A photo-identification study of the Atlantic grey seal (*Halichoerus grypus*) at haul-outs along the coast of Cardigan Bay SAC

A dissertation submitted in partial fulfilment of the requirements for the degree of Master of Science (MSc) in Marine Biology
Bangor University

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Submitted in September, 2017.

In association with:

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A photo-identification study of the Atlantic grey seal (*Halichoerus grypus*) at haul-outs along the coast of Cardigan Bay SAC

Stephanie Rachel Byford, 2017

Abstract

Few studies have been conducted on grey seal populations at haul-out sites along the coast of Cardigan Bay SAC, which limits the knowledge of the biological aspects associated with these small populations. The primary objective was to obtain high quality images of the Atlantic grey seal and use them in photo-identification analysis to investigate intra-specific interactions to address the hypotheses that a) male and female Atlantic grey seals show haul-out site fidelity, b) abundance, haul-out behaviour and site fidelity of grey seals are influenced by environmental conditions and c) the population structure of grey seals is similar at each haul-out site. Boat and land-based surveys that obtained photographs as well as biological and environmental data, were conducted between June and July 2017 at haul-out sites along the coast of Cardigan Bay SAC. Out of the 46 individuals identified, only 26% were re-sighted. The abundance, behaviour and site fidelity of grey seals were not solely influenced by the environmental factors. The populations of grey seals followed traditional population structures corresponding to larger colonies. This study was limited by the time constraints and its conclusion prior to the breeding season. This may have influenced the results by limiting the number of grey seals that were able to be identified, along with the environmental conditions that were restricted to marginal differences. Increasing the duration of the study period may allow the opportunity to identify larger numbers of individuals, gain further understanding of the population structure and identify whether substantial changes in environmental conditions influence the abundance, behaviour and site fidelity of grey seals. This study served as a starting point for future studies that can compare findings, and accumulate re-sightings data, as well as suggesting the need for further conservation and monitoring of grey seal populations along the coast of Cardigan Bay SAC.

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CD-Rom containing:

- Boat-based survey data for each entire survey as well as grey seal sightings data collected from June to July 2017.
- Land-based survey data for each entire survey, grey seal sightings as well as behavioural observation data collected from June to July 2017.
- A photo-identification catalogue of 46 grey seals identified at haul-out sites along the coast of Cardigan Bay SAC with accompanying information.
- A copy of this thesis as a Microsoft Word document.

Acknowledgements

I am incredibly grateful to my supervisors' Dr Peter Evans and Professor Chris Richardson for all of their advice, guidance and support throughout this study, as well as being given a fantastic opportunity which I have thoroughly enjoyed. Additional thanks to my field supervisor Katrin Lohrengel, who assisted me during the surveying period of this study and arranged a number of surveying opportunities, which otherwise would not have been possible. Further thanks to the Dolphin Spotting Boat Trips, for allowing me to conduct surveys on their boats and to the Cardigan Island Coastal Farm Park, for granting me access to conduct land-based surveys. I would also like to thank my mum and dad for their unwavering support and motivation which has been crucial throughout this study. In addition, I would like to thank my sister Danielle and Chris Clarkson for supporting me during periods of tough times and always being there to keep me going. Thanks also to all my friends, especially Ewan Byers, Lee Stevenson, Grace Rodgers and all of the Sea Watch Foundation volunteers, for their constant motivation as well as making sure that I relaxed and enjoyed myself. Finally, I would like to say a special thanks to Dafydd Lewis for his encouragement, and willingness to provide additional photographs and data as well as always being able to make me laugh and ensuring that I had plenty of coffee to keep going during long days of surveying.

Glossary and abbreviations

Anthropogenic impacts	Disturbance or effects caused by human activities
Matrillines	Ancestral line descending from a female matriarch
Haul-out	A behaviour involving moving out of the water to spend a period of time on land
Parturition	The act of giving birth to young
Philanthropic	A generous or selfless behaviour that benefits others
Polygynous	Males that mate with more than one female
Site Fidelity	Remaining faithful to one haul-out site by returning intra-seasonally and/or annually
Tenure	Occupying and holding territory at a specific haul-out site
GLM	General linear model
SAC	Special Area of Conservation
VPB	Visitor Passenger Boat

1. Introduction

1.1. Grey seal morphology, worldwide distribution and abundance

The grey seal (*Halichoerus grypus*) is one of 19 species that belong to the family Phocidae (true seals), commonly known as the "earless" seals for the reason that the species in this family lack external pinnae (Lockley, 1966; Bonner, 1981). They also have shorter furred fore-flippers and restricted mobility on land from non-rotatable hind-flippers (Martin & Reeves, 2002). However, grey seals are able to produce fast and agile swimming movements due to their streamlined, fusiform body-shape (Bonner, 1981; Bowen *et al.,* 2003), as well as having a thick subcutaneous layer of blubber which offers insulation, the protection of internal organs, and assisting hydro-dynamic locomotion (Worthy, 1991; Martin & Reeves, 2002). Its broad roman shaped nose and wide spread nostrils (Miller & Boness, 1979) make it morphologically distinguishable from other Phocidae species, such as the harbour seal (*Phoca vitulina*), which by comparison has a small narrow nose with closely set "v" shaped nostrils. Grey seals are sexually dimorphic, where males (bulls) can grow to 2.1m-2.3m in length and weigh between 240kg-298kg as well as being typically darker in colouration (Figure 1a). By comparison females (cows) are smaller in size reaching between 1.8m-2m in length and 174kg-207kg in weight. Furthermore, females are lighter in colouration with contrasting darker pelage patterns (Figure 1b), and the dorsal side is commonly darker compared to the ventral side (Ralls, 1977; Lindenfors *et al.,* 2002; Beck *et al.,* 2003; Klimova *et al.,* 2014). Additionally, male grey seals can live for more than 20 years, whilst females can live for more than 30 years (Beck *et al.,* 2007).

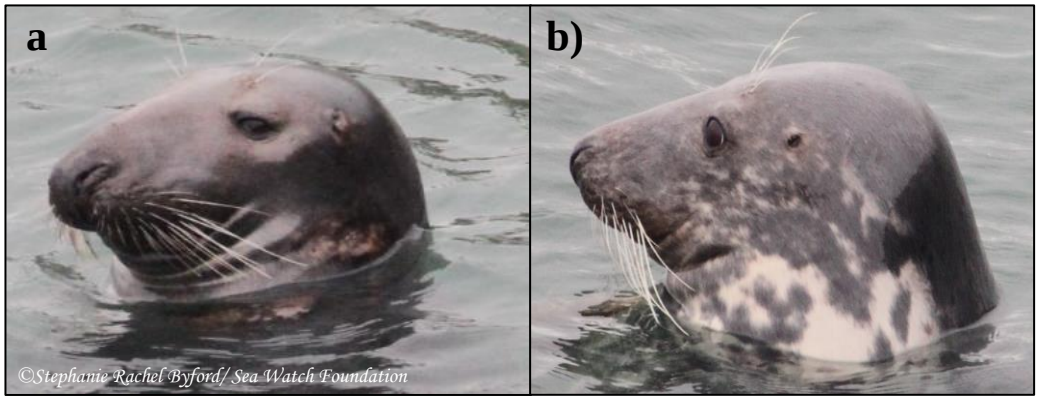

Figure 1. Photographs of a) male grey seal (*H. grypus*) with characteristic dark colouration and scarring on the neck region and b) female grey seal (*H. grypus*) with characteristic lighter colouration and dark pelage patterns at Cardigan Island in July 2017.

There are three geographically isolated populations of grey seals: 1) The Eastern Atlantic population, being the largest population of grey seals accounting for approximately 45% of the worldwide population, is located around the coast of the UK, Ireland, and with smaller aggregations along the northern coast of Europe, Iceland and the Faroe Islands (SCOS, 2016), 2) The Western Atlantic population, situated along the north eastern coast of the United States and into southern Canada (Cameron, 1967), and 3) The Baltic population, which is restricted to the Baltic Sea (Harding & Härkönen, 1999). These three populations form a total estimated population size of between 400,000 to 600,000 worldwide, with all three estimated to be increasing in population size, with the most significant increase to be found in the North Sea population with an increase of 4% p.a. (Bowen, 2016; SCOS, 2016).

1.2. Grey seal biology

1.2.1. Annual life cycle

Breeding Season

The timing of the breeding season will vary depending on the population of grey seals. The season commences from early September through to late December for the eastern Atlantic population, late December until mid-late February for the western Atlantic population, and late February to March for the Baltic population (Hook & Johnels, 1972; Anderson *et al.*, 1975; Boness & James, 1979). Grey seals are capital breeders and therefore do not feed whilst breeding, but instead rely on the fat reserves that have accumulated prior to the start of the breeding season (Anderson *et al.*, 1975; Beck *et al.*, 2003). The breeding season involves parturition with post-natal care, followed by mating which usually takes place separately involving three main phases, as described by Hewer (1957). The first phase commences during the first few weeks of the breeding season, where a steady increase of seals appear at the haul-out sites. Depending on the population, the females may appear first (Hewer, 1957; Anderson, 1975) or a few males may arrive at the haul-out site first (Twiss *et al.*, 1994). This is dependent on the haul-out site itself, as the territories of males vary from a traditional linear fashion with females positioned along a long narrow beach (Amos *et al.*, 1993; Harrison *et al.*, 2006), to territories where females are scattered two-dimensionally across island swards (Pomeroy *et al.*, 1994). Alternatively, the male territories can consist of bays and caves along a stretch of coastline that has several inlets with only a few females found in each (Davies, 1949). However, females usually appear first if they are heavily pregnant as they require flat beached areas to give birth, and the whole parturition period is confined to the beach with the

female not moving back into the water during this time (Fogden, 1971). Over the next seven to ten days, the number hauling out will increase and some may begin to pup. In addition, conflicts between males with regards to territory will begin with the defeated individual leaving the colony and the remaining few males taking up their claimed territory. The second phase is approximately two to three weeks long and consists of an increase in the rate of females pupping as well as dominant males establishing territories. The pups are born with a thick white coat and remain with their mother for the entirety of the lactation phase, depending entirely on the high fat milk produced by the mother (Boyd & Laws, 1962; Lang *et al.*, 2011). Hence, the lactation stage is an important phase that may determine the survival of the pup, as insufficient milk production may result in the pup not surviving long after the post-weaning phase (Hall *et al.*, 2001). This phase has also been suggested as the reason behind the low survival rate of grey seal pups (Summers *et al.*, 1975; Harwood & Prime, 1978). The final phase of the breeding season shows the peak of copulation which most commonly takes place in the sea, mainly underwater. Grey seals are polygynous, and therefore this will usually involve the mating of several females with one male, with the male being the dominant individual in the colony that has tenured territory. Male grey seals can reach sexual maturity at the of age six years, but at this age they will not usually be able to mate successfully due to being outcompeted by older, stronger males (Anderson & Fedak, 1985; Godsell, 1991; Lidgard *et al.*, 2005). In comparison, female grey seals reach sexual maturity at the age of three to five years, and it has been suggested that the later age of maturity may result in a higher chance of pup survival (through further growth of the mother), which in turn results in a greater allocation of resources towards milk production (Bowen *et al.*, 2006). During this phase, the pup will begin to moult its white fur and produce a shorter darker coat (Boyd & Laws, 1962), and rely on the fat reserves produced during the lactation phase for a period of three to four weeks before transitioning to independent feeding and moving into the sea to forage (Noren *et al.*, 2008).

Moulting Season

The annual grey seal moult commences in the spring, approximately three to five months after the breeding season has concluded, and lasts for between one to three months (Davies, 1957; Boily, 1995). This period involves the shedding of the fur grown throughout the year and the renewal of new fur which is essential for maintaining thermal regulation (Leeney *et al.*, 2010). The grey seal moulting season occurs on land as this has been suggested to enhance the process, and for this reason the number of grey seals hauled-out is greatest at this time

compared to any other time of the year (Schop *et al*., 2017). When grey seals are hauled-out during the moulting phase, it reduces the time available for other crucial activities such as foraging and/or movements to new areas, and thus this is an energy reducing activity that may increase the risk of predation (Boily, 1995). There has been limited effort made to conduct studies during the moulting season of the grey seal and therefore the behaviour and movements of grey seals during this season is relatively unknown. However, it has been proposed that the annual moult occurs in sequence of age-sex classes, potentially due to the reproductive cycle and individual body condition, with juveniles moulting first, then adult females, and lastly adult males (Daniel *et al*., 2003; Cronin *et al*., 2014). There is considerable variation between the onset of the moulting season where Schop *et al*. (2017) observed a difference of 28 days between the commencing of the moult of grey seals in the Wadden Sea over two years, suggesting that this variability may be associated with a variation between individuals and the population structure of grey seals at the haul-out site.

Foraging

After the two main haul-out periods during the breeding and moulting seasons, grey seals will relocate back into the water to explore new areas and to predominately partake in foraging activities. These foraging activities are crucial for the survival of grey seals as they are needed to replace the energy reserves lost whilst fasting during the breeding and moulting seasons (Anderson & Harwood, 1985). Furthermore, the reproductive success as well as the survival of the offspring may also be determined by the level of fat reserves produced during foraging activities. Grey seals feed on a variety of fish and are known to feed on anything they are able to obtain. However, their diet is most commonly composed of benthic and demersal species, such as sandeels (*Ammodytes* spp.), cod (*Gadus morhua*) and flounders (e.g. *Platichthys flesus*) (Hammond *et al.,* 1994; Ridoux *et al.,* 2007), where short duration dives were proposed to be associated with foraging activities for the reason that the majority of the dive time spent during short dives was near to the sea bed (Thompson *et al.,* 1991). Foraging activities can take place near to haul-out sites or in offshore waters and are dependent on the individual. Some individuals travel long distances of >100km from their previous haul-out site, or travel short localised distances remaining close to their haul-out sites (McConnell *et al.,* 1999). These short movements are usually associated with the food resources available, as large numbers of individuals are known to remain near haul-out sites where there is a high abundance of prey species (Thompson *et al*., 1991; Sjöberg & Ball, 2000). Furthermore, another benefit of foraging near haul-out sites is that less energy is expended than that used

whilst migrating to new areas, and this energy saving can instead be reserved for periods of fasting during the breeding and moulting seasons (McConnell *et al.,* 1999; Cardinale *et al.,* 2003).

1.2.2. Haul-out site use vs breeding sites

The use of a haul-out site is determined by a variety of factors that are specific to the annual life cycle phase that is occurring during that time. For example, during periods between the main breeding and moulting seasons, grey seals will not haul-out for long durations as they need to partake in more vital activities such as foraging, and will therefore only usually haul-out for thermoregulation, periods of rest and to avoid predators (McConnell *et al.,* 1999). Furthermore, over this foraging period grey seals may travel large distances and use different haul-out sites depending on their position at the time of hauling out (Thompson *et al.,* 1991). This indicates that an individual may have been seen at multiple sites at large distances apart over this time period, but grey seals have been equally observed to remain close to their breeding and moulting sites whilst foraging if there are enough prey resources (Sjöberg & Ball, 2000). In comparison, site fidelity is associated with grey seals, where individuals or groups have been observed to return to the same breeding haul-out site over a consecutive number of years (Pomeroy *et al.*, 1994; Twiss *et al.*, 1994). However, the choice of a breeding haul-out site is more selective compared to those haul-out sites used during other phases of the annual life cycle, as the site selected may directly affect a pup's survival and/or a seal's reproductive success (Hall *et al.,* 2001). One example that was suggested to be associated with the level of site fidelity to a breeding site was access to a sufficient food supply, as well as the lack of potential predators present within close proximity of the haul-out site (Karlsson *et al.,* 2005). Alternatively, topography and environmental conditions may also influence the level of breeding haul-out site fidelity for both returning individuals and first-time breeders, as an unpredictable topography that can change appearance annually may result in individuals not recognising the same breeding haul-out site the following year (Weitzman *et al.,* 2016). Moreover, the topography of a haul-out site may also influence the level of pup mortality, as haul-out sites with large rock formations and gullies could result in the separation of the pup from its mother which may consequently cause the death of the trapped pup as a result of starvation (Baker & Baker, 1988). In comparison, the environmental factors found at the breeding haul-out sites have been suggested to influence mating success, as a site with greater tidal influence resulted in greater attention from the males towards those females that had to travel further down the beach to reach the water's edge (Ambs *et al.*, 1999).

1.2.3. Juvenile and adult dispersal

After a post-weaned pup moves off into the water, it spends its first two years at sea exploring new areas and will not usually return to its birthing site during this time (Davies, 1957). Juveniles can travel over 600km during this exploration period and have been observed to haul-out close to foraging grounds (Reilly, 1991). Furthermore, juvenile grey seals that have not reached sexual maturity may continue to forage during the major breeding and moulting seasons as they are not able to mate and do not have pups, so they are able to focus on foraging activities which in turn will enhance their growth and reproductive success once sexual maturity is reached (Bowen *et al*., 2006). However, there are exceptions where a number of juveniles have been known to remain at their birthing ground for this period. The reason for this still remains relatively unclear, but possible reasons have been suggested to be associated with the condition of the pup at the time it leaves its birthing beach. Individuals that have a weaker condition and thus a lower chance of survival remain close to their birthing haul-out sites (Anderson *et al.,* 1979). The benefit of remaining close to the birthing haul-out site is that less energy is required for migration to its foraging grounds, as well as having an increased chance of avoiding predators due to having a familiar haul-out site close by in comparison to those travelling to new areas with unfamiliar environments, and the possibility of not being able to avoid predators by hauling-out (Hall *et al.,* 2001). On the other hand, adult grey seals frequently display site fidelity towards breeding sites and return annually to these sites, with some remaining within close proximity of the breeding ground throughout the entire year. It has been suggested, however, that the degree of dispersal is dependent on the size of the grey seal colony as well as the food resources that are available in those areas. A large degree of adult dispersal has been observed in larger colonies compared to small colonies and it has been suggested that the reason for this is driven by a need to locate sufficient food resources to sustain the group (Davies, 1957; Sjöberg & Ball, 2000). A higher degree of site fidelity has been observed in adult females compared to adult males, probably because the females with previous successful experience at a breeding haul-out site are more likely to return instead of travelling to a new area that may not result in successful parturition or mating (Pomeroy *et al.,* 1994). Adult male grey seals display a higher degree of dispersal than females, as they do not have to find suitable areas to give birth and are therefore predominantly focused on finding breeding grounds at which they can hold tenure and successfully mate (Bjørge *et al.,* 2002). However, if a male is not able to hold tenure or is defeated by another male, it will often move away from the colony in search of new haul-out

sites where there is a greater chance of successfully mating (Twiss *et al.,* 1994; Klimova *et al.,* 2014).

1.3. Grey seal exploitation and conservation

Since the Stone Age, grey seals have been hunted for a variety of products such as meat, oil and fur. During this period, grey seal pups were predominately targeted as they were often left hauled-out alone weeks after being born and were therefore easiest to hunt due to the limited tools available for hunting (Härkönen *et al.,* 2007). This resulted in a substantial decline in the abundance of grey seals with the artefacts of more than 400 seal pups being identified from this time along the European coastline (Clark, 1946). With the advancement in techniques and tools used for seal hunting, such as the use of harpoons, traps and firearms, the products obtained from grey seal hunting became more recognisable and of greater commercial interest. This resulted in a large increase in the number of grey seals being hunted each year for commercial purposes. Orkney and the Farne Islands alone reported a 35% increase in the number of grey seals that were killed over an 11 year period between 1964 and 1975 (Summers, 1978). As the abundance of grey seals drastically decreased worldwide, predominately in the UK, the grey seal became the first marine mammal in the UK to be protected by law in the Grey Seal Protection Act of 1914. More recently, this was incorporated into the Conservation of Seals Act introduced in 1970, which prohibits any takings, injuries or kills of grey seals in the UK (CSA, 1970). In the United States, the Marine Mammal Protection Act was established in 1972 due to the severe decrease in grey seal abundance and other marine mammals there, aimed at preventing further harm and disturbance to grey seals and other marine mammals (MMPA, 1972). Although these laws have been introduced and the level of hunting grey seals has decreased, illegal hunting in addition to the disturbance of grey seals still remains. This is especially the case for interactions between fishermen and grey seals, where decreases in fish stocks have been observed in areas where fisheries and populations of grey seals overlap (Leeney *et al.,* 2010). Furthermore, although the worldwide abundance of grey seal populations is considered to be increasing, which has led to the status classification of "Least Concern" by the International Union for Conservation of Nature (IUCN) (Bowen, 2016), grey seals still remain threatened by numerous anthropogenic impacts including bycatch and entanglement, pollution, habitat loss and degradation (Morizur *et al.,* 1999; Bjørge *et al.,* 2002; Allen *et al.,* 2012).

1.4. Grey seal populations along the Welsh coast

The populations of grey seals that haul-out along the Welsh coast have been studied and monitored since 1947, where an estimated total of 100 grey seals were observed to utilise Ramsey Island, Pembrokeshire as a haul-out site during the breeding season. Baines & Evans (2012) found that the highest concentration of pup production was at Ramsey Island and in northwest Pembrokeshire, suggesting that these areas are important breeding grounds for grey seals with individuals returning on an annual basis. In addition, Strong *et al.* (2006) found an increase in pup production from 140 in 2000, to 168 in 2005. The grey seal populations along the Welsh coast have been observed to remain in the coastal waters throughout the year, utilising these areas during non-breeding seasons for localised foraging activities which are confined to the Irish Sea (Figure 2) (Baines & Evans, 2012). This suggests that immigration between populations during the non-breeding seasons may be occurring, with individuals or groups of individuals travelling to new areas to forage, and then returning to a specific haul-out site to breed (Stringell *et al.*, 2014).

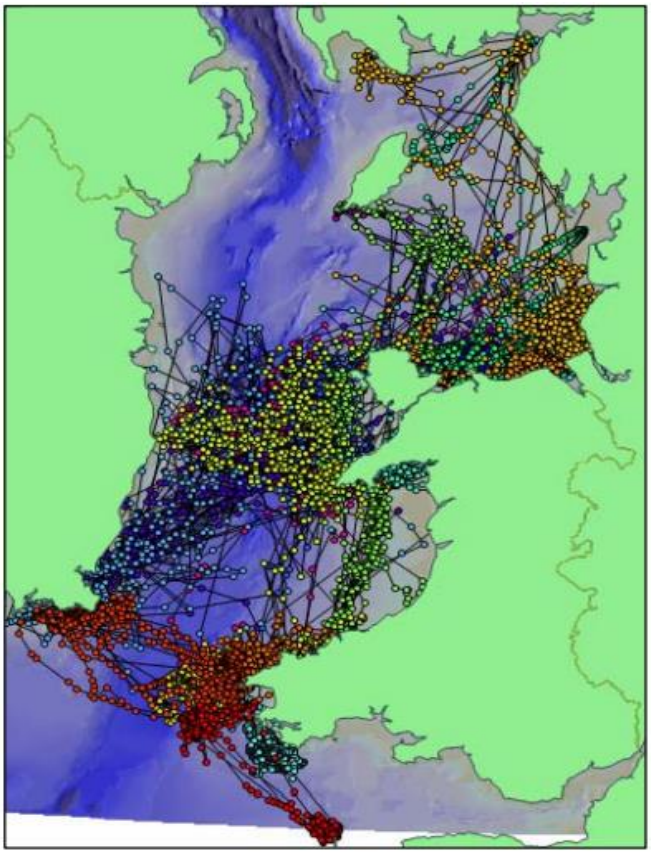

Figure 2. Movement foraging patterns of 19 grey seals (*H. grypus*) tagged from Skomer Island (Pembrokeshire), Bardsey Island (Gwynedd) and Hibre Island (Chesire) in June 2004. Source: Baines & Evans 2012.

In comparison, the use of haul-out sites in North Wales are predominately focused in three districts: Llŷn/Lleyn Peninsula and Bardsey Island, West Hoyle Sandbank and Anglesey (Westcott & Stringell, 2004), with a total adult population in North Wales estimated to be between 242-307 (Stringell *et al.*, 2014). The haul-out sites in North Wales were observed to be used by a greater number of individuals during the breeding season in September and October, where an average of 96 pups were born in 2003 and 2004 (Westcott & Stringell, 2004). However, as more than 50% of the total pup production in North Wales occurs in cryptic habitats such as caves and small coves, the total population size of grey seals in North Wales may be underestimated due to the difficulty in locating and observing grey seals and parturition that may be present in these cryptic habitats (Stringell, 2014).

1.5. Grey seals in Cardigan Bay Special Area of Conservation (SAC)

1.5.1. Abundance and distribution and haul-out use

Small populations of grey seals inhabit a variety of areas along the coastline of Wales, extending from North Wales and the Isle of Anglesey to Pembrokeshire. The coast of Cardigan Bay Special Area of Conservation (SAC) has been relatively poorly studied in relation to the abundance and distribution of grey seals. However, it was estimated that the number of pups born within this area ranged from between 20-100 in 1994 and 2001, with an average sightings rate between 0.01 to 0.4 per hour (Figure 3). This area is used by grey seals throughout the year, with the highest sightings observed in July to September (Baines & Evans, 2012), coinciding with the period just prior to breeding, suggesting that it represents a haul-out location during this annual life cycle phase. Furthermore, a total of 14 grey seal pupping sites have been identified between New Quay and Cemaes Head (WTSWW, 2015) which include beaches (both secluded and public access), caves and bays with large rock formations (Lewis, 2005). The movement of grey seals, including foraging activities, in the Cardigan Bay SAC remains relatively localised with the majority thought to be contained within the Irish Sea. Photo-identification studies have shown that both male and female grey seals return to haul-out sites in the Cardigan Bay SAC during the pre-breeding season in addition to remaining within the area intra-seasonally (Lewis, 2005; WTSWW, 2015).

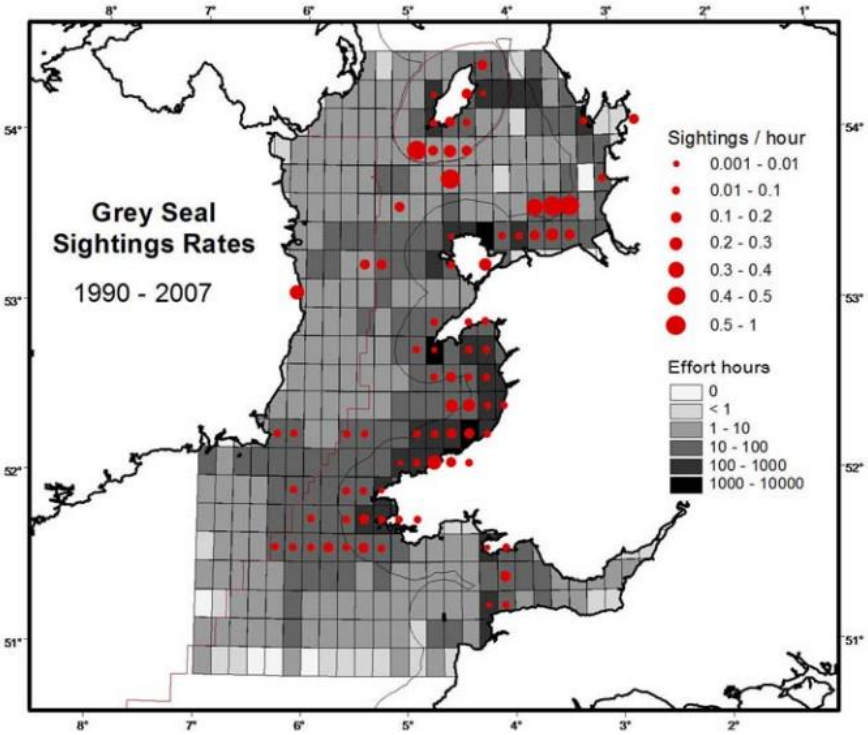

Figure 3. Long-term Atlantic grey seal (*H. grypus*) sightings rate (sightings/hour) from 1990-2007 obtained from boat and land-based surveys in the Irish Sea. Source: Baines & Evans 2012.

1.5.2. Grey seal conservation and monitoring

Grey seals come under ANNEX II of the EU Habitats Directive. The species is present as a qualifying feature and is therefore protected under the legislation in this area, but it is not the primary reason for the site selection of Cardigan Bay SAC (NRW, 2010). The main concern for grey seals within the Cardigan Bay SAC is disturbance at haul-out sites through human activities, such as tourist vessels, walkers and other recreational activities that may encourage man to approach these grounds. The primary conservation objective for grey seals in Cardigan Bay SAC is to maintain a favourable conservation status (population size stability), natural range and structure, and function within its habitat (CCW, 2005). This is accomplished through a variety of management action plans and regulations that should be complied with in this Special Area of Conservation, and includes increasing the awareness of grey seal conservation, monitoring the grey seal populations as well as anthropogenic activities including chemical and plastic pollution and recreational activities, to ensure they do not negatively affect its conservation status. Furthermore, boats within the Cardigan Bay SAC must follow a code of conduct if a grey seal is encountered by restricting their speed, course and distance to ensure that the animal is not disturbed or harassed (CCW, 2005; NRW, 2010).

1.6. Rationale, aims, objectives and hypotheses

As a top marine predator, grey seals help maintain the marine food web by regulating the abundance of lower trophic species (Bowen, 1997), and are therefore of ecological as well as economic importance by providing local jobs via tourism in a variety of countries (Strong & Morris, 2010). Therefore, studying the biology and movement patterns of grey seals in different populations is an essential requirement for conservation efforts. Grey seals are the only species of pinniped that breed in Wales (Baines & Evans, 2012) with a constant, if not increasing, abundance, having been observed during the last ten years. However, the majority of studies have been conducted on populations in North Wales and in Pembrokeshire (Westcott, 2002; Westcott & Stringell, 2003, 2004; Strong *et al.*, 2006; Baines & Evans, 2012; Stringell *et al.*, 2014), with limited effort conducted at known haul-out sites along the coast of Cardigan Bay SAC (Lewis, 2005). Furthermore, as the majority of grey seal pups are born in cryptic habitats, such as caves and restricted inlets, biological data associated with grey seals during major breeding and moulting seasons in addition to periods out of these seasons, are limited. This stimulates the need for further research to be conducted on the biological aspects associated with the small population of grey seals found along the coast of Cardigan Bay SAC. This study will therefore focus on the following primary objective and hypotheses:

Primary objective:

- To obtain high quality images of the Atlantic grey seal at haul-out sites along the coast of Cardigan Bay SAC, and use them in photo-identification analysis to investigate intra-specific interactions.

Hypotheses:

a). Male and female Atlantic grey seals show haul-out site fidelity amongst populations along the coast of Cardigan Bay SAC.

b). Abundance, haul-out behaviour and site fidelity of grey seals between sites are influenced by environmental conditions.

c). The population structure of grey seals is similar at each haul-out site, with females outnumbering males hauled-out, and a smaller abundance of small or juvenile males in comparison to large adult males.

2. Study area and methods

2.1. Cardigan Bay Special Area of Conservation

2.1.1. Bathymetry, topography and sedimentology

Cardigan Bay is one of the largest bays in the British Isles, encompassing an area of approximately 5500km^2 (Gregory & Rowden, 2001), as well as reaching over 100km across the western extent of the bay. Cardigan Bay Special Area of Conservation (SAC) extends from Ceibwr Bay, Pembrokeshire to Aberarth, Ceredigion (Figure 4a). It has a shallow, smooth bottom topography that gradually slopes in an offshore direction with a maximum water depth of 50m (Tucker & Arter, 1987; Gregory & Rowden, 2001). The southern area of Cardigan Bay SAC is deeper in comparison to the northern region due to a large proportion of the northern area being nearshore, as well as having an increased accumulation of shore-transverse ridges (Evans, 1995). The sedimentology of Cardigan Bay SAC (Figure 4b) varies from muddy and fine sand, predominately in the northern region, to gravelly and coarser sand in the southern region of the bay (Jones, 1971; Dobson & Whittington, 1987; Evans, 1995).

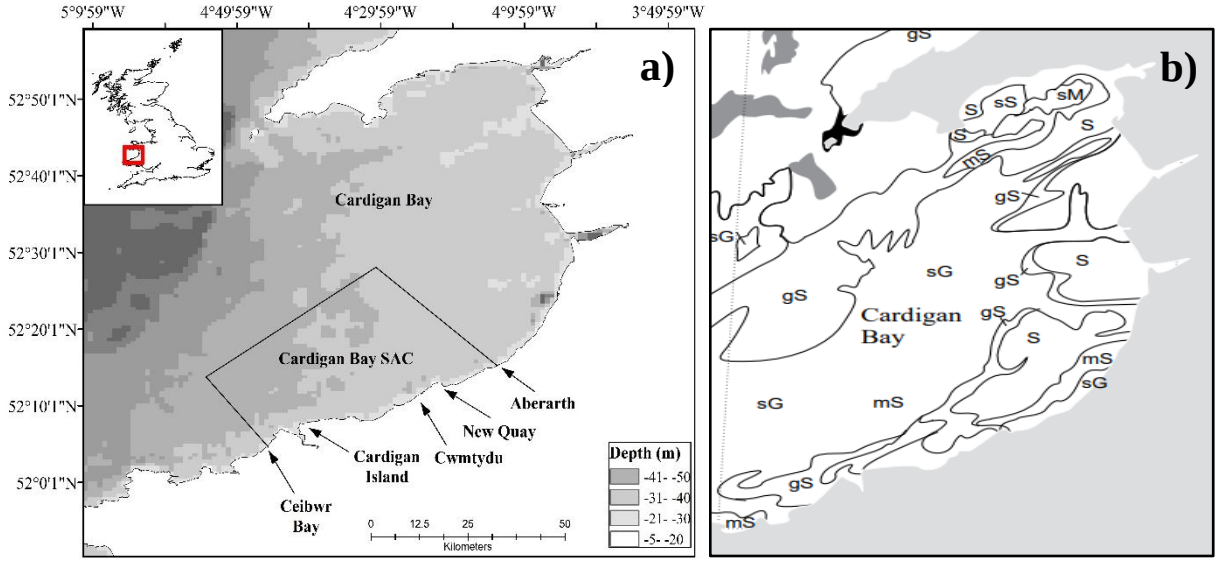

Figure 4. a) Map and bathymetry of Cardigan Bay, West Wales, identifying the three main grey seal haul-out site locations (New Quay, Cwmtydu and Cardigan Island) which were surveyed during this study and the border of Cardigan Bay Special Area of Conservation (SAC), b) Sedimentology of Cardigan Bay, Wales. Sediment type: S= sand, sM = sandy mud, mS= muddy sand, gS= gravelly sand and sG= sandy gravel. Source: Evans, 1995.

2.2.2. Tides, exposure and temperature

Cardigan Bay is an inlet of the Irish Sea where the tidal current enters from the south through the St. George's Channel and flows northward, meeting the southward-moving current near the Isle of Man (Gregory & Rowden, 2001). This results in weak currents moving northwards during an ebbing tide and southwards during a flooding tide. In addition, the tidal regime of the Cardigan Bay SAC area exhibits semi-diurnal tides which ranges from approximately two metres during neap tides to four metres during spring tides (Evans, 1995). The Cardigan Bay SAC area is exposed to dominant south-westerly winds that for 75% of the time will exceed 3.5 $m.s^{-1}$ (Evans, 1995) but can also be exposed to winds greater than 19 $m.s^{-1}$, which can leave the bay subject to high wave action and sea states above the Beaufort scale 4. The sea surface temperature ranges from 6 to 8.5ºC during the winter period, reaching the lowest temperature between February and March and maximal temperatures of 14 to 16ºC during the summer season, with maximum temperatures observed during August and September (Evans, 1995).

2.1.3. Coastal habitats and grey seal haul-out sites

The coast of Cardigan Bay SAC is formed by high sea cliffs composed predominately from slate rocks that can reach a maximum height of approximately 200m. Furthermore, the erosion of the softer slates found in this region has resulted in narrow bays with denser volcanic rock headlands (Evans, 1995). This has resulted in coastal habitats along the coast of the Cardigan Bay SAC that are predominantly rocky shores, usually within small pebbled bay areas, rocky and/or pebbled beaches or cryptic habitats such as deep rock caves. Three primary haul-out sites (Seals Bay, Cwmtydu and Cardigan Island) were selected for land observation surveys within this study, as each of them are known to have regular sightings of Atlantic grey seals. Additional sites, such as Cemaes Head and Ynys Lochtyn were used during the trial week of surveying. However, these sites could not be visited regularly due to unpredictable weather conditions and difficulty in reaching observation points, and therefore were not included in the data analysis.

Seals Bay

Seals Bay (52º12'55.3"N, 004º22'36.6"W), situated below New Quay headland and in close proximity to Birds Rock, is an area consisting of large flat rock formations in addition to small pebbled beaches and rock caves (Figure 5). It is a known haul-out site of Atlantic grey seals

in New Quay, Wales, and can be viewed from both the land (looking down from the cliffs) and from the sea on board boats. The rocks within the bay are often affected by the tide, with the majority, if not all of the rocks being submerged during high tide. Furthermore, this area may also be subject to high wave exposure during periods of rough weather or levels of high sea state (Beaufort scale >3). However, the small sloped beaches present provide ideal habitats for new-born pups.

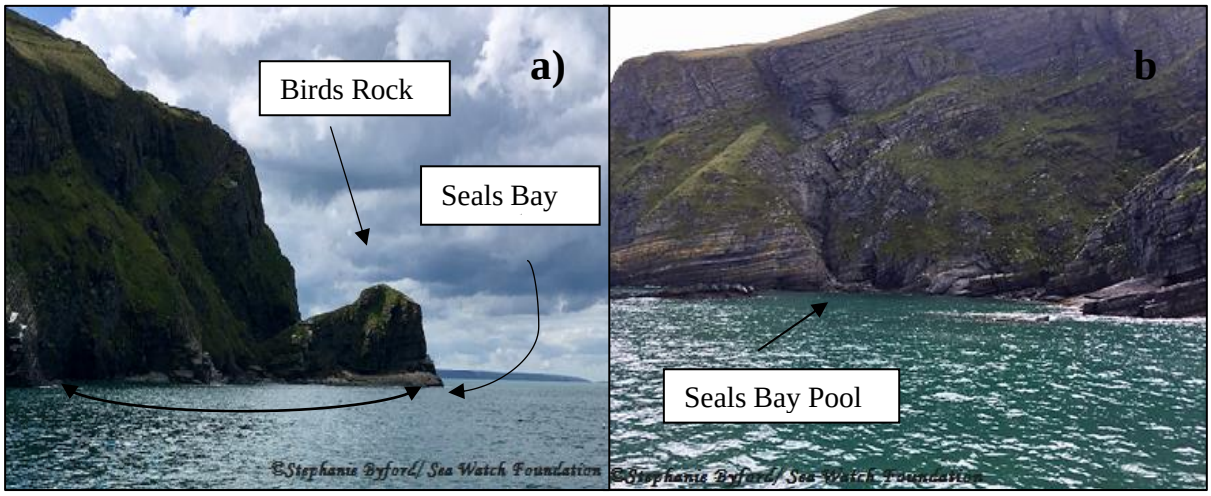

Figure 5. Photograph of a) Birds Rock and Seals Bay and b) in more detail a pool within Seals Bay taken from a visitor passenger boat (*Ermol VI*/Dolphin Spotting Boat Trips).

Cwmtydu

Cwmtydu beach (52º11'31.8"N, 004º24'25.3"W) is a small pebbled bay situated approximately two miles (by sea) south of New Quay, Wales. The beach itself is located within a small bay area and is therefore better protected from high wave action and dominant south-westerly winds (Figure 6a). Cwmtydu is a pebbled rocky beach that consists of small coves and caves (Figure 6b) along the outer region of the bay coastline. This area is a well-known place for the Atlantic grey seals to pup during the breeding season, where they will either be situated within the small caves or hauled-out on the beach itself. However, during high tide, the majority of the beach is submerged and therefore the deeper caves will usually be more commonly used as they provide shelter and protection for both mother and pup.

Figure 6. Photographs of a) Cwmtydu Beach, Llandysul, West Wales and b) a cave situated on the Western region of Cwmtydu beach.

Cardigan Island

Cardigan Island (52º07'51.7"N, 004º41'17.5"W) is an uninhabited island situated north of Cardigan, Ceredigion, West Wales. It has an area of approximately 0.15km^2 and is owned and protected by The Wildlife Trust of South and West Wales. Cardigan Island is situated <200m from the coastline and comprises of a number of small beaches and large rocks around its exterior. Furthermore, the small area between the island and the coastline consists of a number of large flat rocks that are exposed at low tide. The main coastline of Cardigan Bay SAC consists of sheltered bay areas and caves which are frequently used by grey seals, especially during the pupping season. Access to Cardigan Island for members of the public is not permitted and therefore the only way to observe this area was via boat trips travelling past the island, or from the Cardigan Island Farm Park that extends down to the edge of the coastline opposite Cardigan Island (Figure 7).

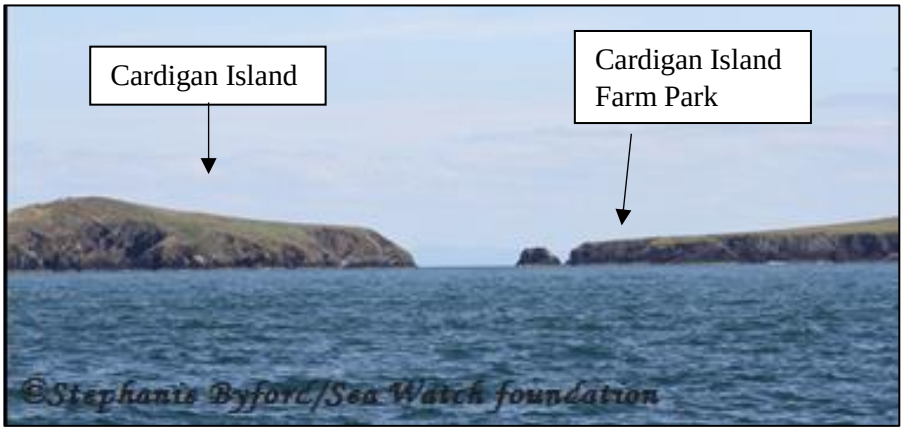

Figure 7. Photograph of Cardigan Island, Cardigan, West Wales and the edge of Cardigan Island Farm Park taken from a visitor passenger boat (*A Bay To Remember*).

2.2. Photo-identification

Photo-identification of grey seals is a method that involves identifying the distinct markings of individuals from photographs of individuals or groups of individual grey seals (Hiby *et al.,* 2013). This process involves initial identification of an individual from a specific marking pattern that can then be used to re-identify the same grey seal from photographs taken in different locations or on separate occasions. Therefore, the re-identification of individual grey seals in conjunction with data such as location and dates can be used to analyse grey seal population dynamics, trends in spatial distribution, and abundance estimates. The method of photo-identification has been applied to numerous marine species, with different morphological components being examined depending on the species. For example, scars and nicks present on the dorsal fin are used as distinguishing marks for the identification of some cetaceans such as the bottlenose dolphin, (*Tursiops truncatus)* (Wiirsig & Jefferson, 1990) and the pelage pattern on the head and neck region of some pinnipeds such as the grey seal (Vincent *et al.,* 2001).

2.2.1. Advantages and disadvantages

As previously mentioned, when correctly applied, photo-identification can provide useful information on a variety of parameters associated with the selected population of grey seals. Furthermore, photo-identification is a non-invasive technique that does not require capture or harm to the subject organism, and therefore the use of this method has a decreased risk of causing the animal distress whilst obtaining the data (Graham & Roberts, 2007). In comparison to traditional tagging methods, such as satellite tagging and hot-iron branding, photo-identification is a relatively inexpensive method used to obtain and record data (Hiby *et al.,* 2007). However, there are also a number of disadvantages to using photo-identification as a method to assess grey seal populations. Firstly, photographs of certain individuals that are not correctly identified (false rejections) may produce inaccurate results such as an individual being identified as two separate individuals. To reduce the chance of false rejections, Hiby *et al.* (2013) suggests that the photographs used for identification should be restricted to those of the highest quality in order to increase the chance of being able to re-identify an individual. In addition, all photographs captured should be pre-screened by assessing the quality of the image and the distinctiveness of the markings in order to reduce the chance of mis-identification and increase the accuracy of the results (Wiirsig & Jefferson, 1990). Furthermore, there is limited control in regard to the camera angle and position of the

subject organism being photographed as well as the natural lighting conditions available; consequently, this may result in data for analyses such as capture-mark-recapture (CMR) being lost or ineffectual (Miller, 1990).

2.2.2. Photo-identification methods and techniques

As part of both boat and land-based surveys, between 10 and 15 photographs of each individual grey seal were taken for each sighting. In order to produce high quality photographs that could be used to distinguish markings, the camera used was a Canon EOS 7D digital SLR with a 70-300mm zoom lens + 1.4x tele-converter (Defran *et al.*, 1990). The land-based surveys allowed an increased time to capture images of individuals situated in one location for a longer period of time, in comparison to the boat surveys which realistically could only remain in close proximity to the animals for a few minutes. Although photographs were taken of individuals both hauled-out and in the water, the presence of the water obstructing identifiable markings was taken into consideration. However, as the study period commenced before the start of the pupping season, there were less opportunities to photograph grey seals hauled-out, and therefore attempts to photograph individuals in the water were also made. All photographs taken were initially stored that same survey day using a 2GB SD Flash disk card rather than using the internal camera memory which was not able to store as large a volume of images.

A strict procedure was followed when photographing an individual grey seal in order to obtain a high quality image that was then used for photo-identification. This involved capturing images of the seal broadside to the photographer, of the head and neck region of the individual (Figure 8). The reason for this is that the pelage patterns and markings located on these areas are the distinguishing features used for photo-identification of grey seals as they are less likely to change or be altered over time, in comparison to pelage markings found on other areas of the body (Vincent *et al*., 2001). However, photographs were still taken if an individual was positioned at an unsuitable angle and/or its head and neck region were not positioned broadside on, as they could potentially still be used for photo-identification. Furthermore, the photographs taken consisted of an individual filling approximately a third to a quarter of the total area of the photograph in order to produce images with details at high resolution. Both left and right sides of the individual were taken in order to obtain pelage markings from both sides, thus aiding the accuracy of identifying an individual.

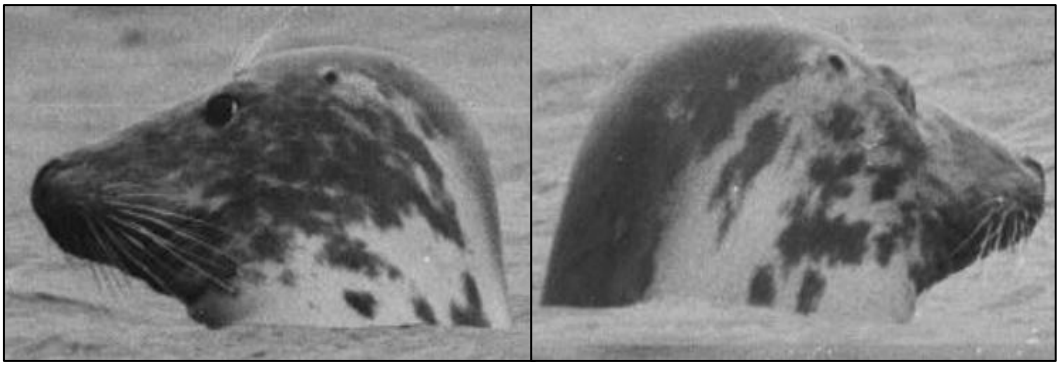

Figure 8. High quality image used for photo-identification of a female grey seal (*H. grypus*), captured broadside on of the head and neck regions. Source: Vincent *et al*., 2001.

2.3. Boat and land surveys

2.3.1. Visitor passenger boat trips

Surveys were conducted on visitor passenger boat trips (VPB). The Dolphin Spotting Boat Trip vessels, the *Ermol V* (two-hour duration from New Quay to Ynys Lochtyn) and the *Ermol VI* (one-hour duration from New Quay to Cwmtydu, Figure 9) are 10-metre long pleasure crafts, with an average speed of 7 to 8 knots that are based in New Quay, and were the boats used most often during the surveying period. However, dedicated surveys with the Sea Watch Foundation boat and two-hour surveys on the visitor passenger boat, *A Bay to Remember*, were also used (when available) during the period of data collection. Boat surveys were used as they provided access to haul-out areas that were not usually accessible or visible from the land. For additional visual advantage, the surveys were conducted from the roof of the boats and involved completing two survey forms printed on waterproof paper (see Appendix 1): the first included information based on the entire survey, and the second was a separate form for sightings made during that specific survey. Both survey forms included the date, start and end times, total abundance, and environmental conditions (Table 1). The estimated distance (m) away from the animal measured by visual observation, was also recorded on the sightings form in addition to the location of the boat, determined using a handheld GPS (Garmin, eTrex Venture HC) at the time of each sighting. In addition to the sightings form being completed, photographs were taken of grey seals either hauled-out or in the water, specifically targeting the head and neck region (for further information on photo-identification techniques and methods used, see section 2.2.2). Surveys on the visitor passenger boats were conducted between four to six days per week for seven weeks from the 14th June 2017, and consisted of surveys between one and four hours per day. Although there were specific areas such as Seals

Bay and Cwmtydu that were more likely to have grey seal sightings, a dedicated search was conducted throughout the whole survey using binoculars (Olympus 8 x 40 DPSI, Field view: 8.2º) to scan 180º from 90º Left to 90º Right.

Figure 9. Photograph of The Dolphin Spotting Boat Trip *Ermol VI* vessel that was used for one-hour boat surveys from New Quay to Cwmtydu, Ceredigion between June and July 2017.

Limitations

The survey periods were restricted by the running times of the visitor passenger boats that did not commence until 11am and would be weather dependent, and did not run at all in sea states above Beaufort scale 3. However, surveys were conducted during different tidal phases and in different weather conditions and sea states, allowing comparisons of the abundance and behaviour of grey seals under different environmental conditions. The majority of surveys were conducted on the one-hour boat trip as these were most likely to remain close to the coastline allowing a greater opportunity for sightings of hauled-out grey seals. However, the two-hour boat trips did travel further along the coast to Ynys Lochtyn and therefore permitted a greater number of locations to be observed, but did not run as consistently due to weather conditions that prohibited them from travelling far down the coast. When land surveys were being conducted, opportunities to survey grey seals from the boats were not possible and therefore opportunistic data and photographs were collected by the skipper Dafydd of the *Ermol VI* vessel, who had a copy of the data form and had previous experience of photographing grey seals.

Table 1. Environmental parameters (tidal phase, sea state, air and sea temperature (ºC) and general weather conditions) measured and data collection methods used during the surveys conducted on the visitor passenger boat trips.

Environmental Condition	Units or Category	Method obtained
Tidal phase	High, low, ebb or Flood	Daily tide times
Sea State	Beaufort scale, 0-3	Visual observation
Air & Sea Temperature	ºC	Handheld thermometer and/or average daily temperatures
General weather conditions	Written description	Visual observation

2.3.2. Land-based surveys

Land-based surveys were conducted at three main haul-out sites: Seals Bay, Cwmtydu beach and Cardigan Island. As previously described, these sites were chosen based on previous sightings of grey seals that had been found to commonly haul-out in these areas and would therefore provide the greatest chance of observing and photographing them. The land-based surveys involved scanning the selected site for grey seals using binoculars over a period of one to two hours depending on the weather. The short survey periods also allowed for land surveys at different sites and boat surveys to be conducted on the same day to ensure the highest possibility of sighting and photographing grey seals. Fifteen land-based survey hours were spent at each haul-out site in order to reduce bias between sites when analysing site fidelity data. Furthermore, the land-based surveys were conducted during different tidal phases (high, low, ebb and flood) using daily tides, as well as at different times of the day and in a variety of weather conditions. The reason for this was to be able to compare the abundance and behaviour of grey seals under different environmental conditions as well as to determine the likelihood of sighting these animals at certain times of the day. The two survey forms (entire survey and sightings) used during the boat surveys were also used for land-based surveys, and therefore during each survey the date, start and end time, location in degrees^{o}, minutes', seconds" (obtained using a handheld GPS), abundance, estimated distance (m) and environmental conditions (Table 1) were recorded for the entire survey, and for any sightings made during the survey period. Furthermore, photographs were also taken of grey seals when sighted using the techniques and methods described in section 2.2.2.

Behaviour observations

During land-based surveys, behavioural observations were made and recorded when a grey seal was sighted. The behaviour observations only took place during land-based surveys as the boats were not able to stay for a long enough duration to observe grey seal behaviour due to being required to follow the regulated code of conduct. Although these observations were intended to be made when an individual was hauled-out, behavioural observations were also made if an individual was present in the water, as individuals would not always haul-out during surveys. However, behavioural data would only be used for analysis if that individual was present for the entire behaviour survey period. This survey involved observing and recording the behaviour of grey seals for 15-minute intervals over one hour. In addition, the date, start and end time, location, abundance, environmental factors (Table 1) and wave action (high, medium or low) were also recorded on a waterproof behaviour survey form (Appendix 1) in order to relate the behaviour of grey seals to environmental factors, and therefore address the hypothesis: that abundance, behaviour and movement between sites are influenced by key environmental conditions (See section 1.6.)

Limitations

Land-based surveys were restricted by the tide times as certain tidal phases would only be available to be surveyed on certain days. Furthermore, the surveys conducted at Cardigan Island were restricted by the opening hours of the Cardigan Bay Island Farm Park, which varied depending on the days of the week and weather conditions. Due to the pupping season being towards the end of August through to autumn, there were fewer individuals hauled-out than may be seen during the pupping season. Therefore, behavioural observations were also taken when individuals were present in the water, in order to determine whether there were any differences in the general behaviour of grey seals under different environmental conditions.

2.4. Photo-identification: data processing and statistical analysis

2.4.1. Collation and cataloguing of images

In order to organise and manage the photographs taken during a survey, the photographs were copied and removed from the SD memory card and stored using a systematic filing system that involved each photograph being named using the format: Year Month Day_ Individual ID Number_ Survey type (Land Location or Boat_Vessel). For example, an image captured

of individual 001 on 1st July 2017 from the *Ermol VI* vessel would have an image name of 170701_001_Boat_ErmolVI. The reason for using this system was to ensure that all photographs could be easily located and related back to their origin. All photographs taken were pre-screened and rated based on their image quality ("excellent", "good" or "poor"), with any photographs that received a "poor" quality image rating excluded from the photo-identification examination (Table 2). Furthermore, the position of the individual grey seal was categorised (broadside on, head on, or other), with head on (head and nose facing the photographer) positions being excluded from photo-identification examination in addition to positions that did not display a clear broadside on pelage marking. The reason for this pre-screening process was to ensure that only the highest quality images were used in order to be able to photo-identify individuals accurately. Photo-identification of an individual involved examining each photograph by eye, a) to recognise one or multiple distinctive markings of an individual, and b) to use those markings to re-identify the same individual over time (Figure 10).

Table 2. Summary table showing poor, good and excellent photograph quality ratings with descriptions and photographic examples used during the pre-screening process for photo-identification of the Atlantic grey seal (*H. grypus*) along the coast of Cardigan Bay SAC.

Photograph Quality Rating	**Description**	**Photographic example**
Poor	Not focused Low resolution High glare Pelage markings unclear	
Good	In focus Mid-high resolution Mid-low glare Some pelage markings clear	
Excellent	In focus High resolution Low-no glare Clear pelage markings	

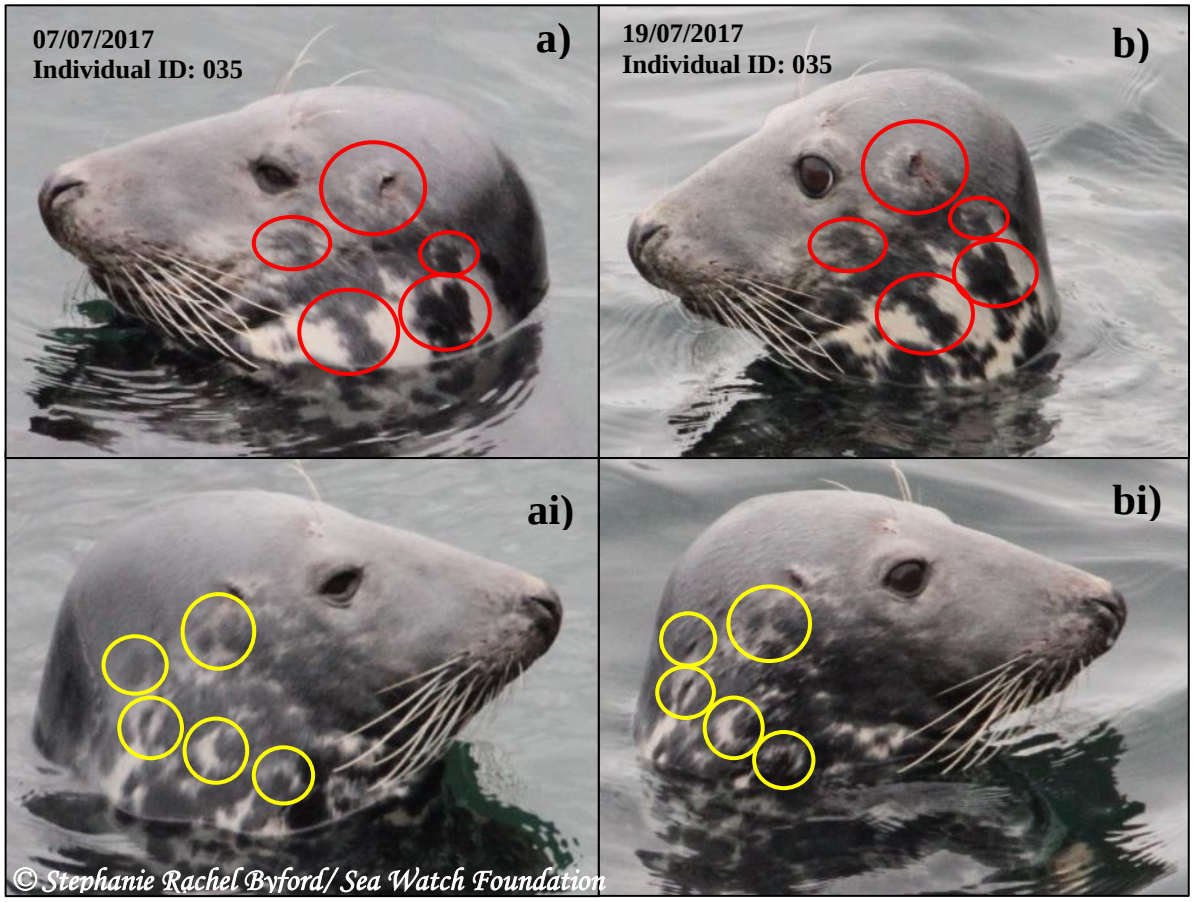

Figure 10. Photographs used for the initial identification of an individual Atlantic grey seal (*H. grypus*) (035) on 07/07/2017 using pelage markings on the a) left and ai) right side of the head and neck region. Re-identification of the same individual on the 19/07/2017 using the same pelage markings on the b) left and bi) right side of the head and neck region.

As previously discussed, the pelage markings found either on the left, right or both sides of the individual grey seal's head and neck region were used to both initially identify and re-identify an individual. This process involved creating a database in Microsoft Excel which consisted of images of each individual grey seal, in addition to the details related to that individual and the specifics of each confirmed photograph used to ID an individual (Table 3). Once an individual had been initially identified and added to the database, photographs were examined against the database to aid the photo-identification process and accumulate details such as date, time and location of a specific individual throughout the survey period. When the photographs were examined, the gender of an individual grey seal was identified by the coloration of the pelage markings, where males were identified by their broader shaped head and darker colouration, in addition to scars that may be present on their neck region from conflicts with conspecifics (Beck *et al.*, 2003), in comparison to females that have lighter colouration with contrasting dark pelage patterns and are usually noticeably smaller in body

size (Vincent *et al.*, 2001). Furthermore, each identified grey seal was aged based on examination of the photographs taken. The age of a grey seal was categorised into four age groups (Table 3) which were mainly determined by the size (where older seals are noticeably larger compared to juveniles) and/or maturity, such as if a female is pregnant or if a male has scarring from conflicts with conspecifics and/or wrinkling of the skin around the neck region, which usually indicates that a male has reached sexual maturity (Figure 11).

Table 3. Column headings (ID reference number, distinguishing marking, gender, age category, and photograph) and description of the information recorded in the grey seal (*H. grypus*) photo-identification database in conjunction with the highest quality images of the associated individual.

Column Headings	**Description**
ID reference	Individual grey seal ID reference number. First identified individual being 001 and the second 002.
Distinguishing Marking	Brief description of marking initially used to identify an individual.
Gender	Male or Female
Age Category	Young (0-1 years), Juvenile (2-3 years), Young Adult (3-5 years), Adult (5+ years)
Photograph	Side of head captured (Left or Right) in addition to date, time and location associated with that image.

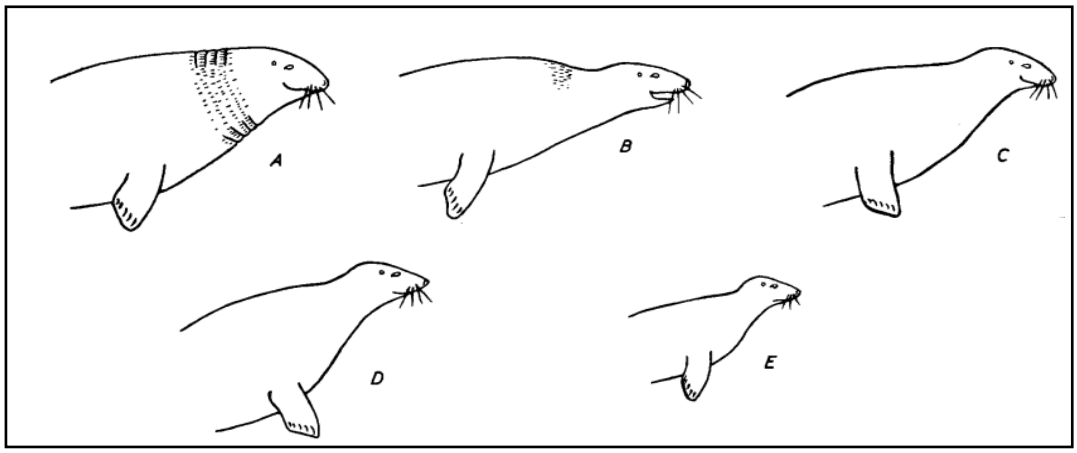

Figure 11. Diagram of the head and shoulder region of a grey seal (*H.* grypus) that is a a) fully mature adult male, b) young adult male that is newly sexually mature with wrinkling on the neck region, c) young adult male that is newly sexually mature without wrinkling on the neck region, d) female of breeding age, and e) juvenile of either sex. Source: Hewer, 1957.

2.4.2. Biological data input, collation and statistical analysis programmes

After each survey, the data was input into separate excel spreadsheets for a) land-based surveys including all recorded information from: the entire land survey data form, the sightings data form and the behaviour observation data form and b) boat surveys including all recorded information from: the entire boat survey data form and the data form. This information was used for both statistical analysis in the statistics programme R, and for examining behaviour observational data, with all graphs created in Microsoft Excel. The statistical programme R was used, as it is both a flexible and powerful software programme that has a variety of packages and functions that are appropriate for a variety of statistical analyses (Ihaka & Gentleman, 1996). The coding used in R for the statistical tests applied in this study are described in Appendix 2.

General linear models (GLM) were used to analyse the environmental data as they are more robust when conducting analyses on different data types and allow the family to be specified to suit the data being analysed (Lee & Nelder, 2003). For example, the family binomial was used to analyse the proportion of grey seals hauled-out as this data consisted only of values of 0 for not hauled-out and 1 for hauled-out. On the other hand, the family poisson was used to analyse abundance data and environmental factors where the data consisted of values from 0 to an infinite positive number. However, a two or three-way ANOVA was used instead of a GLM when analysing the differences between fixed categorical factor(s) and the continuous outcome variable, as the data was balanced and produced an output with a more direct comparison between differences in the levels of each factor and the outcome variable, compared to those produced using a GLM. Nonetheless, both GLM and ANOVA were only conducted when the following assumptions were met:

1) The data is independently distributed
2) The dependent variable is normally distributed (Levenes Test)
3) There is homogenity of variances (Shapiro Wilk Test).

2.4.3. Hypothesis a). Male and female Atlantic grey seals show haul-out site fidelity amongst populations along the coast of Cardigan Bay SAC

Re-sighting of individual grey seals using photo-identification

For this study, site fidelity was identified as an individual returning to the same haul-out site during the survey period. This was established through the identification of individual grey

seals from the photographs taken during the survey period (section 2.4.1.). Initial identification was not included in site fidelity analysis and therefore only those individuals identified more than once were used in a two-way ANOVA to examine differences in site fidelity (the number of re-sightings of an individual) and a) location and b) gender. Cwmtydu was not used for this statistical analysis as the only individual identified at that haul-out site was not re-sighted.

Individual identification and distribution

The grey seals that were initially identified and re-sighted, using photo-identification techniques were plotted onto a map (using ARC GIS) for the survey period of June and July 2017. These maps consisted of the location where the individual was observed as well as details on the number of times that individual was re-sighted in that month. These maps contained the individuals observed at both Seals Bay and Cardigan Island and therefore allowed a visual comparison between the number of individuals sighted and re-sighted at each haul-out site. Furthermore, these maps identify the location of each identified individual observed throughout this study and summarise the movements and site fidelity related to each individual in comparison to the grey seal catalogue, which depicts both photographs and more detailed information in relation to each individual grey seal identified (Appendix 3). In addition, the photographs taken during this study were compared to an existing collection of photographs taken along the coast of Cardigan Bay SAC in 2015 and 2016 by the Sea Watch Foundation, and used to examine site fidelity by identifying the same individuals using photo-identification techniques as described in section 2.4.1.

2.4.4. Hypothesis b). Abundance, haul-out behaviour and site fidelity are influenced by environmental factors

The data used to address this hypothesis was the abundance recorded during each boat and land-based survey, the haul-out behaviour that was recorded during land-based surveys only, and the date, time, locations and environmental conditions (sea state, tidal phase, and sea and air temperature) associated with each survey recorded.

Abundance and environmental factors

The sea state, tidal phase, air and sea temperature (ºC) and the total abundance data that were combined from both the boat and land-based surveys were used to investigate any differences

in the total abundance of grey seals with changes in the four environmental factors. A GLM was used to analyse the differences in the abundance of grey seals (dependent variable) with changing environmental factors (independent variables). If a significant difference was found ($p<0.05$) between one of the environmental factors and grey seal abundance, a GLM post-hoc test was used to identify the specific variable level that differed in total grey seal abundance. In addition a GLM was used to examine the influence of all environmental factors on the total abundance of grey seals in order to compare the outcomes of each environmental factor with the outcomes that take into account the influence of four independent variables. Furthermore, the lunar cycle was compared to the average grey seal abundance per day over the entire survey period in order to identify changes in grey seal abundance with phases of the moon and subsequently spring and neap tides.

Sea state, tidal phase and behaviour

A GLM was used to analyse differences in the number of grey seals hauled-out and not hauled-out at Beaufort sea states (1-3). The difference between the percentage of grey seals hauled-out at different sea states could not be compared between survey sites as not all of the sea states were observed at each location during behavioural surveys. Furthermore, a GLM was also used to examine the differences between the number of grey seals hauled-out (given as a percentage) and not hauled-out at different tidal phases (low, ebb, flood and high). Using the observations recorded during the behavioural surveys, the most prominent behaviours (Table 4) were presented on graphs, showing the percentage of individuals that displayed the behaviours for individuals that were hauled-out and the behaviours for individuals situated in the water.

Air/ sea surface temperature and behaviour

A GLM was used to examine the relationship between both air and sea temperature with the percentage of grey seals hauled-out compared to those present in the water. This analysis consisted of land-based data only as the number of grey seals hauled-out was not collected during boat surveys. Furthermore, all four environmental factors were used in a GLM to examine the influence of the environmental factors on the number of grey seals hauled-out compared to those present in the water when all environmental factors were taken into consideration.

Table 4. The five most predominant behaviours displayed by grey seals (*H. grypus*) that were hauled-out and not hauled-out along the coast of Cardigan Bay SAC from June to July 2017.

Behaviour	Description
Hauled-out	
Head movements	Rotation or lifting of the head and neck region only
Body movements	Rotation or lifting of any part of the body excluding the head and neck region (e.g. lifting hind flipper)
Attracted by human	Head movement in response to noise produced by a human
Attracted by boat	Head movement directed in response to approaching boat
Moved into water	Whole body moved from being hauled-out on a rock into the water
Not hauled-out	
Long dives	Diving for more than three minutes
Short dives	Diving for less than three minutes
Float	Body floating horizontally on the water surface
Contact	Direct contact between two individual grey seals
Bottling	Body positioned vertically in water with head out (circular rotation of whole body in this position is displayed)

Site fidelity and environmental factors

Photo-identification of individual grey seals (as described in section 2.4.1.) was used to determine which individuals were returning to the same haul-out sites and then relate those re-sightings back to key environmental factors. A GLM was used to examine the differences between 1) tidal phase, 2) sea state, 3) air temperature (ºC) and 4) sea surface temperature (ºC) and site fidelity (the re-sighting of an individual at the same haul-out site), using data collected from individual grey seals that were identified and sighted more than once. A GLM post-hoc test was used to identify which tidal phases had significant differences ($P<0.05$) in site fidelity. Differences in the four independent variables (as described above) and site fidelity were first examined using a univariate approach and then were combined (a multivariate approach) within the GLM to examine the influence of all four environmental factors on site fidelity.

2.4.5. Hypothesis c). Population structure of grey seals is similar at each haul-out site with females outnumbering males and a smaller abundance of small or juvenile males in comparison to large adult males

Abundance of male and female grey seals

Photo-identification of individual grey seals (as described in section 2.4.1.) was used to examine the gender population dynamics of grey seals along the coast of Cardigan Bay SAC. A two-way ANOVA was used to examine the differences between the number of females and males at each site and between the haul-out sites a) Seals Bay and b) Cardigan Island. Cwmtydu haul-out site was not included in this analysis as only one individual female was identified during the survey period. A Tukey post-hoc test was used to identify the significant differences between the number of males and females at each haul-out site.

Age of male and female grey seals

The method of photo-identification described above and as described in section 2.4.1. was also used to examine the age population dynamics of grey seals along the coast of Cardigan Bay SAC. A three-way ANOVA was used to examine the differences between age (categorised as described in Table 3), gender and location of individual grey seals identified along the coast of Cardigan Bay SAC. In addition, the groups (more than one) of identified individuals that were observed together were presented in a table with both their age, gender and the location of where they were observed. This was used to analyse the group dynamics observed in populations of grey seals along the coast of Cardigan Bay SAC. Cwmtydu haul-out site was not included in this analysis, as only one individual female was identified during the survey period and therefore could not be used for comparison.

3. Results

3.1. Hypothesis a). Male and female grey seals show haul-out site fidelity amongst populations along the coast of the Cardigan Bay SAC

3.1.1. Re-sightings of grey seals using photo-identification

From the 46 grey seals that were initially identified, only 26% were re-sighted during the seven- week survey period from June to July 2017 (Figure 12), where 92% of these were female and 8% were male (Figure 12). There were no significant differences between a) the number of re-sighted individuals and the location of the haul-out site (ANOVA, $F_{1,45} = 0.475$, $p = 0.50$) and b) the number of re-sighted individuals and the gender of each identified grey seal (ANOVA, $F_{1,45} = 1.182$, $p = 0.28$). Furthermore, the interaction between gender and the location of the haul-out site did not significantly affect the number of grey seals that were re-sighted over the survey period (ANOVA, $F_{1,45} = 0.475$, $p = 0.50$). The number of times an individual was re-sighted decreased from 13 individuals that were re-sighted once, to 1 individual re-sighted (the maximum) 6 times over the survey period (Figure 13).

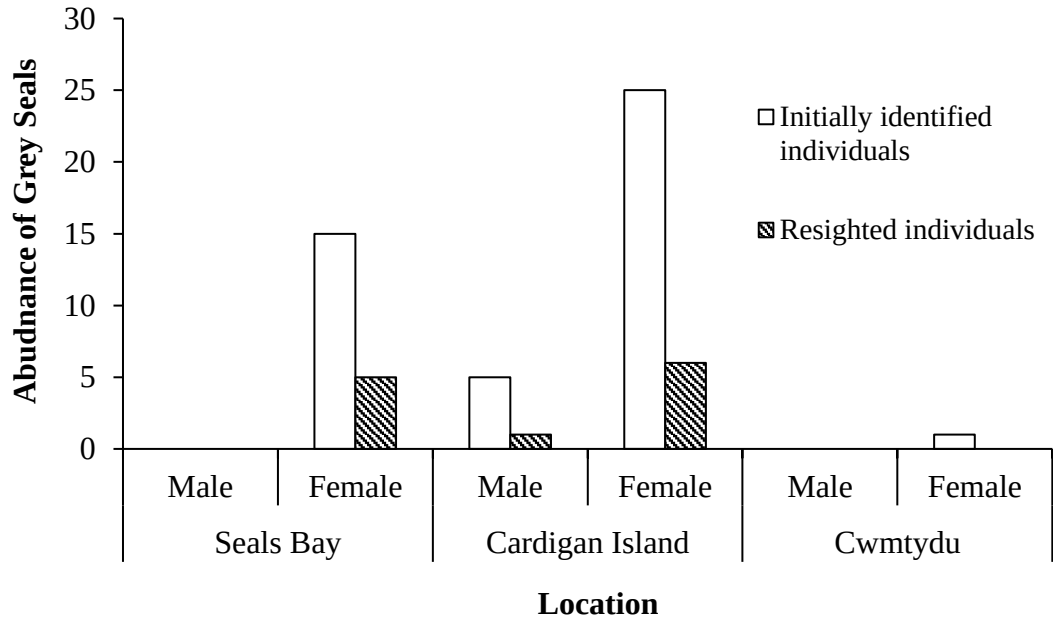

Figure 12. The abundance of male and female grey seals (*H.* grypus) that were initially identified and re-sighted at the three haul-out sites (1. Seals Bay, New Quay, 2. Cardigan Island, Cardigan, and 3. Cwmtydu, Llandysul) along the coast of Cardigan Bay SAC from June to July 2017.

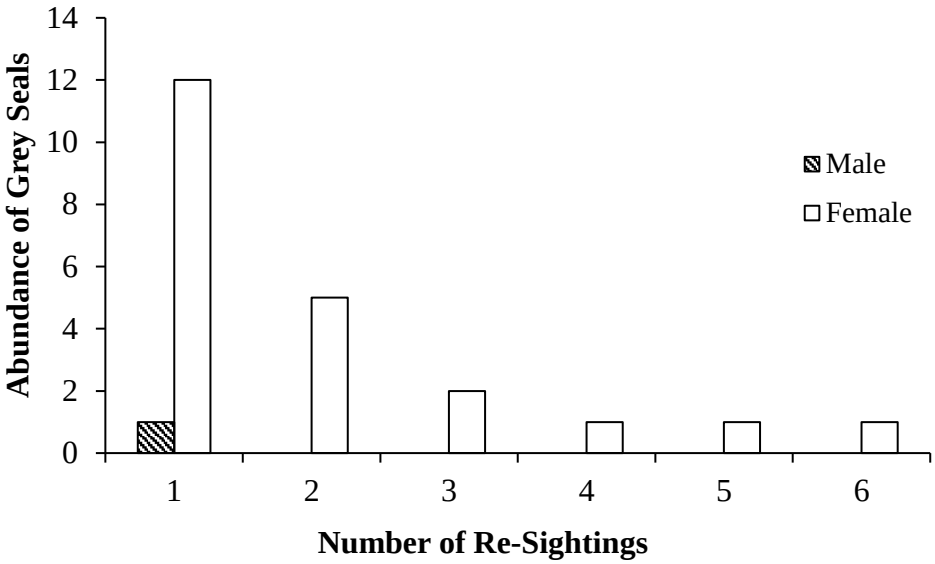

Figure 13.The abundance of male and female grey seals (*H. grypus*) that were re-sighted between 1- 6 times (1= first time after initial identification) over the survey period from June to July 2017 along the coast of Cardigan Bay SAC.

3.1.2. Individual identification and distribution

The abundance of identified grey seals in Seals Bay increased from 7 in June to 12 in July (Figure 14). At the haul-out site of Seals Bay, the grey seal 020 was the individual with the highest number of sightings over the entire survey period, in comparison to the 10 individuals that were only sighted once over June and July 2017 (Figure 14). However, there were a number of individuals that were sighted at Seals Bay more than once over this period including: 010, 005, 001 and 031 (Figure 14). In comparison to the site fidelity observed at Seals Bay, Cardigan Island had a total of six individuals that were sighted more than once over the survey period, including: 007, 009, 014, 027, 035 and 039 (Figure 15), whilst the other 24 individuals were only sighted once during this time (Figure 15). When comparing the individuals identified in this study to photographs of grey seals captured along the coast of Cardigan Bay SAC in 2015 and 2016, three individuals were re-identified: 001, 005 and 033 through photo-identification techniques. Supplementary information on each individual identified is described in the grey seal catalogue in Appendix 3.

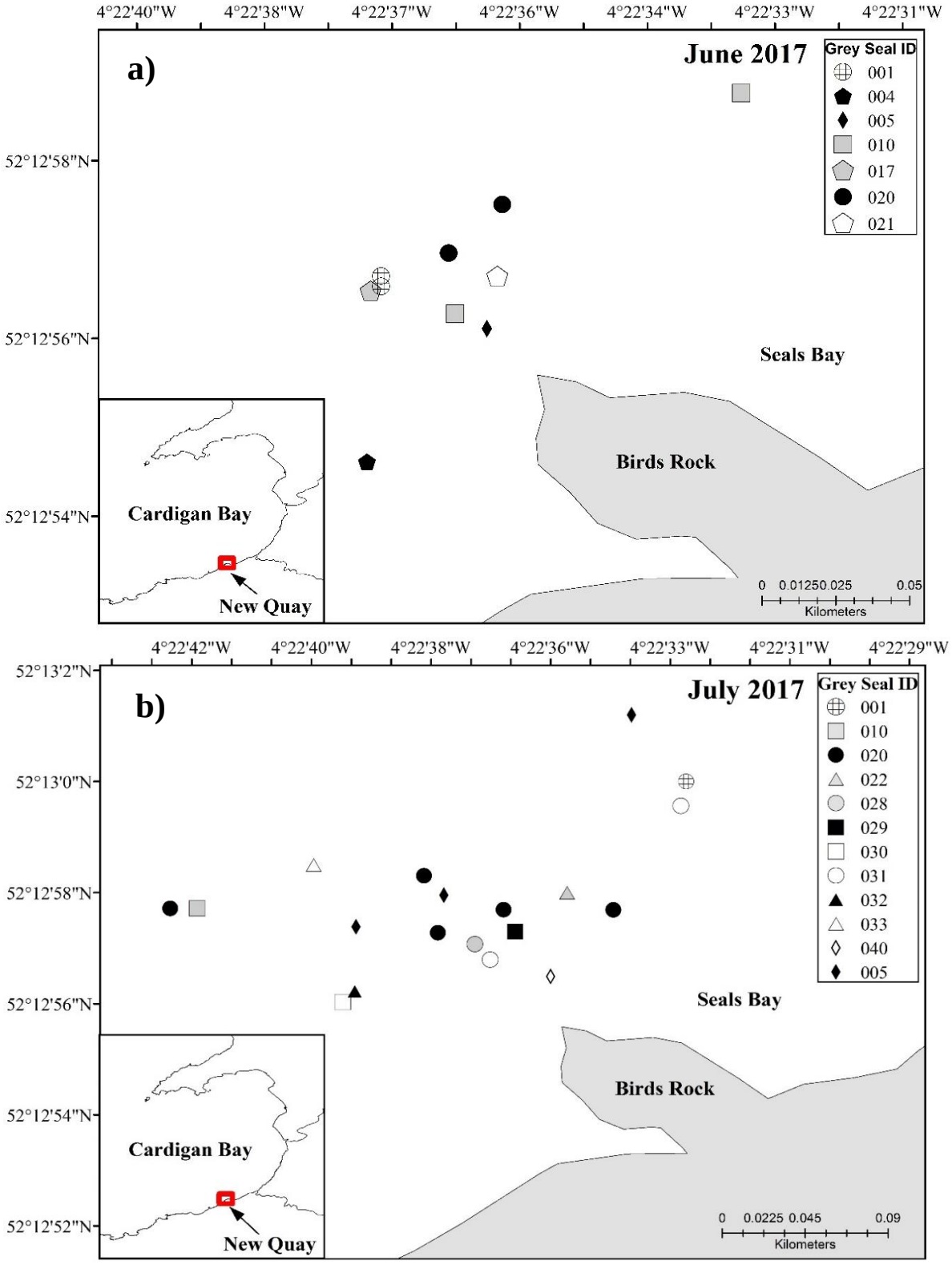

Figure 14. Figure 14. Map of Seals Bay haul-out site, New Quay, illustrating individual grey seals (*H. grypus*) (grey seal ID number) sighted in a) June 2017 and b) July 2017 during boat and land-based surveys. The number of times an individual is displayed signifies the number of days that same individual was observed.

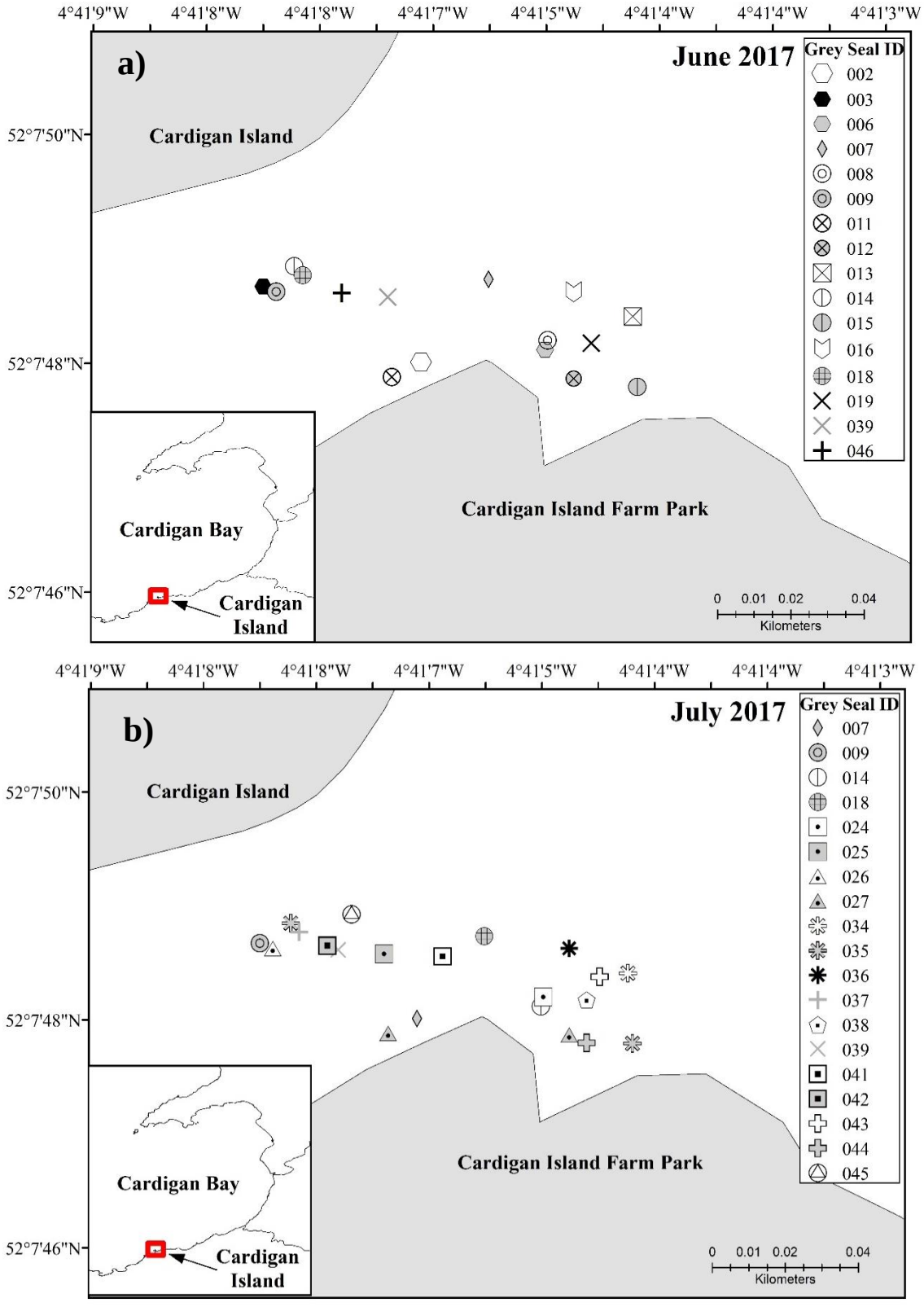

Figure 15. Map of Cardigan Island haul-out site, Cardigan, illustrating individual grey seals (*H. grypus)* (grey seal ID number) sighted in a) June 2017 and b) July 2017 during boat and land-based surveys. The number of times an individual is displayed signifies the number of days that same individual was observed.

3.2. Hypothesis b). Abundance, haul-out behaviour and site fidelity are influenced by key environmental factors

3.2.1. Abundance and environmental factors

Abundance and sea state

The average abundance of grey seals found along the coast of Cardigan Bay SAC was greatest in Beaufort sea states 1 and 2, both having an average abundance of two individuals for each survey, by comparison to sea state 3 which had an average abundance of one individual per hour (Figure 16). However, the abundance of grey seals ranged from 0-6 individuals for sea state 1, 0-8 individuals for sea state 2, and 0-7 individuals for sea state 3. Only sea states 1 to 3 were observed during the survey period, where there was no statistically significant difference observed between these three sea states, and the abundance of grey seals along the coast of Cardigan Bay SAC (GLM, $X^2 = 169.73$, $p = 0.11$, slope= -0.1785 ± 0.1136).

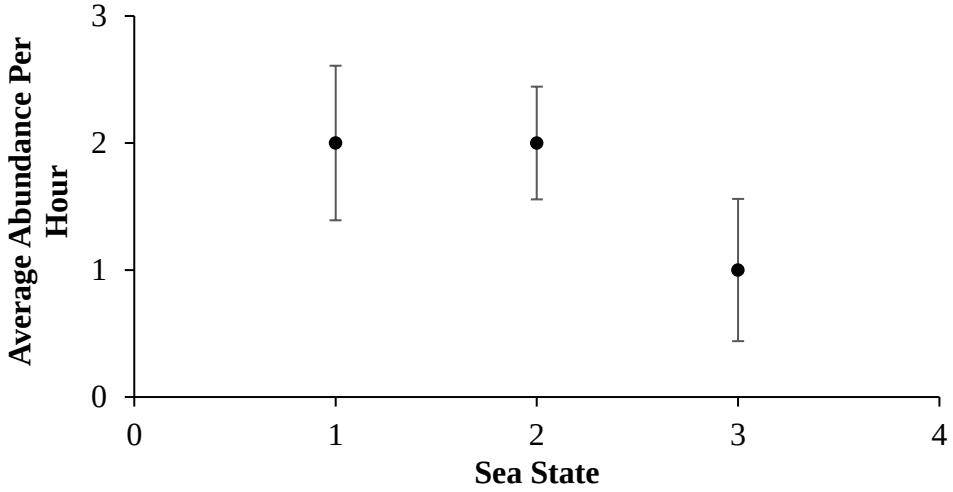

Figure 16. Average abundance (± 95% C.I.) of grey seals (*H. grypus*) and sea states ranging from Beaufort Scale 1-3 along the coast of Cardigan Bay SAC from June to July 2017.

Abundance and tidal phase

The greatest average abundance of two grey seals per hour was observed at low and ebb tide, and the lowest average abundance of one grey seal per hour was observed at both flood and high tide (Figure 17). The abundance of grey seals along the coast of Cardigan Bay SAC ranged between 0-8 individuals at low tide and 0-2 individuals at high tide. There was a significant difference between the phase of tide and the abundance of grey seals (GLM, $X^2 = 193.08$, $p < 0.001$), with significant differences in abundance found between flood and ebb

tides (GLM post-hoc, p <0.001), ebb and high tides (GLM post-hoc, p = 0.002), low and flood tides (GLM post-hoc, p <0.001), and low and high tides (GLM post-hoc, p <0.001).

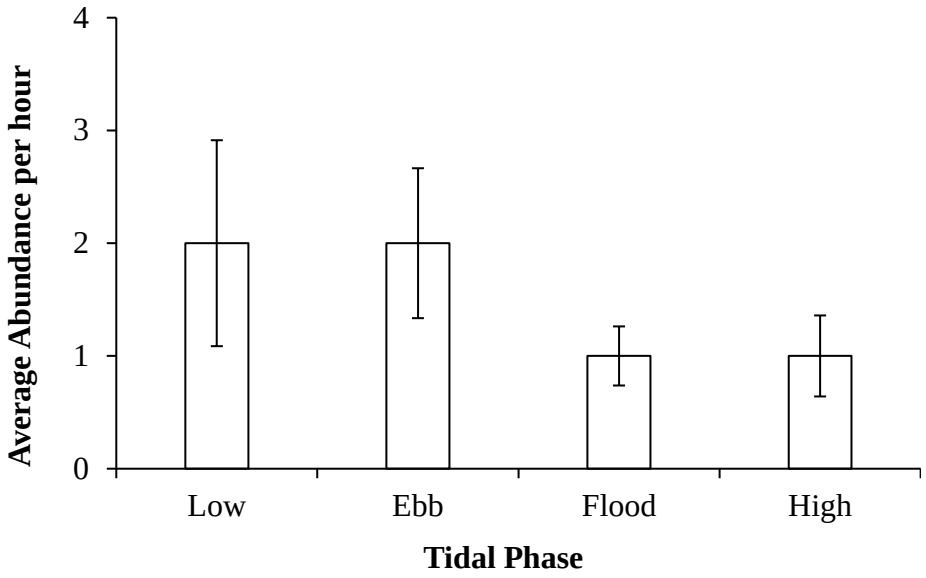

Figure 17. Average abundance (± 95% C.I.) of grey seals (*H.grypus*) at different tidal phases (low, ebb, flood and high) along the coast of Cardigan Bay SAC from June to July 2017.

Abundance and air/sea surface temperature

The air temperature (˚C) along the coast of Cardigan Bay SAC, West Wales ranged from 12.9˚C to 20˚C, and fluctuated daily during the seven-week survey period from June to July 2017 (Figure 18). The greatest fluctuation in air temperature over a period of one day was from 20˚C down to 15.5˚C, where only an average of one grey seal was observed. The air temperature did not show a linear relationship or trend with grey seal abundance (Figure 18) (GLM, $X^2 = 228.67$, p = 0.15). The sea surface temperature (˚C) along the coast of Cardigan Bay SAC, West Wales displayed a change of 2.7˚C throughout the entire seven-week survey period and ranged from 12.8˚C to 15.5˚C (Figure 18). The abundance of grey seals fluctuated throughout the survey period in comparison to the sea surface temperature, which showed a gradual increase throughout this time (Figure 18). However, there was no significant relationship between grey seal abundance and sea surface temperature, (GLM, $X^2 = 228.67$, p = 0.50). The observed average grey seal abundance was greater on full and new moons (spring tide) by a range of 1-6 individuals compared to the observed average abundance during the first and third quarter lunar phases (neap tide) (Figure 18).

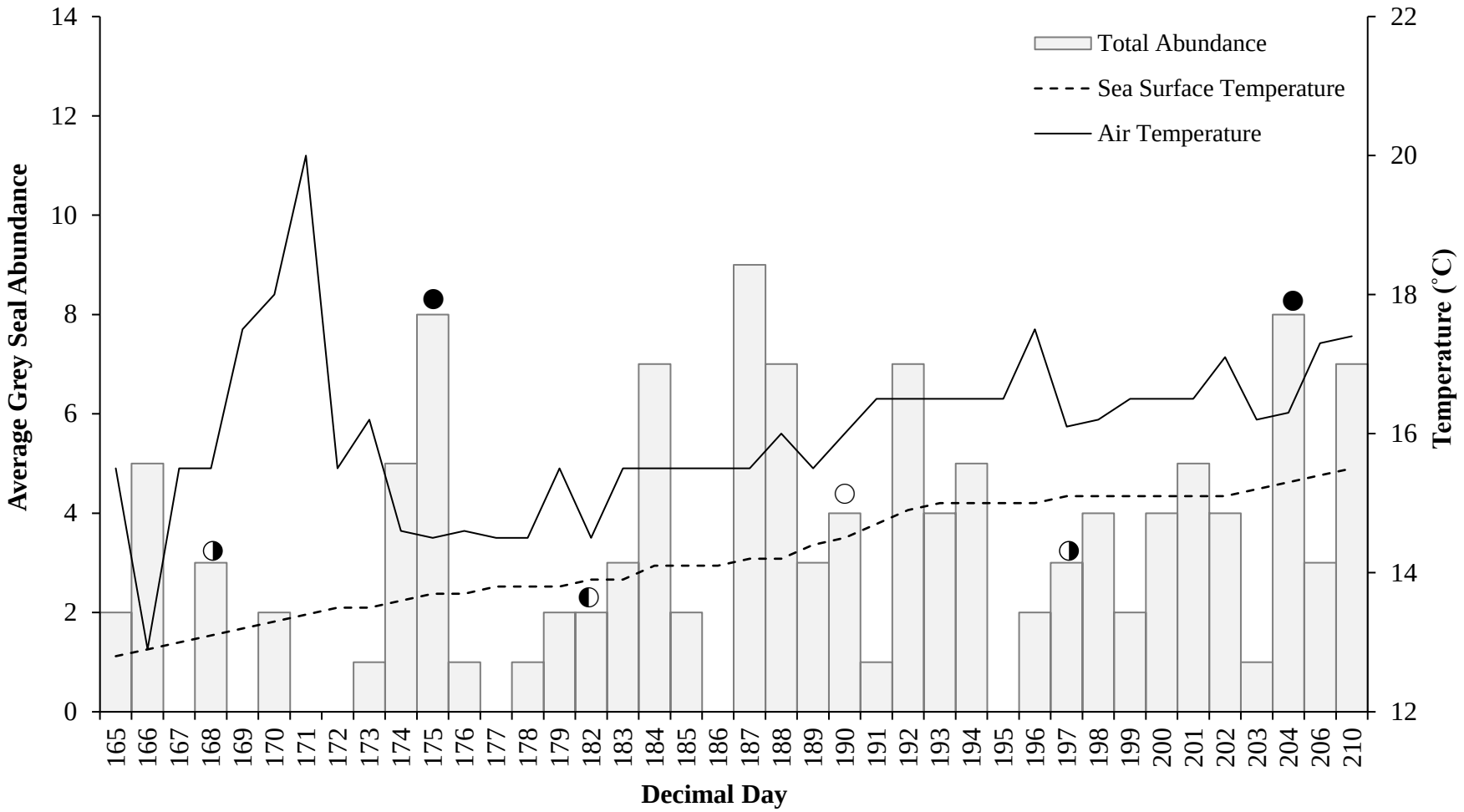

Figure 18. Grey seal (*H. grypus*) abundance over time (decimal days) with associated sea surface and air temperature (˚C) for the survey period commencing from 14th June until the 29th July 2017 along the coast of Cardigan Bay SAC, West Wales. Lunar cycle phase presented above corresponding decimal day: First quarter ◐, Full moon ○, Third quarter ◑, New moon ●.

Abundance and the influence of all environmental factors

Tidal phase and sea state were observed to significantly influence the abundance of grey seals when taking into consideration all environmental factors (Table 5), whereas both air temperature and sea surface temperature where not shown to significantly influence the changes in the abundance of grey seals observed between June and July 2017 (Table 5).

Table 5. GLM numerical results for the abundance model for the following environmental factors: tidal phase, sea state, air temperature and sea surface temperature.

Predictors	**Chi.sq**	**p-value**
Tidal Phase	26.953	<0.001
Sea State	39.035	0.02
Air Temperature	26.533	0.51
Sea Surface Temperature	26.326	0.65

Deviance explained= 0.406%

3.2.2. Behaviour and environmental factors

Behaviour and sea state

The percentage of grey seals that were observed as hauled-out varied between sea states, with the greatest percentage of grey seals hauled-out at sea state 2 with more than 50% of all observed individuals hauled-out rather than remaining in the water (Figure 19). However, there were no grey seals hauled-out at sea state 3 during the behavioural observation surveys. There was no significant difference observed between changes in sea state and the number of grey seals hauled-out (GLM, $X^2 = 27.346$, $p = 0.96$, slope = -0.02377 ± 0.47503).

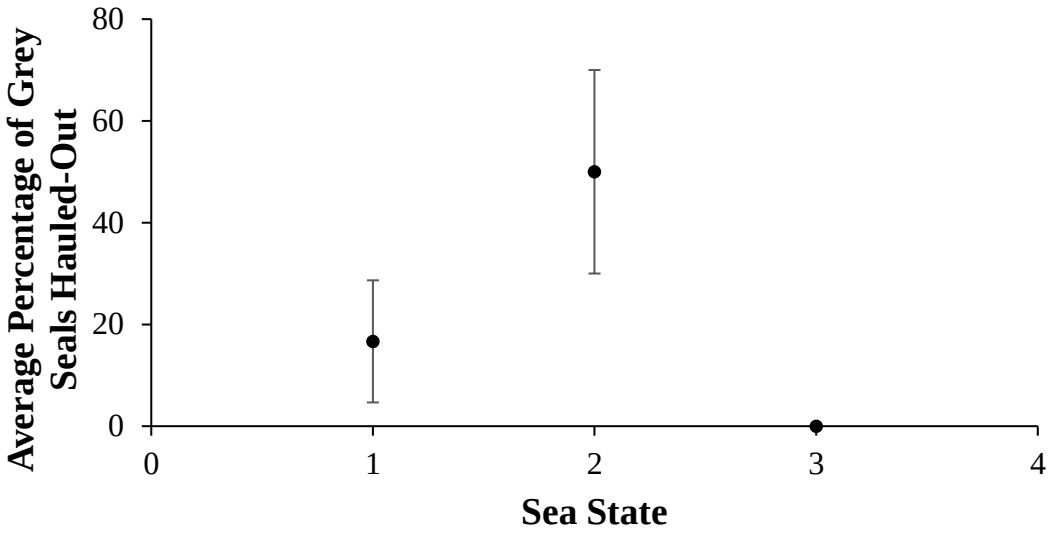

Figure 19. The proportion of grey seals (*H. grypus*) hauled-out (%) (± 95% C.I.) in Beaufort sea states 1-3 along the coast of Cardigan Bay SAC from June to July 2017. Sample size = 44.

Grey seals displayed a higher percentage of behaviours when hauled-out in sea state 2 compared to sea state 1 (Figure 20), where only three out of five behaviours were displayed, with all individuals displaying head movements. When grey seals were hauled-out at sea state 2, all five behaviours were displayed by a range of between 30%-65% of individuals. Furthermore, body movements and attraction to human activity were displayed by more than 50% of all individuals compared to those in sea state 1 (Figure 20). When grey seals were not hauled-out, short dives were displayed in all three sea states, whereas bottling and contact with other individuals were not observed in sea state 3 (Figure 20). The percentage of individuals floating on the water surface decreased by 58% from sea state 1 to 3, and, similarly, contact between individuals also decreased by 33% from sea states 1 to 3 (Figure 20). However, as these behaviours decreased, the percentage of individuals observed showing long dives increased by 50% from sea states 1 to 3 (Figure 20).

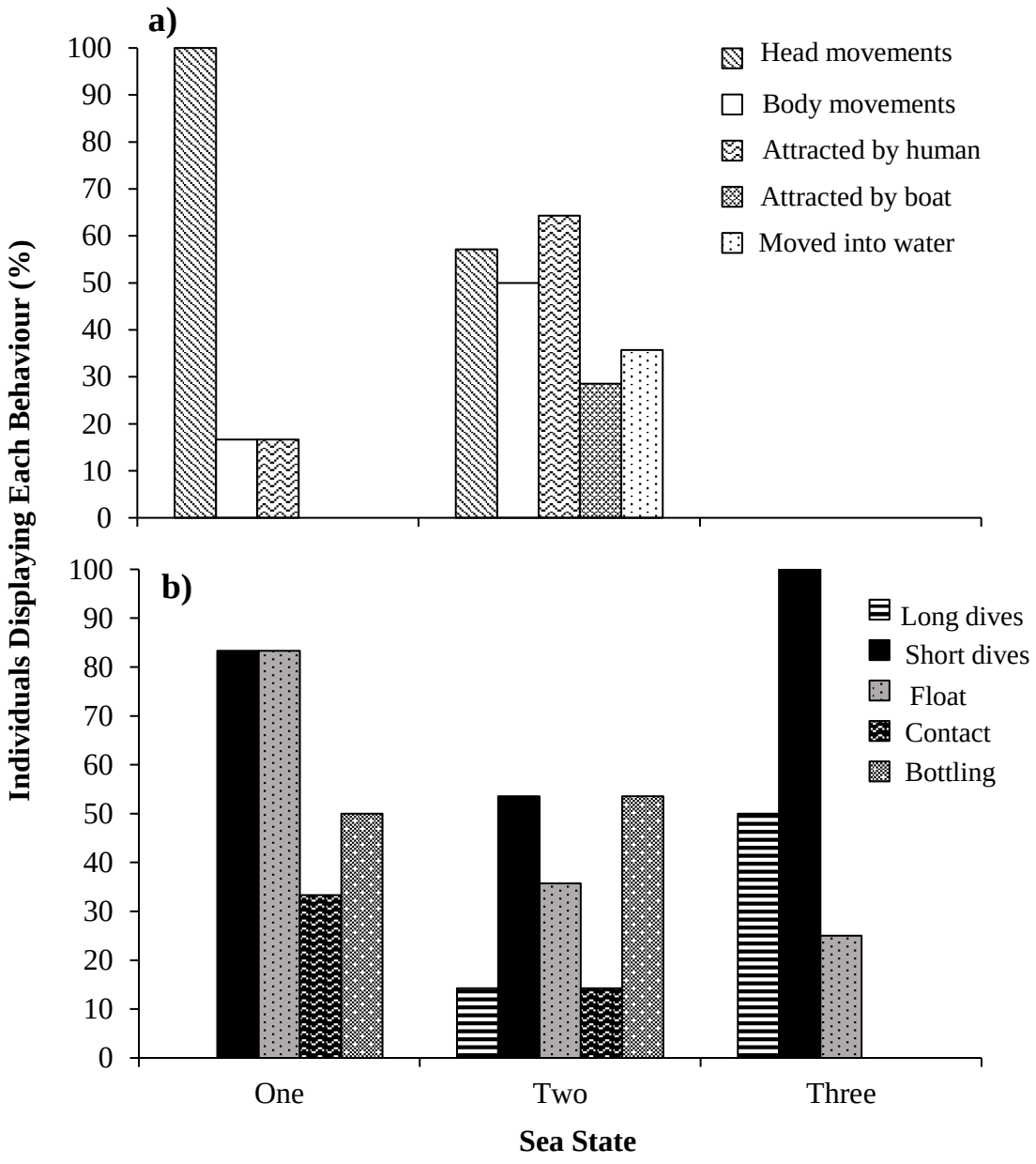

Figure 20. Percentage of individual grey seals (*H. grypus*) displaying five common behaviours in Beaufort sea states 1-3 when a) hauled-out (behaviours include: head movements, body movements attracted by human, attracted by boat and moved into water) and b) not hauled-out (behaviours include: long dives, short dives, float, contact with other seals and bottling) along the coast of Cardigan Bay SAC from June to July 2017.

Behaviour and tidal phase

The total proportion of grey seals observed as hauled-out in comparison to those not hauled-out decreased with increasing tidal height (Figure 21), with 58% of all grey seals observed hauled out at low tide compared to the 16% that were observed at high tide. There were no significant differences between the observed proportion of grey seals hauled-out and the change in tide during the survey period (GLM, $X^2 = 50.375$, $p = 0.17$).

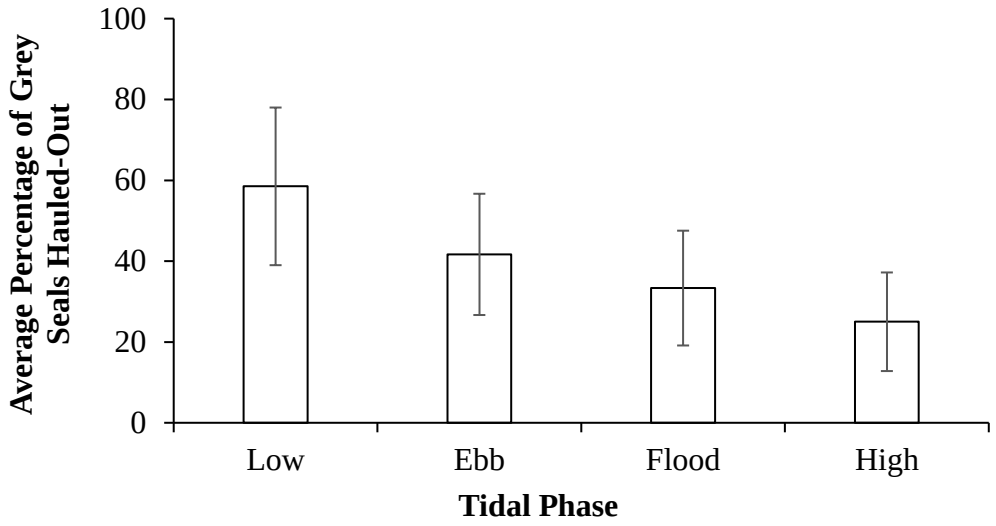

Figure 21. The proportion of grey seals (*H. grypus*) hauled-out (%) (± 95% C.I.) at four tidal phases (low, ebb, flood and high) at haul-out sites along the coast of Cardigan Bay SAC from June to July 2017. Sample size = 44.

When grey seals were hauled-out, a minimum of four out of the five behaviours were observed at each tidal phase (Figure 22). The percentage of individuals that displayed head movements remained consistently high for all tidal phases, ranging from 80% to 100% (Figure 22). Similarly, the percentage of individuals that were attracted by humans also remained high between the tidal phases, with a range of 60% to 75%. However, both body movements and movement back into the water were highest at high tide, with 68% of grey seals displaying these behaviours in comparison to less than 15% that were observed during low tide (Figure 22). When grey seals were not hauled-out, the percentage of individuals that displayed floating on the water surface and close contact with other individuals decreased by more than 40% from low tide to high tide (Figure 22). In comparison, the percentage of individuals that dived for long periods increased from 14% at low tide to 65% at high tide (Figure 22). More than 50% of individuals displayed short periods of diving and bottling for all tidal phases.

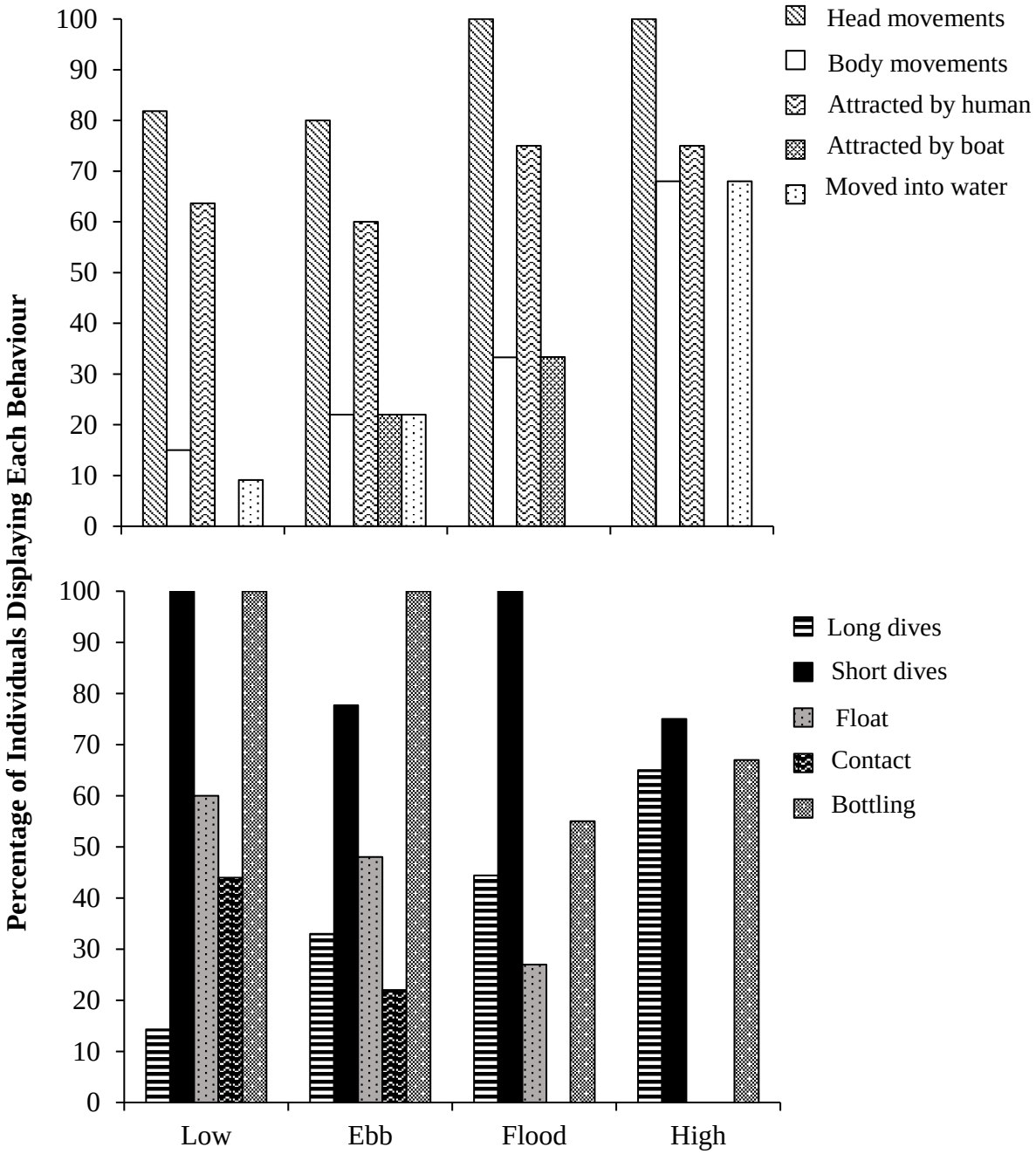

Figure 22. Percentage of individual grey seals (*H. grypus*) displaying five common behaviours at tidal phases: low, ebb, flood and high when a) hauled-out (behaviours include: head movements, body movements attracted by humans, attracted by boats and moved into water), and b) not hauled-out (behaviours include: long dives, short dives, float, contact with other seals and bottling) along the coast of Cardigan Bay SAC from June to July 2017.

Behaviour and air/sea surface temperature

The air temperature fluctuated between 14˚C-16.5ºC, while the sea surface temperature gradually increased from 12.8˚C to 15.1ºC (Figure 23), during land-based surveys from between 14th June to 19th July 2017 along the coast of Cardigan Bay SAC. The percentage of grey seals observed as hauled-out in comparison to those present in the water also fluctuated over the survey period, from 0% to 100% (Figure 23). The percentage of grey seals hauled-out did not show a significant difference with changes in air (GLM, $X^2 = 50.946$, $p = 0.25$) or sea surface temperature (GLM, $X^2 = 52.079$, $p = 0.57$).

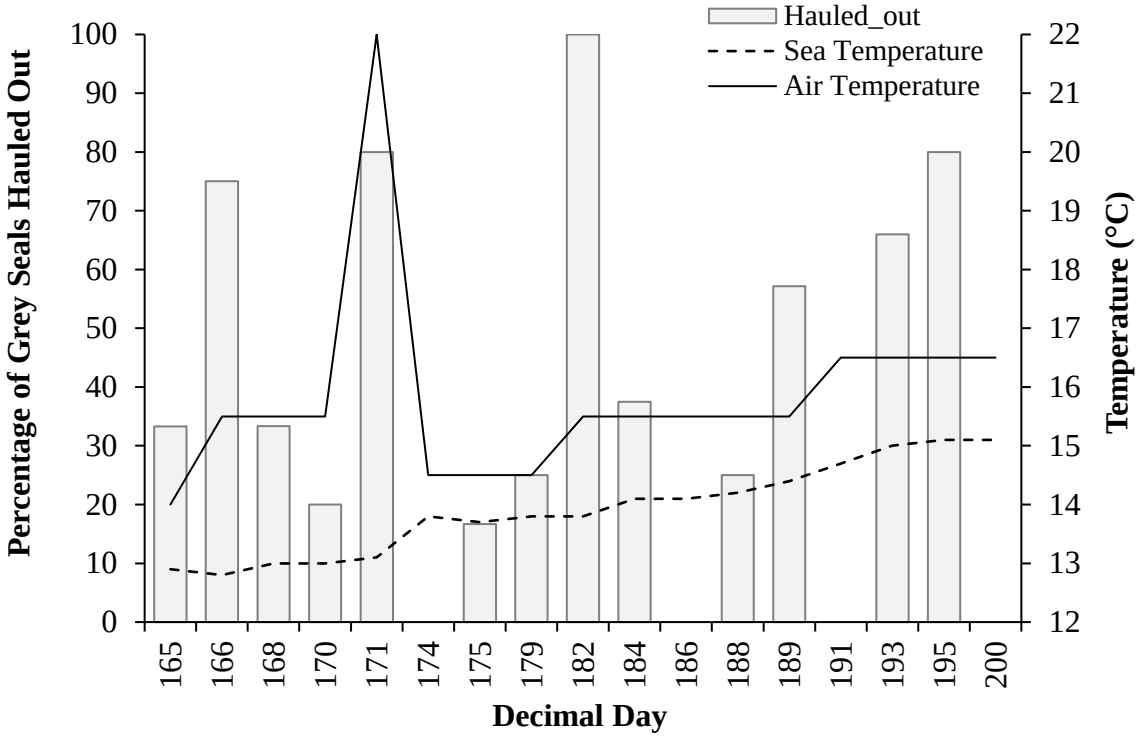

Figure 23. Percentage of grey seals (*H. grypus*) hauled-out over time (decimal days) with associated sea surface and air temperature (˚C) for the survey period commencing from 14th June until the 19th July 2017 along the coast of Cardigan Bay SAC, West Wales.

Behaviour and the influence of all environmental factors

When taking into consideration the influence of all four environmental factors, there were no significant difference in the number of hauled-out grey seals compared with those present in the water and changes in all environmental factors (Table 6).

Table 6. GLM numerical results for the proportion of grey seals (*H. grypus*) hauled-out model for the following environmental factors: tidal phase, sea state, air temperature and sea surface temperature.

Predictors	**Chi.sq**	**p-value**
Tidal Phase	26.246	0.29
Sea State	25.884	0.55
Air Temperature	25.167	0.39
Sea Surface Temperature	22.664	0.11

Deviance explained= 0.171%

3.2.3. Site fidelity and environmental factors

Site fidelity and sea state

Individual grey seal re-sightings were only observed at sea states 1 and 2. The difference in the average number of re-sightings between these sea states was only 2% (Figure 24), and both sea states were observed to have similar numbers of re-sightings of individuals. There was a significant difference observed between the number of returning individuals and changes in sea state (GLM, X^2= 49.483, p = 0.02, slope= -0.6067± 0.2552).

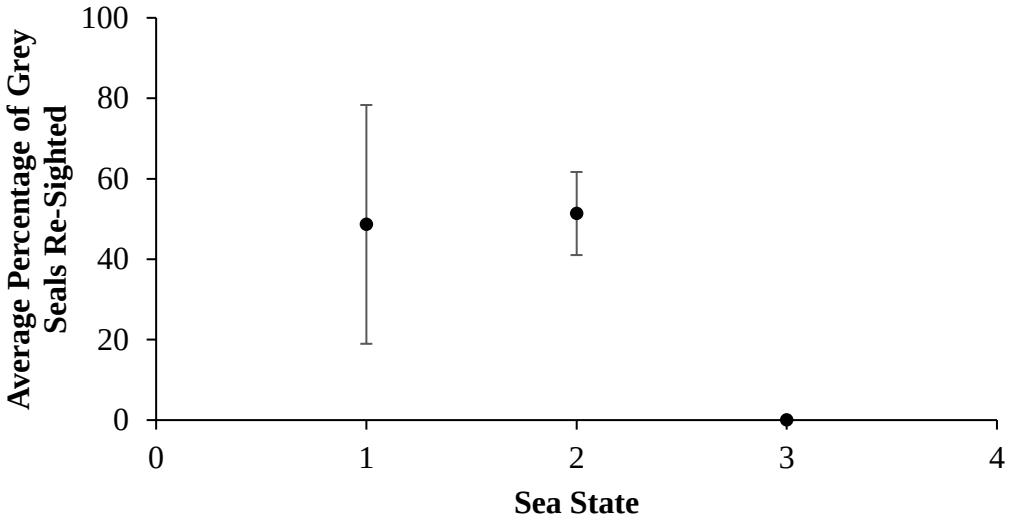

Figure 24. Average percentage of grey seals (*H. grypus*) (±95% C.I.) that were re-sighted along the coast of the Cardigan Bay SAC in Beaufort sea states 1-3 from June to July 2017. Sample size = 37.

Site fidelity and tidal phase

Re-sightings of individuals occurred during all four tidal phases, while the greatest number of individuals that returned to the same site were found during an ebbing tide and the lowest at high tide (Figure 25). There was a significant difference between the tidal phase and number of individuals that returned to the same haul-out site (GLM, $X^2 = 44.192$, $p<0.001$), with those differences observed between low and high tide (GLM post hoc, $P = 0.008$), ebb and flood (GLM, post hoc, $p = 0.006$) and ebb and high (GLM, post hoc, $p = 0.006$).

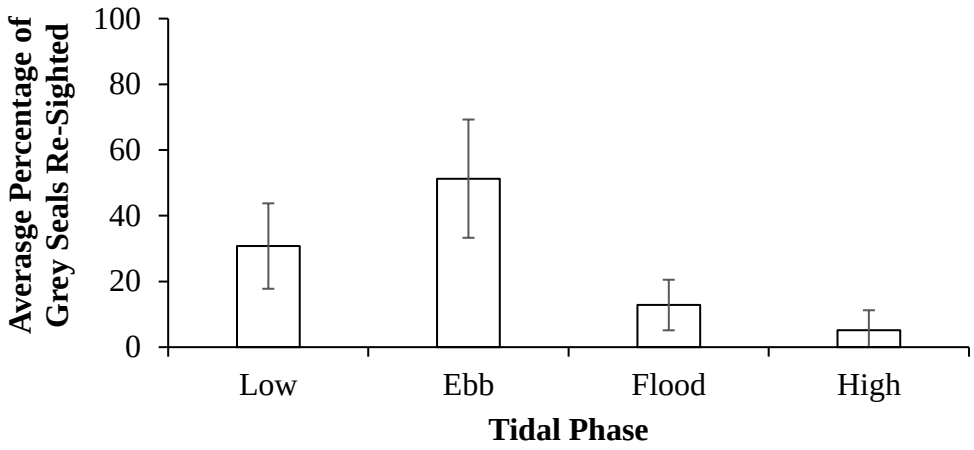

Figure 25. Average percentage of grey seals (*H. grypus*) (±95% C.I.) that were re-sighted along the coast of the Cardigan Bay SAC at four tidal phases (low, ebb, flood and high) from June to July 2017. Sample size = 37.

Site fidelity and air/sea surface temperature

The number of individual grey seals that returned to the same haul-out site was not influenced by changes in air (GLM, $X^2 = 52.685$, $p = 0.51$) and sea surface temperature (GLM, $X^2 = 52.132$, $p = 0.20$) (Figure 26) and constantly fluctuated throughout the survey period. There was a gradual increase in sea surface temperature from the 14th June to 19th July. However, the number of returning individuals continued to fluctuate between one and four with an increase in sea surface temperature. Additionally, the number of individuals re-sighted did not differ on days with an air temperature of 14ºC and an air temperature of 22ºC (Figure 26).

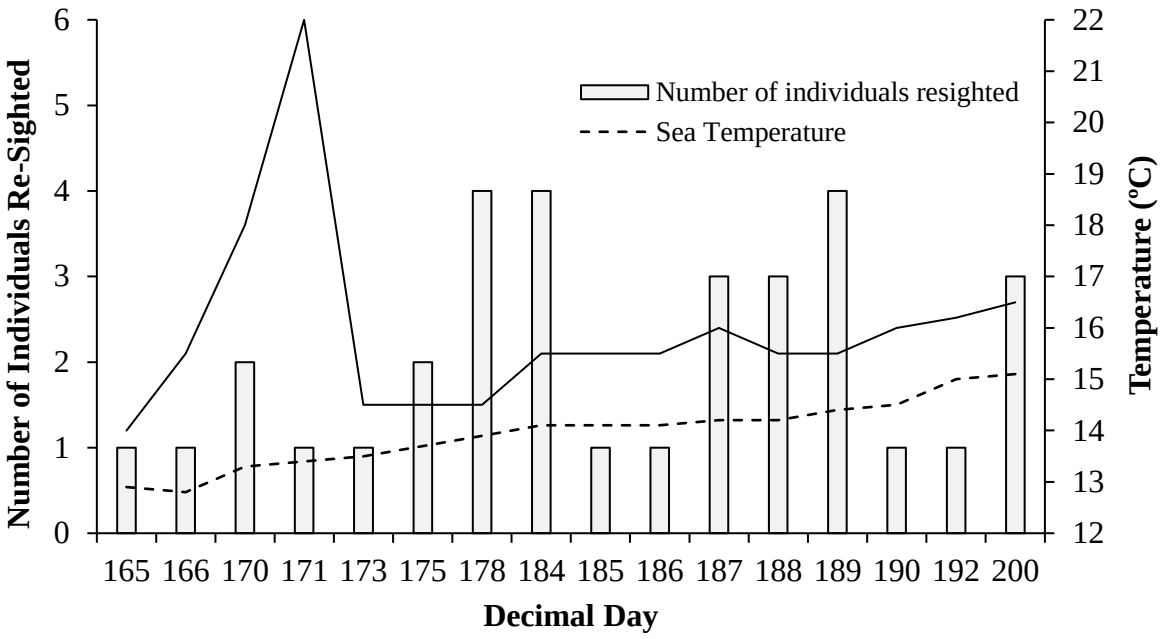

Figure 26. Number of individual grey seals (*H. grypus*) re-sighted over time (decimal days) with associated sea surface and air temperature (˚C) for the survey period commencing from 14th June until the 19th July 2017 along the coast of Cardigan Bay SAC, West Wales. Sample size = 37.

Site fidelity and the influence of all environmental factors

When taking into consideration the influence of all four environmental factors, tidal phase had a significant influence on the number of individuals that were re-sighted during the study whilst the remaining three environmental factors: sea state, air and sea temperature did not significantly influence grey seal site fidelity (Table 7).

Table 7. GLM numerical results for the site fidelity model for the following environmental factors: tidal phase, sea state, air temperature and sea surface temperature.

Predictors	**Chi.sq**	**p-value**
Tidal Phase	49.358	0.01
Sea State	47.149	0.14
Air Temperature	46.020	0.29
Sea Surface Temperature	45.047	0.32

Deviance explained= 0.181%

3.3. Hypothesis c). Population structure of grey seals is similar at each haul-out site with females outnumbering males and a smaller abundance of small or juvenile males in comparison to large adult males

There were 46 individual grey seals (41 females and 5 males) that were identified using photo-identification techniques along the coast of Cardigan Bay SAC. There was a significant difference between the number of males and females along the coast of Cardigan Bay SAC (ANOVA, $F_{1,40} = 9.303$, $p = 0.004$). The significant differences in the number of males and females were observed within both haul-out sites: Seals Bay (ANOVA, $F_{1,28} = 33.669$, $p < 0.001$) and Cardigan Island (ANOVA, $F_{1,12} = 33.669$, $p < 0.001$), as well as between the two haul-out sites (Figure 27).

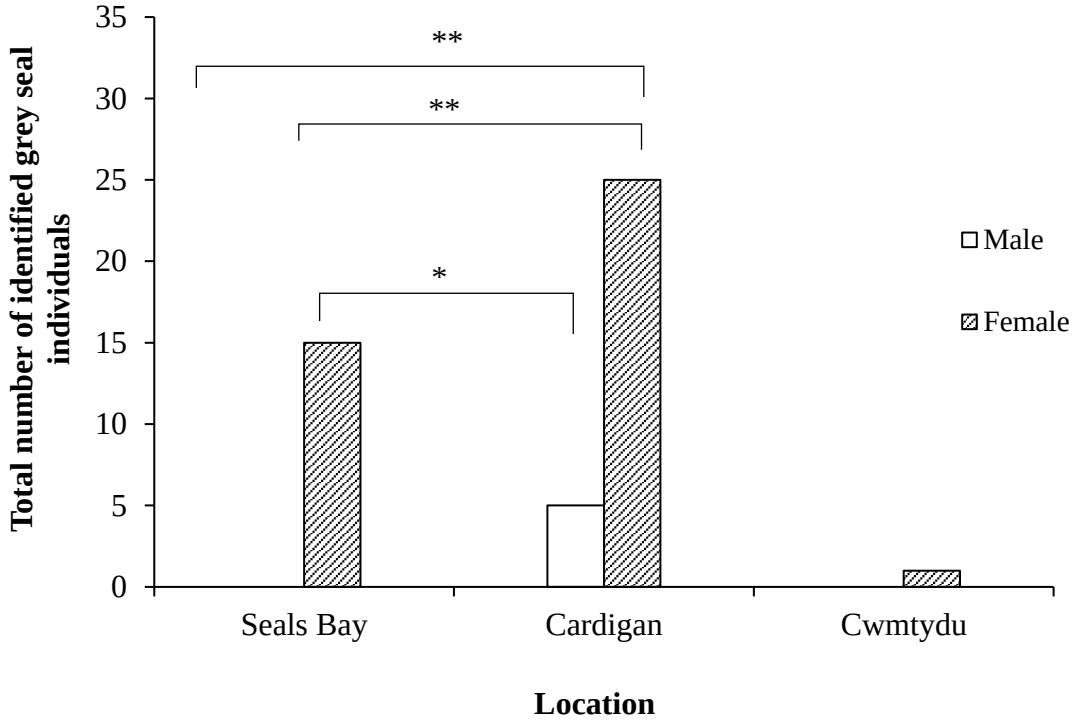

Figure 27. Total number of male and female grey seals (*H. grypus*) at three haul-out sites along the coast of Cardigan Bay SAC, West Wales (1. Seals Bay, New Quay, 2. Cardigan Island, Cardigan and 3. Cwmtydu, Llandysul) identified using photo-identification from photographs taken between June and July 2017. GLM post-hoc test results given for Seals Bay and Cardigan: * indicates $p<0.05$ and ** indicates $p<0.001$.

The ages of photo-identified grey seals ranged from young through to adult along the coast of Cardigan Bay SAC. However, not all age categories were observed at each haul-out site, with the maximum of three age categories being observed at a single haul-out site (Figure 28). The age category with the greatest number of individuals was adults (5+ years) and the lowest were young (0-1 years) (Figure 28). Individual female grey seals were observed for each age category, whilst males were only identified as being young adults (3-5 years) or adults (Figure 28). There were significant differences identified between a) the number of sightings of grey seal individuals along the coast of Cardigan Bay SAC in each age category ($F_{3,46} = 4.594$, $p = 0.004$), and b) the number of grey seals in each age category between haul-out sites ($F_{2,46} = 3.212$, $p = 0.05$). In comparison, there was no significant difference in the number of males and females in each age category along the coast of Cardigan Bay SAC ($F_{3,46} = 1.581$, $p = 0.21$).

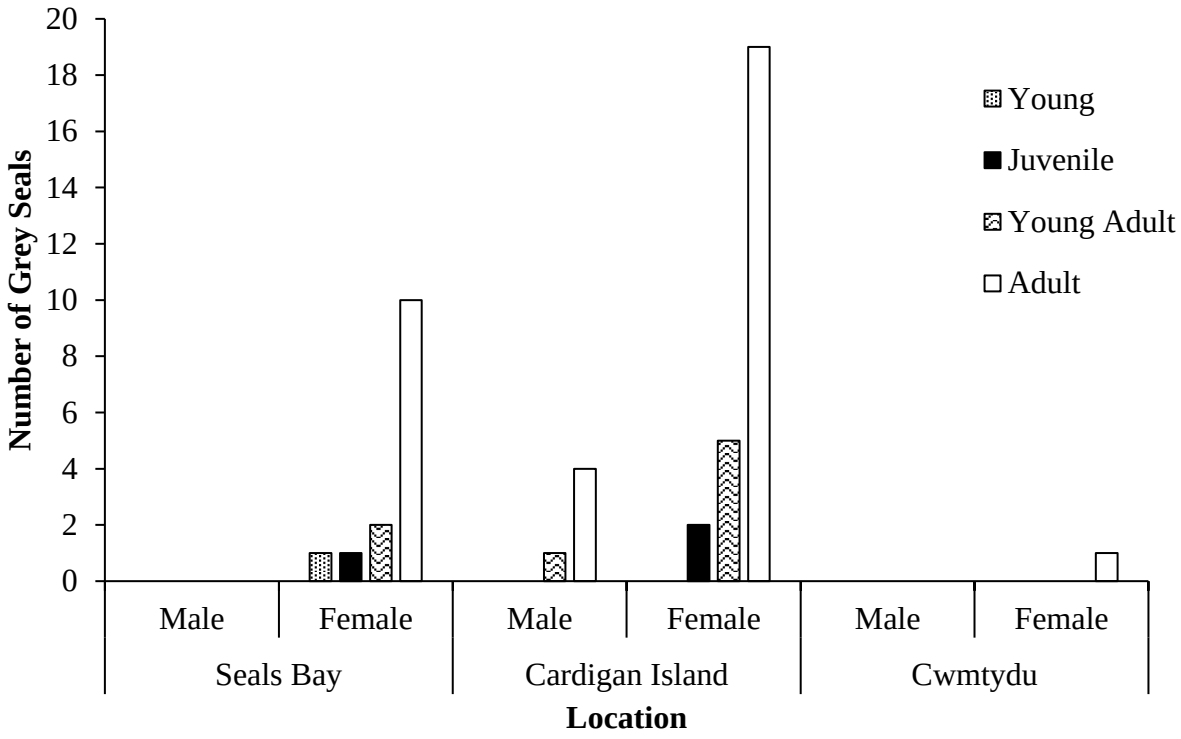

Figure 28. Number of both male and female grey seals (*H. grypus*) at three haul-out sites along the coast of Cardigan Bay SAC, West Wales (1. Seals Bay, New Quay, 2. Cardigan Island, Cardigan and 3. Cwmtydu, Llandysul) in four categorised age groups (young, juvenile, young adult and adult), identified using photo-identification from photographs taken between June and July 2017.

The group dynamics observed in the population of grey seals along the coast of Cardigan Bay SAC varied between groups of all females, observed only at Seals Bay (Figure 29), and groups of males and females, observed at Cardigan Island (Figure 29). The all-female groups that were associated together in Seals Bay consisted of a range of ages: adults only, young and juveniles, and adults and young (Table 8). There were zero males present at Seals Bay and therefore the male: female ratio ranged between 0:2 - 0:5 (Table 8). In comparison, males were observed as present in more than 60% of grey seal groups at Cardigan Island. However, when the males were present, the number of females would always outnumber the number of males, with a male: female ratio of between 1:6 - 2:5 (Table 8). All age groups except the young age category were observed within the groups at Cardigan Island, varying from groups with adults only to groups with adults, young adults, and juveniles. Groups that consisted of one male were observed adults whereas groups consisting of two males were either both adults or a young adult and mature adult (Table 8).

Figure 29. Photographs of grey seal (*H. grypus*) group dynamics along the coast of Cardigan Bay SAC from June to July 2017, identifying a) female group of grey seals at Seals Bay, New Quay (taken from a visitor passenger boat: *Ermol VI*/Dolphin Spotting Boast Trips), b) two males grey seals at Cardigan Island, Cardigan and c) a male (top) and female (bottom) grey seal at Cardigan Island.

Table 8. Population dynamics of grey seals (*H. grypus*) at two survey haul-out site locations (Seals Bay, New Quay and Cardigan Island, Cardigan) using photo-identification of individuals taken in June and July 2017. Identified individuals (ID code, gender and age) observed together, in addition to the date of which they were photographed and the male: female ratio is presented. Gender: Male: ♂, Female: ♀, Age: A: Y: Young (0-1 years), J: Juvenile (2-3 years), YA: Young Adult (3-5 years), A: Adult (5+ years).

Location & Date	Individual Grey Seal ID Code	Gender	Age	Male: Female
Seals Bay				
14/06/2017	001	♀	A	0:2
	004	♀	A	
20/06/2017	020	♀	Y	0:2
	021	♀	J	
27/06/2017	001	♀	A	0:3
	010	♀	A	
	020	♀	Y	
04/07/2017	005	♀	A	0:5
	028	♀	A	
	029	♀	A	
	030	♀	A	
	050	♀	A	
06/07/2017	005	♀	A	0:5
	020	♀	Y	
	031	♀	A	
	032	♀	A	
	033	♀	A	
08/07/2017	005	♀	A	0:3
	020	♀	Y	
	031	♀	A	
Cardigan Island				
15/06/2017	002	♀	A	1:5
	003	♀	A	
	006	♀	A	
	007	♀	A	
	008	♀	A	
	039	♂	A	
24/06/2017	011	♀	A	2:7
	012	♂	A	
	013	♀	A	
	014	♀	A	
	015	♀	J	

Location & Date	Individual Grey Seal ID Code	Gender	Age	Male: Female
Continued…				
	016	♀	A	
	018	♀	A	
	019	♀	A	
	046	♂	A	
03/07/2017	007	♀	A	1:6
	014	♀	A	
	018	♀	A	
	024	♀	A	
	025	♂	A	
	026	♀	A	
	027	♀	YA	
07/07/2017	027	♀	YA	2:5
	034	♀	A	
	035	♀	A	
	036	♀	YA	
	037	♂	YA	
	038	♀	A	
	039	♂	A	
12/07/2017	041	♀	YA	0:4
	042	♀	J	
	043	♀	A	
	044	♀	A	
19/07/2017	009	♀	YA	0:4
	035	♀	A	
	045	♀	YA	

4.0. Discussion

4.1. Hypothesis a). Male and female grey seals show haul-out site fidelity amongst populations along the coast of the Cardigan Bay SAC

4.1.1. Haul-out site fidelity along the coast of Cardigan Bay SAC

Forty-six grey seals were identified using photo-identification techniques during this study between June and July 2017. However, only 24% of the seals (12 out of 46) were observed to show haul-out site fidelity by returning to a haul-out site more than once over the survey period. By comparison, there were no identified individuals sighted at the other chosen haul-out sites, but the low site fidelity observed may suggest that the grey seals are moving between haul-out sites rather than remaining at one. Due to the shortness of the study, it is difficult to determine whether haul-out site fidelity is being displayed on a smaller scale, or whether the number of re-sightings would increase with a longer survey period. Karlsson *et al.* (2005) describes the variation in site fidelity of grey seals at haul-out sites in Swedish coastal waters. It was found that out of 636 sightings only 0.5% returned to one haul-out site, in comparison to 31% that returned to another haul-out site. Therefore, an increased survey period could assist in determining whether the scale of site fidelity displayed by grey seal populations along the coast of Cardigan Bay SAC is high with regular re-sightings, or whether individuals return but on a less regular basis compared to other grey seal populations.

The timing of this study's survey period concluded before the start of the breeding season, which usually commences in late August to early September, peaking in November. Therefore, gestating female grey seals (identified based on the examination of the body size and recognition of the enlargement of the stomach region) that were identified in this study (001, 031 and 005) were re-sighted more than once during the survey period, and may have been preparing to give birth in these areas, which may explain the greater number of re-sightings. These observations correspond with the observations described by Davies (1949) who found gestating females to haul-out more regularly leading up to giving birth in order to preserve energy stores for the upcoming lactation period, where the female will fast for more than two weeks. There are a variety of benefits in returning to the same haul-out sites, such as having greater efficiency in exploiting resources, such as food, where a site previously established with a reliable food source would be more beneficial than travelling to a new area with limited or unreliable food resources. In addition, if female grey seals had previously given birth at one haul-out site and the pup survived, the female would be more likely to return to the same area during the breeding season rather than travel to new areas that may result in a higher pup

mortality rate (Weitzmann *et al.,* 2016). Furthermore, two of the pregnant females found at Seals Bay in this study (001 and 005) were also identified at Seals Bay in photographs taken in 2015. Therefore, this increases the possibility that haul-out site fidelity has occurred over a number of years at haul-out sites along the coast of the Cardigan Bay SAC. However, the photographs taken in 2015 were captured in April and May which would correspond with the moulting season of the Atlantic grey seal population, and thus suggests that this area is used for both the breeding and moulting seasons.

The conditions and resources present along the coast of the Cardigan Bay SAC provide suitable areas for grey seals to breed and moult, in addition to having a plentiful food supply. As the Cardigan Bay SAC area has fishing regulations that manage fisheries in order to maintain fish stocks (CCW, 2009), there are reliable supplies of a variety of fish species which would ensure that the grey seal populations residing in this area would not have to travel great distances in order to successfully forage. Furthermore, although grey seals will eat a variety of fish, their diet is described as consisting mainly of benthic or demersal species, and therefore areas such as the coast of Cardigan Bay SAC which reach a maximum depth of only 50m, would present greater opportunities for successful foraging activities. Similarly, Huon *et al.* (2015) described grey seals as having a tendency to remain in depths shallower than 50m, as the shallower areas provided suitable food resources that required a shorter dive duration as opposed to deeper offshore areas. The abundance of potential prey such as flounder (*Platichthys flesus)* and dab (*Limanda limanda*) along the coast of the Cardigan Bay SAC increases during the winter months (Lyons *et al.,* 2006), which is when grey seals (specifically females) leave the haul-out sites to forage and replenish depleted fat reserves that were lost during the breeding season. Thus, the haul-out site fidelity observed along the coast of Cardigan Bay SAC may be related to a number of factors including the successful reproduction and rearing of pups, as well as ideal and stable food resources that are in close proximity to the haul-out sites. A study conducted on the site fidelity of grey seals at Sable Island, Nova Scotia between 2004 and 2014 observed low site fidelity (only 2.9% of females returned at least once to their previous breeding site), which was proposed to be related to the unrestricted human access to the breeding site in addition to the unpredictable topography of the sand dune haul-out site (Weitzman *et al.,* 2016). In comparison, the haul-out sites along the coast of Cardigan Bay SAC are relatively protected against human activity with areas such as Seals Bay being inaccessible to humans except for access gained by boat. Also, the rocky habitats found along the coast of Cardigan Bay SAC provide familiar and more stable areas for pups (Twiss *et al.,*

2001) and therefore these reasons may influence the level of site fidelity observed in populations found along the coast of Cardigan Bay SAC.

4.1.2. Gender specific haul-out site fidelity

The number of individuals that were re-sighted consisted mainly of females, with only one out of five identified males re-sighted. This may be due to a variety of reasons including the timing and duration of this study's survey period that concluded before females began pupping, and may have reduced the potential opportunity of re-sighting a higher number of males. To support this, Anderson *et al.* (1975) also found that male grey seals only appeared at haul-out sites after females had arrived and begun pupping. Furthermore, the reduced number of males that were re-sighted may also have been due to their dark pelage coloration which increases the difficulty in being able to distinguish distinctive markings (Karlsson *et al.*, 2005). Sjöberg *et al.* (2000) suggest that both juvenile and male grey seals may show a lower haul-out site fidelity as they exhibit exploratory foraging behaviour whilst they allow the females to arrive first, therefore allowing them to continue to build up fat reserves prior to the breeding season. With regards to the same individuals returning together, Pomeroy *et al.* (2000) suggest that in an established breeding colony where the number of pups born and survival rates remain stable, matrillines (groups of related individuals) can provide advantages over congregations with unfamiliar or unrelated individuals such as having an increased access to resources, including limited space in small haul-out site areas, a reduction in antagonistic behaviour with individuals residing nearby, and an increased chance of philanthropic behaviour such as cross-suckling. The current study suggests that the populations along the coast of the Cardigan Bay SAC may have individuals that are related, due to the observation of the same individuals returning from previous years in addition to the friendly behaviour observed between females and uncharacteristically between two males (Figure 29). However, due to the short duration of this study it is not possible to confirm whether the individuals observed are related. Further investigation would need to be conducted in order to identify whether this small colony of grey seals shows both haul-out site fidelity to a specific haul-out site and with the same individuals.

4.2. Hypothesis b). Abundance, haul-out behaviour and site fidelity are influenced by key environmental factors

4.2.1. Abundance, proportions of hauled-out grey seals and environmental factors

The abundance (Figure 16) and proportion of grey seals hauled-out (Figure 19) were not influenced by fluctuations in sea state. The proportion of grey seals that hauled-out was

predicted to increase as the sea state decreased due to the calmer and flatter conditions (for example, those observed in sea state 1), that creates less disruption from wave action to the rocks upon which the individuals were hauled-out (Boyd, 1991). However, the differences between Beaufort sea states 1 and 2 are marginal, with small wavelets at sea state 2 in comparison to ripples observed in sea state 1. Therefore, the change in sea states that were observed in this study may not have produced substantial changes in the environment to result in a significant change in abundance. Thus a larger variation in sea state and a greater change in environmental conditions may have had a greater influence on the change in abundance of grey seals. Furthermore, the rocks that are used to haul-out on along the coast of Cardigan Bay SAC are positioned relatively high above the tide line in comparison to the mean water height at low tide. Therefore, this may also reduce the environmental changes such as an increased exposure to wave action during periods of increased sea states. By comparison, large wavelets and an increased exposure to wave action present a greater chance of individuals being disturbed when they are hauled-out, specifically new-born pups (Baker, 1984). This suggests that the individuals observed prior to the breeding season may only haul-out when the environmental conditions are more suitable and less unpredictable in preparation for the forthcoming breeding season, when longer periods of hauling out activities are maintained.

The abundance and number of grey seals that hauled-out along the coast of Cardigan Bay SAC did not show a strong association with tidal phases. Although the average percentage of grey seals hauled-out did decrease from low to high tide (Figure 21), there was not a significant influence in the number of individuals hauled-out at different tidal phases. On the other hand, the average abundance of grey seals was observed to be influenced by the tidal phase, with the lowest abundance observed at high tide and the highest abundance at low tide. At low tide, a greater proportion of the rock used to haul-out onto would be more exposed compared to high tide when some rocks would be submerged completely. Therefore, this would be a reasonable explanation as to why a greater number of grey seals were a) present and b) hauled-out at low and ebb tides compared to flood and high tides. However, as this study was conducted prior to the start of the breeding season, it is possible that the number of individuals hauled-out was reduced by the lack of returning individuals which would have begun to haul-out more often as the breeding season commenced. Leeney *et al.* (2010) observed a similar trend with grey seals in Cornwall and the Isles of Scilly, UK in 2007, where the largest number of grey seals hauled-out was observed at mid-ebb tides. This study was conducted during the moulting season when a larger number of grey seals hauled-out for longer periods of time and therefore

it is suggested that a longer based study which takes into consideration the major life-cycle seasons, should be conducted to determine the underlying relationship between tidal phase and proportion of grey seals hauled out.

In relation to changes in air and sea surface temperature, grey seals are endotherms and are not dependent on external sources for controlling their body temperature. Due to this, the slight increase in sea surface temperature over the survey period (Figure 23) may not have been substantial enough to observe changes in the number of grey seals hauled-out. Thus, to investigate the relationship between sea surface temperature and haul-out behaviour, a study should instead be conducted over a longer time period, with a greater change in sea surface temperature (for example, from winter to summer). Similarly, the fluctuation in air temperature observed during this study did not appear to influence the number of grey seals hauled-out and whereas the number of individuals hauled-out did fluctuate over the survey period, there was no obvious association with changes in air temperature. This was also observed by Lonergan *et al.* (2011) who monitored the proportion of hauled-out grey seals with an air temperature ranging between 8º-21ºC, from the northern coastline in Scotland down the East coast of Britain in 2007-09. Lonergan *et al.* (2011) found fluctuations in the number of individuals that hauled-out during the study period and although it was suggested that these periods of hauling out could be affected by environmental factors such as air temperature, the lack of evidence and association between the two suggested that the changes in the proportion of hauled-out grey seals may have been related to alternative factors still to be explored.

4.2.2. Behavioural observations and environmental factors

The behavioural observations noted during changing sea states and tidal phases may have corresponded with the number of grey seals hauled-out in addition to other biological activities. The number of grey seals that were observed diving for longer durations increased from sea states 1 to 3 (Figure 20) as well as from low to high tide (Figure 22). This trend may be due to the limited space on a rock that is available during high tides, and subsequently grey seals would therefore spend this time diving deeper and for longer periods of time to forage. The number of individuals floating on the surface of the water also decreased from sea states 1 to 3 and from low to high tide. This suggests that during periods of low water and calmer sea states, grey seals will save energy by resting as opposed to the less favourable and more energy depleting conditions found during high tide and rougher sea states that limits the space available to haul-out. Thompson *et al.* (1991) found that grey seals may expend less energy (through having a lower metabolic rate) when breathing intermittently during periods of rest in

stable conditions compared to when the conditions are unpredictable, as individuals are less likely to commit to long periods of rest in such conditions.

4.2.3. Site fidelity and environmental factors

The re-sightings of individuals during this study were most commonly observed during ebb tides and at Beaufort sea states of 1 and 2. The increase in re-sightings during ebb sites and in calmer sea states may be for the same reasons as those previously described, where the low tide and calmer sea state provides a more stable environment for an individual to haul-out, compared to during rougher sea states with greater wave action and reduced rock or beach space availability. However, this behaviour may also change depending on the season, as pregnant females (those that are close to pupping) are more likely to haul-out during ebbing tides when there is more space available on the beach to give birth without needing to take into consideration the incoming tide (Hook & Johnels, 1972). In comparison, Fogden, (1971) observed that once the female grey seal had given birth to the pup, she was more likely to haul-out to let the pup suckle at high tide, as this resulted in the female remaining close to the water's edge as well as being able to remain in close contact with the pup. In addition, Hewer (1957) observed that the increase in the number of females hauling out during the breeding season was potentially attributed to the rocky shore habitat where access was difficult depending on the tidal phase. Similarly, the rocky shore habitats caves and small beaches found along the coast of Cardigan Bay SAC may be more difficult to access during high tide because they quickly become submerged during the flooding tide. Therefore, during the breeding season, an increase in the number of returning individuals (specifically pregnant females) may be associated with the ease of access to the haul-out site at low tide. However, as this study did not survey during the breeding season, further investigation would need to take place to determine whether individuals returning to haul-out sites return during specific tidal phases and sea states, and whether these patterns vary depending on the season.

4.3. Hypothesis c). Population structure of grey seals is similar at each haul-out site with females outnumbering males and a smaller abundance of small or juvenile males in comparison to large adults

The population structure of grey seals along the coast of Cardigan Bay SAC displayed both similarities and differences between haul-out sites. Seals Bay was observed to have only female grey seals present, whilst Cardigan Island had both males and females. Female grey seals are gregarious during the breeding season, hauling-out in either small (Figure 29a) or large groups in order to avoid predation as well as to increase the chance of successful breeding and reducing

antagonistic behaviour by hauling-out at known sites with familiar individuals (Pomeroy *et al.,* 2005). However, as previously mentioned, male grey seals will usually haul-out near the start of the breeding season, or later after the pup has been weaned (Bones & James, 1979). Thus, the lack of males observed at Seals Bay may be due to the timing of this study which concluded prior to the breeding season and hence, male grey seals may still be building fat reserves through foraging activities which are important for the commencement of breeding when the males will also fast (Anderson & Fedak, 1985). Alternatively, Seals Bay may be a haul-out site that is primarily used by female grey seals for parturition and/or resting, whilst Cardigan Island may instead be used predominately as a mating site for grey seals and hence the number of male grey seals at this site would be greater than those at Seals Bay, as there may be an increased chance of successfully mating.

When males were present, they were always out-numbered by females (Table 8). This is typically seen in grey seal colonies as they are polygynous, and therefore would have an increased chance of successful fertilisation from less competition between fewer males (Bones & James, 1979; Ambs *et al.,* 1999). Furthermore, this polygynous behaviour would usually lead to aggressive behaviour, and Bones & James (1979) observed males chasing and threatening each other in order to establish tenure over a specific area or group of females, with the strongest and usually largest male succeeding. Interestingly, aggressive behaviour was not observed at Cardigan Island, where in fact a young adult male and adult male came into close contact and displayed amicable behaviour towards one another (Figure 29b). The closeness observed between these two males may be for a number of reasons. It may be an example of a mating tactic displayed by male grey seals through courtship behaviour with a female (Figure 29c), and therefore during this time the male will only focus on one female rather than mating with multiple females, and would consequently be less aggressive towards other males (Ambs *et al.,* 1999). Alternatively, small populations of grey seals have been suggested to have inter-related colonies where males will show higher site fidelity to a haul-out site where their father or brother is also hauled-out. Pomeroy *et al.* (2000) observed that related male seals found in close proximity of each other displayed less aggressive behaviour to one another in comparison to individuals that were not related or were "outsiders" to the colony. On the other hand, the behaviour between male grey seals in this study may simply be due to the timing of the study which concluded before the breeding season commenced, when male grey seals traditionally display more aggressive behaviour towards one another. This study did observe a larger number of adult males compared to young or juvenile male grey seals, for the possible reason

that male grey seals will often display exploratory foraging behaviour when they are young, as they are unable to outcompete the older stronger males (Lidgard *et al*., 2001). However, further investigation would need to be conducted in order to understand whether this is the reason behind a higher abundance of older males compared to young or juvenile males, in addition to whether the male grey seals along the coast of Cardigan Bay SAC show overall less aggressive tendencies to each other compared to other populations, or whether these tendencies vary depending on the season.

4.4. Limitations and recommendations for future studies

The surveying period of this study was confined to a small window of time, which concluded before the start of the Atlantic grey seal breeding season. In addition to this, access to a number of haul-out sites during this period was limited. Therefore, this must be taken into consideration when interpreting the results, as the number of grey seals observed during this study's survey period may substantially increase during the breeding season and, consequently, the small sample size from this study may not be as accurate as a larger sample size found during the breeding season. Furthermore, the effects of environmental factors on abundance, haul-out behaviour and site fidelity were restricted by the shortness of the survey period to limited changes in environmental conditions. Therefore, in order to determine a relationship between these factors, future studies should be conducted over a period of years rather than months. These studies should include observations during the grey seal breeding season and across their annual life-cycle to investigate the level of site fidelity and the influence of environmental factors on abundance, haul-out behaviour and site fidelity of populations of grey seals along the coast of Cardigan Bay SAC. Although photo-identification was found to provide useful information with regards to site fidelity as well as the individual photo-identification of grey seals along the coast of Cardigan Bay SAC, other methods of monitoring grey seal abundance and behaviour, such as tagging technology or the use of drones for cryptic habitats, would allow further investigation into the movement patterns of individual grey seals (Pomeroy *et al.,* 2000; Stringell *et al.,* 2014). This would also enable access to areas that cannot be easily reached from boat or land-based surveys, and where close proximity to the animal is required for photo-identification techniques. The importance of high quality photographs must be taken into consideration when conducting a photo-identification study. The restricted time available during surveying periods made capturing a sufficient number of high quality images very difficult, which resulted in a lower probability of identifying an individual.

4.5. Management strategies for the conservation of grey seal populations along the coast of Cardigan Bay SAC

Although this study was conducted over a short period, it is apparent that the coastline encompassing the Cardigan Bay SAC is an important area for the Atlantic grey seal from the abundance and re-sightings of individuals found during this study, along with previous surveys conducted within this region (Baines & Evans, 2012). This study identified 46 individuals and that did not include individuals that could not be identified due to their image being captured on poor quality photos. Also, counting the number of individuals may not produce accurate measurements of abundance, as this study showed that the estimated abundance could be incorrect when examining photographs that identified more or less individuals than estimated. For example on 24th June 2017, during a land-based survey at Cardigan Island, an estimated abundance of six individuals was recorded. However when the photographs taken that day were examined, there were nine individuals that were identified from their distinctive pelage patterns. Therefore, direct counts may be underestimating the number of grey seals present in the Cardigan Bay SAC area, and for this reason conservation efforts should be focused on determining the abundance of grey seals in addition to the reasons for which they use the area, such as for foraging and breeding. Although the Cardigan Bay SAC is primarily for the protection and management of bottlenose dolphins (*Tursiops truncatus*), the Atlantic grey seal is another species requiring protection within the Cardigan Bay SAC (CCW, 2009), hence the management and regulations conducted in the SAC should assist in conserving the grey seal population. Nevertheless, as tourist activities increase, so do boat and fishing trips, the level of boat traffic and noise and litter pollution in this area, (Pierpoint *et al.*, 2009), which may consequently affect the grey seal population. Therefore, further management regulations should be considered in order to determine the long term effects on grey seal populations along the Cardigan Bay SAC due to an increase in tourism.

5. Conclusion

Using photo-identification techniques, this study demonstrated that there is a thriving population of Atlantic grey seals that exhibited both inter-season site fidelity as well as annual site fidelity at haul-out sites along the coast of Cardigan Bay SAC. However, due to the short duration of this study and the limited number of previous studies conducted on the grey seal populations along the coast of the Cardigan Bay SAC, the extent of site fidelity observed was difficult to determine, and would require future studies to record data throughout the annual life cycle of the grey seals, spanning over a period of years. The use of photo-identification to examine site fidelity in conjunction with using the photographs to compare re-sightings data on individuals from existing catalogues such as the Natural Resources Wales grey seal identification catalogue, has proved to be a reliable and cost-efficient method of obtaining large amounts of data related to the abundance, distribution and population dynamics of grey seals. It was important, therefore, that sufficient high quality images were obtained in order to ensure the accuracy of the data by increasing the opportunity for an individual to be identified. The environmental factors of sea state, air and sea surface temperature did not strongly influence the abundance, haul-out behaviour and site fidelity of grey seals along the coast of Cardigan Bay SAC. However, the tidal phase appeared to moderately influence these variables, but it was also demonstrated from some weak correlations that other factors may also be contributing to the observed changes. Therefore, further investigation is needed to establish what drives the fluctuations in abundance, haul-out behaviour, and site fidelity. The populations of grey seals observed along the coast of Cardigan Bay SAC follow traditional population structures similar to those observed in larger colonies, such as the number of females outnumbering the males. However, the observed relationships between male grey seals in these populations was unusual, suggesting possible differences in population structure within small populations (that may have higher levels of relatedness), compared to those seen in larger colonies.

This study was limited by the length of duration and the fact it concluded prior to the major haul-out breeding season, where a greater number of grey seals would more likely be identified. A longer survey period may have also allowed a chance to gain a further understanding of the relationships and breeding behaviour within small colonies along the coast of Cardigan Bay SAC. However, this study has served as a starting point from which future studies can compare findings, and build up re-sightings data using the photo-identification catalogue produced, as well as supporting the need for future conservation and increased management and monitoring of the grey seal populations along the coast of Cardigan Bay SAC.

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7. Appendices

Appendix 1. Survey forms used to collect data for a) grey seal sightings and b) the entire survey during both boat and land-based surveys, and c) behavioural observations during land-based surveys only.

a) Grey Seal Photo-Identification Observation Survey: Boat or Land Sighting Form

Observer Name:

Sheet Number:

Date	Start Time	End Time	[1]Location (D°M')	Total Abundance	Tidal Phase	[2]Sea State	Air Temp. (°C)	Sea Surf.Temp. (°C)	General Weather	[3]Est. Dist. (m)	Comments

[1]For land-based surveys only
[2]Sea state in Beaufort scale
[3] Estimated distance away from observer

b) Grey Seal Photo-Identification Observation Survey: Land or Boat Entire Survey

Observer Name: Sheet Number:

Date	Start Time	End Time	[1]Location (D°M')	Total Abundance	Tidal Phase	[2]Sea State	Air Temp. (°C)	Sea Surf. Temp. (°C)	General Weather	[3]Photos	Comments

[1]For land-based surveys only
[2]Sea state in Beaufort scale
[3] Y= Taken or N= Not Taken

C) Grey Seal Photo-Identification Behaviour Observation Survey:

Observer Name: Sheet Number:

Date	Start Time	End Time	Location (D°,M')	Total Abundance	Tidal Phase	[1]Sea State	Air Temp (°C)	Sea Surf Temp (°C)	General Weather	[2]Est. Dist. (m)	[3]Wave Action	[4]Behaviour obs.

[1] Sea state in Beaufort scale
[2] Estimated distance away from observer
[3] H= High. M= Mid. L= Low

[4] Behaviour codes: **LD**= Long dives, **SD**= Short dives, **HO**= Hauled-out, **Bot**= Bottling, **BF**= Body float, **CCS**= close contact with another seal, **HM**= Head movements, **BM**= Body movements, **DC**= Direct contact with another seal. **Cur**= Curious.

Appendix 2. Example code used for statistical tests that were conducted during this study in the statistical software programme R.

Two-Way ANOVA

M1<aov(Dependent~as.factor(Independent1)*as.factor(Independent2) , data=DataFrame)

summary(M1)

Three-Way ANOVA

M2<aov(Dependent~as.factor(Independent1)*as.factor(Independent2)*as.factor(Independent 3), data=DataFrame)

summary(M2)

Post-hoc test for ANOVA

TukeyHSD(M1 or M2, conf.level=0.95)

General Linear Model (GLM)

M3<-glm(Dependent~Independent, family=poisson (or binomial), data= DataFrame)

summary(M3)

anova(M3, test= "Chisq")

Multivariate General Linear Model (GLM)

M4<-glm(Dependent~Independent1+Independent2+Independent3+Independent4, family= poisson, data= DataFrame)

summary(M4)

anova(M4, test= "Chisq")

Assumptions for ANOVA and GLM

Test for homogeneity of variance:

leveneTest(Dependent~Independent, data=DataFrame)

Test for normal distribution:

res<- resid(Model)
hist(res)
shapiro.test(res)

Appendix 1. Grey seal (*Halichoerus grypus*) photo-identification catalogue 2017

Catalogue Name: **001**

Nickname: **Birdy**

Haul-Out Site Location: **Seals Bay**

Gender: **Female**

Age Category: **Adult**

First Sighting: **27/07/2015**

Last Sighting: **08/07/2017**

Total Number of Sightings: **5**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2015				1	1							
2017						2	1					

Catalogue Name: **002**

Nickname: **Marilyn**

Haul-Out Site Location: **Cardigan Island**

Gender: **Female**

Age Category: **Adult**

First Sighting: **15/06/2017**

Last Sighting: **15/06/2017**

Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						1						

Catalogue Name: **003**

Nickname: **Pearl**

Haul-Out Site Location: **Cardigan Island**

Gender: **Female**

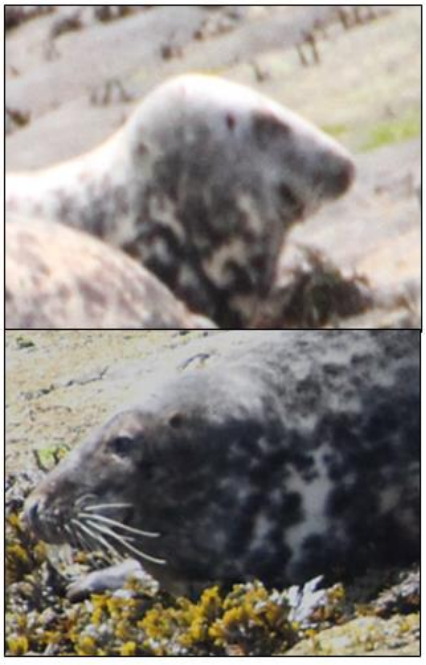
Age Category: **Adult**

First Sighting: **15/06/2017**

Last Sighting: **15/06/2017**

Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						1						



Catalogue Name: **005**

Nickname: **Asteroid**

Haul-Out Site Location: **Seals Bay**

Gender: **Female**

Age Category: **Adult**

First Sighting: **27/05/2015**

Last Sighting: **08/07/2017**

Total Number of Sightings: **5**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2015					1							
2017						1	3					

Catalogue Name: **008**

Nickname: **None**

Haul-Out Site Location: **Cardigan Island**

Gender: **Female**

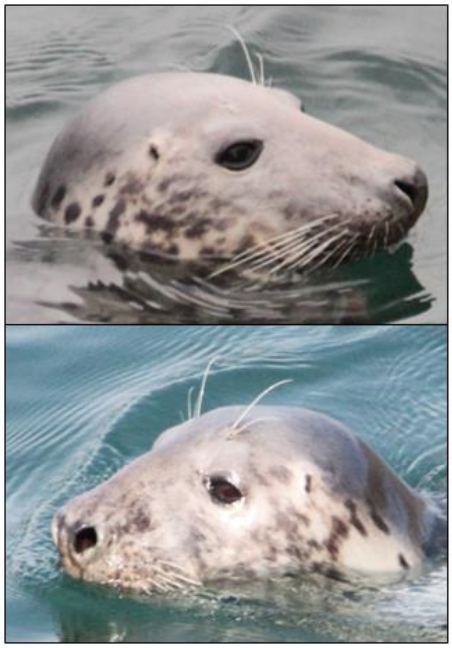
Age Category: **Adult**

First Sighting: **15/06/2017**

Last Sighting: **15/06/2017**

Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2015						1						



Catalogue Name: **009**

Nickname: **None**

Haul-Out Site Location: **Cardigan Island**

Gender: **Female**

Age Category: **Adult**

First Sighting: **19/06/2017**

Last Sighting: **19/07/2017**

Total Number of Sightings: **2**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						1	1					

Catalogue Name: **010**

Nickname: **None**

Haul-Out Site Location: **Seals Bay**

Gender: **Female**

Age Category: **Adult**

First Sighting: **22/06/2017**

Last Sighting: **11/07/2017**

Total Number of Sightings: **3**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						2	1					

Catalogue Name: **011**

Nickname: **None**

Haul-Out Site Location: **Cardigan Island**

Gender: **Female**

Age Category: **Adult**

First Sighting: **24/06/2017**

Last Sighting: **24/06/2017**

Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						1						

Catalogue Name: **012**

Nickname: **Pops**

Haul-Out Site Location: **Cardigan Island**

Gender: **Male**

Age Category: **Adult**

First Sighting: **24/06/2017**

Last Sighting: **24/06/2017**

Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						1						

Catalogue Name: **013**

Nickname: None

Haul-Out Site Location: **Cardigan Island**

Gender: **Male**

Age Category: **Adult**

First Sighting: **24/06/2017**

Last Sighting: **24/06/2017**

Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						1						

Catalogue Name: **014**

Nickname: **None**

Haul-Out Site Location: **Cardigan Island**

Gender: **Female**

Age Category: **Adult**

First Sighting: **24/06/2017**

Last Sighting: **03/07/2017**

Total Number of Sightings: **2**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						1	1					

Catalogue Name: **015**

Nickname: **Cleo**

Haul-Out Site Location: **Cardigan Island**

Gender: **Female**

Age Category: **Juvenile**

First Sighting: **24/06/2017**

Last Sighting: **24/06/2017**

Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						1						

Catalogue Name: **020**

Nickname: **Floydina**

Haul-Out Site Location: **Seals Bay**

Gender: **Female**

Age Category: **Young**

First Sighting: **20/06/2017**

Last Sighting: **19/07/2017**

Total Number of Sightings: **7**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						2	5					

Catalogue Name: **021**

Nickname: **None**

Haul-Out Site Location: **Seals Bay**

Gender: **Female**

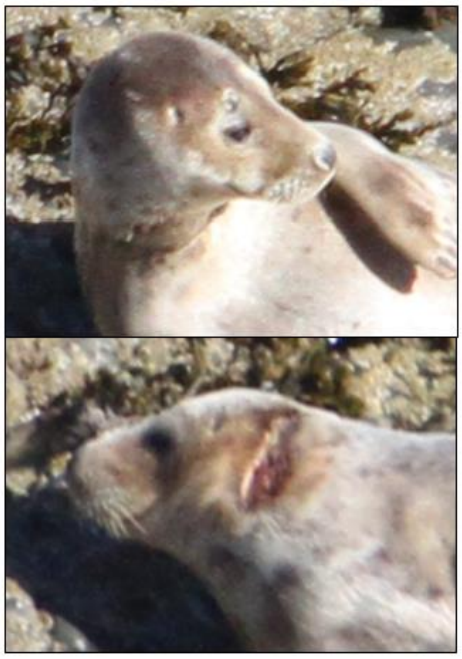
Age Category: **Juvenile**

First Sighting: **20/06/2017**

Last Sighting: **20/06/2017**

Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						1						



Catalogue Name: **022**

Nickname: **None**

Haul-Out Site Location: **Seals Bay**

Gender: **Female**

Age Category: **Juvenile**

First Sighting: **01/07/2017**

Last Sighting: **01/07/2017**

Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							1					

Catalogue Name: **024**

Nickname: **Comet**

Haul-Out Site Location: **Cardigan Island**

Gender: **Female**

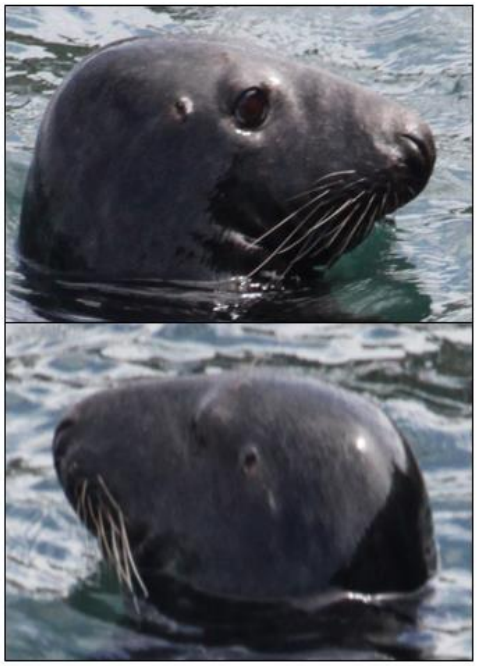
Age Category: **Adult**

First Sighting: **03/07/2017**

Last Sighting: **03/07/2017**

Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						1						



Catalogue Name: **025**

Nickname: **None**

Haul-Out Site Location: **Cardigan Island**

Gender: **Male**

Age Category: **Young Adult**

First Sighting: **03/07/2017**

Last Sighting: **03/07/2017**

Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							1					

Catalogue Name: **026**

Nickname: **None**

Haul-Out Site Location: **Cardigan Island**

Gender: **Female**

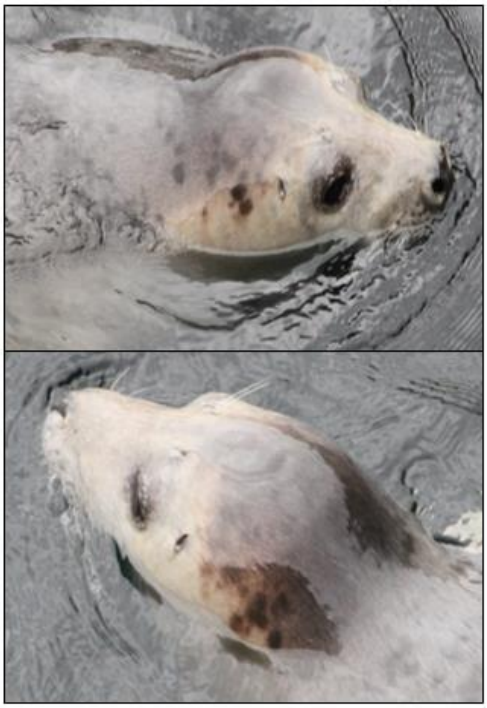
Age Category: **Adult**

First Sighting: **03/07/2017**

Last Sighting: **03/07/2017**

Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							1					



Catalogue Name: **027**

Nickname: **None**

Haul-Out Site Location: **Cardigan Island**

Gender: **Female**

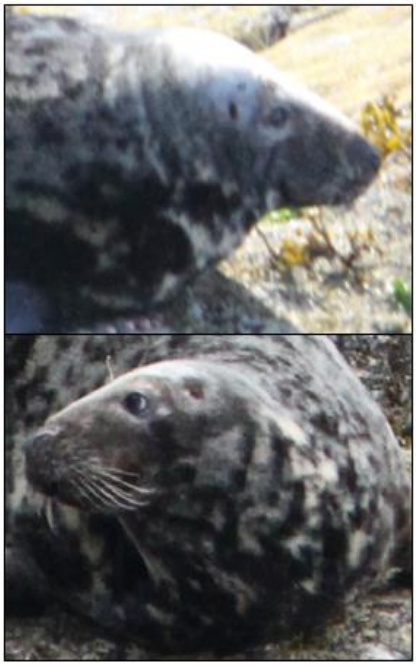
Age Category: **Young Adult**

First Sighting: **03/07/2017**

Last Sighting: **07/07/2017**

Total Number of Sightings: **2**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							2					



Catalogue Name: **031**

Nickname: **None**

Haul-Out Site Location: **Seals Bay**

Gender: **Female**

Age Category: **Adult**

First Sighting: **06/07/2017**

Last Sighting: **08/07/2017**

Total Number of Sightings: **2**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							2					

Catalogue Name: **034**

Nickname: **None**

Haul-Out Site Location: **Cardigan Island**

Gender: **Female**

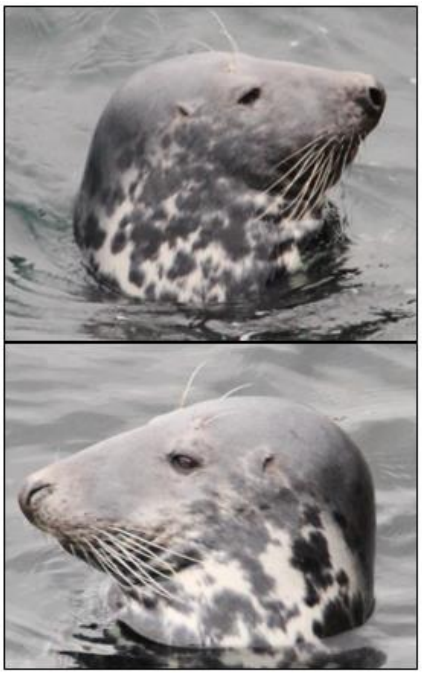
Age Category: **Adult**

First Sighting: **07/07/2017**

Last Sighting: **07/07/2017**

Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							1					



Catalogue Name: **035**

Nickname: **None**

Haul-Out Site Location: **Cardigan Island**

Gender: **Female**

Age Category: **Adult**

First Sighting: **07/07/2017**

Last Sighting: **19/07/2017**

Total Number of Sightings: **2**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							2					

Catalogue Name: **038**

Nickname: **None**

Haul-Out Site Location: **Cardigan Island**

Gender: **Female**

Age Category: **Adult**

First Sighting: **07/07/2017**

Last Sighting: **07/07/2017**

Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							1					

Catalogue Name: **039**

Nickname: **Starsky**

Haul-Out Site Location: **Cardigan Island**

Gender: **Male**

Age Category: **Adult**

First Sighting: **15/06/2017**

Last Sighting: **07/07/2017**

Total Number of Sightings: **2**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						1	1					

Catalogue Name: **045**

Nickname: **None**

Haul-Out Site Location: **Cardigan Island**

Gender: **Female**

Age Category: **Young Adult**

First Sighting: **19/07/2017**

Last Sighting: **19/07/2017**

Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							1					

Catalogue Name: **046**

Nickname: **None**

Haul-Out Site Location: **Cardigan Island**

Gender: **Male**

Age Category: **Adult**

First Sighting: **24/06/2017**

Last Sighting: **24/06/2017**

Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						1						

Catalogue Name: **004**
Nickname: **None**
Haul-out Site Location: **Seals Bay**
Gender: **Female**
Age Category: **Adult**
First Sighting: **14/06/2017**
Last Sighting: **14/06/2017**
Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						1						

Catalogue Name: **006**
Nickname: **None**
Haul-out Site Location: **Cardigan Island**
Gender: **Female**
Age Category: **Adult**
First Sighting: **15/06/2017**
Last Sighting: **15/06/2017**
Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						1						

Catalogue Name: **007**
Nickname: **None**
Haul-out Site Location: **Cardigan Island**
Gender: **Female**
Age Category: **Adult**
First Sighting: **15/06/2017**
Last Sighting: **03/07/2017**
Total Number of Sightings: **2**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						1	1					

Catalogue Name: **016**
Nickname: **None**
Haul-out Site Location: **Cardigan Island**
Gender: **Female**
Age Category: **Young Adult**
First Sighting: **24/06/2017**
Last Sighting: **24/06/2017**
Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						1						

Catalogue Name: **028**
Nickname: **None**
Haul-out Site Location: **Seals Bay**
Gender: **Female**
Age Category: **Adult**
First Sighting: **04/07/2017**
Last Sighting: **04/07/2017**
Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							1					

Catalogue Name: **029**
Nickname: **None**
Haul-out Site Location: **Seals Bay**
Gender: **Female**
Age Category: **Adult**
First Sighting: **04/07/2017**
Last Sighting: **04/07/2017**
Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							1					

Catalogue Name: **036**
Nickname: **None**
Haul-out Site Location: **Cardigan Island**
Gender: **Female**
Age Category: **Young Adult**
First Sighting: **07/07/2017**
Last Sighting: **07/07/2017**
Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							1					

Catalogue Name: **041**
Nickname: **None**
Haul-out Site Location: **Cardigan Island**
Gender: **Female**
Age Category: **Young Adult**
First Sighting: **12/07/2017**
Last Sighting: **12/07/2017**
Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							1					

Catalogue Name: **042**
Nickname: **None**
Haul-out Site Location: **Cardigan Island**
Gender: **Female**
Age Category: **Juvenile**
First Sighting: **12/07/2017**
Last Sighting: **12/07/2017**
Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							1					

Catalogue Name: **043**
Nickname: **None**
Haul-out Site Location: **Cardigan Island**
Gender: **Female**
Age Category: **Adult**
First Sighting: **12/07/2017**
Last Sighting: **12/07/2017**
Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							1					

Catalogue Name: **044**
Nickname: **None**
Haul-out Site Location: **Cardigan Island**
Gender: **Female**
Age Category: **Adult**
First Sighting: **12/07/2017**
Last Sighting: **12/07/2017**
Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							1					

Catalogue Name: **017**
Nickname: **None**
Haul-out Site Location: **Seals Bay**
Gender: **Female**
Age Category: **Adult**
First Sighting: **16/06/2017**
Last Sighting: **16/06/2017**
Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						1						

Catalogue Name: **018**
Nickname: **None**
Haul-out Site Location: **Cardigan Island**
Gender: **Female**
Age Category: **Young Adult**
First Sighting: **24/06/2017**
Last Sighting: **03/07/2017**
Total Number of Sightings: **2**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						1	1					

Catalogue Name: **019**
Nickname: **None**
Haul-out Site Location: **Cardigan Island**
Gender: **Female**
Age Category: **Adult**
First Sighting: **24/06/2017**
Last Sighting: **24/06/2017**
Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017						1						

Catalogue Name: **023**
Nickname: **None**
Haul-out Site Location: **Cwmtydu**
Gender: **Female**
Age Category: **Adult**
First Sighting: **01/07/2017**
Last Sighting: **01/07/2017**
Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							1					

Catalogue Name: **030**
Nickname: **None**
Haul-out Site Location: **Seals Bay**
Gender: **Female**
Age Category: **Adult**
First Sighting: **04/07/2017**
Last Sighting: **04/07/2017**
Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							1					

Catalogue Name: **032**
Nickname: **None**
Haul-out Site Location: **Seals Bay**
Gender: **Female**
Age Category: **Adult**
First Sighting: **06/07/2017**
Last Sighting: **06/07/2017**
Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							1					

Catalogue Name: **033**
Nickname: **None**
Haul-out Site Location: **Seals Bay**
Gender: **Female**
Age Category: **Adult**
First Sighting: **27/05/2015**
Last Sighting: **06/07/2017**
Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2015					1							
2017							1					

Catalogue Name: **037**
Nickname: **None**
Haul-out Site Location: **Cardigan Island**
Gender: **Male**
Age Category: **Young Adult**
First Sighting: **07/07/2017**
Last Sighting: **07/07/2017**
Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							1					

Catalogue Name: **040**
Nickname: **None**
Haul-out Site Location: **Seals Bay**
Gender: **Female**
Age Category: **Adult**
First Sighting: **10/07/2017**
Last Sighting: **10/07/2017**
Total Number of Sightings: **1**

Year	J	F	M	A	M	J	J	A	S	O	N	D
2017							1					