### 3.3 | Sex and age class inference

#### 3.3.1 Parameter optimization

Optimal values for *fr, maxf, mr and maxm* varied more across bootstrap iterations in models fit with *R – Dorsal* than *R – Flipper* (**Table 2**), resulting in generally higher levels of uncertainty associated with models based on *R – Dorsal* than *R – Flipper* (**Figure 3**). *Fr* values were highly variable in both models, resulting in a high degree of uncertainty in modeling *R* of smaller (< 6 m) whales (**Figure 3**). Still, the divergence in *R* between males and females after *chm* was consistently more pronounced in models based on *R – Flipper* metrics, partly because large males had disproportionately higher *R - flipper* metrics than the rest of individuals, while their *R - dorsal* measures remained closer to the general population (**Figure 5**). Estimates of asymptote parameters (*maxf* and *maxm*) were generally more stable than growth parameters (*fr* and *mr*), although some iterations of the *R – Dorsal* model resulted in distant outliers of the male-specific parameters (*mr* and *maxm*; **Figure 4**)

**Table 2**. Bootstrapped means and 95th percentile confidence intervals (95% CI) based on 1000 iterations for parameters relating sperm whale length (m) and nose-to-body ratio (R) metrics based on snout to the caudal base of the dorsal fin (R – Dorsal) and on snout to the flipper insertion point (R – Flipper). Parameters reflect the growth rate of females and small males (≤ 6 m) (fr), the female asymptote of R (maxf), the growth rate of larger males (> 6 m) (mr), and the male asymptote of R (maxm).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *R* Metric | *fr* [95% CI] | *maxf*[95% CI] | *mr* [95% CI] | *maxm*[95% CI] |
| *R* - *Dorsal* | 2.8 (0.63 - 14.9) | 0.65 (0.64 - 0.65) | 0.2 (0.01 - 0.62) | 0.89 (0.22 - 4.79) |
| *R - Flipper* | 2.26 (0.5 - 33.64) | 0.3 (0.3 - 0.3) | 0.05 (0.01 - 0.16) | 2.05 (0.45 - 6.89) |

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**Figure 3.** Bootstrapped logistic curves of the total length (m) and the nose-to-body ratio of sperm whales based on measures of the snout to the caudal base of the dorsal fin (A) and snout to the base of the flipper (B). Theoretical male curves are shown in violet and theoretical female curves are shown in green. The average R values across iterations are shown by light violet and green lines for males and females respectively. Dashed vertical lines indicate the minimum body lengths associated with sperm whale sex and age classes as follows: length at birth (4 m; NB), juvenile (J; 5.5 m), sub-adult (SA; 7.6 m ), adult female (AF – 8.5 m), adult male and mature female (AM/MF – 10 m), maximum female length (Fmax – 12 m), and mature male (MM – 13.7). (Best 1979, Best et al. 1984, Rice 1989, Mendes et al. 2007).

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**Figure 4.** Distribution of bootstrapped parameter estimates for R – Flipper and R – Dorsal models.

#### 3.3.2 Posterior probabilities of being female

Models based on *R – Dorsal* metrics resulted in higher uncertainty for individual *P(f)* estimates than *R – Flipper* models (**Figure 5**). Models fit with *R – Flipper* consistently (i.e., 95% *CI* width < 0.05) assigned a high probability of an individual being female (*P(f) > 0.95*) to 21 individuals ranging from 9.8 – 12.5 m and *R – flipper* measures between 0.28 – 0.31. This length range coincides with the 10 – 12 m range of mature females based on whaling data (Best et al. 1984). *R -Flipper* models also resulted in a consistently low probability of individuals being females (*P(f)* < 0.05) values for 5 individuals between 12.9 – 16.1 m and *R flipper* 0.38 – 0.41, which can be classified as males based on their length and behavioural context. Conversely, in models fit with *R – Dorsal*, only two individuals that could be assumed to be mature males based on their sizes (ID = 01 & 81) were consistently assigned low *P(f)* values. No individuals were consistently assigned a high *P(f)* value based on *R – Dorsal* models.

We found models based on *R – flipper* metrics resulted in more reasonable individual *P(f*) values than *R – Dorsal* based models. For example, while individual 74 (mean *TL =* 10.78 m, 95% *CI =* 10.63 – 11.06 m), which was observed receiving peduncle dives, had a consistently high probability of being a female on *R – Flipper* models (mean *P(f)* = 0.99, 95% *CI =* 0.99 – 1.00) , it had low *P(f)* estimatesassociated with high levels of uncertainty(mean = 0.12, 95% *CI* = 0 – 0.44). Similarly, individual 04, which was a large male (mean *TL =* 15.2 m, 95% *CI =* 14.9 – 15.5 m), was assigned a near-zero *P(f)* estimate with high certainty based on *R – Flipper* models (mean < 0.001, 95% *CI width =* 0), but an intermediate *P(f)* value with wide uncertainty based on *R – Dorsal* models (mean = 0.50, 95% *CI* = <0.001 – 0.97).Given that *R – Flipper* models resulted in more certainty and consistency with contextual and previous knowledge, we explore the peduncle dive patterns in the following section considering the predictions made by said model.

A diagram of a diagram of a variety of dots and lines

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**Figure 5.** Bootstrapped mean Length (m) and nose-to-body ratio (R) for individual sperm whales based on (A) rostrum – dorsal fin and (B) rostrum–flipper. Point colours reflect the mean posterior probability of individuals being female, P(fem), and point sizes indicate the 95th percentile confidence interval width for P(Fem). Point shape denotes whether individuals were observed being suckled on by other individuals. Individuals that were observed suckling and known males (> 13.7 m) are labelled for reference. Dashed vertical lines indicate the minimum body lengths associated with sperm whale sex and age classes as follows: calf (4 m; NB), juvenile (J; 5.5 m), sub-adult (SA; 7.6 m ), adult female (AF – 8.5 m), adult male and mature female (AM/MF – 10 m), maximum female length (Fmax – 12 m), and mature male (MM – 13.7). (Best 1979, Best et al. 1984, Rice 1989, Mendes et al. 2007).

#### 3.3.3 Peduncle dive patterns

We inspected xxx mins of the footage from which we extracted whale measurements. Within this footage, we found three individuals doing and 12 individuals receiving peduncle dives out of the 90 individuals for which we had at least one total length measurement (**Figure 6**). We were able to measure more individuals receiving peduncle dives than those performing them because the frequent diving involved in performing peduncle dives often resulted in an arched body position which was not suitable for accurate length measurements.

Length measurements of individuals that performed peduncle dives either fell within the total length ranges corresponding to calves (n = 1) or juveniles (n = 3; **Figure 6**). Individuals that received peduncle dives ranged from 8.9 – 12.5 m length, corresponding to the overlapping age/sex classes including adult to mature females and subadult – adult males. While not all individuals measured could be assigned *P(f)*, most of those that did (n = 4) had a high probability and certainty of being female based on *R- Flipper models*. Still, two individuals receiving peduncle dives (IDs = 75 & 11) had a lower average *P(f)* given their *R – Flipper* measurement*,* albeit associated with very wide confidence intervals **Figure 5**.

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**Figure 6.** Mean total length (m) distribution of individual sperm whales observed doing, receiving, or not involved in peduncle dives (PD). Points are colored by the mean P(f) estimated using R – flipper models or are shown in gray if R – flipper measurements could not be extracted.