Determining Body Mass of Wild Pigs from Body Measurements

Faith E. Kruis[1], *Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA 30602 & Jones Center at Ichauway, 3988 Jones Center Dr., Newton, GA 39870*

L. Mike Conner, *Jones Center at Ichauway, 3988 Jones Center Dr., Newton, GA 39870*

James C. Beasley, *Savannah River Ecology Laboratory, Warnell School of Forestry and Natural Resources, University of Georgia, PO Drawer E, Aiken, SC, 29802 & Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA 30602*

Michael T. Mengak, *Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA 30602*

Abstract: Animal body mass can be used to estimate age, determine health status, or guide dosage when administering sedatives. Because it can be difficult to weigh live large animals, using morphometric measurements to estimate body mass is sometimes used in field studies. Several statistical models exist for estimating domestic pig mass from morphometric measurements, but models based on domestic animals are likely unreliable estimators of wild pig (*Sus scrofa*) body mass due to known hybridization between domestic and wild pigs, and variable environmental conditions. The goal of this project was to evaluate several easily obtainable morphometric measurements as predictors of wild pig body mass and compare our estimates with those of models developed from both wild and domestic pigs. We measured neck girth, heart girth, body length, and body mass from 127 wild pigs in Florida and Georgia, and 450 wild pigs in South Carolina. Our best-supported linear model included body length as the best predictor of wild pig body mass. Our body length and heart girth univariate models produced similar estimates to those of other published models using these attributes, providing evidence that these models may be broadly generalizable. We also compared estimates from our model to estimates from models derived from domestic pigs and found significant differences between our model and two of the models developed from domestic pigs. Thus, while body mass may be reliably estimated from simple morphometric measurements from wild pigs, our results suggest morphometric models produced for domestic pigs are not reliable predictors of wild pig body mass.

Key words: body mass estimation, domestic pigs, feral swine, morphometric measurements, *Sus scrofa*

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Direct measurement of large mammal body mass is often difficult in field settings. Obtaining animal body mass, though, is necessary for meeting many research objectives that include determining age, health status, or correct dosage for administering sedatives (Sweitzer et al. 1997, Fenati et al. 2008, Schlichting et al. 2015, Drimaj et al. 2019). Because it can be difficult to weigh live large animals, using easily obtainable morphometric measurements to estimate body mass is sometimes used in field studies (Bell et al. 1997, Amaral et al. 2010, Barrett et al. 2021, Baruzzi et al. 2023).

Wild pigs (*Sus scrofa*) can exceed 100 kg and therefore could be difficult to weigh in the field (Mayer et al. 2020). Equations that predict pig body mass from morphometric measurements are available; however, most of these equations were developed for commercial pig producers using domestic animals (Groesbeck et al. 2002, Mutua et al. 2011, Sungirai et al. 2014, Walugembe et al. 2014). Most wild pigs in the U.S. are hybrids with domestic and wild origins, and therefore retain some phenotypic and biological attributes of domestic pigs (Keiter et al. 2016, Smyser et al. 2020, Mayer 2021). However, there is often considerable phenotypic variability among wild and domestic pigs (Smyser et al. 2020), and it is likely that body mass-predicting equations developed for domestic pigs may be inappropriate for use with wild pigs. Domestic and wild pigs also differ in selective pressures, both of which directly influence growth rate and morphometric features (Pedone et al. 1995, Sungirai et al. 2014, Drimaj et al. 2019). For instance, domestic pigs are placed under favorable conditions (i.e., less selective pressures) that generally result in earlier maturity, larger litters, and heavier body mass than wild pigs, depending on their ancestry (Comer and Mayer 2009). These conditions have resulted in more vertebrae and faster growth rates for domestic pigs relative to wild pigs (Hammond 1962, Tohara 1967, Mikawa et al. 2011). In addition, domestic pigs are provided with veterinary care and ad libitum access to food and water, whereas wild pigs must opportunistically locate resources that fluctuate in availability and quality, thereby increasing their energetic demands.

1. E-mail: faithk99@live.com

Despite the differences between domestic and wild pig morphometric characteristics, models developed for domestic pigs have been used to estimate body mass of wild pigs, perhaps because models that are explicitly developed for wild pigs have not been readily available until recently (Baruzzi et al. 2023). Therefore, models to predict body mass from morphometric measurements should be explicitly developed for wild pigs. Baruzzi et al. (2023) confirmed the validity of using morphometric measurements to predict body mass of wild pigs by generating models from six measurements for wild pigs in Mississippi. These models were validated across eight areas in Australia, Guam, and the U.S. using wild pigs of both sexes and a variety of sizes.

Given that wild pigs exhibit extensive morphometric variation both within and among populations across their invasive range (Mayer and Brisbin 2009), our objective for this study was to further evaluate the extent to which morphometric measurements can be used to estimate wild pig body mass across multiple populations within the southeastern U.S. In addition, we further explored our data to test the hypothesis that models developed for predicting body mass of domestic pigs would not be reliable for use in free ranging wild pig populations.

Study Area

We conducted our study on private and public lands in southwestern Georgia, northern Florida (hereafter SW GA/N FL due to proximity to each other), and central South Carolina. Properties in SW GA/N FL ranged in elevation from 52 m to 82 m and were dominated by agricultural fields of corn (*Zea mays*), cotton (*Gossypium* spp.), peanut (*Arachis hypogaea*), and pecan (*Carya illinoinensis*) or upland landscapes dominated by loblolly pine (*Pinus taeda*), longleaf pine (*P. palustris*), and shortleaf pine (*P. echinata*). Mean annual temperature across the SW GA/N FL properties was 19–20 C, and mean annual precipitation was 134–145 cm (NOAA 2022). All samples from South Carolina were obtained from the Savannah River Site (SRS), a 780 km^2 U.S. Department of Energy property located in the upper coastal plain (Mayer and Brisbin 2009). The SRS ranged in elevation from 20 m to 130 m and was dominated by managed upland pine forests (i.e., loblolly, longleaf, and shortleaf pine), riparian landscapes, and forested swamp land. No agricultural lands were present on the SRS. Mean annual temperature was 18 C, and mean annual precipitation was 122.5 cm (Chinn et al. 2022).

Methods

Data Collection

On the SW GA/N FL properties, wild pigs were removed by U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) Wildlife Services personnel via trapping and ground shooting from May 2021 to June 2022. On SRS, wild pigs were captured and euthanized by SRS-contracted trappers or captured, anesthetized, processed, and released by University of Georgia personnel as part of ongoing research activities from April 2017 to May 2021. Trappers placed whole corn in areas with evidence of wild pig activity (e.g., tracks, wallows, rooting, rubbing) and erected remotely triggered, corral-style traps once the target pigs visited the bait for several nights. Detailed descriptions of capture and handling procedures for SRS can be found in Keiter et al. (2017) and Chinn et al. (2022). We euthanized or anesthetized captured wild pigs and measured neck girth (NG), heart girth (HG), and body length (BL) with a cloth measuring tape (Figure 1), and measured body mass using either a dial or digital scale. Handling of wild pigs in SW GA/N FL and SRS occurred under approved University of Georgia Institutional Animal Care and Use Committee (IACUC) protocols (A2020 04-028-R1, A2023 01-030-Y1-A0, A2015 12-017, A2015 05-004, A2019 01-012, A2018 06-024, A2021 12-001, and A2021 04-013).

Statistical Analysis

We used univariate linear models to predict wild pig body mass from morphometric measurements. Our models regressed ln-transformed body mass against ln-transformed NG, HG, and BL. We ln-transformed body mass and each morphometric predictor to meet linearity assumptions (James and McCulloch 1990, Dobson 1992) as evaluated by quantile-quantile plots in the 'stats' package in program R (R Core Team 2023). We focused analysis on univariate models to avoid multicollinearity issues due to our highly correlated predictors. Furthermore, univariate models require fewer field measurements and therefore more incentive to calculate wild pig body mass. We evaluated all univariate models

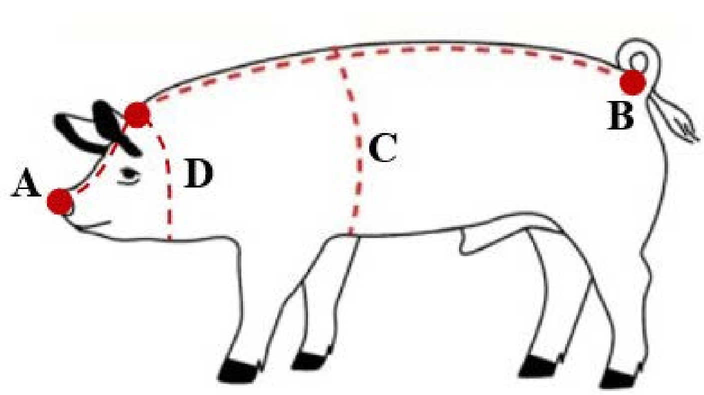

Figure 1. Diagram of the morphometric measurements taken on wild pigs (*Sus scrofa*) in central South Carolina and southwestern Georgia/northern Florida from April 2017 to June 2022. Measurements included body length (A-B), heart girth (C), and neck girth (D). Measurements were taken on wild pigs while in a lateral recumbent position. Diagram modified from Pater (2007).

(including a null model) using Akaike's Information Criterion adjusted for small sample size (AIC_c) using the 'AICcmodavg' package (Mazerolle 2020) in R (R Core Team 2023). We considered the model with the least AIC_c as the best model (Burnham and Anderson 2002). We used coefficient of determination (R^2) to assess the proportion of the variation in wild pig body mass that was explained by each model. We used the beta coefficients from the top model(s) to create equation(s) predicting body mass of wild pigs from their morphometric measurements.

We then evaluated models developed for wild and domestic pigs to determine how well each predicted body mass of wild pigs in our sample and compared the estimated body masses to those generated from our top model(s). We used our wild pig measurements to predict pig body mass using models from Groesbeck et al. (2002), Sungirai et al. (2014), and Baruzzi et al. (2023). The model produced by Walugembe et al. (2014) was based on domestic pigs <40 kg. Therefore, we tested this model using the wild pigs <40 kg ($n = 77$) available in our sample. The models developed from both wild pigs (Baruzzi et al. 2023) and domestic pigs (Groesbeck et al. 2002, Sungirai et al. 2014) used combinations of HG and BL to predict body mass and therefore could be applied to our wild pig data. The Baruzzi et al. (2023) models included:

$$\text{Body mass} = e^{(-9.56 + 2.82 \times \ln[\text{BL}])} \quad \text{and}$$
$$\text{Body mass} = e^{(-6.73 + 2.38 \times \ln[\text{HG}])},$$

where body mass was measured in kg, and BL and HG were measured in cm. Walugembe et al. (2014) used HG and length from the midpoint of the ears to the base of the tail to calculate body mass in domestic pigs. We collected the latter measurement on a subset of our wild pigs weighing <40 kg and used these data to include the Walugembe et al. (2014) model in our analysis. Although other models exist for domestic pigs, they could not be evaluated using our data because they incorporated different measurements (e.g., age; Ježek et al. 2011), were developed using larger pigs (mean: 116 ± 14.5 [SE] kg; Knauer and Wiegert 2017) than available in our data set, or because model coefficients were not provided (Mutua et al. 2011). We calculated the true differences and absolute value of the differences between the actual wild pig body mass and estimated body mass for each model, using the mean raw difference as a measure of bias and the mean absolute value of the differences as a measure of precision. We used an ANOVA and Tukey's honestly significant difference (HSD) test from the 'stats' R package (R Core Team 2023) to determine if there were differences ($P \leq 0.05$) among the estimated body masses generated from the alternative models and our wild pig model.

Results

We collected morphometric measurements from 127 wild pigs (62 males, 65 females) from SW GA/N FL and 450 wild pigs (89 males, 361 females) from the SRS. The mean body mass of wild pigs in our data set was 45.42 kg (SD = 22.71) and included 151 males and 426 females. Our best-supported model was the BL univariate model, which explained 94% of the variation in wild pig body mass (Table 1; Figure 2). This model was expressed as:

$$\text{Body mass} = e^{(-9.78 + 2.851 \times \ln[\text{BL}])}.$$

We evaluated five models developed for domestic and wild pigs using our wild pig data. The Groesbeck et al. (2002) model underestimated body mass for smaller pigs and slightly overestimated body mass for larger pigs (Figure 3A). Meanwhile, the Sungirai et al. (2014) model overestimated body mass for all pigs (Figure 3B), and the Walugembe et al. (2014) model slightly underestimated body mass for pigs <40 kg (Figure 3C). Both the BL and HG models from Baruzzi et al. (2023) produced body mass estimates similar to those of our best-supported model (Figure 4). Although our HG model received no support for being the best model based on AIC_c ranking ($\Delta AIC_c = 12.11$), we included it in comparisons with domestic and wild pig models (Figure 4B) because HG is commonly measured in field settings, and our HG model still explained 94% of the variation in wild pig body mass (Table 2). The HG model was expressed as:

$$\text{Body mass} = e^{(-7.671 + 2.599 \times \ln[\text{HG}[)}.$$

To facilitate use, we provided guides for estimating wild pig body mass with our BL and HG models (Table 2 and Table 3).

The absolute value of the differences (i.e., precision) of our best-supported wild pig model using BL differed ($P < 0.001$) from those of Groesbeck et al. (2002) and Sungirai et al. (2014; Figure 5). The Walugembe et al. (2014), our HG, Baruzzi et al. (2023) HG, and Baruzzi et al. (2023) BL models produced similar precision as our top wild pig model ($P = 0.891$, 0.994, 0.969, and 0.982,

Table 1. The univariate models used to evaluate wild pig (*Sus scrofa*) body mass in central South Carolina and southwestern Georgia/northern Florida. Wild pig body mass and morphometric measurements were collected between April 2017 and June 2022. Models include ln-transformed body mass regressed against ln-transformed body length (lnBL), heart girth (lnHG), and neck girth (lnNG). Included for each model are the number of parameters (K), sample-size adjusted Akaike's Information Criterion (AIC_c), Akaike differences (ΔAIC_c), the AIC_c model weight (*wi*), and the coefficient of determination (R^2).

Model	K	AIC_c	ΔAIC_c	*wi*	R^2
lnBL	3	–310.04	0.00	1.00	0.940
lnHG	3	–297.93	12.11	0.00	0.939
lnNG	3	133.45	443.48	0.00	0.871
Null	1	3146.82	3456.86	0.00	–

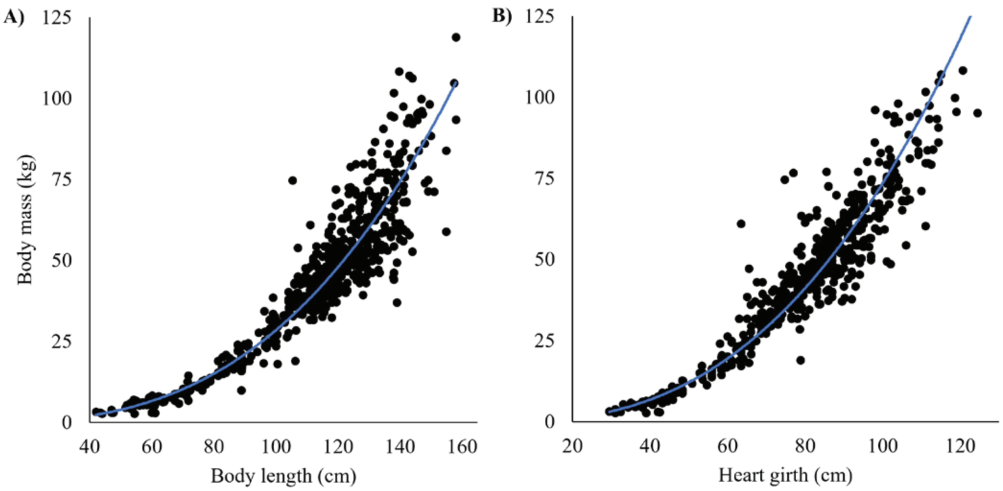

Figure 2. Relationship between wild pig (*Sus scrofa*) body mass (kg) to A) body length and B) heart girth, both measured in cm. Actual body mass is depicted with black points while estimated body mass is depicted with a blue line. Estimated body mass is from models developed from morphometric measurements taken on wild pigs (*Sus scrofa*) in central South Carolina and southwestern Georgia/northern Florida from April 2017 to June 2022.

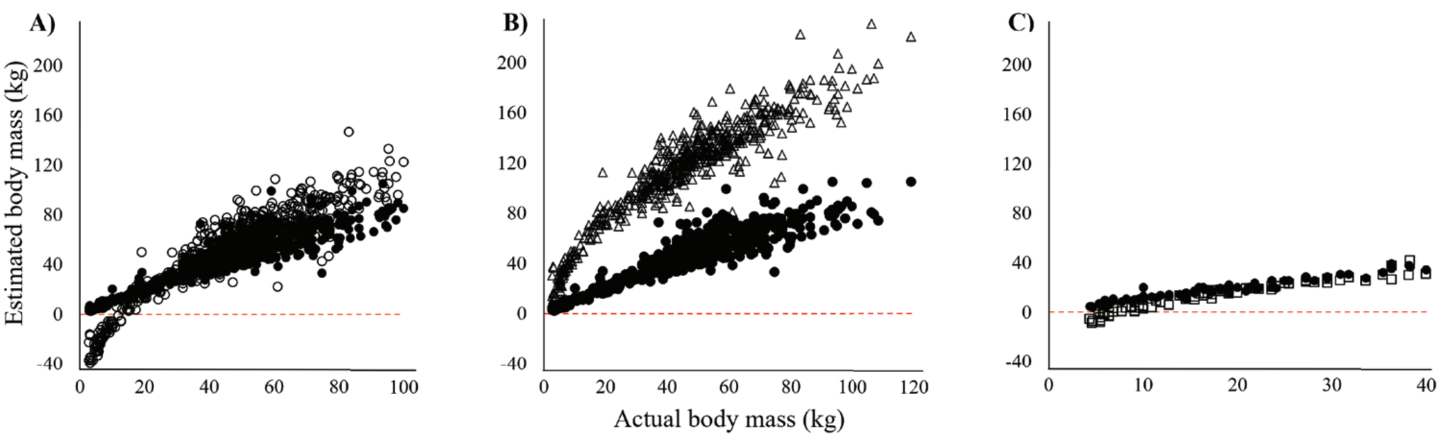

Figure 3. Comparison of actual wild pig (*Sus scrofa*) body mass (kg) and estimated body mass (kg) when using previously published models derived from domestic pig morphometric measurements. In each panel, our best-supported wild pig model is depicted with filled circles relative to models of: A) Groesbeck et al. (2002) with transparent circles; B) Sungirai et al. (2014) with transparent triangles; and C) Walugembe et al. (2014) with transparent squares. Note: Models in panel C only applied to pigs <40 kg.

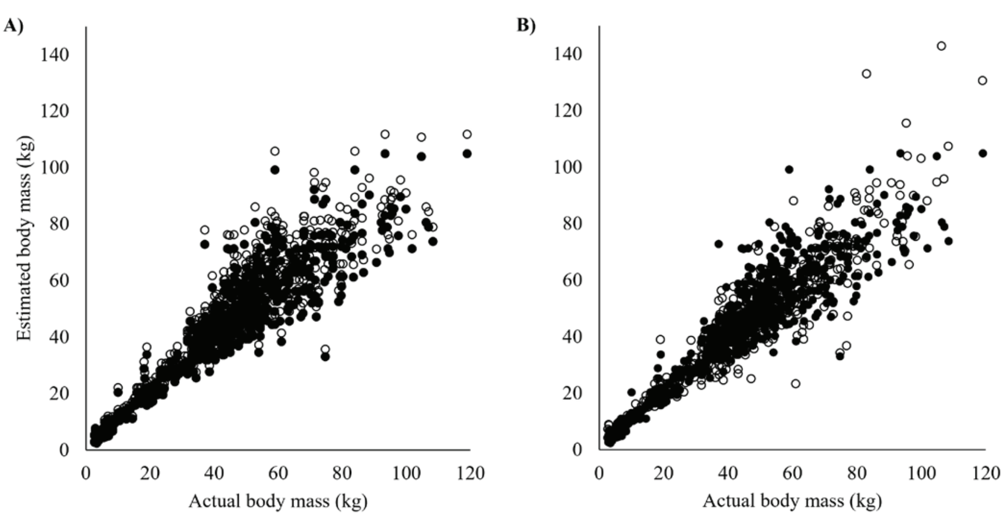

Figure 4. Comparison of actual wild pig (*Sus scrofa*) body mass (kg) and estimated body mass (kg) when using previously published models created from wild pig morphometric measurements. In each panel, our best-supported wild pig model (using body length as a predictor) is depicted with filled circles relative to: A) the body length and B) heart girth models from Baruzzi et al. (2023) with transparent circles.

Table 2. Wild pig (*Sus scrofa*) body mass estimated using the best-supported body length (BL) model generated from wild pig data in central South Carolina and southwestern Georgia/northern Florida. Body length is measured as the length from the tip of the snout to the base of the tail where the tail meets the body. Model: Weight (kg) = $e^{(-9.78 + 2.851 \times \ln[BL])}$, with BL in cm.

	Body length (cm)																													
	42	**46**	**50**	**54**	**58**	**62**	**66**	**70**	**74**	**78**	**82**	**86**	**90**	**94**	**98**	**102**	**106**	**110**	**114**	**118**	**122**	**126**	**130**	**134**	**138**	**142**	**146**	**150**	**154**	**158**
Weight (kg)	2	3	4	5	6	7	9	10	12	14	16	19	21	24	27	30	34	37	41	46	50	55	60	66	71	77	84	90	98	105

Table 3. Wild pig (*Sus scrofa*) body mass estimated using the heart girth (HG) model generated from wild pig data in central South Carolina and southwestern Georgia/northern Florida. Heart girth is measured as circumference of body just behind shoulder and forelegs. Model: Weight (kg) = $e^{(-7.671 + 2.599 \times \ln[HG])}$, with HG in cm.

	Heart Girth (cm)																										
	30	**34**	**38**	**42**	**46**	**50**	**54**	**58**	**62**	**66**	**70**	**74**	**78**	**82**	**86**	**90**	**94**	**98**	**102**	**106**	**110**	**114**	**118**	**122**	**126**	**130**	**134**
Weight (kg)	3	4	6	8	10	12	15	18	21	25	29	34	39	44	50	56	63	70	77	86	94	103	113	123	134	145	157

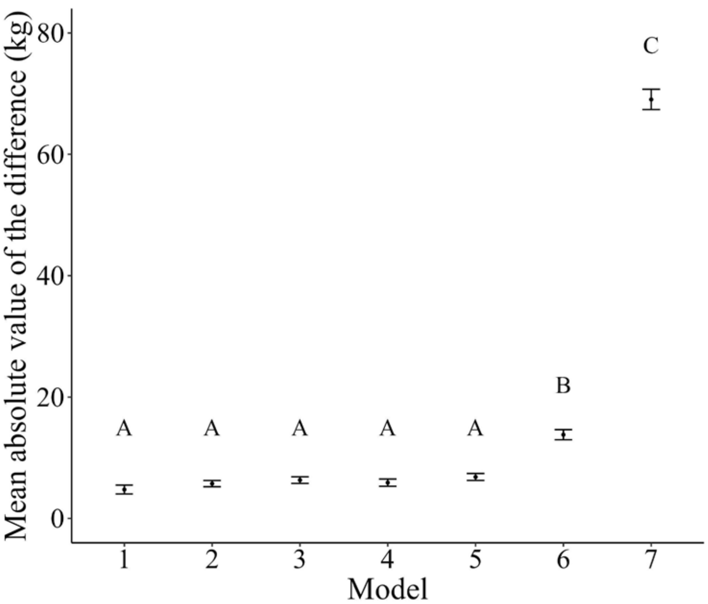

Figure 5. The mean and 95% CI of the absolute value of the difference between actual body mass and estimated body mass (used as an estimate of model precision) for each domestic and wild pig (*Sus scrofa*) model. Models are ordered as follows: 1 = Walugembe et al. (2014); 2 = heart girth model from Baruzzi et al. (2023); 3 = body length model from our study; 4 = heart girth model from our study; 5 = body length model from Baruzzi et al. (2023); 6 = Groesbeck et al. (2002); 7 = Sungiari et al. (2014). Black dots represent the means for each model. Models with unique letters are statistically different ($P < 0.05$).

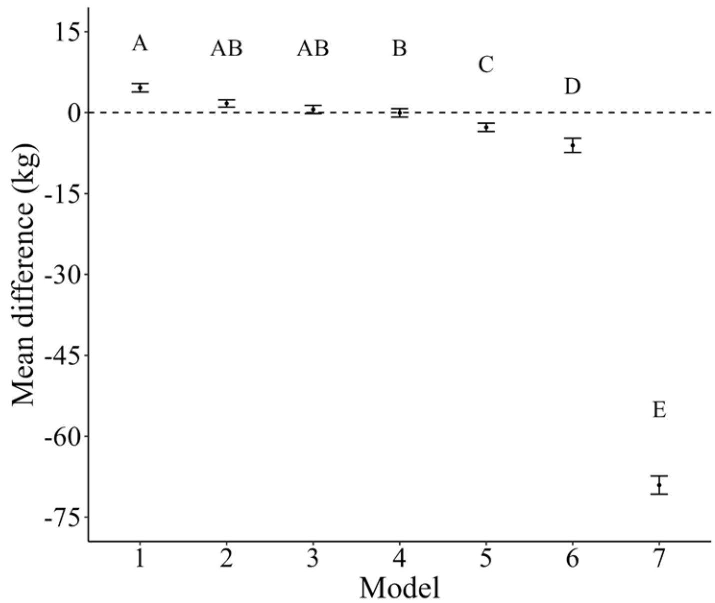

Figure 6. The mean difference and 95% CI between actual body mass and estimated body mass (used as an estimate of model accuracy or bias) for each domestic and wild pig (*Sus scrofa*) model. Models are ordered as follows: 1 = Walugembe et al. (2014); 2 = heart girth model from Baruzzi et al. (2023); 3 = body length model from our study; 4 = heart girth model from our study; 5 = body length model from Baruzzi et al. (2023); 6 = Groesbeck et al. (2002); 7 = Sungiari et al. (2014). Models are considered unbiased if their confidence intervals overlap with 0. Black dots represent the means for each model. Models with unique letters are statistically different ($P < 0.05$).

respectively). The true differences (i.e., accuracy or bias) of our best-supported wild pig model differed ($P < 0.001$) from those of Groesbeck et al. (2002), Sungirai et al. (2014), and Baruzzi et al. (2023) BL models (Figure 6). The Walugembe et al. (2014), our HG, and Baruzzi et al. (2023) HG models produced similar accuracy as our top wild pig model ($P = 0.116$, 0.981, and 0.740, respectively).

Discussion

Our results demonstrated that easily obtainable morphometric measurements can be used as precise and accurate predictors of wild pig body mass, and that models we developed using data from wild pigs can better estimate wild pig body mass than those developed using data from domestic pigs. Importantly, two of the three models developed using domestic pigs resulted in biased estimates of wild pig body mass. The Groesbeck et al. (2002) model overestimated overall body mass of larger wild pigs and underestimated body mass of smaller wild pigs, whereas the Sungirai et al. (2014) model consistently overestimated body mass. Overestimation of wild pig body mass by the Groesbeck et al. (2002) and Sungirai et al. (2014) models is likely attributed to differences in environmental characteristics among domestic and wild pigs. In contrast, the Walugembe et al. (2014) model underestimated wild pig body mass likely because this model only used data from domestic pigs <40 kg (Ježek et al. 2011). Magnitude of underestimation of wild pig body mass associated with the Groesbeck et al. (2002) and Walugembe et al. (2014) models is evidenced by negative predicted body mass for smaller wild pigs.

We determined that BL was the most informative predictor of wild pig body mass. This supports the findings of Baruzzi et al. (2023) who demonstrated that BL accounted for 96% of the variation in wild pig body mass. The coefficients of our BL model were very similar to the BL model of Baruzzi et al. (2023). We anticipated this result because the Baruzzi et al. (2023) BL model reliably estimated wild pig body mass across several locations such as Alabama, Australia, and Hawaii, illustrating the consistency of morphometric measurements in predicting body mass.

Our findings and those of Baruzzi et al. (2023) suggest body morphometrics can be used to precisely and accurately estimate wild pig body mass. Both modeling efforts yielded similar coefficients when using BL or HG, therefore we recommend using either of our models or those generated by Baruzzi et al. (2023) rather than models derived using domestic pigs when estimating wild pig body mass from morphometric measurements. There is more variability in body mass as wild pigs become heavier, possibly attributed to concomitant variation in reproductive status among female wild pigs which breed year-round throughout our study area. This variability was documented by the HG and BL models produced by both Baruzzi et al. (2023) and our study. Thus, there remains room for improvement when estimating the body mass of larger wild pigs. Morphometric measurements likely fluctuate less than body mass throughout the year due to environmental variation (Barrett 1978, Mayer 2021), and we encourage future research to evaluate how well our models generalize relative to seasonal variation of food and water availability.

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Literature Cited

Amaral, R. S., V. M. F. Da Silva, and F. C. W. Rosas. 2010. Body weight/length relationship and mass estimation using morphometric measurements in Amazonian manatees *Trichechus inunguis* (Mammalia: Sirenia). Marine Biodiversity Records 3:e105.

Barrett, M. A., N. J. Harriel, and S. E. Barrett. 2021. Improving estimates of body mass in American black bears using morphometrics and non-linear models. Ursus 32(e5):1–9.

Barrett, R. H. 1978. The feral hog on the Dye Creek Ranch, California. Hilgardia 46:281–355.

Baruzzi, C., N. P. Snow, K. C. VerCauteren, B. K. Strickland, J. S. Arnoult, J. W. Fischer, M. P. Glow, M. J. Lavelle, B. A. Smith, D. Steakley, and M. A. Lashley. 2023. Estimating body mass of wild pigs (*Sus scrofa*) using body morphometrics. Ecology and Evolution 13:e9853.

Bell, C. M., M. A. Hindell, and H. R. Burton. 1997. Estimation of body mass in the southern elephant seal, *Mirounga leonina*, by photogrammetry and morphometrics. Marine Mammal Science 13:669–682.

Burnham, K. P. and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach, 2nd edition. Springer-Verlag, New York, New York.

Chinn, S. M., P. E. Schlichting, T. J. Smyser, C. F. Bowden, and J. C. Beasley. 2022. Factors influencing pregnancy, litter size, and reproductive parameters of invasive wild pigs. Journal of Wildlife Management 86:e22304.

Comer, C. E. and J. J. Mayer. 2009. Wild pig reproductive biology. Pages 51–75 i*n* J. J. Mayer and I. L. Brisbin, Jr., editors. Wild pigs: biology, damage, control techniques, and management. SRNL-RP-2009-00869, Savannah River National Laboratory, Aiken, South Carolina.

Dobson, F. S. 1992. Body mass, structural size, and life-history patterns of the Columbian ground squirrel. American Naturalist 140:109–125.

Drimaj, J., J. Kamler, M. Hošek, J. Zeman, R. Plhal, O. Mikulka, and T. Kudláček. 2019. Reproductive characteristics of wild boar males (*Sus scrofa*) under different environmental conditions. Acta Veterinaria Brno 88:401–412.

Fenati, M., A. Monaco, and V. Guberti. 2008. Efficiency and safety of xylazine and tiletamine/zolazepam to immobilize captured wild boars (*Sus scrofa* L. 1758): analysis of field results. European Journal of Wildlife Research 54:269–274.

Groesbeck, C. N., R. D. Goodband, J. M. DeRouchey, M. D. Tokach, S. S. Dritz, J. L. Nelssen, K. R. Lawrence, and M. G. Young. 2002. Using heart girth to determine weight in finishing pigs. Kansas Agricultural Experiment Station Research Reports 10:166–168.

Hammond, J. 1962. Some changes in the form of sheep and pigs under domestication. Zeitschrift für Tierzuchtung und Zuchtungsbiologie 77:156–158.

James, F. C. and C. E. McCulloch. 1990. Multivariate analysis in ecology and systematics: panacea or Pandora's box? Annual Review of Ecology and Systematics 21:129–166.

Ježek, M., K. Štípek, T. Kušta, J. Červený, and J. Vícha. 2011. Reproductive and morphometric characteristics of wild boar (*Sus scrofa*) in the Czech Republic. Journal of Forest Science 57:285–292.

Keiter, D. A., A. J. Davis, O. E. Rhodes, Jr., F. L. Cunningham, J. C. Kilgo, K. M. Pepin, and J. C. Beasley. 2017. Effects of scale of movement, detection probability, and true population density on common methods of estimating population density. Scientific Reports 7:9446.

_____, J. J. Mayer, and J. C. Beasley. 2016. What's in a "common" name? A call for consistent terminology for referring to non-native *Sus scrofa*. Wildlife Society Bulletin 40:384–387.

Knauer, M. and J. Wiegert. 2017. Weighing pigs without a scale? All you need is a tube to measure heart girth. National Hog Farmer. < https://www.nationalhogfarmer.com/animal-health/weighing-pigs-without-scale-all-you-need-tube-measure-heart-girth>. Accessed 20 January 2022.

Mayer, J. J. 2021. Body mass variation in an introduced wild pig population with changing ancestry. SNRL-STI-2021-00110, Savannah River National Laboratory, Aiken, South Carolina.

______ and I. L. Brisbin, Jr. 2009. Wild pigs: biology, damage, control techniques and management. SRNL-RP-2009-00869, Savannah River National Laboratory, Aiken, South Carolina.

______, T. J. Smyser, A. J. Piaggio, and S. M. Zervanos. 2020. Wild pig taxonomy, morphology, genetics, and physiology. Pages 7–31 *in* K. C. VerCauteren, J. C. Beasley, S. S. Ditchkoff, J. J. Mayer, G. J. Roloff, and B. K. Strickland, editors. Invasive wild pigs in North America: ecology, impacts, and management. CRC Press, Boca Raton, Florida.

Mazerolle, M. J. 2020. AICcmodavg: Model selection and multimodel inference based on (Q)AIC(c). R package version 2.3-1.

Mikawa, S., S. Sato, M. Nii, T. Morozumi, G. Yoshioka, N. Imaeda, T. Yamaguchi, T. Hayashi, and T. Awata. 2011. Identification of a second gene associated with variation in vertebral number in domestic pigs. BMC Genetics 12:5.

Mutua, F. K., C. E. Dewey, S. M. Arimi, E. Schelling, and W. O. Ogara. 2011. Prediction of live body weight using length and girth measurements for pigs in rural Western Kenya. Journal of Swine Health and Production 19:26–33.

National Oceanic and Atmospheric Administration (NOAA). 2022. Climate at a glance. National Oceanic and Atmospheric Administration, Washington, D.C., <https://www.ncdc.noaa.gov/cag/>. Accessed 24 September 2022.

Pater, S. 2007. How much does your animal weigh? University of Arizona Cooperative Extension, Cochise County, Arizona.

Pedone, P., S. Mattioli, and L. Mattioli. 1995. Body size and growth patterns in wild boars of Tuscany, Central Italy. Journal of Mountain Ecology 3:66–68.

R Core Team. 2023. R: A language and environment for statistical computing. Version 4.1.2. R Foundation for Statistical Computing, Vienna, Austria.

Schlichting, P. E., C. L. Richardson, B. Chandler, P. S. Gipson, J. J. Mayer, and C. B. Dabbert. 2015. Wild pig (*Sus scrofa*) reproduction and diet in the Rolling Plains of Texas. Southwestern Naturalist 60:321–326.

Smyser, T. J., M. A. Tabak, C. Slootmaker, M. S. Robeson II, R. S. Miller, M. Bosse, H. J. Megens, M. A. M. Groenen, S. R. Paiva, D. A. de Faria, H. D. Blackburn, B. S. Schmit, and A. J. Piaggio. 2020. Mixed ancestry from wild and domestic lineages contributes to the rapid expansion of invasive feral swine. Molecular Ecology 29:1103–1119.

Sungirai, M., L. Masaka, and T. M. Benhura. 2014. Validity of weight estimation models in pigs reared under different management conditions. Veterinary Medicine International 2014:530469.

Sweitzer, R. A., G. S. Ghneim, I. A. Gardner, D. Van Vuren, B. J. Gonzales, and W. M. Boyce. 1997. Immobilization and physiological parameters associated with chemical restraint of wild pigs with Telazol and xylazine hydrochloride. Journal of Wildlife Diseases 33:198–205.

Tohara, S. 1967. Pig improvement with special reference to the number of vertebrae - variation of the number of vertebrae in pigs. Japan Agricultural Research Quarterly 2:29–34.

Walugembe, M., G. Nadiope, J. D. Stock, K. J. Stalder, D. Pezo, and M. F. Rothschild. 2014. Prediction of live body weight using various body measurements in Ugandan village pigs. Livestock Research for Rural Development 26:96.