drones

Communication

A Rapid UAV Method for Assessing Body Condition in Fur Seals

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Abstract: Condition indices correlating body lipid content with mass and morphometric measurements have been developed for a variety of taxa. However, for many large species, the capture and handling of enough animals to obtain representative population estimates is not logistically feasible. The relatively low cost and reduced disturbance effects of UAVs make them ideal for the rapid acquisition of high volume data for monitoring large species. This study examined the imagery collected from two different UAVs, flown at 25 m altitude, and the subsequent georeferenced orthomosaics as a method for measuring length and axillary girth of Australian fur seals (*Arctocephalus pusillus doriferus*) to derive an index of body condition. Up to 26% of individuals were orientated correctly (prostrate/sternal recumbent) to allow for body measurements. The UAV-obtained images over-estimated axillary girth diameter due to postural sag on the lateral sides of the thorax while the animals are lying flat in the sternal recumbent position on granite rocks. However, the relationship between axillary girth and standard length was similarly positive for the remotely- and physically-obtained measurements. This indicates that residual values from the remotely-obtained measurements can be used as a relative index of body condition.

Keywords: body condition; axillary girth; Australian fur seals (*Arctocephalus pusillus doriferus*)

1. Introduction

The ability to monitor body condition in free-ranging animals is central to determining population health and the factors that influence it [1,2]. This is particularly important for understanding the potential influence of environmental change on wildlife populations [3]. Correspondingly, numerous condition indices that correlate body lipid content with mass and morphometric measurements have been developed for various taxa [4–6]. However, for many large species, the capture and handling for mass and morphometric measurements of sufficient numbers of animals to obtain representative population estimates is not logistically feasible [7–9]. Photogrammetry has been used successfully to measure size and estimate condition in several large mammal species [10–13]. Such techniques, however, can be limited by the ability to obtain sufficient quantities of high quality (i.e., correct aspect, no visual obstructions) imagery without disturbing the target subjects.

Advances in unmanned aerial vehicle (UAV) technology have provided opportunities for obtaining photographic data on a range of animals for a variety of purposes from abundance estimates to information on reproductive behaviour and success [14–16]. The relatively low cost and minimal disturbance effect of such techniques make them ideal for the rapid acquisition of large amounts of data for use in monitoring programs [17,18]. Indeed, recent studies using UAVs for measuring body condition and mother–calf energy transfer in cetaceans highlight their potential for monitoring environmental influences on reproductive success and population health [19]. Pinnipeds, with their propensity to densely aggregate in breeding colonies or haul-outs, lend themselves to being subjects for body condition monitoring using UAVs. With precise ground control targets and the use of structure from motion processing, it is now possible to generate high-resolution centimetre-precision mosaics that provide opportunities for imaging haul out sites; allowing the calculation of morphometrics for large numbers of individuals with minimal disturbance. This study aims to validate the use of UAVs as a means of measuring the relative index of body condition in otariid seals.

2. Materials and Methods

In the present study, the feasibility of using a UAV to measure body condition was tested on a colony of Australian fur seals (*Arctocephalus pusillus doriferus*). The study was conducted at Kanowna Island (39°09′S, 146°18′E) in northern Bass Strait, south-eastern Australia. The island hosts the third largest breeding colony for the species, with an annual production of ca 3400 pups during the November–December pupping season [20]. Photographic data from UAVs were collected opportunistically on 10 March 2017 as part of concurrent vegetation mapping studies on the island. During the early morning, a 3DR Solo quadcopter (3D Robotics, Inc., Berkeley, CA, USA) carrying a Sequoia multispectral camera (Parrot Drones SAS, Paris, France) was used while in the afternoon the same area was flown using a DJI Phantom 4 (Da-Jiang Innovation, Shenzhen, Guangdong, China) with an in-built 12 MP camera. During the middle of the day, in response to warm ambient temperatures (>25 °C), the majority of seals left the colony to thermoregulate in the adjacent water, limiting the chances of repeated measurements of the same individuals.

The 3DR Solo and DJI Phantom 4 were flown using Mission Planner and Pix4DCapture autonomous flight planning software, respectively. Each flight was conducted at an altitude of 25 m above the terrain at approximately 2 $m \cdot s^{-1}$, flown in a cross-hatch design with 60% overlap and 60% side-lap for the images. This altitude was chosen to minimize distress to the animals while achieving the highest resolution possible. The flight speed was dictated by the altitude to ensure clear imagery and the cross-hatch design was chosen to minimize voids in the data. Ground Control Points (GCPs) marked with a Topcon Hiper SR RTK GPS (Topcon Corporation, Tokyo, Japan) were used to increase the accuracy of the mapping models. The operation was conducted under Civil Aviation Safety Authority (Australia) < 2 kg Remotely Piloted Aerial Systems (RPAS) regulations with both airframes being restricted to flying in winds < 15 kt, temperatures < 35 °C, and visual meteorological conditions conducive to flight operations. Neither flight elicited any noticeable impact on seal behavior (*pers. obs*).

The UAV-captured images were processed in Pix4Dmapper Pro (version 3.1.23., Pix4D Inc., Lausanne, Switzerland) using structure-from-motion processing. Structure-from-motion processing searches for matching features, called keypoints, in overlapping images. Using the keypoints, the camera parameters can be calibrated to exterior parameters (the position and orientation of images) using bundle adjustment from the matched points and the GCPs (prioritized by using larger weights). The computed 3D position of matched points is then densified and textured with corresponding images. The orthomosaic is then generated by projecting every textured pixel onto a 2D plane [21]. Once processed, the orthomosaics had a ground resolution of 0.76 $cm \cdot pixel^{-1}$ and a model RMS error of 5.1 cm. For the DJI Phantom 4, processing produced a ground resolution of 1.08 $cm \cdot pixel^{-1}$ and a model RMS error of 6.3 cm. The stitched georeferenced orthomosaics were analyzed in ArcGIS (version 10.2.2, Environmental Systems Research Institute Inc., Redlands, CA, USA). Seals were first assessed for visual quality and posture, and only individuals where the body shape outline was clearly visible, the animal was in sternal recumbent position and the insertion point of the trailing edge of the fore-flippers could be seen, were included in the analyses (Figure 1). Standard length (tip of tail to tip of snout [22] and axillary width (trunk width at the trailing edge of the fore-flipper) were measured using the software ruler tool (±0.5 cm).

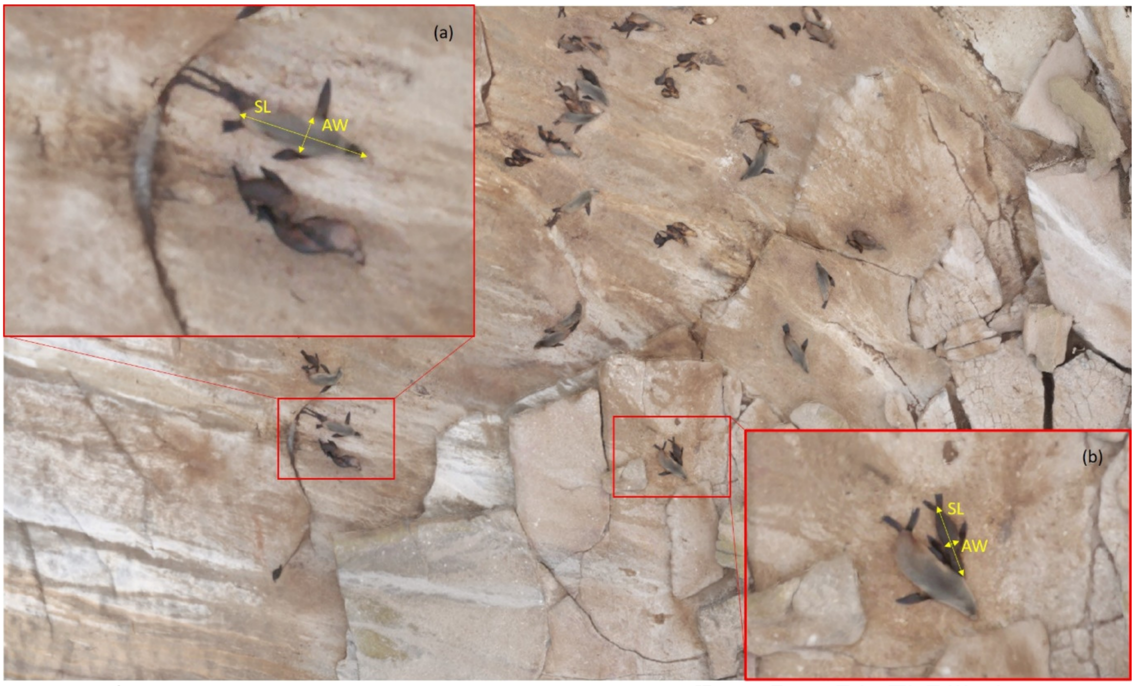

Figure 1. Representative image obtained via UAV (Parrot Sequoia) of Australian fur seals showing measurements of standard length (SL) and axillary width (AW, used to estimate axillary girth) on an adult female (**a**) and a 3–4 month old pup (**b**).

As the ambient temperature during the UAV data capture was relatively high, the number of animals ashore as a proportion of the total colony was relatively low (i.e., many individuals thermoregulating in the water). Nonetheless, a total of 273 and 98 individuals were visible in the stitched Parrot Sequoia and DJI Phantom 4 images, respectively. Of these, 26% and 11% could be measured, comprising 41 adult females and 41 pups (3–4 months old). Adult females were identified from their body shape, pelage colour and/or being in association with pups, while pups were identified by their black pelage. Few adult males and juvenile individuals were present at the colony at the time of the drone flights and none of them in the stitched image met the criteria suitable for measuring. Measurements were conducted independently by two observers and the mean of both values were recorded. Where measurements differed by more than 5%, a third measurement was conducted and the closest two were averaged.

The axillary width measurement was assumed to approximate the diameter of a circle, representing axillary girth, calculated as:

$$\text{Axillary girth} = \text{width} \times \pi \text{ (cm)}$$

Axillary (or chest) girth is a commonly used measurement of body condition in a range of taxa [23–26], including pinnipeds [27], reflecting the depth of subcutaneous fat deposits around the thorax [28,29]. However, axillary girth scales with overall body size, and therefore, the residual (observed—expected) value of the relationship between axillary girth and standard length for an individual is used as an index of its body condition. In Australian fur seals, such residual values have been shown to be positively correlated with sternal blubber depth ([30], Arnould and Warneke unpublished data), confirming their use as an index of body condition. To assess the accuracy of UAV-acquired data, the relationship between axillary girth and standard length (±0.5 cm) was determined in data collected from adult females (n = 391) and 3–4 months-old pups (n = 93) manually measured at Kanowna Island as part of other studies since 1997 [31–36].

3. Results and Discussion

The selection of individuals and their measurements were conducted over a total of 8.5 h giving an average of 6.2 min to measure each seal. Measured standard length and estimated axillary girth ranged from 132.0–164.0 cm (Mean ± SE: 147.5 ± 1.2 cm) and 101.5–138.5 cm (118.5 ± 1.4 cm) respectively for adult females, and from 65.0–103.0 cm (79.2 ± 1.30 cm) and 49.0–90.0 cm (69.3 ± 1.7 cm) respectively for pups (Figure 2). Using the non-linear weighted least squares in the R statistical environment [37], the relationship between axillary girth and standard length was best described by separate power functions for adult females ($y = 2.8 \cdot x^{0.75}$) and pups ($y = 0.39 \cdot x^{1.2}$), where y is Axillary girth (cm) and x is Standard Length (cm).

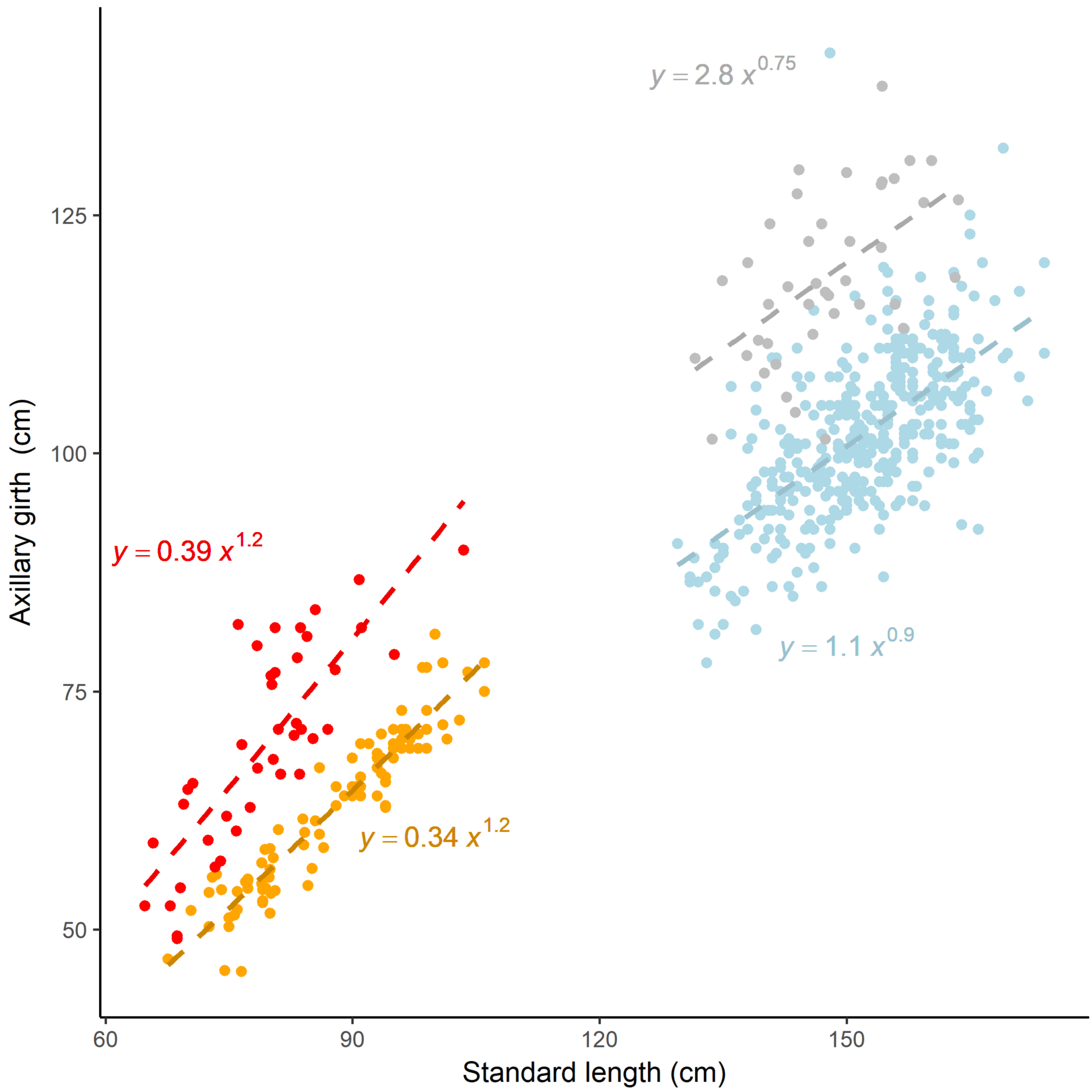

Figure 2. Plots of the relationship between Axillary Girth and Standard Length of Australian fur seals measured by UAV (adult females: grey, pups: red) and physically measured in individuals captured between 1997–2017 (adult females: blue, pups orange). Dashed lines and inset text represent the fitted power relationships to each group of data.

Standard length in these animals ranged from 129.5–174.0 cm (152.0 ± 0.5 cm) and 67.5–106.0 cm (88.0 ± 1.0 cm) for adult females and pups, respectively (Figure 2). The standard lengths of UAV-measured adult females were significantly ($t_{430} = 3.09$, $P < 0.01$) less than the sample manually measured since 1997. However, there has been a trend of decreasing body size in adult female

Australian fur seals over this period [32,33,36] and the standard lengths of UAV-measured adult females were not different to the mean (148.2 ± 1.02 cm) observed in 2012–17 (t_{99} = 0.45, P > 0.65). The significant difference (t_{87} = 5.30, P < 0.001) in standard length between the UAV- and manually-measured pups is consistent with previous studies documenting inter-annual variation in maternal provisioning conditions and pup growth in otariid seals [38–40].

For both adult females (101.9 ± 0.4 cm) and pups (62.9 ± 0.9 cm), the physically-measured axillary girths were significantly less (t_{431} = −12.00, P < 0.0001 and t_{132} = −3.76, P < 0.001, respectively) than those estimated from the UAV images (Figure 2). This is likely due to the axillary widths measured in the UAV-obtained images over-estimating axillary girth diameter because of postural sag on the lateral sides of the thorax while the animals are lying flat in the sternal recumbent position on granite rocks. Indeed, an over-estimation in axillary diameter of just 5 cm would account for the *ca* 18 cm difference between the mean remotely-measured and physically-measured axillary girths for adult females and pups, respectively. There is also potential for variation in the measurement techniques of physically captured individuals, which is minimised in the remote measurement of naturally recumbent individuals. Nonetheless, the relationship between axillary girth and standard length was similar for the remotely- and physically-obtained measurements (Figure 2, Table 1).

Table 1. Summary results of non-linear least squares modelling of power relationships (Axillary girth = a * Standard Length b) fitted to measurements taken from captured and remotely-measured Australian fur seals.

	Age Class	*n*	Parameter	Estimate	SE	*t*	*P*
Capture	Adult female	391	a	1.112	0.309	3.598	0.0003
			b	0.899	0.055	16.27	<0.0001
	Pup	93	a	0.339	0.068	4.931	<0.0001
			b	1.166	0.045	25.865	<0.0001
Remote	Adult female	41	a	2.78	2.513	1.106	0.275
			b	0.751	0.18	4.154	0.0001
	Pup	41	a	0.394	0.235	1.673	0.102
			b	1.182	0.136	8.691	<0.0001

Importantly, this indicates that residual values from the remotely-obtained measurements can be used as a relative index of body condition for adult female and pup Australian fur seals, which is in agreement with the physically-obtained measurements in previous studies [41]. While further data are required for confirmation, this technique should be applicable to all age/sex classes for this, and most likely other otariid species.

4. Conclusions

This study demonstrated a rapid, minimally disruptive means of measuring a relative index of body condition in potentially large numbers of otariid seals. The relatively inexpensive availability of UAVs and their ease of use make such data collection on a regular basis feasible for researchers and wildlife managers. However, some factors may limit wider application of such technologies. For example, the UAV models used in the present study require flights to be conducted at wind speeds <15 kt; conditions met on only ~40% of days at the colony in the present study. Similar wind regimes are likely to occur at many other coastal locations where otariid seal colonies are situated. In addition, civil aviation and/or wildlife disturbance regulations in some locations may prevent the use of UAVs at seal colonies. Additional trials may be required with other species and UAV models to ascertain the level (if any) of disturbance effects. Lastly, the current study only measured individuals lying in the sternal recumbent position, and obtaining measurements on sufficient numbers of animals may be influenced by the colony substrate and/or ambient temperature affecting the posture of the animals. Additional trials should be conducted to assess the accuracy of measurements obtained via UAV for animals in different postures.

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