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Marine mammals in the Western English Channel, a survey from the Rame Head Peninsula

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Abstract

This paper presents the first records of marine mammals in Plymouth Sound National Marine Park (NMP), and over 1000 individual animal observations were recorded. Marine mammal temporal and spatial distributions were quantified for the first time at Rame Head, a vantage point overlooking the NMP and the Western English Channel. A biodiversity hotspot, the Western English Channel supports many species of marine mammals, yet it is subject to increasing anthropogenic pressures, such as heavy shipping, which could significantly impact populations. Whilst marine mammals are well studied, their distributions and population sizes remain largely unknown; effective conservation of these animals requires monitoring to quantify these patterns.

Shore-based surveys were conducted over two months, and observational data were collected. Observation rates were analysed against a suite of environmental variables to identify trends. Key species identified were the harbour porpoise (*Phocoena phocoena*), common dolphin (*Delphinus delphis*) and grey seal (*Halichoerus grypus*), with common dolphins accounting for over half of the observations. Observation rates were variable, and correlation was detected with several environmental variables. Observation rates of all species peaked during the mid-cycle phase of the spring/neap cycle. Furthermore, an increased sea state correlated with decreased observation rates for all species. Surprisingly, the tidal phase had no significant correlation with observation rates. Limited assumptions can be drawn about the harbour porpoise as correlations were found with minimal variables. In comparison, some clear trends were identifiable for common dolphins and grey seals.

This study indicates significant variability in marine mammal distributions around Rame Head; however, further investigations are needed to gain a deeper understanding. Specifically, extending the study's timeframe and including a thorough investigation into the local oceanography could provide valuable insights. While monitoring changes in marine mammal populations can present challenges due to the instability seen within their ranges and behaviours, we must dedicate effort to quantifying these variables and enabling effective conservation management. These findings increase our understanding of marine mammal populations within the Western English Channel and can help inform future conservation policy.

Keywords: Marine, Mammal, Survey, Visual, Western English Channel, Rame Head.

Introduction

Marine mammals in the English Channel are well studied; however, abundance (McClellan *et al.*, 2014) and distribution patterns (Silber *et al.,* 2017) are still relatively unknown. Furthermore, much of our knowledge stems from strandings data, e.g. (Leeney *et al.*, 2008 & Peltier *et al.*, 2016), giving a potentially skewed picture of population numbers. Reliable information on abundance and distribution is essential for informing conservation management (Brakes & Dall, 2016 & Marshall, Glegg & Howell, 2014). Halpern *et al. (* 2008) classified the English Channel as very highly impacted by human activities and highlighted shipping as a significant contributor. Shipping contributes to several threats facing marine mammals, including noise pollution (Erbe *et al.*, 2019 & Halliday *et al.*, 2017) and ship strikes; however, the impacts on local marine mammal populations are unknown. Therefore, to ensure effective conservation strategies are implemented, we must quantify marine mammal distributions within the English Channel. This research aimed to provide a snapshot of marine mammals observed from Rame Head whilst identifying spatial and temporal distribution patterns.

Marine mammals

The UK is home to 28 species of cetaceans, and two species of pinnipeds regularly occur, the grey seal (*Halichoerus grypus*) and the common seal (*Phoca vitulina*). Marine mammals, especially cetaceans, provide a wide array of ecosystem services, benefitting humanity and biodiversity. Often found at the top of the food chain, marine mammals are essential for controlling prey populations and maintaining balanced ecosystems (Kiszka, Heithaus & Wirsing, 2015). Marine mammals are further linked to ocean productivity (Pyenson & Vermeij, 2016), nutrient recycling, and carbon sequestration (Durfort *et al.*, 2021); furthermore, population sizes can be useful as key indicators for the health of entire ecosystems (ASCOBANS, 2013). Therefore, the continued presence of marine mammals in UK waters can provide multiple benefits, environmentally, economically and societally, and the conservation of these species should be of great concern.

The English Channel is an area of high marine biodiversity and is home to many marine mammals. The harbour porpoise, a highly protected species, are the most often encountered cetacean species found within the English Channel (Laran *et al.*, 2017), potentially amplified by the significant southwards shift seen in their range within the North Sea (Hammond *et al.*, 2013). This range shift has been possible to identify due to the long-term monitoring offered by the 'SCANS I-III programmes' (Hammond *et al.,* 2021), highlighting the importance of long-term datasets in conservation management. There has also been some scientific effort dedicated to monitoring harbour porpoises in the south-west of the UK (Buttifant, J, L., 2021 & Pierpoint, 2008); and further studies such as MacLeod, Brereton & Martin (2009) & Pikesley *et al.* (2012) have attempted to quantify trends in cetacean distribution patterns in this area. However, there is still a significant knowledge gap regarding marine mammal distributions within the English Channel.

The English Channel comprises two separate basins, proposed as two distinct ecosystems, the Eastern English Channel and the Western English Channel, where Rame Head is located (Dauvin, 2012). One study, in particular, found that in comparison with the Eastern English Channel, 95% of all dolphin observations were recorded in the Western English Channel (McClellan *et al.,* 2014). Species such as the minke whale and the common dolphin are also more prevalent in the Western English Channel than in the Eastern (Evans & James, 2016). When focusing on the Rame Head extent, there are many observational records of marine mammals; however, there is a lack of dedicated scientific effort to quantify marine mammal distributions in this area. The Environmental Records Centre for Cornwall and the Isles of Scilly (2021) have records of ad-hoc sightings of marine mammals within the Rame Head extent dating back to 1900. These records include regular sightings of the most common cetaceans and pinnipeds; common dolphins (*Delphinus delphis*), harbour porpoises (*Phocoena phocoena*) and grey seals, along with rarer sightings of animals such as the Risso's dolphin (*Grampus griseus*), the humpback whale (*Megaptera novaeangliae*), and the killer whale (*Orcinus orca*). If we are to understand distribution patterns fully, there is a need to further monitor marine mammal populations within the Western English Channel.

Visual surveys

Effective conservation planning must include monitoring the health of the populations (García-Barón *et al.,* 2021), enabling changes in population dynamics to be identified and investigated in real-time. Monitoring and research into populations and distribution patterns are a legal requirement for small cetaceans under the ASCOBANS (1994) agreement. Therefore, to ensure the UK fulfils its legal obligations regarding marine mammal conservation, more significant efforts must be made to monitor their populations. Visual surveys remain one of the primary methods for monitoring marine mammal populations (Hammond *et al.*, 2021 & Smith *et al.*, 2020). Small scale visual surveys conducted from shore are cheap to facilitate (Williams *et al.*, 2017) and enable long-term sustained effort from a specific location; therefore, they are an attractive option for conservation, a historically underfunded area of research (Bos, Pressey & Stoeckl, 2015). Rame Head's location enables surveys of the Western English Channel and the entrance to Plymouth Sound simultaneously. Moreover, the height above sea level of Rame Head affords the observer an increased visible survey area compared to boat platforms.

Rame Head

Rame Head is a coastal headland on the Rame Peninsula in Cornwall, UK, Figure 1. The headland faces the Western English Channel and is flanked by the entrance to Plymouth Sound, to the east, and Whitsand and Looe Bay to the west.
Whitsand and Looe Bay is a large, shallow, sandy bay exposed to strong tidal flows, separated from Plymouth Sound by the Rame Peninsula (Uncles, Stephens & Harris, 2015). Plymouth Sound is a busy port that serves international and domestic shipping, travel, the Royal Navy and important fisheries. The English Channel is one of the busiest seaways globally (Garrett *et al.,* 2016), and large amounts of traffic enter Plymouth Sound via this route. High levels of shipping activity, such as those found within this area, pose many threats to marine animals, including noise disturbance, increased likelihood of ship strike accidents, and increased marine pollution (Avila, Kaschner & Dormann, 2018).

The Rame Head Peninsula experiences semi-diurnal tides with a mean tidal range of 3.5m and a maximum tidal range of ~5m during spring tides (Uncles, Stephens & Harris, 2015); the area is also subject to strong tidal currents as waters flow in and out of Plymouth Sound. Tidal streams in the area are generally clockwise, with current velocities ranging from 0.2 knots during neap tides to 0.9 knots during spring tides (visit My Harbour, 2022). Sea surface temperatures range from approximately

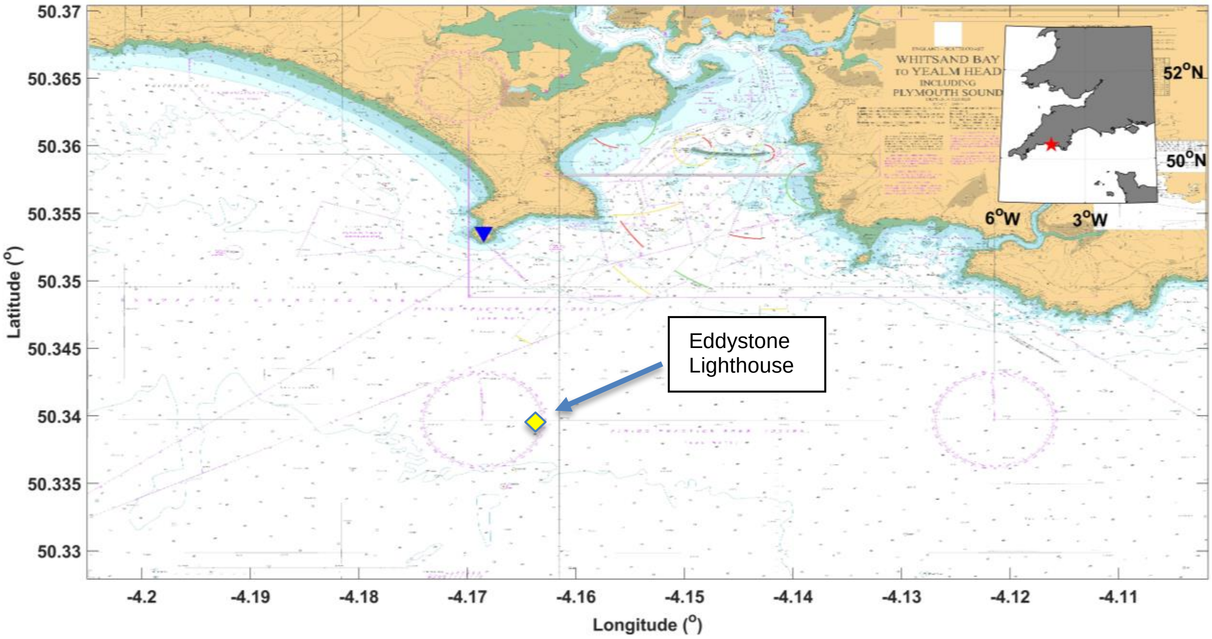


Figure 1: The study region, including Rame Head, Plymouth Sound, and the surrounding areas, survey station depicted by blue triangle. Inset map highlights Rame Head's location within the Southwest of the UK (Edina, no date). Map created in MATLAB.

8°C in winter to 18°C in summer. The Rame Head Peninsula is at the centre of multiple internationally and nationally recognised conservation designations, both terrestrial and marine. However, our knowledge of marine mammal distributions within the area is limited; therefore, it is vital to devote further resources to quantifying marine mammal distributions.

Terrestrial designations

The conservation designations in place around Rame Head can be seen in Figure 2. Rame Head is partially within the Cornwall Area of Natural Beauty (AONB); AONBs are portions of land protected by the CROW Act (2000) to conserve and enhance their natural beauty. Managed and designated by Natural England, AONBs must have a management plan which includes monitoring (GOV.UK, 2018). The area also encompasses a section of the South Cornwall, Heritage Coast. Heritage coasts are non-statutory areas established to conserve flora and fauna of the land and sea, also managed by Natural England (GOV.UK, 2015); however, these designations do not recognise specific species or habitats; therefore, the protection offered by them is limited.

Furthermore, according to duties in law, the area is designated as a Site of Special Scientific Interest (SSSI), where features of particular interest, either wildlife, geology, or landform, exist (Rees *et al.,* 2019). The Rame Head & Whitsand Bay SSSI, introduced in 1996, extends approximately 8km along the coastline, either side of the headland. Features of note for designation are predominantly geological, although many plant species are also listed. In particular, the area hosts the largest colony, in Great Britain, of a nationally rare species, shore dock (*Rumex rupestris*) (Natural England, no date).

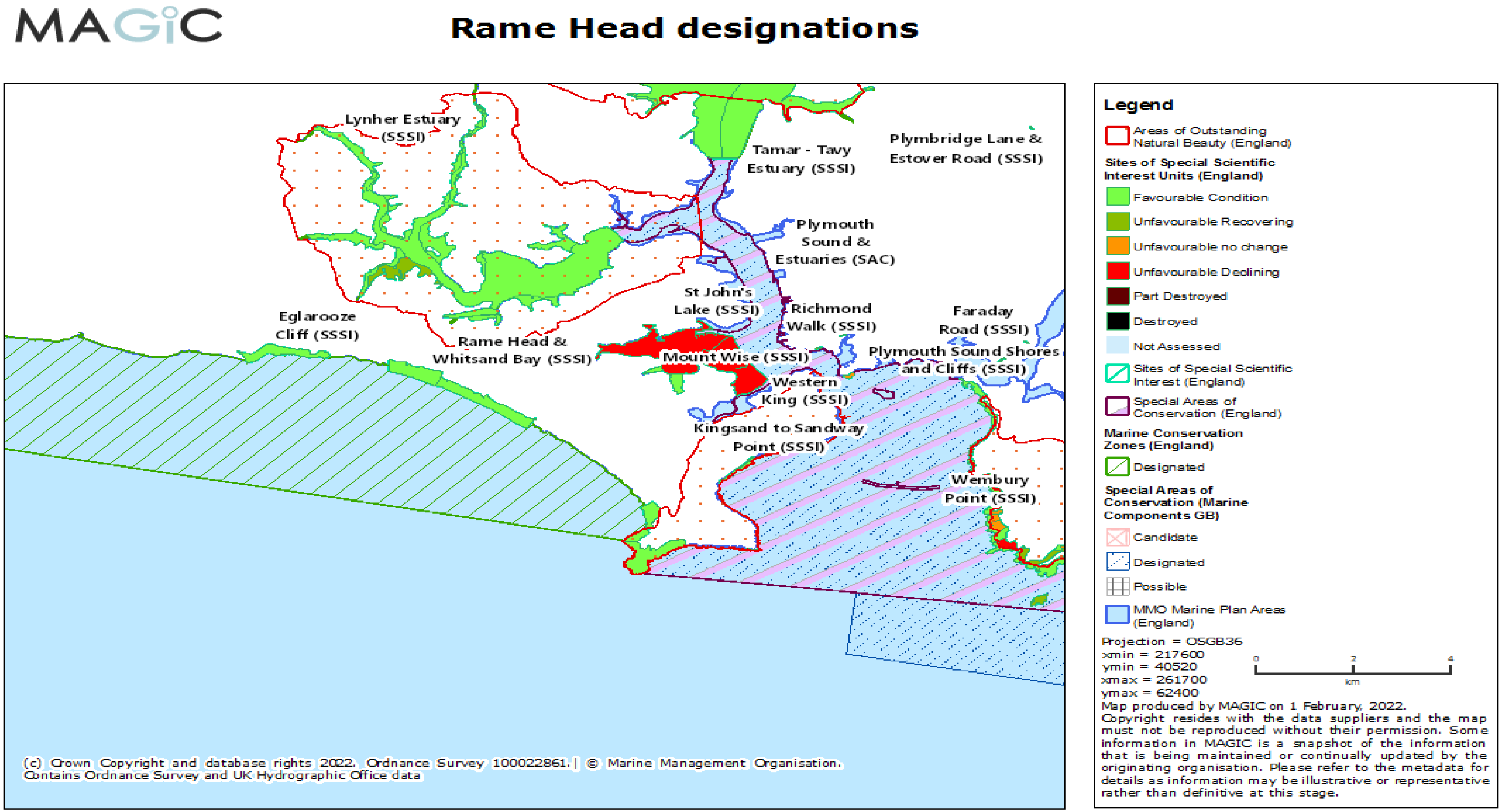


Figure 2: Map of conservation designations for the Rame Head area. Areas of Outstanding Natural Beauty, Sites of Special Scientific Interest, Special Areas of Conservation, and Marine Conservation Zones are highlighted (Marine Management Office, 2022).

Marine designations

Marine designations include the Whitsand and Looe Bay: Marine Conservation Zone (MCZ) came into force at the end of 2013 and encompasses the whole bay to the west of Rame Head. The designation covers an area of 52km^2 and is up to 25m deep (GOV.UK, 2013); however, the entire bay is of relatively uniform depth. Eight habitats and associated species are protected under the MCZ, including seagrass beds, rocky intertidal habitats, and various sandy habitats. Furthermore, species of conservation significance are offered detailed protection, such as the pink sea fan (*Eunicella verrucosa*); marine mammals, however, are not listed as having specific protections (UK Government, 2013).

The Plymouth Sound and Estuaries: Special Area of Conservation (SAC) was designated under the NATURA 2000 network in 2005 (JNCC, 2015). SACs were designated in response to the Habitats Directive 1992 (HD) and are designed to protect Annex II species; protections should include proper abundance monitoring. Annex II species include bottlenose dolphins (*Tursiops truncatus*), harbour porpoise (*Phocoena phocoena*), and grey seals (*Halichoerus grypus*); whilst these species are listed as present within the SAC, their populations are unknown due to data deficiency. The Joint Nature Conservation Committee (JNCC) further report that the SAC offers protection for habitats listed under Annex I of the HD, such as sandbanks, mudflats, and reefs; and Annex IV species, including all cetaceans, require specific protections to be applied to the full extent of their natural range. Moreover, both grey and common seals are listed under Annex V of the HD; therefore, sites must be managed considering the ecological needs of these species. Although Natural England are responsible for managing the SAC, no specific management plan exists (JNCC, 2015).

Furthermore, in 2019, Plymouth Sound National Marine Park (NMP) was established, the first of its kind in the country. The park currently covers Plymouth Sound and the surrounding tributaries and extends south, past Rame Head, to Eddystone Rocks and Eastwards as far as the River Yealm. It is proposed to be further extended Eastwards to Start Point and Westwards to Looe Island (Plymouth City Council, 2019). A marine park designation recognises an area as valuable for its environment and the community's well-being. The designation of Plymouth Sound as an NMP does not add any specific protections for the biodiversity found within; rather, it makes a statement that the UK values the rich marine environment and ecosystems. Therefore, whilst Rame Head is recognised as a treasure trove of natural features, many of which are under strict protection, marine mammals are little mentioned, and where they are, there is a lack of data on population sizes; therefore, without more effective monitoring, it is unclear whether conservation targets are being met. without more effective monitoring, it is unclear whether conservation targets are being met.

Research aims

Rame Head is an important gateway between Plymouth Sound and the Western English Channel and is surrounded by diverse marine habitats. Successful marine environment management requires an understanding of the ecosystem and its functioning, and quantifying marine mammal abundance and distribution patterns is imperative to building practical conservation tools. Ongoing monitoring is needed to understand population dynamics and the effects of implemented conservation measures. To date, little scientific effort has been dedicated to surveying marine mammal populations within this area. Therefore, this research aimed to characterise observations of marine mammals around the Rame Head Peninsula, providing a baseline dataset. Investigations were specifically targeted to identify correlations between marine mammal sightings and various environmental conditions, including tidal phase, water depth, sea state, and distance from shore. Spatial and temporal patterns of marine mammal variability were also examined.

Methodology

Study area

Survey data were collected during shore watches from an observation point 95.8m above mean sea level at St Michael's Chapel, Rame Head, UK, (50.313852°, -4.2230489°). The south-facing headland offers a > 180° field of view and overlooks Eddystone Lighthouse and Whitsand Bay. The visible horizon is > 37km away; however, the survey area extends only up to ten kilometres from the observation point due to the reduced detection function. The depth of the survey area ranges from approximately 0- 55m, with an average depth of ~ 44m.
Figure 3 shows the survey area split into bins, according to bearing and distance from the observation point, used to record marine mammal sighting locations. The bins were 30° wide (starting at a 75° bearing and continuing to 335°) and were of increasing distances which were non-linear in scale (e.g., 01-200m, 201-300m, 301-400m, 401-500m, 501-750m, 751-1000m, 1001-1500m, 1501-2000m, 2001-3000m, 3001-4000m, 4001-6000m, 6001-8000m, 8001-10,000m).

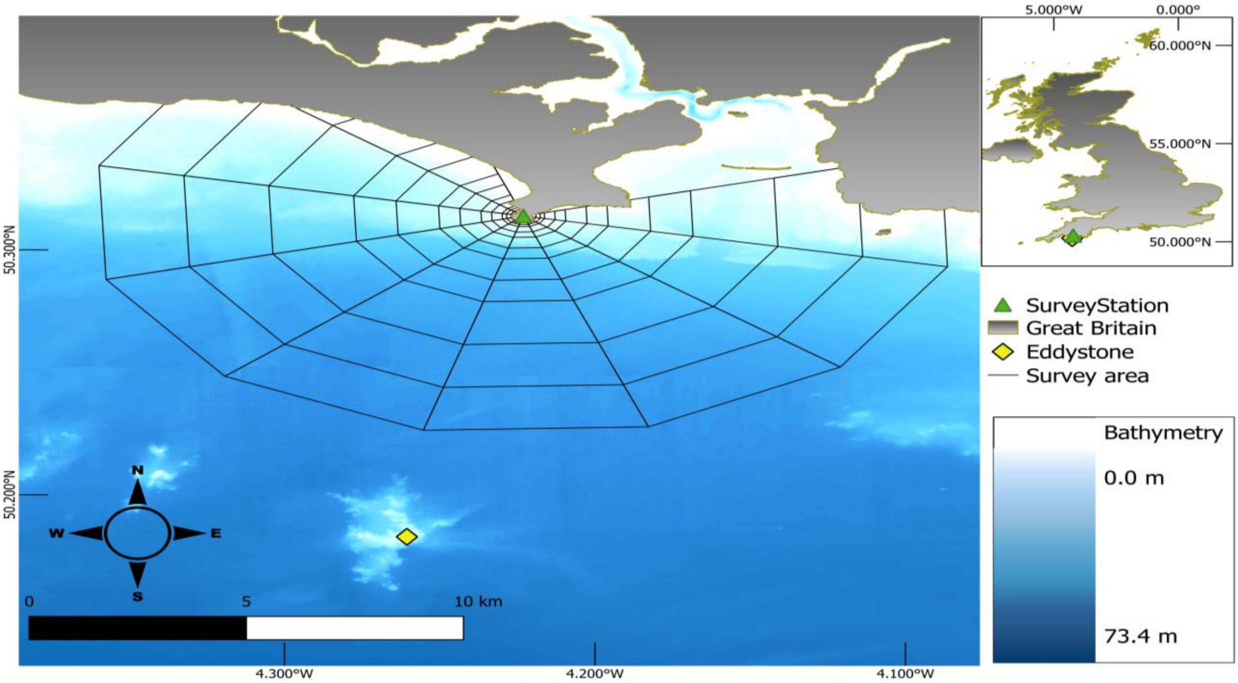


Figure 3: Overview map of the study area and location at Rame Head, UK; survey area extent shown with grid highlighting observational bins. Inset map shows study location within the UK. Bathymetry data resolved to 1 Arc second (Edina, 2020). Map created using the Free and Open Source QGIS software.

Visual surveys
Surveys were conducted over eight weeks in July/August 2021. Data were collected during four-hour-long watches, conducted daily where possible, with multiple watches completed some days and scans conducted every 30 minutes throughout. Watches depended on daylight hours and acceptable weather conditions and were conducted over various tidal phases and different portions of the day. Acceptable weather conditions were defined as visibility > 5km, the chance of rain < 20%, and wind speeds < 20kn. Furthermore, watches were limited to periods with Beaufort sea state ≤ 3 to minimise bias due to sea state. Environmental data, including Beaufort sea state, wind speed and direction, visibility, glare, cloud coverage, tidal phase, air temperature, and start and end times, were also recorded at each scan. As seen in Figure 4, an observer trained in survey techniques and marine mammal identification completed all survey effort. Tidal phases were defined as Spring tides = +/- 2 days of the full moon and new moon, Neap tides = +/- 2 days of 1st quarter and 3rd quarter moon, and Mid tides = all other days. High and Low tides were defined as when high or low slack tide occurred within the 4-hour watch period.

Figure 4: Photo of the observation point, equipment set up and observer. Location outside St Michael's Chapel, Rame Head, UK. Photo taken facing westwards, with Looe and Polperro in the background.

Scans were conducted using a Kowa TSN- 821 telescope equipped with a 20-60x zoom eyepiece and tripod, set to 20x zoom for scanning. Bushnell H_2O Waterproof 8x42 binoculars were also used for short-range observations. The entire field of view, beginning at the horizon and working landwards, from east to west, was scanned using the telescope in concentric sweeps for each scan. Marine mammals sighted during scans were recorded with date, time, compass bearing and distance from the observation point, species, heading, number of animals, and behaviour where possible. Distance measurements were estimated using a range stick, a basic piece of equipment enabling quick but potentially low accuracy range estimations in the field (OSC, 2004). Range sticks are specific to the user and the location they will be used due to the measurements used creating them. Horizontal lines corresponding to ranges are marked on a stick or ruler. Specific data about the user and the observation site are used to calculate where to assign these lines on the range stick; using this formula:

$$Ci = \frac{bh(v-d)}{(h^2 + vd)}$$

Where Ci = calliper interval (how far from the top of the range stick, distances are assigned) in centimetres, b = distance from the observer's eye to the range stick when held with arm extended, in centimetres, h = height above mean sea level of the observer's eye in metres, d = distance to object in metres, and v = visual horizon in metres- calculated by:

$$v = 3838\left(h^{\frac{1}{2}}\right)$$

The calliper intervals are then marked onto the range stick (or ruler) and assigned to the distance for which they were calculated. Once complete, the range stick provides distance measurement estimations when held up to the horizon, see Figure 5.

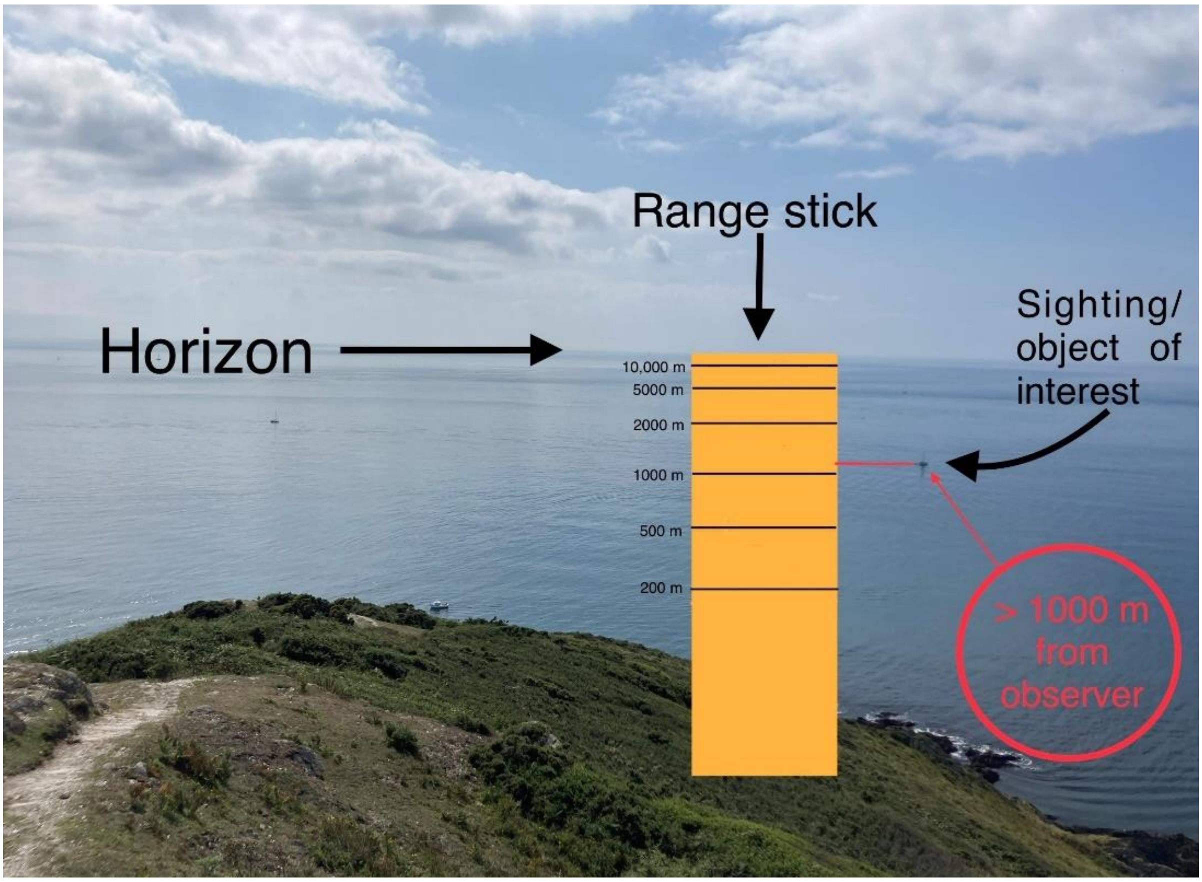


Figure 5: Representative of how a range stick is used in the field. Holding the stick with an outstretched arm, the top of the stick must be lined up with the horizon. The target object can then be lined up with a distance range, as shown by the example of the boat in the photo (based on techniques from Ocean Science Consulting Limited (2004))

Estimating error in positional data

To reduce potential errors in location estimation by the observer, range estimation was calibrated against buoys with known distances from the observation point. However, some errors are unavoidable, and so were calculated as follows. Range stick user error can arise from (1) the misreading of the range stick, (2) wind, and (3) the obscuring of the horizon; while 2 & 3 can be mostly ignored as surveys did not take place in windy conditions or on low visibility days, 1 was calculated as the median value between two ranges. A further potential source of error were variances caused by sea-level fluctuations; variances in sea level of +/- 2.5m accounting for maximum tidal range were calculated and applied to the range stick formula; this produced an average error margin of +/- 5m per 200m. Furthermore, whilst swell and waves could also cause fluctuations in sea height, surveys were limited to calm seas, minimising this issue. Angular positions were estimated using a compass, and sightings were grouped into bins 30° wide; errors associated with compass reading were calculated as +/- 15°.

Data processing and temporal analysis

Environmental data were assigned to each marine mammal sighting. Previous studies have found **distance to shore** (Chavez-Rosales *et al.*, 2019) and current velocities and tidal fronts, both driven by the **spring-neap cycle and tidal phase** (Kuletz *et al.*, 2015), to be critical variables affecting marine mammal observations; therefore, these were selected for analysis along with**: time of day, sea state, and water depth.** Analysis was focused on the three species with multiple observations, the harbour porpoise (*Phocoena phocoena*), common dolphin (*Delphinus delphis*), and grey seal (*Halichoerus grypus*). Analysis was completed on the number of sightings rather than individual animals observed to ensure results were not skewed by duplication. Sightings of different species are assumed to be independent; therefore, they were analysed separately. Observations were converted to a rate to account for any bias in the survey effort, and these rates of observations were then plotted against the classified variables to identify trends. Chi-Squared' Goodness of Fit' tests were applied to the observation rates of each species against the classified variables. These tests calculate whether the observed frequency distributions differ significantly from the expected frequency distributions. The resulting value of χ^2 was used to calculate the p-value and detect the level of significance.

Spatial analysis

Sighting locations, identified as the centre of the corresponding survey bin, were converted from a distance and bearing, to decimal degree coordinates, enabling spatial analysis. GIS was used to plot sightings data geographically and interrogate the bathymetric conditions and distance from shore of sighting locations. Sightings data were mapped over high-resolution bathymetry data in QGIS v 3.16.14. Depth ranges were split into 5-metre incremental bins for analysis, and distance from shore was analysed at 1000m intervals; these variables were plotted against all three species, and Chi-Squared' Goodness of Fit' tests were applied. Group sizes of harbour porpoise and common dolphin sightings were also plotted and analysed for trends using the Chi-Squared' Goodness of Fit' tests; however, grey seal group sizes were not analysed as they were predominantly observed solitarily.

Results

Surveys

A total of 41 watches were conducted between 14/07/2021 and 31/08/2021, with 382 scans achieved over the eight-week period, totalling 164 hours of effort (Fig. 6). Watches were completed during a range of tidal phases and periods of the day to minimise bias. Survey effort by hour was distributed mainly evenly throughout the tidal phases and periods of the day, shown in Figure 7. Marine mammals were observed during 28 watches and 87 scans, converting to a sighting rate of 70% during watches and 26.5% for scans (Fig. 7). In total, 147 sightings of marine mammals yielded 1071 individual animal observations. Sightings by species are as follows: harbour porpoises (*Phocoena phocoena*) were observed 20 times with 73 individual animal observations, common dolphins (*Delphinus delphis*) were observed 86 times with 941 individual animal observations, grey seals (*Halichoerus grypus*) were observed 29 times with 29 individual animal observations, and minke whales (*Balaenoptera acutorostrata*) were observed once with one individual animal observation. There were also 11 sightings of unknown Delphinidae species with 27 individual animal observations. Varying group sizes were observed, with common dolphins especially showing the widest range, from 1-30 individuals. Grey seals, by comparison, were predominantly observed solitarily. Observations were made on 18 of the 24 days of survey effort.

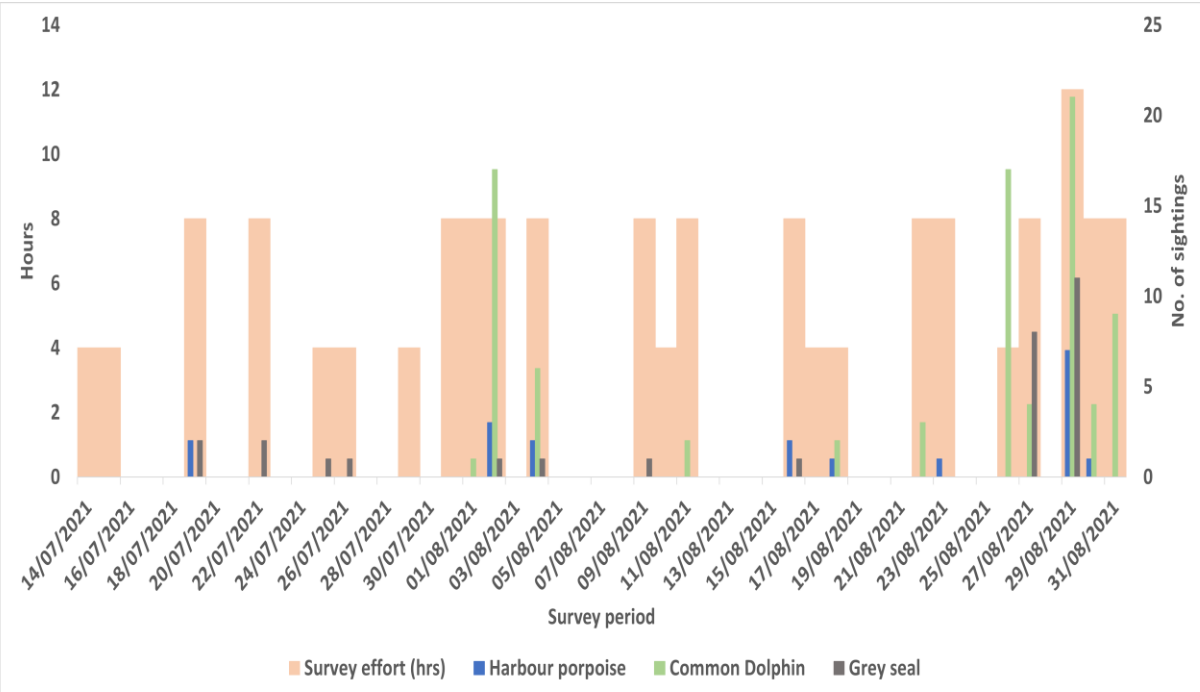


Figure 6: Marine mammal surveys were conducted from Rame Head, UK, from 14/07/2021 through 31/08/2021. The spread of survey effort hours per day and the sightings of harbour porpoise, common dolphins, and grey seals are shown. Days with no survey effort were due predominantly to unsuitable weather conditions.

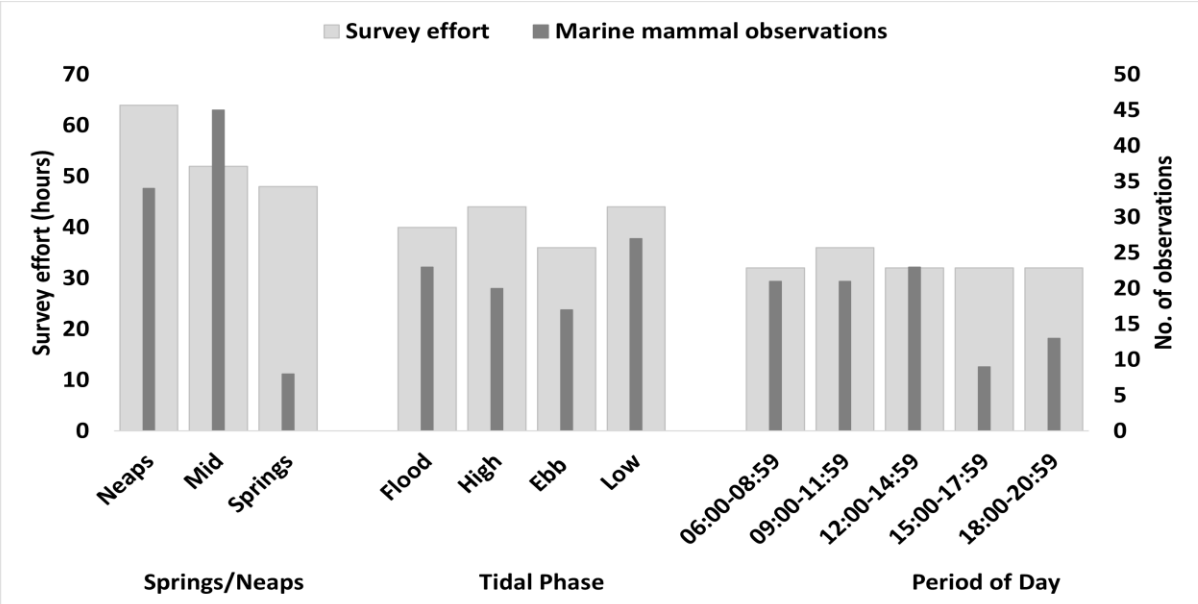


Figure 7: Surveys were completed at St Michael's Chapel, Rame Head, UK, from 14/07/2021- 31/08/2021. A breakdown of survey effort by hour across various tidal phases and periods of the day and the number of marine mammal observations recorded for each phase is shown here.

Spring/neap cycle
Variations across the **spring/neap cycle** show observation rates to be highest during mid-cycle for all species observed, seen in Figure 8. Springs have the lowest observation rates for all species but the grey seal.

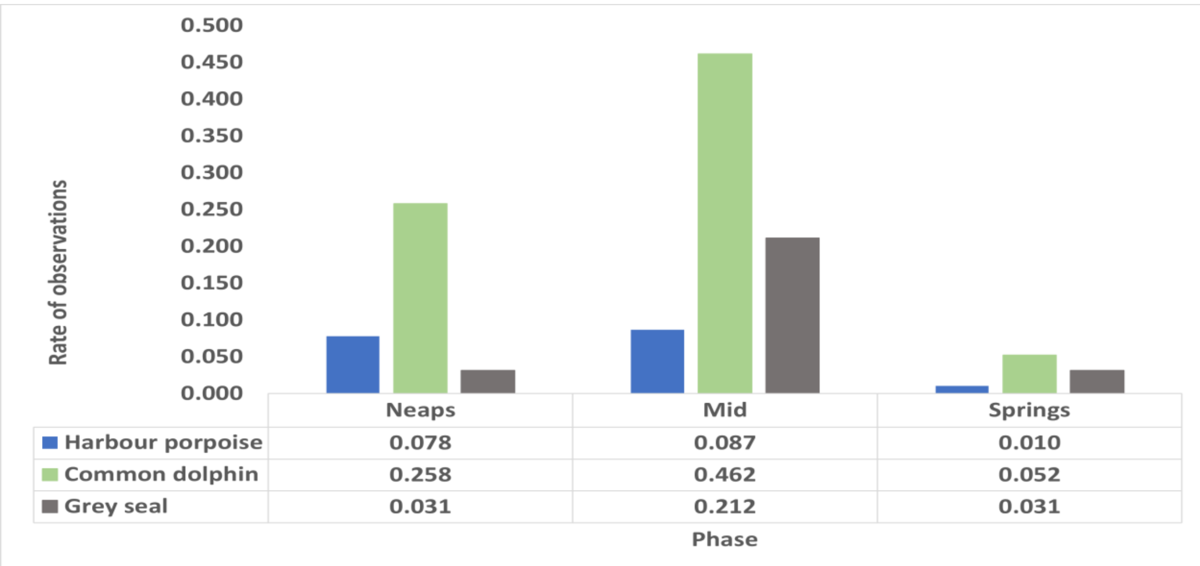


Figure 8: Marine mammal sightings displayed as the rate of observation against the Spring/Neap phase. All species are observed more frequently during the mid-cycle, with the neap cycle having the subsequent highest observations. Surveys were completed at St Michael's Chapel, Rame Head, UK, from 14/07/2021- 31/08/2021.

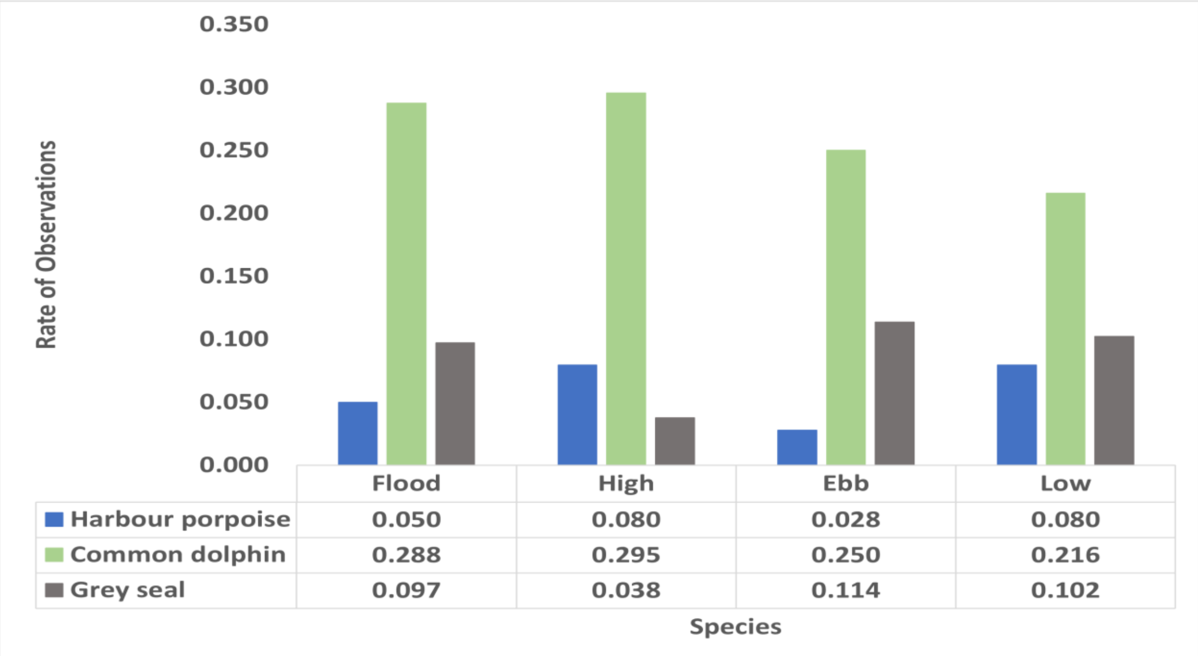
The observation rate distributions for all species across the **spring/neap cycle** differ significantly from equal frequency distributions, see Table 1.

Table 1: Results of Chi-Squared 'Goodness of Fit' tests for marine mammal observations against phases of the spring neap cycle. (Significance: ns = p>0.05, * = p≤0.05, ** = p≤0.01, *** = p≤0.001)

Species	**Degrees of freedom**	**χ^2 value**	**p-value**
Harbour porpoise	2	7.30	0.02599**
Common dolphin	2	33.23	<0.00001***
Grey seal	2	23.66	<0.00001***

Tidal phase

Figure 9 highlights observation rates against the **tidal phase**. Variation of observation rates across the tidal phase is minimal. All species shown were observed more frequently during high tide. However, harbour porpoise observation rates are increased during high and low tides, with lower observation rates when tides are ebbing or flooding. Common dolphins are observed more frequently during high and flood tides; however, grey seals are observed mainly on the ebb or low tide.



	Flood	High	Ebb	Low
Harbour porpoise	0.050	0.080	0.028	0.080
Common dolphin	0.288	0.295	0.250	0.216
Grey seal	0.097	0.038	0.114	0.102

Figure 9: Marine mammal sightings are displayed as the rate of observation against the tidal phase. No distinct pattern was observed for any species. Surveys were completed at St Michael's Chapel, Rame Head, UK, from 14/07/2021- 31/08/2021.

Compared to other studies, such as Nuuttila et al. (2017), the variation in observations across the **tidal phase** is not significant for any species, Table 2.

Table 2: Results of Chi-Squared 'Goodness of Fit' tests for marine mammal observations against tidal phase. (Significance: ns = p>0.05, * = p≤0.05, ** = p≤0.01, *** = p≤0.001)

Species	**Degrees of freedom**	**χ^2 value**	**p-value**
Harbour porpoise	3	3.60	0.30802 ns
Common dolphin	3	1.91	0.59130 ns
Grey seal	3	3.97	0.26472 ns

Portion of day

Marine mammal observations occurred throughout the day and are plotted against 3-hour periods in Figure 10. Harbour porpoise observations show a trend of increased observations in the earlier parts of the day, with the period of 06:00-08:59 having the highest observation rate. Whilst grey seals and common dolphins show higher observation rates during the two periods between 09:00-11:59 and 12:00-14:59.

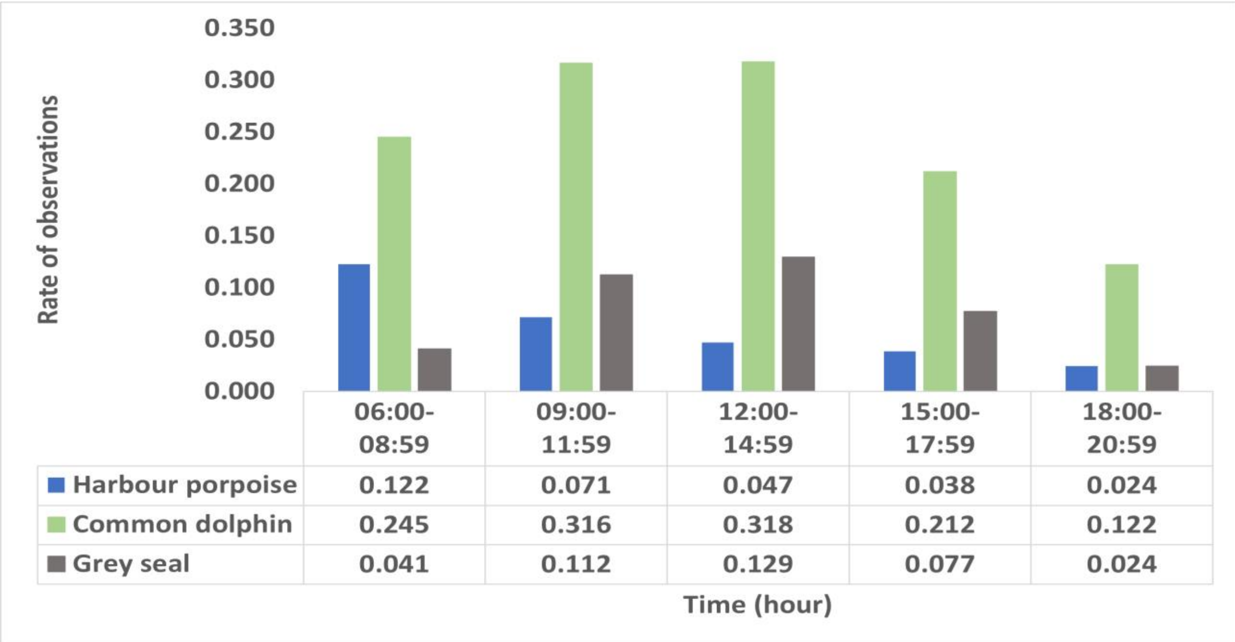


Figure 10: Marine mammal observation rates are displayed against the time of day. Harbour porpoises show a trend of higher observations earlier in the day. However, both the grey seal and the common dolphin occur more often in the middle portion of the day. Surveys were completed at St Michael's Chapel, Rame Head, UK, from 14/07/2021- 31/08/2021.

Observation rates were significantly affected by the **periods of the day** for common dolphins and grey seals; no significance was found for harbour porpoise observation distributions, Table 3**.**

Table 3: Results of Chi-Squared 'Goodness of Fit' tests for marine mammal observations calculated against different periods of the day. (Significance: ns = p>0.05, * = p≤0.05, ** = p≤0.01, *** = p≤0.001)

Species	Degrees of freedom	χ^2 value	p-value
Harbour porpoise	4	6.50	0.16479 ns
Common dolphin	4	29.12	<0.00001***
Grey seal	4	16.34	0.00260***

Sea state

Figure 11 presents observation rates against **sea state** on the Beaufort scale. Similarly, to previous studies (Aniceto *et al.*, 2018), a general trend of all species being observed more frequently during periods of lower sea state was observed. Observation rates were highest for all species during periods of sea state 1.5. Above sea state three, observations are negligible.

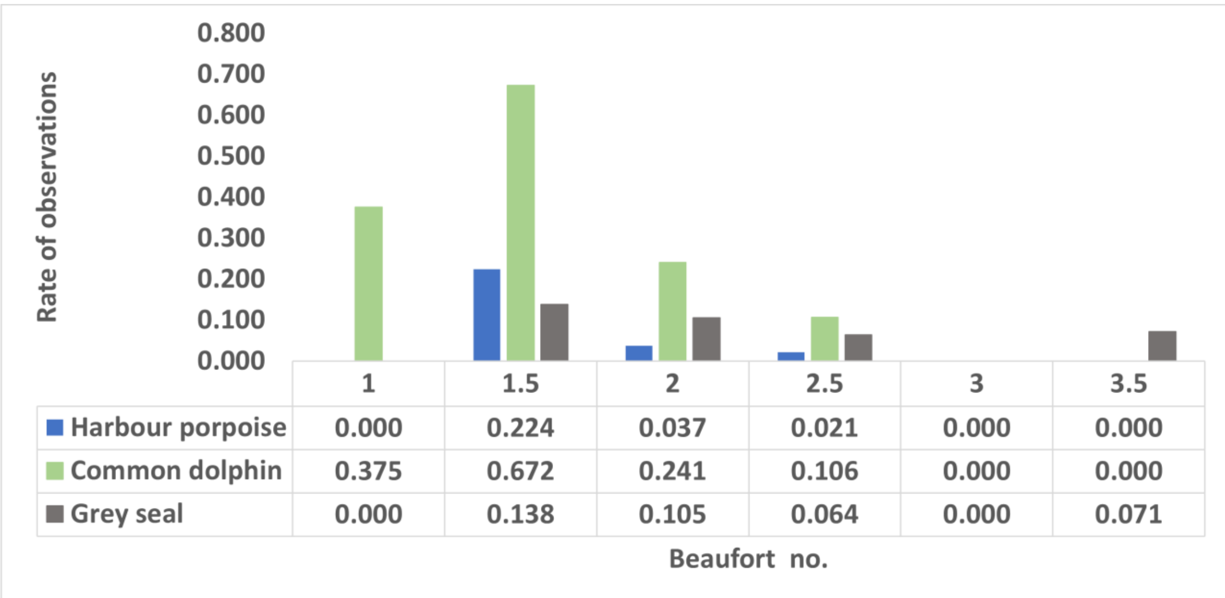


Figure 11: Surveys were completed at St Michael's Chapel, Rame Head, UK, from 14/07/2021-31/08/2021. Sightings of different species are displayed as the rate of observation against sea state (Beaufort scale). All species are observed more frequently during sea states of 1.5. Sea states of 3 and above show minimal.

Sea state significantly affected observation rates for all species, Table 4.

Table 4: Results of Chi-Squared' Goodness of Fit' tests for marine mammal observations calculated against sea state. (Significance: ns = p>0.05, * = p≤0.05, ** = p≤0.01, *** = p≤0.001)

Species	Degrees of freedom	χ^2 value	p-value
Harbour porpoise	5	38.47	<0.00001***
Common dolphin	5	114.27	<0.00001***
Grey seal	5	43.06	<0.00001***

Spatial analysis

Marine mammal observations were distributed inconsistently across the survey area, Figure 12. Findings show that common dolphin observations occur primarily in deeper waters, further from the shore and that the opposite is true for grey seals. No trend was observed in the spatial variability of harbour porpoise observations. Harbour porpoise and common dolphin observations occur across the survey area, whereas grey seal observations are predominantly clustered around the headland, see Figure 13. Furthermore, while some of the survey bins showed high numbers of observations, many had no observations.

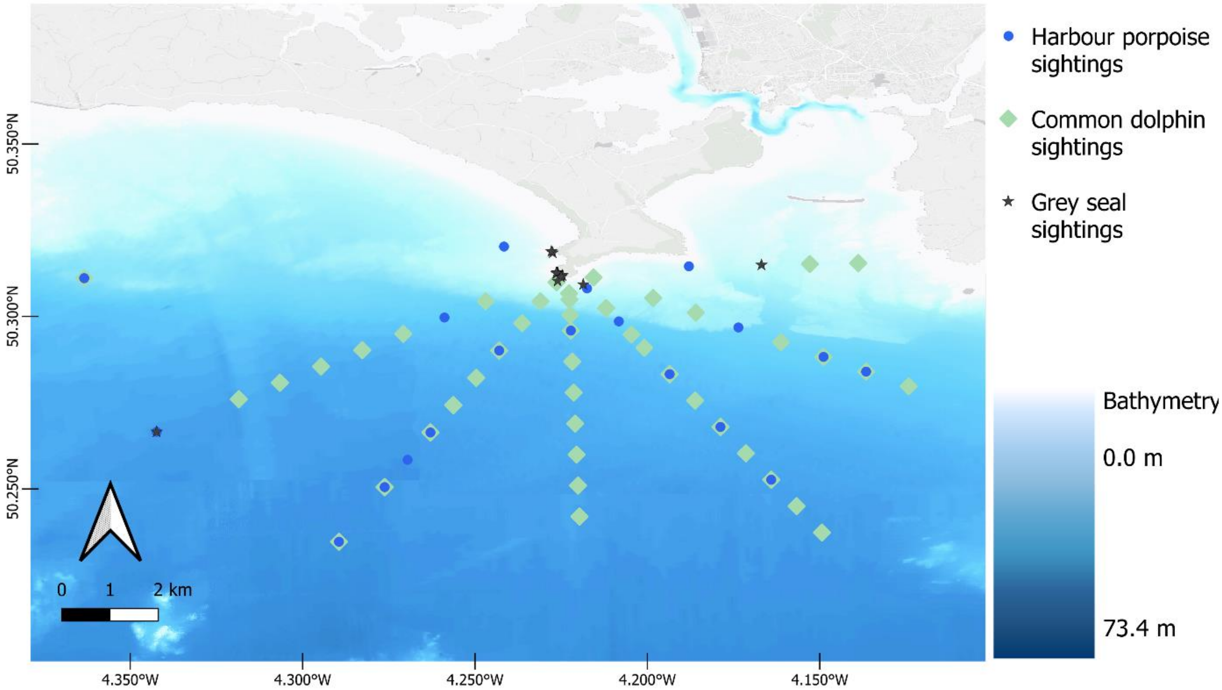


Figure 12: Locations of marine mammal sightings by species. Grey seals are observed primarily in shallow coastal areas, whereas observations of harbour porpoise and common dolphins range across the survey area. Surveys were completed at St Michael's Chapel, Rame Head, UK, from 14/07/2021 to 31/08/2021. Bathymetry data resolved to 1 Arc second (Edina, 2021). Map created using the Free and Open Source QGIS software.

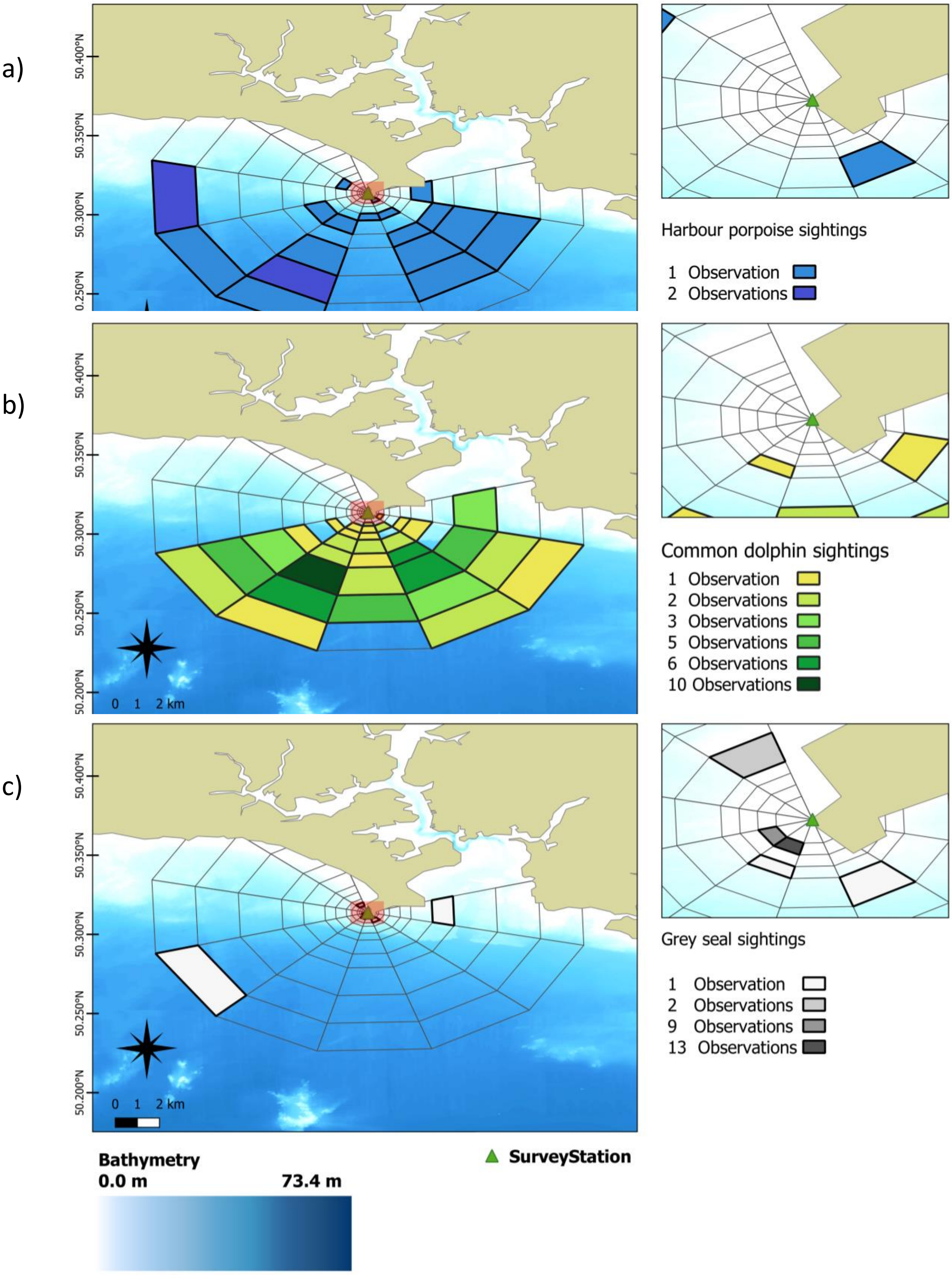


Figure 13: Spatial distribution of number of observations for a) harbour porpoise, b) common dolphin, and c) grey seals. Marine mammal surveys were completed at St Michael's Chapel, Rame Head, UK, from 14/07/2021 to 31/08/2021. Inset maps highlight the centre of survey area, denoted by pink boxes on main maps. Bathymetry data resolved to 1 Arc second (Edina, 2021). Map created using the Free and Open Source QGIS software.

Distance from shore

Figure 14 highlights observation distributions compared to the **distance from shore**. Common dolphin observations follow a near-normal distribution across the distance ranges, with a peak seen around 5-6km from shore. Harbour porpoise observations were relatively evenly spread across distances, whilst grey seal observations were primarily < 1000m of the shore.

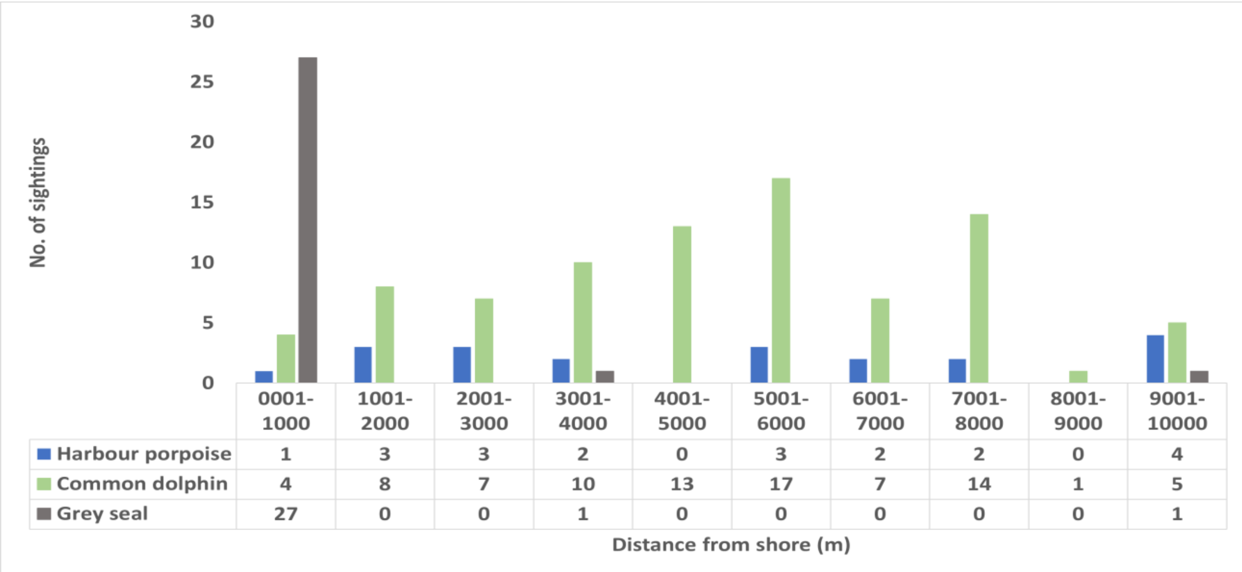


Figure 14: Marine mammal observations by distance in metres from shore. Surveys were conducted at St Michael's Chapel, Rame Head, UK, from 14/07/2021- 31/08/2021

The frequency distribution of observation rates significantly differs from equal frequency distributions for common dolphins and grey seals when looking at **distance from shore,** see Table 5**.** However, for harbour porpoises, there is no significant difference.

Table 5: Results of Chi-Squared 'Goodness of Fit' tests for marine mammal observations calculated against distance from shore. (Significance: ns = p>0.05, * = p≤0.05, ** = p≤0.01, *** = p≤0.001)

Species	**Degrees of freedom**	**χ^2 value**	**p-value**
Harbour porpoise	9	8.98	0.43912 ns
Common dolphin	9	28.72	0.00722***
Grey seal	9	245.64	<0.00001***

Water depth

Water depth was a significant variable for observations of common dolphins and grey seals; however, not for harbour porpoise observations. Figure 15 presents observations as a function of **water depth**. For aggregated sightings, the highest numbers occurred at depths of 45.1 - 50m, with 50.1 – 55m having the subsequent highest sightings; high numbers of sightings were also observed in the 0.1-5.0m range. When species are separated, grey seals are predominantly observed in shallow areas. In contrast, common dolphins show a clear preference for deeper waters. No significant trend is observed in harbour porpoise distribution.

a)
b)

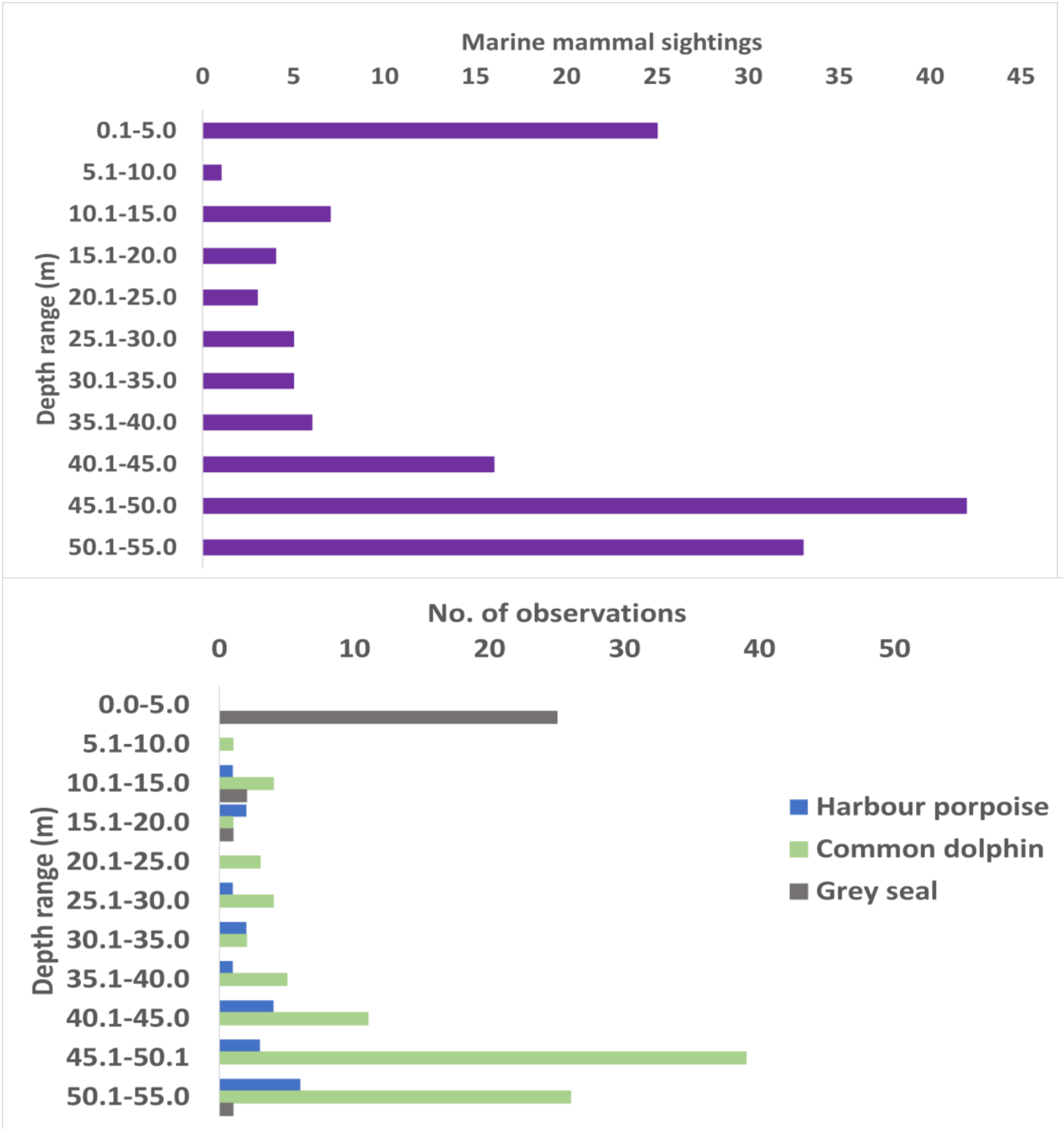


Figure 15: Marine mammal observations depth data. Surveys were completed at St Michael's Chapel, Rame Head, UK, from 14/07/2021 to 31/08/2021. Panel a) shows aggregated marine mammal sightings by depth range of observation locations. Panel b) shows observations by species across the depth range.

Water depth significantly affects observation rates for common dolphins and grey seals; however, it does not significantly affect harbour porpoise observation rates, see Table 6.

Table 6: Results of Chi-Squared 'Goodness of Fit' tests for marine mammal observations calculated against water depth. (Significance: ns = p>0.05, * = p≤0.05, ** = p≤0.01, *** = p≤0.001)

Species	**Degrees of freedom**	**χ^2 value**	**p-value**
Harbour porpoise	10	11.07	0.35209 ns
Common dolphin	10	59.24	<0.00001***
Grey seal	10	91.49	<0.00001***

Group size analysis
Marine mammal observations ranged from group sizes of 1 individual to 30 individuals, as shown in Figure 16. Common dolphin group sizes ranged from 2 to 30, with a mean group size of 10.94 and a standard error of 0.70 (Table 7). Harbour porpoises were observed in smaller groups with one to ten individuals seen at a time; the porpoise mean group size was 3.65 and had a standard error of 0.70.

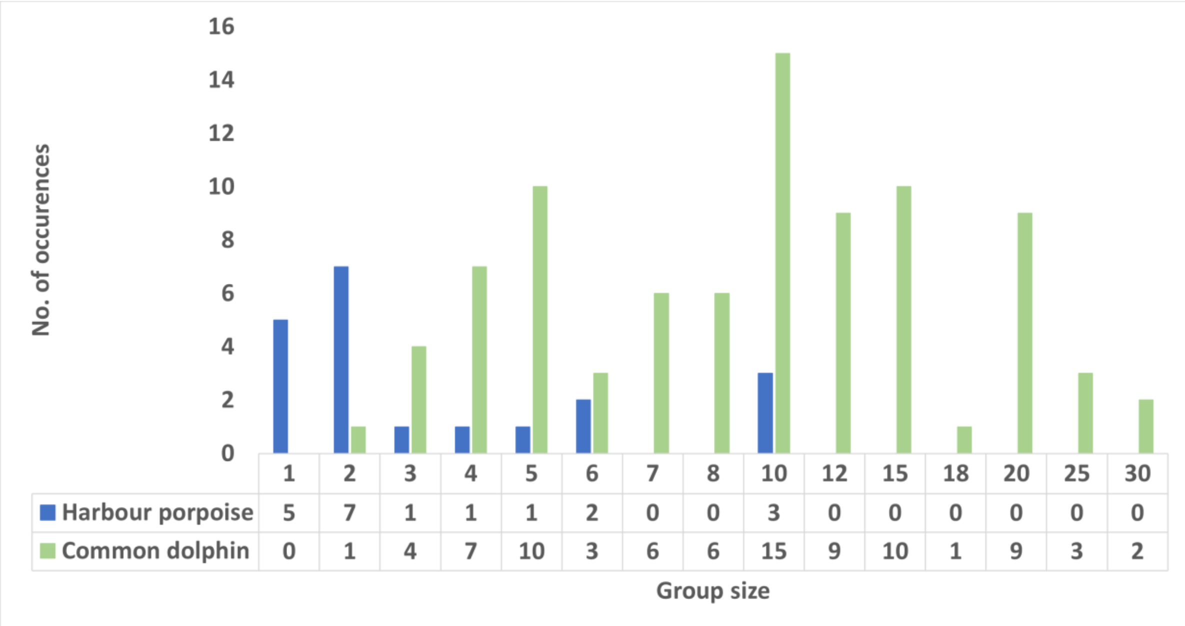


Figure 16: Observed group sizes as a function of the number of occurrences for harbour porpoise and common dolphins. Note the non-linear scale. Surveys were completed at St Michael's Chapel, Rame Head, the UK, from 14/07/2021 to 31/08/2021.

The frequency distributions of **group size** observations significantly differ from equal frequency distributions for harbour porpoise and common dolphins, see Table 7.

Table 7: Results of Chi-Squared 'Goodness of Fit' tests for marine mammal observations calculated against group size. (Significance: ns = p>0.05, * = p≤0.05, ** = p≤0.01, *** = p≤0.001)

Species	**Degrees of freedom**	**χ^2 value**	**p-value**	**Mean group size**	**Standard error**
Harbour porpoise	8	20.50	0.08601***	3.65	0.70
Common dolphin	13	35.77	0.00064***	10.94	0.70

Discussion

Surveys
These surveys evaluated marine mammal distributions around the Rame Head Peninsula, furthermore, these observations represent the first records of marine mammals within the Plymouth Sound National Marine Park. Observations of marine mammals occurred on 18 of the 24 days of surveyor effort, with many days having multiple observations. Marine mammals observed include the most common

cetaceans found in UK waters, the common dolphin (*Delphinus delphis*) and the harbour porpoise (*Phocoena phocoena*) (Hammond *et al*., 2013); however, bottlenose dolphins (*Tursiops truncatus*), another commonly noted species, were not observed. Furthermore, there were multiple grey seal (*Halichoerus grypus*) sightings, and a singular minke whale (*Balaenoptera acutorostrata)* was observed. Whilst species of large fish, such as basking sharks (*Cetorhinus maximus*), sunfish (*Mola mola*), and Atlantic bluefin tuna (*Thunnus thynnus*), have been recorded within the survey area (ERCCIS, 2021), these were not observed during this study.

With over half of the observations, the common dolphin was the most frequently observed species (n = 86); potentially affected by seasonality as late summer is known to see peaks of common dolphin sightings (Pikesley *et al.*, 2012). These peaks are possibly linked to increased sea surface temperatures (Cox *et al.*, 2017). Interestingly, harbour porpoises were observed at a lower rate (n = 20) than common dolphins; however, their predominantly solitary behaviour can reduce detectability (Williamson *et al.*, 2017). Furthermore, visual surveys cannot capture nocturnal activity, which may be significant for the harbour porpoise (Nuuttila *et al.*, 2017). Marine mammals are highly mobile and can spend extensive periods entirely underwater; furthermore, they are often migratory species and may travel considerable distances. For these reasons, visual surveys can often be too small to fully capture abundance patterns (Kaschner *et al.*, 2012). Therefore, for the purposes of this research, abundance was not inferred, only that the animals were present.

This research focused efforts on shore-based surveys due to the low-cost and easy accessibility afforded by them. There are, however, some limitations to shore-based surveys; several variables relating to the environment (sea state, time of day, and visibility) and the surveyor (training and experience) can affect data robustness (Parsons *et al.*, 2009). Moreover, marine mammals may spend extended periods submerged between breaths, further inhibiting visual detection certainty (Forney, 2009). Nevertheless, shore-based surveys are non-invasive, do not alter animal behaviour, offer low-cost solutions, and can require lower skill levels than vessel-based surveys (Giacoma, Papale & Azzolin, 2013). Therefore, they are a suitable and effective method of monitoring marine mammal distributions in a specified area.

Temporal variability

Marine mammal distributions showed variability across a range of temporal scales. The spring/neap cycle causes fluctuations in primary productivity (Sharples, 2007), which can temporarily alter food webs and drive feeding patterns. Similar to previous studies (Simonis *et al.*, 2017), this research found this cycle to be significant to the rates of observations (Table 1). Naylor (2001) suggested that distribution variations during the spring/neap cycle are driven by the absence or lack of moonlight; however, as this study focussed its efforts during daylight hours only, that is unlikely to be the controlling influence. Tidal ranges typically vary at Rame Head by up to 5m during the spring/neap cycle. Observation rates fluctuated across the spring/neap phases, but increased observations occurred during mid-cycle with a tidal range of ~ 3.5m. Current velocities are also variable across the spring/neap cycle, and physical processes such as these can play an essential part in the distributions and behaviours of prey species (Bailey & Thompson, 2010). Prey distributions are strongly linked to marine mammal distributions (Pendleton *et al.*, 2020). Therefore, increased sightings seen during mid-cycle are conceivably correlated to an increase in prey availability at those times, driven by the physical processes in action.

Similarly to the findings of Goodwin (2008), the tidal phase was not significant to observation rates of any species; however, this is in direct comparison to other studies of harbour porpoise observations (Pierpoint, 2008), where the tidal phase was significant. Sightings of harbour porpoises are limited (n = 20); therefore, there may not be enough data to detect trends accurately (Figure 6); an extended study period may offer opportunities to identify trends unseen here. Remarkably, harbour porpoises show greater variability in their behaviours, i.e., fewer variables were significant to their observation rates than other species. Table 8, linking back to the results, presents the level of significance each environmental variable had on the observation rates of each species. Except for the tidal phase, all variables significantly influenced observation rates for common dolphins and grey seals. In contrast, observation rates for the harbour porpoise were only significantly affected by the spring/neap cycle and the sea state.

Table 8: Level of significance of each variable analysed for each species (Significance: ns = P>0.05, * = P ≤0.05, ** = P≤0.01, *** = P≤0.001)

Variable	Harbour porpoise	Common dolphin	Grey seal
Spring/neap cycle	**	***	***
Tidal phase	ns	ns	ns
Portion of day	ns	***	***
Sea state	***	***	***
Distance from shore	ns	***	***
Water depth	ns	***	***

Data collected when the sea state was above Beaufort scale two are theoretically compromised due to a reduced detection function and should, therefore, potentially be discounted from any future work. Furthermore, the sea state was observed to be non-homogeneous across the survey area, calling for an adjustment to the methodology that would allow these variances to be accounted for and recorded.

Spatial Variability

Quantifying spatial distributions of marine mammals is crucial to understanding their behaviours, and a key component of this is distance estimation. Accurate distance estimation is a critical assumption of the methods used for this research and would be even more imperative if abundance were to be inferred (Buckland *et al.*, 2005). Errors in distance estimations were investigated and, as seen elsewhere, increased with greater distance from the observation point (Borchers *et al.*, 2009 & Nadeau & Conway, 2012). However, the calculated distance error margins were considerably less than the size of the assigned survey bins. Therefore, sightings were confidently assigned to the survey bins without the need to further account for errors.

Cox *et al.* (2018) discussed how the interaction of tidal currents and depth are important factors in habitat usage of marine mammals. While this research highlighted water depth as a significant factor in observation rates, further investigations into current velocities, such as Jones *et al.* (2014), could increase understanding of these trends. Distance from shore was significant for common dolphins, with observations peaking around 6km (Figure 14). There are no significant changes in water depth across this area; therefore, another factor must be driving these findings. Intriguingly, common dolphins have shown a preference for coastal waters when with calves or feeding (Cañadas & Hammond, 2008), and calves are primarily born during July/August (Westgate & Read, 2007), perhaps explaining the high numbers of common dolphins observed during this study. Extending the study to cover a greater timescale, and to include all seasons, would enable seasonal variations, such as these, to be captured.

Limitations

Replication promotes precision; therefore, extending this survey to develop the dataset further would be desirable and produce more conclusive results. Future recommendations have been suggested throughout the text; they include increasing the timescale of the survey and including other factors for data analysis, such as current velocities and tidal streams. Furthermore, as water temperatures and Chlorophyll-a concentrations are closely linked with prey retention (García-Barón *et al.,* 2020), these could be investigated in the context of marine mammal spatial variability. Moreover, as seen in Figures 8-10, distribution patterns are unstable and show significant variability over time; therefore, it is difficult to make long-term assumptions using time-limited data, and efforts must be made to develop long-term datasets.

Conclusions

The Western English Channel hosts populations of many important marine mammals, for which we still lack a complete understanding of their distributions. Throughout this research, four marine mammal species, including common dolphins (*Delphinus delphis*) and harbour porpoise (*Phocoena phocoena*), were observed, with over 1000 individual animal observations. Observation rates vary across a wide range of environmental factors, revealing the animal's highly complex behaviours and needs. Common dolphins were the most frequently observed species, and correlations were seen with all variables analysed. In contrast, harbour porpoise observations only correlated with a few environmental variables; however, they also had fewer sightings, so trends were harder to detect.

The spring/neap cycle significantly affected all species observed, with observations peaking during mid-cycle (Figure 8), potentially driven by prey availability. Sea state was also a critical variable and highlighted the need to develop further the methodology used. Water depth and distance from shore both influenced sightings of common dolphins and grey seals (Figures 14 & 15); however, without further investigations into the oceanography of the region, the reasons for this are still unclear. Increasing the length of the study could allow for further insights into marine mammal behaviours, such as seasonal variations in distributions.

Investing in long-term monitoring programmes for marine mammals is imperative to ensuring effective conservation policies are implemented and maintained. Rame Head is suggested as a potential location to develop such a programme. Whilst there are some challenges when monitoring marine mammals, and the methodology used here could be improved, it is clear that visual surveys are a valuable tool when trying to quantify marine mammal distributions.

This was the first study to dedicate sustained survey effort to quantifying marine mammals around the Rame Head Peninsula. Furthermore, it is also the first paper to document sightings of marine mammals within the new Plymouth Sound National Marine Park. The results presented here provide a snapshot of the observations at Rame Head and can act as a starting point to understanding the local ecology.

These results can also be applied to the broader region of the Western English Channel and can be helpful when developing marine mammal conservation strategies. However, further investigations will help build an understanding of the complete picture of marine mammal distributions in this important region.

Future work

Although specific marine mammal species are well known and protected in the English Channel, data on abundance and distribution patterns is limited. Due to this lack of data and understanding of marine mammal distributions, we have little idea whether we meet our legal obligations regarding their conservation. Population monitoring must be continued within the Western English Channel to ensure we quantify how anthropogenic pressures are affecting the local populations. It is proposed that funding be secured to develop a year-round effective monitoring program within this critical region.

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