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# Morphological differences between coastal bottlenose dolphin (*Tursiops aduncus*) populations identified using non-invasive stereo-laser photogrammetry

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## Electronic supplementary material:

**Supplementary Table S1.** Summary of minimum ($L_{min}$) and maximum ($L_{max}$) total lengths estimated for male (M), female (F) and unknown-sex (U) Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) from south-west and Shark Bay regions. Asymptotic length ($L_{\infty}$) estimates predicted by the Richards growth model (RGM) are also shown with 95 % confidence intervals. Both south-west and Shark Bay RGMs were subset to investigate male and female growth, as well as for all sampled individuals combined (A).

| Region | Sex | n | $L_{min}$ (cm) | $L_{max}$ (cm) | $L_{\infty}$ (cm) | $L_{\infty}$ 95 % CI (cm) |
|---|---|---|---|---|---|---|
| South-west | M | 39 | 105.7 | 254.4 | 246.1 | 239.2 – 254.5 |
| | F | 56 | 106.1 | 256.8 | 244.5 | 239.9 – 250.7 |
| | U | 34 | 106.9 | 218.7 | - | - |
| | A | 129 | - | - | 244.5 | 240.6 – 248.6 |
| Shark Bay | M | 24 | 157.8 | 209.9 | 201.9 | 199.2 – 205.1 |
| | F | 42 | 139.9 | 210.5 | 200.5 | 196.7 – 205.3 |
| | U | 8 | 102.8 | 198.6 | - | - |
| | A | 74 | - | - | 200.6 | 198.1 – 203.4 |

**Supplementary Table S2.** Summary of corrected Akaike's information criterion ($AIC_c$) model selection output for the four candidate growth models: The Richards (RGM), original von Bertalanffy (OvB), typical von Bertalanffy (TvB) and Gompertz (GOM), used to describe the length-at-age data obtained from the south-west and Shark Bay regions. The most parsimonious models are highlighted in bold.

| Region | Candidate model | $AIC_c$ | $\Delta AIC_c$ | $w_i$ | Log Likelihood |
|---|---|---|---|---|---|
| South-west | **RGM** | **961.13** | **0.00** | **1** | **-477.47** |
| | TvB | 1003.74 | 42.61 | 0 | -497.71 |
| | OvB | 1003.74 | 42.61 | 0 | -497.71 |
| | GOM | 1013.00 | 51.86 | 0 | -502.34 |
| Shark Bay | **RGM** | **522.98** | **0.00** | **0.49** | **-257.20** |
| | OvB | 524.64 | 1.65 | 0.22 | -258.03 |
| | TvB | 524.64 | 1.65 | 0.22 | -258.03 |
| | GOM | 526.81 | 3.82 | 0.07 | -259.11 |

**Supplementary Table S3.** Mean total length ($L_{50}$) and age ($A_{50}$) estimates at which 50% of individuals are predicted to be independent and reproductive for the first time. Logistic regression models were run for both south-west (SW) and Shark Bay (SB) regions. Both adult male and female dolphins (A) were used in independence analyses, with only female (F) dolphins used to estimate first reproduction values. A significance level of 0.05 was used to determine the effect of age and total length on the probability of a dolphin being independent or reproductive for the first time. *** $p < 0.001$.

| Parameter | Region | Sex | n | $A_{50}$ (95% CI) (years) | Sig. | $L_{50}$ (95% CI) (cm) | Sig. |
|---|---|---|---|---|---|---|---|
| Independence | SW | A | 77 | 3.01 (2.58-3.39) | *** | 187.20 (180.07-191.18) | *** |
| | SB | | 27 | 4.86 (4.37-4.92) | *** | 162.45 (151.97-168.27) | *** |
| First reproduction | SW | F | 56 | 10.35 (9.65-11.33) | *** | 224.38 (220.94-226.45) | *** |
| | SB | | 42 | 11.91 (10.51-12.92) | *** | 185.40 (181.39-190.08) | *** |

**Supplementary Table S4.** Summary of median length-at-age estimates and HPD values derived from the sensitivity analysis. Age-specific regional differences in total length and their Welch Two-Sample t-test significance levels are included (p = 0.05). Total length at age x is represented as TLx, for example, total length at age 1 = $TL_1$. *** p < 0.001.

| Region | $TL_1$ (cm) (95 % HPD) | $TL_3$ (cm) (95 % HPD) | $TL_{12}$ (cm) (95 % HPD) | $TL_{25}$ (cm) (95 % HPD) |
|---|---|---|---|---|
| South-west | 155.9 (155.3-156.5) | 187.1 (186.5-187.7) | 228.0 (227.6-228.4) | 239.3 (238.8-239.9) |
| Shark Bay | 120.1 (118.4-122.2) | 149.5 (148.2-151.1) | 192.0 (191.5-192.6) | 200.1 (199.5-200.6) |
| Δ TL (cm) | 35.8 | 37.6 | 36.0 | 39.2 |
| Significance | *** | *** | *** | *** |

**Supplementary Table S5.** Study sites and the estimated number of individual dolphins identified, in addition to the commencement years and *ad-hoc* data collection. Periods of lasermetric data collection for the current study are also included.

| Site | Commencement of dedicated dolphin research (year) | *Ad-hoc* data available from (year) | Number of individuals identified | Laser-derived data collection period |
|---|---|---|---|---|
| Bunbury | 2007 | 1989 | 500[1] | May 2016 _ January 2017 |
| Mandurah | 2016 | 1987 | 500[2] | June 2016 – March 2017 |
| Shark Bay | 1984 | 1960s | 1,600[3] | October 2016 |

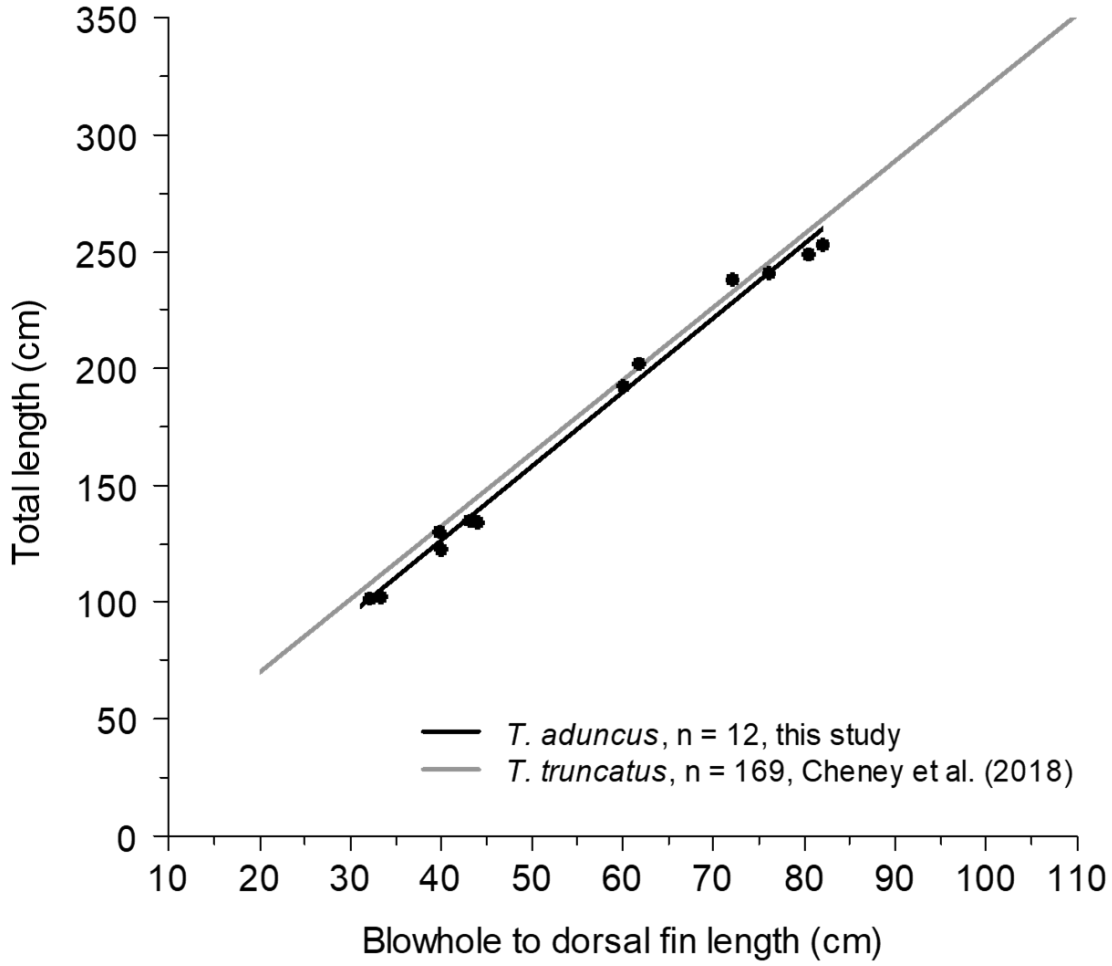
[1] J. Symons (August, 2016, pers. comm)

[2] K. Nicholson (March, 2018, pers. comm)

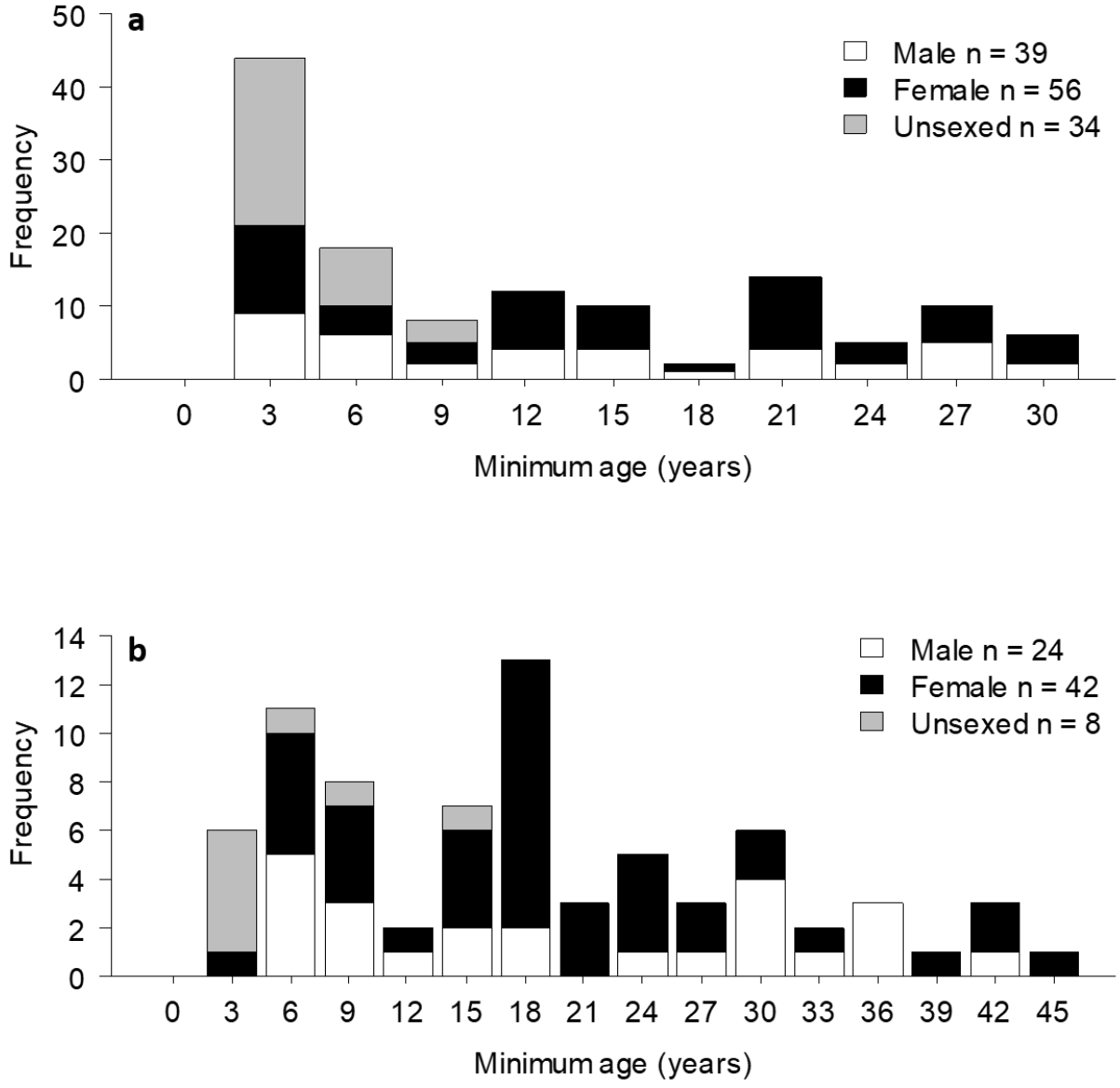
[3] Karniski et al. (2015)

**Supplementary Table S6.** Mean parameter estimates for asymptotic length ($L_\infty$) and Brody growth coefficient (*K*) derived from Richards growth models (RGM) fitted to length-at-age data for male (M) and female (F) *Tursiops aduncus* in south-west and Shark Bay study regions. Richards growth model parameter estimates for all sexes combined (male, female and unknown-sex individuals) are also included. Parameters $t_0$ and *p* are modelling artefacts with no biological meaning, with some starting values fixed (*) to shape the growth curve.

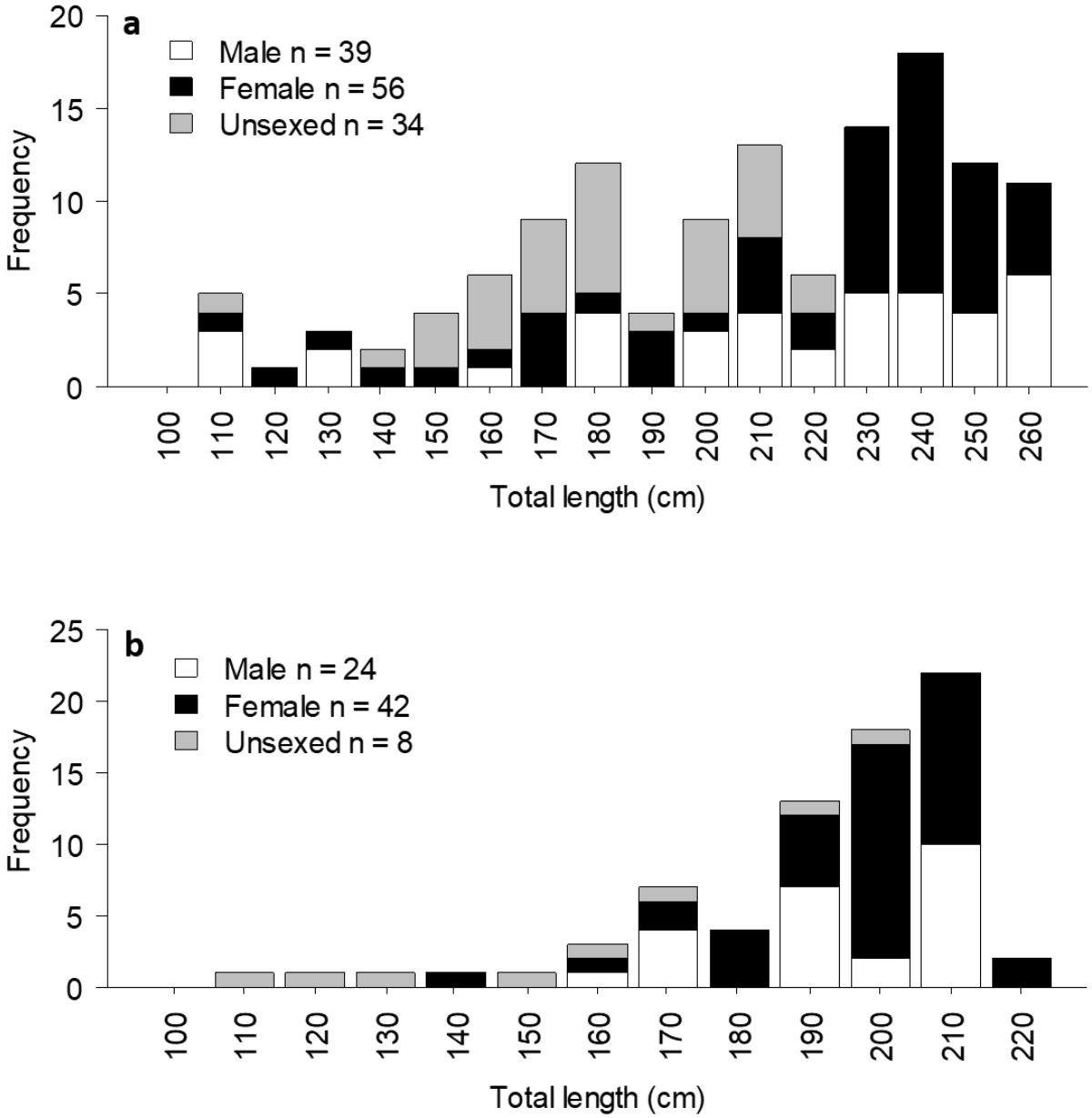
| Region | Sex | n | $L_\infty$ (cm) | *K* ($yr^{-1}$) | $t_0$ | *p* |
|---|---|---|---|---|---|---|
| South-west | M | 39 | 246.1 | 0.11 | -0.30* | 0.24* |
| | F | 56 | 244.5 | 0.13 | -0.37* | 0.24* |
| | A | 129 | 244.5 | 0.12 | -0.38* | 0.24* |
| Shark Bay | M | 24 | 201.9 | 0.17 | -1.90* | 0.53* |
| | F | 42 | 200.5 | 0.17 | -0.88 | 0.35 |
| | A | 74 | 200.6 | 0.19 | -1.50 | 0.50* |



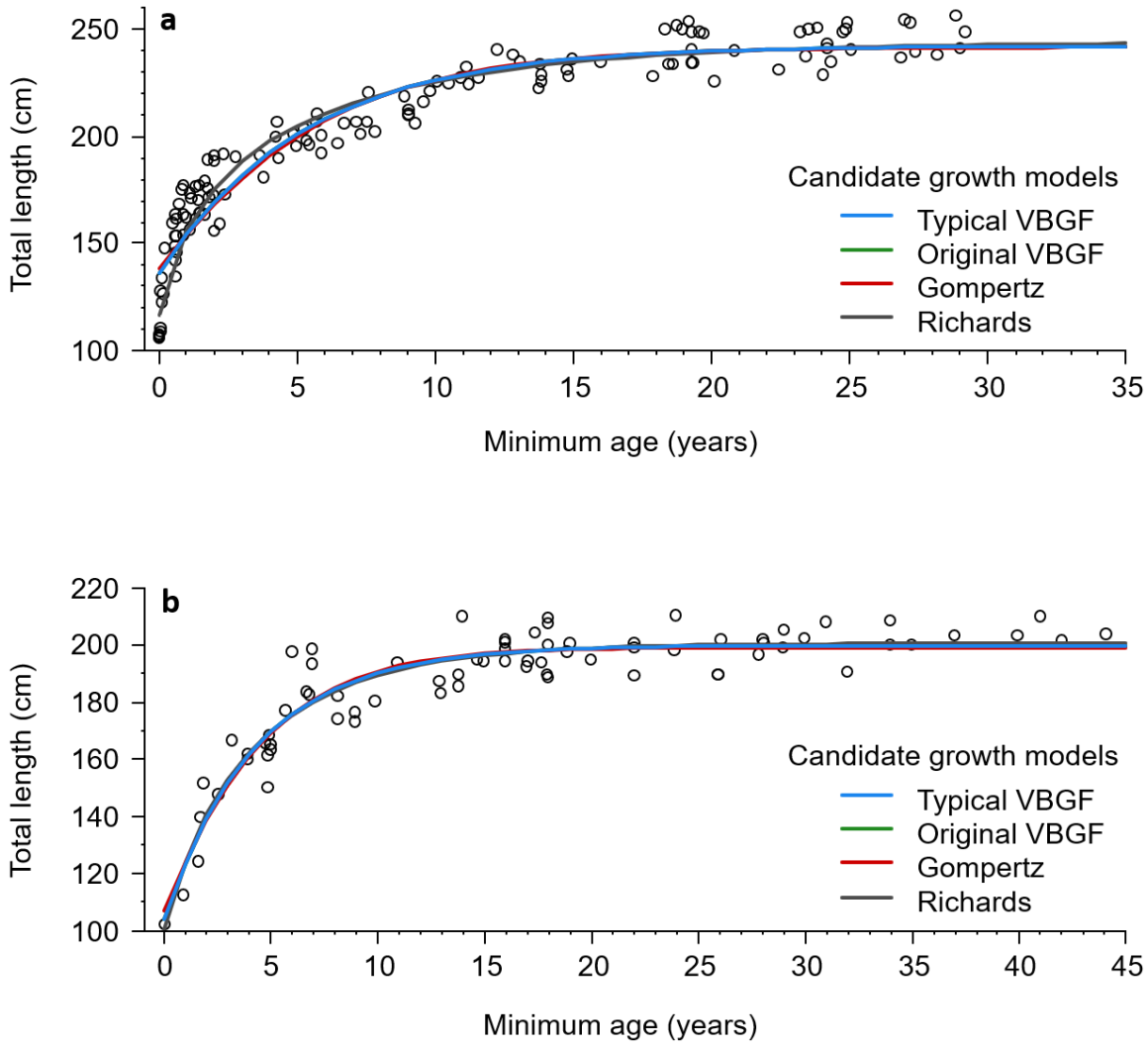

**Supplementary Fig. S1.** Linear relationship between total length (TL) and blowhole-to-dorsal fin (BH-DF) length for stranded *Tursiops aduncus* (n = 12, black points and line) in south-western Australia ($F_{1,10} = 1341$, $P < 0.001$, $R^2 = 0.992$, TL = 5.0583 + 3.17 × BH-DF). The grey line depicts the BH-DF to TL relationship for *Tursiops truncatus* (n = 169, $R^2 = 0.964$, y = 3.1314x+7.0626) presented in Cheney et al. 2018.



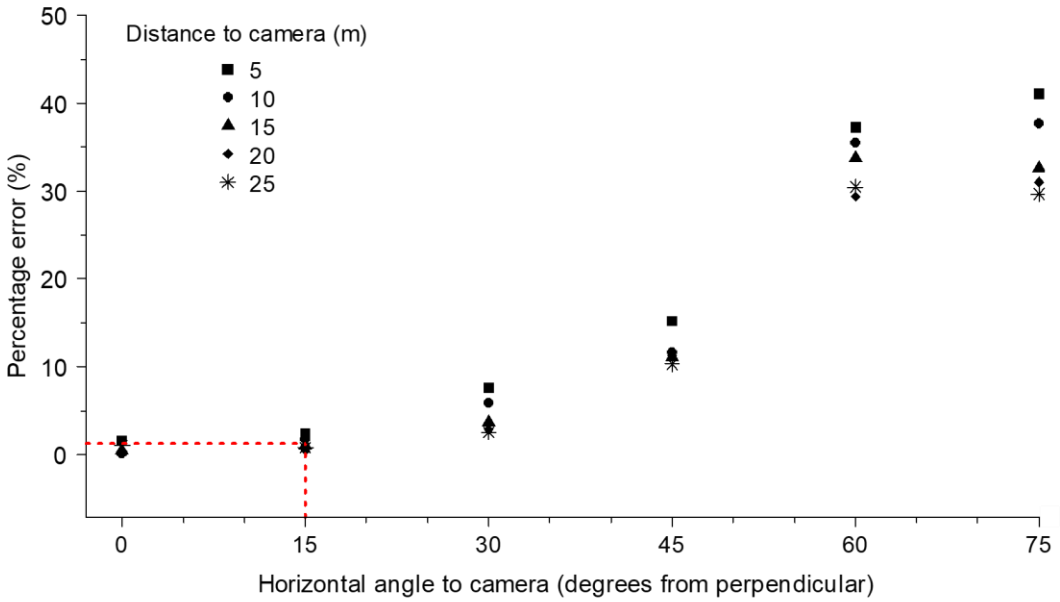

**Supplementary Fig. S2.** Age-frequency distributions of male (white), female (black) and unknown-sex (grey) bottlenose dolphins sampled in a) south-west and b) Shark Bay study sites. Age bins represent the three years prior to the bin in question, e.g. the '3' bin represents ages from 0 to 3 years.



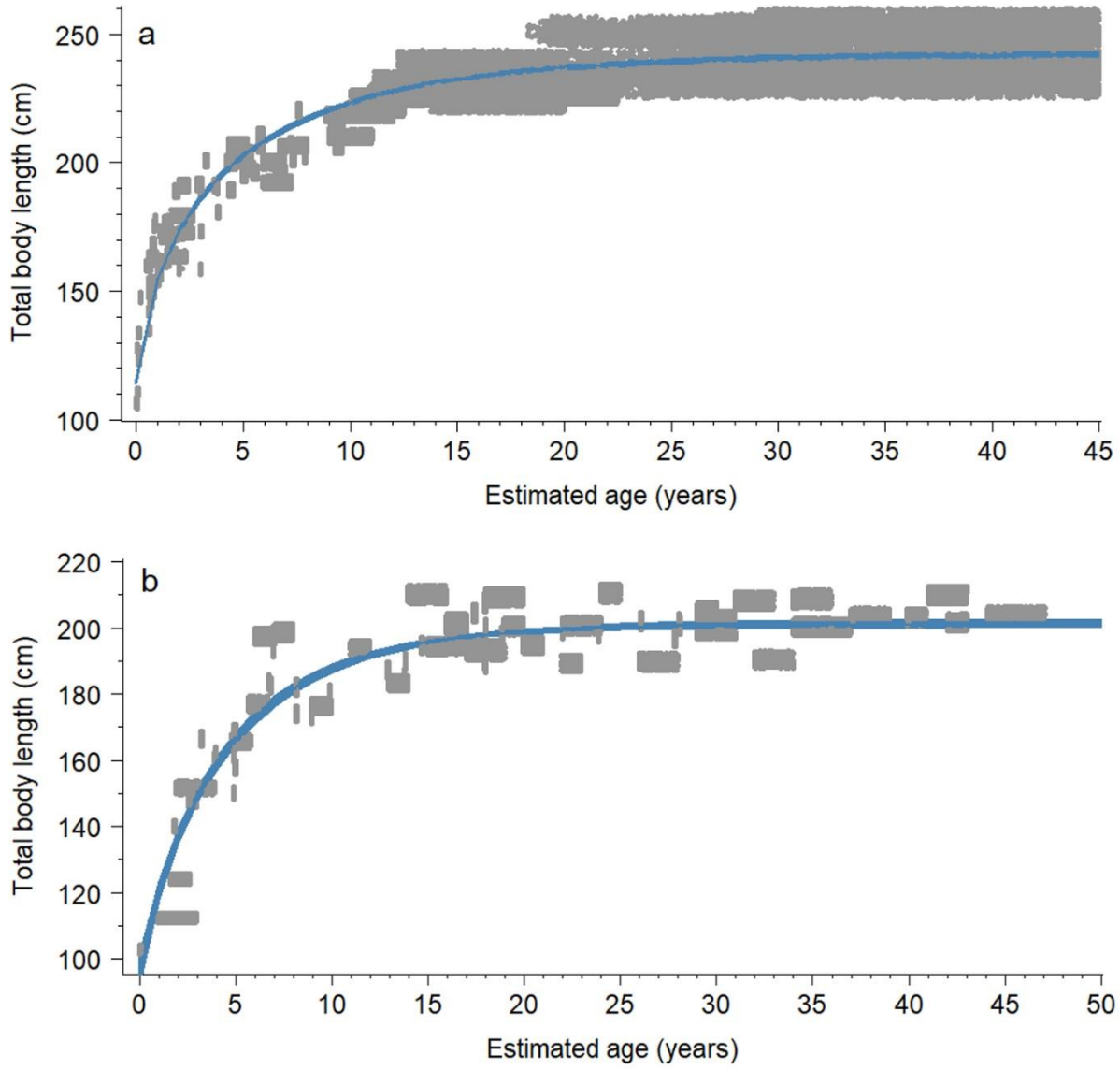

**Supplementary Fig. S3.** Length-frequency distributions of male (white), female (black) and unknown-sex (grey) bottlenose dolphins sampled in a) south-west and b) Shark Bay study sites. Length bins represent the 10 cm prior to the bin in question, e.g. the '110' bin represents lengths between 100-110cm.



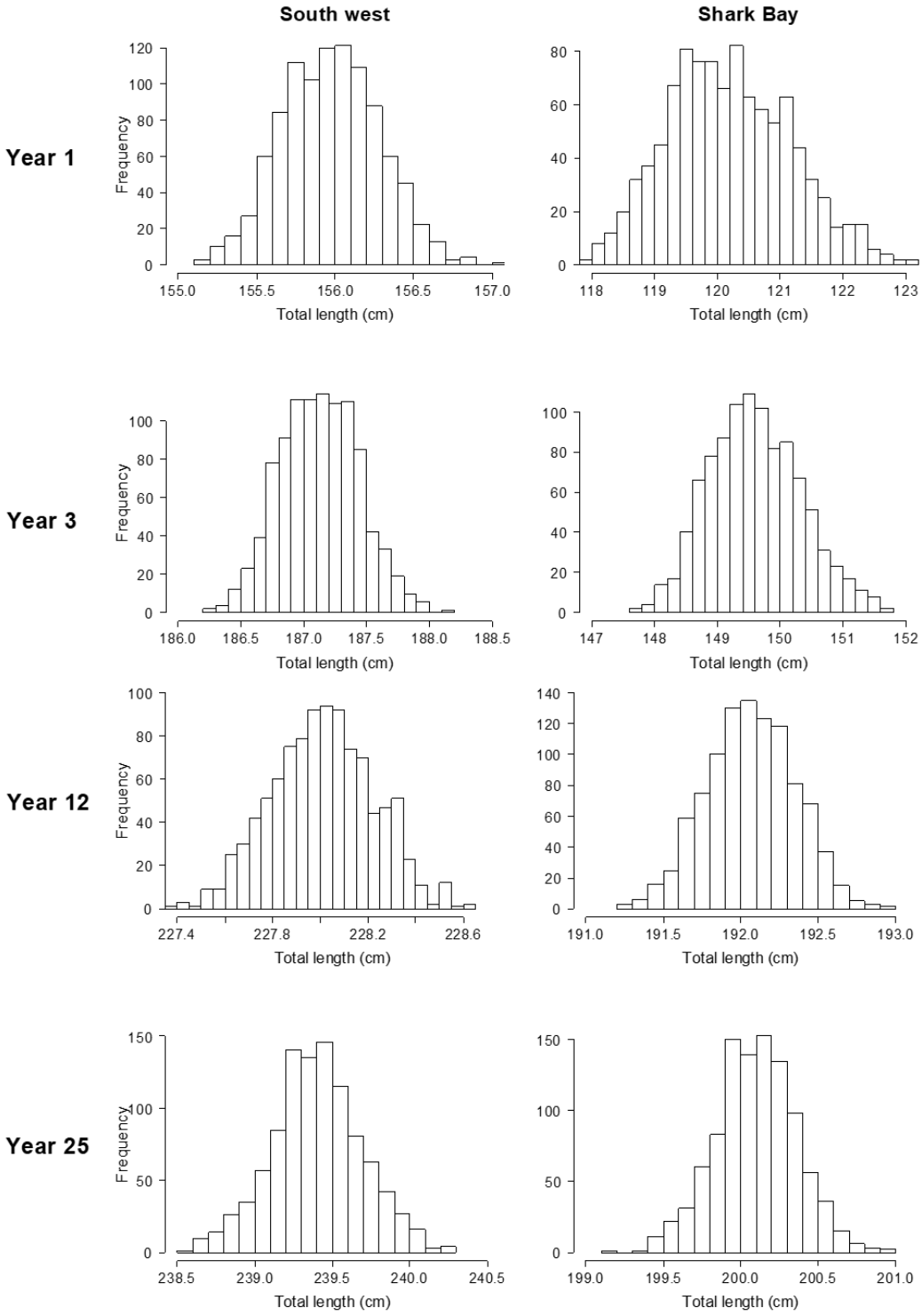

**Supplementary Fig. S4.** Visual representations of each of the candidate model fits (see legend) relative to the length-at-age data collected in each study site (A, south-west, n = 129; B, Shark Bay, n = 74).



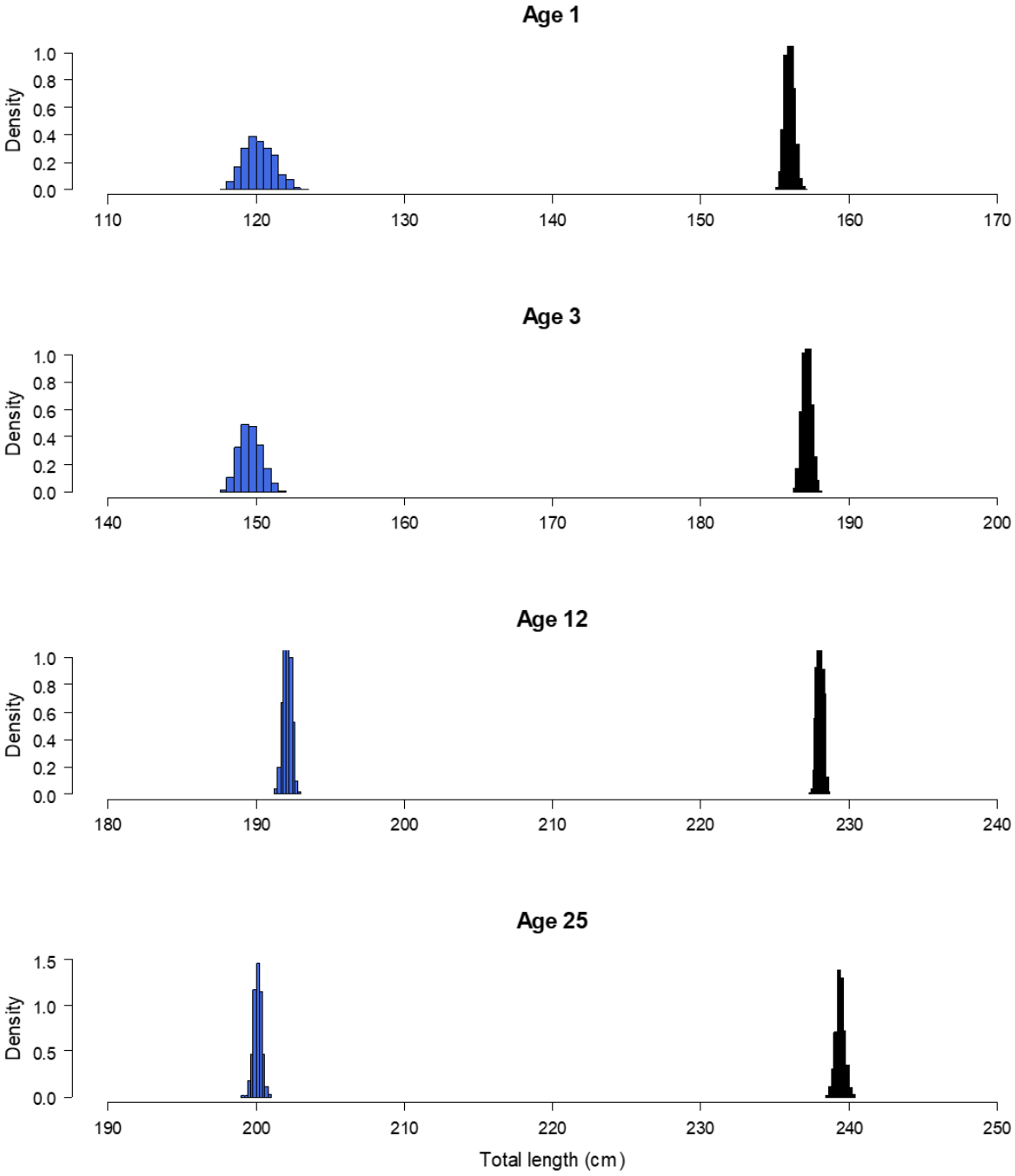

**Supplementary Fig. S5.** Measurement error results from the three-dimensional dolphin replica experiment. At horizontal angles of 0 - 75°, measurements of a known distance were made in 15° increments over five intervals (5 - 25 m; n = 270). The red dashed lines highlight the mean measurement error value of 1.27% (0.84 cm) obtained at an angle of 15° from perpendicular.



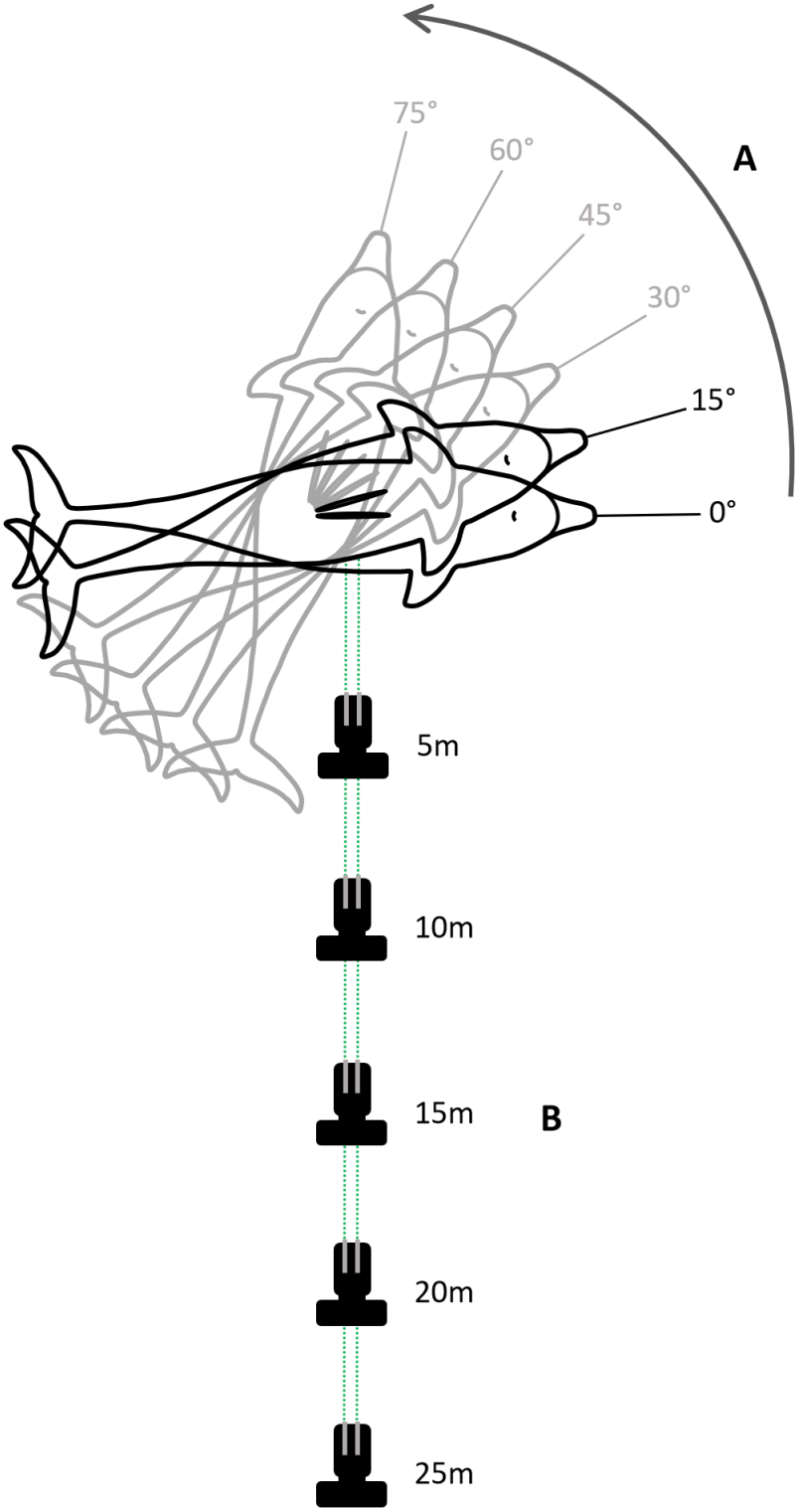

**Supplementary Fig. S6.** Sensitivity analysis: bootstrapped distributions (grey) characterising the relative measurement and age-estimation error associated with each individual sampled in the south-west (a) and Shark Bay (b) study site. Bootstrapped Richards growth curves are displayed in blue.




**Supplementary Fig. S7.** Sensitivity analysis of potential measurement and age-estimation error, with frequency distributions of model parameter values for total length of south-west and Shark Bay dolphins at ages 1, 3, 12, and 25, obtained from 1,000 bootstrap iterations.




**Supplementary Fig. S8.** Bootstrapped (1,000 iterations) density distributions of model length-at-age values across the four tested ages: 1, 3, 12, and 25 years. Note significant differences in total length between the south-west (black) and Shark Bay (blue) regions, demonstrated by the lack of overlapping distributions across length.




**Supplementary Fig. S9.** Schematic description of the 3D bottlenose dolphin (*T. aduncus*) replica experiment used to test the influence of horizontal angle and distance on measurement accuracy and precision. The dolphin replica (TL = 210 cm) was rotated in 15° increments (a), with angles at 15° or less from perpendicular (black dolphins) used in image selection. Photographs were taken at each angle in five distance increments between 5 - 25m (b).

## LITERATURE CITED

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