Manx Wildlife Trust
Treisht Bea-Feie Vannin

Calf of Man Seal Survey

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Mollie Kirk and Breeshey Harkin

Dr Lara Howe

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Summary

The annual grey seal pupping survey took place on the Calf of Man from 9th September to the 3rd November 2020. The seal breeding sites were monitored on a two-day rotation, surveying the north-west and south-east sides of the island alternatively. Monitoring included photographing the adult seals for individual identification, recording the first sightings of the pups and tracking their subsequent development through to weaning. The photographs of the adult seals were compared to the existing catalogues for males and females, with any new seals added to the catalogue for future reference. This allowed assessment of the level of site fidelity shown by the females returning to the Calf of Man to give birth, as well as the males returning to specific territories to maximise mating opportunities. 46 females were identified as returning seals, with catalogue histories ranging from 2 – 12 years. 35 of these females gave birth to a pup this season. In addition, 91 females were added to the catalogue, 13 of whom gave birth this season. Identification of returning males was more challenging due to the lower stability of their pelage markings over time, however, 5 were identified from the existing catalogue, with 9 added as newly identified seals.

62 pups were recorded on the Calf this season, although this number may be a slight underestimate due to the possibility of additional pupping sites not visible from the land. 22 of these pups were tracked through to weaning; their photographs have been added to the identification catalogue to facilitate future recognition of natal philopatry. Of the seal pups that were not monitored through to the final stage of development, some may have moved location however others may have deceased in the poor weather that was experienced in late October and early November, particularly on the south side of the island. Mortality was confirmed in 6 pups, the majority of which appeared to be stillborn or less than two days old. Allo-suckling was identified at one site during the season, highlighting the need for greater understanding of this behaviour.

Investigation of the use of remote camera technology for future data collection was trialled at three pupping sites; a method that would further reduce the impact of human disturbance on the seals. Time-lapse was found to be a more successful method than motion sensor photography, however further trials are needed to confirm its utility for monitoring sites that are more challenging to access. The continuation of visits to the Calf by the public through September and October poses another question for future discussion, with the aim of addressing how to facilitate positive interactions between visitors and the seals without causing distress and disturbance to the pregnant and lactating mothers. Possible ideas and solutions are presented. There is scope and potential to

extend the study of grey seals on the Calf and the Isle of Man, to contribute to our own understanding and management of our transient seal population as well as the wider understanding of the spatial structure and movement within the wider Irish Sea. With the increasing challenges of climate change, loss of biodiversity, disturbance of haul-out and pupping sites, and potential negative interaction with fisheries, it is vital to increase our understanding and protection of this important marine apex predator.

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Introduction

Grey seal distribution

Grey seals, *Halichoerus grypus*, are a large sexually dimorphic phocid (Bowen, 2016). There are two recognised subspecies of grey seals, the Northeast Atlantic grey seal and the Northwest Atlantic grey seal (Bowen 2016). The population sizes of both subspecies are thought to be increasing, with a worldwide population estimate of 316,000 mature individuals and a total population size of approximately 632,000, as reviewed in the 2016 IUCN Red List assessments (Bowen, 2016). Grey seals have a cold temperate to sub-Arctic distribution in the North Atlantic (Hall 2002), with three populations isolated by geography as well as timing of reproduction (Bonner 1981). The distribution of resident grey seals is shown in Figure 1, however vagrants can be found as far south as New Jersey in the western Atlantic and Portugal in the eastern Atlantic (Rice 1998).

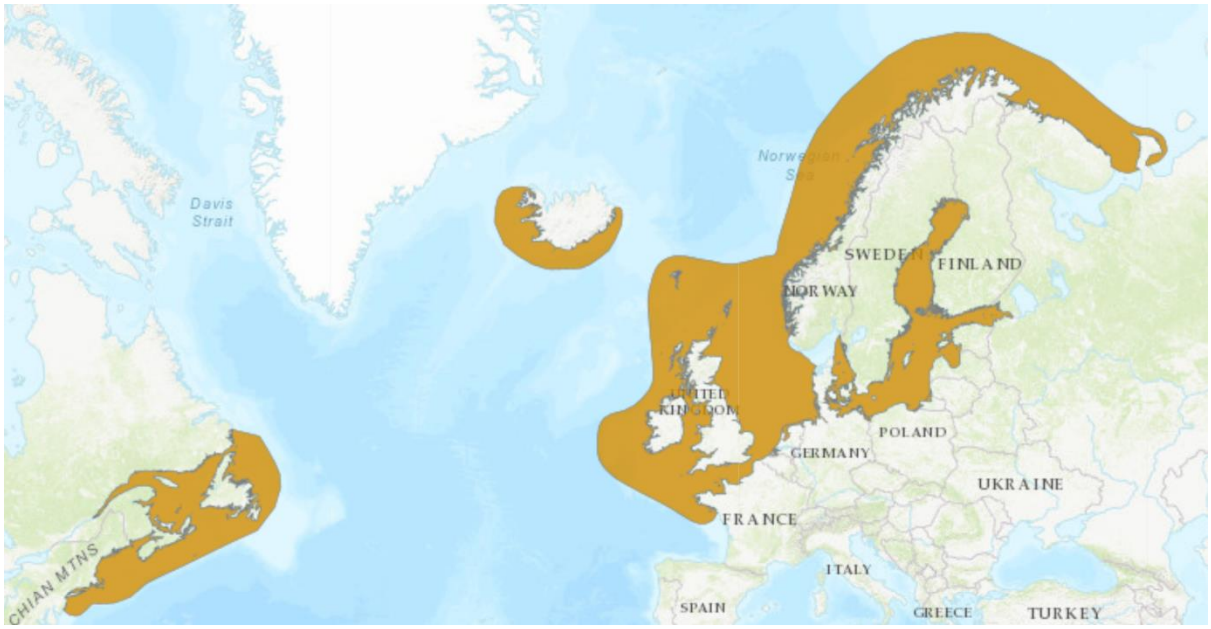

Figure 1. The geographic range of resident grey seals in the North Atlantic (Bowen, 2016).

The British Isles are home to two species of Phocidae, grey seals (*Halichoerus grypus*) and harbour seals (*Phoca vitulina*) (Figure 2). Harbour seals, also known as common seals, are the most widespread of the pinnipeds on a global scale (Lowry, 2016), however they are something of a rarity in British waters (Manx Wildlife Trust, n.d.(a)). While 34-50% of the world's grey seal population are estimated to breed around the British Isles (Kiely *et al.,* 2000; Russel *et al.,* 2019; Sayer *et al.,* 2019), in the Irish Sea, and specifically Manx waters, no harbour seal pups have been observed to survive past weaning (Stone et al., 2013). As such, grey seals have been the focus of surveys and marine

research in this part of the world. In general, marine mammals are notoriously difficult to monitor due to their pelagic and highly mobile nature (Gordon et al., 2003), however seals remain tethered to the land for periods of moulting, breeding and resting, where they 'haul out' in large colonies (Sawyer et al., 2019). These periods present a valuable opportunity to gather data on population size and fecundity that will also provide an indication of the health and sustainability of the local marine ecosystem (Kaschner et al., 2001).

Figure 2. Factsheet comparing visible differences between grey and harbour seals (Cornwall Seal Group, 2017).

Grey seals in Manx waters

The Isle of Man's rocky coastline and abundant waters provide excellent habitat for grey seals. They use coastal areas all around the island, with common haul-out sites including the Sound, Langness and Maughold (Figure 3) and are a protected species under the Isle of Man Wildlife Act 1990 (Stone *et al.,* 2013). The Calf of Man, a small islet half a mile off the southwest of the main island, has long been seen as significant for Manx seals (Duck, 1996) (Figure 4). Owned by Manx National Heritage, the Calf is one and half miles long and one mile wide, with its highest point rising 421 feet above sea level (BBC, 2008). It is a dedicated bird observatory, with two wardens and a full-time volunteer in residence from March to November, and presents an isolated habitat with a high number of grey seals consistently observed (Sharpe 2007). It is the main breeding site for grey seals on the Isle of Man and has been monitored by the Manx Wildlife Trust through an annual seal pupping survey

since 2009 (Stone et al., 2013). The surveys are carried out by two volunteers who reside on the Calf for the duration of the pupping season.

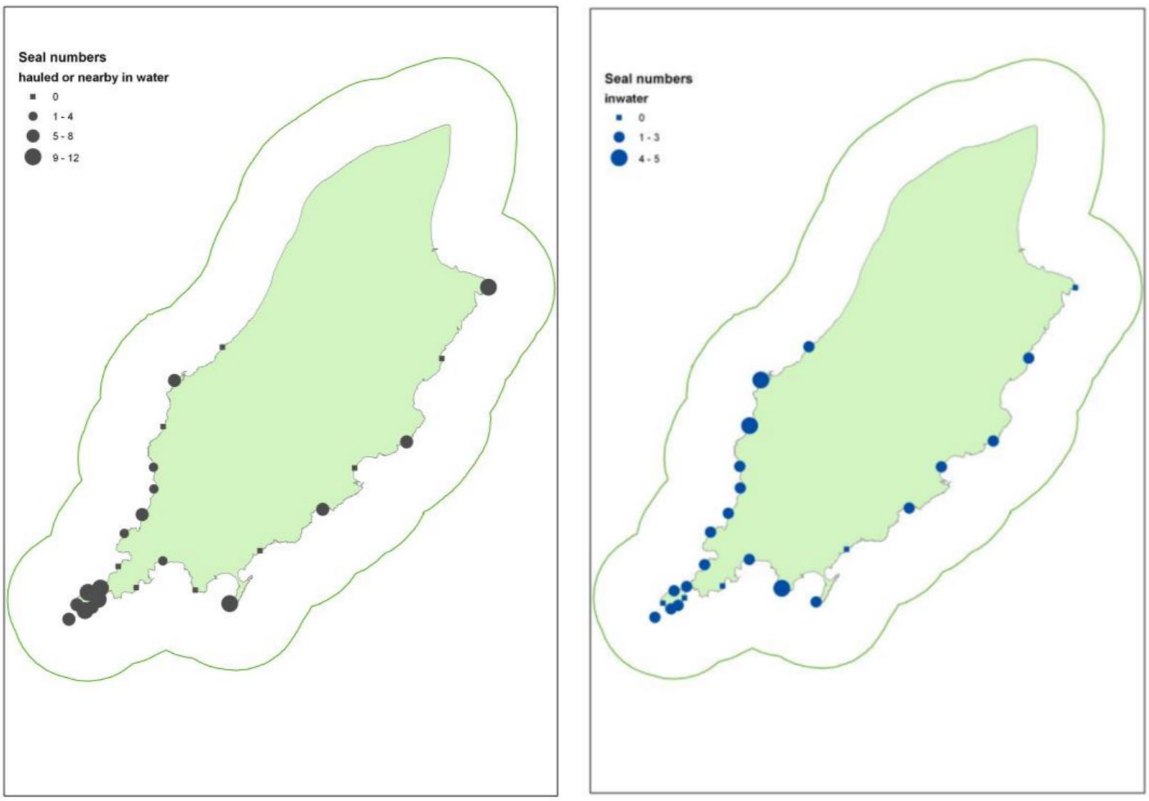

Figure 3. Maps of the Isle of Man showing the seal numbers counted during haul-out (left) and in water (right) during the 2006-2007 season (Stone et al., 2013).

The central position of the Isle of Man makes it an important staging post for seals in the Irish and Celtic seas; as well as hauling-out to give birth on land during the pupping season, seals can be observed around the Manx coastline resting between foraging trips. While the Irish Sea population is estimated to consist of between 5,198 – 6,976 individuals (Kiely *et al.,* 2000), there are no current estimates on local Manx population size, although monthly counts of individuals observed around the island range from 135 to 405 (Parsons and Howe, 2017; Stone *et al.,* 2013). Data sharing with the Cornwall Seal Group Research Trust has identified one female who moved between the Calf of Man and Cornwall from 2012—2018, successfully breeding on the Calf on four occasions (Howe, 2020). Satellite tagging has also yielded valuable insights, with a team at St Andrews tracking seals from the Dee Estuary, England moving to the Calf for breeding, and tagged seals from Strangford Lough, Ireland have also travelled to the Calf, confirming these seals are part of a dynamic system (Howe, 2020). Satellite tagging of 19 grey seals in Wales from July to December 2004 showed the

wide-ranging movements of individual seals across the Irish Sea during this period, including trips to the Isle of Man (Hammond *et al*., 2005).

Figure 4. The Calf of Man, a rocky islet found off the south west of the Isle of Man (Manx Wildlife Trust, n.d.(b)).

Grey seal biology and behaviour

Grey seals differ in size across the various populations (Bowen, 2016). In the United Kingdom, the average length of male grey seals is 2 m, compared to 1.8 m for females (Bonner, 1981). Males weigh an average of 233 kg, however this can extend to a maximum of 310 kg, while females are considerably lighter, with a mean weight of 155 kg (Bonner, 1981). Grey seals are often based at specific haul-out sites from which they make short foraging trips, feeding up to several hundred kilometres offshore for an average of 2.3 days (McConnell *et al.,* 1999), although they may occasionally move to a new haul-out site and begin foraging in a new region (Bowen, 2016).

Grey seals are generalist predators whose diet consists of a wide range of species. Studies have analysed their gut contents, both morphologically and via DNA barcoding, as well as the fatty acid profiles of their blubber and the stable isotopes of liver and muscles to learn more about seal foraging habits (Tverin *et al.,* 2019). Sampling of scats from Scotland and East England showed considerable seasonal and regional variability in prey species, with an overall preference for sandeel and large gadids (Wilson and Hammond, 2019). Ad hoc faecal analysis of seal scats on the Isle of Man has yielded a similar high proportion of various gadid species, and a post-mortem of a Manx seal in 2010 found the stomach contents to consist of two octopuses (Stone *et al.,* 2013).

Grey seals follow a distinct annual cycle throughout their life history: a winter/spring moult, followed by alternate haul-out and foraging periods, and an autumn/winter breeding season (Kiely *et al.,* 2000). Pupping dates differ between populations, ranging from September to March (Bowen, 2016). The pupping season on the Calf of Man runs from September to November, with an average of 54 annual births recorded since formal surveys began in 2009 (Manx Wildlife Trust, 2020). Female grey seals reach sexual maturity at 4 years with the first pup born at approximately 5.2 years of age (Fedak and Anderson, 1982), while male grey seals reach sexual maturity at 6 years old when their growth starts to plateau and they are capable of the aggressive displays required to gain dominance and secure mating success (Twiss, 1991).

Grey seals are colonial breeders, aggregating at specific locations to give birth to a single pup that suckles intensively for 15-21 days during which the females remain on site and do not feed (Fedak and Anderson, 1982; Pomeroy *et al.,* 1999). At the end of this period, the seal pups moult their lanugo and develop an adult-type pelage (Russell *et al.,* 2019). After weaning, the adult females return to the sea and the pups remain on land until their moult is complete, a period known as the post-weaning fast, during which they lose up to 25% of their body mass (Noren *et al.,* 2018). The duration of the post-weaning fast can vary from 9-40 days (Baylis *et al.,* 2019), before the fully moulted pups leave their site of birth and enter the sea where they must learn to forage and feed (Russell *et al.,* 2019). This capital breeding model requires the females to accumulate stores of body fat during their seven months of foraging at sea prior to giving birth, increasing their foraging efforts in the final two months (Sparling *et al.,* 2006) to accumulate the energy reserves necessary to sustain both them and their pup during the period between birth and weaning. Females lose an average of 65 kg during the period of lactation (Fedak and Anderson, 1982), thus maternal energy storage prior to pupping is of high importance to both offspring survival and female fitness (Sparling *et al.,* 2006).

On completion of weaning, the female seals mate with the male who has maintained dominance of that pupping location through repeated physical contests with rival males (Bubac et al., 2018). The most successful males tend to be larger, stronger and more experienced and have larger energy reserves allowing them to spend less time foraging (Fedak and Anderson, 1982). Following fertilisation, females will then delay implantation of the blastocyst (Turner *et al.,* 1956), which may allow them additional time to accumulate greater energy reserves for the subsequent gestation and lactation periods (Hall et al., 2001).

Pup survival and dispersal

The probability of survival within the first year of life is often low for large mammals, thus understanding this period in a seal's life history is central to our understanding of their population dynamics (Hall *et al.,* 2001). First-year mortality in grey seal pups is high, ranging from 38% for females to 80% for males at some breeding locations (Hall *et al*., 2001) and causes of death in young seals include starvation, injuries, infections and accidents (Kastelein and Wiepkeme, 1988). Pup survival is related to condition at weaning, with larger pups showing a higher rate of first-year survival (Hall *et al.,* 2001). Mass of pups at weaning can differ by more than 50% (Pomeroy *et al.,* 1999), and appears to have a greater effect on survival probabilities in males than females (Hall *et al.,* 2001).

Satellite tagging of five recently weaned pups in Iceland showed two broad strategies in their transition from nutritional dependence to independence, with some pups remaining near their birthing location, and others dispersing to locations more than 300 km away (Baylis *et al.,* 2019). 11 pups born in a German colony were also tracked for the first nine months of life. They moved widely throughout the southern North Sea, in some cases as far as Dutch or UK waters (Peschko *et al.,* 2020). Their behaviour reflected a transition from naivety to experience, with gradual increases in foraging range, effort and efficiency over time (Peschko *et al.,* 2020). It has been suggested that a seal pup's pre-weaning behaviour may influence their post-weaning dispersal, with some neonates remaining ashore throughout weaning and moulting and others developing swimming skills much earlier (Baylis *et al.,* 2019). Their condition at weaning may also be a factor here; larger pups are able to withstand a longer fasting period and achieve greater foraging dive capabilities (Bennett *et al.,* 2010).

Female site fidelity

In some parts of the world, female grey seals have been shown to display considerable site fidelity with regards to their pupping locations (Pomeroy *et al.,* 1994). Choice of pupping location may be influenced by previous reproductive success or failure, familiarity with local conditions, predictability of habitat quality and experience level of the breeding seal (Weitzman *et al.,* 2017). Returning to a known site may have various benefits including more efficient exploitation of resources, greater success in dominance interactions and escape from predation, as well as greater overall survival and reproductive success (Weitzman *et al.,* 2017). Such philopatry has been well documented at the Scottish island of North Rona, where 93% of female seals marked in 1985 returned to breed in at least one season over the next four years, and 27% of the seals were recorded as present in all five breeding seasons studied: they returned even when their previous pup had died (Pomeroy *et al.,* 1994). This high level of site fidelity has continued over time, confirmed in further studies over a decade later, and similar patterns of philopatric behaviour have been observed in female seals at the Isle of May (Pomeroy *et al.,* 2001). In addition, females born at North Rona subsequently pupped closer to their natal sites than could be expected by chance, with significant consequences for the social and genetic structure of breeding colonies (Pomeroy *et al.,* 2001).

This level of site fidelity is not, however, consistent across all grey seal pupping sites. Sable Island, Nova Scotia has an unpredictable and changing sand dune landscape, very different from the rocky gullies and fixed topography of sites such as North Rona (Weitzman *et al.,* 2017). Studies from 2004 – 2014 on Sable Island concluded that only 2.9% of females returned to a previous pupping site (Weitzman *et al.,* 2017). Weitzman *et al.* (2017) concluded that female 'identity' (unmeasured variation in individual characteristics) accounted for most of the variance in dispersal decisions, however, the degree of dispersal also depending on factors such as the physical structure of the habitat, the density of seals and the parity of the mothers. It has also been suggested that dispersing to new pupping sites may facilitate colonisation and allow full occupancy of all available breeding sites (Weitzman *et al.,* 2017).

In addition to fidelity with regards to breeding site, studies have explored potential patterns in grey seal birthdates, as well as implications for the interrelationship between these two features of life history. Marked females on North Rona gave birth on virtually the same date each year over a period from 1979 – 1989, leading to suggestions that the first females ashore may determine the pupping site locations of subsequent females (Anderson *et al.,* 1975). These early-pupping females could thus determine the distribution of the entire breeding colony (Pomeroy *et al.,* 1994). Timing

of births can also have important consequences for reproductive success and survival (Bowen *et al.,* 2020), and further research has explored changes to birth date phenology with a focus on the possible intrinsic and environmental causal factors. Over 27 years of study, the mean birthdates of grey seals on Sable Island advanced by 15 days, although individual births within a season could occur over a period of as much as 45 days (Bowen *et al.,* 2020). This shift in birthdate was largely attributed to the random effect of female identity and, to a lesser extent, parity, with inexperienced mothers giving birth later in the season; however, there was also an effect of climate forcing by changing trends in atmospheric circulations[1] (Bowen *et al.,* 2020).

Male site fidelity

Although previously described as territorial, male grey seals are also thought to hold spatial occupancies. Unlike their polar counterparts, the Northern and Antarctic fur seals, male grey seals dominate groups of females rather than a specific geographic location (Twiss et al., 1994), and their aggressive displays are to defend groups or individual females rather than a specific location or territory (Twiss, 1991). The daily locations of socially active males were recorded over three breeding seasons at North Rona, where researchers were able to define areas of occupancy for 38 individual males (Twiss *et al.,* 1994). These males showed high site fidelity that was not shown to be related to individual mating success dominance, arrival date or length of stay (Twiss *et al.,* 1994), and male philopatry was also observed in grey seal colonies at the Isle of May (Pomeroy *et al.,* 2001). High site fidelity suggests that individual recognition of potential rival males as well as potential mates may be possible and, combined with trends in female site fidelity, gives the potential for full sibling offspring in successive breeding seasons (Twiss *et al.,* 1994).

Photo identification of grey seals

Grey seals have been studied on an individual level using various methods of identification and tracking, including tagging, branding, use of paint dyes and satellite telemetry (Walker *et al.,* 2012). Such studies can provide information on many aspects of seal biology and behaviour, from distribution and abundance, to movement, habitat use and life history; although many of these methods are limited by their duration, expense, or invasiveness (Sayer *et al.,* 2019). Photo-identification, however, is a 'powerful and cost-effective method' (Kiely *et al.,* 2000, 35) which is minimally invasive and can support studies of individuals over their lifetime (Sayer *et al.,* 2019).

[1] Namely the Atlantic Multidecal Oscillation (AMO) and the North Atlantic Oscillation (NAO).

Grey seals are a suitable species for photo-identification studies due to both their life history and physical appearance. They are relatively long-lived, sometimes more than 35 years (Pomeroy et al., 1999), are large and conspicuous, particularly when hauled-out of the water, and have unique patterns and scars on their pelage which remain visible and stable throughout their lives (Sayer *et al.,* 2019). The patterns on the pelage tends to darken with age, particularly in the first year of life, which serves to reinforce their legibility in females (Vincent *et al.,* 2001) (Figure 5). However, this darkening process can result in the already darker males becoming increasingly difficult to distinguish over time (Vincent *et al.,* 2001), potentially restricting the use of photo-identification in male grey seals (Figure 6). Further, scars obtained from fighting with conspecifics may sometimes aid identification but may also change or be added to over time, again presenting a challenge to consistency (Paterson *et al.,* 2013).

Figure 5. Unique pelage markings on female grey seals remain stable over time and allow for individual photo-identification (Manx Wildlife Trust, 2020).

Figure 6. The pelage of males is darker and darkens with age, making it challenging to identify individuals, although scarring may be useful if the markings remain consistent over time (Manx Wildlife Trust, 2020).

Data collection for photo-identification ideally consists of a context photograph to show location, followed by photographs of individuals seals from a variety of angles (Sayer *et al.,* 2019). Sayer *et al.* (2019) suggest that for quality control purposes, photographs that are distant or blurred must be discarded, and the processing and compilation of a photo-identification catalogue should be carried out by a single database coordinator. They recommend the use of key word description of dominant patterns and the inclusion of photographs from a variety of angles and conditions (e.g. wet, dry, moulting). Positive identification from the catalogue occurs when at least five patterns can be matched in their relative positions by the catalogue coordinator and confirmed by at least one trained and experienced moderator (Sayer *et al.,* 2019).

Other methods of photo-identification include the use of a defined rectangle on the seal's head which is converted to a black and white 'mask' depending on the pattern and percentage of black pixilation in the image; a technique which was shown to generate a greater number of correct matches compared to straightforward inspection of photographs when trialled on untrained volunteers at a North Wales field site (Beaumont and Goold, 2007). Some organisations are beginning to utilise computer-aided identification technology, such as Extract Compare Software (Sayer *et al.,* 2019) or purpose-written image-processing software, such as in the estimation of the Baltic grey seal population of over 15,000 individuals using six years of photographs (Hiby *et al.,* 2007).

An additional advantage of photo-identification is the potential for contribution by non-specialist photographers, so-called 'citizen science' (Sayer *et al.,* 2019). Public involvement in conservation programmes can be a 'powerful tool' for tackling the challenges of conservation (McKinley *et al.,* 2017, 15), increasing environmental education, promoting public advocacy, action and environmental stewardship, and, ultimately, informing policy (Silvertown *et al.,* 2013). Concerns have been raised regarding the accuracy of citizen-collected data (Aceves-Bueno *et al.,* 2017; McKinley *et al.,* 2017), however careful matching of the type of project and type of public participation can provide high-quality data (McKinley *et al.,* 2017). With effective instruction and the ease of digital photograph sharing, people can engage with and contribute to photo-identification catalogue development, increasing the number of seals recorded as well as the angles and situations in which they are photographed (i.e. land- and boat-based).

Recent research has explored the possibilities of remote camera technology as another minimally invasive method of studying grey seals, removing the disturbance bias of in-person recording and allowing for continuous data collection when human observers cannot be present (Heaney, 2018).

Heaney (2018) trialled the use of automated time-lapse cameras at a location in Cornwall to study seasonal patterns of haul-out behaviour, the influence of environmental conditions on haul-out, counts of pups during the breeding season and the effects on human disturbance. It was concluded that camera trap technology can provide a viable method for the collection of fine-scale data on a continuous time series in relation to grey seal behaviour and ecology (Heaney, 2018).

Disturbance events and impacts

Anthropogenic disturbance of grey seals can take numerous forms and may have long-term impacts that are not visible or anticipated during the disturbance event itself. Seals are at greatest risk of disturbance when hauled-out, a pinniped behaviour used for resting, warming up, moulting, breeding and lactating (Heaney, 2018). Under the Manx Wildlife Act 1990, seals are protected from being killed, injured or taken, as well as any action that may damage, or destroy areas they occupy for shelter or protection (Stone *et al.,* 2013). This includes any disturbance to seals when they are using such a location (Stone *et al.,* 2013); a key aspect of the Act when considering how best to protect this species. Seals are also listed under Appendix III of the Bern Convention 1979, adhered to by the Isle of Man via their relationship with the United Kingdom, thus strengthening the need for conservation of grey seals and their habitats with regards to planning and development, pollution, and education (Stone *et al.,* 2013). Special Areas of Conservation have been established in English and Irish waters with grey seals as a feature, as well as in Northwest France, and in some areas such as Cornwall, seals gain additional protection within designated Sites of Special Scientific Interest (Sayer *et al.,* 2019).

Disturbance, bycatch and entanglement are three of the main negative impacts of human activity on seals (Sayer *et al.,* 2019). The foremost threat to seals in and around the Isle of Man is disturbance, primarily at haul-out and pupping sites (Stone *et al.,* 2013). Disturbance can stem from people walking, aircraft (including drones), unaccompanied dogs, boats, kayaks and jet skis, and can lead to displacement, stampedes, flushing, increased vigilance, reduced food provisioning and abandonment of young, with potential implications on foraging and breeding success, reproductive rates and activity patterns in general (Heaney, 2018). A study in Cornwall recorded flushing disturbances of seals on 39% of days during data collection (Heaney, 2018) and, at a site in North Lincolnshire, female seals gave birth later in the season in areas of higher disturbance, resulting in a shorter lactation period with potential negative impacts on pup growth rates (Lidgard, 1996).

A study of seal disturbance was carried out from The Sound on the Isle of Man, observing seals hauled out on Kitterland, a small island, with significant disturbance observed on 57% of study days, primarily due to recreational boat use (Peters, 2007). Various governmental and charitable organisations subsequently worked to raise awareness of this issue, with safe boat operation courses facilitated by the Department of Agriculture, Fisheries and Forestry in 2006, 2008 and 2009 (Stone *et al.,* 2013), and WiSE courses in 2018 (the UK's national training scheme for minimising disturbance to marine wildlife). Police warnings were issued following reports of further disturbance on Kitterland in October 2010 (BBC, 2010), and a study around the Isle of Man in 2011-2012 confirmed the need for stricter enforcement to protect seals from the effects of disturbance (Britton, 2012). Disturbance specific to the Calf of Man may also stem from recreational water use by boats and kayaks, as well as fishing, walking and the everyday activities of the wardens and food supply boat.

Recent research on the impact of disturbance events on organisms has started to explore the effects of individual differences in the personality, temperament, behavioural types and coping styles of organisms, as well as their adaptive value and fitness consequences (Shuert *et al.,* 2019; Twiss *et al.,* 2012; Twiss *et al.,* 2020). It is possible to differentiate between the stress-coping styles of individuals in a range of mammal species, defined along the pro-reactive axis. Proactive individuals are less responsive to environmental stimuli and show reduced behavioural flexibility, however reactive individuals are more flexible and more responsive to stimuli (Twiss *et al.,* 2020). A novel auditory stimulus was given to nursing female seals to elicit changes in their pup-checking behaviour; the extent to which individual females changed their rates of pup checking in disturbed and undisturbed conditions varied from proactive females who showed little change, to reactive females who increased their vigilance markedly (Twiss *et al.,* 2012). These reactive mothers were also shown to have more variation in their daily mass loss during weaning, resulting in more varied growth rates of their pups (Twiss *et al.,* 2012). This was confirmed in further studies that used resting heart rate variability to differentiate between the stress-coping styles of the individual female seals, with reactive mothers again showing more variable reproductive outcomes (Twiss *et al.,* 2020).

Context and applications of data collection

The 2016 IUCN Red List assessment of the global grey seal population categorised grey seals as a species of 'least concern', with an upwards trend in population growth thanks to the protective measures invoked by many countries to limit seal harvest, culls, disturbance and by-catch, as well as

regulations that have stopped or reduced the use and discharge of toxic pollutants (Bowen, 2016). Nonetheless, grey seals continue to face numerous threats that pose a significant challenge to their current population status. From fishing and harvesting of aquatic resources, to effluent pollution from industry, agriculture, forestry and military activities, as well as habitat shifting and alteration as a result of climate change and severe weather (Bowen, 2016); it is vital that we continue to monitor and protect this charismatic species. Levels of persistent organic pollutants (POPs), such as DDT, remain high in blubber sampled from Scottish seal pups, with resulting risks for energy balance, endocrine status and immune function (Robinson *et al.,* 2019), and additional endocrine disrupting compounds (EDCs) were found to be accumulating through the diet of grey seals in the south Baltic (Nehring *et al.,* 2017). Microplastics are another area of increasing concern, with evidence of these particles in the digestive systems of every seal sampled in southern Ireland (Hernandez-Milan *et al.,* 2019), around the British coast (Nelms *et al.,* 2019) and the German North Sea and Baltic Sea (Philipp *et al.,* 2020). For such reasons, the IUCN[2] recommends the continued management of land, water and sites utilised by grey seals, as well as the need for ongoing assessment of population trends (Bowen, 2016).

The British Isles are a vital location with regards to grey seal ecology and behaviour, with a resident population making up approximately 40% of the world's grey seals (Russell *et al.,* 2019), as well as evidence that around 50% of the world's population breeds in these waters (Kiely *et al.,* 2000). As such, there can be no doubt we have a key role to play in conservation and research (Sayer *et al.,* 2019). Effective management of a species is 'dependent on knowledge of its abundance and trends therein' (Russell *et al.,* 2019, 25); knowledge that has been amassed on an annual basis on the Calf of Man since 2009, as well as in wider scale reports such as for the government's Manx Marine Environmental Assessment. These studies provide vital information regarding seal sightings, pupping numbers and individual seal identification as well as suggesting numerous areas for future consideration. In respect to a vulnerable migratory species such as the grey seal which represents a 'natural heritage asset' that must be preserved (Sayer *et al.,* 2019, 1221), we must continue to develop our knowledge to inform marine spatial planning and effective species management, and to maintain a harmonious relationship with fisheries, tourism and recreational activities. Marine vertebrates can act as important indicators of change in marine environments (Heaney, 2018), and grey seals play a vital role in maintaining the structure of the marine community and serving as

[2] The International Union for the Conservation of Nature is a union of governmental and non-governmental organisations and is considered the global authority on the status and safeguarding of the natural world (IUCN, 2021).

indicators of biodiversity and ecosystem health (Kiely et al., 2000). As such, annual reports such as this may become ever more relevant in the context of the Island's UNESCO Biosphere status and projects such as the proposed Climate Change Bill.

Aims and objectives of this report

This study collected data over a two-month period on the Calf of Man, from 9th September – 3rd November 2020. The primary focus of the data collection was the monitoring and recording of the seal pups born at locations visible from the land, providing a total count for the seal pups born on the Calf of Man this season. In addition, the adult seals were photographed with the aim of using the existing Manx Wildlife Trust grey seal catalogue to attempt photo-identification of returning males and females. The total number of seals counted each day at the sites visited was recorded, as well as a whole-island count carried out twice over the duration of the survey. These data allow continued monitoring of the Calf of Man seal population which can be analysed in the context of annual records dating back to 2009. The implications of this comparative data as well as the current season's findings are discussed in the following sections.

Additional review of the Manx Wildlife Trust's photo-identification catalogue was carried out to allow for more user-friendly comparison of photographs. Any inaccuracies or duplications were corrected, and any incomplete records were updated where possible. Seals that were photographed and did not match any images in the catalogue were added as 'new seals' and assigned a number and a catalogue folder. An additional catalogue folder was created for recording the seal pups that were monitored to a sufficiently late stage in their development such that they had moulted to reveal their adult pelage markings. This was created with the aim of future identification of any of these pups that may return to the Calf of Man. Camera traps were trialled in several locations to carry out preliminary investigations as to their utility as a non-invasive method for future data collection.

Materials and methods

Fieldwork

The data collection was carried out on the Calf of Man from 9th September to 3rd November by volunteers Mollie Kirk and Breeshey Harkin, with guidance from returning volunteer Mike Prior and Manx Wildlife Trust Marine Officer Dr Lara Howe during the first week of the survey. Previous seal breeding surveys have identified the 12 sites utilised for pupping by grey seals on the Calf that are visible from the land, located in areas with suitable haul-out platforms (Figure 7). These sites are described in detail in Table 1. Six sites were visited on foot each day, ensuring all sites were monitored on a two-day rotation. This allowed for adequate tracking of the seal pups whilst minimising the level of disturbance from human presence at the pupping sites. All seals and pups present at a site, whether hauled-out or in the water, were counted at each visit and, on two occasions (10/09/2020 and 10/11/2020), a whole-island count of the adult seals was carried out by the seal volunteers and the Estate Warden.

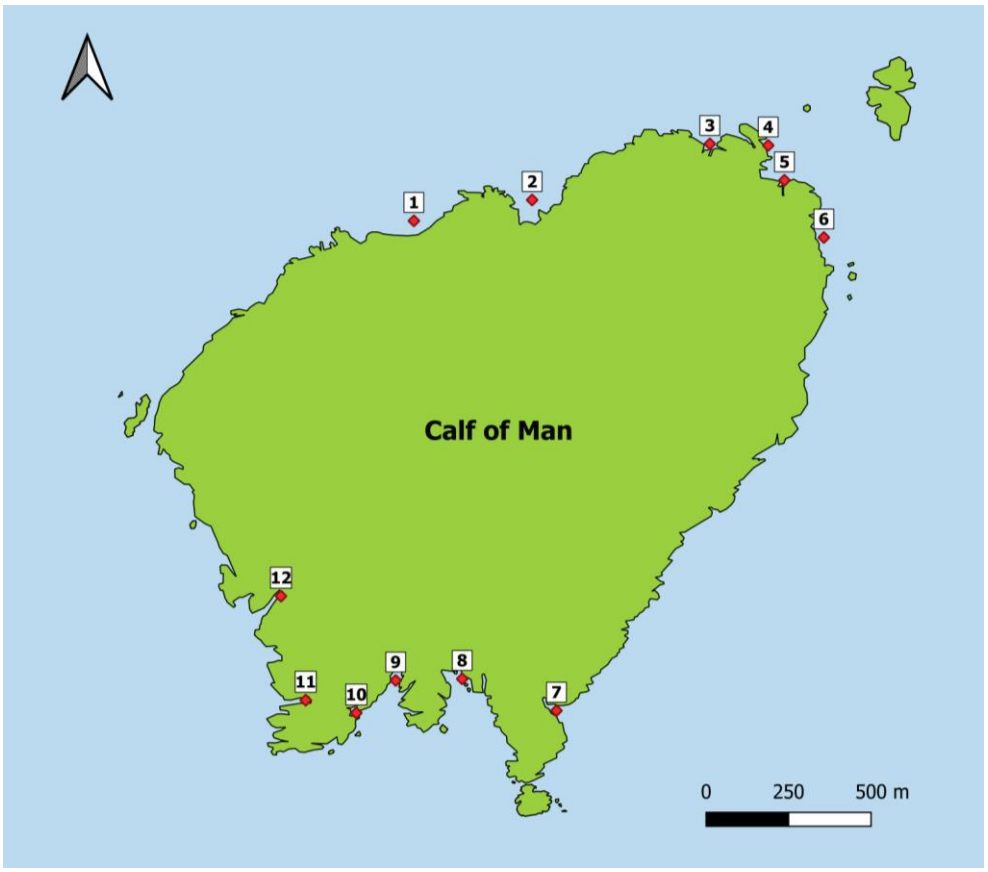

Figure 7. Map showing location of the 12 grey seal pupping sites identified on the Calf of Man produced using QGIS software. Names and descriptions of the sites can be found in Table 1 below.

Site number	Site name	Approx. area (m^2)	Description of site
1	Baie Fine	10,222	Wide and narrow section of exposed shore with steep cliffs. Large boulders create shelter and haul-out sites. Large cave on east of site. Limited visibility from land at a considerable distance from sea level.
2	Gibbdale Bay	7,022	Wide, sheltered bay with steep surrounding cliffs and large outcrops of rock from the water. The west has a long, sheltered, steep inlet. Much of the haul-out space is reduced at high tide.
3	West of Cow	3,216	A series of steep-sided inlets sheltered by a rocky outcrop. Very little haul-out area.
4	Cow Harbour	21,029	West side consists of a series of flat rocky outcrops sheltering a slipway and a disused boathouse. To the east are two large, flat pebble bays. There is a small cave at the back of the east bay. Slipway is used irregularly throughout the year for landings.
5	Grants' Harbour	2,319	Small, concrete harbour wall on the east of the harbour with a small haul-out space. Three naturally formed gulleys to the west with smaller haul-out areas. Very sheltered areas. Harbour wall is used irregularly throughout the year for landings.
6	The Cletts	13,836	Wide sheltered area of flat bedrock with a series of inlets and one large, sheltered inlet at eastern edge. Rocky outcrops in the water provide haul-out space at low tide.
7	South Harbour	21,821	Wide, open, sheltered bay. Concrete jetty running through the centre, with large, gentle sloping boulder field and pebble beach surrounding it. Haul-out space available at high tide. The sheltered jetty is regularly used to land visitors and cargo throughout year.
8	The Puddle	21,103	Three small bays/inlets with gentle sloping pebble beaches with steep headland and rocky outcrops between, varying in exposure. Large areas of beach exposed at low tide. Occasionally used by kayakers for landing or for fishing off perimeter rocks.
9	Mill Giau	9,632	Access gully to the sea consisting of sloping grassland intersected by a small river mouth. Grassland contains several freshwater pools, then runs down to pebble beach with steep cliff edges. Considerable haul-out space on grass and beach at high tide.
10	Leodan	7,861	Small inlet with pebble beach sheltered by an outcrop of headland. Some beach remains for haul-out at high tide.
11	Smugglers' Cave	2,111	Deep gully ending in two caves. Little rock is exposed at high tide except within the caves and a small ledge on the south side of the bay. Visibility into caves is very poor.
12	Ghaw Lang	8,352	Deep gully with large boulders, and steep cliff edges creating an exposed haul-out. Haul-out area greatly reduced at high tide and gully can be exposed and turbulent during storms with an onshore wind.

Table 1. Description of the 12 seal pupping sites visible from the land on the Calf of Man.

Photographs of all pups and mothers were taken during each site visit, as well as any other adults with sufficient pelage exposure for potential photo-identification. All photographs were taken with a Canon EOS 70D DSLR camera fitted with a 70-300mm 1:4-5.6 lens at an optimum distance of 50 metres from the seals, although this was not always practical due to the nature of site or the location of the seals. Wherever possible, photographs were taken of both sides of a seal's head, ideally with wet pelage to expose the fur patterns more clearly. Any scars or identifying marks were also photographed, and each pup was photographed to assess its stage of development. Any relevant behaviours, such as suckling, were photographed to allow for confirmation of filial relationships. Conspecific fights between male seals were photographed or filmed, and the birth of one seal pup was filmed at Mill Giau. Allo-suckling behaviour was observed at another site, The Puddle, and photographed in detail. On occasions when insufficient data was collected during the initial site visit, a return visit was carried out later that day, sometimes requiring the surveyor to sit out-of-sight for a few hours until the necessary photographs could be taken of the required seal or behaviour.

Pup developmental stages

The photographs of the pups were assessed using a system of classification into five stages, which can be related to pup age (Kovacs and Lavigne, 1986; Radford *et al.,* 1978; Russell *et al.,* 2019). Detailed descriptions and photographs of these developmental stages can be found in Appendix A. The first three stages consist of pups in their lanugo, defined by their changing body shape over these first 15 days of life. Stages four and five are characterised by the moulting of this natal coat, to be fully replaced by their adult pelage at the end of stage five. Use of these developmental stages allowed for tracking of the growth of the seal pups, all of whom were named using a single letter of the alphabet (the letter 'V') as per the ongoing system on the Calf of Man.

Photo-identification

Photographs of adult seals taken at the pupping sites were compared with a catalogue of individuals recorded previously on the Calf of Man, consisting of some 296 females and 45 males. There was a particular focus on identifying this season's breeding females who were photographed with pups, allowing for continued analysis of the levels of site fidelity shown by returning females. Males were also photographed with the aim of identifying individuals returning to specific territories as compared to previous seasons and surveys. Seals that were photographed and did not match any images in the catalogue were added as 'new seals' and assigned a number and a catalogue folder,

establishing a record of their individualised pelage patterns and any marks such as scarring, and noting the dates and locations in which they were observed.

Catalogue reviews

Additional review of the Manx Wildlife Trust's photo-identification catalogue was carried out with the aim of selecting the most useful photographs and compiling them into a shortened catalogue, separated into the left and right sides of the seals, allowing for more user-friendly comparison of photographs. Seals that had been previously misidentified or catalogued more than once were corrected, and any seals in the 'near miss'[3] section of the catalogue were moved into the master catalogue if their photograph records were now deemed sufficiently complete. An additional catalogue folder was created for recording the seal pups that were monitored to a sufficiently late stage in their development such that they had moulted to reveal their adult pelage markings. This was created with the aim of future identification of any of these pups that may return to the Calf of Man, thus allowing for recognition of natal philopatry.

Review of previous survey data

Some preliminary analysis was also undertaken of the data collected on the Calf of Man from 2009 – 2019. This data comprises the following:

1. Total number of seal pups born during the survey
2. Daily number of adult seals counted at each pupping location during the survey
3. Birth date of the seal pups (or the first sighting which is usually within 1-2 days from birth)
4. Progress of the seal pups through the five developmental stages
5. Records of identified pup mortality
6. Photo-identification of the female seals and their chosen pupping location
7. Photo-identification of the male seals and their location

There is considerable scope for continued analysis of this data set, however, initial focus was on the pupping locations of the females to create a predictive data set based on site fidelity trends. A spreadsheet was constructed using a numerical code for each pupping site matched to the relevant

[3] Referred to as the 'Left Right Nearly' section of the identification catalogue, this consists of photographs of seals that are of poor quality or that contain one side of their pelage only, making re-identification challenging.

females. This allowed prediction of the most likely photographic records within the catalogue that would yield a match if that female were a returning seal, potentially speeding up the process of photo-identification.

Camera trap preliminary trials

Remote camera technology was trialled at three sites to investigate its use for future seal monitoring. The camera traps were set up before or during the occupation of the sites by breeding seals, and at various distances from the seals (Table 2). Most of the cameras were programmed with a motion sensor to trigger photograph capture; however, one was set up to take photographs every 15 minutes during daylight hours. One of the cameras was set up before the arrival of the seals, thus it was possible to place it much closer to the site in question (Figure 8).

Location of camera	Photograph setting	Approximate distance from seals (metres)	Aims
Grant's Harbour	Motion sensor	1-5	To record photographs throughout the survey, including birth and suckling
South Harbour	Motion sensor	2-10	To assess the disturbance response of the female and pup to day visitors and boat docking
The Puddle (inlet closest to South Harbour)	Motion sensor	10	To identify the mother for a pup who had never been observed with a female seal
The Puddle (main inlet)	Time-lapse (every 15 minutes)	20-30	To understand the full picture of the female-pup relationships at this more complex site

Table 2. Summary of the camera traps set up at various times and locations during this year's survey.

Figure 8. Photograph showing the location of the camera trap at Grants' Harbour. The camera is highlighted with a yellow square.

Results

All raw data tables for the figures below can be found in Appendices B and C.

Pup data trends

A total of 62 pups were recorded on the Calf of Man over the duration of the survey (Appendix B). Figure 9 compares this to the total number of pups recorded over previous survey years, ranging from a minimum of 26 pups in 2009 to a maximum of 84 pups in 2016. Data was collected over a period of 58 days, a slightly longer range than in previous years, with the aim of gaining a more complete understanding of the start and end of the pupping season on the Calf of Man. The number of new pups observed for the first time in each week of the survey is displayed in Figure 10, giving an indication of the spread of pupping dates over the duration of the season and allowing comparison of this year's data with the mean trends since 2009. The date a pup is first recorded may represent the birth date of the pup, however in other cases the pup may have been born a day earlier due to the rotation in visitation of the north and south pupping sites.

Of the 62 pups, 7 were confirmed as dead during the survey: the second highest mortality rate since 2009 (Figure 11). 22 of the pups were tracked all the way through to Stage 5 of development, marked by weaning and full moulting of their natal coat. This corresponded to 35.5% of pups, comparable to a mean of 35.1% for the past eleven years of data collection.

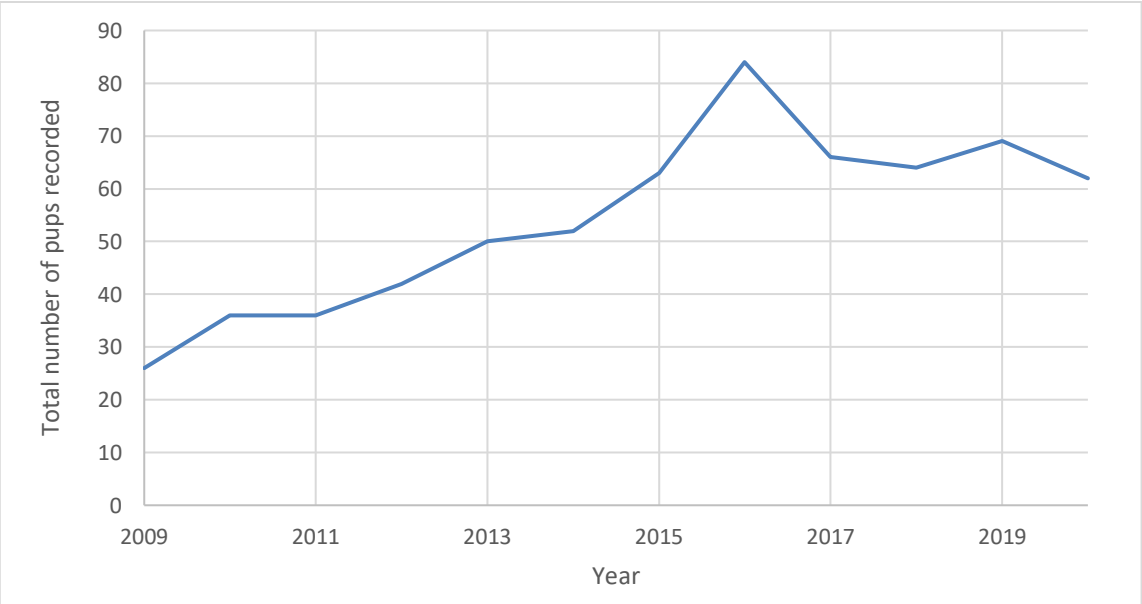

Figure 9. Graph showing the trends in seal pup production from 2009 – 2020, data collected by a range of volunteers during the annual Manx Wildlife Trust seal pupping surveys on the Calf of Man.

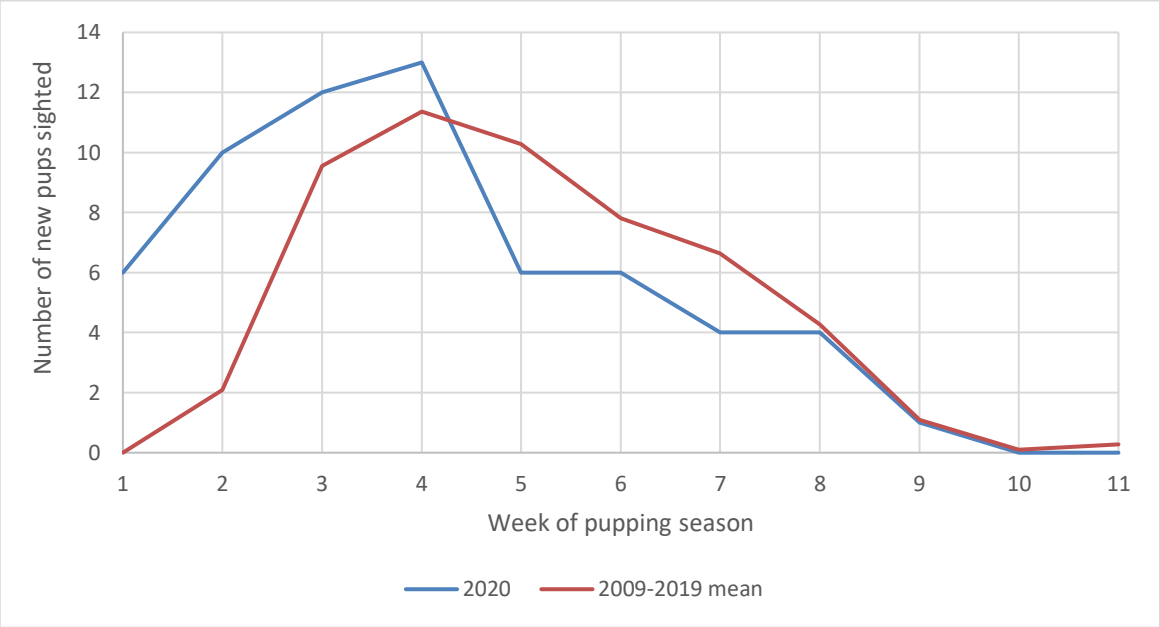

Figure 10. Graph showing the spread of pupping dates over the 9 weeks of the survey (red line), with the peak of births falling during week 4 (30/09/2020 – 06/10/2020). This is compared to the mean spread of pupping dates from the past decade (blue line).

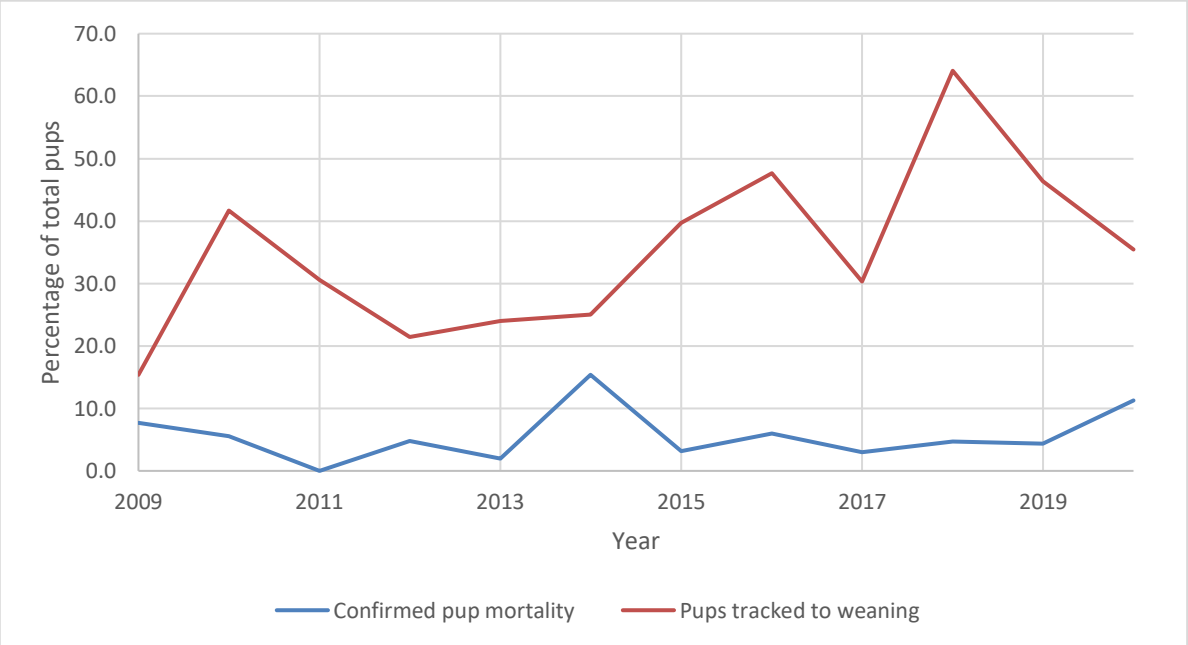

Figure 11. Percentage of pups confirmed as dead each year (blue line), as well as the percentage of pups successfully tracked through to Stage 5 of development (red line).

The number of pups recorded at each of the 12 recognised pupping sites is presented in Figure 12, generated using QGIS software. In Figure 13, this is compared to the mean number of pups recorded at each location over the previous 10 years of the survey (2009 – 2019).

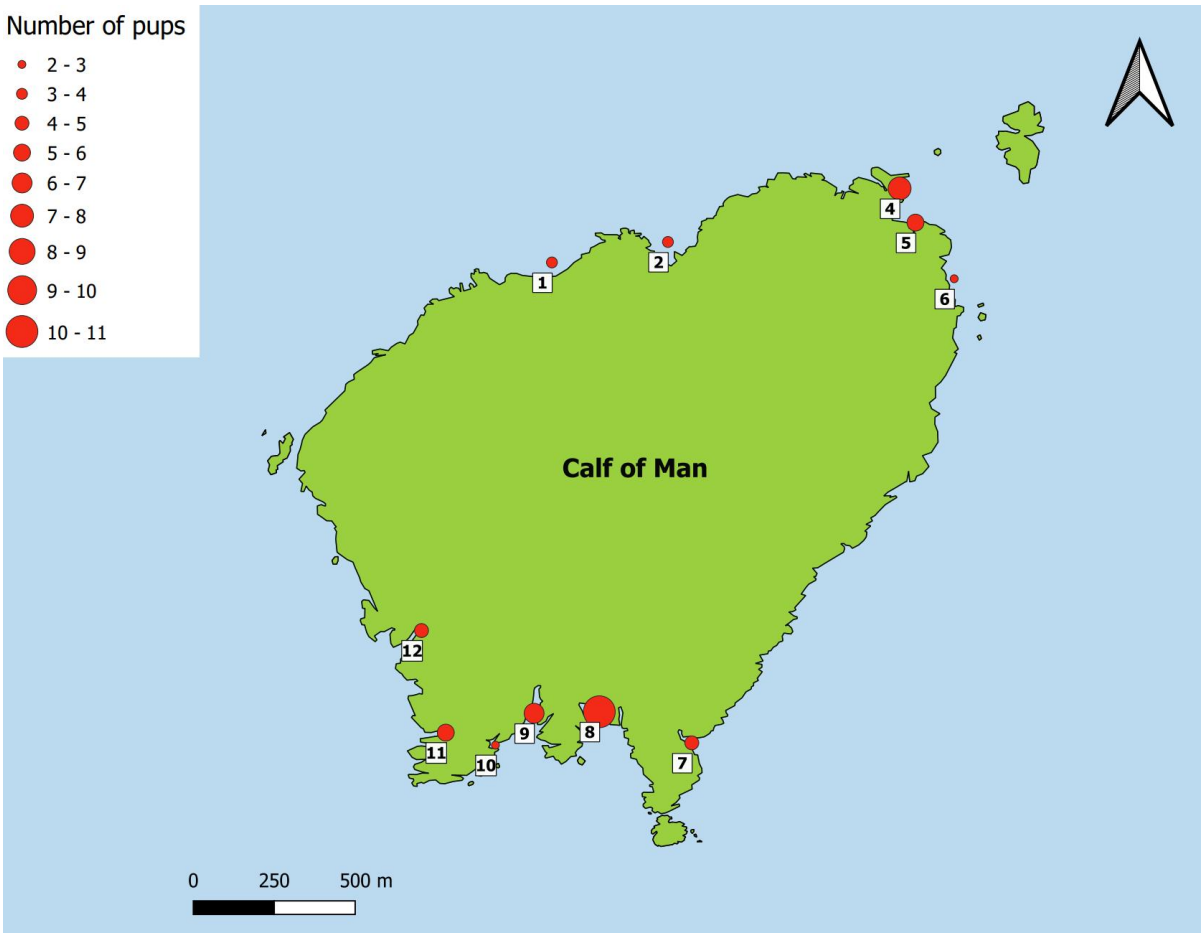

Figure 12. Map showing the distribution of pups around the Calf of Man in the 2020 pupping season, produced using QGIS software. The relative size of the red dot corresponds to the number of pups born at this location. The names of the twelve sites can be found in Table 1.

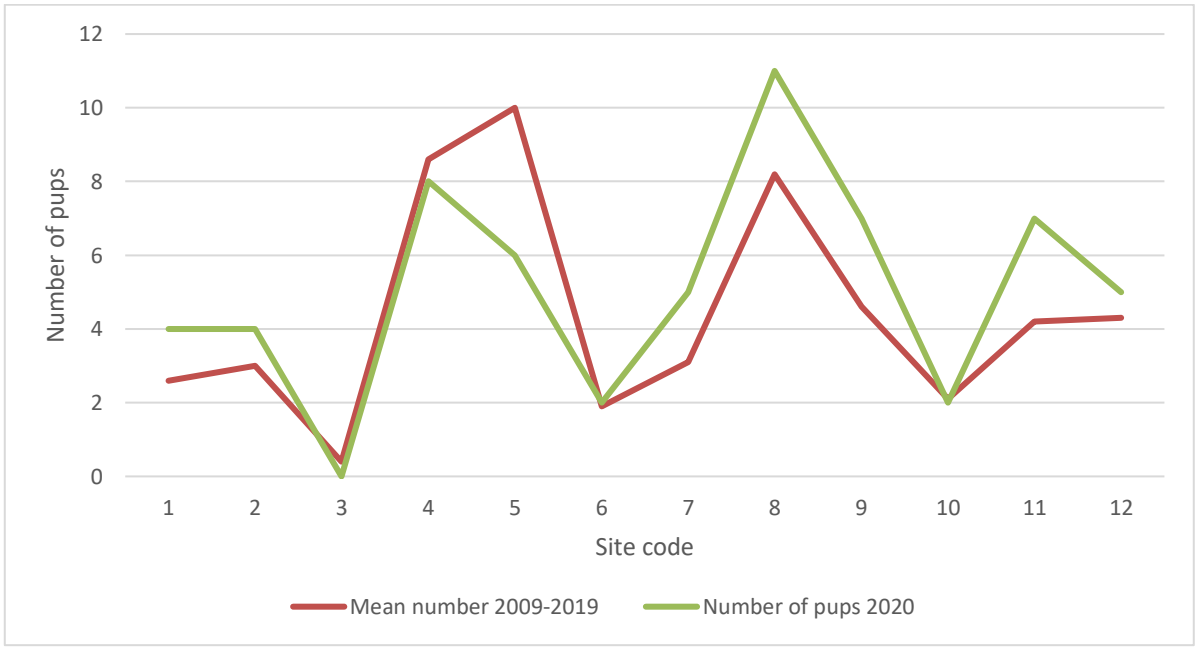

Figure 13. The number of pups born at each of the 12 sites in 2020 (green line), compared to the mean number over the past ten years (red line). The names of the twelve sites can be found in Table 1.

Adult distribution

The number of adult seals (males and females) observed at each pupping site during the survey was recorded in a daily log, with each site visited every other day. The average number of adults counted in each of the 12 locations was calculated (Appendix B) and used to construct Figure 14 using QGIS software, showing the mean distribution of the adult seals around the Calf of Man during the 2020 pupping season. In addition, the results of the whole island seal count undertaken on two dates within the survey are included in Table 3.

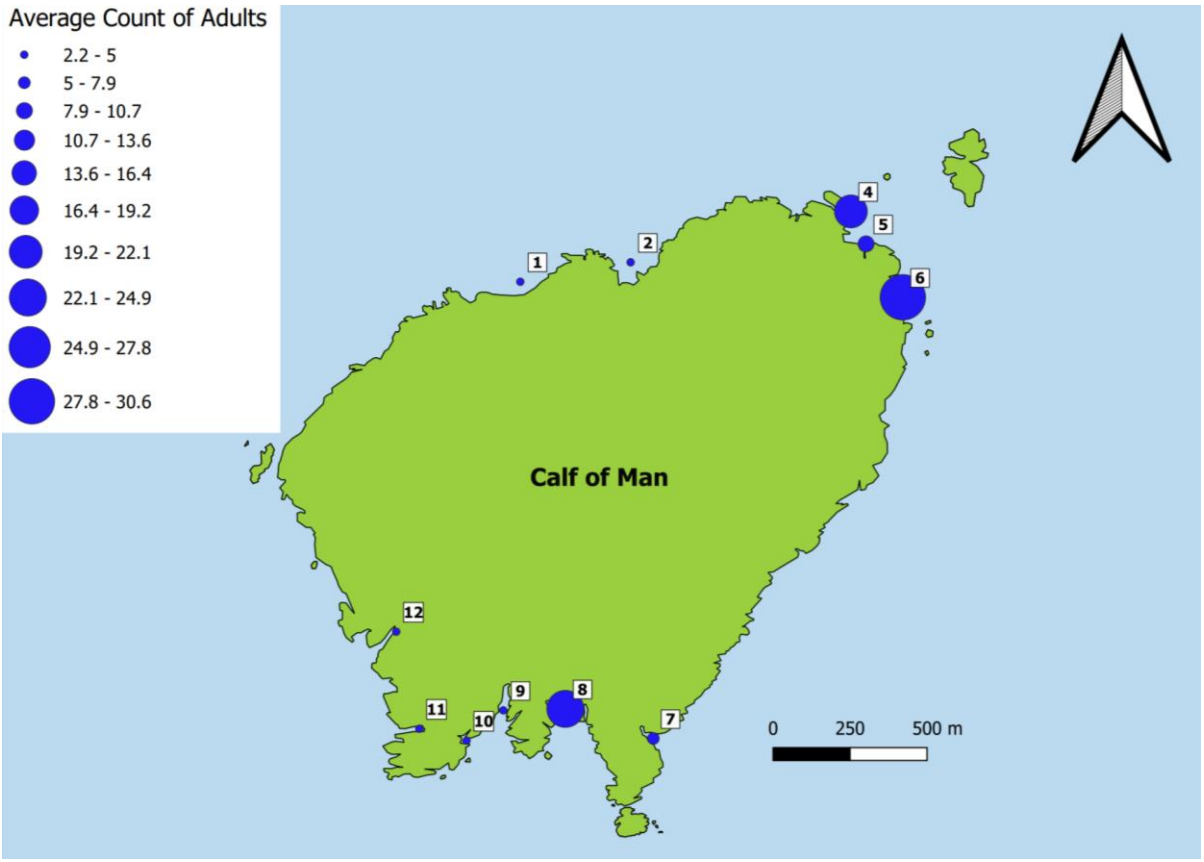

Figure 14. Map showing the mean distribution of adults around the Calf of Man in the 2020 pupping season, produced using QGIS software. The relative size of the blue dot corresponds to the mean number of adults counted at this location. The names of the twelve sites can be found in Table 1.

Date of whole-island count	Number of adults recorded
10/09/2020	287
10/11/2020	279

Table 3. Number of adult seals counted during each of the dedicated whole-island seal counts undertaken on two dates within the pupping survey.

Photo identification of females

Total number of female seals photographed	137
Returning females identified from MWT catalogue	46
Returning females observed to reproduce	35
New females added to catalogue	91
New females observed to reproduce	13
Additional pups unmatched to an adult female	14

Table 4. Summary of adult females present during the Calf of Man breeding season 2020.

Photo-identification was attempted of all females photographed during the survey (Table 4). 46 of the 137 female seals (33.6%) that were successfully photographed[4] were matched to seals in the existing Manx Wildlife Trust catalogue, with catalogue histories stretching back as far as 2008 in one case. Of the females that were observed either suckling or giving birth to a pup, 35 were known to the catalogue, representing 56.5% of the births recorded on the Calf this season. 91 seals did not generate a positive match with any seals in the existing catalogue, thus were added as new seals this year, with a record of the pupping site in which they were observed (Table 5). 13 of these were matched to a pup during the season (representing 21.0% of births). There were an additional 14 pups recorded on the Calf which were not successfully matched to an adult female (representing 22.6% of births). This indicates that either some of the 89 other seals photographed did, in fact, give birth, or that additional reproductively active females were present but were not photographed. Suggestions for addressing this are discussed at the end of the report.

Site	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Percentage of seals added to catalogue (%)	5.5	5.5	25.3	5.5	8.8	11.0	2.2	12.1	7.7	11.0	4.4	1.1

Table 5. The locations by percentage of the 91 new female seals added to the ID catalogue this year.

Photo-identification was aided by using previous pupping site records to predict the females most likely to be present at a particular site. These females could be prioritised when searching for a

[4] A successful photograph was defined as one with sufficient clarity and from the appropriate angle necessary to identify unique pelage markings on at least one side of the seal's head or body.

positive match, and only when this was unsuccessful was it necessary to search through the catalogue in its entirety. Organisation of the catalogue into specifically selected close-up photographs of each seal also assisted in the photo-identification process and allowed a few catalogue errors to be corrected, such as four seals who were present in duplicate (Table 6). It is possible that more duplicates may exist, particularly in seals with only one side of their pelage photographed.

Catalogue duplicates	Corrected ID number
003 and 026	003
045 and 086	086
256 and 282	256
288 and 301	288

Table 6. Record of the female seals in the catalogue identified as duplicate entries. The right-hand column shows the single catalogue number that has been selected for continued use.

The 22 pups that were successfully observed through to stage 5 of development were photographed and added to a new section of the photo-identification catalogue (Figure 15). Grey seals have been shown to display natal philopatry (Pomeroy *et al.,* 2001) and owing to the stability of their pelage markings, attempting to match future adult seals to these pup photos could provide an interesting and useful avenue for future study. Catalogues of stage 5 pups were also attempted from the photographs available from 2014 and 2015 on the Manx Wildlife Trust data bank.

Figure 15. ID catalogue photograph of the right side of seal pup 'Vita' born at Mill Giau on 22/09/2020 to female catalogue number 181. The clarity and stability of the pelage markings should allow future identification of this seal should they return to the Calf of Man in future seasons.

Female pupping site fidelity

198 females have pupped on the Calf of Man from 2009 – 2020. Of these seals, 47.5% have returned for more than one season, with a mean of 2.4 seasons across the data set, although one individual (catalogue number 007) has returned and reproduced in 11 of the 12 years[5] (Figure 16). Of the seals who have only pupped in one season, 28.0% have been sighted in other years, even though they have not been observed to reproduce on those occasions. Some of these additional sightings have been in years preceding successful pupping, some have been in years following their recorded reproduction. Of the 94 returning females (seals that have pupped on the Calf two or more times), 87.2% have utilised two or less pupping sites, showing a high level of site fidelity (Figure 17).

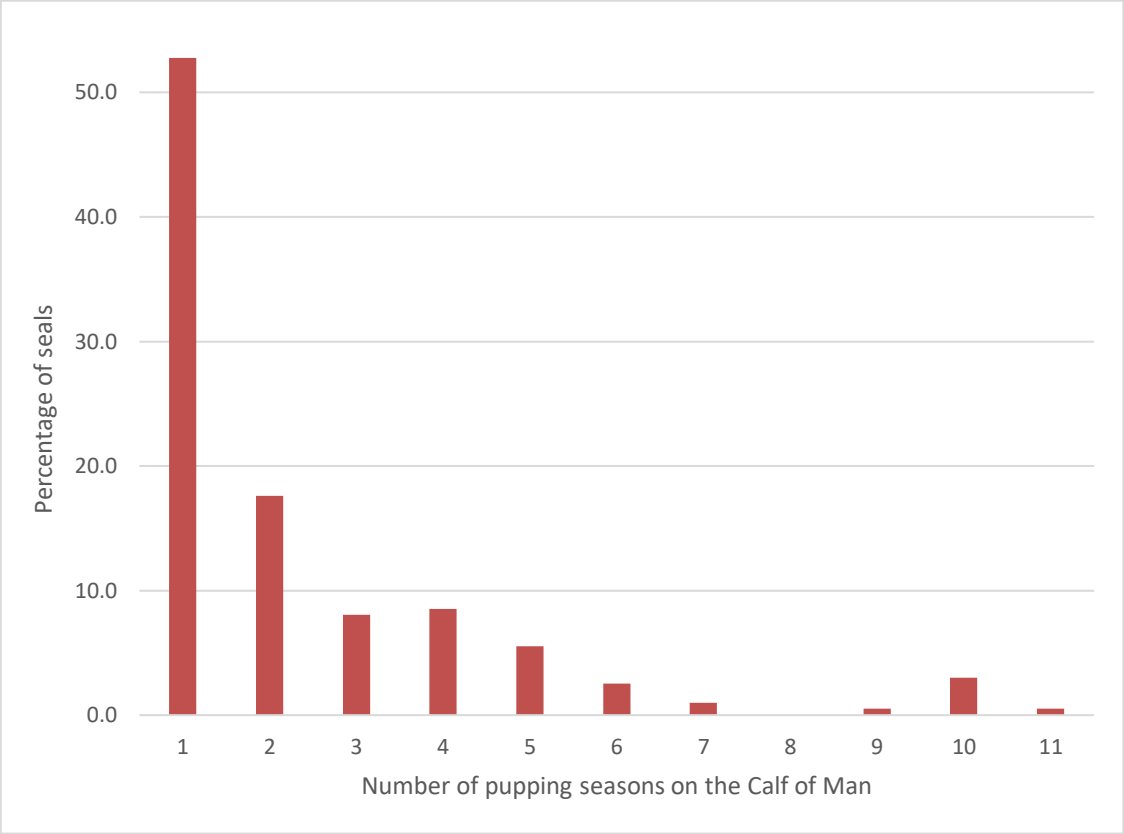

Figure 16. The number of pupping seasons in which the 187 female seals who have pupped on the Calf of Man since 2009 have been observed to reproduce, shown as a percentage.

[5] Female 007 was not recorded as present on the Calf of Man during the 2018 survey. In every year apart from this one, she has returned and given birth to a pup at Grants' Harbour.

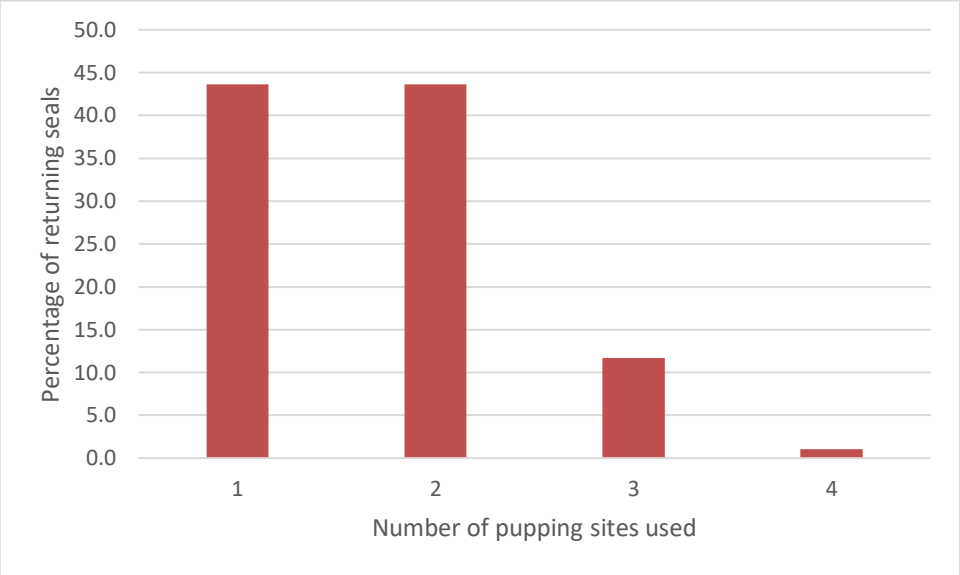

Figure 17. The number of pupping sites used by the 94 seals that have reproduced for two or more pupping seasons on the Calf of Man, shown as a percentage.

Photo identification of males

Site number	Date of first recording	Date of last recording	Percentage of survey days present (%)*	Maximum number present at one time
1	17/10/2020	21/20/2020	10.7	1
2	18/09/2020	29/10/2020	32.1	2
3	09/09/2020	31/10/2020	10.7	1
4	08/09/2020	03/11/2020	53.6	3
5	03/10/2020	03/11/2020	25.0	3
6	23/09/2020	31/10/2020	14.3	2
7	30/09/2020	03/11/2020	17.9	2
8	22/09/2020	03/11/2020	28.6	2
9	18/09/2020	28/10/2020	50.0	2
10	12/09/2020	28/10/2020	25.0	1
11	18/09/2020	22/10/2020	32.1	1
12	24/09/2020	20/10/2020	14.3	1

*Table 7. Overview of the recorded sightings of male grey seals on the Calf of Man in the 2020 breeding season. *The percentage of days present is calculated out of 28 days due to the sites being visited every other day.*

Returning males identified from MWT catalogue	5
Returning males observed in same location as previous years	3
New males added to catalogue	9

Table 8. Summary of the photo-identification of male seals in 2020.

Male seals were observed and photographed less frequently than females and pups, from a minimum of 10.7% to a maximum of 53.6% of survey days. In many cases they were not recorded at a site until the end of September or start of October, and it was rare to see them with other males. On the few occasions when up to three males were present at a site, violent fights could occur between the males. A notable example between two males was filmed at Cow Harbour on 7th October (Manx Wildlife Trust, 2020), the most popular location for males during the survey with 8 different individuals recorded at this site. A male seal was also filmed attacking a female when hauled-out on the rocks at the mouth of Mill Giau on 14th October (Manx Wildlife Trust, 2020). Table 7 summarises the observation statistics for male grey seals during the 2020 breeding season.

As discussed, photo-identification of male seals posed a significant challenge. Dry pelage during haul-out added to the existing issues of darkening and unstable markings, however a total of five seals from the catalogue were positively identified, three of whom were recorded in locations they have been associated with in previous survey years (Table 8). The other two returning males were recorded at locations adjacent to previously recorded sites, namely Grant's Harbour rather than Cow Harbour and Mill Giau rather than The Puddle (site numbers 5 and 4, and 9 and 8 respectively on Figure 7). This may be suggestive of some level of male site fidelity, despite the small sample size. Nine additional males were photographed in sufficient detail to be compared to the existing catalogue; however, no positive matches were identified. These seals have been added to the catalogue for future reference.

Camera trap preliminary trials

The camera traps were moved between various locations during the survey (Table 2). Observations regarding their success in meeting the aims outlined in Table 2 are summarised below (Table 9). Overall, proximity to the seals was a significant factor in how useful the resulting images were for individual seal identification, with the camera at Grant's Harbour generating the only images that could be used for photo-identification. Further, a time-lapse setting, active during daylight hours only, appears to be a more reliable and useful method of generating photographs. The cameras

triggered via motion sensor were too often set off by birds or at night and were generally too far away from the seals for their movement to trigger a reliable series of useful images.

Location and camera setting	Aims	Observations and outcomes
Grant's Harbour (Motion sensor)	To record photographs throughout the survey, including birth and suckling	No births were recorded on the camera, however over 3,000 images were taken over the duration of the survey. The photos were of sufficient quality to facilitate positive photo-IDs of a number of females and pups, and suckling was also recorded, confirming filial relationships. Five new females were added to the ID catalogue from the photos. However, a lot of photos were taken at night or triggered by birds, thus a time-lapse setting for regular photos during daylight hours may be preferable.
South Harbour (Motion sensor)	To assess the disturbance response of the female and pup to day visitors and boat docking	Very few photos were triggered by the seals at this location, instead it was people walking past or birds that triggered the motion sensor. This did facilitate some useful photos of the proximity of the day visitors and seals (Figure 18), however the camera needed to be closer to the seals to collect more useful data on their behaviour and responses.
The Puddle (inlet closest to South Harbour) (Motion sensor)	To identify the mother for a pup who had never been observed with a female seal	Again, this camera was too far from the seal pup in question to be triggered by their movement/appearance of the mother. Photos were triggered by bird movement, but this was mainly at night. A time-lapse setting may have proved more useful. Ultimately, this trial did not meet the aim of identifying the unknown mother.
The Puddle (main inlet) (Time-lapse, every 15 mins)	To understand the full picture of the female-pup relationships at this more complex site	The time-lapse setting worked very successfully in this trial, generating a full spectrum of photos throughout daylight hours. This revealed a whole picture of the movements of the seals and pups throughout the day, highlighting the extent to which the pups were relocating around the beach. Unfortunately, the camera was too far away to generate images with sufficient detail to identify individual mothers and pups.

Table 9. Summary of the outcomes and observations from the camera trap preliminary trials to inform future use of this technology for seal surveys.

Observation of disturbance impacts

No quantitative analysis was undertaken of the impact of disturbance on the seals and their pups on the Calf of Man during the 2020 season. However, qualitative observations of numerous disturbance events were recorded over the duration of the survey, which are summarised here.

South Harbour

South Harbour was the primary location impacted by human disturbance throughout the pupping season. The only access to the boat dock is via a narrow slipway, cutting directly through the beach and thus past the seal pupping locations (Figure 18). Disturbance ranged from boat landings for transporting day visitors, to use of the two storehouses by the Calf Wardens, as well as the weekly boat collections of waste and delivery of the food supplies, both of which are transported by motorised vehicles to and from the harbour. In addition, there were one-off events such as the removal of livestock from the Calf which sporadically added to the level of disturbance.

Five pups were recorded at South Harbour this year, with an average of 3.1 pups over the past decade. Of these five pups, one was stillborn, and another was sighted only once (soon after birth). The other three were tracked through to Stages 2, 4 and 5. South Harbour is the largest pupping site on the Calf, comparable to Cow Harbour and The Puddle: sites which recorded a total of 8 and 11 pups respectively this year. In addition, it is a popular haul-out site, particularly towards the end of the pupping season, with up to 100 adult seals counted on a few occasions (Figure 23). The degree of site fidelity shown by female seals at South Harbour was compared to the mean site fidelity trends across the other 11 pupping sites to assess the possible impact of human disturbance on a seal's decision to return to South Harbour (Appendix D). With regards to individual seals at South Harbour, of note is seal number 098 who has pupped at South Harbour every year since 2013 (except for 2015 when she was not observed on the Calf in any location). She pups close to the slipway each time, however, still appeared to be distressed and vocalised at passers-by when they came too close or found themselves between her and her pup.

Figure 18. Photograph taken by the motion sensor camera trap at South Harbour. The pup of seal 098 ('Vivian') is highlighted with a yellow circle to the right of the slipway.

Day visitor numbers

The number of day visitors landing on the Calf of Man was recorded by the Calf Wardens in their daily log. Due to the unusually good weather and calm sea conditions in September and October, many more day trips were possible during the seal breeding season this year compared to previous years where day trips have tended to stop in early September. In general, the presence of the day visitors did not cause major disruption to the seals and sometimes provided valuable opportunities to talk to and educate the public about the work of the pupping survey (an area which could be formalised and expanded in future). However, on some occasions, the day visitors got too close to the pups, usually to take photographs, or were loud and disruptive, sometimes flushing the seals back into the sea. Usually this seemed due to a lack of awareness of the impacts of their actions.

The day visitor numbers relating to the seal pup survey period are displayed in Figure 19 for further discussion regarding the impact of human disturbance on the seal breeding season and possible opportunities for future mitigation.

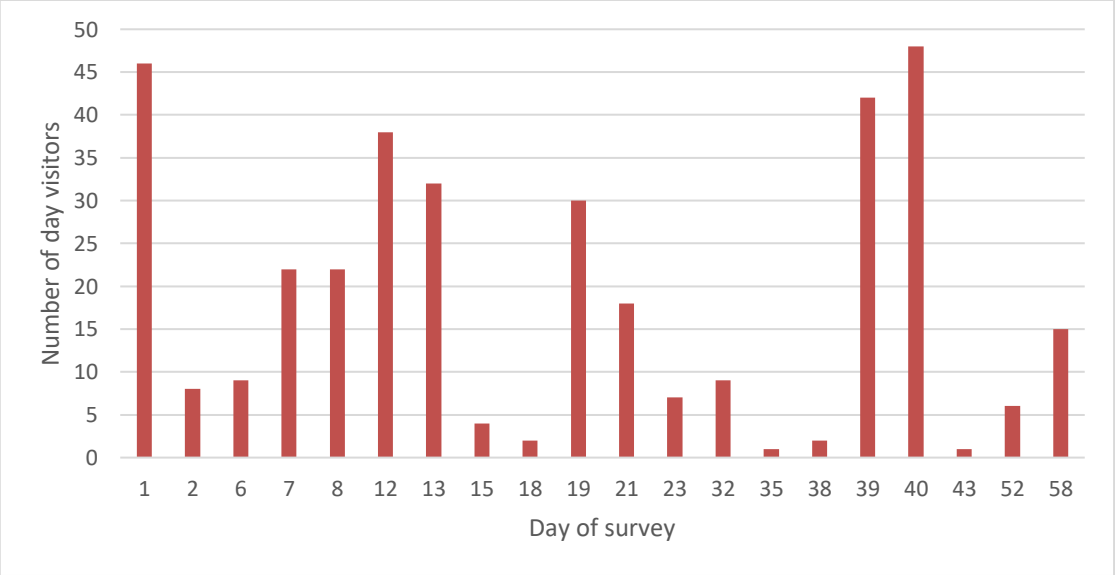

Figure 19. The number of day visitors landing on the Calf of Man over the duration of the seal breeding survey. The days with 0 visitors are not displayed in the graph.

Cow Harbour/Grants Harbour landing

In general, the level of disturbance at Cow and Grant's Harbours was relatively low, limited to day visitors walking along the footpaths or use of the bird hide at Cow Harbour by the Wardens. However, on the 17th October, due to unsuitable conditions at South Harbour, 42 visitors were brought by boat to Grant's Harbour, with boat remaining in the harbour for the duration of their visit. Pupping site numbers 1 – 6 were surveyed that day, and 4 of the 7 pups seen two days

previously at Cow Harbour and 2 of the 6 pups seen two days previously at Grant's Harbour were unable to be located. There were also fewer adult seals counted along this coastline than in the previous count (34 compared to 55 seals two days previously). On return to the sites two days later, the pups were once again accounted for, but two of the mothers at Grant's Harbour (005 and an unidentified female) remained unaccounted for over the rest of the survey period.

Estate management

Potential disturbance of the pupping sites was observed due to estate management activities such as collecting stones from South Harbour for track repairs in the poor weather, or the landing and storage of the materials for the new bird hide. Sometimes such estate work is unavoidable, but some aspects could potentially be planned and undertaken in advance, with the knowledge that those sites will be used by the breeding seals from September to November. In addition, beach cleaning of the pupping sites should ideally be undertaken before the season begins as a large amount of litter pollution seems to accumulate on the beaches of the Calf (Figure 20 and Figure 21). Large-scale beach cleans were not able to take place this year due to the restrictions placed on volunteers landing on the Calf of Man due to Covid-19.

Figure 20. Photograph taken at Mill Giau on 28 September 2020 showing the level of rubbish accumulation at some of the pupping sites, ranging from shoes to plastic bottles, and their proximity to the developing seal pups (Manx Wildlife Trust, 2020).

Figure 21. Seal (catalogue number 194) photographed at Ghaw Lang on 04 October 2020 with a blue cable restricting her neck. She was subsequently photographed without it (Manx Wildlife Trust, 2020).

Additional observations

Allo-suckling

Alloparental care is when an individual provides nutrition, protection, or other forms of care to nonfilial offspring (Maniscalco *et al.,* 2007). Allo-suckling has been observed in pinnipeds such as South American fur seals (Franco-Trecu *et al.*, 2010) and Stellar sea lions (Maniscalco *et al.,* 2007) as well as grey seals (McCulloch *et al.,* 1999), where 17 cases of allo-suckling were observed in 68 hours of observation on the Isle of May in 1997. Hypotheses for its occurrence in mammals despite the seemingly maladaptive energetic costs are reviewed by Roulin (2002). Allo-suckling has been observed in grey seals on the Calf of Man in previous seasons, such as at Cow Harbour in 2019 (Andrew *et al.,* 2019), and was observed at The Puddle during the 2020 pupping season. On the 18th October, the female seal (catalogue number 119) was photographed suckling her own pup, 'Vans', as well as a younger pup, 'Vim', (the pup of female 257) (Figure 22). Female 257 was observed at The Puddle on 10th October but was not positively identified by the survey team after this date. Qualitative observations suggested that the pup 'Vim' grew more slowly than the other pups at this site, and he was only recorded as reaching Stage 3/4 of pup development.

Figure 22. Female (catalogue number 119) photographed suckling her own pup 'Vans' (left-hand pup), before being subsequently photographed suckling the right-hand pup, 'Vim' (the offspring of female catalogue number 257). Photograph taken at The Puddle on 18th October 2020 (Manx Wildlife Trust, 2020).

Relocation of late-stage seal pups

Throughout the survey, in addition to the pups which had been born at each site, older pups were sometimes transiently observed in various locations, usually in the final stages of development and having not been seen previously at that site (Table 10). They were not observed to be in contact with any adult female seals and were often only recorded on one site visit. Attempts were made to match them via photo-identification of their emerging adult pelage to known pups from other Calf sites who would have fitted that stage of development, but there was only one positive match to confirm this. The pup 'Vannin' who was born to female 004 at Cow Harbour on 26th September, was subsequently photographed post-weaning at South Harbour on 11th November. These additional pup sightings have not been included in the pup totals for this season as they could not be matched to a site or a female, and there were 40 seal pups who disappeared before reaching the final stages of development who may account for these random occurrences. There is also the possibility that they were born on the main Isle of Man and then observed on the Calf post-weaning.

Stage of pup development	Site (Site number)	Day(s) observed
5	West of Cow (3)	27/10/2020
3 – 4	Cow Harbour (4)	09/10/2020, 11/10/2020
5	Grant's Harbour (5)	21/10/2020
5	Grant's Harbour (5)	23/10/2020
5	Grant's Harbour (5)	02/11/2020, 03/11/2020

3 – 4	The Cletts (6)	09/10/2020
4 – 5	The Cletts (6)	11/10/2020
4	South Harbour (7)	02/10/2020
3	South Harbour (7)	04/10/2020
3	South Harbour (7)	12/10/2020
5	South Harbour (7)	18/10/2020
5	South Harbour (7)	18/10/2020
5	South Harbour (7)	20/10/2020
5	South Harbour (7)	20/10/2020
5	South Harbour (7)	20/10/2020
4	South Harbour (7)	24/10/2020
5 (Positive ID: Vannin)	South Harbour (7)	04/11/2020
4	The Puddle	18/10/2020

Table 10. The additional pups that were recorded at various locations throughout the survey, usually for one day only. Their stage of development is also included, as well as the name of the one pup who was identification through a positive photo-identification match of their unique pelage markings.

Variation in seal birth dates

Some initial analysis of the data available from 2009 – 2019 recording the pupping date of individual seals was undertaken as an interesting avenue for future, more detailed consideration. In some cases, the birth date of a pup was recorded in the annual spreadsheets, however, due to the method of visiting sites every two days, a pup was not recorded until it was a day old. For these pups, their birthdate was set at one day prior to the date they were logged in the spreadsheet, although there is still a small margin for error here. This preliminary analysis can be found on the seal survey hard drive (Manx Wildlife Trust, 2020).

Discussion

Pup numbers

The overall number of pups (62 individuals) recorded on the Calf of Man this season is generally comparable to the trend observed over the past few years (Figure 9), with a mean of 54.2 pups and median of 57.0 pups since 2009 (Appendix C). The shape of the trendline in Figure 9 is suggestive of a plateau in pup production, following the expected population growth curve for a population reaching carrying capacity in an ecosystem. Historically, grey seal populations crashed in many areas in the early 20th century due to hunting pressures, and population recovery was hindered by exposure to various environmental pollutants (Kauhala *et al.,* 2019). However, subsequent restrictions on hunting and pollutants have improved grey seal reproductive health and population sizes have therefore increased. The UK grey seal population has increased continuously since the first systematic attempts to quantify seal population size and formal surveying began in the 1960s: the current population probably represents the highest population size since human colonisation of the Northern and Western Isles during the Neolithic period (Thomas *et al.,* 2019).

Recently, however, this growth rate appears to be slowing; indeed, overall pup production in the UK began to level off in the mid-1990s, with growth rates in the Inner and Outer Hebrides and Orkney, for example, slowing from approximately 6% in the mid-1980s to less than 1% in 2002 (Thomas *et al.,* 2019). Each of these breeding populations initially overshot their carrying capacity slightly, before undergoing a small decline in the following years (Thomas *et al.,* 2019); this is comparable to a similar trend recorded on the Calf from 2016 – 2020 (Figure 9). Explanations for this levelling-off of pup production and slowed population growth include at-sea density-dependent processes such as foraging conditions, as well as local colony-level processes that influence recruitment to the breeding colony, including habitat quality and the conspecific-attraction hypothesis[6] (Russell *et al.,* 2019; Stamps, 1988). Nonetheless, not all grey seal populations appear to be reaching their carrying capacity, with the breeding population in the North Sea continuing to grow almost exponentially (Thomas *et al.,* 2019).

When compared to more specific, localised colony trends, annual pup numbers on the Calf could be considered surprisingly low given the size of the Calf of Man, the relative lack of human disturbance,

[6] Gregarious, colonial species such as grey seals seek out and benefit from the proximity of conspecifics, a behaviour observed during selection of and recruitment to breeding sites in female seals (Russell *et al.,* 2019; Stamps, 1988).

and the land area still unused at some of the larger pupping sites. A review of the long-term study on North Rona from 1978 – 1989 also noted the large areas of available space unoccupied by breeding seals (Pomeroy *et al.,* 1994); it might be expected that sites with growing populations would show an expansion in the size of pupping sites, as has occurred on the Isle of May where the land used by seals for breeding has increased as the population has grown (Pomeroy *et al.,* 2016). Seals have started to breed in parts of the island that were previously unused, with an increase from only a few seal pups in the mid-1970s, to 1,408 pups born in 1994 (Pomeroy *et al.,* 2006). Now nearly 2,500 pups are born each year on the Isle of May (Nature Scot, 2020).

While comparison of the Calf of Man to other similar Irish Sea pupping sites may prove instructive, only 10% of grey seal colonies in the Irish Sea are monitored as regularly as the Calf of Man; biannual surveys are more common, often using photographic aerial surveys to reduce human disturbance (Russell *et al.,* 2019). Comparable ground-based surveys do, however, take place on Lundy Island in the Bristol Channel and Skomer Island, South Wales. Skomer Island covers a similar area to the Calf (2.5 - 3km^2) and has a similar number of pupping sites; there are 18 pupping sites in total, with six sites that are the focus of daily recording throughout the breeding season (Wilkie and Zbijewska, 2019). Skomer and the Calf also have comparable maximum adult seal counts, with a maximum haul-out count of 285 on Skomer in 2019 (Wilkie and Zbijewska, 2019) and up to 287 seals counted around the Calf in 2020 (Table 3). However, the Calf of Man recorded 70.9% fewer seal pups in 2019[7] (this increases to 73.8% fewer when compared to the Calf of Man's 2020 data). Photographs of Skomer suggest that the island has very sheltered pupping sites with large flat beaches and many caves, which may be more suitable for pupping than the Calf's exposed and rocky coastline: up to 54 pups were recorded at one site on Skomer compared to a maximum of 11 pups at The Puddle on the Calf in 2020. At the other end of the comparative scale is Lundy Island in the Bristol Channel, which is larger than the Calf of Man (with an area of 4.45km^2) but only recorded a pup count of 28 in 2018, despite having 16 apparent pupping sites and a large adult haul-out count of 239 individuals (Woodfin Jones, 2018).

Selection of breeding site by grey seals is multifactorial, influenced by factors such as a seal's own birth location, and potential recruitment via foraging preferences or following more experienced females, driven by the various advantages of site fidelity discussed earlier in the report. Seals may also move breeding site if a more suitable one becomes available: studies in the Outer Hebrides

[7] 69 seals were born on the Calf of Man in 2019, while 237 births were recorded on Skomer in 2019 (Wilkie and Zbijewska, 2019).

have shown a preference for seals to relocate to low-lying islands with extensive beach areas and wide, unrestricted access if they become available for use (Russell *et al.,* 2018). Further research into the trends and driving factors in pup production at Irish Sea breeding sites is needed to gain greater insight. There is a lack of understanding as to the factors involved in colony-specific dynamics within long-lived animal populations (Russell *et al.,* 2019), and these weaknesses tend to exist due to the prevalence of studies of single, local populations rather than multisite studies (Breton *et al.,* 2006). A clearer understanding of the adult grey seal population size on the Calf of Man, as well as the relationship between the Calf and mainland Manx seals, may also prove useful and is discussed further in the relevant section below. It is also worth considering the possibility that pup numbers have been slightly underestimated on the Calf of Man: a small number of seals could feasibly be pupping at locations not visible from the land. Certainly, the appearance of dead pups floating around the Calf (such as the one observed from a boat at Kione ny Halby on 18th October 2020, Appendix B) as well as the Stage 4 and 5 pups that could not be assigned a birth site or mother (Table 10) are suggestive of at least a few additional births that have gone unrecorded this year. Aerial or sea-based surveys may assist in detecting some of these births, or the use of remote camera technology could be trialled at sites such as Baie Fine or Smuggler's Cave where the view from the land is greatly restricted.

Additional pup trends

The spread of pupping dates was of particular interest this season due to the decision to begin the survey earlier in the season with the aim of being present on the Calf of Man for the first birth of the season. This was nearly achieved, with six pups recorded during the first two days of the survey, four of which had been born either that day or the day before (although one of these was a stillborn carcass). No further new pups were recorded until the 19th September, indicating that we did begin the survey earlier enough this year to gain a more accurate understanding of the full breadth of the pupping season (Figure 10), removing the bias towards an artificially high number of pups recorded in week one in previous surveys. There is a normal distribution in the spread of birth dates across the season, both in 2020 and in the mean values for 2009 – 2019, although there is a skew in the 2020 data towards the start of the season, with fewer births in the middle of the season than average: up to a difference of 4.3 fewer births in week five. Nonetheless, the range of births across the season is similar in both cases, and the tailing off at the end of the season follows the same pattern. The peak in pup numbers in 2020 falls in week four (corresponding to 30th September – 6th October). This peak has ranged from week three to week six (corrected to ensure dates correspond

across all survey years) over the past 11 years (Appendix C), however week four has been the mean peak in births from 2009 – 2019. It would be interesting to compare these within-season trends in the timing and spread of pupping with other grey seal colonies.

Having attempted to capture the start of the pupping season it was, in fact, the tail-end of the season that was not fully covered by this year's survey, with a new birth recorded on the day the survey volunteers departed from the Calf and a further birth the following day reported by the Warden and volunteer team who remained in residence for a further week. While it may not be feasible to extend the length of the survey due to the deteriorating weather and sea conditions at this time of year, if it was possible to visit the Calf on a small number of subsequent day trips in early November this may prove a useful opportunity to photograph these final pups and mothers and achieve the photo-identification and determination of filial relationships that was not possible with the final pups born this season. An informal visit by the survey team on 29th November 2020 allowed for the additional recording of eight pups who remained at three of the pupping sites: Cow Harbour, Grant's Harbour and The Puddle (Appendix D)[8]. All of the pups were at Stage 4 or 5 of development, and no positive matches were achieved with photographs of emerging pelage markings from pups photographed during the survey. No adult females were observed alongside these pups. While the gap between the survey and this visit was too large to identify these pups or link them with the existing survey data, it did show the potential utility of post-survey check-ups.

Confirmed pup mortality was recorded when the remains of a deceased pup were visible to surveyors. Seven pups were confirmed deceased this season, representing 11.3% of the pups born on the Calf of Man in 2020, higher than the average of 5.7% from 2009 – 2019 (Figure 11), although mortality rates have varied from 0.0 – 15.4% over this period (Appendix C). Mortality rates vary significantly between locations and years, with a wide range of mortality statistics reported in the current literature, and an overall understanding that the probability of surviving to one-year of age in large mammals such as seals is often low (Hall *et al.,* 2001). In 2019, for example, only 77% of pups were known or assumed to have survived on Skomer (Wilkie and Zbijewska, 2019). Pup mortality can be due to a wide variety of factors, with post-mortem examination suggesting starvation and infections are the proximate causes of death, as well as other factors including drowning, trauma and stillbirths (Anderson *et al.,* 1979). These causes correlate with a number of the deaths recorded at the Calf this season: six of the deceased pups were either stillborn or died

[8] A deceased adult female was also observed and photographed on this visit, lying on the floor of the inlet at South Harbour (see Appendix D). Photo-identification was attempted but was unsuccessful.

aged 0-2 days, and the seventh pup died at Stage 3 of development during a storm on the south side of the Calf. This storm was particularly devastating to the pupping sites at Smugglers' Cave and Ghaw Lang, after which no pups were observed at these locations for the rest of the season. While only one pup carcass was observed at Ghaw Lang (on 22nd October), it is possible that other pups at these sites also died during the poor weather. Furthermore, it is feasible that pups at other sites died during the survey but were not recorded as such; only 22 of the 62 pups (35.5%) were observed through to Stage 5 of development and moulting to their adult pelage (Figure 11), a similar percentage when compared to previous surveys. It is challenging to track individual pups for the 18 – 25 days before weaning and full moulting due to their mobility within, and sometimes between, pupping sites, and our reliance on using their mothers to identify them until they have developed sufficient adult markings to be individually recognised on their own. Successfully recording and photographing the pups through to Stage 5 can aid our understanding of pup development and our accuracy of factors such as filial relationships and mortality rates, and is the only way to facilitate future assessment of natal philopatry without marking or tagging the seal pups.

Thus, it may be useful to review how pup development is assessed and analysed on the Calf of Man to gain a more accurate understanding of development trends and mortality rates in future surveys. For example, the survey at Skomer also makes predictions regarding their likelihood of a pup's survival from the day they are last seen. They utilise a five-point scale that categorises the size and condition of the pup from a score of one (very small) to five (exceptionally large) (Wilkie and Zbijewska, 2019). If a pup that has been given a score of one or two disappears before moulting it is assumed not to have survived, however those scoring three or above are assumed to be successful (Wilkie and Zbijewska, 2019). Such a system may allow a more realistic assessment of pupping success, in addition to the existing practice of recording any direct observations of deceased pups.

Another challenge to understanding individual pup development was the appearance of pups, usually at Stage 4 or 5 of development, at a site that was not their natal location (Table 10), termed 'wandering pups' by the surveyors at Skomer (Wilkie and Zbijewska, 2019). These pups were not accompanied by an adult female and were unable to be matched to pelage markings on known moulting pups, except for the pup 'Vannin' who was recorded at South Harbour on 4th November after having reached Stage 5 of development at Cow Harbour on 17th October. The positive identification of Vannin showed that it is possible for moulted pups to move considerable distances around the Calf, and thus the pups who were not tracked to the later stages of development at their natal sites may just have moved elsewhere to complete their moulting. For this reason, these

'wandering' pups were not included in the pup totals for this year as it could not be determined whether they represented a new birth or a relocated existing birth. It is thought that the larger of these pups will finish their moult once they have established themselves at a new site (such as those that spent at least two days at Cow Harbour and Grant's Harbour (Table 10)), however the smaller pups or those who only hauled-out for one day may have been abandoned or become separated from their mothers and may not survive (Wilkie and Zbijewska, 2019). The Skomer report in 2019 attributed the appearance of these 'wandering pups' to storm or spring tide events (Wilkie and Zbijewska, 2019). For such occurrences on the Calf of Man it would be interesting to determine any potential links with pups born on the Isle of Man, and whether moulting pups can disperse to this extent, possibly driven by the greater level of human disturbance on the main island.

Pup distribution

The distribution of births across the 12 recognised pupping sites has been reasonably constant over the past 11 years, and Cow Harbour, Grant's Harbour and The Puddle have consistently been the most popular pupping locations (Figure 13). Cow Harbour and The Puddle are large, pebbled beaches with haul-out room above the high tide line and shelter created by the topography of the land surrounding these rocky inlets, forming logical pupping sites (Table 1). Grant's Harbour is extremely sheltered, but is a much smaller site, made up of long, narrow inlets into the surrounding rock rather than one large, beached area. Only one pup was born in each of the smaller inlets, however, three pups were born in the larger inlet, an area with a small beach that remains exposed at high tide. Slightly fewer pups were born at Grants' Harbour this year: six pups compared to a mean of ten over the previous ten years, and this was also true of Cow Harbour, which was the most popular pupping site in 2019. In 2019, 24 pups were born across these two adjacent sites, compared to only 14 pups in 2020. However, more pups were born at each of the southern pupping sites in 2020, with notable increases at The Puddle and Mill Giau. The Puddle was the most popular pupping site in 2020, although two of the 11 pups born at The Puddle this year were stillborn. In 2020, more pups than average were recorded at Baie Fine, Gibbdale Bay and Smugglers' Cave, which may be a more accurate representation of the annual births here; lower numbers in previous years may have been due to the challenges of viewing these sites from the land. The locations with the fewest pups were again consistent with previous findings, with no pups born at West of Cow and three or fewer born at The Cletts and Leodan. For West of Cow and Leodan this can be logically explained by a lack of both haul-out space and shelter; in fact, pups have only been recorded at the West of Cow location in three out of the past 11 years. The Cletts is a larger site with greater haul-out space

available, however it is fairly exposed to wind, sea and the strong tidal movements through The Sound, thus it seems to be favoured for adult seal haul-out at low tide but not utilised as a regular pupping site. At present, it is hard to determine whether these variations in pup numbers by site are real and in need of discussion and explanation, or whether they are due to improvements and changes in survey methods. Further data collection over the coming seasons will help to clarify this important question with regards to trends in pupping site use.

It is also worth considering the distribution of pups between the northern sites (1 – 6) and the southern sites (7 – 12) on the Calf which has, on average, been fairly equally distributed over previous survey years, apart from some occasional tips in favour of one side or the other in individual years. This is somewhat of an arbitrary distinction to draw within the data set as the north-south divide has been constructed by the survey team to structure the schedule of their survey visits, rather than being any meaningful biological or geographical divide. Nonetheless it is useful to consider this aspect of the data as any significant deviation away from an equal divide may require reconsideration of the survey process to ensure that surveyors are dealing with equitable surveying requirements within the 'every other day' system of site visits. This year there were slightly more pups born in the southern sites than the northern sites (57% compared to 43%), however this does not represent a significant deviation from the norm.

Adult distribution

The process of recording the distribution of adult seals around the Calf during the 2020 breeding season consisted of a single count taken every other day at each of the 12 sites. This number included all adult males and females, both hauled-out and in the water. For this reason, it is a fairly generalised data set taken from daily 'snapshots' in time captured during the short time the survey team was present at that site. In general, these counts were undertaken in the morning, however if weather conditions were poor, survey visits were sometimes moved to the afternoon. Nonetheless, an average of the counts across the whole season was calculated (Appendix C) and used to construct Figure 14 to give a visual representation of where adult seals were usually congregating on the Calf. In keeping with previous survey results, The Puddle and The Cletts had the highest average adult seal count, followed by Cow Harbour and Grant's Harbour. Very few adult seals were recorded at the other eight sites. The Puddle and The Cletts are the second and third largest sites with considerable haul-out areas which accounts for their popularity, particularly among the non-breeding females who are not tied to a pupping site. The largest of the sites, however, South Harbour has a

surprisingly low average adult count. Despite having ample opportunities for haul-out (both at high and low tide), on some survey days no adult seals were recorded at this site (and it had only the sixth highest number of pups). However, towards the end of the season, the number of adult seals at South Harbour greatly increased, with over 100 adult seals recorded on 4th November, representing over 35% of the maximum number of seals counted during the whole-island adult counts (Table 3). Greater aggregations of hauled-out seals were seen at several other sites in November, replacing the smaller groups of mothers and pups that had predominated for the previous two months (Figure 23).

To gain further insight into the distribution of adult seals around the Calf during this period it may be more useful in future surveys to distinguish between hauled-out and swimming seals, males and females (including breeders and non-breeders) to allow for more nuanced analysis. This would facilitate more meaningful discussion and understanding of behavioural trends. For example, it may aid understanding of the relationships between individual males and their breeding territories, as well as features of female reproductive behaviour such as movement during lactation which may have implications for pup growth and subsequent survival, as well as ability of surveyors to confirm the identity of the breeding females and their filial relationships to specific pups. Only 22 out of 140 breeding females studied on North Rona were found to move more than 20 metres from their pup during observations throughout the lactation period (Pomeroy *et al.,* 1994), however this did not seem to be consistent with the behaviours the survey team witnessed on the Calf this season. Thus, clearly defined, quantitative data collection on adult distribution may assist in learning more about the specific ethology of grey seal breeding in this location.

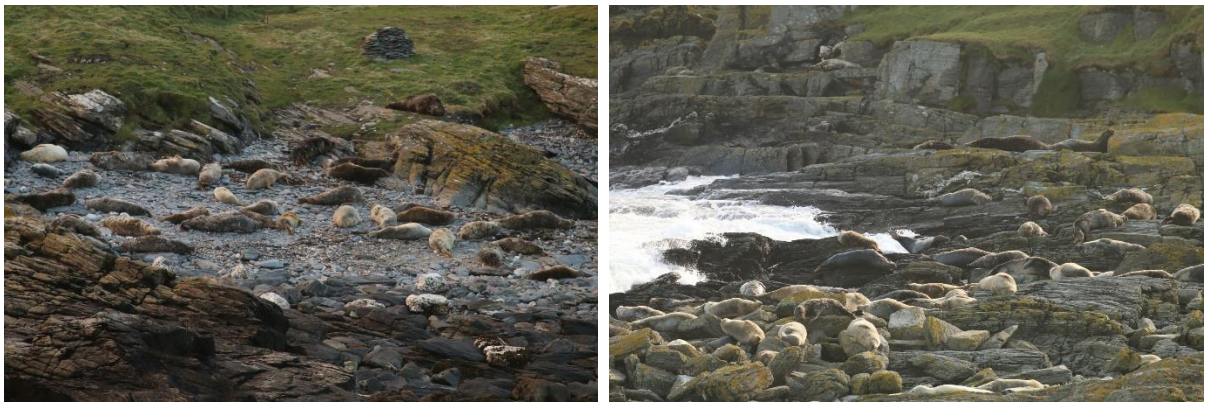

Figure 23. Dense aggregations of hauled-out seals recorded at numerous sites towards the end of the pupping season. Left: Cow Harbour, 3rd November. Right: South Harbour, 3rd November. (Manx Wildlife Trust, 2020).

With regards to the size of the adult grey seal population on the Calf of Man, the whole-island counts are the most relevant data collected during the breeding season (Table 3). These were taken during the morning on two days, one month apart, counting all seals present in the water and hauled-out. Further, the counts were taken by two teams, each walking half of the Calf's coastline concurrently to limit the possibility of counting a swimming or relocating seal twice. The highest of these counts totalled 287 individuals on 10th September, giving an approximation of the Calf grey seal population during the breeding season. This is comparable to counts in previous seasons and on the Isle of Man. More regular whole-island counts at other times of year would be useful in developing a more regular data-set and greater understanding of population dynamics, such as determining resident seals versus 'visiting' seals, something that could be aided by future projects such as flipper tagging or satellite tagging. Some work has already been done in this respect by other research groups around the British Isles, using satellite tagging technology as well as photo-identification of individuals. This has led to elucidation of links between the Calf of Man and Cornwall, the Dee Estuary and Strangford Lough in relation to grey seal mobility between neighbouring colonies (Howe, 2020). This gives us a small window of understanding with regards to seal mobility and movement ecology, expansion of which would be significant with regards to our wider understanding of grey seals population in the Irish and Celtic Seas.

In addition to more regular on-site seal counts and possible use of tagging technology, it may also be possible to use the pupping counts to estimate the size of the grey seal population on the Calf. This is achieved through the use of mathematical models which are useful when only one component of population, such as newborn offspring, can be readily or reliably surveyed (Thomas *et al.,* 2019). Grey seals are a good example of such a population; given their extensive at-sea mobility and often wide dispersal, population monitoring at many locations has focused on pup counts (Thomas *et al.,* 2019). Such mathematical models have been developed and refined by numerous individuals and research groups over the years (Harwood and Prime, 1978; Hewer, 1964; Lidgard, 1999; Thomas *et al.,* 2019), resulting in statistical techniques that can utilise annual estimates of pup production, alongside a single estimate of total population size and other informative demographic data, to produce an age-structured population model (Thomas *et al.,*2019). The resulting model can be used to infer population size and trends over multiple years and may provide a possible avenue for future mathematical analysis of the Calf of Man data set with the necessary statistical expertise.

Photo-identification

Photo-identification proved an extremely useful tool this season as in previous years; returning seals were tracked (in some cases for their 11th sighting at the Calf) and new seals were added to the catalogue. Of the seals photographed during the survey, a comparable proportion of females and males were identified as returning seals (33.6% and 35.7% respectively), although this may be an underestimate due to the challenges of photo-identification, both in obtaining an image of sufficient quality and in the process of by-eye comparison to the catalogue. The first of these issues may be assisted by increased use of camera traps in future surveys, and the latter by continued review and refinement of the existing catalogue to make it more accurate and user-friendly. Nonetheless, photo-identification allowed 56.5% of the pups born this season to be matched to a returning female, facilitating more nuanced analysis of these females' breeding behaviour, discussed below. This is a similar percentage to the 2019 survey in which 56.5% of mothers were identified, however a higher overall number of female seals were successfully recognised in 2019 (73.4%). This may simply be due to the lower number of seals photographed that season (less than 50% of the total number photographed in the 2020 survey), perhaps due to a focus on photographing potential breeding females as opposed to any seals present at that pupping site. In contrast, as many seals as possible were photographed this season with the specific aim of expanding the photo-identification catalogue. In relation to the male seals, as observed this year, only a small number of males were photographed and identified in the 2019 season.

Photo-identification should continue to form an important component of the Manx Wildlife Trust's work with regards to the Calf and Manx grey seal populations. It is an extremely cost-effective method of data collection and analysis and, while a little laborious at times, it has contributed greatly to our understanding, particularly when data has been shared with groups in Cornwall and the Dee Estuary. Without the ease of funding for tagging (which only serves as a temporary method of tracking), photo-identification remains the most effective way for us to monitor the grey seal population in the long-term. Therefore, it is recommended that continued review of the photo-identification catalogue is carried out in preparation for the 2021 breeding season, to eliminate any remaining duplicates and continue building the 'close-up' photograph selection that allowed for more efficient catalogue comparison this season. In addition, reviewing and updating the accompanying spreadsheets aided in data analysis and in predicting the most likely females to be present at a pupping site. Continuing to use this information to aid photo-identification may prove increasingly useful as the catalogue expands in size.

The quality of the photographs in the male photo-identification catalogue is lower than for the females, mostly due to the reduced and unstable markings on their pelage and the difficulty of encountering them in a suitable situation conducive to high-quality photographs. Nonetheless, it would also be constructive to review and organise this section of the catalogue as more secure recognition of the male seals at the Calf may open up an area of analysis and understanding that is somewhat lagging behind at present. In addition, the future identification of returning Calf seal pups could also contribute a new research avenue within the current data set. Continued photographing of each season's moulted pups would facilitate a catalogue collection that can be compared to mature seals in the future, with the hope of identifying the natal philopatry recorded at other grey seal colonies. Pup photographs from previous surveys could also be reviewed so that any of sufficient quality could be included in this catalogue, as was attempted this season from the 2014 – 2015 pup photographs. Female grey seals give birth to their first pup at approximately 5.2 years of age (Fedak and Anderson, 1982), thus our data set already consists of sufficient years' worth of photographs to facilitate an immediate search for evidence of potential natal philopatry.

Finally, photo-identification may be a valuable and productive area in which increase the public's contribution to 'citizen science' on the Island, as has been achieved at other grey seal locations. Members of the public are already encouraged to report their seal sightings to the MWT Marine Officer, however, if suitable information was made available to volunteers and water-users (for example, with regards to the quality of photographs required for the photo-identification process and a reminder of the existing code of conduct for behaviour around the seals), they may be able to contribute further. This would potentially generate a wider range of photographs taken from different perspectives, at different times of year and at more locations around the Island.

Site fidelity

Female breeding site fidelity is one of the primary areas of analysis feasible from the Calf of Man data set: with records currently spanning 12 years, it is possible to elucidate the long-term reproductive patterns of a number of individual seals, notably the eight females that have returned in nine or more seasons. The pupping site fidelity of female grey seals has been documented at a range of well-studied colonies, most notably the Scottish islands (Pomeroy *et al.,* 1994; Pomeroy *et al.,* 2001). There is evidence of this behaviour at the Calf of Man, with 47.5% of females returning to breed in at least two seasons since 2009. Over half of the births in the 2020 breeding season were to returning mothers. This contributes useful data to the wider discussion on grey seal site fidelity, furthering the conversation regarding the factors and variables that may lead to this behaviour. It

would seem that this is not a universal grey seal behaviour, as shown by studies on Sable Island, thus there remains a need to test and explore explanations for grey seals' decision to return to a previous site or disperse to a new one. Numerous hypotheses have been proposed, which are presented in the introduction and well-summarised in Weitzman *et al.* (2017). Determining the potential for testing any of these hypotheses in future surveys on the Calf of Man would be a productive and interesting future consideration. It may also be worth exploring the publication of this site fidelity data set to contribute to the wider body of understanding amongst the academic community, confirming the presence of this behaviour on the Calf of Man to give further context to existing published works.

The records on the Calf of Man are suitably detailed to allow assessment of within-island site fidelity in addition to the larger scale understanding of seals returning to the Calf as a whole. Of the 12 pupping sites surveyed, 87.2% of the returning female seals utilise two or less of the sites, showing an extremely high level of fidelity to specific breeding locations. Exploring possible reasons for a change of site would further contribute to our understanding of the site fidelity behaviour discussed above. In some individual cases it is possible to make a plausible, although anecdotal, hypothesis for this behaviour; in the case of seal number 040, she bred at The Puddle in 2014 but lost the pup, and then moved to Grant's Harbour in 2015 where she successfully raised a pup that year and in three subsequent years. Thus, it could be hypothesised that her change of pupping site was driven by that reproductive failure in 2014. However, the data for other individuals is less instructive: seal number 062 has bred on the Calf four times, utilising a different site each time without evidence of causal factors such as deceased pups. Inexperience in reproduction may play a role in site selection, as well as timing of reproduction; arriving at the preferred pupping site to find it fully occupied and being forced to select another site. The lead-up to site selection can be tracked to a certain degree by photo-identification, for example a new seal added to the catalogue this year, number 307, was photographed heavily pregnant at Gibbdale Bay on 3rd October, and then gave birth to a pup at Cow Harbour the following day. Photo-identification also tracked the movements of seal 194 who had previously pupped three times at The Puddle, although her pup was recorded as deceased in 2019. She was sighted at The Puddle on 22nd September, at which point there was only one pup present at this site, however, she was recorded at neighbouring Mill Giau on 28th September where she successfully raised a pup to Stage 5 of development. Dedicated photo-identification and tracking between-site movement may continue to shed light on our understanding of these finer-scale reproductive behaviours.

Of the seals who have only reproduced once on the Calf of Man, 28.0% have been sighted without a pup in other years. This represents another area which would be interesting to explore further. Preliminary assessment of the data shows that some seals are visiting the Calf of Man in seasons preceding their commencement of breeding, suggesting they may be immature individuals yet to reach reproductive maturity. In other cases, however, the year(s) without a pup fall after reproductively successful seasons, perhaps implying an unsuccessful conception or pregnancy, or a miscarriage or stillbirth; areas of increasing interest given the pressures seals face from competition with fisheries and the potential impacts of disturbance. These are extremely difficult hypotheses to test; however, continued recording and potential future photo-identification of the pups born on the Calf may allow better understanding of the first of these scenarios at least, identifying immature seals who may be returning to their natal sites in the years preceding their own pupping.

In addition to site fidelity, research has explored the timing of individual seal reproduction, another possible avenue for analysis within the Calf data set. Synchronisation in birthdate has been shown in seals on North Rona (Anderson *et al.,* 1975), although variation of up to 45 days between years has been recorded at the Sable Island colony (Bowen *et al.,* 2020). These patterns are of increasing relevance in relation to possible impacts of climate change, with mean birthdates on Sable Island advancing by 15 days over 27 years of study (Bowen *et al.,* 2020). Determination of birthdates is possible in most cases within the Calf data set with a margin of error of one day[9] and some initial organisation and compilation of this data was initiated this season. This was embarked on before later corrections and additions to the female seal catalogue (and lacks the 2020 survey data), so needs checking and updating to ensure the data is correct and complete. However, preliminary analysis shows a mean variation of 15.3 days in the birthdates of the breeding seals on the Calf from 2019 – 2009, with a number of seals giving birth on exactly the same day each season across multiple years, or only varying by 1 – 3 days. Other seals, however, can vary by up to 37 days (although, interesting this female has pupped in five consecutive years and the birthdates have become increasingly aligned over this time, with only one day's variation between their most recent recorded pupping in 2018 and 2019). It would be possible to compare this variation in dates to the reproductive parity of the seals to test for the effect on experience on consistency in birthdate, and it would also be possible to gauge how these mean birthdates have varied since 2019 to see whether the observations at Sable Island are also evident on the Calf of Man. There may be additional hypotheses to explore within this data, and it provides another potential wealth of information that

[9] As sites are visited every other day, a pup might not be recorded until a day after its birth. Birthdate can be confirmed by the presence of blood or placenta and is only logged on the spreadsheet if these are present.

should be analysed to ensure the maximum knowledge can be gained from the breadth of data recorded over the past 12 years. Knowledge of the approximate date within the survey that a specific female is likely to pup may also help with photo-identification, allowing for a suggested subset of the images to be considered first in order to speed up the photo-matching process when identifying a mother.

Unmatched pups and mothers

22.6% of the pups recorded on the Calf of Man in the 2020 breeding season were not linked to an adult female, leaving a significant gap in the data set in relation to these 'missing' mothers, for example in the long-term tracking of returning seals and site fidelity. However, while it may not have been possible to confirm positively a filial relationship (i.e. through birth or suckling), there were often additional female seals that were hauled-out at the pupping sites who showed evidence of having given birth or suckled pups this season. In some cases, this was due to the presence of blood suggesting recent parturition and in others, due to a seal presenting her nipples or showing evidence of worn or bleeding nipples suggestive of suckling (Figure 24). In future, these seals could also be recorded (detailed location and date) and identified, if possible, via the photo-identification catalogue. They could then be logged and analysed as potentially having given birth that season, allowing their inclusion in the data set with appropriate caveats regarding the lack of confirmation of a pup. This may allow for explanation of years where returning seals seem to have 'gaps' in their reproductive history; it may simply be that they were not matched to a pup that year rather than their failure to return to the Calf or to produce a pup.

Figure 24. Female photographed presenting her nipples in preparation for her pup to approach and suckle (left side) and additional female showing blood around her reproductive tract suggestive of recent parturition (right side). Photographs taken at Smuggler's Cave (left) and Cow Harbour (right) (Manx Wildlife Trust, 2020).

Remote camera technology

Cameras were set up at four sites over the course of the survey (Table 2), varying their distance from the seals and their method of photography (motion-sensor or timer). The outcomes of these trials are summarised in Table 9; however, the main conclusions were confirmation of the necessity for the camera to be in close proximity to the seals to gain clear photographs of their unique pelage markings, and the use of a timer set to capture regular photographs during daylight hours being more useful than images triggered by the motion sensor. In the motion sensor setting, the movement of the seals did not seem to trigger the camera and thus it was primarily the movement of roosting birds at night that generated images. Combining the proximity of the camera at Grant's Harbour with the timer setting of the camera at The Puddle would provide an ideal set-up for the use of camera traps in future surveys. If a number of cameras could be installed just prior to the breeding season in areas that are challenging to photograph, or where it would be useful to collect a more complete set of photographs for behavioural analysis, this could prove an interesting avenue for the use of remote technology with minimal animal disturbance in future years.

Indeed, certain pupping sites remain incredibly difficult to photograph in person. Smugglers Cave is repeatedly mentioned by seal survey teams as one of the most challenging locations due to the low light conditions and the steep cliffs surrounding the caves which prevent the photographer from getting close to the pupping sites on foot. Varying the camera set-up, such as using a slow shutter speed, did facilitate some improvement in photograph quality, however the challenges of direct sunlight, high winds and wet weather proved problematic regardless. It was very difficult to determine whether pups were present in the caves until they were old and mobile enough to move closer to the sea or begin swimming. Baie Fine and Gibbdale Bay also presented challenges: the seal haul-out platforms are a considerable distance from the viewing and photography points above, and the seals can move into the rocks and small caves taking them (and their pups) completely out of sight from the land. As a result, 57% of the mothers that remained unidentified at the end of the survey were from Smugglers Cave, Baie Fine and Gibbdale. Accessing these sites, perhaps by boat or kayak, prior to the breeding season and determining the feasibility of setting up camera traps presents an interesting possible solution that could be trialled in future years. Planning for their retrieval at the end of the season would also be necessary. Although a camera trap was set up at the main Grant's Harbour inlet, it was actually the smaller inlets that were more challenging to photograph, thus they represent another (more accessible) option for future camera trap use. Overall, it can be concluded that camera traps do present a workable method of collecting a

considerable volume of data (for identification and behaviour) with minimal seal disturbance and minimal input of time and effort from the survey team.

Impact of observed disturbance

The extent and impact of human disturbance on the breeding seals was an area of increasing concern for the survey team this season. With good weather extending throughout much of September and into October, there were a high number of day visitors during this time, with 48 visitors recorded on the 18th October, by which point there had been 46 successful seal births around the island. There are a range of documented negative impacts of human disturbance on seals (see pages 17 – 18 of this report), and examples of distressed mothers and cases of abandonment were observed on the Calf this season. While many day visitors behaved responsibly, there were observed instances of disruptive behaviour, often in order to take photographs, eliciting vocalisations from the mothers or flushing hauled-out seals back into the sea. In many cases, the visitors seemed unaware and unconcerned as to the consequences of their actions.

Disturbance concerns centred on South Harbour, and to a lesser extent Cow Harbour and Grant's Harbour, due to their use for boat landings to drop off and collect visitors or supply food and provisions. South Harbour does seem to have a much lower pup density than would be expected for its size, although whether this is due to the human disturbance or a combination of various factors is difficult to determine. In addition, the females that have pupped at South Harbour appear to show a slightly different pattern of site fidelity when compared to trends at the rest of the pupping sites (see Appendix D for data and comparative graph). Notably, a much higher percentage of seals have only pupped once at South Harbour (78.9% compared to a mean of 49.7% at the other 11 sites), and fewer have returned for two breeding seasons. Only two seals have chosen to return to South Harbour for more than two seasons (one for four seasons and one for seven seasons[10]); apart from this, it would appear that seals only use this site for pupping on one occasion and seem to be put off from returning in future years. Further analysis is needed to explore these trends, including considering whether these seals subsequently relocate to different pupping sites or do not return to the Calf at all. Looking at the catalogue histories of the seals in question, over half of them have not been observed on the Calf subsequent to their one pupping season at South Harbour. However, a small number, such as catalogue number 049, have simply relocated to a different pupping site: this

[10] This may be attributable to differences in individual personality as recently explored by Twiss *et al.,* (2012); Twiss *et al.,*(2020), depending on the seal's placement on the pro-reactivity axis.

particular female pupped at South Harbour in 2011, but then returned to either Mill Giau or Grant's Harbour for a further six breeding seasons. It is also important to note that there are six additional females who have pupped at South Harbour over this period who have not been identified or assigned a catalogue number. Given the size of the data set, this is a significant number and their site fidelity behaviour may have the potential to alter the trends observed. Nonetheless the available data should not be overlooked, particularly in relation to the suggestion that females are choosing not to return to South Harbour to breed. If human disturbance is a factor in this, then mitigating and reducing it to the lowest possible levels must be a priority. South Harbour is a large and sheltered site which seals should have the opportunity to utilise for successful breeding.

At Cow Harbour and Grant's Harbour, the majority of disturbance was limited to one specific occasion, with 42 visitors landing and returning via boat at Grant's Harbour in late October. On this day, 46% of the pups at these sites were unaccounted for, and 38% fewer adults were observed along this section of coastline compared to the previous survey count. Two of the mothers at Grant's Harbour remained unaccounted for in all subsequent site visits, suggesting they abandoned their pups at this point: this is a significant and highly concerning possible impact of the day visitor landings. It is vital that this issue is addressed and mitigation strategies are discussed and established. A balance must be found between allowing visitors to experience the beauty and nature of the Calf of Man, but achieving this goal in a sustainable and sensible way, with no negative impact on the seals (or other organisms present on and around the island).

The final area of disturbance considered by the survey team focused on the estate management activities that brought wardens and volunteers in close proximity to the breeding seals. With advance planning, it may be possible to avoid many of these situations, for example collecting stones for track repairs earlier in the season and storing them until needed, however, other aspects of estate management that respond to situations as they arise are impossible to avoid. However, it is still important to ensure these activities are carried out quickly and quietly so as to cause minimal disturbance. In addition, as discussed earlier, there is a need for extensive beach cleans of the pupping sites and inlets in August to avoid the hazards observed this season in relation to large quantities of litter present around the coastline.

Allo-suckling

During this year's survey, one instance of allo-suckling was confirmed and documented on 18th October (Figure 22), where a female seal at The Puddle (catalogue number 119) suckled a non-filial

pup (Vim) in addition to her own (Vans). It was suspected that this behaviour had taken place on other occasions, but it was challenging to confirm due to the similarity between the pups who were, at that stage, still showing their white natal coats. The non-filial pup had previously been linked with seal number 257, who had pupped on 10th October, four days after seal number 119, and had been observed suckling her pup. However, this female was not positively identified by the survey team after 10th October, whereas seal number 119 continued to be observed at the site until the confirmed allo-suckling on 18th October, after which she was also not subsequently identified at this site. The non-filial pup, Vim, appeared to grow more slowly than other pups of a similar age and it was assumed that female 257 had abandoned it. Whether this abandonment took place before or after the allo-suckling was not clear. Allo-suckling, while documented in grey seals at other sites (McCulloch *et al.,* 1999), is a poorly understood seal behaviour. Five hypotheses for its existence are reviewed by Roulin (2002) and their relevance to the observed instance of all-suckling on the Calf is discussed in Table 11.

Hypothesis	Relevance to allo-suckling event on Calf of Man
Misguided parental behaviour	No evidence to support or refute (however, this is the most attractive explanation in the absence of evidence to support any benefit to this behaviour).
Females reciprocate by nursing each other's offspring	No evidence of reciprocal allo-suckling was observed by the survey team.
Females nurse related juveniles for inclusive fitness benefits	The genetic relationship between seal numbers 119 and 257 is unknown, and it is also unknown whether there is any paternal link between the two pups, therefore it is impossible to assess this hypothesis on current evidence.
Females nurse unrelated offspring to evacuate surplus milk	It is difficult to assess this hypothesis, however, given that neither pup was weaned, it is unlikely that female 119 had surplus milk. Her own pup was only 12 days old on the date the allo-suckling was confirmed, therefore should have continued to require milk for another 6-13 days.
Inexperienced females that have lactated spontaneously or lost their own offspring nurse unrelated offspring to improve their maternal skills	Neither female was inexperienced (119 reproduced at Mill Giau in 2018 and 2019; 257 reproduced at The Puddle in 2016 and 2018) and neither had lost their own offspring on this occasion, thus this hypothesis holds no relevance.

Table 11. Discussion of the allo-suckling event on the Calf of Man in relation to hypotheses for these behaviours presented and reviewed in Roulin (2002).

In his review, Roulin (2002), finds evidence in support of misguided behaviour, reciprocal behaviour and surplus milk evacuation, however also acknowledges that the hypotheses are not mutually exclusive and their explanations are more intricate than first assumed. In addition, studies in Stellar sea lions have most commonly observed allo-suckling at sites with a high density of pups and in primiparous females (Maniscalo *et al*., 2007). However, only five pups were present in this area of The Puddle on the date that the allo-suckling was confirmed, and both of the mothers (119 and 257) have pupped on the Calf previously (although this season is the first season they have both pupped at The Puddle). The outcome for the two pups, Vans and Vim, was also unclear as the survey team were unable to identify them individually and track them through the five stages of development. Subsequent to the 18th October, they were not observed in close contact with adult seals (which allows identification of the pup via the mother's unique pelage), and no photographs were taken with evidence of their own adult-like pelage markings. Thus, it is impossible to draw conclusions as to the positive or negative outcome of this particular allo-suckling behaviour in relation to pup growth, development and survival. More research is needed to understand and explain both the drivers and consequences of this seemingly maladaptive behaviour.

Allo-suckling was also observed in the 2019 survey at Cow Harbour, and the relevant survey team raised the issue of using suckling interactions to determine mother-pup relationships (Andrew *et al.,* 2019). Allo-suckling events may certainly add confusion to this process but, at present, it seems to occur on a very low scale within the breeding population so should not have a significant impact on overall determination of filial relationships. However, the behaviour has now been recorded in two consecutive surveys, thus is a behaviour that future teams should be aware of and look out for in future data collection. Further recording and analysis of allo-suckling on the Calf of Man will contribute to our compilation of information on this behaviour and potentially allow for clearer discussion of its causes and outcomes.

Future recommendations

Consideration of the data collected during the survey, alongside qualitative observations and additional avenues of analysis and exploration, has facilitated the compilation of a list of recommendations for future seal breeding surveys (Table 12). These recommendations are primarily aimed at making the process of data collection more efficient and accurate, as well as further limiting the negative impact of human disturbance on the breeding seals. Many of these points have been discussed within the relevant sections of this report, and any remaining suggestions are outlined below.

Area of relevance	Specific recommendations
Data collection	Continuation of an early arrival on the Calf of Man to capture the start of the breeding season
	Possible post-survey visits to record and photograph remaining seal pups
	Waterproof case for camera for use in wet weather (case purchased and donated to Manx Wildlife Trust by survey team)
	Possible purchasing of a camera lens better suited to taking high-quality seal photos from a distance e.g. telephoto zoom lens, super zoom lens
	Continued creation of catalogue of left- and right-side photographs of moulted seal pups for future natal philopatry identification (and review of past surveys to collate existing photographs)
	Inclusion of females showing evidence of suckling (e.g. presenting nipples) as seals that likely reproduced during the season (even if no pup can be definitively linked to them)
	Continued trialling of remote camera technology at various hard-to-access sites, set for timed photo capture in daylight hours
	Recording of more detailed information on adult distribution at each pupping site e.g. number of males and females, hauled-out versus swimming etc. to facilitate more nuanced analysis
Current data analysis	More efficient use of hard-drive – only have one copy of catalogue photographs to prevent slowing down of drive response time
	Use of two laptops by the survey team during time on the Calf to maximise data analysis efficiency (a personal laptop was used by one of the team this year which allowed the surveyors to work independently)
	Continued review and correction of photo-identification catalogue, including a 'best photo' section for easy comparison
	Full review and organisation of the male photo-identification catalogue and checking for inaccuracies in data set to make this a more reliable and useful aspect of data analysis in future surveys
	Formalise photo-identification process with specific guidance for confirming a positive match (e.g. see guidance in Sayer *et al.,* 2019)
	Continuation of new spreadsheet logging pupping sites for each catalogued seal to predict most likely mothers at each site, narrowing down options during initial search for photo-identification matches
Additional data analysis possibilities	Investigate possible use of pup numbers to estimate Calf of Man grey seal population size to gain a clearer understanding of the adult population (may be applicable on the Isle of Man as well)
	Review of how pup development is assessed and recorded, possibly incorporating systems such as in place on Skomer (see page 47)
	Continued analysis of existing data to identify patterns in birthdates and possible factors affecting birthdates, including climate change
	Implementation of a similar seal breeding survey on the Isle of Man to begin to understand the breeding season and seal population in this location and allow sharing of data with the Calf to identify possible pup movements between islands

	Wider sharing and publication of current data set to contribute to and take part in discussion and research publications regarding population structure and dynamics in Irish Sea region
	Re-engagement with EIRPHOT database[11]
	Investigation of possibility of flipper tagging or satellite tagging of adult seals or pups to track wider movements and pup dispersal patterns
	Exploration and ideas generation for additional hypotheses that could be tested on the Calf of Man (either during the seal survey or as additional data collection projects) e.g. investigating site fidelity hypotheses
Limiting disturbance	Review policy for use of Grant's Harbour for boat landings during seal breeding season
	Temporary signage placed at key sites during breeding season to make visitors aware of appropriate behaviour (i.e. sites where day visitors come in close contact with the breeding seals due to position of path etc.)
	Briefing given on board boat prior to landing on the Calf to inform and educate day visitors about the seal breeding season and appropriate protocols for maintaining a safe distance and minimising disturbance
	Advance planning of timing and execution of estate management activities to limit disturbance of breeding sites during Sept - Nov
Public involvement and education	Involvement of public in 'citizen science' contribution to the photo-identification catalogue e.g. boat users, kayakers, coastal walkers, divers (with appropriate briefing regarding photograph quality and suitable behaviour when in close proximity to grey seals)
	More formal engagement of day visitors with the survey team to educate and discuss seal breeding (supply the surveyors with MWT branded clothing e.g. hats to make them more recognisable)
	Litter picking at the seal breeding sites in the late summer prior to the breeding season (possibly engaging Beach Buddies as previously)

Table 12. Overview of recommendations for future Calf of Man seal breeding surveys.

[11] EIRPHOT is a dataset containing photographs of over 9,000 grey seals throughout the Irish and Celtic seas owned by Natural Resources Wales. The data was collected as part of seal monitoring to provide insights on site fidelity, movements, connectivity survival and longevity (Langley et al., 2020).

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Appendices

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	

Table 13. Details of the timings and recognition features of the five stages of grey seal pup development. Developed by Kovacs and Lavigne (1986); Radford et al., (1978).

Appendix B – Results of pup survey 2020

Pup Name (V)	Date first seen	DOB (if known)	Location	New location (if moved)	Mother ID	Suckling or birth observed
Valerie	09/09/2020		PU			N
Vic	09/09/2020		BF		120	Y
Vaila	09/09/2020		GI		019	N
Victoria	10/09/2020	10/09/2020	BF		-	N
Vlad	09/09/2020		SC		-	N
Vanish	09/09/2020		SC		-	N
Velma	19/09/2020		GI		309	Y
Vivian	20/09/2020	20/09/2020	SH		098	N
Voirrey	20/09/2020		LE		199	Y
Valentine	20/09/2020		PU		303	N
Vanilla	20/09/2020	20/09/2020	GL		248	Y
Vanessa	20/09/2020	20/09/2020	GL		305	Y
Vimto	21/09/2020	21/09/2020	MG		203	Y
Vinny	22/09/2020	22/09/2020	SC		299	Y
Vita	22/09/2020	22/09/2020	MG		181	Y
Volvo	22/09/2020		PU			N
Violet	24/09/2020	24/09/2020	GL		034	Y
Viking	24/09/2020	24/09/2020	SC		288	Y
Vernon	24/09/2020		SC		-	N
Verity	24/09/2020		SC		086	N
Valencia	24/09/2020		MG		265	Y
Vaughan	26/09/2020		GL		193	Y
Villanelle	26/09/2020		GL		046	Y
Venus	26/09/2020		MG		304	Y
Vannin	27/09/2020	26/09/2020	CH	SH 11/04/20	004	Y
Velvet	28/09/2020	28/09/2020	MG		194	Y
Venture	29/09/2020	29/09/2020	SC		308	N
Valiant	30/09/2020		PU		136	Y
Velcro	29/09/2020		BF			N
Vision	01/10/2020		GH		-	Y
Vegemite	01/10/2020		GH	Inlet to main GH	005	N
Vea	01/10/2020		CL		306	N
Violet	02/10/2020		MG		008	Y
Victorious	03/10/2020		GH		074	Y
Vanora	04/10/2020		SH		185	N
Vindaloo	04/10/2020	04/10/2020	CH		307	Y
Vaquita	05/10/2020		GH		196	Y
Vela	05/10/2020		CH		256	Y

Valen	05/10/2020		MG		150	Y
Veronica	06/10/2020		PU		095	Y
Vans	06/10/2020		PU		119	Y
Vera	07/10/2020		CH		014	Y
Valkyrie	07/10/2020		CH		-	N
Vino	07/10/2020		GH		007	N
Vim	10/10/2020	10/10/2020	PU		257	Y
Viva	11/10/2020		BF		240	N
Vixen	12/10/2020		LE		302	Y
Vada	16/10/2020	16/10/2020	PU		373	Y
Vegan	17/10/2020		GI			N
Vienna	15/10/2020		CH		376	N
Vegas	18/10/2020		Kione ny Halby			N
Varec	19/10/2020	19/10/2020	GI		310	Y
Vancouver	20/10/2020		PU		230	Y
Vinegar	21/10/2020		SH		294	Y
Vodka	27/10/2020		GH		360	Y
Voldemort	27/10/2020		CL		374	N
Vagabond	27/10/2020		SH		-	N
Viper	29/10/2020		CH		298	N
Voodoo	01/11/2020		SH		251	N
VoteBiden	02/11/2020		CH		377	Y
Valeera	03/11/2020		PU		-	N
Viscount	05/11/2020		PU		-	N

Table 14. Overview of the pups recorded on the Calf of Man in the 2020 breeding season. The complete spreadsheet including information on developmental stage timings can be found on the MWT hard drive.

Appendix C – Raw data

The data in this section relate to Figures 9 – 14.

Year	Number of pups recorded
2009	26
2010	36
2011	36
2012	42
2013	50
2014	52
2015	63
2016	84
2017	66
2018	64
2019	69
2020	62
Mean	**54.2**
Median	**57.0**

Table 15. Number of pups recorded on the Calf of Man each season, with the mean number calculated in the final row. Relates to Figure 9.

Week	Start date	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18	'19	Mean	'20
1	09/09	0	0	0	0	0	0	0	0	0	0	0	**0.0**	6
2	16/09	0	2	7	5	6	0	0	1	1	1	0	**2.1**	10
3	23/09	13	13	6	9	2	4	2	0	15	18	23	**9.5**	12
4	30/09	3	3	5	1	10	14	16	25	15	16	17	**11.4**	13
5	07/10	3	8	8	14	0	16	15	16	10	9	14	**10.3**	6
6	14/10	5	5	2	7	17	1	9	14	9	12	5	**7.8**	6
7	21/10	1	2	7	4	4	12	7	15	12	5	4	**6.6**	4
8	28/10	1	3	1	0	6	5	10	9	3	3	6	**4.3**	4
9	04/11	0	0	0	1	2	0	4	4	1	0	0	**1.1**	1
10	11/11	0	0	0	1	0	0	0	0	0	0	0	**0.1**	0
11	18/11	0	0	0	0	3	0	0	0	0	0	0	**0.3**	0

Table 16. Weekly number of pups recorded for the first time during the annual surveys. The mean number for 2009 – 2019 is calculated (in bold text) to act as a comparison to the 2020 data. Relates to Figure 10.

Year	Number confirmed dead	Percentage	Number tracked to Stage 5	Percentage
2009	2	7.7	4	15.4
2010	2	5.6	15	41.7
2011	0	0.0	11	30.6
2012	2	4.8	9	21.4
2013	1	2.0	12	24.0
2014	8	15.4	13	25.0
2015	2	3.2	25	39.7
2016	5	6.0	40	47.6
2017	2	3.0	20	30.3
2018	3	4.7	41	64.1
2019	3	4.3	32	46.4
2020	7	11.3	22	35.5
Mean		**5.7**		**35.1**

Table 17. The number and percentage of pups confirmed dead each year, and the number and percentage followed through to weaning (Stage 5). Mean percentages calculated in each case. Relates to Figure 11.

Site number	Number of pups	Location of site
1	4	Point (-4.81881641453639276 54.05909958058868625)
2	4	Point (-4.8133444159245613 54.05966636355664434)
3	1	Point (-4.80511718886037276 54.06122119083764943)
4	8	Point (-4.80241830104930045 54.06114626040074)
5	6	Point (-4.80166724241630405 54.06020165148064649)
6	2	Point (-4.79984324287902542 54.05864824787928313)
7	5	Point (-4.81221782797506492 54.04580945258238955)
8	11	Point (-4.81658112098580737 54.04667039532298389)
9	7	Point (-4.81965688491141186 54.04662839852993272)
10	2	Point (-4.82148088444868872 54.04574645607181793)
11	6	Point (-4.8238234720897033 54.04609293569825468)
12	7	Point (-4.82496794238760174 54.0489171618770925)

Table 18. The number of pups recorded at each site with the location of the site used for QGIS mapping in Figure 12.

Year	Pupping site code											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
2009	1	3	1	5	6	1	0	2	1	0	0	4
2010	0	2	0	8	9	0	1	2	2	3	4	5
2011	3	1	0	7	11	1	1	3	0	0	4	5
2012	3	2	0	6	7	3	1	3	3	1	5	7
2013	2	1	0	11	12	3	3	8	1	2	3	4
2014	4	4	0	8	7	0	3	10	1	4	6	5
2015	8	5	0	6	12	0	3	12	6	3	7	1
2016	1	6	2	10	11	10	6	16	10	2	5	3
2017	1	3	1	9	14	0	5	16	8	3	3	3
2018	2	3	0	11	11	0	4	8	11	3	5	6
2019	4	3	0	14	10	3	7	10	8	2	4	4
Mean	**2.6**	**3.0**	**0.4**	**8.6**	**10.0**	**1.9**	**3.1**	**8.2**	**4.6**	**2.1**	**4.2**	**4.3**
2020	4	4	0	8	6	2	5	11	7	2	7	5

Table 19. Number of pups recorded at each of the 12 recognised pupping sites from 2009 – 2020. The mean for 2009 – 2019 is calculated. Relates to Figure 13.

Site number	Mean number of adults	Location of site
1	2.9	Point (-4.81881641453639276 54.05909958058868625)
2	3.1	Point (-4.8133444159245613 54.05966636355664434)
3	5.1	Point (-4.80511718886037276 54.06122119083764943)
4	19.6	Point (-4.80241830104930045 54.06114626040074)
5	8.8	Point (-4.80166724241630405 54.06020165148064649)
6	30.6	Point (-4.79984324287902542 54.05864824787928313)
7	7.5	Point (-4.81221782797506492 54.04580945258238955)
8	22.2	Point (-4.81658112098580737 54.04667039532298389)
9	4.9	Point (-4.81965688491141186 54.04662839852993272)
10	2.2	Point (-4.82148088444868872 54.04574645607181793)
11	3.0	Point (-4.8238234720897033 54.04609293569825468)
12	3.0	Point (-4.82496794238760174 54.0489171618770925)

Table 20. The mean number of adults recorded at each site over the duration of the survey with the location of the site used for QGIS mapping in Figure 14.

Appendix D – Additional data analysis

Number of seasons	Number of seals at SH	% of seals at SH	Number of seals at other 11 sites	% of seals at other 11 sites
1	15	78.9	89	49.7
2	2	10.5	33	18.4
3	0	0.0	15	8.4
4	1	5.3	17	9.5
5	0	0.0	11	6.1
6	0	0.0	5	2.8
7	1	5.3	1	0.6
8	0	0.0	0	0.0
9	0	0.0	1	0.6
10	0	0.0	6	3.4
11	0	0.0	1	0.6

Table 21. Comparison of site fidelity trends at South Harbour and the other pupping sites on the Calf, showing the number of seasons a female seal has returned to breed at South Harbour and at the other 11 pupping sites.

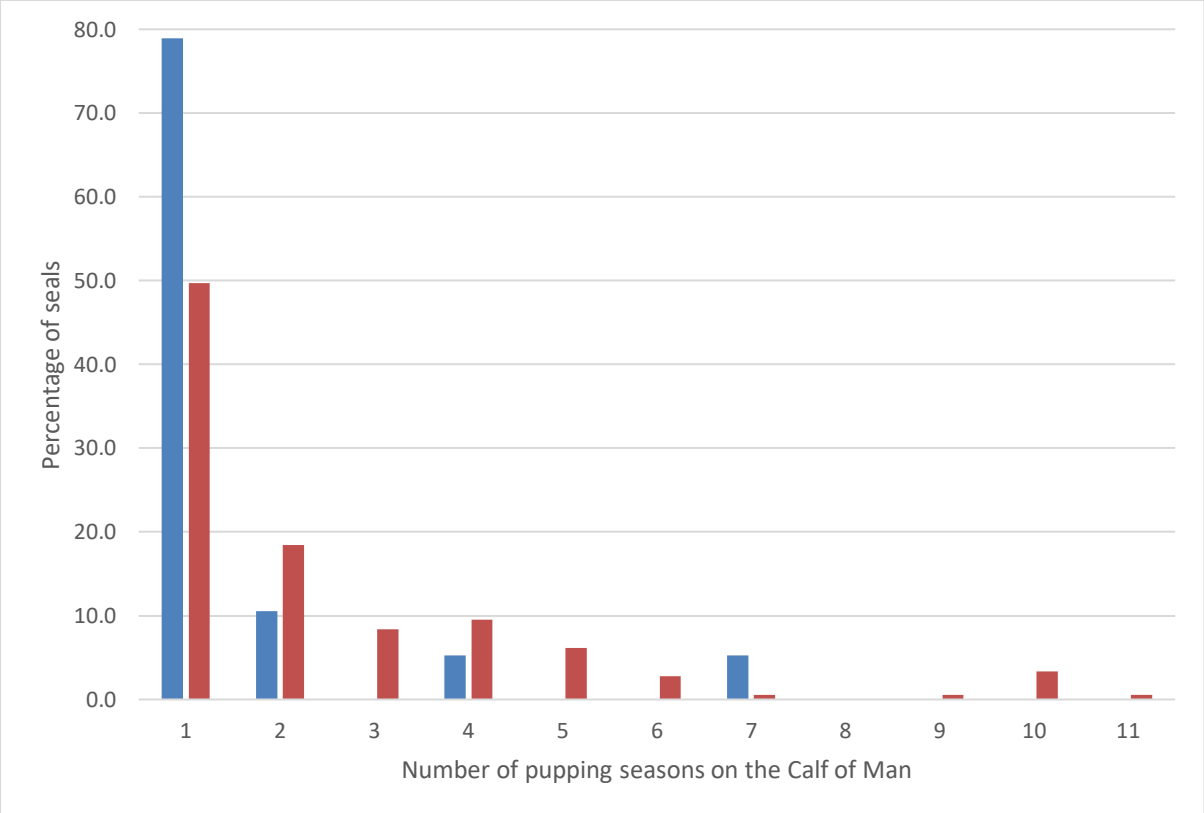

Figure 25. Comparison of site fidelity trends at South Harbour and the other pupping sites on the Calf. The number of seasons a seal has returned to South Harbour to reproduce is shown as a percentage (blue), alongside the mean percentage for the other 11 sites (red).

Site	Number of pups observed	Development stages
Cow Harbour	3	5
Grant's Harbour	2	5
The Puddle	2	4 - 5
Total	**7**	

Table 22. Counts of the additional pups photographed during the post-survey visit of the Calf on 29th November 2020. The stage of development (1 – 5) of the pups is also recorded.

Figure 26. Photograph of dead seal on the sea floor at South Harbour taken on the post-survey visit 29th November 2020. No successful matches with the photo-identification catalogue were achieved.

Appendix E – Glossary of terms

Term	Definition
Allo-suckling	When a female feeds a pup that is not her own offspring.
Blastocyst	A pre-embryonic structure in the development of mammals.
Endocrine	Relating to the hormones and hormone-producing glands.
Fecundity	The capability of an individual or population to produce offspring.
Filial relationship	A link between the parent and their direct offspring.
Hauled-out	When seals come out of the water and spend time on dry platforms.
Lanugo	The white hair that covers seal pups before their first moulting.
Moulting	When seals shed their hair and replace it with a new growth of hair.
Natal philopatry	When a seal remains in or habitually returns to their location of birth.
Parity	The number of times a female has given birth.
Parturition	The process of labour and delivery of offspring.
Pelage	The hair covering a seal's body.
Pelagic	Living in or frequenting the open ocean.
Phocid	One of the three main groups within the seal lineage.
Phocidae	The taxonomic family that consists of the earless, or true, seals.
Pinnipeds	The diverse group of all seals varieties that includes the Phocids.
Scats	Seal faeces (analysed to gather data on behaviour, life history etc.)
Sexually dimorphic	Differences between males and females of the same species.
Site fidelity	The tendency to stay within or habitually return to a specific location.
Subspecies	Different populations of the same species showing some variation.
Vagrants	Individuals that appear well outside their normal geographic range.