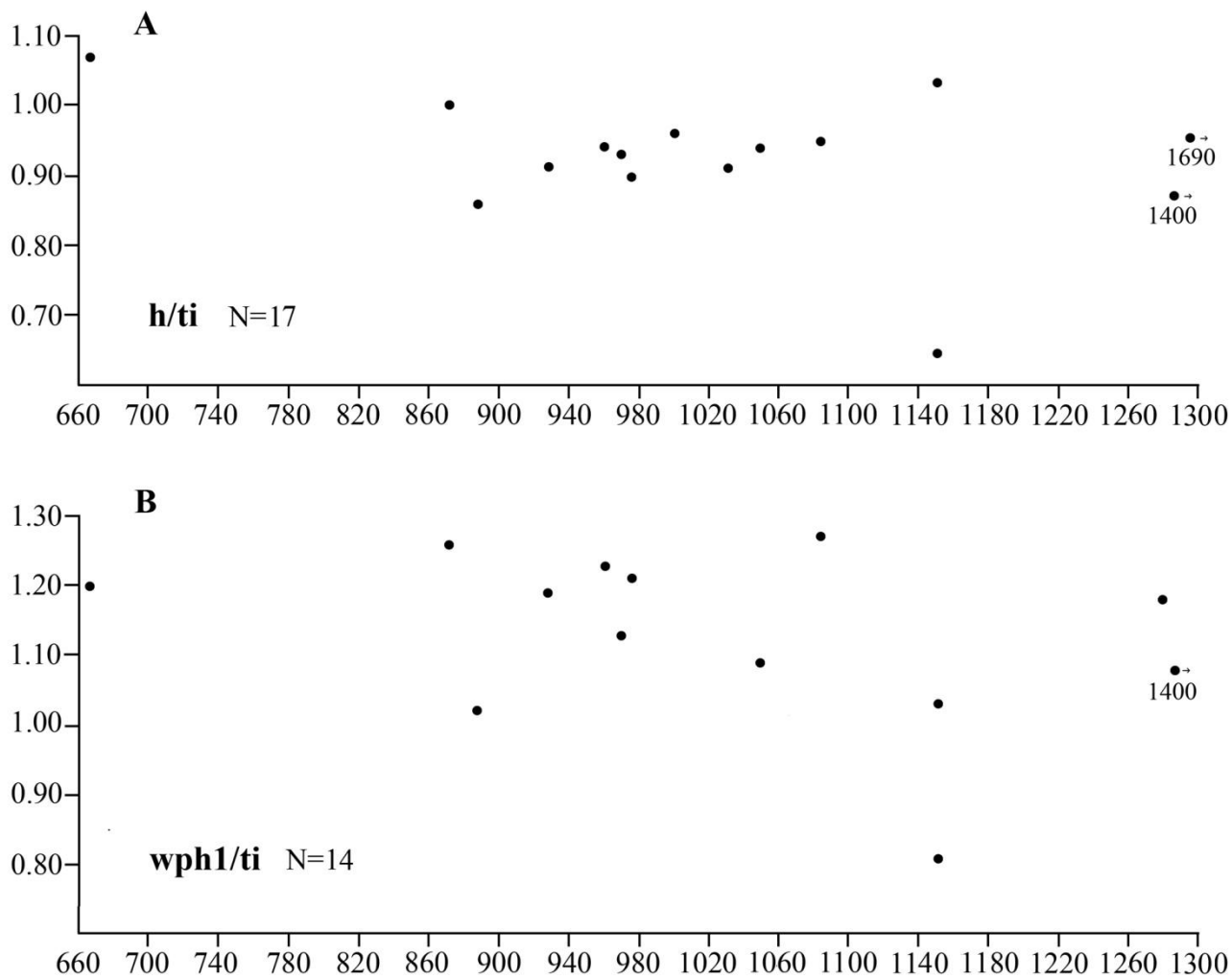
The humerus/tibia (tibiotarsus) length ratio has been calculated in 17 specimens with the wing span ranging 665-1690 mm. The ratio ranges 0.65-1.07 (extreme values are emphasized in red bold in the list below).

Wing span: 665 mm	h/ti: <b>1.07</b>
Wing span: 870 mm	h/ti: 1.00
Wing span: 890 mm	h/ti: 0.86
Wing span: 935 mm	h/ti: 0.91
Wing span: 960 mm	h/ti: 0.94
Wing span: 970 mm	h/ti: 0.93
Wing span: 975 mm	h/ti: 0.90
Wing span: 1000 mm	h/ti: 0.96
Wing span: 1030 mm	h/ti: 0.91
Wing span: 1050 mm	h/ti: 0.94
Wing span: 1085 mm	h/ti: 0.95
Wing span: 1150 mm	h/ti: <b>0.65</b>
Wing span: 1150 mm	h/ti: 1.03
Wing span: 1400 mm	h/ti: 0.87
Wing span: 1690 mm	h/ti: 0.95
Wing span: -	h/ti: 0.82 h 61 mm
Wing span: -	h/ti: 0.84 h 79 mm

The wing phalanx1/tibia (tibiotarsus) length ratio has been calculated in 14 specimens with wing span ranging 665-1400 mm. The ratio ranges 0.81-1.27 (extreme values are emphasized in red bold in the list below).

Wing span: 665 mm	wph1/ti: 1.20
Wing span: 870 mm	wph1/ti: 1.26
Wing span: 890 mm	wph1/ti: 1.02
Wing span: 935 mm	wph1/ti: 1.19
Wing span: 960 mm	wph1/ti: 1.23
Wing span: 970 mm	wph1/ti: 1.13
Wing span: 975 mm	wph1/ti: 1.21
Wing span: 1050 mm	wph1/ti: 1.15
Wing span: 1085mm	wph1/ti: <b>1.27</b>
Wing span: 1150 mm	wph1/ti: <b>0.81</b>
Wing span: 1150 mm	wph1/ti: 1.03
Wing span: 1285 mm	wph1/ti: 1.18

Wing span: 1400 mm    wph1/ti: 1.08  
 Wing span: - mm    wph1/ti: 1.08    wph1: 80 mm



SI Fig. 2 - The humerus/tibia (tibiotarsus) (h/ti, A) and wing phalanx 1/tibia (tibiotarsus) (wph1/ti, B) length ratios vs. wing span (x-axis, in millimetres) of *Dorygnathus banthensis* specimens based on measurement data from Padian (2008a) and reported in the text. The wing span (in mm) is reported near the plot of a specimen falling outside the plotting area.