



Seasonal occurrence and condition of leopard seals at an extralimital Sub-Antarctic Island

Michael D. Ross¹ · Monica Leitner¹ · W. Chris Oosthuizen² · Marthán N. Bester¹ · Rowan K. Jordaan¹ · Michael D. Voysey^{1,3} · Everhard C. Conradie¹ · Banele Dosi¹ · Sean Evans¹ · Kyle J. Lloyd^{1,2,4,5} · Zafar Monier¹ · Jean Purdon^{6,7} · Ryan R. Reisinger⁸ · Yinhlá D. Shihlomule¹ · J. S. Frederik van der Vyver¹ · P. J. Nico de Bruyn¹

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Abstract

Leopard seals (*Hydrurga leptonyx*) occur mainly south of the Antarctic Polar Front, but immatures, in particular, seasonally move beyond this range during the austral winter and spring, typically under increased sea ice conditions. Extralimital occurrences of leopard seals can be observed at several sub-Antarctic islands where they haul out to rest. We present new records of leopard seal sightings at Marion Island, southern Indian Ocean, from 2006 to 2024 and discuss fluctuations in their seasonal and annual abundance (drawing on data collected since 1980) and body condition based on regular surveys. The eastern beaches at Marion Island were surveyed every 7–10 days while the western beaches were visited monthly. Observed leopard seals were photographed and given a body condition score based on the visibility of bony protrusions. From 2006 to 2024, we identified 35 presumed unique immature leopard seals between July and November, with a peak in September, all being immatures. Individuals to which we could assign body condition scores were either in good or excellent condition. This contrasted with the prevailing hypothesis that leopard seal body condition deteriorates with decreasing latitude. However, we could not determine whether this was because of an actual shift in body condition or because we used a different scoring system from other studies. We recommend adopting a standardised scoring system for visually estimating pinniped body condition and a global repository to monitor leopard seal haul-outs. As an apex predator, leopard seals may be important indicators in Antarctic and sub-Antarctic ecosystems, and monitoring changes in their distribution and body condition may indicate environmental and biological changes in these remote regions.

Keywords Body condition · Immature · Marion Island · Pinniped · Seasonal transient · Southern Ocean

✉ Michael D. Ross
mikersosstri@gmail.com

¹ Department of Zoology and Entomology, Mammal Research Institute, University of Pretoria, Hatfield, South Africa

² Centre for Statistics in Ecology, the Environment and Conservation, Department of Statistical Sciences, University of Cape Town, Cape Town, South Africa

³ Department of Organismic and Evolutionary Biology, Harvard University, Cambridge, USA

⁴ Landscape Conservation Programme, BirdLife South Africa, Johannesburg, South Africa

⁵ Afromontane Research Unit, Department of Entomology, University of the Free State, Phuthaditjhaba, South Africa

⁶ Department of Nature Conservation, Tshwane University of Technology, Pretoria, South Africa

⁷ Mammal Research Institute Whale Unit, Department of Zoology and Entomology, University of Pretoria, Hatfield, South Africa

⁸ School of Ocean and Earth Science, University of Southampton, European Way, Southampton SO14 3ZH, UK

Introduction

Leopard seals (*Hydrurga leptonyx*) are pagophilic (preference or dependence on sea ice) pinnipeds with a circumpolar distribution in the Southern Ocean (Rogers 2018). They occur mainly south of the Antarctic Polar Front (APF), between 50° and 80° S, especially in the outer areas of the Antarctic pack ice (Bester et al. 1995, 2002; Meade et al. 2015). While leopard seals primarily rely on sea ice as a platform for breeding, moulting and resting, year-round sightings have been recorded at Heard Island (Gwynn 1953), Îles Kerguelen (Bester 1981; Borsa 1990), South Georgia (Walker et al. 1998) and locations well north of the APF, including South America (Aguayo-Lobo et al. 2011; Borrás-Chavez et al. 2024) and New Zealand (Hupman et al. 2020). Regular seasonal sightings of leopard seals on other extralimital sub-Antarctic Islands (McDonald, Macquarie and Marion; Bester et al. 2006; van der Linde et al. 2022) and the Falkland Islands (van der Linde et al. 2022), and sporadic sightings as far north as South Africa (34° S; Vinding et al. 2013), Australia (33° S; Shaughnessy et al. 2012) and the Cook Islands (21° S; Berry 1960) have also been reported.

The seasonal occurrence of leopard seals at locations north of the APF is associated with increased sea ice extent and decreased sea surface temperatures at high latitudes during the austral winter (Rounsevell and Eberhard 1980; Bester and Roux 1986). As the sea ice around the Antarctic continent extends, leopard seals move northwards towards the marginal ice zone. Seasonal transients at extralimital sites north of the APF are typically immature seals that are generally reported to be in poor body condition, suggesting an inverse relationship between latitude and body condition (Rounsevell and Pemberton 1994; van den Hoff et al. 2005). It is possible that these immature leopard seals periodically extend the northern extent of their distribution due to intraspecific competition for food resources, aggression from conspecifics, to exploit a seasonally abundant food resource and/or juvenile dispersal/exploration (Bester and Roux 1986; Rogers 2009; Aguayo-Lobo et al. 2011).

The number of leopard seal haul-outs at extralimital sites north of the APF oscillates on a 3–5 year cycle (Rounsevell and Eberhard 1980; Walker et al. 1998), with higher numbers, earlier arrivals and longer periods of residency coinciding with years of above-average winter sea ice extent and lower-than-average winter sea surface temperatures (Jessopp et al. 2004). Despite annual fluctuations, some sites north of the APF have reported an increased number of leopard seal haul-outs in recent years; 2009–2023 in South America (Borrás-Chavez et al. 2024), 2015–2018 in New Zealand (Hupman et al. 2020)

and 2017–2022 in Australia (Shaughnessy et al. 2024). Whether this is a local or global trend is unknown, as is the cause, with hypotheses including increased observer effort, population growth, and environmental modification due to climate change (Vaughan et al. 2003; Aguayo-Lobo et al. 2011).

Leopard seals are key apex predators in Antarctic waters and could be used as an indicator species of environmental change or disruptions to the food web (Croxall et al. 2002; Krause et al. 2017). However, the species' behaviour and population dynamics remain poorly understood, largely due to their solitary behaviour, aquatic lifestyle and low natural densities (Southwell et al. 2008; Bengtson et al. 2011; Bender et al. 2023). It is important to continue reporting on opportunistic leopard seal sightings at the distributional edge of their natural range (e.g. Bester 2021; van den Hoff 2024), and note any shifts in population demographics or distribution to improve our understanding of the species and its environment (Bester 2021; Bender et al. 2023).

Marion Island (46°54'S, 37°45'E) is an extralimital haul-out site for leopard seals located north of the APF at the edge of their core distribution. Regular surveys of discrete beaches on this sub-Antarctic island between 1980 and 2005 recorded 19 immature leopard seals in both poor and good condition (Bester et al. 2006). These sightings suggested that leopard seals at Marion Island should be regarded as seasonal transients rather than vagrants. This study provides a follow-up synthesis and discussion of leopard seal sightings at Marion Island from 2006 to 2024 to establish if there have been any changes in their frequency of occurrence and body condition.

Methods

A long-term mark-recapture study of southern elephant seals (*Mirounga leonina*) using plastic flipper tags was formalized at Marion Island (Fig. 1) in 1983 to replace earlier sporadic recordings of seals that were tagged with monel-metal tags from 1974 to 1980 (Condy and Bester 1975; Condy 1979; Bester et al. 2011). Trained observers conducted tag-resight surveys and counts of southern elephant seals on all beaches on the eastern side of Marion Island (32 beaches along a 51.9 km coastline) every 7 days (but since 2020, every 9 days) during the breeding season (mid-August to mid-November) and every 10 days during the moulting period (mid-November to mid-April) each year from 1983. Surveys were also conducted every 10 days during the winter (mid-April to mid-August) since 1990. Beaches on the western side of the island were visited monthly during the moulting period from 1983 to 1990 and monthly year-round from 1990. Leopard seal sightings were recorded during these regular surveys, with

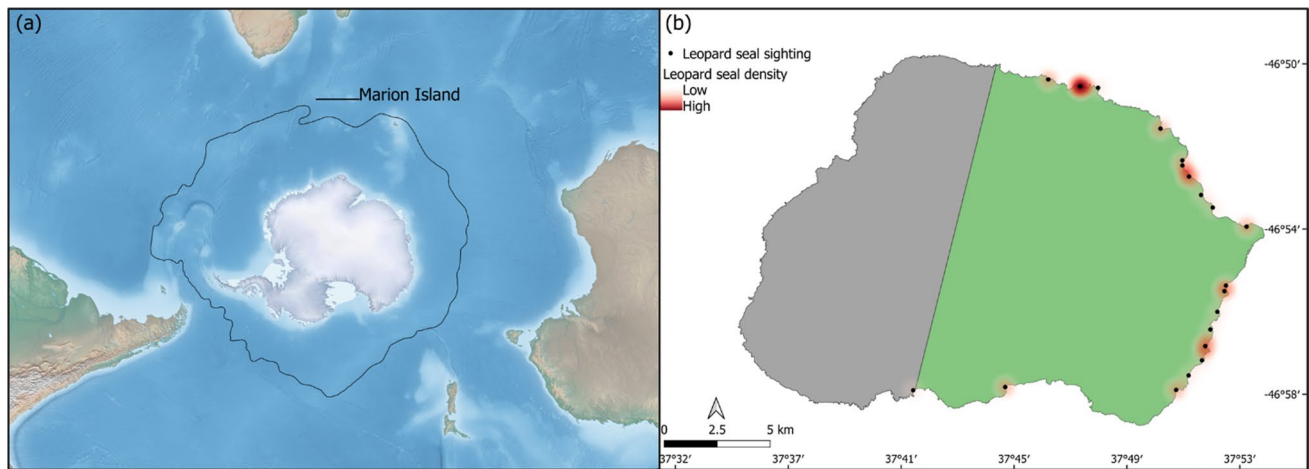


Fig. 1 **a** Marion Island's location in the Southern Ocean and its proximity to the Antarctic Polar Front (solid black line; frontal data from Orsi et al. (1995)). **b** Heatmap showing the locations and density of leopard seal haul-outs at Marion Island between 2006 and 2024. The

beaches along the eastern aspect of the island (shown in green) were typically surveyed every 7 to 10 days, while the beaches along the western aspect (shown in grey) were surveyed monthly year-round

incidental sightings obtained from other field assistants stationed at the island also included in the database.

When a leopard seal was observed, the location, date, general condition, age class and behaviour were noted, and whenever possible, the seal was photographed for individual identification (Forcada and Robinson 2006) and post-hoc assessment of body condition (Gray et al. 2009; Hupman et al. 2020). Each seal's condition was scored on a five-point scale, based on the visibility of bony protrusions on leopard seals following Hupman et al. (2020) (see also Gray et al. 2009). A side-view photograph of each seal was assessed and scored according to visible protrusions of the sagittal crest, zygomatic arch, neural spines, rib bones and pelvic bones, with each feature either given a score of 0 (no protrusion visible) or 1 (protrusion visible), resulting in an overall score of 0 (no protrusions visible) to 5 (all bony protrusions visible). Body condition scores can be interpreted as: 0 (excellent condition); 1–2 (good condition); 3–4 (poor condition); and 5 (severe condition) (Hupman et al. 2020). To maintain consistency in body condition analysis, only seals pictured in side-view photographs were scored. Body condition was scored by a single observer, with 9 of 28 scored seals verified by a second, independent observer. Leopard seals observed within a year were individually identified based on photographic comparison. In cases where there were no photographs, a leopard seal was assumed to be a unique individual if the sighting occurred more than a month apart from other sightings. Given that all sighted leopard seals were immature, and considering the relatively short time they spend in this life history phase (Rogers 2009), we treated sightings between years as unique, as did Bester et al. (2006), further facilitating comparisons.

Results and discussion

We recorded 35 presumed individual leopard seals at Marion Island over 19 years between 2006 and 2024 (approximately two individuals per annum over 52 km of coastline; Fig. 1). The number of seals varied annually (range 0–6) (Fig. 2), with sightings usually recorded from July to November, most occurring in September (Fig. 2). All leopard seals observed at Marion Island were immature, and those whose condition could be scored from photographs (29 of 35 seals) were in either good ($n = 15$) or excellent condition ($n = 14$; Fig. 2). Some were reported to have superficial injuries, and one had a suspected broken jaw and deep lacerations.

Leopard seal sightings were distributed on the eastern side of Marion Island, with a relatively even split between sightings on the north- and south-eastern coastlines (Fig. 1). This is likely a function of the island's geography as the eastern aspect of the island has pebble and boulder beaches, which are mainly absent from the western, windward coast (Rudolph et al. 2022), rendering the latter largely inaccessible to leopard seals.

Our study confirms that leopard seals are regular seasonal visitors to Marion Island. After one was recorded in the period of southern elephant seal monitoring 1974–1985 (MRI Unpublished Records), Bester et al. (2006) reported five assumed unique seals in the following decade 1986–1995, and 13 between 1996 and 2005. We recorded slightly higher occurrences, with 15 presumed unique individuals in the decade 2006–2015 and 20 from 2016 to 2024. Various studies have reported recent increases in leopard seal haul-outs, including those in Chile (271% increase in sightings between 2009 and 2023 compared to pre-2009) (Aguayo-Lobo et al. 2011; Borrás-Chavez et al. 2024), New

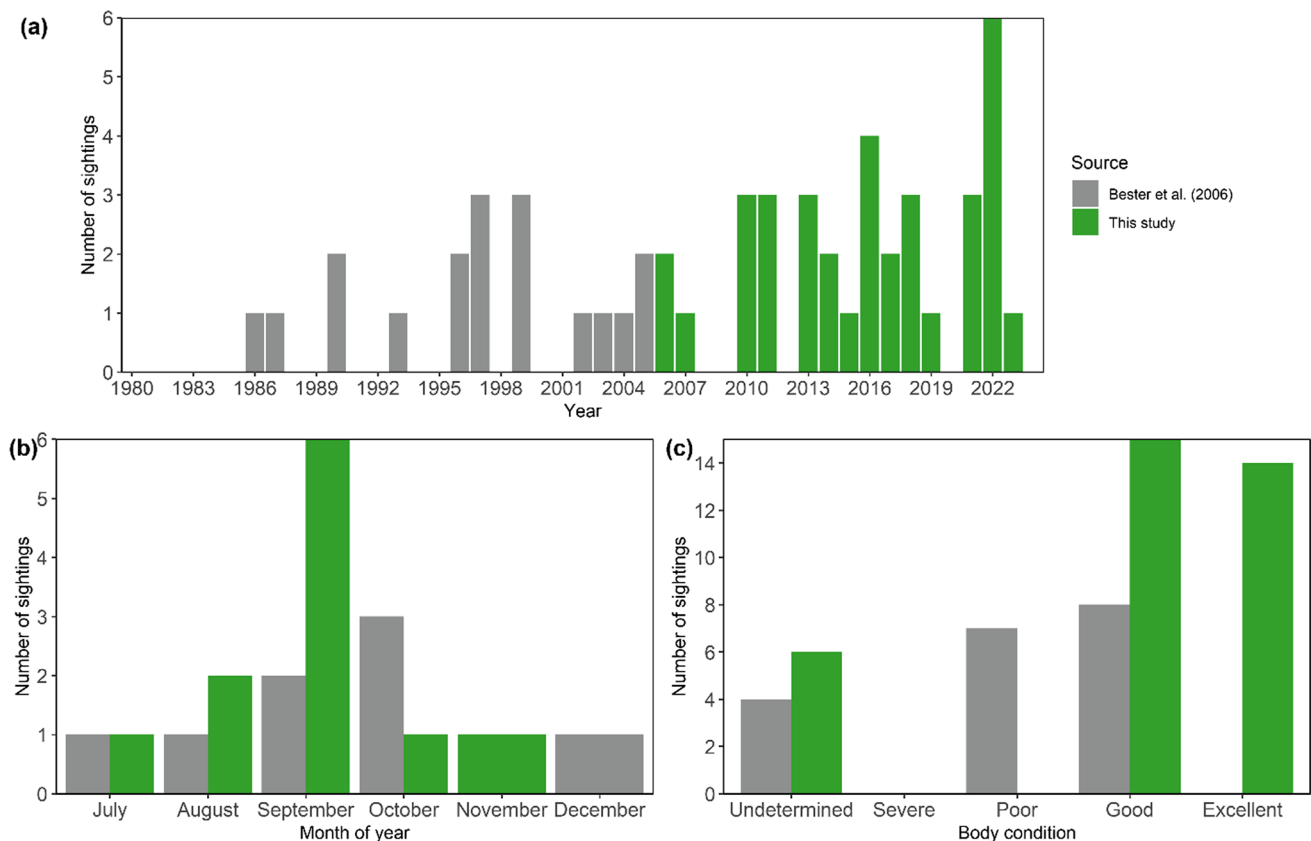


Fig. 2 Leopard seal sightings at Marion Island over two survey periods (1980–2005 and 2006–2024) according to **a** year, **b** month of the year, and **c** body condition

Zealand ($n = 171$ sightings between 2000 and 2009; $n = 2101$ between 2010 and 2018) (Hupman et al. 2020), and South Australia (sightings rates increased from 1.2 seals per year between 1979 and 2009 to 2.8 seals per year between 2017 and 2022) (Shaughnessy et al. 2024). The studies in Chile, New Zealand and Australia relied primarily on opportunistic reporting, except for a component of Borrás-Chavez et al. (2024), and as a result, researchers had difficulty quantifying the contribution of increased observer effort and/or better reporting to these elevated number of observations. Variable observer effort should have much less effect at Marion Island, where regular surveys across the same area have been routinely made over the past 40 years. However, even with regular surveys, some factors (e.g. the number of observers present, and amount of time observers spent conducting surveys or other non-survey work) probably affected observer effort over time. Despite these caveats, Marion Island remains one of few sites in the Southern Ocean with relatively consistent long-term survey effort for seals (Bester et al. 2011). While slightly more leopard seals have been observed on Marion Island since 2006, there is no evidence for large shifts in haul-out patterns, as observed at Chile and New Zealand (Aguayo-Lobo et al. 2011; Hupman et al.

2020; Borrás-Chavez et al. 2024). We also did not find a multi-year cyclical pattern in occurrence of leopard seals, as observed at some other sites north of the APF (Rounsevell and Eberhard 1980; Walker et al. 1998; Shaughnessy et al. 2024). Relative consistency in haul-out patterns across years may suggest stability in environmental conditions, food availability and population demographics of leopard seals during the study period.

The prevalence of immature leopard seals at Marion Island support the hypothesis that primarily immature leopard seals are found north of the APF (Siniff and Stone 1985; Rounsevell and Pemberton 1994; Bester et al. 2006). This does not appear to hold true elsewhere with New Zealand reporting sightings of mainly adult seals, even in the northern parts of North Island ($\sim 35^\circ$ S) (Hupman et al. 2020), and Chile similarly reporting primarily adults (Borrás-Chavez et al. 2024). Peak haul-out from August to October as observed in this study is consistent with sightings reported by Bester et al. (2006) for Marion Island, where the peak was also September, as was recorded at Îles Kerguelen (Bester and Roux 1986; Borsa 1990), South Australia (Shaughnessy et al. 2012), South Georgia (Walker et al. 1998) and New Zealand (Hupman et al. 2020). Sightings peaked slightly

earlier in Chile, from July to August (Aguayo-Lobo et al. 2011). Antarctic sea ice is at its maximum extent during September (Parkinson and Cavalieri 2012), likely facilitating the northward movement of leopard seals.

The immature leopard seals seen on Marion Island are likely seasonal transients (Bester et al. 2006). Typically, seasonal transients remain hauled-out for only a few days (Forcada and Robinson 2006). While this was the general pattern on Marion Island, at least five individuals remained at the island for longer than a week, and two were seen multiple times over the course of five weeks. One was seen on three occasions between 23 September and 27 October 2013 at two different beaches, while the other was seen on four separate beach check occasions between 15 September and 22 October 2022 at the same beach. These observations of individuals leaving and returning to the island throughout the five-week sighting period, coupled with no visible deterioration in body condition during this time, suggests that at least some leopard seals feed within the vicinity of Marion Island. This is further supported by observations of three leopard seals defecating, the scat of one containing penguin feathers, the other two probably euphausiids. King penguins (*Aptenodytes patagonicus*) and gentoo penguins (*Pygoscelis papua*) are present at Marion Island during August to October, and macaroni penguins (*Eudyptes chrysolophus*) from early October (Ryan and Bester 2008). All three species are preyed upon by leopard seals at other island sites (Bester and Roux 1986; Borsa 1990; Walker et al. 1998). The general transient nature of immature leopard seals is highlighted by the presence of goose barnacles on one individual, suggesting that it had been at sea for an extended period (Setsaas and Bester 2006). This represents the third record of barnacles on a leopard seal, following records from Tristan da Cunha (Bester et al. 2017) and Australia (Shaughnessy et al. 2024).

Despite a few seals being recorded with superficial injuries and one with a suspected broken jaw, all were in either good or excellent condition, which is in line with recent studies from New Zealand and Chile (Aguayo-Lobo et al. 2011; Hupman et al. 2020; Borrás-Chavez et al. 2024). However, it is in contrast to previous findings from Marion Island, where individuals were often in poor condition (Bester et al. 2006). We suggest three possible explanations for an apparent shift in body condition scores: 1) chance, 2) an actual shift in body condition, or 3) utilizing different body condition scoring methods. It is unlikely that 29 seals (6 seals did not receive a body condition score) were all in good or excellent condition by chance with none in poor condition, when the prevailing belief is that many should be in poor condition and Bester et al. (2006) reporting 7 of 19 sighted leopard seals to be in poor condition. Previously, body condition was estimated by researchers on site who did not receive specific training

regarding the evaluation of the body condition of leopard seals, as they mainly worked with elephant seals. It is therefore plausible that leopard seals, which are naturally slimmer than elephant seals (for descriptions see Bester 2014a, 2014b), were considered to be in poorer condition than their more robust beach companions (Duignan 2003). In this study, we utilized the classification method employed by Hupman et al. (2020) that was specifically developed for leopard seals, and only on seals for which there were side-view images. Given our concerns about the comparability of body condition scores, we are unable to disentangle whether our scores result from an actual shift in body condition or a different method of evaluating seal condition. To mitigate issues of inconsistent body condition classification in the future, we suggest the use of photographs to score animals and the adoption of a standardized leopard seal scoring system such as proposed by Hupman et al. (2020).

Because of their reliance on sea ice and their trophic position, leopard seals could be used as indicator species, highlighting environmental and biological changes in the remote Antarctic and sub-Antarctic regions (Gray et al. 2009; Krause et al. 2017; Bender et al. 2023). While our knowledge of leopard seal ecology has increased considerably, particularly with the development of telemetric devices (Staniland et al. 2018), there is a need to continue reporting their haul-out patterns and any observable changes therein. To facilitate this process, we recommend creating a global repository or the universal adoption of existing repositories (e.g. iNaturalist, GBIF etc.) to consolidate records and other information about this elusive predator to enable indirect monitoring of changes in the Antarctic and sub-Antarctic regions.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s00300-025-03378-6>.

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Data Availability All the recorded observational data can be found in the appendix. Leopard seal photographs are available from the corresponding author upon reasonable request.

Declarations

Competing Interests The authors declare no competing interests.

Ethical Approval Data were gathered without handling the animals, whilst all field assistants were operating under institutional ethical approval for all fieldwork through the Animal Ethics Committee of the Faculty of Veterinary Science, University of Pretoria (AUCC040827022, AUCC040827-023, AUCC040827-024, EC077-15, NAS003/2021). All research was carried out under permit from the Director-General, Department of Environmental Affairs, South Africa, and with annual Prince Edward Island research and access permits.

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References

- Aguayo-Lobo A, Acevedo J, Brito JL, Paola Acuña G, Bassoi M, Secchi ER, Rosa LD (2011) Presence of the *Leopard seal*, *Hydrurga leptonyx* (De Blainville, 1820), on the coast of Chile: an example of the Antarctica - South America connection in the Marine environment. *Oecol Aust* 15:69–85. <https://doi.org/10.4257/oeco.2011.1501.07>
- Bender AN, Krause DJ, Goebel ME, Hoffman JI, Lewallen EA, Carolina AB (2023) Genetic diversity and demographic history of the leopard seal: a Southern Ocean top predator. *PLoS ONE* 18:e0284640. <https://doi.org/10.1371/journal.pone.0284640>
- Bengtson JL, Laake JL, Boveng PL, Cameron MF, Bradley Hanson M, Stewart BS (2011) Distribution, density, and abundance of pack-ice seals in the amundsen and ross seas, Antarctica. *Deep-Sea Res* 58:1261–1276. <https://doi.org/10.1016/j.dsr2.2010.10.037>
- Berry JA (1960) The occurrence of a leopard seal (*Hydrurga leptonyx*) in the tropics. *J Nat Hist* 3:591–591. <https://doi.org/10.1080/00222936008651062>
- Bester MN (1981) Fur seals *Arctocephalus* and leopard seals *Hydrurga leptonyx* at the Courbet Peninsula. *Kerguelen S Afr J Antarct Res* 10(11):35–37
- Bester MN (2021) Status of pinnipeds on mid-Atlantic ridge islands, South Atlantic Ocean. *Polar Biol* 44:865–871. <https://doi.org/10.1007/s00300-021-02838-z>
- Bester MN, Roux J-P (1986) Summer presence of leopard seals *Hydrurga leptonyx* at the Courbet Peninsula, Iles Kerguelen. *S Afr J Antarct Res* 16:29–32
- Bester MN, Erickson AW, Ferguson WH (1995) Seasonal change in the distribution and density of seals in the pack ice off princess Martha Coast, Antarctica. *Antarct Sci* 7:357–364. <https://doi.org/10.1017/S0954102095000502>
- Bester MN, Ferguson JWH, Jonker FC (2002) Population densities of pack ice seals in the Lazarev Sea, Antarctica. *Antarct Sci* 14:139–143. <https://doi.org/10.1017/S0954102002000676>
- Bester MN, de Bruyn PJN, Oosthuizen WC, Tosh CA, McIntyre T, Reisinger RR, Postma M, van der Merwe DS, Wege M (2011) The marine mammal programme at the prince edward islands: 38 years of research. *Afr J Mar Sci* 33:511–521. <https://doi.org/10.2989/1814232X.2011.637356>
- Bester MN, Bester WA, Wege M, Schofield RA, Glass TA (2017) Vagrant leopard seal at Tristan da Cunha Island, South Atlantic. *Polar Biol* 40:1903–1905. <https://doi.org/10.1007/s00300-017-2073-8>
- Bester MN, Hofmeyr GJG, Kirkman SP, Chauke LF, De Bruyn PJN, Ferreira SM, Makhado AB, Maswime TAM, McIntyre T, Mulaudzi TW, Munyai FM, Pistorius PA, Radzilani PM, Ramunasi AJ, Tshithabane NH, Wilkinson IS (2006) The leopard seal at Marion Island, vagrant or seasonal transient? *S Afr J Wildl Res* 36:195–198. <https://hdl.handle.net/10520/EJC117238>
- Bester MN (2014a) Leopard seal. In: Hund A (ed) *Antarctica and the Arctic Circle: A geographic encyclopedia of the earth's polar regions*. ABC-CLIO, Santa Barbara pp 455–457
- Bester MN (2014b) Southern elephant seal. In: Hund A (ed) *Antarctica and the Arctic Circle: A geographic encyclopedia of the earth's polar regions*. ABC-CLIO, Santa Barbara pp 670–672
- Borras-Chavez R, Soteres RL, Gómez-González G, Martínez F, Fernández-Ferrada N, Castillo-Aguilar M, Moreno Azua F, Dougnac C, Arredondo C, Brown N, Sperou ES, Bonin CA, Goebel ME, Guerrero AI, Donke M, Kienle SS (2024) Occurrence, residency, and habitat characterization of leopard seals in Chile. *Front Ecol Evol* 12:1448098. <https://doi.org/10.3389/fevo.2024.1448098>
- Borsa P (1990) Seasonal occurrence of the leopard seal, *Hydrurga leptonyx*, in the Kerguelen Islands. *Can J Zool* 68:405–408. <https://doi.org/10.1139/z90-059>
- Condy PR (1979) Annual cycle of the southern elephant seal *Mirounga leonina* (Linn.) at Marion Island. *S Afr J Zool* 14:95–102. <https://doi.org/10.1080/02541858.1979.11447655>
- Condy PR, Bester MN (1975) Notes on the tagging of seals at Marion and Gough Islands. *S Afr J Antarct Res* 5:45–47
- Croxall JP, Trathan PN, Murphy EJ (2002) Environmental change and Antarctic seabird populations. *Science* 297:1510–1514. <https://doi.org/10.1126/science.1071987>
- Duignan PJ (2003) Disease investigations in stranded marine mammals, 1999–2002. Department of Conservation Science Internal Series. <http://www.conservation.co.nz/upload/documents/science-and-technical/dsis104.pdf>. Accessed 01 September 2024
- Forcada J, Robinson SL (2006) Population abundance, structure and turnover estimates for leopard seals during winter dispersal combining tagging and photo-identification data. *Polar Biol* 29:1052–1062. <https://doi.org/10.1007/s00300-006-0149-y>
- Gray RB, Rogers TL, Canfield PJ (2009) Health assessment of the leopard seal *Hydrurga leptonyx*, in Prydz Bay, Eastern Antarctica and NSW, Australia. In: Kerry KR, Riddle MJ (eds) *Health of Antarctic wildlife: A challenge for science and policy*. Springer, Berlin, pp 167–192
- Gwynn AM (1953) The status of the leopard seal at Heard Island and Macquarie Island, 1948–1950, Australian National Antarctic Research Expedition Interim Report no. 3. Antarctic Division, Department of External Affairs, Melbourne
- Hupman K, Visser IN, Fyfe J, Cawthorn M, Forbes G, Grabham AA, Bout R, Mathias B, Benninghaus E, Matucci K, Cooper T, Fletcher L, Godoy D (2020) From vagrant to resident: occurrence, residency and births of leopard seals (*Hydrurga leptonyx*) in New Zealand waters. *New Zeal J Mar Freshw Res* 54:1–23. <https://doi.org/10.1080/00288330.2019.1619598>

- Jessopp MJ, Forcada J, Reid K, Trathan PN, Murphy EJ (2004) Winter dispersal of leopard seals (*Hydrurga leptonyx*): environmental factors influencing demographics and seasonal abundance. *J Zool* 263:251–258. <https://doi.org/10.1017/S0952836904005102>
- Krause DJ, Hinke JT, Perryman WL, Goebel ME, LeRoij DJ (2017) An accurate and adaptable photogrammetric approach for estimating the mass and body condition of pinnipeds using an unmanned aerial system. *PLoS ONE* 12:1–20. <https://doi.org/10.1371/journal.pone.0187465>
- Meade J, Ciaglia MB, Slip DJ, Negrete J, Márquez MEI, Mennucci J, Rogers TL (2015) Spatial patterns in activity of leopard seals *Hydrurga leptonyx* in relation to sea ice. *Mar Ecol Prog Ser* 521:265–275. <https://doi.org/10.3354/meps11120>
- Orsi AH, Whitworth T III, Nowlin WD Jr (1995) On the meridional extent and fronts of the Antarctic circumpolar current. *Deep Sea Res Part I* 42:641–673. [https://doi.org/10.1016/0967-0637\(95\)00021-W](https://doi.org/10.1016/0967-0637(95)00021-W)
- Parkinson CL, Cavalieri DJ (2012) Antarctic sea ice variability and trends, 1979–2010. *Cryosphere* 6:871–880. <https://doi.org/10.5194/tc-6-871-2012>
- Rogers TL (2009) The leopard seal, *Hydrurga leptonyx*. In: Perrin WF, Würsig B, Thewissen JGM (eds) *Encyclopedia of marine mammals*, 2nd edn. Academic Press, San Diego, pp 673–674
- Rogers TL (2018) The leopard seal, *Hydrurga leptonyx*. In: Perrin WF, Würsig B, Thewissen JGM, Kovacs KM (eds) *Encyclopedia of marine mammals*, 3rd edn. Academic Press, San Diego, pp 550–552
- Rounsevell D, Eberhard I (1980) Leopard seals, *Hydrurga leptonyx* (Pinnipedia), at Macquarie Island from 1949 to 1979. *Aust Wildl Res* 7:403–415. <https://doi.org/10.1071/WR9800403>
- Rounsevell D, Pemberton D (1994) The status and seasonal occurrence of leopard seals, *Hydrurga leptonyx*, in Tasmanian waters. *Aust Mammal* 17:97–102. <https://doi.org/10.1071/AM94010>
- Rudolph EM, Hedding DW, de Bruyn PJN, Nel W (2022) An open access geospatial database for the sub-Antarctic Prince Edward Islands. *S Afr J Sci* 118:1–8. <https://doi.org/10.17159/sajs.2022/12302>
- Ryan PG, Bester MN (2008) Pelagic predators. In: Chown SL, Frone-man PW (eds) *The Prince Edward Islands: Land-sea interactions in a changing ecosystem*. Sun Press, Stellenbosch, pp 121–164
- Setsaas TH, Bester MN (2006) Goose barnacle (*Lepas australis*) infestation of the subantarctic fur seal (*Arctocephalus tropicalis*). *Afr Zool* 41:305–307. <https://doi.org/10.1080/15627020.2006.11407368>
- Shaughnessy PD, Kemper CM, Ling JK (2012) Records of vagrant phocid seals (family *Phocidae*) in South Australia. *Aust Mammal* 34:155–169. <https://doi.org/10.1071/AM11036>
- Shaughnessy PD, Tomo I, Gibbs SE, Kemper CM, Stemmer D (2024) Records of leopard seals *Hydrurga leptonyx* ashore in South Australia, 2017–2022. *Aust Mammal* 46:AM22041. <https://doi.org/10.1071/AM22041>
- Siniff DB, Stone S (1985) The role of the leopard seal in the trophodynamics of the Antarctic marine ecosystem. In: Siegfried WR, Condy PR, Laws RM (eds) *Antarctic nutrient cycles and food webs*. Springer, Berlin, pp 555–560
- Southwell C, Paxton CGM, Borchers D, Boveng P, Rogers TL, de la Mare WK (2008) Uncommon or cryptic? challenges in estimating leopard seal abundance by conventional but state-of-the-art methods. *Deep-Sea Res Pt I* 55:519–531. <https://doi.org/10.1016/j.dsr.2008.01.005>
- Staniland IJ, Ratcliffe N, Trathan PN, Forcada J (2018) Long term movements and activity patterns of an Antarctic marine apex predator: the leopard seal. *PLoS ONE* 13:e0197767. <https://doi.org/10.1371/journal.pone.0197767>
- van den Hoff J (2024) Incidental pinnipeds at high latitudes of the Vestfold Hills, Prydz Bay, East Antarctica. *Antarct Sci* 6:1–6. <https://doi.org/10.1017/s0954102023000391>
- van den Hoff J, Fraccaro R, Mitchell P, Field I, McMahon C, Burton H, Blanchard W, Duignan P, Rogers TL (2005) Estimating body mass and condition of leopard seals by allometrics. *J Wildl Manag* 69:1015–1023. [https://doi.org/10.2193/0022-541X\(2005\)069\[1015:EBMACO\]2.0.CO;2](https://doi.org/10.2193/0022-541X(2005)069[1015:EBMACO]2.0.CO;2)
- van der Linde K, Visser IN, Bout R, Krause DJ, Forcada J, Siniff D, Stone S, Fyfe J, Fernández-Ferrada N, Macallan K, Savenko O, Cooper TE (2022) A review of leopard seal (*Hydrurga leptonyx*) births and pups using a standardised age-class classification system. *Polar Biol* 45:1193–1209. <https://doi.org/10.1007/s00300-022-03053-0>
- Vaughan DG, Marshall GJ, Connolley WM, Parkinson C, Mulvaney R, Hodgson DA, King JC, Pudsey CJ, Turner J (2003) Recent rapid regional climate warming on the Antarctic Peninsula. *Clim Change* 60:243–274. <https://doi.org/10.1023/A:1026021217991>
- Vinding K, Christiansen M, Hofmeyr GJ, Chivell W, McBride R, Bester MN (2013) Occurrence of vagrant leopard seals, *Hydrurga leptonyx*, along the South African coast. *S Afr J Wildl Res* 43:84–86. <https://doi.org/10.3957/056.043.0101>
- Walker TR, Boyd IL, McCafferty DJ, Huin N, Taylor RI, Reid K (1998) Seasonal occurrence and diet of leopard seals (*Hydrurga leptonyx*) at Bird Island, South Georgia. *Antarct Sci* 10:75–81. <https://doi.org/10.1017/S0954102098000108>

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