Manx Wildlife Trust
Treisht Bea-Feie Vannin

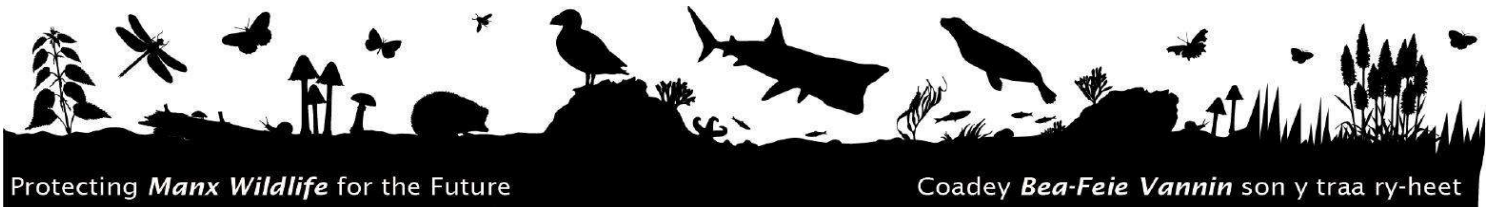
Calf of Man Seal Survey

Autumn 2025

Bea O'Neill and Alex Leaver

Dr. Lara Howe

Manx Wildlife Trust | 7-8 Market Place, Peel, IM5 1AB, Isle of Man | Charity No IOM 225 044
(01624) 844432 | enquiries@manxwt.org.uk | www.manxwt.org.uk
Facebook.com/ManxWildlifeTrust @manxnature



Contents

With thanks to the Department of Environment, Food and Agriculture for supporting this project.

Summary

Pup Census:

- A total of 111 seal pups were recorded and monitored on the Calf of Man during the 2025 survey period.
- Pup numbers have been increased steadily over the years, reaching new peaks in 2023, 2024, and 2025 respectively.
- The survey revealed the timing and distribution of pup births across the island, with certain sites being more productive than others.
- An All-Island Census maximum count of 281 Grey seal individuals within the 2025 season was lower than in the 2024 season.

Pup Development and Mortality:

- Out of the 111 pups observed, 92 were born on the Calf of Man, with 19 being wanderers.
- The confirmed mortality rate of pups during the survey period was 13.51%, the third highest recorded mortality rate since records began.
- Factors contributing to pup mortality included stillbirth and adverse weather conditions.

Site Fidelity:

- Over half of the identifiable breeding cows (53%) were returning mothers, indicating a degree of site fidelity.
- Site fidelity analysis showed that 84% of returning mothers pupped at a site they had pupped in before, with 0% of mothers pupping at a site they had never pupped at before but in the same section as previous pupping events.
- A small number of returning cows (6%) were recorded as pupping within a new section.
- Across returning mums 51% had only ever been seen pupping at one site and a further 30% only at two, suggesting a high degree of site fidelity in returning cows.

Birthdate Analysis:

- Returning mothers pupped 3.464 days earlier in the 2025 season than they did in 2024.
- This represented a statistically significant advancement of birthdates.
- Mothers have been recorded as pupping earlier almost every year in the Calf of Man pupping surveys.
- This advancement may be a result of storm aversion and warming sea temperatures.

Use of Thermal Drone Technology (UAS):

- This survey represented the third in which drone technology has been implemented and the second with thermal drone technology.
- This has proven to be a valuable tool in monitoring seal populations on the Calf, especially in inaccessible areas along the North West coast.
- Drones facilitated the identification of pups, monitoring of growth stages, and collection of high-definition images for individual identification.

● Previously established elevation controls were adhered to so that there was minimal risk of disturbing seals.

Additional Observations:

● Disturbances caused by human activities were minimal in the 2025 season due to adverse weather conditions limiting the number of day visitors to the island.
● Brown rat activity was identified during pupping season and investigated.
● An unusually high mortality rate was recorded in Mill Giau, a sheltered bay on the South coast.

The research conducted on the Calf of Man Island has provided valuable insights into grey seal pup mortality, site fidelity of returning mothers, and the effectiveness of using drone technology for wildlife monitoring. The findings contribute to our understanding of seal population dynamics and habitat conservation efforts in the region. Efforts to understand the impacts of anthropogenic induced climatic changes on breeding grey seals is vital for the continued conservation of grey seal populations on the Calf of Man Island. Suggestions for future research are highlighted throughout the study.

Introduction

Background

The British Isles are home to two species of “true” seals (family *Phocidae*): the grey seal (*Halichoerus grypus*) and the common or harbour seal (*Phoca vitulina*). Both species were historically overexploited across Great Britain. Seals were hunted for their meat, fur, and oil, used in products such as soap and lamps, and were also culled by fishermen who viewed them as competitors for fish stocks. As a result, the British grey seal population declined to around 500 individuals by the early 20th century. Both species are now protected on the Isle of Man under the Wildlife and Countryside Act (1976) and the Manx Wildlife Act (1990). Enforcement of these protections has allowed populations to recover, with population numbers now stabilising.

Monitoring seal populations in the British Isles remains important. Modern threats have shifted from hunting and culling to bycatch and entanglement in fishing gear, depletion of prey stocks, and increasing storm frequency. For example, the Baltic Sea grey seal population, recovering from similar historical exploitation, has struggled to recover. This is due to a combination of overfishing reducing prey availability, warmer winters reducing sea-ice upon which they breed, and increased risk of mortality by bycatch (Carroll et al., 2024). While the population has been growing, an annual growth rate of 5.1% was recorded between 2003 and 2021, below the 7% threshold for “good status” (HELCOM, 2023).

As well as this, marine predators that spend time on land, such as seals, can act as sentinels of marine ecosystem health. As top predators, they respond quickly and measurably to changes in oceanographic conditions, habitat quality, and prey availability (Hazen et al., 2019). They also exert top-down control within food webs, meaning their fitness and survival depend on the productivity of lower trophic levels. Land-based predators are particularly valuable for monitoring due to their conspicuous nature and accessibility compared to species that remain exclusively at sea. As such, monitoring seals can provide valuable insight into marine ecosystem health in the British Isles.

Grey seals are the most populous seal species in Great Britain, with an estimated population of over 150,000 individuals. This represents approximately 40% of the global population and 95% of the European population, with an estimated 37% of the global population breeding in the British Isles. In contrast, harbour seals, although widespread around Britain, are seen less frequently (Manx Wildlife Trust., 2020). Consequently, most population monitoring in British waters focuses on grey seals. It is complex to monitor populations in the water as seals are highly mobile and monitoring activity underwater is complex (Russell et al., 2013). As such, breeding season is an opportune time to assess population health with estimates of pup production providing the basis for assessing grey seal abundance across the British Isles (Thompson, 2024). Grey seals in Britain form a single metapopulation and exhibit large-scale seasonal movements so understanding breeding patterns in distinct locations provides insight to the health of the overall population.

During pupping season, female grey seals return to specific colonies to give birth to a single pup. Breeding females remain tied to their chosen sites for the duration of lactation, as pups are fully dependent for approximately 15–21 days. During this period, pups suckle intensively while females fast (Fedak and Anderson, 1982; Pomeroy et al., 1999). Once weaning is complete, females leave the colony, and pups remain ashore until they complete their moult. In this time, pups shed their

white lanugo coat to reveal their adult pelage, a waterproof, unique patterned coat that can be used to identify individuals throughout their lives (Russell et al., 2019). This post-weaning fasting period lasts around 9 to 40 days, during which pups may lose up to 25% of their body mass (Baylis et al., 2019; Noren et al., 2008). Once fully moulted, hunger drives pups to enter the sea to learn to forage and feed (Russell et al., 2019).

First-year, post-weaning mortality is high, ranging from 38% in females to 80% in males (Hall et al., 2001). Body condition at weaning is strongly linked to first-year survival, making the study of maternal energetic investment critical for understanding population dynamics (Hall et al., 2001). Because females fast during lactation, all nutrients transferred to offspring via lipid-rich milk, as well as those required for maternal metabolism, are drawn from stored reserves (Iverson et al., 1993). Weaning mass therefore reflects maternal investment and is positively correlated with juvenile survival, making it a reliable proxy for reproductive fitness (Iverson et al., 1993; Hall et al., 2001; Bowen et al., 2015). As such, it is important to study the early life stages of pups to better inform understanding of grey seal population dynamics.

In addition to monitoring pup success, breeding season provides a good opportunity to monitor site fidelity in breeding females. Grey seal cows are known to show significant site fidelity in pupping location influenced by previous pupping success, familiarity with local conditions, predictability of habitat quality and experience level of the female (Pomeroy et al., 1999; Weitzman et al., 2017). On completion of weaning, the female seals mate with the male who has maintained dominance of that specific pupping location through repeated physical contests with rival males (Bubac et al., 2018). Due to the crossover between pupping and mating season, this period allows for study of population size of mature adults and their site fidelity. As early as postweaning moult, grey seals are left with an individual pelage which can be used to identify them, much like human fingerprints. These unique patterns remain visible and stable throughout their lives but do darken with age (Sayer et al., 2019; Vincent et al., 2001). Matching identification photographs of individual pelage from previous breeding seasons gives insight to the level of site-fidelity and number of returning individuals within the population.

Manx waters are particularly important for grey seal populations, with around 100 to 400 of the British population being observed around the Isle of Man at any given time (Howe and Parsons, 2017). The Isle of Man's productive waters and rocky coastline provide the perfect habitat for grey seals with the Calf of Man, a small islet half a mile off the mainland, being recognised as a significant site for Manx seals (Duck, 1996). The Calf is the main breeding site for grey seals around the Isle of Man, isolated rocky beaches and caves make favourable conditions for pupping sites (Stone et al., 2013). The isolation of the islet results in low anthropogenic disturbance making it an ideal pupping site as well as a prime location to study a mostly undisturbed seal pupping colony. The pupping season has been monitored annually by Manx Wildlife Trust since a pilot study was undertaken in 2009, seal pupping surveys are undertaken daily from September to November. Long term data collection allows an insight into site fidelity and the importance of the Calf as a pupping site in the Irish Sea.

Historically, grey seal pup monitoring on the Calf has been conducted manually through intensive ground-based surveys. However, this approach is time-consuming, labour-intensive, and limits access to many sites on the Calf due to its rocky coastline (Hollings et al., 2018). It also poses safety risks, as researchers must navigate hazardous terrain (Kellenberger et al., 2018). In addition to the danger for researchers, ground-based counts can cause disturbance to seals, particularly

due to the sensitive nature of pupping season. Maternal cows are particularly sensitive to anthropogenic disturbance, and human presence can lead to pup abandonment or injury from stampeding adults, particularly in densely populated areas (Burton et al., 1975).

To mitigate these risks, drone-based monitoring has been introduced to the island. Uncrewed Aerial Vehicles (UAVs) have been proven to be effective for surveying conspicuous species over large, remote spatial areas (Beaver et al., 2020). Although they have shorter flight times than light aircraft, UAVs can operate at lower altitudes while still capturing higher-resolution imagery, providing a cost-effective, logistically efficient, and safer alternative to both aerial and ground-based surveys without compromising data quality (Pfeifer et al., 2019). Grey seals on the Calf frequently pup in inaccessible, cliff-surrounded areas that are difficult to survey on foot, making the island an ideal candidate for UAV-based monitoring. UAVs are now used alongside traditional surveys to access these sites, map seal distribution to inform ground survey routes, and reduce disturbance while collecting high-quality imagery.

Aims and objectives

The primary aim of this survey is to produce a seal pup census on the Calf of Man, identifying the survival rate and number of pups born on the island. This information can be used to inform conservation efforts around the Isle of Man and provide an insight into the population dynamics of grey seals in the UK as a whole.

- This aim focuses on three objectives:
  - Survey seal pupping sites identified in previous surveys counting the number of pups present at each site.
  - Monitor development stages and mortality events, including probable cause, of individual pups for the duration of the survey period.
  - Compare seal pup census data with that collected in previous surveys to determine trends in survival rates, pupping times, and number of birth events.

The secondary aim of this survey is to study site fidelity in female grey seals, both the percentage of females returning to the island itself, and the number of females returning to specific sites and sections within the island.

- This aim focuses on two objectives:
  - Collecting photographic identification images of adult seals, particularly females with pups.
  - Compare images to the existing catalogue of known individuals to determine whether the seal is returning or a new individual, adding new individuals when necessary to ensure the information is available for future comparisons.

Methods

Study site

The Calf of Man is a largely uninhabited island located half a mile off the South-west coast of the Isle of Man. Considered to be an important habitat for grey seals as the rocky inlets and beaches provide ideal habitat for seal birth site selection. Annual grey seal pup surveys have been conducted by the Manx Wildlife Trust since 2009 and have allowed the identification of 17 sites across the island that are utilised for pupping (figure 1). During the survey season 14 of these are monitored on alternate days. Sites along the steep, rocky East and West coasts were surveyed less frequently due to the historical absence of pups at these sites. Surveying of Kitterland could only be conducted by drone due to its isolated location and was therefore only surveyed when the conditions allowed, aiming for a minimum of once a week. If pups were found outside of the designated survey sites they were added to the survey route as appropriate. For site fidelity these sites were grouped based on geographical boundaries and proximity, based on the 2023 season sections.

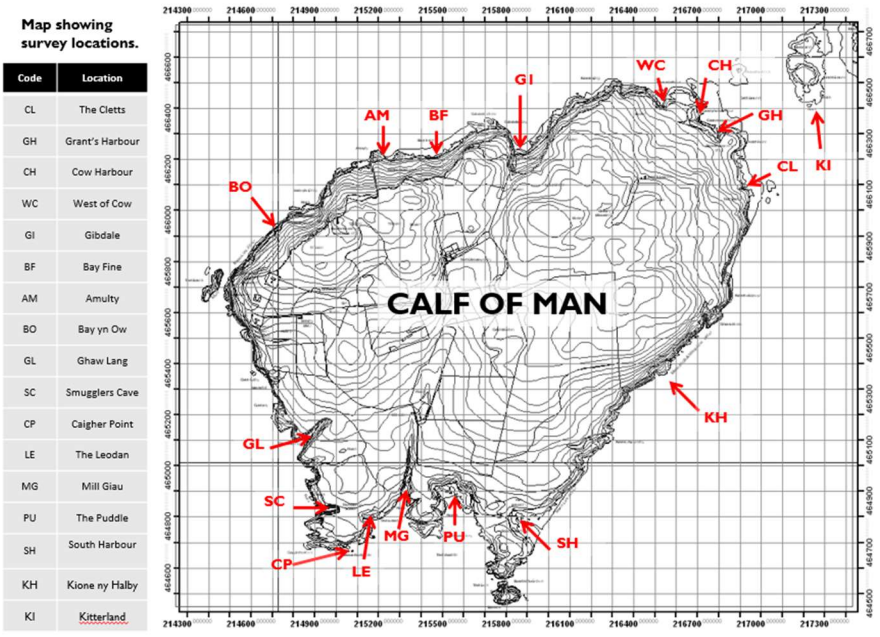


Figure 1. Map of the Calf of Man showing the 17 pupping sites identified across the island.

Data collection

The breeding season on the Calf of Man occurs primarily between September and early November (Stone et al. 2013), and data collection has been carried out over this period since 2009. This year surveying began on September 2nd and ended on 5th November and was conducted by volunteers Bea O'Neill and Alex Leaver, with guidance from Manx Wildlife Trust Marine Officer Dr Lara Howe. Devised from the 17 sites, two survey routes were formed by compiling the sites on the

Northern coastline (AM-CL) and the Southern coastline (GL-SH). Routes were surveyed on alternating days to accurately track pupping across the island while mitigating human disturbance.

The daily surveys had two main aims: firstly to undertake a pup census and secondly to monitor the adult seal population size and carry out photo identification to determine site fidelity. Upon reaching each site the number of pups present was noted, including the age classification of each pup, and the number of births, deaths and stage 5 departures since the site was last visited. During observation, any pup behaviour confirming filial relationships, such as suckling, was recorded and photographed. On occasions where initial site visits did not provide suitable information a return visit was carried out later in the day or at another date to ensure pups and mothers were reliably matched wherever possible.

Furthermore, at each site the number of adults, both hauled-out and in the water, was recorded. Adult seals were photographed using a Nikon Coolpix P100 digital camera with a 24-300mm lens. To ensure effective photo identification, focus was on achieving high-quality photographs of both the head and flank of each side of the seal, showing clear natural pelage markings. Using high-quality photographs of individuals increases the chance of re-identifying known individuals and reduces the chance of false rejections resulting in duplication (Hilby et al., 2013). Photographs were primarily taken of cows with pups, clearly pregnant individuals, or individuals assumed to be breeding females to aid the tracking of pups and to support site fidelity analysis.

A number of sites across the island have geographical restrictions, such as cliffs, rocky outcrops and sea level caves, limiting the number of seals and pups that can be seen and identified during cliff top surveys. In 2021 boat surveying was introduced to combat this challenge, and in 2023 Uncrewed Aerial Systems (UAS: commonly known as drones) were trialled, with the introduction of thermal imaging technologies in the 2024 season. For the 2025 season DJI Mavic 3 Thermal UAS was used for daily and full island surveys. The use of standard and thermal aerial imagery allowed reduced wildlife disturbance, improved researcher safety, enhanced time efficiency, and boosted data collection at challenging sites, such as Smugglers Cove, Amulty and Baie n'Ooig. The powerful zoom capabilities and thermal detection technology allowed easy observation of seals in remote or hidden areas without the need to approach individuals.

Pup development stages

Pups were photographed and their developmental stages assessed using a five stage classification (see Appendix 1). A combination of physical appearance and behavioural characteristics can relate to pup age (Kovacs and Lavigne, 1986; Radford et al., 1978; Russell et al., 2019). Characteristics observed include pup coordination, percentage of lanugo coat vs moulted pelage, and size and shape of the individual. The appearance of fresh afterbirth, umbilical cord, blood on or around the mother, and natal staining of the white lanugo coat were used to indicate recent births. Tracking pup developmental stages allows easier monitoring and identification of seal pups as they may move around or away from the site or section in which they were born. It also allows an improved understanding of pup survival rates, and the expected development time of individuals from birth to full stage 5 development. All pups were named with the beginning of a single letter of the alphabet ('the letter 'C') as per the naming tradition of the Calf of Man. Seal pups that survived past the third development stage were considered successful and assumed to have survived, unless they were in poor condition (Hewer, 1964).

Wanderers

A wanderer is defined as a pup which arrives at a site unaccompanied by a cow at stage 3, 4 or 5 of development and where their natal beach is unknown. 19 pups were recorded as wanderers. Large wanderer pups typically establish themselves on a beach to finish their moult while smaller individuals, typically abandoned or separated, usually disappear within days. The appearance of 'wandering' pups is commonly linked with storm and spring tide events. Wanderers observed at stage 5 development could possibly be pups born and recorded on the island but which have left their birthing site prior to any stage 5 photos being recorded. Wanderers were photographed and their pelage patterns catalogued allowing their presence to be tracked.

Photo Identification

Photographs of adult seals taken at pupping sites were compared with a catalogue of individuals recorded previously on the Calf of Man, consisting of 671 cows and 61 bulls prior to the 2025 season. Breeding females are the focus of the identification catalogue - identifying females with pups allows analysis of site fidelity at both a site specific and a whole island level. Photographed seals that were photographed and did not match any individuals in the catalogue were added as new individuals. They were assigned identifying numbers, a record of their individualised pelage patterns was recorded, and the date and locations at which they were observed were noted.

Camera trapping

Camera traps are a non-invasive and relatively inexpensive tool allowing the observation of animal behaviour (Brassine & Parker, 2015), without human disturbance (Di Cerbo & Blancardi, 2012). In this study the camera traps were used to monitor pups, including confirmation of filial relationships, confirmation of abandonment, pup presence and the date that pups were born. A total of 5 camera traps were deployed: one at South Harbour, two at the Puddle, one at Grants Harbour, and one at Cow Harbour.

Full island census

Island wide surveys were completed on a monthly basis from March to November, initially by the Estate Wardens and then by the seal volunteers over the pupping season. These consisted of a whole island count of adult seals along the island's coastline in addition to pupping sites. During the 2025 season, whole island surveys were undertaken using the thermal drone technology as in 2024, replacing the previous method of boat surveys. All individuals were recorded across the whole coastline of the island, not just pupping sites, and classified by life stage (adult or pup) and species (grey or harbour). Towards the end of the season the full island surveys were undertaken in greater detail where sex and positioning (hauled out on rocks or in the sea) were recorded, and sub-adults were categorised separately.

Data analysis

Testing to ascertain if the number of pups sighted on the Calf has changed significantly over the long-term survey period was undertaken using a simple linear regression model. Before undertaking analysis the data was checked for linearity and outliers, the data met assumptions and the test was deemed appropriate for determining the linear relationship between time and pup numbers on the island.

Birthdate analysis testing was undertaken to test if there was a significant advancement in birthdates from 2024 to 2025. This testing was done on the pupping cohort as a whole and separately on mothers who had pupped in both the 2024 and 2025 season. The data for the whole cohort did not meet assumptions of normality in a Shapiro-Wilk test (p-value<0.05), so a non-parametric Wilcoxon Signed Rank test was undertaken. Contrastingly, the returning mum's data met assumptions of normality in a Shapiro-Wilk test (p-value>0.05), as such a parametric unpaired t-test was undertaken.

Statistical analyses and data visualisations were undertaken in RStudio using the dplyr, ggplot2, car, and tidyr packages (R Core Team, 2023; Wickham, 2023; Wickham, 2016; Fox and Weisberg, 2019; Wickham et al., 2024). Statistical significance was accepted at $\alpha \leq 0.05$ for all tests. Means are reported as mean ± standard deviation unless stated otherwise.

Results

Pup census

A total of 111 grey seal pups were recorded on the Calf of Man in the 2025 pupping season. This marked the highest count of unique pups identified on the Calf since surveys began in 2009, and the first season in which over 100 individuals were identified. Of these, 92 pups were born on the island and 19 were classified as wanderers. Both figures are higher than in any previous season (Figure 2). A significant positive relationship between survey year and the total number of grey seal pups recorded on the Calf was observed. The model explained 83% of the variation in pup numbers ($R^2 = 0.83$). Total pup count increased by an estimated 4.15 pups per year ($\beta = 4.147 \pm 0.485$ SE), and the effect of year was deemed highly significant ($t_{15} = 8.549$, $p < 0.001$) while residual variation was low (residual SE = 9.799). Wanderer counts have been inconsistent across years as they have not always been classified, producing an overall mean of 5.113 ± 6.7 wanderers per season. When years with no wanderers are excluded, the mean increases to 7.25 ± 6.956 individuals, indicating that the 2025 total was substantially above typical levels. Improved survey quality in recent years has also increased confidence in wanderer estimates, with 16 recorded in 2021 and 14 in both 2023 and 2024. Counts are likely to continue increasing with clearer parameters for identifying wanderers.

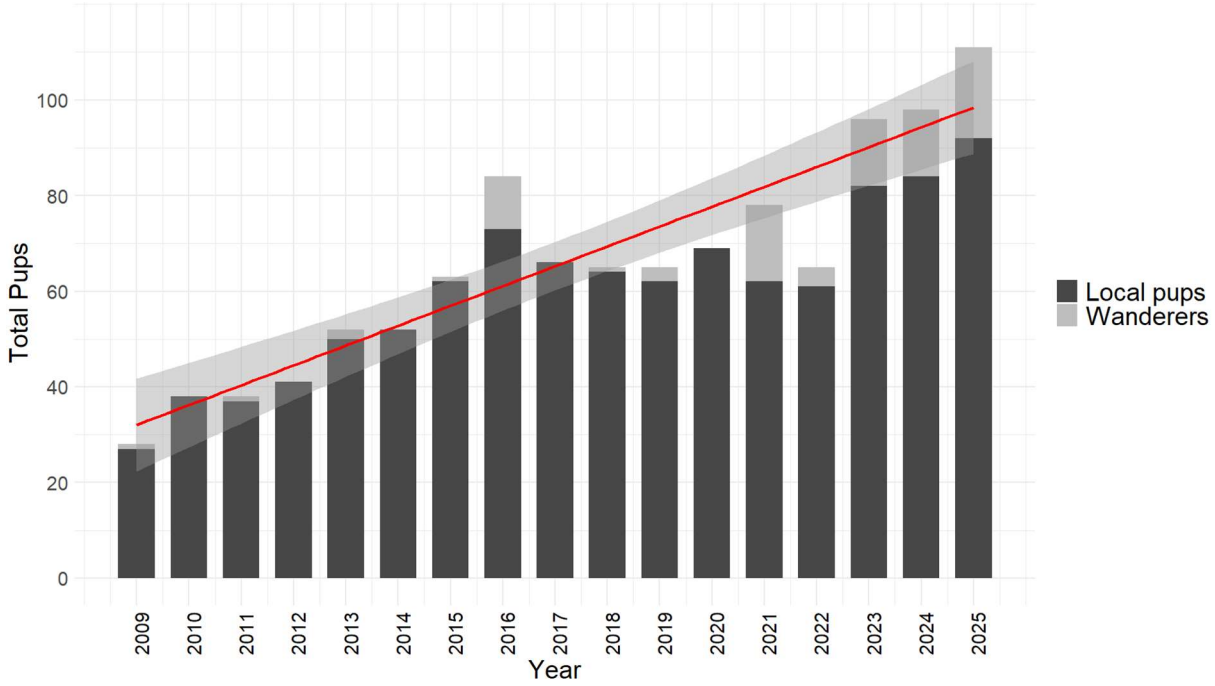


Figure 2. Number of grey seal pups born on the Calf of Man (dark grey bars) and late-stage wandering pups observed without an associated mother (light grey bars) during survey seasons from 2009 to 2025. The red line shows the fitted linear regression, with light grey shading indicating the standard error of the estimate.

Since surveys began in 2009, an average of 60.118 ± 17.723 pups have been born on the Calf each season. This number has been steadily increasing over time, reflecting changes in survey methods and breeding behaviours (Figure 3). An initial peak of recorded on-island births occurred in 2016 with 73 pups, followed by a plateau from 2017 to 2022 with an average of 64.6 births each year. At this point the Calf was considered close to its pupping capacity with around 65 births expected each year. The introduction of aerial surveying in 2023 coincided with successive record counts, resulting in 82 births recorded in 2023, 84 in 2024, and 92 in 2025. As such, there was a

significant positive relationship observed between survey year and the number of pups born on the island. Year explained 82.7% of the variation in on-island births ($R^2 = 0.827$). Birth numbers increased by an estimated 3.19 pups per year ($\beta = 3.191 \pm 0.377$ SE), and the effect of year was highly significant ($t_{15} = 8.46$, $p < 0.001$). Residual variation was low (residual SE = 7.62).

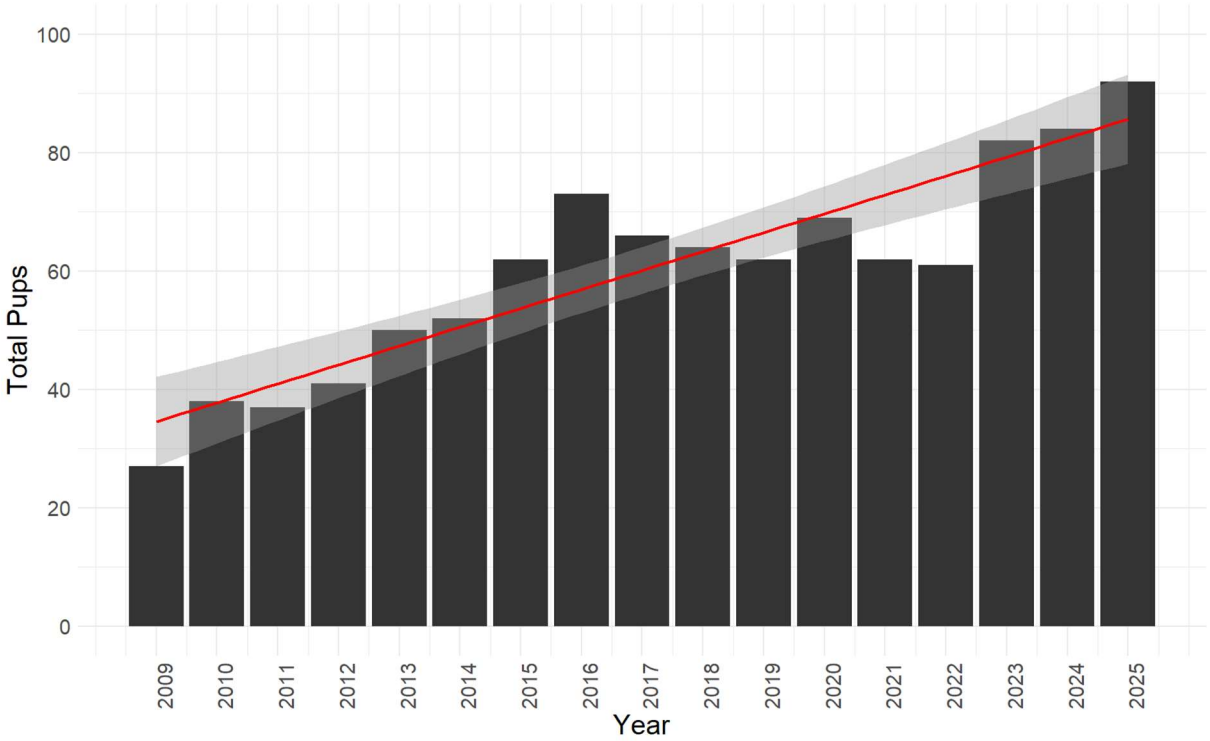


Figure 3. Total number of pups born on the Calf of Man in survey seasons from 2009 to 2025. The red line indicates the fitted linear regression with light grey shading representing the standard error of the estimate.

Of the 111 pups recorded on the Calf in 2025, 20 pups were classified as deceased. Fifteen deaths were confirmed while a further five pups were assumed to have died having gone missing at an early developmental stage. Confirmed deaths represented 13.51% of recorded pups (third highest mortality), increasing to 18.02% when all assumed deaths were accounted for. This was the highest mortality rate since surveys began in 2009, exceeding the previous highest mortality rate of 16.67% in 2024 and the earlier high of 13.73% in the 2014 season. The average mortality rate over the 17-year survey period is 6.7% indicating that the mortality rate observed in 2025 was well above the expected level. Most deaths were attributed to unknown causes (N = 6), followed by storm-related mortality during Storm Amy (N = 5), and stillbirths (N = 4; Figure 4).

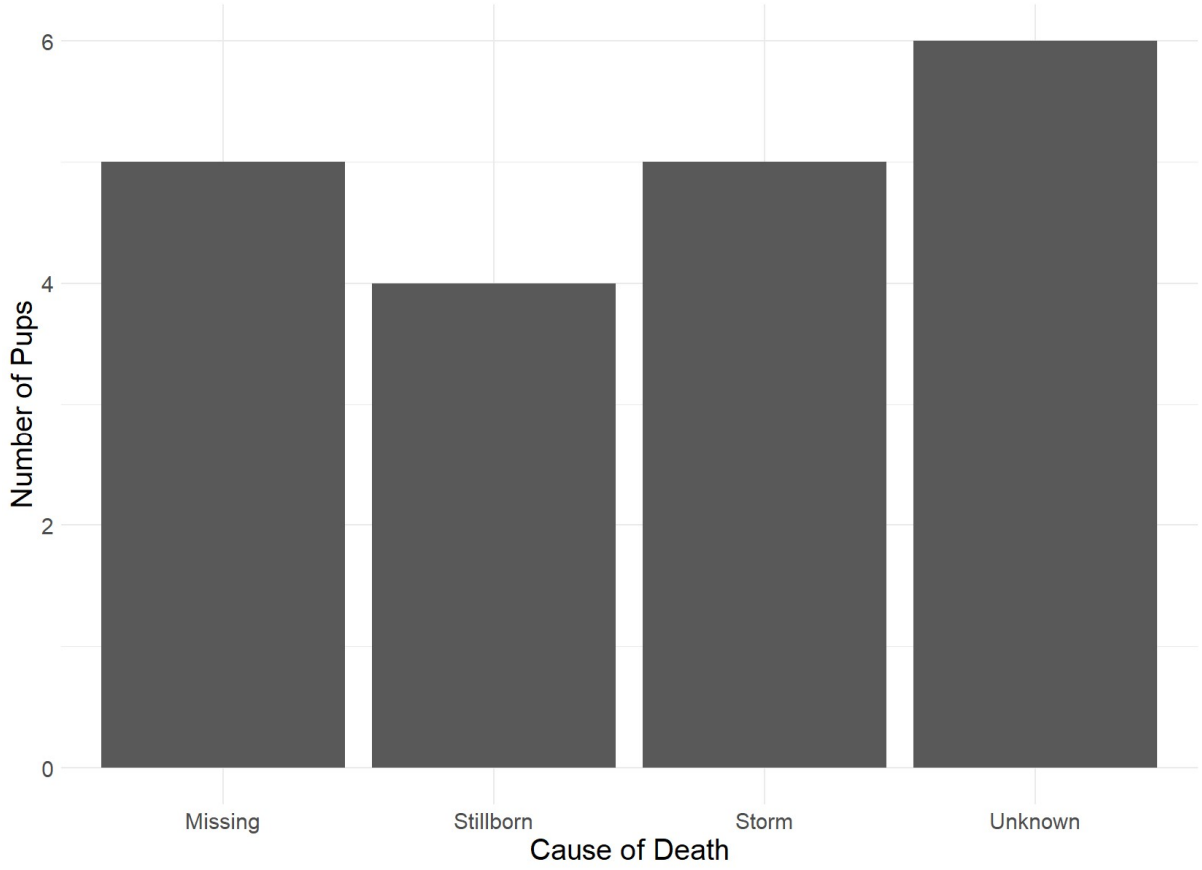


Figure 4. The causes of pup mortalities recorded in 2025. Confirmed and assumed mortalities are included - all assumed fall under the 'missing' category.

Pup deaths were spread relatively evenly across sites, with mortalities recorded at 10 of the 16 pupping sites used. Incidences of mortality were highest at MG, GL, and PU with three deaths recorded at each site. Contrastingly, no deaths were observed at AM, BO, GH, KI, CL, or SH. The highest mortality rate was observed at Leodan where 66.67% of recorded pups died. Mortality rates were also high at GL (60%), SC, and KH (50%) (Figure 5).

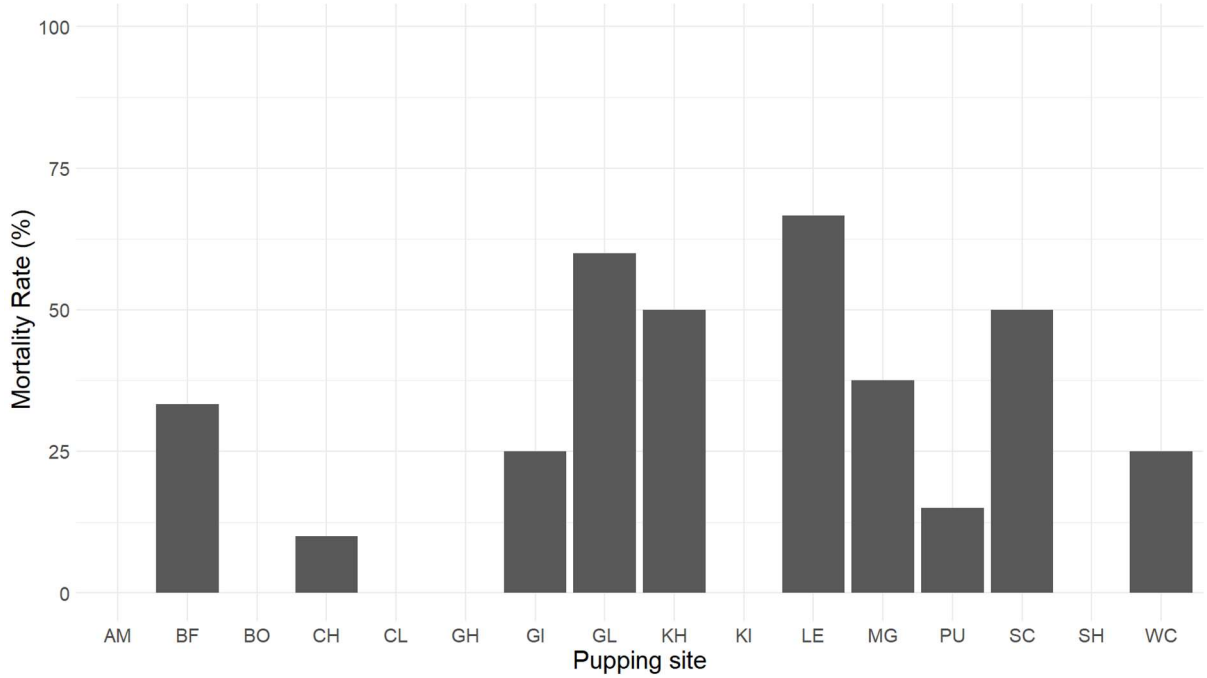


Figure 5. The mortality rate across the 16 sites on the Calf of Man where pups were sighted in the 2025 season.

Most mortalities occurred early in development. The mean developmental stage at death was 1.7±0.733, with nine pups dying at stage 1 and eight at stage 2 (Figure 6). Only three pups died at stage 3; two were storm-related and one resulted from unknown causes at MG. There were two additional deaths from unknown causes recorded at MG at a similar point in the survey period.

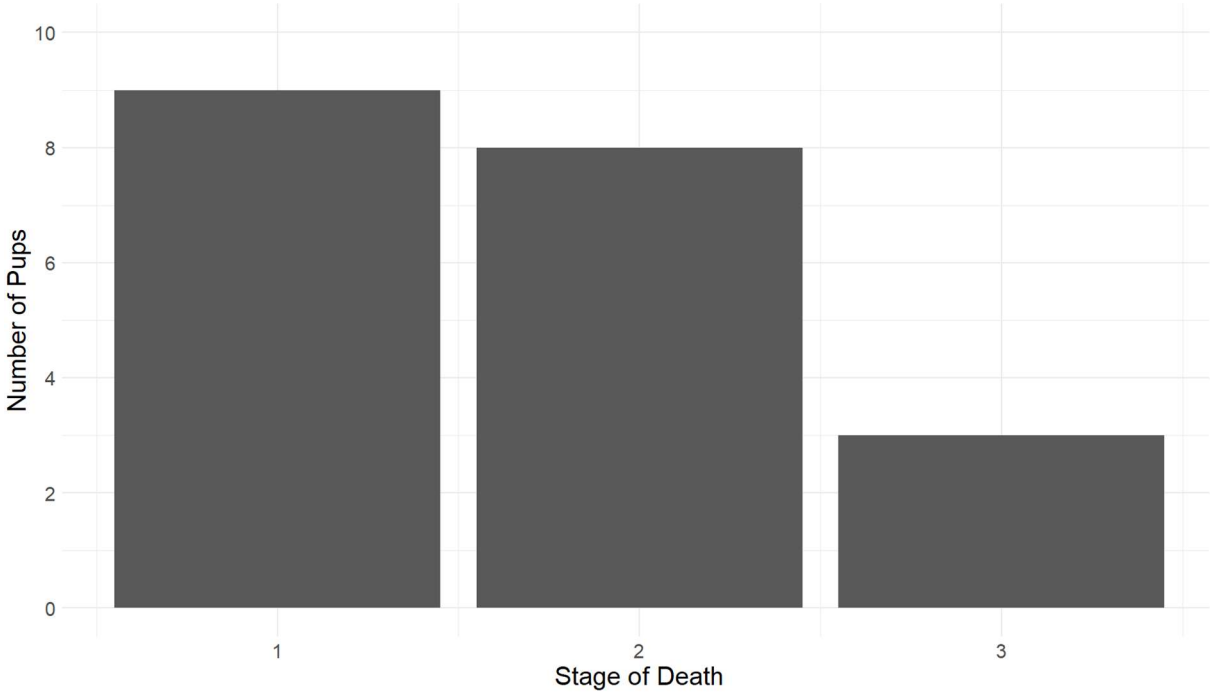


Figure 6. The stage of death at which pup mortalities occurred on the Calf of Man in the 2025 pupping season.

Pup distribution

In the 2025 season, pups were recorded at 16 different sites across the Calf (Figure 7). One new pupping site was observed in 2025, Kione yn Halby, bringing the total number of recorded pupping sites on the Calf up to 17. No pups were seen at CP or KR despite sightings in previous years. The

site with the highest pup abundance was PU (20 pups), closely followed by SH (15 pups) and CH and GH (10 pups each). These four sites accounted for 49.55% of all pup records on the island with PU alone accounting for 18.018% of records. Only one pup was sighted at AM, making this the site with the lowest frequency of pup sightings. Birth distributions followed a similar pattern whereby PU had the highest number of births (18 pups) followed by SH and GH (10 pups) and CH (9 pups). A single birth was recorded at both KH and WC while no pups were born at AM or KI.

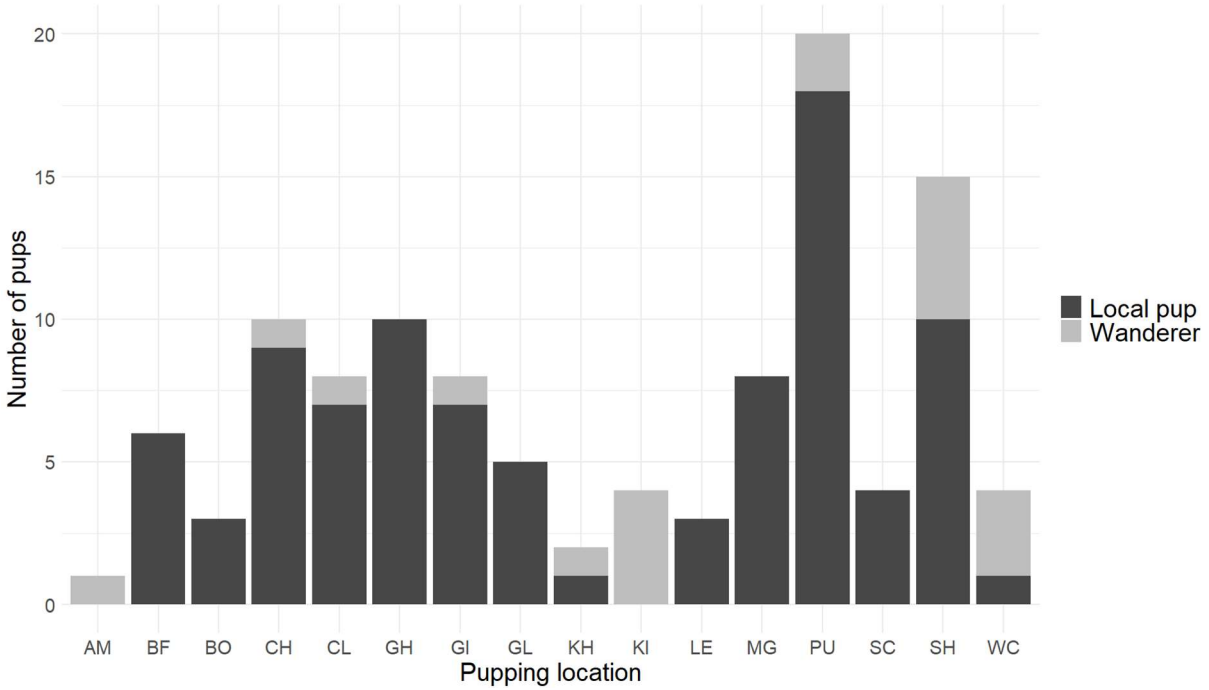


Figure 7. The number of pups born at each pupping location (dark grey bars) and number of late stage wandering pups observed at each site (light grey bars) in the 2025 pupping season.

Site fidelity

In the 2025 pupping season, 82 cows were identified as mothers. There were 35 new individuals identified (42.683%) with 47 cows having been previously recorded in the photographic ID catalogue (57.317%). Of the 47 previously known cows, 43 had pupped on the Calf in earlier years (52.439%) while four had only been sighted without pups (4.878%). There were 14 individuals which had been recorded across multiple seasons both with and without pups (17.073%). The identity of 29 mothers could not be determined: 10 pups born on the Calf were never seen with an adult, and 19 pups were wanderers meaning they were unaccompanied. Eight pups with unidentified mothers died; three were never observed alive, and five were found dead at stages 1 or 2.

In 2025, 36 females pupped at sites they had pupped at in previous seasons. This represents 43.902% of all identified mothers and 83.721% of females that had pupped on the Calf in earlier years. This indicates a high degree of site fidelity among returning cows as well as a fairly high turnover rate of breeding individuals, with more than half of the identified mothers being new to the island. Of the returning cows, 51.16% have only ever pupped in one site with a further 30.23% having only pupped in two sites (Table 1). No cows had pupped in more than four sites representing a high degree of site fidelity with a clear preference in females to return to the same site year on year.

Table 1. Number and proportion of mothers recorded during the 2025 pupping season that had pupped on the Calf of Man in previous years, grouped by the number of distinct pupping sites they have used across seasons.

Number of Sites	Number of Seals	Percentage of Returning Cows (%)
1	22	51.16
2	13	30.23
3	6	13.96
4	2	4.65

Site fidelity varied depending on the site (Figure 8). There were no returning mothers sighted at CL or KH. The first pup ever recorded at KH was sighted in the 2025 season so this was not surprising, but multiple pups are sighted annually at CL, suggesting a high turnover rate of breeding females at this site. Fidelity rates were lowest at section 6 (BF, GI, and BO) (Figure 9), few births have been recorded at these sites across the survey period with UAVs allowing better visibility at these sites. As such fidelity rates may be negatively skewed at these sites due to a less well-defined ID catalogue.

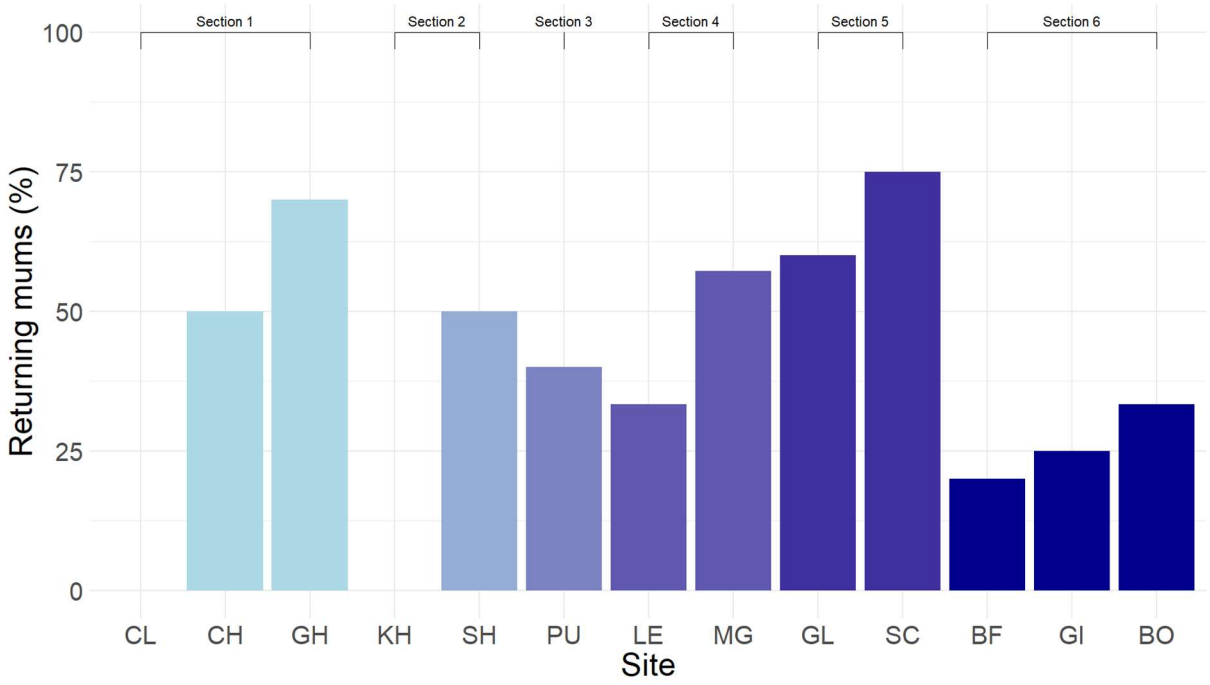


Figure 8. Proportion of mothers returning to the same pupping sites on the Calf of Man in 2025 where they had pupped in previous seasons. Sites are grouped by island section, indicated by black bars at the top of the figure. Section 7 is excluded as no pups were born in this section in 2025.

Sites were first grouped into sections in the 2023 season to observe if site fidelity was specific to site or could be more dependent on terrain and area. Sites were split into seven sections based on proximity and geographical boundaries (Figure 9). In the 2025 season 7 individuals pupped in entirely new sections in which they had never pupped before while 36 pupped in a site they had previously pupped in (Figure 10). There were no recorded individuals that pupped in a new site

that was within the same section despite some sites, such as Cow Harbour and Grants Harbour, being in close proximity.

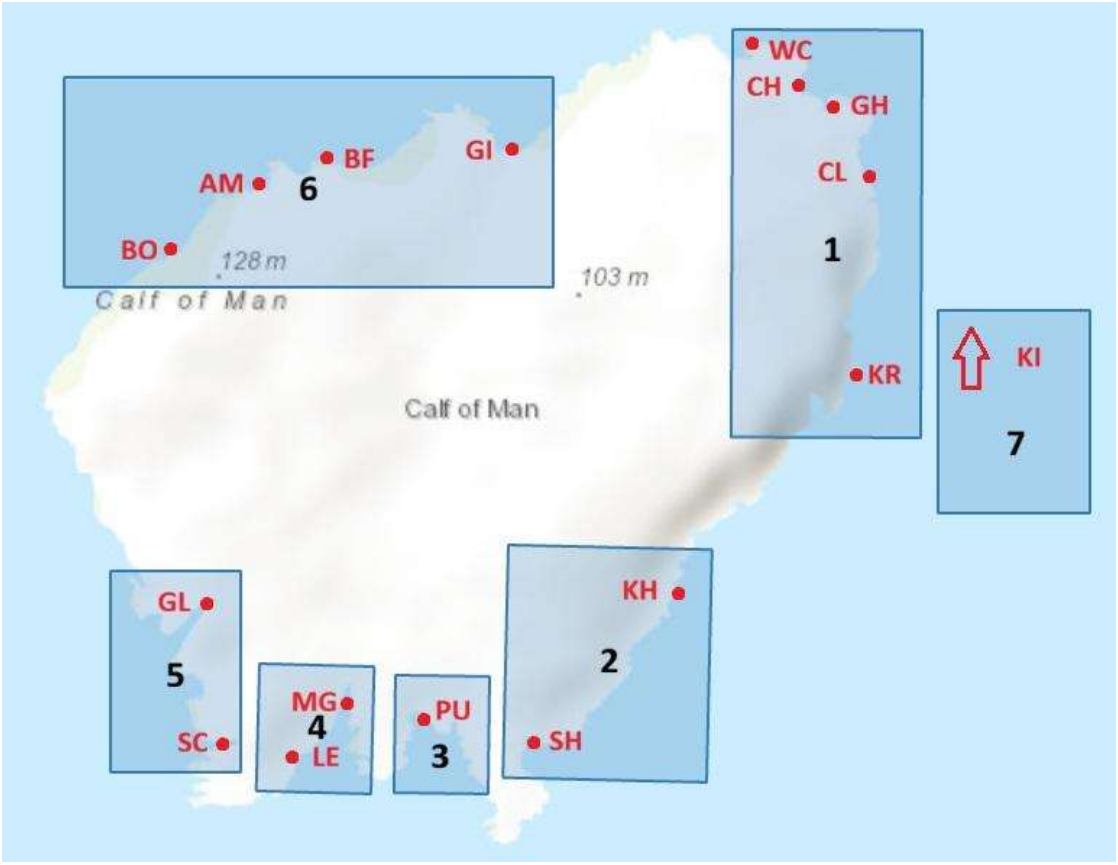


Figure 9. A map of the Calf of Man showing all 16 identified pupping sites grouped into 7 separate sections defined by geographical proximity and natural boundaries. Sites are identified with red text whereas section numbers are identified with black text. See figure 1 for site codes. Caigher Point, the 17th site is excluded due to no pups born here in 2025.

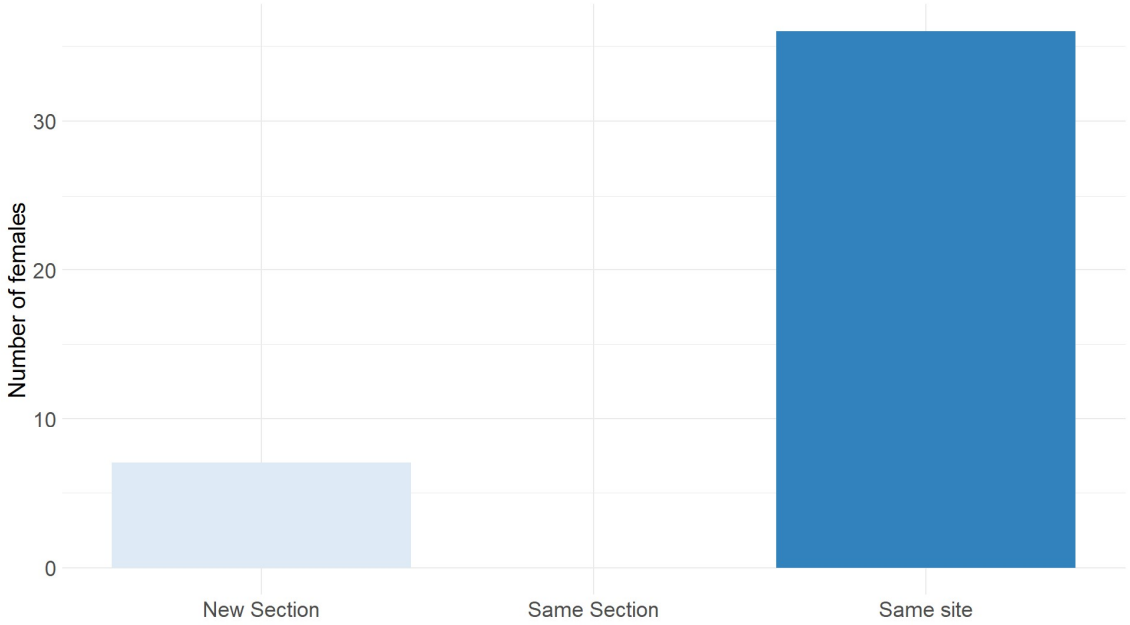


Figure 10. The number of females returning to the Calf of Man in 2025 to pup who pupped in a new site and section (pale blue), a new site within the same section (light blue), and the same site entirely (mid blue) that they had in their last pupping season.

Birthdate analysis

Birthdate analysis showed that cows pupped on average 0.609 ± 15.666 days earlier in 2025 than in 2024 (Figure 11). There was no statistically significant change in birthdates between the two years (p = 0.188). The first recorded pup of 2025 was born earlier than in 2024 and the latest pup was born later representing a wider range of birthdates in 2025. In both years most pups were born in late September.

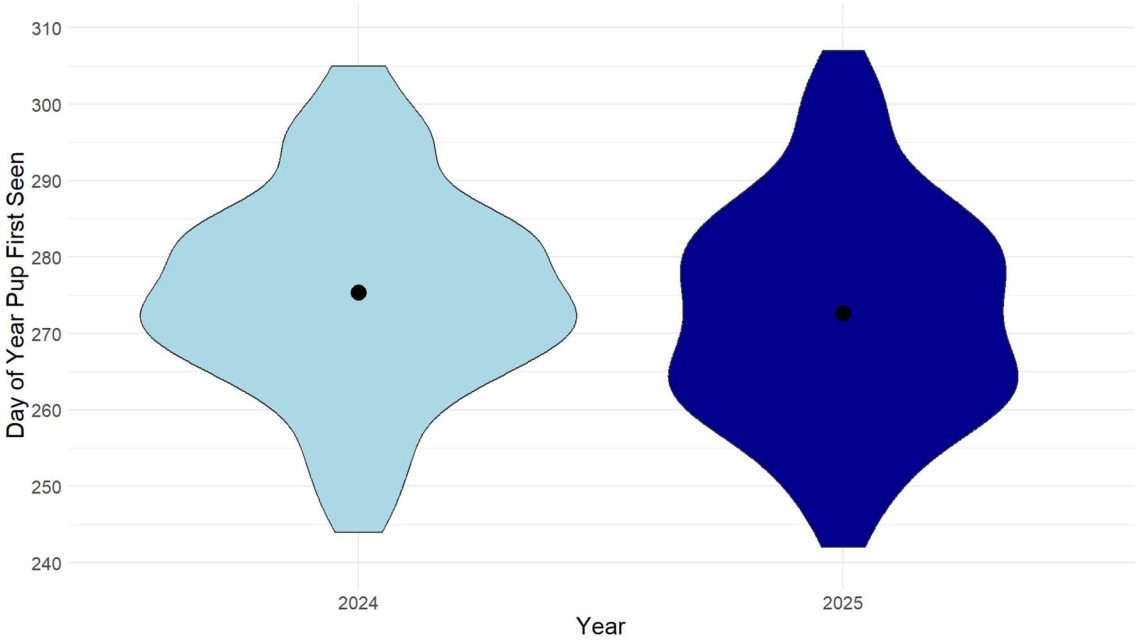


Figure 11. Distribution of the day of year on which pups were first observed in the 2024 (light blue) and 2025 pupping seasons (dark blue). Data represents all pups born on the Calf of Man across both seasons (2024 N= 84; 2025, N= 92). Black points indicate the mean first-observation date for each season. The day of first observation is used as a proxy for date of birth, as it provides an unambiguous measure.

Cows which had pupped on the island in both 2024 and 2025 pupped on average 3.464 ± 8.652 days earlier in 2025 than they did in 2024 (Figure 12, N=28). One female pupped on the same calendar day in both years and at the same site. The shift in pupping dates in returning mums was statistically significant (p = 0.005) with analysis of means showing that returning cows pupped earlier in 2025 than in 2024.

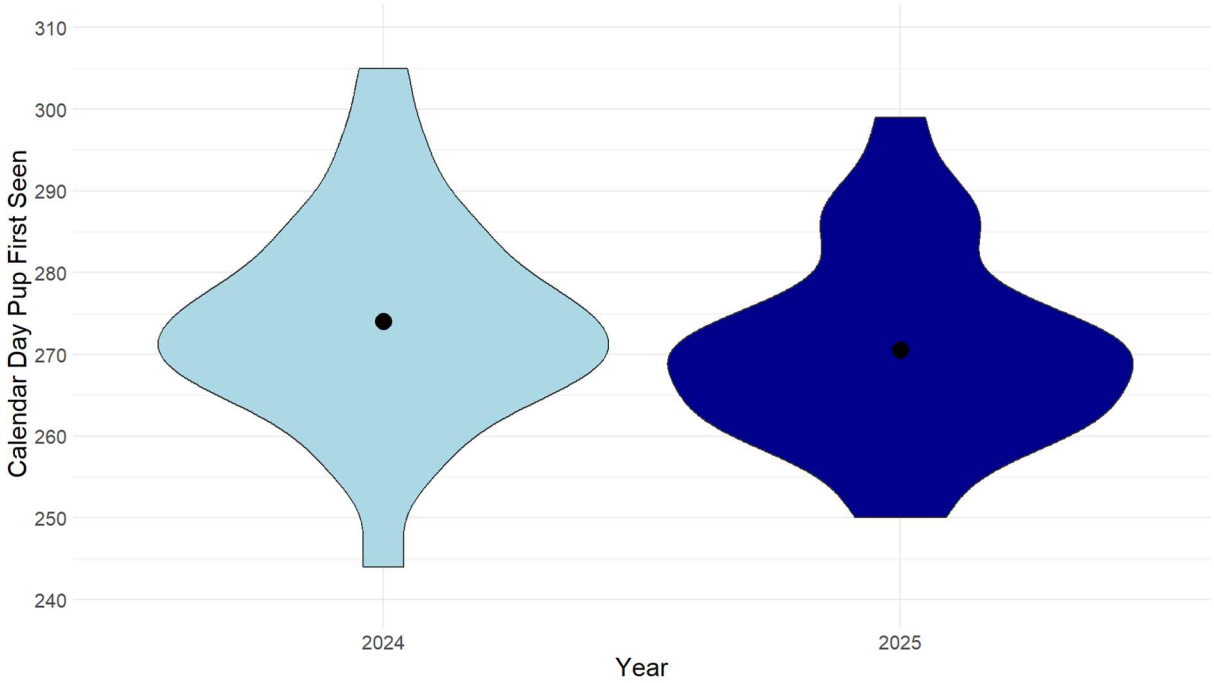


Figure 12. Distribution of the day of year on which pups were first observed in the 2024 (light blue) and 2025 pupping seasons (dark blue). Data represents pups born to returning mothers who pupped on the Calf of Man in both the 2024 and 2025 season (N=28). Black points indicate the mean first-observation date for each season. The day of first observation is used as a proxy for date of birth, as it provides an unambiguous measure.

All-island census

Mean seal abundance varied markedly among haul-out sites across the full-island censuses (Figure 13). A small number of sites consistently supported the highest seal numbers with KI, CL, PU, SH and WC showing mean counts exceeding 20 individuals. These sites also recorded the highest maximum counts, with peak abundances reaching 94 individuals at CL and 64 at KI. In contrast, several sites supported consistently low numbers of seals throughout the survey period. Mean counts at sites such as CP, KH, LE and GI were below two individuals, with maximum counts not exceeding three seals, indicating infrequent or opportunistic use.

Variability in seal numbers differed substantially among sites. Core haul-out sites generally exhibited higher standard deviations, reflecting pronounced fluctuations between censuses, whereas low-use sites showed relatively low variability and consistently low counts. KI, CL and SH exhibited progressive increases in abundance between early and late surveys. These sites recorded relatively low to moderate counts during the initial census but supported substantially higher numbers in subsequent surveys, with peak counts occurring during the later stages of the season. The highest total grey seal count was recorded at 281 on the final full island survey on 30th October, which was significantly lower than the 2024 highest count of 456 individuals.

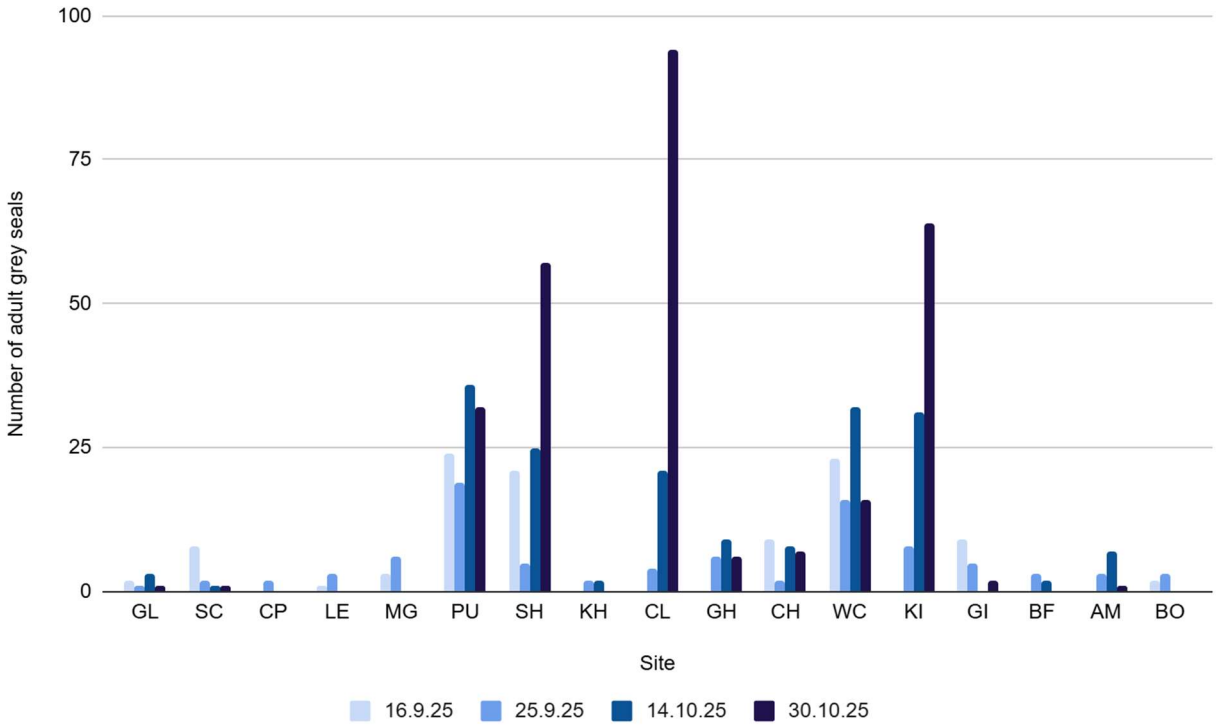


Figure 13. The number of adult grey seals recorded at each haul-out site during the full island surveys conducted on 16/09/2025 (N=102), 25/09/2025 (N=90), 14/10/2025 (N=177) and 30/10/2025 (N=281).

Adult distribution

Seal numbers varied between the sites across the survey season (Figure 14). Kitterland had the highest average adult grey seal count (N=41.8). This site was added in 2023 following UAS surveying and has limited previous population data. Across the other sites usage and distribution this season followed similar patterns as observed in previous years. West Cow (N=22.2), Puddle (N=20.7) and Cletts (N=20.5) had the next highest average adult grey seal counts. While nine of the sites had an average adult grey seal count below four individuals per survey: Ghaw Lang (N=1), Kione ny Halby (N=1.3) Leodans (N=2), Bay n'Oig (N=2.5), Smuggler Cove (N=3), Mill Giau (N=3), Gibdale (N=3.4) and Bay Fine (N=3.4).

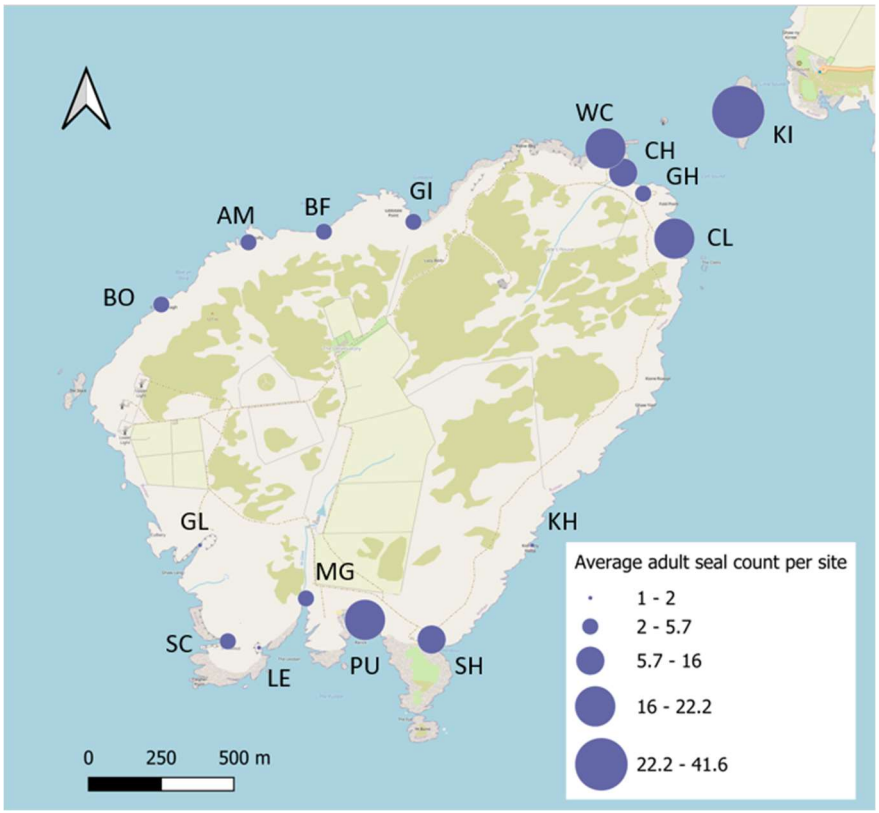


Figure 14. A map of the Calf of Man showing the average numbers of adult grey seals at each pupping site. Symbol size is proportional to seal abundance.

Discussion

Pup numbers

The total number of pups recorded on the Calf in the 2025 pupping season was 111, this was the most productive pupping season recorded on the island since records began in 2009. A significant relationship was observed between time and the number of pup records on the island. From the first survey year in 2009 up until 2015 pup numbers increased annually, most likely as a result of increased survey periods and improved methods. Pup numbers then reached a peak of 75 in 2016 before levelling out between 2017 and 2022. It was speculated that the island had reached carrying capacity at around 65 pups per season. However, record numbers were then counted in the 2023, 2024, and 2025 season successively.

The overall annual population growth of grey seals in the UK has declined noticeably over the last 50 years. An ~6% increase in births was observed between 1984 and 1985 with only a <1% increase between 2002 and 2019 (Thomas et al., 2019). Population booms in the 1980s were likely a result of the introduction of protection for grey seals in the 1976 Wildlife and Countryside Act. In recent years, the population has stabilised resulting in slowed growth but higher adult population numbers. Therefore, the decline in population growth of grey seals across the UK is not expected to be a symptom of an unhealthy population, just a slowing of the population boom observed in the wake of their protection. This means increasing pup numbers on the Calf are likely not explained by general population increases of grey seals across the UK and are a result of more localised factors.

A key driver for increased pup counts on the Calf is the improvement of surveying methods. It is probable that the carrying capacity of the island has not been exceeded for three successive years, rather improved survey methods have allowed for more accurate counts to be made. The 2023 season saw the introduction of aerial surveying through the implementation of a drone. Aerial surveying allowed the detection of pups beyond visual line of sight, such as those in caves and inlets or those at the bottom of steep cliff faces which may avoid detection. Pups were recorded at Baie N'Ooig in the 2023 season for the first time and then again in both the 2024 and 2025 seasons indicating the positive effect of introducing the drone. In the 2024 season a drone with thermal imaging capabilities was implemented, possibly explaining the further increase in pup records in the 2024 season. However, no adjustments were made to the surveying methodology in the 2025 season. Further increase in the number of recorded pups could be a result of interannual variation. Due to the short period of time aerial surveys have been undertaken on the island there is no clear relationship between the survey year and the increase of pups.

Furthermore, in the 2023 survey season, stage 5 wanderers were classified as their own category. This meant they were included in pup counts but kept distinct from pups born on the island. This allowed for standardisation of counts for stage 5 wanderers, ensuring they are included in counts and providing parameters to ensure they are not duplicate counts of stage 5s born on the island. This could explain some of the increase in pup counts if these late stage pups without parental affiliation were not included in earlier seasons counts.

In late 2018, ten Marine Nature Reserves (MNRs) were established in the Isle of Man territorial sea, covering 10.8% of the territorial sea and 51.8% of the inshore (0-3 nautical mile) area. These

reserves were designated to protect marine biodiversity in Manx waters in order to promote sustainable fishing practices (Marine Nature Reserves, 2023). It has been observed that designating areas with reduced fishing pressures has a positive impact on biodiversity as a whole, including higher order predators which may not be the target of fishing pressures themselves (Rojo et al., 2021). Protecting marine habitats improves ecosystem health and function resulting in benefits to higher order predators through bottom up control maintaining trophic web structure (Leenhardt et al., 2015). As such, designation of MNRs around the Isle of Man could be a cause of increased reproductive success in grey seals and therefore the observed increase in pup numbers.

A large number of stage 5 wanderers were identified on the Calf in 2025, further increasing the number of pups recorded on the island. It is proposed that this could be a result of increased storm events in the 2025 season. Storm Amy, an extratropical cyclone, hit the Calf in early October. Gusts of up to 89mph were recorded on the Isle of Man, greatly exceeding the 72mph gusts recorded during Storm Ashley, the major storm event recorded in the middle of the 2024 pupping season. Difficult weather conditions could have made it more likely for developing stage 5s to seek more time on land or be moved from their pupping site to the Calf by strong tides (Wilkie and Zbijewska, 2019).

Mortality

Pup mortality was recorded when the remains of a pup were visible to surveyors or when a pup was recorded as missing before reaching stage 3. There were 20 mortalities recorded in the 2025 season, 18.02% of all recorded pups. Of these, 15 pups were observed deceased (13.51% of recorded pups) and five were recorded as missing at an early life stage. The highest mortality rate since surveys began in 2009 was recorded in this pupping season. It exceeded the previous highest mortality rate of 16.67% in 2024 and the earlier high of 13.73% in the 2014 season.

The main causes of mortality in grey seal pups are starvation, infection, septicaemia, stillbirth, and trauma (Baily, 2014). Of the 15 pups confirmed as deceased, four pups were recorded as stillborn in 2025. Stillbirths in grey seals are typical among first-time mothers (Pomeroy et al., 2000). This has been attributed to factors such as inexperience in birthing, or potential physiological constraints during a seal's first pregnancy (Baker et al., 1995). However, of the four stillborn pups recorded on the Calf in 2025, two had mothers which had pupped before. One had pupped once before, and the other had pupped seven times suggesting there may be other, unobserved, causes for these stillbirths.

A further five pup deaths were attributed to Storm Amy (03/10/2025 to 04/10/2025), the first named storm of 2025 which brought gusts of near 90mph to the Isle of Man. Bad weather conditions increase mortality rate in grey seal pups (Baker and Baker, 1988). Pups have been observed to survive periods with particularly violent seas when inhabiting protected sea cave nurseries (Westcott and Stringell, 2003). However, strong southerly winds resulted in mortality of pups in exposed inlets on the south coast, particularly Ghaw Laing and Smugglers Cove where there was little shelter from storm surges.

The cause of death for the remaining six pups was unknown, though many died at stage 1 or stage 2. Early life stage mortalities are not uncommon in grey seals due to their dependence on their mothers (Quaggiotto et al., 2018). Stage 1 pups also frequently die as a result of unobserved complications from birth, with dystocia being one of the most commonly recorded causes of death

in pups less than three weeks olds (Baker et al., 1998). Mortality observed at Mill Giau was particularly high (See Additional observations).

Pup distribution

As in previous survey years, the Puddle, Cow Harbour, South Harbour, and Grant's Harbour were the four most used pupping sites in the 2025 season. Sites in section 1, the north coast, are less affected by adverse weather conditions due to the short fetch of the Calf Sound and protection from winds by surrounding land masses. Prevailing south-westerly winds commonly blow up on the Calf from the Atlantic following the jet stream, Storm Amy followed this pattern resulting in storm surges in the less sheltered bays along the South coast, particularly in section 5. Studies indicate that females are less likely to choose sites subject to flooding and storm surges (Allen, Bowen & den Hyer, 2022). This likely explains low pup birth numbers and high mortality rates at Ghaw Lang and Smugglers Cove.

Females are believed to select pupping sites based on the habitat (Twiss et al., 2000). Habitat features such as low gradient shores, tidal pool presence, sea access and decreased tidal and storm-surge influences are suggested as the optimal pupping locations (Anderson et al., 1979; Twiss et al., 2001; Weitzman et al., 2017). This likely explains why few pups are born along the East coast of the Calf. This area is dominated by steep cliffs with few haul out spots being difficult to access and highly influenced by tidal changes. In the 2025 season the first pup birth at Kione yn Halby was recorded. The pup was recorded as missing at early stage 2 and was presumed deceased due to unfavourable location and vulnerable age. The mother had never been recorded in the ID catalogue so it is probable she had not pupped many times before, likely resulting in poor site selection. A combination of lack of experience and competition from other, more experienced cows dominating favourable sites likely led to poor site selection decreasing the likelihood of pup survival.

Pupping site selection, and therefore the distribution of pups, appears to depend not only on suitable terrain but also on individual maternal preferences (see Site fidelity). For instance, no pups were born at Amulty in 2025, despite 5 births there in 2024 and 4 in 2023. Numerous births at this site in previous years suggest the site itself is not undesirable, so there must be another variable resulting in no pups being born at this site in 2025. None of the cows identified as returning mothers in 2025 had ever pupped at Amulty before. This suggests that interannual variation in pup distribution may be strongly influenced by the demographic makeup of returning females. If none of the returning females have a relationship with a site it is likely no, or few, pups will be born there.

Site fidelity

Pupping site selection in grey seals is poorly studied but it is understood that they display high levels of site fidelity (Pomeroy et al., 1994, Langley et al., 2020). It is suggested that both males and females are philopatric, meaning they return to their natal sites to breed (Pomeroy et al., 2000). However, grey seals are sensitive to environmental changes and are more likely to return to sites with accessible topography and that are sheltered from inclement weather and storm surges, as well as being influenced by previous reproductive success (Wietzman et al., 2017). It is also suggested that they may rely on social information from other seals to determine habitat quality and improve site choice i.e. not selecting sites with high densities of adult seals which could put young pups at risk. The complex and poorly understood process of pupping site selection in grey

seals suggests that populations are vulnerable to possible changes in their natal sites or frequently used pupping sites. As such, it is important to protect areas where many individuals pup to ensure pupping success and reduce stress in breeding populations.

In 2025, 52.4% of the identified mothers on the Calf had been identified as having pupped on the island in previous years. A further 4.7% had been sighted on the Calf before but had not been seen with a pup until this season. Of these returning cows, 83.7% pupped at a site they had pupped at in previous years with 51.2% having only pupped at one site on the Calf in their lifetimes. This suggests female grey seals display a high degree of site fidelity, as observed across populations (Langley et al., 2020).

Studies of other seal species have shown that females may not be loyal to specific sites as much as general areas. Where sites are poorly distinguished or easily accessed from the same bays or channels females may be as likely to use multiple sites within the same area (Baker et al., 1995). Since the 2023 survey season sites have been grouped into 7 sections based on proximity and access points. It was proposed that section fidelity may be higher than site specific fidelity. However, as in previous seasons, site specific fidelity was more commonly observed than section fidelity in the 2025 season. Females that pupped at a number of different sites often pupped at sites in entirely different sections. The high degree of site specific fidelity implies that females pick pupping sites very specifically and are acutely aware of exact geographical locations. Females are also highly sensitive to failed pupping events, be that stillbirths or mortalities of pups. As such, losing a pup at a given site could drive them to move to an entirely different area of the island, resulting in a new section pupping event rather than a new site.

Birthdate analysis

In addition to site fidelity it is suggested that female grey seals tend to pup on the same date each year with observed patterns in birthdate. However, in recent years a level of plasticity has been observed in pupping dates with sea temperature named as the key influencing factor. An in-depth study of a grey seal colony on Sable Island in Canada noted a 15 year advancement of average birthdate across a 27 year period. Male aggression, female size and body condition, and environmental conditions were all associated with the shift. As well as this, research conducted on Skomer Island, Wales, found that a temperature increase of 2°C was associated with a pupping season advance of approximately seven days at the population level (Bull et al., 2021), which supported results from Sable Island (Weitzman et al., 2017). There has been concern that pupping season is moving forward as global temperatures shift, with previous survey results showing individual more experienced mothers pupping earlier each year. A trend seen in a number of species, with these shifts recognised as an impact of climate change (Root et al., 2003). Continued advancement in birthdates, as a result of anthropogenic climate change and increased sea temperatures may distort the critical synchrony between pups and their food supply.

On the Calf, mothers pupping in the 2025 season who were also observed pupping in the 2024 season had a mean birthdate advancement of more than 3 days. While changes in climate cannot be attributed with certainty to birthdate advancement due to the influence of interannual variation on a single year analysis and a small sample size (N=28), it is important to investigate the effect of anthropogenic climate change on grey seal birthdates so effective management can be put in place to ensure there is minimal negative effect on the species. The primary cause of death in pups born to returning cows was mortalities during Storm Amy. Worsening weather events may be

a concern to experienced mothers resulting in a possible advancement in birthdates. Surveys in 2024 and 2022, and 2021 indicated that an average of 61% of returning mothers pupped earlier than in previous seasons suggesting a gradual advancement of birthdates is being observed on the Calf over time. However, 73% of returning mothers pupped later in 2023 than they had in the previous season suggesting there is not a clear and obvious trend in pupping dates. If grey seals were pupping earlier in response to increasing extreme weather events, birthdates in 2023 would be expected to shift earlier than average. Instead, 2023, the warmest year on record for the Isle of Man, with every month except March and November exceeding previous temperature records showed the opposite pattern. This highlights that changes in pupping phenology are complex and likely influenced by multiple interacting factors.

Camera Traps

The camera traps deployed produced a limited number of usable images for photo identification or matching mother with pups. Grey seals utilise dynamic, tide-dependent haul-out sights that are exposed to wave action, variable lighting and frequent changes in group composition. These conditions limit the likelihood of obtaining consistent, high-resolution images with a clear lateral view of the pelage required for reliable photo identification of individuals (Hilby et al., 2007). The motion operated cameras were often activated at suboptimal moments, such as by high tide, non-target species or obstructed camera views. Limited photos successfully captured seal activity, and group movement and overlapping individuals made analysing these photos challenging.

Most previous successful applications of camera traps in pinniped research have focused on monitoring population presence, haul-out behaviour, activity patterns and habitat use (Gücü et al., 2004; Koivuniemi et al., 2019; van Meurs et al., 2024). Future camera trap usage would benefit from clarification and reframing of the methodology and research objectives. Methodological improvements could include the use of time-lapse photography during known haul-out windows and pilot testing to optimise camera placement and angles. The camera traps could be used to provide valuable supplementary data within the long-term grey seal monitoring by addressing questions relating to temporal patterns of site use, relative haul-out intensity between sites, disturbance responses, and behavioural patterns.

Additional observations

Disturbance

Minimal disturbance to breeding seals was observed during the 2025 pupping season. Anthropogenic disturbance was largely confined to South Harbour, the primary landing site on the Calf of Man, which is used regularly by supply vessels and occasionally by day visitors. Visitor numbers were low in 2025 due to poor weather conditions, and guidance was provided to avoid seals wherever possible, maintain a minimum distance of 50m, and moving quickly away from seals when closer proximity was unavoidable, such as during disembarkation at SH.

Supply vessels are essential for ongoing activities on the island. Docking is constrained to high tide, which exacerbates both the frequency and spatial extent of human–seal interactions. Some disturbance at this site was therefore unavoidable, and most dockings resulted in a degree of seal movement. Adult seals without pups were the most responsive, often entering the water at distances exceeding 20m. In contrast, females with pups typically remained with their offspring and displayed more defensive behaviour towards passing humans. No aggressive interactions were

observed, and although some females temporarily entered the water during periods of increased activity, no prolonged pup abandonment was recorded.

Several females that pupped at SH had used the site in previous seasons and appeared less sensitive to human presence, suggesting site-specific tolerance. SH is a sheltered, low-relief beach with easy access to the sea and tidal pools, characteristics that likely outweigh the costs of intermittent disturbance (Twiss et al., 2000). SH was one of only four pupping sites in the 2025 season where no pups died, outlining why it is a valued pupping site for returning females. As such, continued adherence to distance guidelines, particularly around females with pups, is essential to maintain the low levels of disturbance observed during the 2025 season and allow continued pupping success at this site.

Mill Giau Mortality Rate

An unusually high pup mortality rate of 37.5% was recorded at Mill Giau during the 2025 pupping season, with three of eight pups born at the site confirmed dead. All deaths occurred within a three week period between the 4th and the 25th of September and were attributed to unknown causes. This level of mortality was unexpected given that Mill Giau is a sheltered site on the south coast, comprising a rocky inlet with a low-profile beach and a freshwater stream. The sheltered nature of this bay is highlighted by the fact there were no pup deaths recorded at the site during Storm Amy. This is likely due to its sheltered nature and easily accessible higher ground away from the waterline.

The clustering of mortalities in both time and space raises the possibility of localised factors. It is plausible the deaths were caused by an infectious disease. A harbour porpoise and a gannet were also found dead at the site earlier in the season with no obvious cause; these specimens could have contained harmful pathogens which put vulnerable pups at risk. For example, avian influenza has been shown to transmit to seals and can occur in otherwise healthy grey seal populations at rates comparable to some wild bird populations (Gadzhiev et al., 2024). Outbreaks have caused severe impacts in some pinniped populations, highlighting the importance of continued monitoring (Campagna et al., 2024). However, pups at Mill Giau showed no overt signs of illness, and the observed mortalities may not have been disease-related.

Further investigation was not possible because the site is largely inaccessible during the pupping season, and disturbance risk to other vulnerable pups was considered unacceptable. Continued monitoring of Mill Giau is recommended to determine whether the 2025 mortality event was isolated or whether persistent environmental factors, such as pathogen input from the stream, may be contributing to elevated pup mortality.

References

Baily, J.L. (2014). The pathology and occurrence of pathogens in Scottish grey seals (Halichoerus grypus). *Doctoral dissertation, University of St Andrews.* Available at: https://research-repository.standrews.ac.uk/handle/10023/4856.

Baker, J.R. & Baker, R. (1988). Effects of environment on grey seal (Halichoerus grypus) pup mortality. Studies on the Isle of May. *Journal of Zoology*, 216(3), pp.529–537.

Baker, J.R., Jepson, P.D., Simpson, V.R. & Kuiken, T. (1998). Causes of mortality and non-fatal conditions among grey seals (Halichoerus grypus) found dead on the coasts of England, Wales and the Isle of Man. *Vet Rec*, 142(22), pp.595-601.

Baylis, A.M.M., Porbjornsson, J.G., dos Santos, E. & Granquist, S.M. (2019). At-sea spatial usage of recently weaned grey seal pups in Iceland. *Polar Biology*, 42, pp.2165–2170.

Bowen, W.D., den Heyer, C.E., McMillan, J.I. & Iverson, S.J. (2015). Offspring size at weaning affects survival to recruitment and reproductive performance of primiparous gray seals. *Ecology and Evolution*, *5*(7), pp.1412-1424.

Bubac, C.M., Coltman, D.W., Bowen, D.W., Lidgard, D.C., Lang, S.L.C. & den Heyer, C.E. (2018). Repeatability and reproductive consequences of boldness in female grey seals. *Behavioural Ecology and Sociobiology*, *72*(100).

Büche, B. & Bond, S. (2023). Grey Seal Breeding Census Skomer Island 2023. *NRW Evidence Report number 750, The Wildlife Trust of South and West Wales.*

Burton, R.W., Anderson, S.S. & Summers, C.F. (1975), Perinatal activities in the Grey seal (*Halichoerus grypus*). *Journal of Zoology*, 177, pp.197-201.

Campagna, C., Uhart, M., Falabella, V., Campagna, J., Zavattieri, V., Vanstreels, R.E. & Lewis, M.N. (2024). Catastrophic mortality of southern elephant seals caused by H5N1 avian influenza. *Marine Mammal Science*, 40(1).

Carroll, D., Ahola, M. P., Carlsson, A. M., Sköld, M. & Harding, K. C. (2024). 120-years of ecological monitoring data shows that the risk of overhunting is increased by environmental degradation for an isolated marine mammal population: The Baltic grey seal. *Journal of Animal Ecology*, 93, 525–539.

Duck, C.D. (1996). Important species: seals. In: Barne, J.H., Robson, C.F., Kaznowska, J.P. & Davidson, N.C., (eds.). *Coasts and seas of the United Kingdom. Region 13 Northern Irish Sea: Colywn Bay to Stranraer, including the Isle of Man. Peterborough: Joint Nature Conservation Committee.*

Fedak, M. & Anderson, S. (1982). The energetics of lactation: accurate measurements from a large wild mammal, the grey seal (Halichoerus grypus). *Journal of Zoology*, 198(4), pp.473–479.

Fox, J., Weisberg, S. (2019). An R Companion to Applied Regression, Third edition. Sage, Thousand Oaks CA. https://socialsciences.mcmaster.ca/jfox/Books/Companion/

Gadzhiev, A., Petherbridge, G., Sharshov, K., Sobolev, I., Alekseev, A., Gulyaeva, M., Litvinov, K., Boltunov, I., Teymurov, A., Zhigalin, A. & Daudova, M. (2024). Pinnipeds and avian influenza: a global timeline and review of research on the impact of highly pathogenic avian influenza on pinniped populations with particular reference to the endangered Caspian seal (*Pusa caspica*). *Frontiers in Cellular and Infection Microbiology*, 14, pp.1325977.

Gücü, A.C., Gücü, G. & Orek, H. (2004). Habitat use and preliminary demographic evaluation of the critically endangered Mediterranean monk seal (*Monachus monachus*) in the Cilician Basin (Eastern Mediterranean). *Biological Conservation*, 116(3), 417–431.

Hall, A.J., McConnell, B.J. & Barker, R.J. (2001). Factors affecting first-year survival in grey seals and their implications for life history strategy. *Journal of Animal Ecology*, 70(1), pp.138–149.

Hazen, E.L., Abrahms, B., Brodie, S., Carroll, G., Jacox, M.G., Savoca, M.S., Scales, K.L., Sydeman, W.J. & Bograd, S.J. (2019). Marine top predators as climate and ecosystem sentinels. *Frontiers in Ecology and the Environment*, *17*(10), pp.565-574.

HELCOM (2023) Population trends and abundance of seals. HELCOM core indicator report. Online. [11/11/2025], [https://indicators.helcom.fi/wp-content/uploads/2023/04/Population-trends-and-abundance-of-seals-Harbour-seals_Final_April_2023-1.pdf]

Hewer, H.R. (1964). The determination of age in the grey seal (Halichoerus grypus), sexual maturity, longevity, and a life-table. *Journal of Zoology*, 142(4), pp.593–623.

Hiby, L., Duck, C., Thompson, D., Hall, A. & Harwood, J. (2007). Using photo-identification to estimate the size of a grey seal population. *Journal of Applied Ecology*, 44(2), 425–436.

Hiby, L., Paterson, W. D., Redman, P., Watkins, J., Twiss, S. D., & Pomeroy, P. (2013). Analysis of photo-id data allowing for missed matches and individuals identified from opposite sides. *Methods in Ecology and Evolution*, 4(3), pp.252-259.

Hollings, T., Burgman, M., van Andel, M., Gilbert, M., Robinson, T. & Robinson, A. (2018). How do you find the green sheep? A critical review of the use of remotely sensed imagery to detect and count animals. *Methods in Ecology and Evolution*, *9*(4), pp.881-892.

Howe, L. & Parsons, M. (2017). Isle of Man Seal Survey 2017. *Isle of Man: Manx Wildlife Trust.*

Iverson, S.J., Bowen, W.D., Boness, D.J. & Oftedal, O.T. (1993). The effect of maternal size and milk energy output on pup growth in grey seals (Halichoerus grypus). *Physiological Zoology*, *66*(1), pp.61-88.

Kellenberger, B., Marcos, D. & Tuia, D. (2018). Detecting mammals in UAV images: Best practices to address a substantially imbalanced dataset with deep learning. *Remote sensing of environment*, *216*, pp.139-153.

Koivuniemi, M., Auttila, M., Niemi, M., Levänen, R. & Kunnasranta, M. (2019). Photo-identification of Saimaa ringed seals (*Pusa hispida saimensis*) using camera traps: a non-invasive method for monitoring individuals. *Endangered Species Research*, 38, 237–246.

Kovacs, K. M., & Lavigne, D. M. (1986). Growth of grey seal (Halichoerus grypus) neonates: differential maternal investment in the sexes. *Canadian Journal of Zoology*, 64(9), pp.1937-1943.

Leenhardt, P., Low, N., Pascal, N., Micheli, F. & Claudet, J. (2015). The role of marine protected areas in providing ecosystem services. *Aquatic Functional Biodiversity*, pp. 211-239.

Marine Nature Reserves (2023) Isle of Man Government Website. Available at: https://www.gov.im/MNR (Accessed: 26 November 2025).

Noren, S.R., Boness, D.J., Iverson, S.J., McMillan, J. & Bowen, W.D. (2008). Body condition at weaning affects the duration of the postweaning fast in grey seal pups (Halichoerus grypus). *Physiological and Biochemical Zoology*, 81(3), pp.269–277.

Pomeroy, P., Anderson, S., Twiss, S., & Mcconnell, B. (1994). Dispersion and site fidelity of breeding female grey seals (Halichoerus grypus) on North Rona, Scotland. *Journal of Zoology*, 233, pp.429–447.

Pomeroy, P.P., Fedak, M.A., Rothery, P. & Anderson, S. (1999). Consequences of maternal size for reproductive expenditure and pupping success of grey seals at North Rona Scotland. J*ournal of Animal Ecology*, 68(2), pp.235–253.

Pomeroy, P.P., Twiss, S.D. & Redman, P. (2000), Philopatry, site fidelity and local kin associations within grey seal breeding colonies. *Ethology*, 106, pp.899-919.

Quaggiotto, M. M., Barton, P. S., Morris, C. D., Moss, S. E., Pomeroy, P. P., McCafferty, D. J., & Bailey, D. M. (2018). Seal carrion is a predictable resource for coastal ecosystems. *Acta oecologica*, 88, 41- 51.

R Core Team (2023). R: A Language and Environment for Statistical Computing_. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org

Radford, P. J., Summers, C. F., & Young, K. M. (1978). A statistical procedure for estimating grey seal pup production from a single census. *Mammal review*, 8(1-2), pp.35-42.

Rojo, I., Anadón, J.D. & García-Charton, J.A. (2021). Exceptionally high but still growing predatory reef fish biomass after 23 years of protection in a Marine Protected Area. *PLOS ONE*, 16(2): e0246335.

Russell, D.J.F., McConnell, B., Thompson, D., Duck, C., Morris, C., Harwood, J. & Matthiopoulos, J. (2013), Uncovering the links between foraging and breeding regions in a highly mobile mammal. *Journal of Applied Ecology*, 50, pp.499-509.

Russell, D. J. F., Morris, C. D., Duck, C. D., Thompson, D., & Hiby, L. (2019). Monitoring long-term changes in UK grey seal pup production. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 29(S1), pp.24–39.

Sayer, S, Allen, R., Hawkes, L.A., Hockley, K., Jarvis, D. & Witt, M.J. (2019). Pinnipeds, people, and photo identification: the implications of grey seal movements for effective management of the species. *Journal of the Marine Biological Association of the United Kingdom*, 99(5), pp.1221–1230.

Stone, E., Gell, F. G., & Hanley, L. (2013). Marine Mammals - Seals. In L. J. Hanley, F. G. Gell, K. Kennington, E. Stone, E. Rowan, P. McEvoy, M. Brew, K. Milne, L. Charter, M. Gallagher, K. Hemsley, & P. F. Duncan (Eds.), Manx Marine Environmental Assessment. *Isle of Man Marine Plan* (p. 19). Isle of Man Government.

Thomas, L., Russell, D.J., Duck, C.D., Morris, C.D., Lonergan, M., Empacher, F., Thompson, D. & Harwood, J. (2019). Modelling the population size and dynamics of the British grey seal. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *29*, pp.6-23.

Thompson, D. (2024). Census of grey seals (Halichoerus grypus) around the Southwest England Seal Monitoring Unit by aerial survey during August 2023. *JNCC Report 778 (Survey Report*). JNCC, Aberdeen, ISSN 0963-8091.

Twiss, S.D., Caudron, A., Pomeroy, P.P., Thomas, C.J. & Mills, J.P. (2000). Fine-scale topographical correlates of behavioural investment in offspring by female grey seals, *Halichoerus grypus. Animal Behaviou*r.

Twiss, S.D., Thomas, C.J. & Pomeroy, P.P. (2001). Topographic spatial characterisation of grey seal Halichoerus grypus breeding habitat at a sub-seal size spatial grain. *Ecography*, 24(3), pp.257–266.

van Meurs, R., Brasseur, S., Kirkwood, R. & van der Wal, J.T. (2024). Time-lapse camera monitoring reveals temporal patterns in seal haul-out behaviour at coastal sites. *Diversity*, 16(1), 45.

Vincent, C., Meynier, L. & Ridoux, V. (2001). Photo-identification in grey seals: Legibility and stability of natural markings. *Mammalia*, 65(3), pp.363-372.

Weitzman, J., den Heyer, C., & Bowen, D. W. (2017). Factors influencing and consequences of breeding dispersal and habitat choice in female grey seals (Halichoerus grypus) on Sable Island, Nova Scotia. *Oecologia*, 183(2),pp.367–378.

Westcott, S. M., & Stringell, T. B. (2003). Grey seal pup production for North Wales, 2002. *Marine Monitoring Report No: 5*

Wickham, H. (2016). ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York. https://ggplot2.tidyverse.org

Wickham, H., François, R., Henry, L., Müller, K., Vaughan, D. (2023). dplyr: A Grammar of Data Manipulation_. R package version 1.1.4, https://CRAN.R-project.org/package=dplyr

Wickham H, Vaughan D, Girlich M (2024). _tidyr: Tidy Messy Data_. R package version 1.3.1, https://CRAN.R-project.org/package=tidyr

Wilkie, N. and Zbijewska, S. (2019). Grey Seal Breeding Census Skomer Island 2019. *The Wildlife Trust of South and West Wales: NRW Evidence Report 399.*

Appendix

Appendix A - Developmental stages of grey seal pups

Stage	Age	Characteristics	
Stage 1	0-2 days	Thin baggy-skinned body Yellow stained or white natal fur Conspicuous umbilical cord Docile & poorly coordinated	
Stage 2	3-7 days	Smoother bodyline, few loose folds Neck still distinguishable Umbilical cord atrophied Aware & coordinated	
Stage 3	7-15 days	Rounded or barrel shaped body Neck thickened/indistinguishable Partial moulting from head or flippers May be aggressive on approach	
Stage 4	16-20 days	Rounded body Partial moulting from torso Head & flippers moulted May be aggressive on approach	
Stage 5	18-25+ days	Fully moulted to short fur coat (< 100cm^2 natal coat remaining) May be aggressive on approach