Supplementary Material

Appendix S1. Worldwide published descriptions of leopard seal moult aspects, including pelage appearances, progression, stages (pre-moult, active moult or moult, post-moult) and timing (including peak), from locations across their primary range (Antarctica and the sub-Antarctic islands). Only published descriptions containing details of moult aspects, rather than just the presence of a moulting leopard seal, are included.

Location(s)	Moult pelage appearance(s)	Active moult progression	Moult stage(s)	Moult timing	Reference
Antarctica	Post-moult: darker than active-moult pelage	NA	NA	NA	Gray et al. (2008)
Antarctica	NA	NA	Active	Active moult: February	Nordøy & Blix (2009)
Antarctica	Post-moult: silver-grey	NA	NA	NA	Pussini & Goebel (2015)
Antarctica	NA	NA	Active	Active moult: peak in early February	Krause et al. (2020)
Antarctica	Active moult: browning Post-moult: clean and silvery	NA	Pre; active; post	Pre-moult: typically, before February Active moult: peak in the first week of February	Krause et al. (2021)
Heard Island	NA	NA	Active	Active moult: January, February peak; some between April and June	Brown (1957)
Heard Island	Pre-moult: dark brown and creamy white that is blotched/spotted/marbled Post-moult: blue-grey on the dorsum and silvery-white on the ventrum	NA	Pre	Pre-moult: November and December	Shaughnessy et al. (2000)
Heard Island	Pre-moult or active moult[1]: dingy	Beginning around the base of the hind flippers; finishing along the back and on the fore flippers	Active; post	Active moult: January	Gwynn (1953)
Macquarie Island	Post-moult: silvery				
Macquarie Island	Pre- and active moult: tawny/yellowish Post-moult: silvery	NA	Pre-; active	NA	Ledingham (1979)

[1]Unclear if referring to pre-moult, active moult, or both pre- and active moult pelage.

Appendix S2. Metadata of records in the NZLSD, which were used to determine moult records, included date, time, location, region, approximate latitude and longitude coordinates, and availability of photographs. The photographic quality of photographs in moult records was defined as 'good' when the photographs were clear, in focus and had good lighting, while those that were out of focus or were poorly lit, were defined as 'poor'.

Appendix S3. Photographic examples of observations of leopard seals moulting in New Zealand. The colours of leopard seal pelage in New Zealand were grouped into browned or discoloured. We also include a photographic example of browned pelage alongside post-moult pelage.

Figure S3-1 Side-on perspective of a leopard seal in New Zealand displaying non-uniform browned active moult pelage alongside black areas. Photograph credit: AAG.

Figure S3-2 Side-on perspective of a leopard seal in New Zealand displaying discoloured and non-uniform active moult pelage alongside black areas. Photograph credit: Euan Brook.

Figure S3-3 Side-on perspective of a leopard seal in New Zealand displaying uniform, silvery and short post-moult pelage alongside non-uniform browned pelage and black areas. Photograph credit: Giverny Forbes.

Figure S3-4 Side-on perspective of a leopard seal in New Zealand displaying uniform, silvery and short post-moult pelage alongside longer non-uniform browned active moult pelage. Photograph credit: Giverny Forbes.

Appendix S4. Maximising data and reliability of moult assessment. We only used poor-quality photographs and areas of wet pelage in good and poor-quality photographs when absolutely necessary, according to specific criteria. Where only poor-quality photographs existed of body parts in a moult record, they were only retained when distinct features (following Yochem et al. 1990) of active moult (e.g. black patches) were present. This also applied to areas of wet pelage in good and poor-quality photographs when there were no photographs of that part of the body with dry pelage available from that moult record. In instances where photographs of each side of the body existed but varied in quality (e.g. a poor-quality photograph of the left side of the face and a good quality photograph of the right side of the face), preference was given to using the higher quality photograph. Preference was also given in the same way to areas of photographs that contained dry pelage over those containing wet pelage. However, where moult was only visible in these types of photographs (good quality photographs of other areas where moult was not visible), such moult records were only used to determine an unknown sub-stage of active moult. Areas of wet pelage were excluded from all other moult assessment.

Several other factors were considered to maximise the available data and moult assessment reliability. Firstly, as not all moult records contained photographs of both sides (left and right) of the body, we qualitatively assessed if either side of the body could be used for moult assessment. To do so, we adapted body sections from Badosa et al. (2006) and Cronin et al. (2014) (Appendix S6) and noted those present in photographs of the left and right sides. We then gathered moult records (n = 44 from 34 annual moults) containing photographs (of good quality and containing only dry pelage) of matching body sections on each side of the body and assigned moult codes (adapted from de Kock et al. 2021) that represented varying proportions of pelage appearances and signs of active moult (Appendix S3). Comparison of moult codes (n = 145) revealed minimal variation (4.1%), suggesting that either side of the body could be used in moult assessment. Secondly, we required that a reasonable proportion of the side of the body, which we arbitrarily defined as ≥ 66% of one side or different sections of each side of the body (e.g. shoulders and neck of the left, and the flank of the right), be available for pelage colour and stage assessment. Therefore, only moult records with photographs of at least 66% of the side of the body were included in pelage colour and stage assessment. Thirdly, an unknown sub-stage of active moult was assigned when < 66% of the side of the body was visible. Lastly, the reliability of the principal assessor's moult code assignment and stage/sub-stage assessment was confirmed by an additional assessor using a subsample of 414 photographs from 46 annual moults (53%). Photographs were used from one moult record per annual moult to minimise potential bias on assessment by other moult records in the annual moult (e.g. a moult record in sub-stage 2 in November may influence the assessment of moult stage for later moult records). Agreement with the principal assessor was 84% (n = 546) and 83% (n = 46), respectively.

Any moult record containing a reasonable proportion of the side of the body, including body groups A or E, of a leopard seal in active moult could be used to assist in assigning the pattern of moult (standard or reverse; Daniel et al. 2003). We assigned the standard moult pattern to an annual moult when only body sections in body group A or E displayed signs of active moult or they had progressed further in the active moult compared to other body sections of other body groups. We assigned the reverse moult when only body sections, other than those in groups A or E, displayed signs of active moult or they had progressed further in the active moult compared to body sections in body groups A or E.

Appendix S5. Annual moult data descriptions. As seals typically moult once a year, an 'annual moult' was defined as a collection of moult records that belong to the same annual moult of a seal in any given year. We assigned moult records to different annual moults through photo-ID of (1) pelage patterns and injuries/scars across all moult records, and (2) photo-ID of pelage appearances and signs of active moult for all moult records within a year of each other. When conducting photo-ID of pelage patterns and injuries/scars, we used any of these that were visible from photographs of all angles. A unique individual was only determined when pelage patterns were visible on a photograph of the left side of the face as this was the chosen photograph angle/body section used for individual identification in the NZLSC (Hupman et al. 2020).

When conducting photo-ID of pelage appearances and signs of active moult, temporal and individual factors were considered. For example, a moult record with photographs of pelage appearance of sub-stage 3 in October could be considered as belonging to a different annual moult as a moult record with photographs of pelage appearances of sub-stage 1 in November of the same year. Similarly, signs of active moult in a moult record in June 2018 was compared to signs of active moult in all moult records between June 2017 and June 2019. Sex was also used where possible to assist in assigning moult records to annual moults. For example, if there were only two moult records over a four-year period (e.g. 2001 to 2005) that were within a year of each other (e.g. June and July 2003), we could assign these moult records to different annual moults if they were different sexes. Therefore, two or more annual moults from different years could belong to the same individual, such that an annual moult in 2016 and one in 2018 could belong to the same individual. As such, we include the number of annual moults by unique and undetermined individuals. However, several factors lead us to believe overrepresentation of individuals is minimal. First, as individuals in the NZLSC and NZLSD that are identified using pelage patterns and injuries/scars typically have low resighting rates, it is likely that this is also true of individuals (unique and undetermined) in moult records. Second, we excluded moult records where they could not reliably be assigned to an annual moult, such as if the animal was bald or pelage appearances and signs of active moult were similar but could not be matched and no other features could be used to assign them to an annual moult. Third, because all individuals and annual moults were independently checked by at least one other assessor.

Appendix S6. Body sections and body groups of a leopard seal used for moult assessment in New Zealand. Body sections of a leopard seal (adapted from Badosa et al. 2006; Cronin et al. 2014) used for moult code assignment in the assessment of moult progression and pattern in New Zealand (anterior-posterior): nostrils; snout; eyes; face[1]; top of the head (head)[1]; neck; throat; shoulders; chest[2]; fore flippers; axillae; spine, abdomen[2]; upper and lower flanks[3]; hind flippers. Body sections found on both sides of the body include the nostrils; snout; eyes; face; head; neck; shoulders; fore flippers; axillae; upper and lower flanks. Body groups A–G (adapted from Badosa et al. 2006; Cronin et al. 2014) used to assess the progression and pattern of leopard seals moulting in New Zealand: (A) nostrils, snout, eyes, (B) face and top of the head (head), (C) neck and throat, (D) shoulders and axillae, (E) fore and hind flippers, (F) chest and abdomen, and (G) the spine, upper and lower flanks.

[1]The base of the skull was used to mark the end of the face and head.
[2]The estimated (i.e. when fore flippers were not completely flush to the body) line created between the end of each fore flipper was used to mark the end of the chest and start of the abdomen.
[3]The countershading line was used to demarcate the upper and lower flanks.

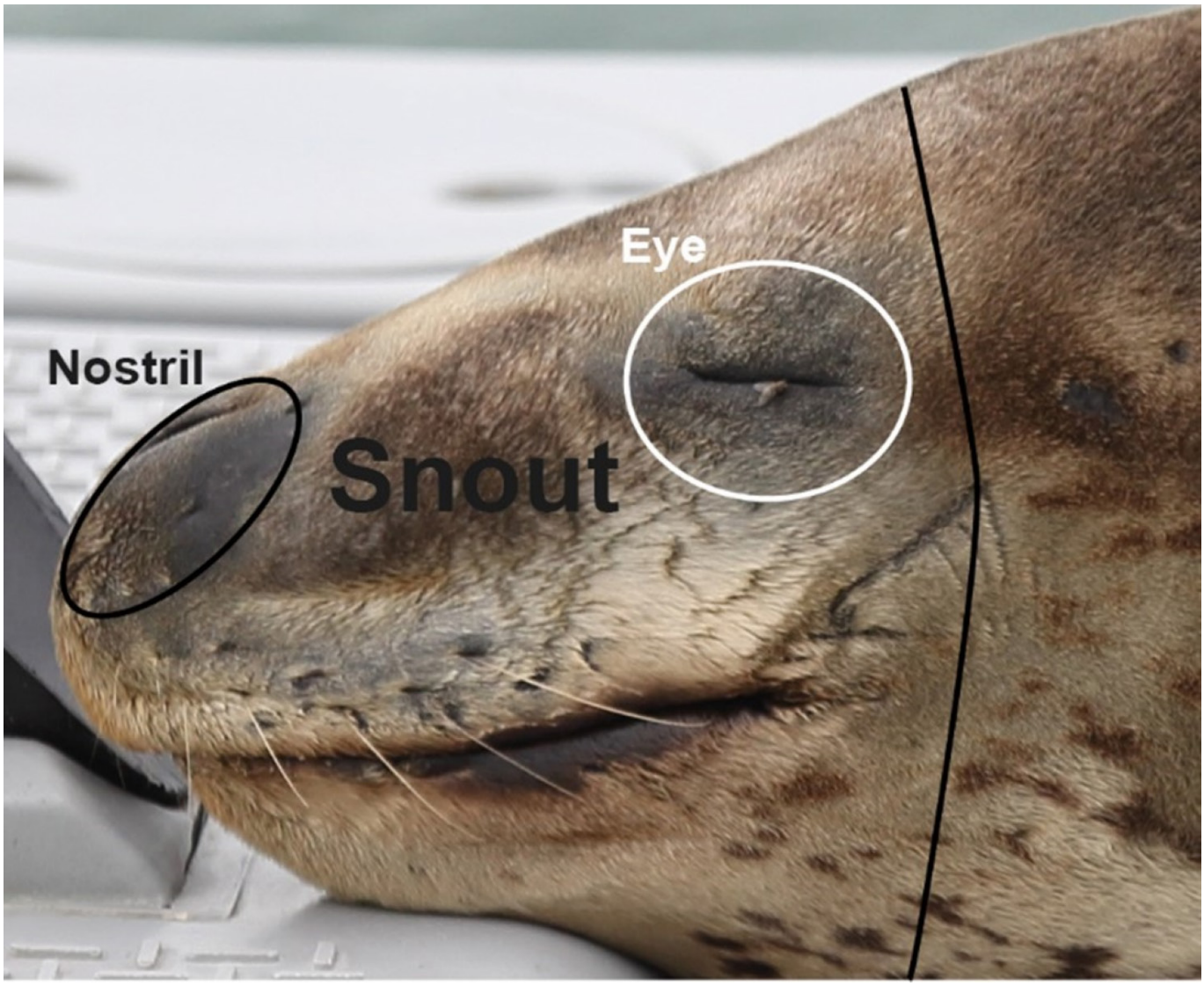

Figure S6-1. Side-on perspective of a leopard seal in New Zealand highlighting the nostril (black oval), snout, and eye (white circle). Photograph credit: INV.

Appendix S7. Moult codes (adapted from de Kock et al. 2021) applied to body sections of leopard seals in New Zealand.

Moult code	Pre-moult pelage	Active moult pelage	Black areas	Post-moult pelage
M0	Present	Absent	Absent	Absent
M1	Absent	> 66%	< 33%	< 33%
M2	Absent	33–66%	33–66%	< 33%
M3	Absent	< 33%	> 66%	< 33%
M4	Absent	< 33%	33–66%	33–66%
M5	Absent	< 33%	< 33%	> 66%
M6	Absent	Absent	Absent	Present

Appendix S8: Pooled number of monthly moult records of leopard seal annual moults in New Zealand per moult stage and active moult sub-stages from 2001 to 2022. Monthly moult records were determined by grouping moult records from each annual moult by pre-moult, active moult sub-stage (including unknown sub-stage), and post-moult. When individuals were observed in multiple annual moults, only monthly moult records from the longest and most complete (i.e. from start to finish) were included. Unknown sub-stage represents monthly moult records with signs of active moult where an active moult sub-stage could not be reliably determined from any moult records in that month. Data are presented around the peak active moult, starting in April, and finishing in the following March.

Stage	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total
Pre	0	0	1	1	2	2	2	2	3	2	0	1	16
Sub-stage 1	1	1	1	3	11	10	14	7	10	5	2	2	67
Sub-stage 2	0	0	0	1	1	6	13	2	8	3	0	1	35
Sub-stage 3	0	0	0	1	1	0	1	0	1	1	2	0	7
Unknown sub-stage	0	1	0	1	0	0	1	0	0	0	0	1	4
Post	0	0	0	0	0	0	0	0	0	1	0	0	1
Total	1	2	2	7	15	18	31	11	22	12	4	5	130

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