## 3. DISCUSSION

**Outline**

Here, we developed a minimally invasive method of inferring individual sperm whale age-class and sex leveraging prior knowledge on sperm whale morphometric development. Nose-to-body ratio measures based on snout to flipper distances (*NRflipper*) reliably captured the sexual dimorphism in sperm whales’ noses, providing a useful means of inferring individual sex. AUV-derived total length estimates we were able to tease apart likely calves, juveniles, larger adult males (bachelors), and mature males. Using a Bayesian approach, we identified some individuals which have a high probability of being mature females with high certainty based that previously would have been assigned fem/juv class. Still, some individuals had uncertain sex assignments.

1. UAV-based Morphometric measurements were consistent with previous research
   1. Max female length falls within range
   2. Mature females – mostly below thee ‘female curve’ – most of the ones observed receiving peduncle dives.
   3. Smallest whales ~ newborns – calves observed giving peduncle dives.
   4. NRflipper for known mature males is highly divergent from that of the rest of the population – despite using a different landmark than previous work.
2. Error estimates are also consistent with other works – despite us using a very cheap drone.
   1. Altimeter-error (captured by *Balaena* measurements) is similar to that of other models.
   2. Bootstrapping likely captured realistic measure of uncertainty, as it is slightly broader than *Balaena* (reflecting error from differences in whale position/visibility of morphological landmarks).
3. Several individuals had high uncertainty and intermediate p(fem) values
   1. May have some measurement error (TL and ratio)
   2. May be ‘intermediate-nosed whales’ - natural variation + intersex whales
   3. No individuals within the SA – Fmax range had high confidence of being male
      1. Males at these ages leave – we primarily followed large groups which have primarily females, calves and juveniles
4. Linear growth of NR for males was surprising
   * 1. Nose continues to grow disproportionately for as long as body continues to grow? – does pressure for larger noses remain even when whales are huge?
     2. Larger > 16 m males would help clarify this
5. Peduncle dive patterns not surprising
   1. Mature females receive, calves & juveniles do, big males not involved.
   2. Some uncertain individuals (high mean p being fem, but high uncertainty) – can’t tell what they are at this point. Likely female given what we know about peduncle diving, but could be a mistake, or reflect non-nursing function (some males do baby sit)
   3. Note it doesn’t represent all the peduncle dive patterns – would be cool to explore, very accessible with drone.
6. Opens door to investigating other social behaviours, including tactile interactions, mating, etc. (like the shark bay dolphins)/ demographic/population structure estimates if sampled individuals are representative of the population (which ours are not!)
   1. If used in longitudinal studies, can track changes in demographic composition (important to inform conservation).
7. Limitations
   1. Parameter estimates for male and female *NRflipper*growth curves were sensitive to measurement error (between images/within individuals), resulting in some uncertainty in p(fem) estimates, especially young ones.
      1. Not many little individuals used! – hard to observe.
      2. Still able to tease apart some age/sex classes.
      3. Are there other alternatives to our optimizing algorithm?
   2. Used a cheap drone with built in barometer – not great
   3. Error estimates seem to resemble those taken with laser (?) a bit odd.
   4. Sperm whale populations have different growth trajectories – Caribbean/Pacific – may not be directly translatable.
   5. Laser altimeter may improve length estimates – narrow ci for lengths, increase certainty of pf
   6. No ground truthing available – could try on population with known sex/age (based on biopsy/genital inspection – not merely on behaviour).
8. Conclusions
   1. We provided a simple approach to infer sex/age classes of sperm whales, allowing finer-grained sex-age classifications.
   2. Using priors on sexual dimorphism can be incorporated for remote measurement to infer demography of species for which this is hard.
   3. Doing this can provide key information for field behaviour and population research while being minimally invasive.

**Sandbox**

Here, we developed a minimally invasive method of inferring individual sperm whale age-class and sex leveraging prior knowledge on sperm whale morphometric development. Using a low-cost, commercially available UAV, we obtained total body length estimates that allowed for more narrow age-class assignments than traditional field work observations.

Nose-to-body ratio measures based on snout to flipper distances (*NRflipper*) reliably captured the sexual dimorphism in sperm whales’ noses, providing a useful means of inferring individual sex. While parameter estimates for male and female *NRflipper*growth curves were sensitive to measurement error (between images/within individuals), optimal models were consistently able to differentiate likely mature females (MF) from males. Still, some individuals between 8.5 – 12 m long were assigned ambiguous probabilities of being female. Additionally, we found that the relationship between *NRflipper*and *TL* for males <17 m is linear, rather than logistic. Our observations of individuals engaging in peduncle diving generally fit our expectations; only calves and juveniles were observed doing peduncle dives, and most individuals receiving peduncle dives fell within the female size range and had a high probability of being female.