A non-invasive approach to measuring body dimensions of wildlife with camera-traps: a felid field trial.

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Running Title: Obtaining body dimensions from wildlife cameras.

Word count:

- Abstract:190
- Main text: 2 615
- Acknowledgments: 24
- Figure legends: 303

Number of figures: 5.

Number of tables: 0.

Abstract:

Dimensions of body size are an important measurement in animal ecology that can provide information on species, sex, diet, and body condition. However, these measurements are difficult to obtain as most methodologies require the capturing and handling live animals. These invasive approaches result in logistical challenges, particularly when studying dangerous or difficult to trap species. We present a novel approach to measuring body dimesons utilising camera-trap images. Unlike prior methodologies, our technique allows for retrospective analysis with existing datasets and eliminates the need for permanent distance markers. We apply our method utilizing feral cats as our study species. The precision of our methodology was evaluated by comparing size estimates across individual cats. Average cat height was 27.4 cm (SE = 0.002 cm) and average length was 52.6 cm (SE = 0.003), with individuals showing consistent measurements across images (average standard error of 0.95 cm for height and 1.9 cm for length). Our method provided precise estimates of body size, highlighting the potential for camera-traps to supplement morphological information in trap-shy populations. We call for further trials of this method, preferably with individuals of known size, to better assess its accuracy.

Key words: body-size, *Felis catus,* invasive species, non-intrusive, trail camera.

Introduction:

Body size can provide important information on the sex, diet, body condition, and potential predators of an animal (Cumming & Cumming 2003). The most common methodologies used to measure mammal body size (hereafter, 'size') involve live trapping (Tarugara *et al.* 2019). This can cause high levels of stress and potentially result in injury or death (Zemanova 2020). Live captures are also financially costly, requiring intense effort (Mills, Godley & Hodgson 2016). Some individuals are trap-shy (Jolly & Dickson 1983), and as such live capture can be biased towards those that are 'trap-happy' (e.g., juveniles, animals in poor condition). For these reasons, many researchers are preferencing non-invasive approaches like camera-traps for wildlife monitoring (Zemanova 2020).

The work of Leorna, Brinkman and Fullman (2022) demonstrates that there are opportunities to measure size with this technology. Their method requires that the sensor size and focal length of the camera-trap to be known, as well as the distance of the animal to the camera-trap for each capture. One approach for distance is to place markers at a camera-trap site for the duration of the monitoring period, to provide a reference scale on each photograph (Hofmeester, Rowcliffe & Jansen 2017; Corlatti *et al.* 2020). These markers are conspicuous and could increase the risk of theft of the camera-trap. One alternative is to use a laser rangefinder, as done by Leorna, Brinkman and Fullman (2022). These cost approximately $500 USD each, constraining the number of stations that can be deployed, and inflating the financial consequences if a station is stolen or vandalised.

In this study, we describe a cost-effective, low-effort, and inconspicuous method for estimating size. Our method can be implemented in pre-existing camera-trap surveys and does not require a permanent distance marker or rangefinder. Our approach can also be retroactively applied to historical data, unlike existing methods. We demonstrate the utility of this method with feral cats, an ecologically damaging, trap-shy invasive predator in Australia. We seek to uncover whether feral cats in Tasmania are larger than domestics, addressing anecdotal reports of 'giant cats' in the wilds of Australia (Menkhorst & Morison 2012).

Method for estimating size from a camera-trap image:

The following steps are required for our approach: i) source the lens specifications of the camera-trap; ii) create a portable reference marker; iii) take a reference image of the marker at each camera-trap location; iv) overlay the image with animal images from the same site in photo-editing software; v) measure desired dimensions of the animal, in pixels, as well as the distance to the animal; vi) convert these measurements from pixels to metres.

Information required to calculate size:

This method employs the pinhole camera approach, which describes the relationship between a two-dimensional image and a three-dimensional scene:

$$\frac{S_i}{d_i} = \frac{S_o}{d_o}$$

Where S_i is the size of the object on the image in pixels, d_i is the distance of the camera sensor to the aperture (i.e., focal length expressed in pixels), S_o is the physical size of the object (in meters) and d_o is the physical distance to the object in meters from the camera (Leorna, Brinkman & Fullman 2022).

Three pieces of information are needed to rearrange this equation to obtain the physical size of an object/animal from an image. These include the camera-trap's focal length (d_i), the sensor size (height and length), measurements in pixels of the animal's dimensions, and the distance of the animal to the camera-trap (d_o). Focal length and sensor size can often be obtained from the user manual or by contacting the camera manufacturer. In cases when these specifications are not available, Megalingam *et al.* (2016) describes a calibration procedure to derive focal length in pixels. The focal length and sensor size are static specifications that will not change between calculations for a given camera model. The pixel measurements of an animal's dimensions and the distance of the animal to the camera-trap will be different for each photograph.

Distance marker and in-field protocol:

These distance marker needs to be portable and create a straight line from the camera-trap while providing visible indicators of distance at regular intervals discernible within camera-trap images. The design of the distance marker is largely dependent on the resources and requirements of the researcher. We created a portable distance marker using a tape-measure marked with different colours every 10cm, to total length of 2.3m (Fig. 1). This length was determined as the longest distance at which the colours on the tape were still reliably distinguishable within a camera-trap image taken by a Cuddeback X-Change Colour Model 1279 with 20-megapixel resolution (the standard device we used throughout this work).

A reference image of the distance marker must be taken at each camera-trap site (e.g., Fig. 1, panel A). This image will later be overlain with animal images taken at the same site. The reference image should contain the distance marker laid flat and out in front of the camera-trap, directly in line with the lens. The camera-trap used to take this reference image should be in the same location and position as the camera-trap used to collect wildlife images. The same model of camera-trap must also be used. After this reference image is taken, the distance marker can be removed from the site.

Pixel measurements:

Images should feature the animal in clear view of the camera-trap and within the range of the distance marker. Images of the study species must be overlain with a reference image of the distance marker at the same site. This can be done using the transparency function in Photoshop, or with any equivalent image editing software that allows for image overlay and pixel measurements. To ensure accurate overlap, the reference image, and the wildlife image, should be aligned using objects in the background, such as trees, stones, or the edges of pathways (Fig. 1). These objects can be traced to make this process easier (e.g., red drawn lines in Fig. 1C). An image should only be used if the animal photographed is parallel to the camera-trap, such that the whole flank can be seen.

Using the ‘ruler’ tool in the photo editing software, a straight, horizontal line is drawn between the animal’s front foot and the distance marker (Fig. 1C). Where it overlaps on the distance marker is the distance of that animal to the camera-trap. The ruler tool must be set to measure ‘pixels’, and then the height and length of the animal, or any other parameters of interest (e.g., head length, tail length, flank length) can be measured.

Estimating physical size from pixel measurements:

The pixel measurements are converted to millimetres using the following equation:

$$Object\ height\ on\ sensor\ (mm) = \frac{Sensor\ height\ (mm)\ x\ Object\ height\ (pixels)}{Sensor\ height\ (pixels)}$$

The object height on the sensor in millimetres can then be converted to its real height in meters using the equation below:

$$Real\ object\ hight\ (m) = \frac{Distance\ to\ object(m)\ x\ Object\ height\ on\ sensor\ (mm)}{Focal\ Length\ (mm)}$$

If measuring length, use sensor length and object length instead of height. Once converted to meters, it can be beneficial to convert these meters to centimetres to improve interpretability.

Demonstration of methodology using feral cats as a case study:

Background information:

Anecdotal reports of large feral cats that have been published within social and popular media (Menkhorst & Morison 2012), but there is an absence of published empirical evidence supporting their existence. Feral cats preferentially predate small mammals with an average body weight of approximately 42 grams, around 1.1% of average feral cat weight (Yip, Rich & Dickman 2015; Fleming *et al.* 2020). As cats get bigger, they consume a greater quantity of prey items and tend to target more diverse prey species (Yip, Rich & Dickman 2015). As such, size is an important factor when assessing the risk cats pose to vulnerable species.

Size is currently assessed by tranquilising or killing and physically measuring cats, the feasibility of which varies between habitats (Fisher *et al.* 2015). Camera-traps have been revolutionary for monitoring feral cats (Bengsen, Butler & Masters 2012) and could be used to provide information on cat size. In this case study we estimate feral cat size within a temperate rainforest/wet-eucalypt forest, an environment where the trapping and culling of live cats is infeasible. The frequent capture and re-capture of feral cats within a pre-existing camera-trap survey in the south-east of Tasmania provided a large dataset for us to opportunistically test and demonstrate our size methodology.

Existing field sites and camera deployment:

We reviewed images from an existing dataset of 53 camera-traps (model: Cuddeback X-Change 1279) that were deployed in the Picton region of Tasmania (**Error! Reference source not found.**). Cameras were secured to trees at animal shoulder height, 30-50 cm. Of the 53 cameras, 48 were set on unsealed forestry roads and six off-road in nearby natural arenas or on game trails. All cameras used a white flash with a passive infrared sensor (being triggered in response to movement and heat).

Processing camera-trap images:

Reference images were taken at camera-traps during using the methodology as described above (see section: *Distance marker and in-field protocol*). Images for size estimation were included only if the cat was within 2.3 meters of the camera and had their flank parallel to the camera-trap. Of the 53 sites, 32 (60%) met these criteria. From the chosen sites, we had access to 327 images of cats for measurement. Of these, 157 were unmarked black cats, and the remaining 170 could be identified to the individual level using their unique coat markings.

Although our method does not require individual identification, using it enables us to scrutinise the standard errors attributed to each individual and thereby assess the precision and consistency of our methodology. To mitigate potential bias from site-specific camera characteristics—such as road width and camera angle—a maximum of ten high-quality images per individual cat were processed for each camera. If a single image was captured for an individual across all sites, then this individual was excluded from our analysis and method demonstration. Using this protocol, 26 individual cats were identified and measured. Cat height (front paw to shoulder) and length (base of tail to nose) were measured in pixels and then converted to centimetres, as described in section above in *Pixel measurements*.

Results from field trial

Feral cat size estimates:

Average cat height and length was 27.4cm (SE = 0.002) and 52.6cm (SE = 0.003), respectively. To provide an indication of precision, measurements for each individual cat were averaged, and standard errors calculated using the bootstrap method in R (R Development Core Team 2010; Canty & Ripley 2017). The average standard error for each individual's height was 0.95cm for height and 1.9cm for length. The tallest individual's average height was 31.6cm (SE = 1.9), and the longest individual's average length was 60.1cm (SE = 1.8). The shortest individual had an average height of 20.2cm (SE = 1.2), and the individual with the shortest length measured at 42.1cm (SE = 0.9) (**Error! Reference source not found.**). The was a strong relationship between height and length across all individuals ($R^2 = 0.83$) (**Error! Reference source not found.**).

Discussion

Our size-estimation method provided consistent estimates of height and length for 26 unique cats, as calibrated against repeated images. Our measurements were close to the expected range of body size for *Felis catus:* 46cm for length and 23-25cm for height (Sunquist 2002). The margin of error varied among individuals: some exhibited consistent size estimates across images, while others showed greater variability. Nevertheless, the average error never exceeded two centimetres for height and six centimetres for length, with most being much lower than this. The key advantages of our methodology for measuring body size in camera-trap images, compared to past studies, are two-fold: (i) the distance marker does not need to remain at the field-site, thus lowering costs and mitigating theft risk. Consequently (ii), this approach can be used to measure animal body size from historical datasets by re-visiting the camera-trap site.

Variation in the measurements for each individual's height and length could be attributed to the differences in the position (Tarugara *et al.* 2019), or some foreshortening introduced by slightly oblique angles (e.g., Fig. 5, top right image). This corroborates the findings of Leorna, Brinkman and Fullman (2022), who noted a decline in measurement accuracy for deer as the distance to the camera-trap increased or when photographed at an angle. Additional variation in our measurements might be introduced by the non-exact nature of our distance marker, which measured distance in intervals of 10cm. This is because the resolution of the camera-trap images was too low to examine more precise intervals. Despite these potential sources of error, the standard errors were small for most individuals, indicating that our method provided consistent measurements.

Many of our useable photographs were collected from camera-traps on unsealed roads. Camera-traps placed off-trail frequently captured cats approaching the camera or walking away from it, making the images unmeasurable. Past studies have shown that roads and trails have higher rates of detection for low-density, wide-ranging predators (Wysong *et al.* 2020). In our study, road locations consistently yielded images of cats positioned with their flanks parallel to the camera-trap, because of the directed linear path of movement (**Error! Reference source not found.**). Therefore, for researchers aiming to measure predators, we advocate the strategic use of roads to optimise capture rates and consequently increase the volume of useable images.

Our method is beneficial in situations where a species cannot be live trapped or handled. Cage traps can suffer heavy biases due to both naturally cautious (untrappable) animals and conversely, trap-happy individuals, such as those in poor condition that are more inclined to take baits or young and naïve individuals (Short, Turner & Risbey 2002). While past research on predators has found that individuals may respond to camera-traps differently (Larrucea *et al.* 2007; Meek *et al.* 2016), these biases appear less pronounced. In cases where live trapping is not applicable, camera-trapping methods like ours provide a supplement to obtain information on morphology.

Our field trial provided the first estimates of the size of feral cats living in south-east Tasmania. The average estimates of length and height for cats in our study was 52.6cm and 27.4cm, which is similar to that of typical domestic cats of 46cm for length and 23-25cm for height (Sunquist 2002). To substantiate the size congruence between domestic and feral cats, future research could undertake a comparative analysis with proximal domestic-cat populations. Such an investigation could determine whether there are any morphological shifts within that introduced population compared its nearby domestic analogues. The cats we measured appeared to be within the normal size range for *Felis* *catus.* As such, our findings do not contain any evidence that supports the phenomenon of Australian "big cats" (Menkhorst & Morison 2012), though we have only sampled a small pocket of the Tasmanian wilderness herein. Our method can be applied to historic datasets to validate claims of unusual cat size, or to track changes in feral cat morphology over time in other long-term camera-trap surveys. Our method offers a cost-effective way for claims of unusual animal size to be validated, whether for the scientific purpose of assessing ecological niche, or for the general interest of the public.

Our study focuses on precision, as we were unable to validate our measurements against true measurements for the size of the feral cats photographed (we undertook no live trapping). We encourage future studies to test our method's accuracy, perhaps with captive populations or in field trails where individuals are being shot and removed. Nonetheless, the high level of precision shown in our field trial, using repeated measures coupled with individual identification, indicates that this method is robust. It can be validly used to provide estimates of relative size, meaning that differences in animal size across populations and time can be evaluated using our method.

Conflict of Interest:

The authors declare no conflict of interest.

Acknowledgments:

We would like to thank the members of the Dynamics of Eco-Evolutionary Patterns (DEEP) research group at the University of Tasmania for their support.

Funding provided by the Australian Research Council (FL160100101).

Authors' contributions:

Alexandra Paton conceived the idea for the paper and designed methodology; Barry Brook and Jessie Buettel were responsible for camera-trap survey data collection; Alexandra Paton analysed the data, with advice from co-authors; Alexandra Paton led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

Data accessibility:

All data and code used will be made available on GitHub.

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Figure legends:

Figure 1: An example of the field photo taken of the measuring tape with 10cm colour blocks to 2.3 meters, a suitable image of a cat, and how the images are superimposed, aligned to ensure the tape-measure is in an accurate position to read distance of the cat to the camera. The red lines in panel C show reference points in the background that were traced to ensure accurate overlay, and the white line indicates the distance of the cat from the camera-trap on the distance marker.

Figure 2: Map of Tasmania showing the camera-trap sites used in this study. Status indicates whether a site provided measurable data, with red points (1) as sites that provided data suitable for size measurements of cats, and white (0) with no useable photos.

Figure 3: Comparisons of average cat length (left) and height (right) with the mean and standard errors for each individual cat (labelled 1 to 26). Note that the x-axis is in descending order for length, and that the Cat IDs on the x-axis match that order to allow for comparisons between individuals. The dashed red line in each graph displays the average length and height across all individuals, and the faint dashed red lines above and below this shows the average upper and lower standard error across individuals.

Figure 4: Relationship between average individual cat length and height (in centimetres) as determined from the camera-trap-derived size estimates. Points are provided for each cat measurement, with the regression line provided in blue and standard error in grey.

Figure 5: On the left, two examples of cats on an angle, making them inappropriate to measure from these camera-trap images. On the right, two examples of cats that are parallel and close to the camera trap, making them good specimens for measurement using these camera-trap images.

Figures

Figure 1:

Figure 2:

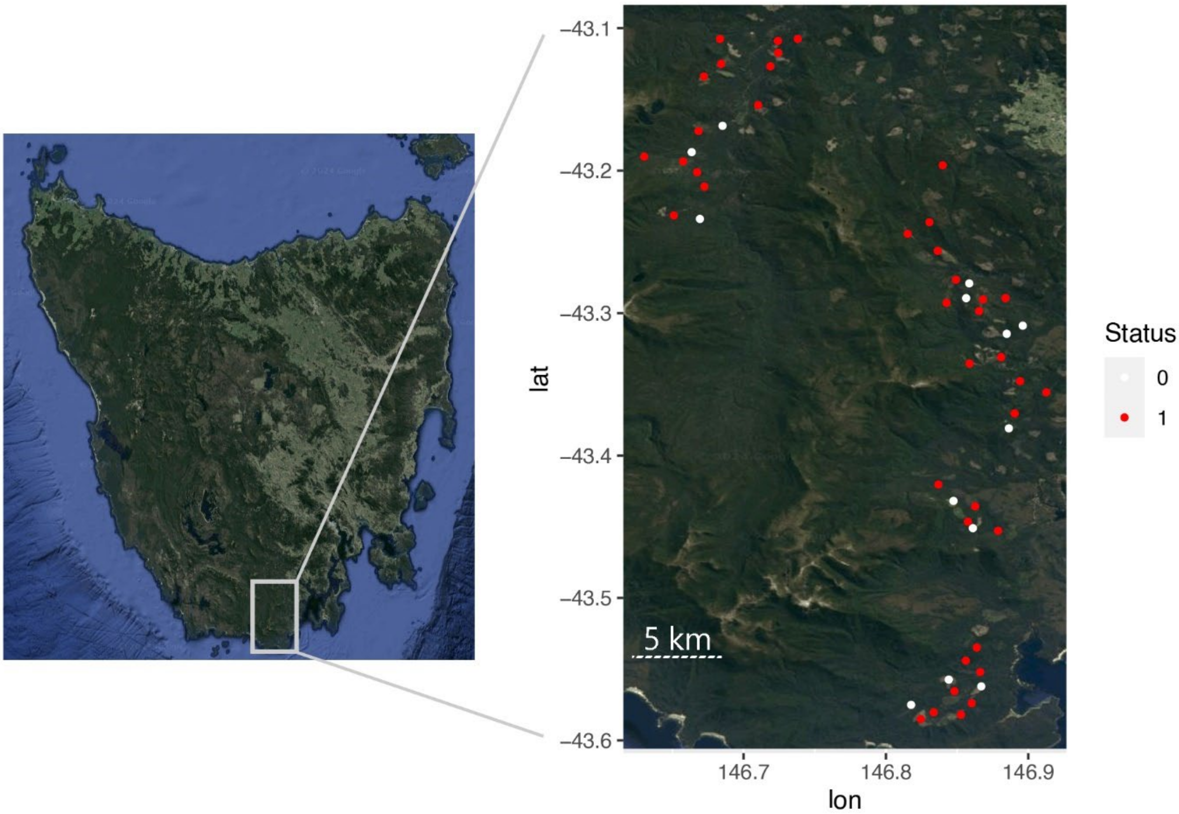
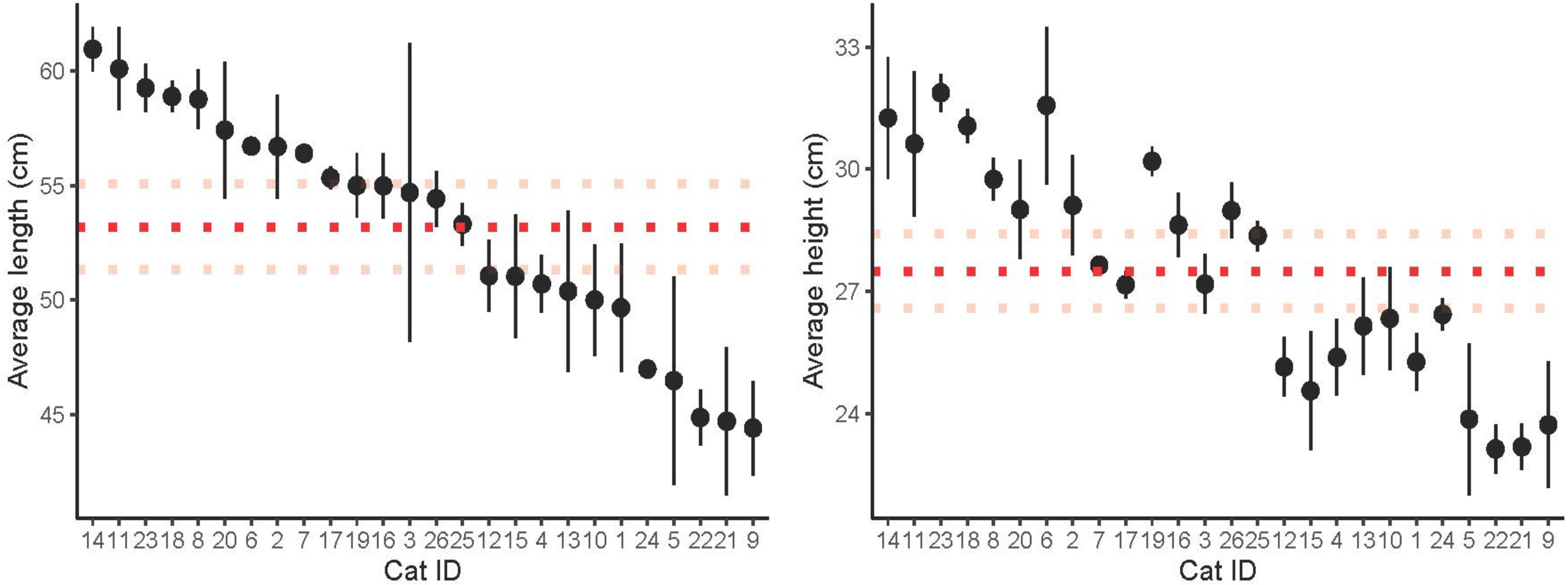


Figure 3:



Average length (cm)
60
55
50
45
14 11 23 18 8 20 6 2 7 17 19 16 3 26 25 12 15 4 13 10 1 24 5 22 21 9
Cat ID
Average height (cm)
33
30
27
24
14 11 23 18 8 20 6 2 7 17 19 16 3 26 25 12 15 4 13 10 1 24 5 22 21 9
Cat ID

Figure 4:

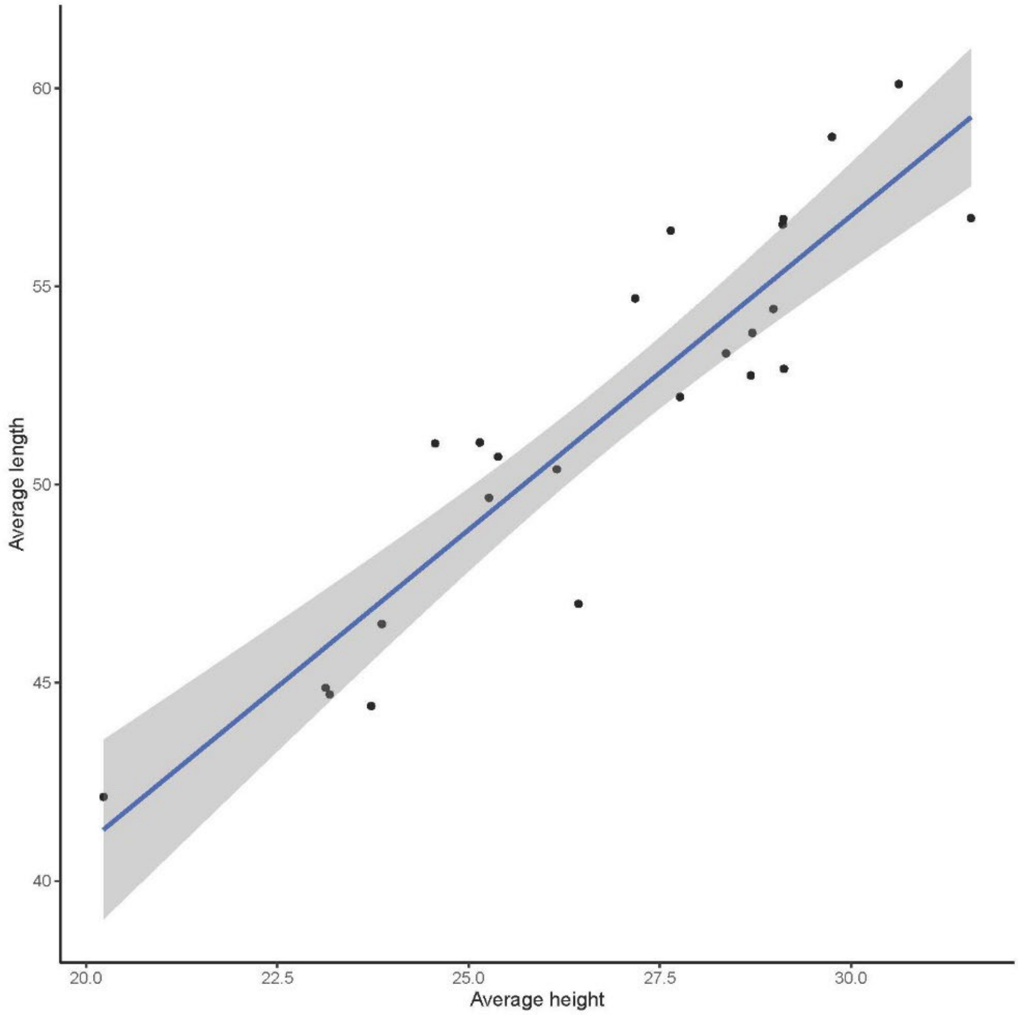

Average length
60
55
50
45
40
20.0
22.5
25.0
27.5
30.0
Average height

Figure 5: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5/21/2020 5:10 PM PW-S5-C5
1/31/2021 12:50 AM PW-S3-C5
11/18/2019 6:58 AM PW-S8-C5