Marine Characterisation Research Project (MCRP)

WP11 Boat Based Seabird and Marine Mammal Survey

2023 Interim Report

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Marine Characterisation Research Project (MCRP)

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Author: Eleanor Falch and James Waggitt

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Glossary

- **AIC**: Akaike information criterion, used to select best performing statistical models.
- **CV:** Coefficient of Variation, indicative of uncertainty in statistical model predictions.
- **EMMP:** Environmental Mitigation and Monitoring Plan
- **ES:** Morlais Environmental Statement.
- **ESAS:** European Seabirds at Sea survey, commonly used to estimate densities of seabirds.
- **esw:** Estimated distance from the transect-line effectively covered by the observer.
- **g(0):** Estimated probability of an observer missing animals on the transect line.
- **GPS**: Global Positioning System
- **LT:** Line Transect Survey, commonly used to estimate densities of marine mammals.
- **n:** Number of samples in the statistical model.
- **MDZ:** Morlais Demonstration Zone
- **mrds:** R package used for distance analyses.
- **PAMGuard:** Software used for hydrophone analyses.
- **SEACAMS2:** An Applied science project, based at Bangor University.
- **SMRU:** Sea Marine Mammal Research Unit, based at St Andrews University.
- **R**: Statistical Software.
- **RSPB**: Royal Society for the Protection of Birds.
- **Pr:** Proportion of minutes where animals were encountered.
- **WP:** Work Package in the Environmental Mitigation and Monitoring Program.

Capability Statement

- Measuring spatial and temporal variation in diving animals (marine mammals, seabirds) occupancy of tidal stream energy development zones help assess how animals could interact with tidal stream turbines. This interim report focusses on 2 boat-based surveys (observations and hydrophone) performed at monthly intervals between May 2022 and April 2023 in the Morlais Demonstration Zone (MDZ). Measurements of encounter rates (animals per km/minutes) and estimates of animal densities (individuals per km^2) within and outwith the MDZ and amongst months are provided.
- Several purchases above £500 were associated with the performance of boat-based surveys: a NUC computer (PO 7119411, No: PBCPQC001277) and a GPS compass (PO: 1094174, No: c2044-1904781).
- In almost all instances, surveys were performed each calendar month. Most surveys were also performed in good conditions, with 58% of surveys performed in < =sea state 1. The use of locally based observers and crew with experience of surveying in the region contributed to this achievement. It is recommended that such approaches are continued in future applications.
- To accommodate datasets collected by Natural Power and SEACAMS2 between 2016-2018 in new analyses, 2 surveys were implemented. Survey A followed the Natural Power approaches and Survey B followed the SEACAMS2 approaches. However, accommodating 2 surveys in 1 day required a reduction in transect distance for Survey A, and a demanding work-schedule. Previous and current datasets remain amalgamable and comparable analyses is still possible. Nevertheless, sourcing and / or developing alternative suitable vessels would reduce constraints and (if desirable) facilitate direct replication of Natural Power and SEACAMS2 approaches in future applications.
- By providing animal densities within the MDZ, these surveys contribute to several Environmental Monitoring and Mitigation Plan (EMMP) indicators and questions. However, it is recommended that information from these surveys is combined with information from complementary activities. For example, information on diving behaviour (WP5, WP12) would improve parameterisation of Collision Risk (CRM) and Encounter Risk (ERM) models. Measurements of short-term variation in animal densities from complementary intensive surveys (data and analyses provided in Final Report) could inform design and development of approaches to detect post-installation changes in site-use.
- Surveys per calendar month have continued since April 2023, and will continue until April 2024. Complementary intensive surveys (3 days in < 1week) have been performed in July 2022, May 2023, June 2023, and September 2023 to understand short-term variation in animal densities. More intensive surveys are possible upto and including April 2024. Finally, since March 2023, all surveys have been accompanied with scientific echosounder measurements to estimate prey availability in the study site. The Final Report will focus on data and analyses from these activities.

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1 Introduction

Measuring spatial and temporal variation in diving animals (seabirds and marine mammals) occupancy of tidal stream energy development sites help assess how populations could interact with installations (Waggitt and Scott 2014). This information is conventionally provided with boat-based surveys. To measure spatial and temporal variation in diving animals use of the Morlais Demonstration Zone (MDZ) in northwest Anglesey, 2 complementary boat-based surveys (observations and hydrophones) have been performed per calendar month since May 2022. Spatial variations of relevance are differences in animal densities (individuals per km^2) within and outwith the MDZ; temporal variations of relevance are differences in animal densities amongst months. By measuring variation in animals densities before installations, boat-based surveys can contribute to several Environmental Monitoring and Mitigation Plans (EMMP) indicators: (I1) Change in use of tidal device array deployment area pre and post installation, (I2) Changes in use of the wider MDZ outside the array deployment area, (I4) Avoidance of array of tidal devices (far field avoidance). Accordingly, these surveys contribute to the following EMMP questions: (Q1) Is there evidence that receptors use the tidal device array deployment areas in the same of similar ways pre and post deployment, (Q2) Is there evidence that receptors use the MDZ in the same or similar ways pre and post deployment, and (Q3) If there evidence of a change to use of the deployment area, is it considered ecologically significant by the advisory group? By providing measurements of animal densities in different scenarios, these surveys can also contribute to: (I9) Validation of Encounter Risk (ERM) and Collision Risk (CRM) models. This interim report will: (1) explain and summarise the survey design, and (2) present data and analyses of monthly surveys between May 2022 and April 2023. A Final Report in May 2024 will: (1) present data and analyses of monthly surveys from May 2022 to April 2024, (2) amalgamate data collected in 2022-2024 with that collected in 2016-2018 (Morlais 2019, Veneruso *et al* 2019), investigating animals spatial and temporal occupancy of the MDZ across 4 years, (3) present data and analysis from complementary intensive surveys (3 days in < 1wk) and echosounder measurements.

2 Methods

2.1 Survey Performance

Surveys covered an area ~ 105km^2 and were centred on the MDZ. In this area, seabed depth is 35 -90m, predominant tides flood to the North and ebb to the South, and mean Spring peak current velocities reach 3.1m^{-1} (Piano *et al* 2015). All surveys were undertaken aboard the Seekat C (Figure 2.1). This 11m catamaran has a forward facing two-level, four-person observer platform with unobstructed views at either 4.5m and 5.5m eye height. The twin 280hp engines allow consistent speeds to be maintained. A specification sheet is provided in the Annex.

2.2 Survey Design

2.2.1 General Approaches

Monthly surveys aimed to identify seasonal (amongst months) and spatial (MDZ versus non- MDZ locations) variations in marine mammal and seabird densities. These aims were achieved by performing 2 separate surveys every month. The rationale for performing these 2 separate surveys were:

(1) In the original Environmental Statement (ES) separate surveys were performed by Natural Power (Survey A: Morlais 2019) and SEACAMS2 (Survey B; Veneruso *et al* 2019) from 2016 – 2018 (Figure 2.2). The former used European Seabirds At-Sea (ESAS) approaches and focussed on seabirds and marine mammals; the latter used Line-Transect (LT) approaches and focussed exclusively on marine mammals. Replicating these approaches would allow amalgamation of datasets and comparative analyses into spatial and temporal patterns in site-use across several years.

(2) Owing to their cryptic and solitary behaviour, estimations of harbour porpoise *Phocoena phocoena* densities must consider availability and perception bias. Survey B used a double-platform approach (Evans and Hammond 2004) which accounts for availability and perception biases by estimating the probability of observers missing animals on the transect-line (g(0)) (Burt *et al* 2014). These approaches used 2 independent observation teams, with the g(0) based upon the proportion of animals detected by one team and missed by the other team. The continuation of double-platform surveys would assist estimates of harbour purpose densities within the MDZ.

As continuing survey A and B was considered advantageous, it was decided to combine these surveys on the same day. More detailed information on Survey A and B is provided below, accompanied with rationale and explanations of slight deviations from previous approaches. However, none of these slight deviations from previous approaches would prevent amalgamation of datasets and comparative analyses. Information on how these analyses could be performed is provided in the discussion.

2.2.2 Survey A

Transects: Survey A originally used the 13 parallel transects designed by Natural Power (Morlais 2019, Figure 2.2). The transect lines of varying length were orientated in a west-east direction and were spaced approximately 0.92 km apart. The vessel travelled south through the transects when the tide is flooding North and travels north when the tide is ebbing south, to avoid double counting seabirds drifting on the water. Whilst performing transects, the vessel maintained a speed over ground of approximately 10 knots. However, following the maiden survey on 15/05/2023, it became evident that completing the original Survey A and Survey B on the same day was not possible. Therefore, to allow both surveys to be completed, only 6 or 7 transect lines were carried out each month. The transect lines were alternated amongst months i.e., odd numbers in one month, followed by even numbers the next month.

Observer Teams: Natural Power surveys used 1 observer team recording both seabirds and marine mammals. However, to improve detection of each taxon on the water, Survey A used 2 observer teams. Observers recording seabirds used ESAS (Camphuysen *et al* 2004) methods whereas those recording marine mammals used LT methods (Evans and Hammond 2004). In ESAS observations are constrained to 300m from the transect, whereas in LT observations are theoretically unconstrained but sightings generally occurred within 1km from the transect. As marine mammals are scarcer than seabirds, using unconstrained LT rather than constrained ESAS should increase sample size for analyses.

Performance: On the lower platform, two experienced observers focussed on detecting seabirds, one scanning for seabirds on both sides of the vessel and the other recording sightings called out by the observer. Whilst Natural Power only covered one side of the vessel, effectively covering both sides is possible because the observation platform has unobstructed views of port and starboard. However, to reduce the chance of seabirds being missed or abundance misrepresented, there was an additional observer at times when there were large aggregations of seabirds present (i.e., during the bird breeding season), with one observer focussing on port and the other observer focussing on starboard. To improve collection of key information, information not relevant to objectives and analyses were not recorded as standard. For example, waders and passerines seen in flight and/or in small numbers were ignored; behaviour was summarised into broad and objective categories rather than complex and subjective categories sometimes used in ESAS approaches. On the upper platform, two experienced observers focussed on detecting marine mammals, both scanning to 90° either side of the vessel for marine mammals, and each recording sightings as they occurred. The observer team rotated tasks regularly to avoid fatigue. Observation conditions were recorded every 5 minutes, and GPS positions were logged every 1 minute. The observation conditions recorded included vessel speed over ground, vessel heading, sea state (Beaufort scale), glare, precipitation, swell height, and visibility. The specific information collected during surveys are provided in the Annex.

FIGURE 2.1: THE SEEKAT C VESSEL USED IN BOAT-BASED SURVEYS SHOWING THE OBSERVATION PLATFORM.

FIGURE 2.2: THE NATURAL POWER (LEFT) SEACAMS2 (RIGHT) TRANSECT LINES USED FOR SURVEY DESIGN A AND B.

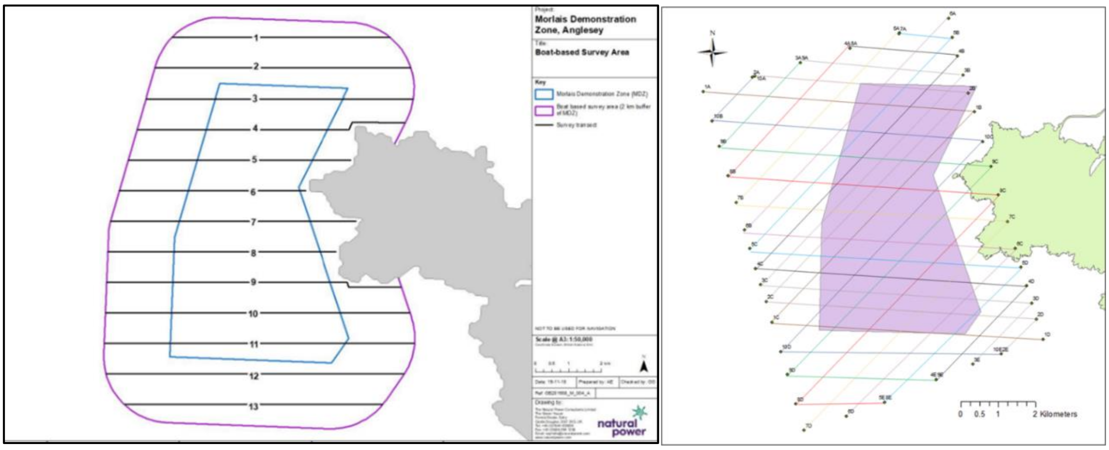
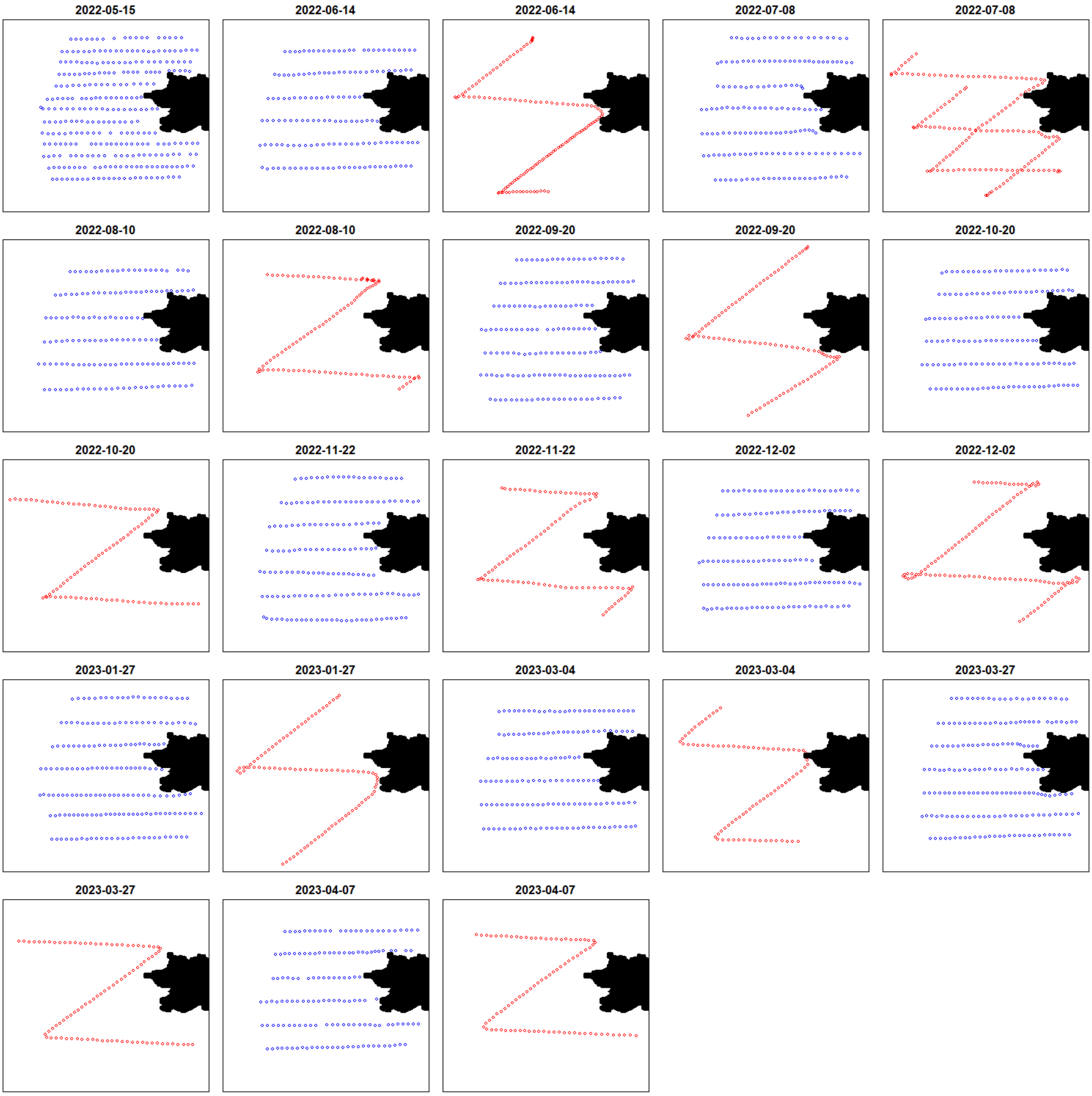


FIGURE 2.3: SURVEY A (BLUE) AND SURVEY B (RED) TRANSECTS PERFORMED DURING EACH SURVEY DATE FROM MAY 2022- APRIL 2023.



2.2.2 Survey B

Transects: Survey B used the 10 zigzag transect routes designed by SEACAMS2 (Veneruso *et al* 2019, Fig 2.2), combining 2 observation teams and a high-frequency stereo hydrophone system (Marine Ecological Research). The transect lines were spaced 1 km apart. This survey design allowed collection of concurrent acoustic and observational information for marine mammals within the MDZ. The hydrophone was primarily deployed to detected harbour porpoise, whose almost continuous vocalisations (Sørensen *et al* 2018) make them suitable for acoustic detection. The vessel moved with the direction of the tide during the survey, reducing the background noise and increasing the likelihood of acoustic detections. One transect was surveyed per month and transects were alternated equally amongst months. Whilst performing these transects, the vessel maintained a speed over ground of approximately 10 knots.

***Observation Team*s**: Both SEACAMS2 and WP11 surveys used 2 observation teams when recording marine mammals. Both observation teams used LT approaches. As with Survey A, LT observations are theoretically unconstrained, but sightings generally occurred within 1km from the transect.

Performance: On the lower platform, two primary observers scan ahead and to 90° either side of the vessel, recording marine mammal sightings as they occurred (as described above). On the upper platform, two independent observers scan ahead of the vessel and to 90° either side of the vessel. When a marine mammal is sighted, the independent observers record the relevant details. Once the animal has passed the bow of the boat, they confirm with the primary observers whether they saw the same animal(s), and if so, record the sighting as a duplicate with an associated level of confidence. To ensure accurate distance estimation, observers practiced on suitable targets (i.e., buoys, small vessels) using rangefinder binoculars before starting surveys. It was not possible to use rangefinder binoculars to provide a distance to the animal during surveys due to the movement of the boat and the brief time the animals spend at the surface. Throughout the transect, the hydrophone was towed approximately 100m behind the vessel. Hydrophone data is recorded and processed by a laptop running the PAMGuard software default porpoise click detector in real time (Gillespie *et al* 2009). Acoustic data was collected during all surveys apart from those conducted in May 2022, as the hydrophone was not yet ready for deployment, and November 2022, due to a technical error. Observers on the viewing platform are unaware of recordings being made by the hydrophone. The specific information collected during surveys are provided in the Annex.

2.2.2 Other Activities

Surveys per calendar month have continued since April 2023, and will continue until April 2024. Complementary intensive surveys (3 days in < 1week) have been performed in July 2022, May 2023, June 2023, and September 2023 to understand short-term variation in animal densities. More intensive surveys are possible upto and including April 2024. Finally, since March 2023, all surveys have been accompanied with scientific echosounder measurements to estimate prey availability in the study site. The Final Report will focus on data and analyses from these activities. Summaries are provided in the Annex.

2.3 Analysis

General Approaches: As only deep-diving seabirds are vulnerable (Waggitt and Scott 2014), analyses focussed on *Alcidae* (common guillemot *Uria aalge*, Razorbill *Alca torda)* and Manx shearwater *Puffinus puffinus*) on the water. Discrimination between common guillemot and razorbill can be challenging at a distance and/or whilst birds are in flight. When identification to species level was not possible, animals were recorded as 'large auks' (520 individuals, 76 sightings). To enable analyses, large auks were reassigned as common guillemot or razorbill based upon their relative contribution per survey. For example, if common guillemot and razorbill contributed 80% and 20% of individuals, respectively, then 10 large auks would be reassigned as 8 common guillemots and 2 razorbills. When these conversions resulted in non-integers, values were rounded to the nearest integer. As all cetaceans are vulnerable, analyses focussed on all species encountered. Animal site-use was quantified using densities (Individuals per km^2), encounter rates (animals per km travelled) and prevalence (minutes with acoustic detections). Following calculation of site-use across surveys, spatial variations in animal densities within and outwith the MDZ, and temporal variation in animal densities amongst months, were extracted and presented.

Seabird Densities: 'Distance' analysis was used to estimate densities of *Alcidae* and Manx shearwater on the water per minute (Thomas *et al* 2010). Such analyses were used by Natural Power to estimate densities. 'Distance' analyses uses recorded distances between animals and the transect line to estimate the area effectively covered (km^2). The area effectively covered is a function of the distance travelled by the vessel and the maximum distance from the vessel in which animals are efficiently detected. The latter is known as the effective strip width (*esw*). The *esw* is estimated using detection functions that quantify relationships between the probability of animals being detected and distance from the vessel, before using these relationships to estimate the probability of animals being missed up to a maximum distance searched (Thomas *et al* 2010). In ESAS approaches, the maximum distance is 300m. Because the *esw* could depend upon weather conditions, detection functions allow variation in detection-distance relationships through the inclusion of relevant covariates (e.g., sea state). The manner of the decline in the probability of detection with distance also depends on species and setup, and detection functions can consider either half-normal or hazard rates when quantifying these relationships. Detection functions were developed using the 'mrds' package (Laake *et al* 2018) in R 3.2.5 (R Core Team 2016). Different combinations of covariates (none, sea state) and rates (half-normal, hazard-rate) were tested for *Alcidae* and Manx shearwater. The detection function producing the lowest Akaike's Information Criteria (AIC) score was used to predict variations in *esw* across surveys. Following the calculation of *esw* each minute, km^2 was calculated using the following equation, whereby *d* is the distance travelled:

$$km^2 = d(2 * esw)$$

Because observers searched both sides of the vessel, the *esw* was doubled in calculations of km^2. Following the calculation of km^2, densities (individuals per km^2) of *Alcidae* and Manx shearwater per minute were calculated using the following equation, where *n* is the number of animals encountered:

$$Individuals\ per\ km^2 = \frac{n}{km^2}$$

Marine Mammal Densities: Distance' analysis was also used to estimate densities of cetaceans per minute. Such analyses were used by SEACAMS2 to estimate densities. For cetaceans, sighting data from survey A was used to estimate densities using the same methods as above but with an *esw* limited to 1000m (~ the maximum sighting distance). This process was repeated for Survey B, although the esw for harbour porpoise was reduced using estimates of g(0) (see Section 2.1) in the following equation:

$$Individuals\ per\ km^2 = \frac{n}{g(0) *\ km^2}$$

Estimates of g(0) considered sea state as an explanatory variables. Unfortunately estimates of g(0) for dolphins were not possible due to limited sightings. However, the likelihood of missing animals surfacing on the transect line is lower for dolphins than harbour porpoise owing to their livelier and aggregative behaviour. Detection functions and g(0) were estimated using the 'mrds' package (Laake *et al* 2018) in R 3.2.5 (R Core Team 2016).

Marine Mammal Prevalence: Clicks identified by the porpoise click detector were verified by eye using PamGuard viewer mode (Gillespie *et al* 2009) and other cetacean vocalisations such as dolphin clicks and whistles were also identified. If more than 7 confirmed vocalisations occurred less than a minute apart, then this was identified as a definite cetacean event (Cucknell *et al* 2017, Gillespie *et al* 2005). The prevalence of animals during surveys was quantified using the number of minutes where detections occurred.

3 Results

3.1 Survey Performance

Summary: 12 monthly surveys were completed between May 2022 and April 2023 (Table 3.1). In May 2022, only Survey A was completed. However, from June 2022 onwards both Survey A and Survey B were usually completed once per month with a few exceptions: (1) Due to weather conditions and vessel availability, surveys were not possible in February 2023; however two surveys were completed in March 2023 (04/03/2023, 27/03/2023) to account for this. The first survey in March 2023 was performed at the very beginning of the month, so data collection occurred as close to February as possible, (2) Survey B was completed twice in July. However, performing Survey B twice per month was deemed unfeasible thereafter owing to restrictions on crew workhours. For the most part, mean speeds of approximately 10kt were obtained, with minimal deviances from means within individual surveys (Table 3.2). The exception was the maiden performance of Survey B on 14/06/2023, which was associated with method refinement.

Conditions: Survey days were selected primarily on the presence and/or expectation of reasonable sea state <=2) or good (sea state <=1) weather conditions. These aims were generally met: 90% of surveys were in sea state <=2 and 58% surveys were in sea state <=1. However, despite a persistent and favourable forecast, a survey was abandoned on-arrival on 09/09/2022 due to substantial swell coupled with wind against tide. These conditions impeded the detection of marine mammals and seabirds on the water. The abandoned survey on 09/09/2023 was subsequently performed on 20/09/2023.

Tidal Coverage: Whilst it is suggested that surveys have an even coverage of tidal states (Jackson and Whitfield 2011), days were never selected on tidal states alone because weather conditions were a major constraint on survey performance i.e., a ‘weather-window’ could not be ignored because they did not coincide with an under-surveyed tidal state. This emphasis on appropriate weather conditions resulted in unbalanced coverage: 53% of observations were during ebb tides, 30% during a flood tide and 17% during slack water (Table 3.3). However, the monthly surveys are fundamentally unsuitable for understanding variation in site-use across tidal states because variation in animal densities caused by seasonal movements likely exceeds that caused by tides. Therefore, differences in animal densities amongst monthly surveys cannot be attributed to tides. The intensive surveys (see Annex) are designed to understand variation in site-use within and amongst days, allowing tidal patterns to be explored.

Hydrophone: The hydrophone was unavailable in May 2022 whilst technical issues occurred in November 2022. Therefore, acoustic detections were not provided for either May 2022 nor November 2022.

3.2 Seabirds

Summaries of focal seabird sightings and distributions per month are shown in Table 3.4 and Figures 3.1 to 3.3. For *Alcidae* and Manx shearwater*,* the selected detection function included a negative relationship with sea state and a hazard rate (see Section 2.4. Tables 3.5 to 3.6). Encounter rates and density estimates per month are shown in Tables 3.7 to 3.9 and Figures 3.4 to 3.5. Seabird density estimates and encounter rates showed similar seasonal patterns, with site-occupancy greatest during summer months. Common guillemot densities peaked in September, razorbill densities peaked in August and Manx shearwater densities peaked in July. For *Alcidae*, density estimates were often greater inside than outwith the MDZ, but numerous exceptions occurred. For Manx shearwater, density estimates were greater inside the MDZ in July but outwith the MDZ In May and August.

TABLE 3.1: SURVEY DATES AND THE TRANSECTS COMPLETED DURING EACH SURVEY FROM MAY 2022- APRIL 2023. A SUBSET OF TRANSECTS WERE PERFORMED PER MONTH. NUMBERS IN SURVEY A AND B IDENTIFY WHICH TRANSECTS WERE PERFORMED.

Date	Survey A	Survey B
15/05/2022	1,2,3,4,5,6,7,8,9,10,11,12,13	-
14/06/2022	2,4,6,8,10,12	8
08/07/2022	1,3,5,7,9,11,13	5,10
10/08/2022	2,4,6,8,10,12	2
20/09/2022	1,3,5,7,9,11,13	6
20/10/2022	2,4,6,8,10,12	1
22/11/2022	1,3,5,7,9,11,13	3
02/12/2022	2,4,6,8,10,12	4
27/01/2023	1,3,5,7,9,11,13	7
04/03/2023	2,4,6,8,10,12	9
27/03/2023	1,3,5,7,9,11,13	1
07/04/2023	2,4,6,8,10,12	2

TABLE 3.2: DISTANCE AND SPEEDS (KNOTS, MEAN AND STANDARD DEVIATION) IN SURVEYS FROM MAY 2022 TO APRIL 2023.

Date	Survey	Distance (Km)	Mean Speed (Kt)	Standard Deviation Speed (Kt)
15/05/2022	A	102.08	10.20	1.18
14/06/2022	A	48.26	10.24	1.07
14/06/2022	B	27.78	7.81	1.62
08/07/2022	A	53.55	10.24	1.09
08/07/2022	B	49.85	9.88	0.97
10/08/2022	A	47.83	10.38	0.63
10/08/2022	B	28.39	9.64	0.99
20/09/2022	A	54.01	9.91	0.61
20/09/2022	B	25.82	9.69	0.40
20/10/2022	A	48.81	10.10	0.90
20/10/2022	B	28.42	9.82	0.77
22/11/2022	A	55.17	9.98	1.52
22/11/2022	B	28.23	10.18	1.03
02/12/2022	A	48.61	9.97	0.76
02/12/2022	B	27.69	9.56	0.75
27/01/2023	A	56.42	9.88	1.01
27/01/2023	B	24.04	9.78	0.41
04/03/2023	A	47.67	9.86	0.58
04/03/2023	B	25.57	9.85	0.57
27/03/2023	A	54.34	9.76	0.83
27/03/2023	B	31.62	9.91	0.55
07/04/2023	A	42.56	9.66	0.77
07/04/2023	B	26.33	9.90	0.88

TABLE 3.3: TIDAL COVERAGE OF THE MONTHLY SURVEYS FROM MAY 2022 TO APRIL 2023. SURVEY COVERAGE IS SHOWN IN BLUE.

Date	LW	LW+1	LW+2	LW+3	LW+4	LW+5	HW	HW+1	HW+2	HW+3	HW+4	HW+5	Range (m)
15/05/2022													5.16
14/06/2022													5.16
08/07/2022													4.37
10/08/2022													4.72
20/09/2022													3.73
20/10/2022													3.95
22/11/2022													4.98
02/12/2022													4.33
27/01/2023													5.5
04/03/2023													4.9
27/03/2023													4.9
07/04/2023													5.6

TABLE 3.4: COUNTS OF FOCAL SEABIRD SPECIES ON THE WATER FOR EACH MONTHLY SURVEY FROM MAY 2022 TO APRIL 2023 AND ANNUAL TOTALS. THERE ARE DIFFERENCES IN THE TOTAL DISTANCE OF TRANSECTS AMONGST MONTHS.

Date	Common Guillemot	Manx Shearwater	Razorbill	Total
15/05/2022	514	361	58	**933**
14/06/2022	110	0	30	**140**
08/07/2022	388	240	43	**671**
10/08/2022	254	203	435	**892**
20/09/2022	477	1	83	**561**
20/10/2022	144	0	4	**148**
22/11/2022	45	0	23	**68**
02/12/2022	24	0	23	**47**
27/01/2023	25	0	5	**30**
04/03/2023	68	0	10	**78**
27/03/2023	85	0	16	**101**
07/04/2023	11	0	16	**27**
Total	**2145**	**805**	**746**	**3696**

FIGURE 3.1: DISTRIBUTION OF COMMON GUILLEMOT IN THE MONTHLY SURVEYS BETWEEN MAY 2022 AND APRIL 2023.

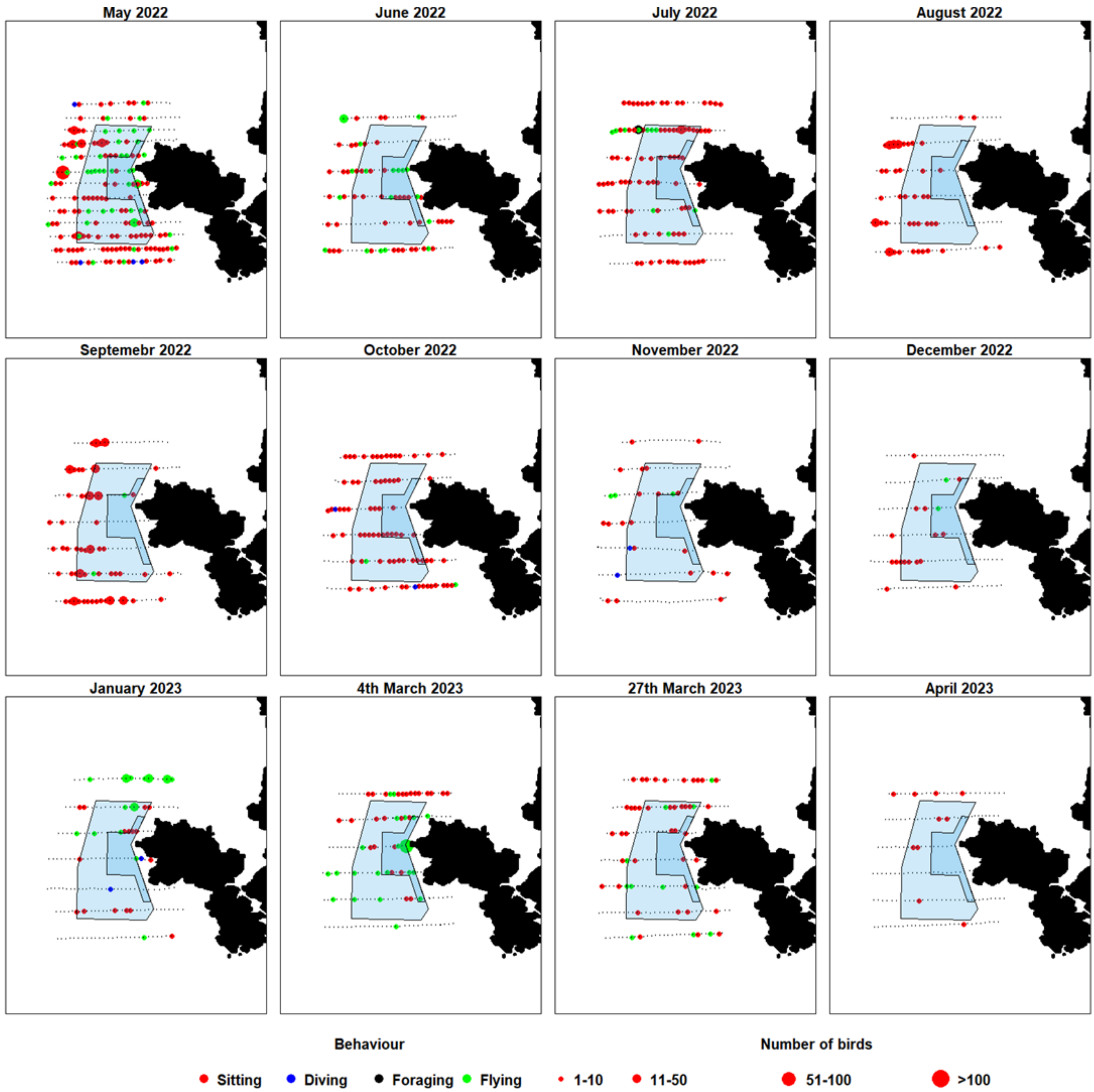


FIGURE 3.2: DISTRIBUTION OF RAZORBILL IN THE MONTHLY SURVEYS BETWEEN MAY 2022 AND APRIL 2023.

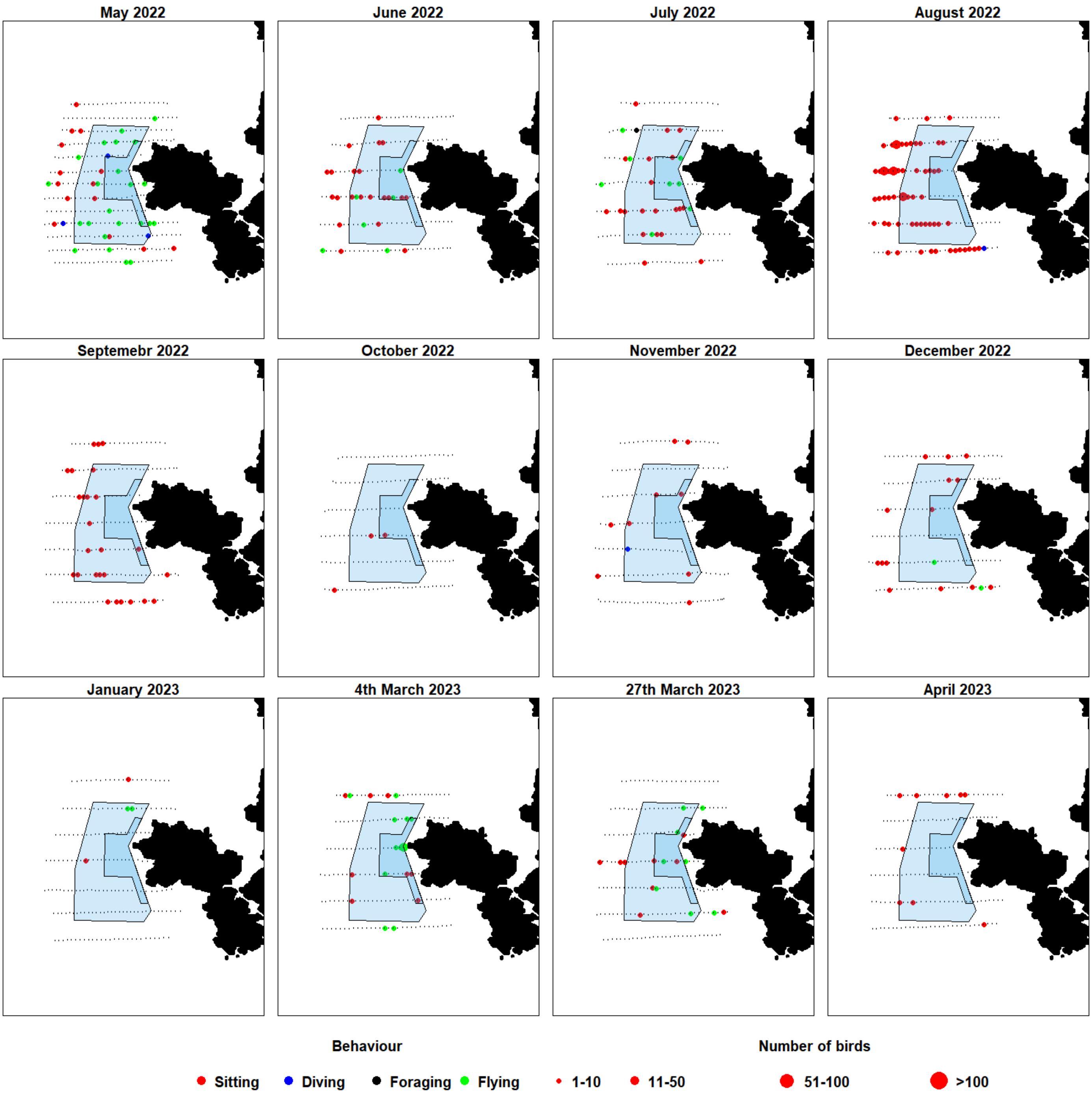


FIGURE 3.3: DISTRIBUTION OF MANX SHEARWATER IN THE MONTHLY SURVEYS BETWEEN MAY 2022 AND APRIL 2023.

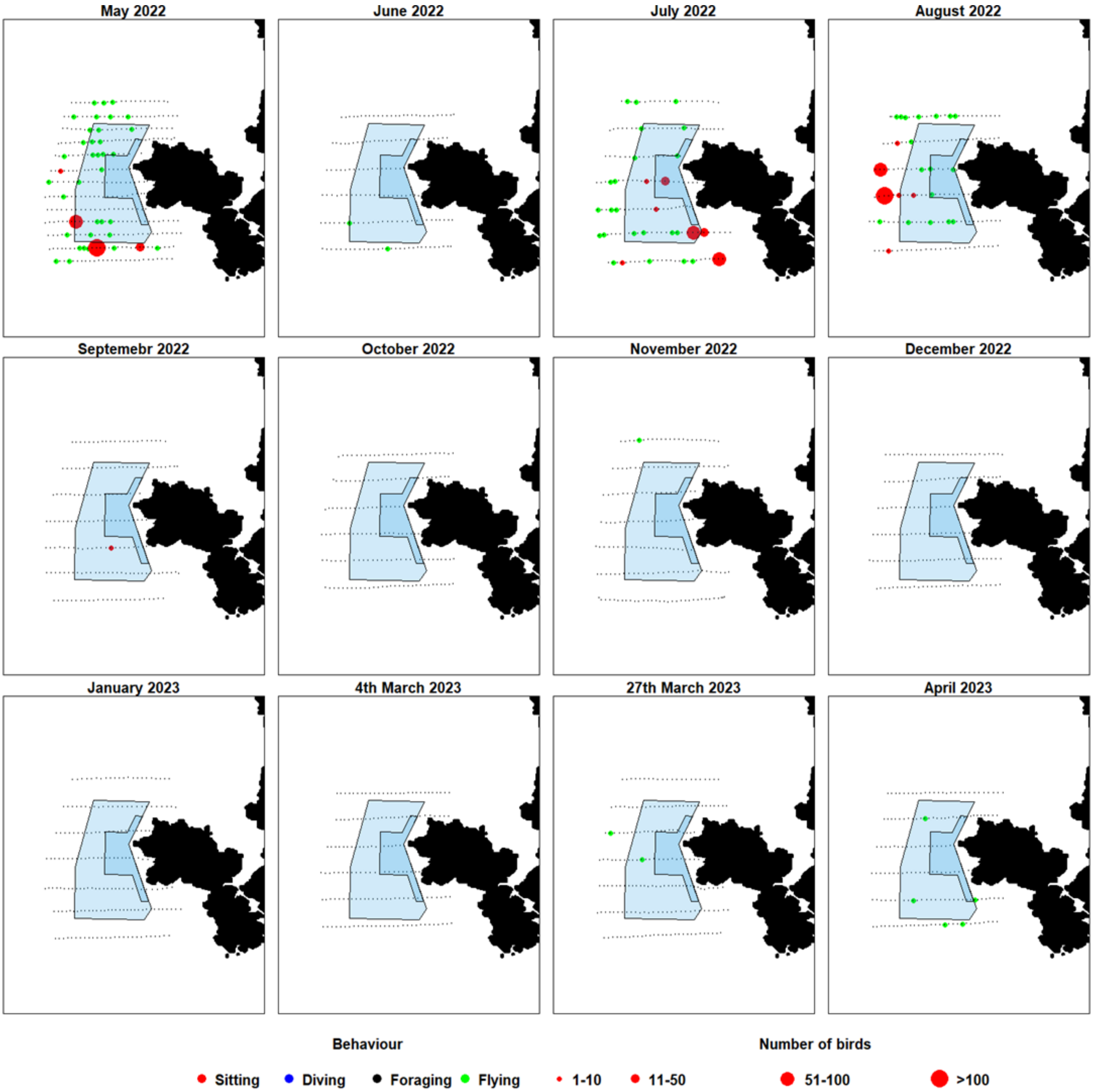


Table 3.5: The sample size (number of sightings), rate, covariates (and associated slopes), coefficient of variation and AIC score of Candidate models for Alcidae (common guillemot and razorbill) detection function.

Sample size	Rate	Covariates	CV	AIC	Slope
1381	Hazard	Sea State	0.03	15194.50	-0.14
1381	Hazard	None	0.04	15202.05	0.00
1381	Half normal	Sea state	0.02	15215.33	-0.09
1381	Half normal	None	0.02	15221.64	0.00

Table 3.6: The sample size (number of sightings), rate, covariates (and associated slopes), coefficient of variation and AIC score of Candidate models for Manx shearwater detection function.

Sample size	Rate	Covariates	CV	AIC	Slope
23	Hazard	Sea State	0.36	246.53	-0.78
23	Hazard	None	0.53	247.98	0.00
23	Half normal	Sea State	0.21	248.26	-0.80
23	Half normal	None	0.13	252.20	0.00

Table 3.7: Outputs from detection functions for common guillemot on the water in the monthly surveys from May 2022 to April 2023 showing estimated strip width (*esw*), coefficient of variation in *esw* (CV), proportion of 1-minute sections with animal encounters (Pr), the estimated area effectively searched (Km^2), the number of animals encountered (Ind) and the estimated density of animals (Ind km^2) per month for inside and outside of the MDZ and across the site.

Date	Zone	*esw*	CV	Pr	Km^2	Ind	Ind Km^2
15/05/2022	MDZ	0.16	0.03	0.40	11.89	114	9.58
	Non-MDZ	0.16	0.03	0.42	19.54	400	20.47
14/06/2022	MDZ	0.15	0.04	0.30	4.86	27	5.56
	Non-MDZ	0.15	0.04	0.33	9.49	83	8.74
08/07/2022	MDZ	0.15	0.04	0.54	6.36	201	31.58
	Non-MDZ	0.15	0.04	0.50	9.73	179	18.40
10/08/2022	MDZ	0.17	0.03	0.25	5.52	37	6.70
	Non-MDZ	0.17	0.03	0.29	9.98	215	21.53
20/09/2022	MDZ	0.13	0.04	0.25	5.55	174	31.34
	Non-MDZ	0.13	0.04	0.36	8.13	303	37.29
20/10/2022	MDZ	0.15	0.04	0.60	4.85	66	13.60
	Non-MDZ	0.15	0.04	0.45	9.04	78	8.63
22/11/2022	MDZ	0.15	0.04	0.14	6.32	19	3.01
	Non-MDZ	0.15	0.04	0.13	9.99	26	2.60
02/12/2022	MDZ	0.14	0.04	0.17	4.65	13	2.80
	Non-MDZ	0.15	0.04	0.07	6.27	11	1.75
27/01/2023	MDZ	0.16	0.03	0.14	6.83	12	1.76
	Non-MDZ	0.16	0.03	0.07	11.66	13	1.12
04/03/2023	MDZ	0.15	0.04	0.22	4.87	30	6.16
	Non-MDZ	0.15	0.04	0.16	9.75	34	3.49
27/03/2023	MDZ	0.16	0.03	0.20	4.80	34	7.08
	Non-MDZ	0.16	0.03	0.23	12.03	49	4.07
07/04/2023	MDZ	0.15	0.04	0.07	4.71	5	1.06
	Non-MDZ	0.15	0.04	0.06	6.69	5	0.75
MDZ	**Mean**	**0.15**	**0.04**	**0.27**	**5.93**	**61.00**	**10.02**
	Median	**0.15**	**0.04**	**0.24**	**5.20**	**32.00**	**6.43**
Non-MDZ	**Mean**	**0.15**	**0.04**	**0.26**	**10.19**	**116.33**	**10.74**
	Median	**0.15**	**0.04**	**0.23**	**9.74**	**49.00**	**4.07**

TABLE 3.8: OUTPUTS FROM DETECTION FUNCTIONS FOR RAZORBILL ON THE WATER IN THE MONTHLY SURVEYS FROM MAY 2022 TO APRIL 2023 SHOWING ESTIMATED STRIP WIDTH (*ESW*), COEFFICIENT OF VARIATION IN *ESW* (CV), PROPORTION OF 1-MINUTE SECTIONS WITH ANIMAL ENCOUNTERS (PR), THE ESTIMATED AREA EFFECTIVELY SEARCHED (KM^2), THE NUMBER OF ANIMALS ENCOUNTERED (IND) AND THE ESTIMATED DENSITY OF ANIMALS (IND KM^2) PER MONTH FOR INSIDE AND OUTSIDE OF THE MDZ AND ACROSS THE SITE.

Date	Zone	*esw*	CV	Pr	Km^2	Count	Ind Km^2
15/05/2022	MDZ	0.16	0.03	0.06	11.89	23	1.93
	Non-MDZ	0.16	0.03	0.05	19.54	35	1.79
14/06/2022	MDZ	0.15	0.04	0.22	4.86	18	3.70
	Non-MDZ	0.15	0.04	0.10	9.49	12	1.26
08/07/2022	MDZ	0.15	0.04	0.21	6.36	30	4.71
	Non-MDZ	0.15	0.04	0.06	9.73	13	1.34
10/08/2022	MDZ	0.17	0.03	0.40	5.52	155	28.09
	Non-MDZ	0.17	0.03	0.40	9.98	271	27.14
20/09/2022	MDZ	0.13	0.04	0.16	5.55	41	7.39
	Non-MDZ	0.13	0.04	0.15	8.13	42	5.17
20/10/2022	MDZ	0.15	0.04	0.04	4.85	3	0.62
	Non-MDZ	0.15	0.04	0.01	9.04	1	0.11
22/11/2022	MDZ	0.15	0.04	0.05	6.32	9	1.42
	Non-MDZ	0.15	0.04	0.05	9.99	14	1.40
02/12/2022	MDZ	0.14	0.04	0.06	4.65	8	1.72
	Non-MDZ	0.15	0.04	0.10	6.27	15	2.39
27/01/2023	MDZ	0.16	0.03	0.01	6.83	4	0.59
	Non-MDZ	0.16	0.03	0.01	11.66	1	0.09
04/03/2023	MDZ	0.15	0.04	0.09	4.87	5	1.03
	Non-MDZ	0.15	0.04	0.03	9.75	5	0.51
27/03/2023	MDZ	0.16	0.03	0.06	4.80	6	1.25
	Non-MDZ	0.16	0.03	0.05	12.03	10	0.83
07/04/2023	MDZ	0.15	0.04	0.04	4.71	6	1.27
	Non-MDZ	0.15	0.04	0.09	6.69	10	1.50
MDZ	**Mean**	**0.15**	**0.04**	**0.12**	**5.93**	**25.67**	**4.48**
	Median	**0.15**	**0.04**	**0.06**	**5.20**	**8.50**	**1.57**
Non-MDZ	**Mean**	**0.15**	**0.04**	**0.09**	**10.19**	**35.75**	**3.63**
	Median	**0.15**	**0.04**	**0.06**	**9.74**	**12.50**	**1.37**

Table 3.9: Outputs from detection functions for Manx shearwater on the water in the monthly surveys from May 2022 to April 2023 showing estimated strip width (*esw*), coefficient of variation in *esw* (CV), proportion of 1-minute sections with animal encounters (Pr), the estimated area effectively searched (Km^2), the number of animals encountered (Ind) and the estimated density of animals (Ind km^2) per month for inside and outside of the MDZ and across the site.

Date	Zone	*esw*	CV	Pr	Km^2	Count	Ind Km^2
15/05/2022	MDZ	0.10	0.33	0.01	7.12	100	14.04
	Non-MDZ	0.11	0.29	0.02	12.88	261	20.26
14/06/2022	MDZ	0.06	0.52	0.00	1.97	0	0.00
	Non-MDZ	0.06	0.56	0.00	3.65	0	0.00
08/07/2022	MDZ	0.06	0.50	0.06	2.71	145	53.56
	Non-MDZ	0.07	0.49	0.03	4.17	95	22.77
10/08/2022	MDZ	0.12	0.27	0.02	3.92	10	2.55
	Non-MDZ	0.11	0.28	0.06	6.88	193	28.04
20/09/2022	MDZ	0.03	1.14	0.01	1.15	1	0.87
	Non-MDZ	0.03	1.21	0.00	1.60	0	0.00
20/10/2022	MDZ	0.05	0.63	0.00	1.68	0	0.00
	Non-MDZ	0.06	0.55	0.00	3.52	0	0.00
22/11/2022	MDZ	0.06	0.55	0.00	2.46	0	0.00
	Non-MDZ	0.06	0.49	0.00	4.27	0	0.00
02/12/2022	MDZ	0.05	0.68	0.00	1.50	0	0.00
	Non-MDZ	0.06	0.51	0.00	2.60	0	0.00
27/01/2023	MDZ	0.10	0.31	0.00	4.28	0	0.00
	Non-MDZ	0.11	0.29	0.00	7.78	0	0.00
04/03/2023	MDZ	0.06	0.56	0.00	1.87	0	0.00
	Non-MDZ	0.08	0.42	0.00	4.76	0	0.00
27/03/2023	MDZ	0.10	0.32	0.00	2.96	0	0.00
	Non-MDZ	0.09	0.36	0.00	6.69	0	0.00
07/04/2023	MDZ	0.07	0.46	0.00	2.09	0	0.00
	Non-MDZ	0.06	0.55	0.00	2.61	0	0.00
MDZ	**Mean**	**0.07**	**0.52**	**0.01**	**2.81**	**21.33**	**5.92**
	Median	**0.06**	**0.51**	**0.00**	**2.28**	**0.00**	**0.00**
Non-MDZ	**Mean**	**0.08**	**0.50**	**0.01**	**5.12**	**45.75**	**5.92**
	Median	**0.07**	**0.49**	**0.00**	**4.22**	**0.00**	**0.00**

FIGURE 3.4: ENCOUNTER RATES OF FOCAL SEABIRD SPECIES ON THE WATER BETWEEN MAY 2022 AND APRIL 2023.

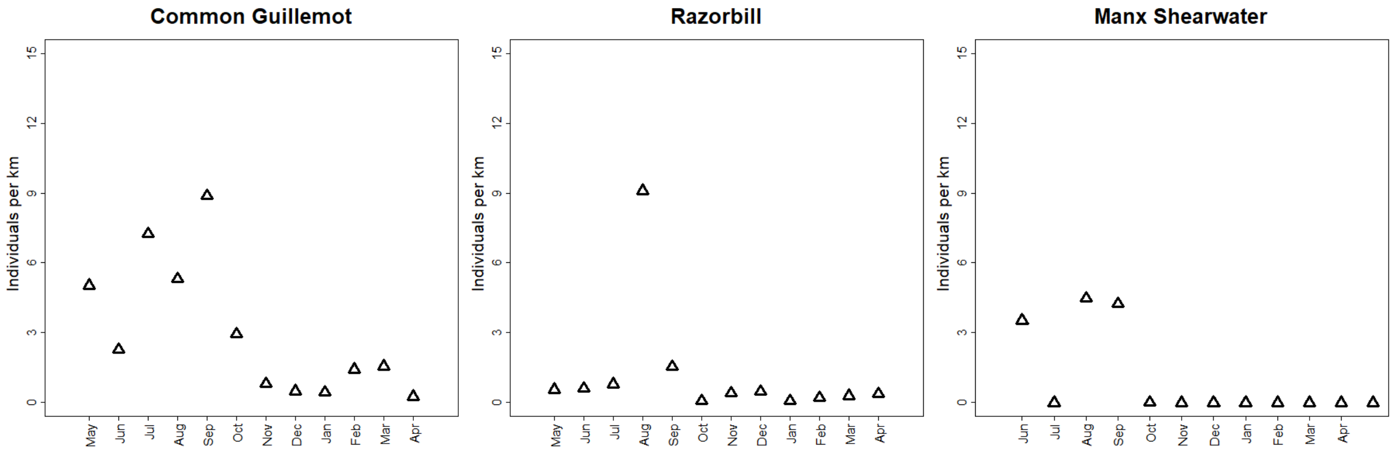
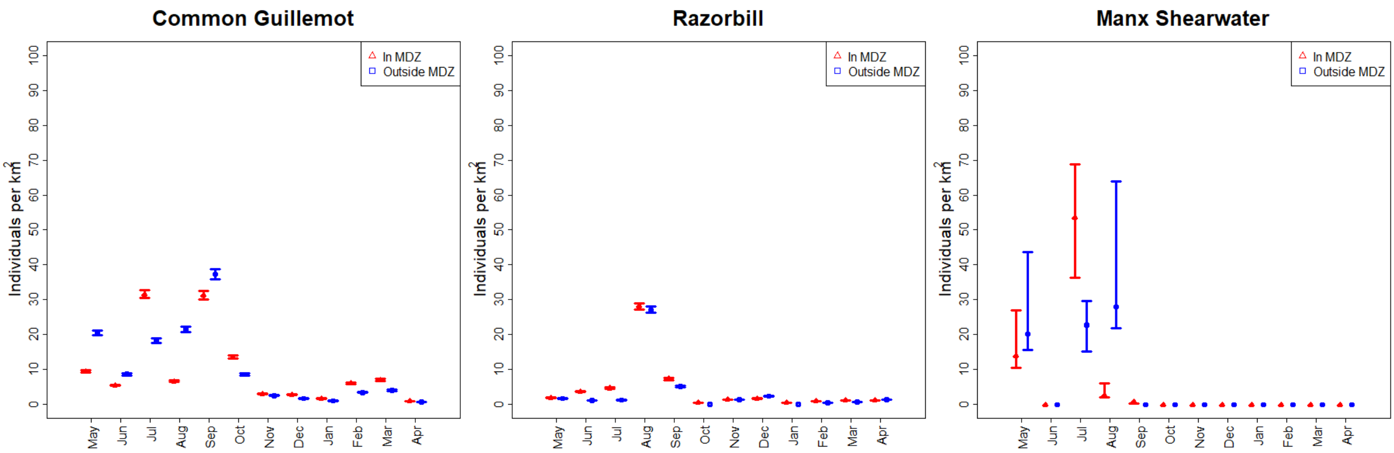


FIGURE 3.5: DENSITY ESTIMATES (+/- STANDARD ERROR) OF FOCAL SPECIES ON THE WATER BETWEEN MAY 2022 AND APRIL 2023.



3.3 Marine Mammals

Overall: Summaries of marine mammal sightings and distributions per month and species are provided in Table 3.10 and Figures 3.6 to 3.9. There were 96 encounters, 170 animals and 3 species seen. Harbour porpoises were encountered most frequently, sighted during every survey as individuals or small groups of 2 – 3 animals. On one occasion, a large group of 6 harbour porpoise were seen. Common dolphins *Delphinus delphis* were seen during September and October 2022 in moderate groups of 6 -16 animals. Risso's dolphin *Grampus griseus* were seen between September and December 2022 as single animals or moderate groups of 8-15 individuals. A small group of 4 unidentified dolphins were seen during December 2022. Post-survey scrutiny of hydrophone recordings confirms these unidentified dolphins were either bottlenose dolphin *Tursiops truncates* or common dolphin.

Survey A: For harbour porpoise, the selected detection function included a hazard rate (Table 3.11). For dolphins, the selected detection function included a negative relationship with sea state and a half-normal rate (Table 3.12). Encounter rates and density estimates for marine mammals are provided in Figures 3.9 to 3.10 and Tables 3.13 to 3.15. Density estimates and encounter rates of dolphins showed similar seasonal patterns, with site-occupancy greatest in autumn months. Densities of harbour porpoise fluctuated amongst months but peaked in winter months. There were no consistent patterns in densities of dolphins within and outwith the MDZ. The 3 highest densities of harbour porpoise occurred inside the MDZ, but no consistent patterns in space-use occurred at other times.

Survey B: For harbour porpoise, the selected detection function included a negative relationship with sea state and a half-normal rate (Table 3.16). For dolphins, the selected detection included a hazard rate (Table 3.17). The estimated g(0) for harbour porpoise was 0.84 (Table 3.18). Encounter rates and density estimates for marine mammals are provided in Figures 3.12 to 3.13 and Tables 3.19 to 3.21. Density estimates and encounter rates showed similar seasonal pattern amongst species, and resembled those from Survey A. Densities of harbour porpoise fluctuated amongst months but peaked in October 2022; Risso's dolphin densities peaked in September 2022; common dolphin densities peaked in September and October 2022. There were no consistent patterns in space-use.

Hydrophone: The proportion of minutes with harbour porpoise acoustic detections across months are provided in Figure 3.14. There were 48 separate events and 156 / 1019 minutes were porpoise positive. The proportion of porpoise positive minutes fluctuated amongst months but peaked in autumn months.

TABLE 3.10: COUNTS OF TARGET MARINE MAMMAL SPECIES FOR EACH MONTHLY SURVEY FROM MAY 2022 TO APRIL 2023 AND ANNUAL TOTALS. THERE ARE DIFFERENCES IN THE TOTAL DISTANCE OF TRANSECTS AMONGST MONTHS.

Date	Common Dolphin	Harbour Porpoise	Rissos Dolphin	Total
15/05/2022		2		**2**
14/06/2022		5		**5**
08/07/2022		10		**10**
10/08/2022		19		**19**
20/09/2022	21	3	8	**32**
20/10/2022	16	15	1	**32**
22/11/2022		8	15	**23**
02/12/2022		13	4	**17**
27/01/2023		1		**1**
04/03/2023		15		**15**
27/03/2023		3		**3**
07/04/2023		1		**1**
Total	**37**	**95**	**28**	**164**

FIGURE 3.6: DISTRIBUTION OF HARBOUR PORPOISE IN MONTHLY SURVEYS BETWEEN MAY 2022 AND APRIL 2023.

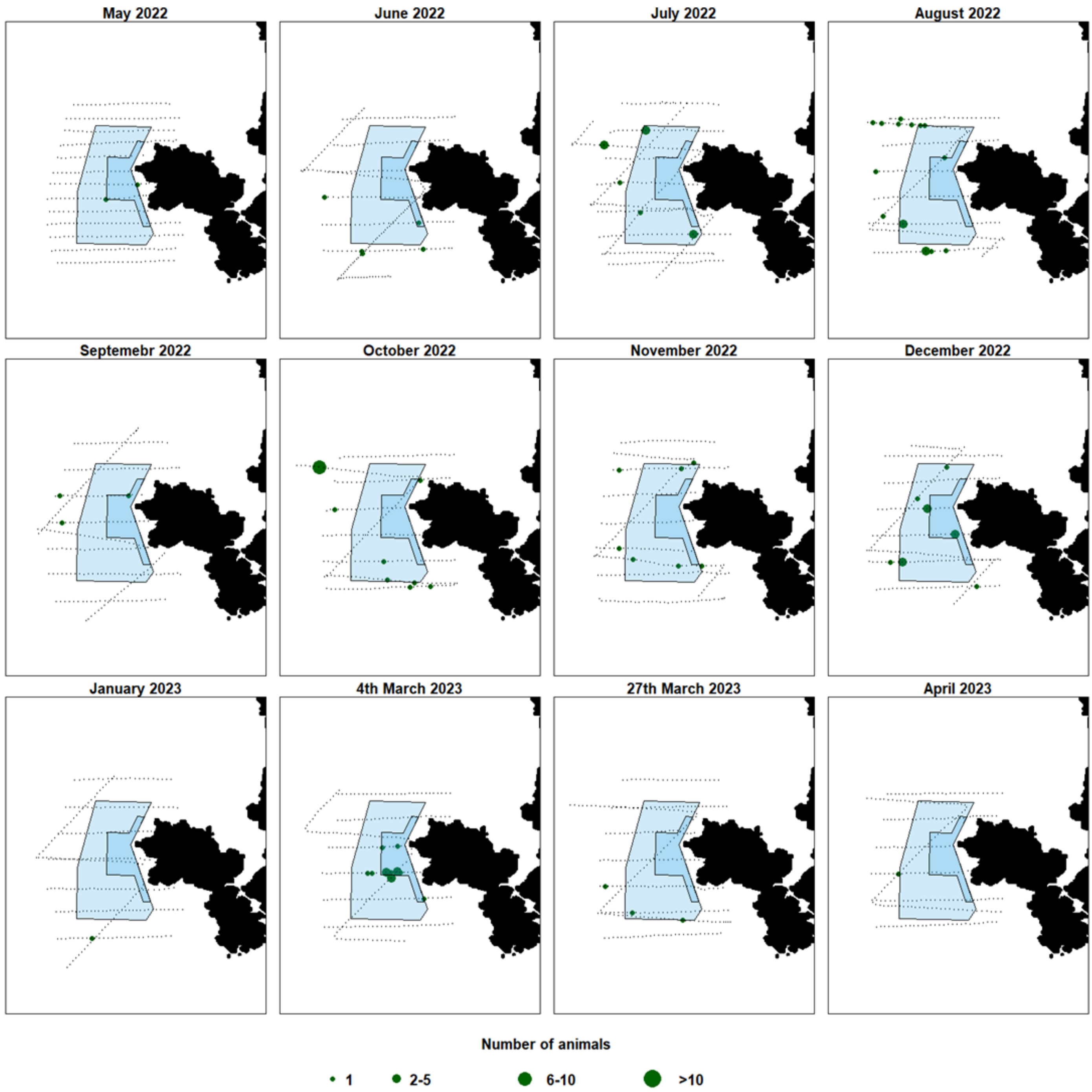


FIGURE 3.7: DISTRIBUTION OF RISSO'S DOLPHIN IN THE MONTHLY SURVEYS BETWEEN MAY 2022 AND APRIL 2023.

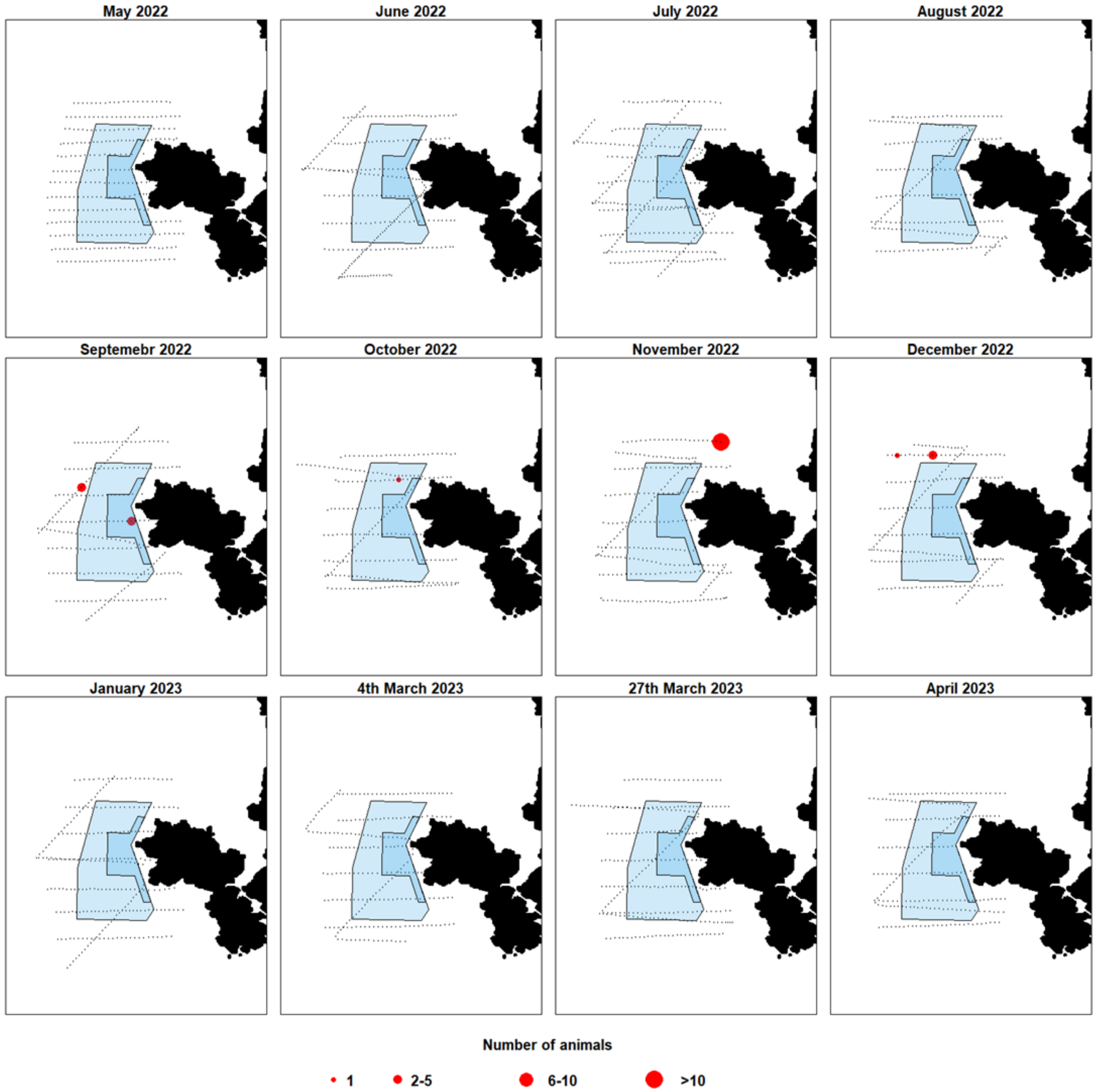


FIGURE 3.8: DISTRIBUTION OF COMMON DOLPHIN IN THE MONTHLY SURVEYS BETWEEN MAY 2022 AND APRIL 2023.

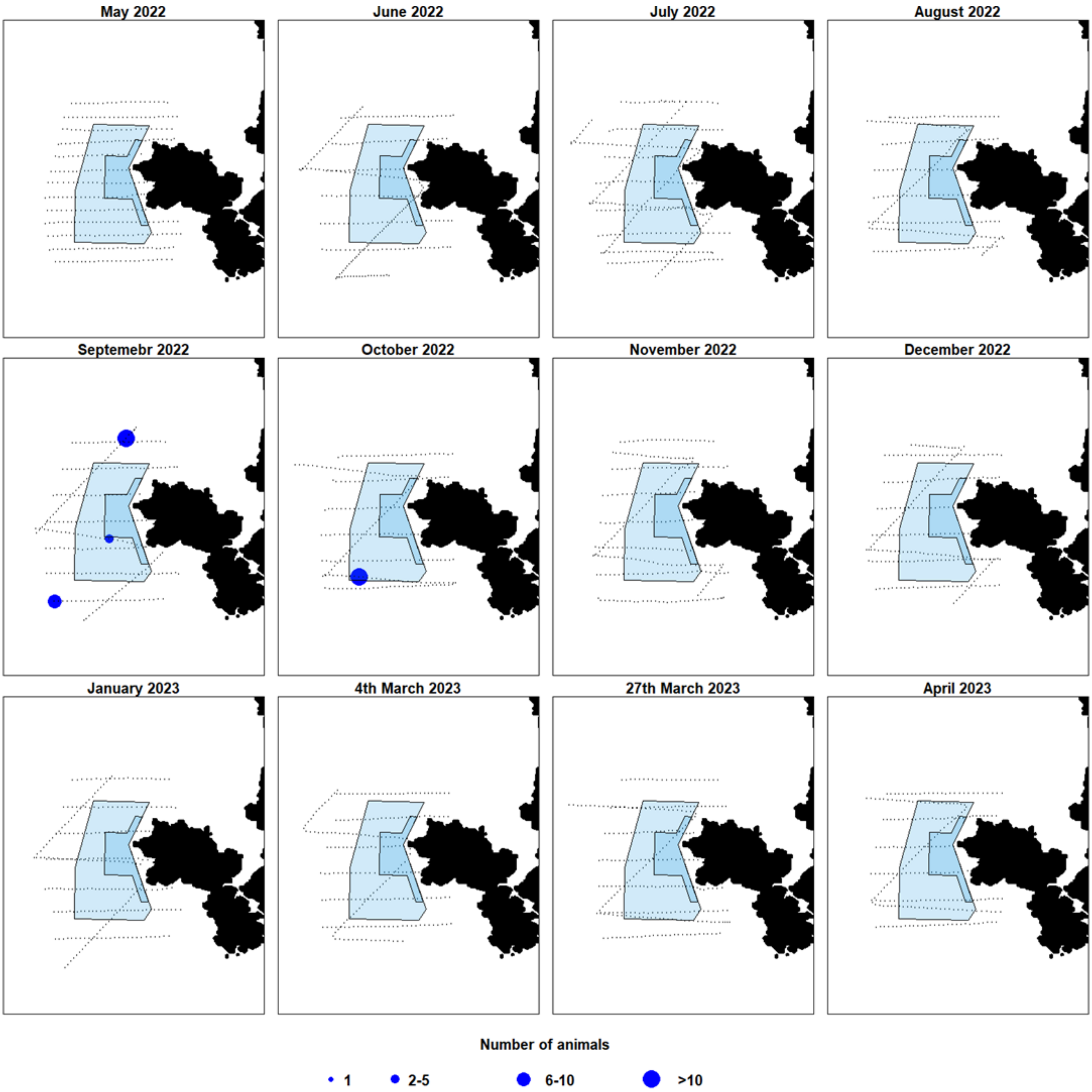


FIGURE 3.9: DISTRIBUTION OF UNIDENTIFIED DOLPHINS IN THE MONTHLY SURVEYS BETWEEN MAY 2022 AND APRIL 2023.

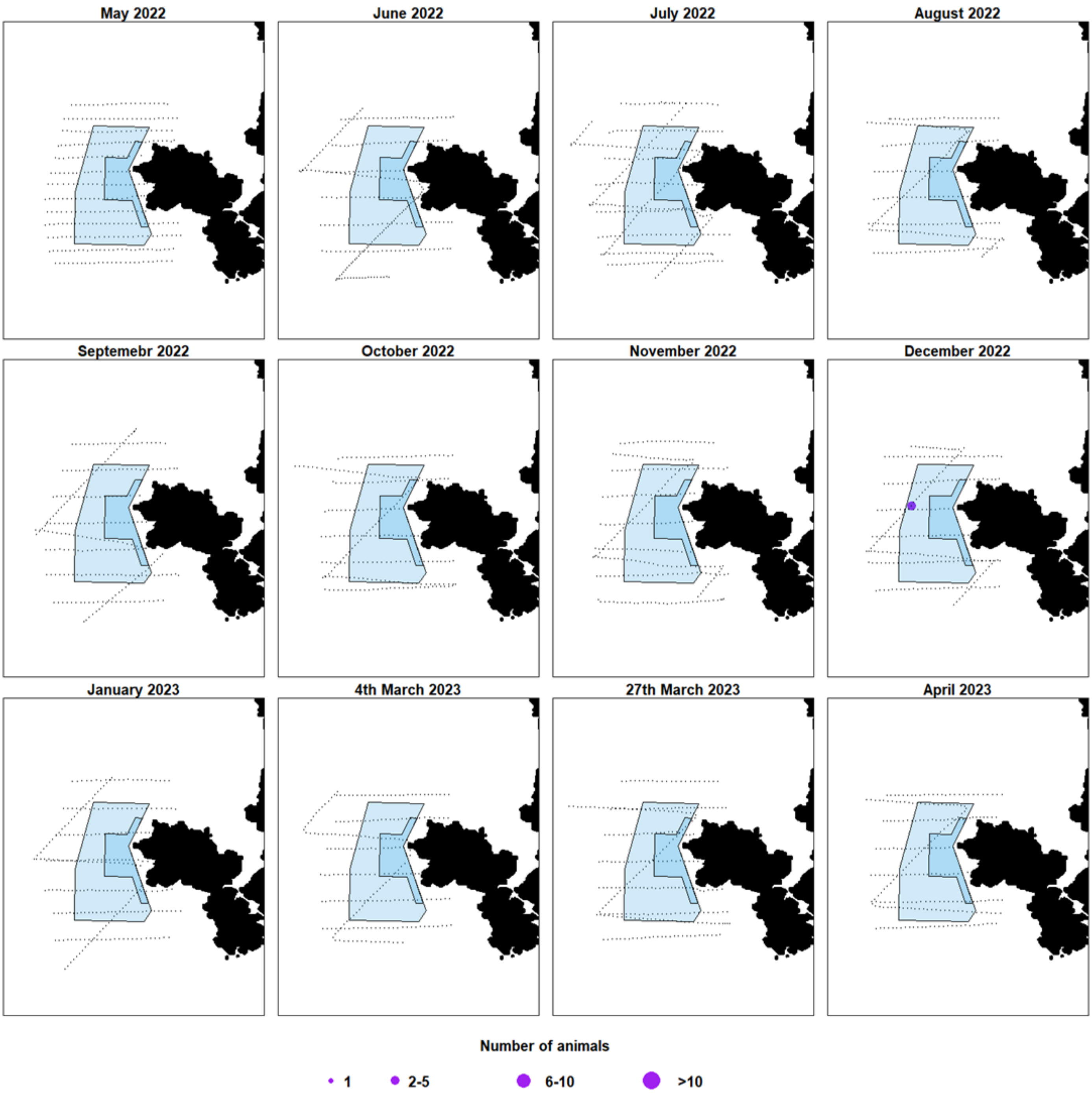


TABLE 3.11: THE SAMPLE SIZE (NUMBER OF SIGHTINGS), RATE, COVARIATES (AND ASSOCIATED SLOPES), COEFFICIENT OF VARIATION AND AIC SCORE OF CANDIDATE MODELS FOR SURVEY A HARBOUR PORPOISE DETECTION FUNCTION.

Sample size	Rate	Covariates	CV	AIC	Slope
45	Hazard	None	0.11	544.88	0.00
45	Half Normal	None	0.09	546.02	0.00
45	Hazard	Sea State	0.11	546.88	0.00
45	Half Normal	Sea State	0.09	547.97	0.04

TABLE 3.12: THE SAMPLE SIZE (NUMBER OF SIGHTINGS), RATE, COVARIATES (AND ASSOCIATED SLOPES), COEFFICIENT OF VARIATION AND AIC SCORE OF CANDIDATE MODELS FOR SURVEY A DOLPHIN DETECTION FUNCTION.

Sample size	Rate	Covariates	CV	AIC	Slope
7	Half Normal	Sea State	0.86	95.84	-0.98
7	Half Normal	None	0.23	96.79	0.00
7	Hazard	None	0.70	97.03	0.00
7	Hazard	Sea State	0.38	102.71	-0.01

TABLE 3.13: OUTPUTS FROM DETECTION FUNCTIONS FOR HARBOUR PORPOISE IN SURVEY A FROM MAY 2022 TO APRIL 2023 SHOWING ESTIMATED STRIP WIDTH (*ESW*), COEFFICIENT OF VARIATION IN *ESW* (CV), PROPORTION OF 1-MINUTE SECTIONS WITH ANIMAL ENCOUNTERS (PR), THE ESTIMATED AREA EFFECTIVELY SEARCHED (KM^2), THE NUMBER OF ANIMALS ENCOUNTERED (IND) AND THE ESTIMATED DENSITY OF ANIMALS (IND KM^2) PER MONTH FOR INSIDE AND OUTSIDE OF THE MDZ AND ACROSS THE SITE.

Date	MDZ	*esw*	CV	Pre	Km^2	Count	Indkm^2
15/05/2022	MDZ	0.29	0.11	0.01	22.19	1	0.05
	Non-MDZ	0.29	0.11	0.00	37.24	1	0.03
14/06/2022	MDZ	0.29	0.11	0.02	9.63	1	0.10
	Non-MDZ	0.29	0.11	0.03	19.08	3	0.16
08/07/2022	MDZ	0.29	0.11	0.03	12.65	6	0.47
	Non-MDZ	0.29	0.11	0.01	19.08	1	0.05
10/08/2022	MDZ	0.29	0.11	0.02	9.79	3	0.31
	Non-MDZ	0.29	0.11	0.05	18.99	6	0.32
20/09/2022	MDZ	0.29	0.11	0.01	12.57	1	0.08
	Non-MDZ	0.29	0.11	0.02	19.14	2	0.10
20/10/2022	MDZ	0.29	0.11	0.02	9.85	1	0.10
	Non-MDZ	0.29	0.11	0.03	19.25	4	0.21
22/11/2022	MDZ	0.29	0.11	0.02	12.53	1	0.08
	Non-MDZ	0.29	0.11	0.02	19.91	2	0.10
02/12/2022	MDZ	0.29	0.11	0.05	9.91	8	0.81
	Non-MDZ	0.29	0.11	0.02	19.25	2	0.10
27/01/2023	MDZ	0.29	0.11	0.00	12.20	0	0.00
	Non-MDZ	0.29	0.11	0.01	20.77	1	0.05
04/03/2023	MDZ	0.29	0.11	0.11	10.81	8	0.74
	Non-MDZ	0.29	0.11	0.01	18.38	1	0.05
27/03/2023	MDZ	0.29	0.11	0.01	11.77	1	0.08
	Non-MDZ	0.29	0.11	0.01	18.94	1	0.05
07/04/2023	MDZ	0.29	0.11	0.00	8.88	0	0.00
	Non-MDZ	0.29	0.11	0.01	13.54	1	0.07
MDZ	**Mean**	**0.29**	**0.11**	**0.03**	**11.90**	**2.58**	**0.24**
	Median	**0.29**	**0.11**	**0.02**	**11.29**	**1.00**	**0.09**
Non-MDZ	**Mean**	**0.29**	**0.11**	**0.02**	**20.30**	**2.08**	**0.11**
	Median	**0.29**	**0.11**	**0.02**	**19.11**	**1.50**	**0.09**

TABLE 3.14: OUTPUTS FROM DETECTION FUNCTIONS FOR COMMON DOLPHIN IN SURVEY A FROM MAY 2022 TO APRIL 2023 SHOWING ESTIMATED STRIP WIDTH (*ESW*), COEFFICIENT OF VARIATION IN *ESW* (CV), PROPORTION OF 1-MINUTE SECTIONS WITH ANIMAL ENCOUNTERS (PR), THE ESTIMATED AREA EFFECTIVELY SEARCHED (KM^2), THE NUMBER OF ANIMALS ENCOUNTERED (IND) AND THE ESTIMATED DENSITY OF ANIMALS (IND KM^2) PER MONTH FOR INSIDE AND OUTSIDE OF THE MDZ AND ACROSS THE SITE.

Date	MDZ	*esw*	CV	Pre	Km^2	Count	$Indkm^2$
15/05/2022	MDZ	0.79	0.45	0.00	59.94	0	0.00
	Non-MDZ	0.81	0.44	0.00	102.88	0	0.00
14/06/2022	MDZ	0.62	0.57	0.00	20.18	0	0.00
	Non-MDZ	0.59	0.61	0.00	37.60	0	0.00
08/07/2022	MDZ	0.68	0.52	0.00	28.97	0	0.00
	Non-MDZ	0.69	0.52	0.00	44.81	0	0.00
10/08/2022	MDZ	0.91	0.40	0.00	29.99	0	0.00
	Non-MDZ	0.88	0.41	0.00	54.89	0	0.00
20/09/2022	MDZ	0.43	0.83	0.01	18.63	0	0.00
	Non-MDZ	0.39	0.93	0.00	25.11	6	0.24
20/10/2022	MDZ	0.54	0.67	0.02	18.21	0	0.00
	Non-MDZ	0.61	0.58	0.00	39.83	0	0.00
22/11/2022	MDZ	0.60	0.60	0.00	25.60	0	0.00
	Non-MDZ	0.66	0.54	0.01	44.80	0	0.00
02/12/2022	MDZ	0.69	0.52	0.00	22.53	0	0.00
	Non-MDZ	0.64	0.56	0.02	42.48	0	0.00
27/01/2023	MDZ	0.86	0.42	0.00	36.01	0	0.00
	Non-MDZ	0.87	0.41	0.00	61.49	0	0.00
04/03/2023	MDZ	0.71	0.50	0.00	23.54	0	0.00
	Non-MDZ	0.80	0.45	0.00	49.99	0	0.00
27/03/2023	MDZ	0.69	0.52	0.00	27.31	0	0.00
	Non-MDZ	0.84	0.43	0.00	54.33	0	0.00
07/04/2023	MDZ	0.57	0.63	0.00	17.15	0	0.00
	Non-MDZ	0.67	0.54	0.00	30.16	0	0.00
MDZ	**Mean**	**0.68**	**0.55**	**0.00**	**27.34**	**0.00**	**0.00**
	Median	**0.69**	**0.52**	**0.00**	**24.57**	**0.00**	**0.00**
Non-MDZ	**Mean**	**0.70**	**0.53**	**0.00**	**49.03**	**0.50**	**0.02**
	Median	**0.68**	**0.53**	**0.00**	**44.81**	**0.00**	**0.00**

TABLE 3.15: OUTPUTS FROM DETECTION FUNCTIONS FOR RISSOS DOLPHIN IN SURVEY A FROM MAY 2022 TO APRIL 2023 SHOWING ESTIMATED STRIP WIDTH (*ESW*), COEFFICIENT OF VARIATION IN *ESW* (CV), PROPORTION OF 1-MINUTE SECTIONS WITH ANIMAL ENCOUNTERS (PR), THE ESTIMATED AREA EFFECTIVELY SEARCHED (KM^2), THE NUMBER OF ANIMALS ENCOUNTERED (IND) AND THE ESTIMATED DENSITY OF ANIMALS (IND KM^2) PER MONTH FOR INSIDE AND OUTSIDE OF THE MDZ AND ACROSS THE SITE.

Date	Zone	*esw*	CV	Pre	Km^2	Count	IndKm^2
15/05/2022	MDZ	0.79	0.45	0.00	59.94	0	0.00
	Non-MDZ	0.81	0.44	0.00	102.88	0	0.00
14/06/2022	MDZ	0.62	0.57	0.00	20.18	0	0.00
	Non-MDZ	0.59	0.61	0.00	37.60	0	0.00
08/07/2022	MDZ	0.68	0.52	0.00	28.97	0	0.00
	Non-MDZ	0.69	0.52	0.00	44.81	0	0.00
10/08/2022	MDZ	0.91	0.40	0.00	29.99	0	0.00
	Non-MDZ	0.88	0.41	0.00	54.89	0	0.00
20/09/2022	MDZ	0.43	0.83	0.01	18.63	5	0.27
	Non-MDZ	0.39	0.93	0.00	25.11	0	0.00
20/10/2022	MDZ	0.54	0.67	0.02	18.21	1	0.05
	Non-MDZ	0.61	0.58	0.00	39.83	0	0.00
22/11/2022	MDZ	0.60	0.60	0.00	25.60	0	0.00
	Non-MDZ	0.66	0.54	0.01	44.80	15	0.33
02/12/2022	MDZ	0.69	0.52	0.00	22.53	0	0.00
	Non-MDZ	0.64	0.56	0.02	42.48	4	0.09
27/01/2023	MDZ	0.86	0.42	0.00	36.01	0	0.00
	Non-MDZ	0.87	0.41	0.00	61.49	0	0.00
04/03/2023	MDZ	0.71	0.50	0.00	23.54	0	0.00
	Non-MDZ	0.80	0.45	0.00	49.99	0	0.00
27/03/2023	MDZ	0.69	0.52	0.00	27.31	0	0.00
	Non-MDZ	0.84	0.43	0.00	54.33	0	0.00
07/04/2023	MDZ	0.57	0.63	0.00	17.15	0	0.00
	Non-MDZ	0.67	0.54	0.00	30.16	0	0.00
MDZ	**Mean**	**0.68**	**0.55**	**0.00**	**27.34**	**0.50**	**0.03**
	Median	**0.69**	**0.52**	**0.00**	**24.57**	**0.00**	**0.00**
Non-MDZ	**Mean**	**0.70**	**0.53**	**0.00**	**49.03**	**1.58**	**0.04**
	Median	**0.68**	**0.53**	**0.00**	**44.81**	**0.00**	**0.00**

FIGURE 3.10: ENCOUNTER RATES OF MARINE MAMMALS IN SURVEY A FROM MAY 2022 TO APRIL 2023.

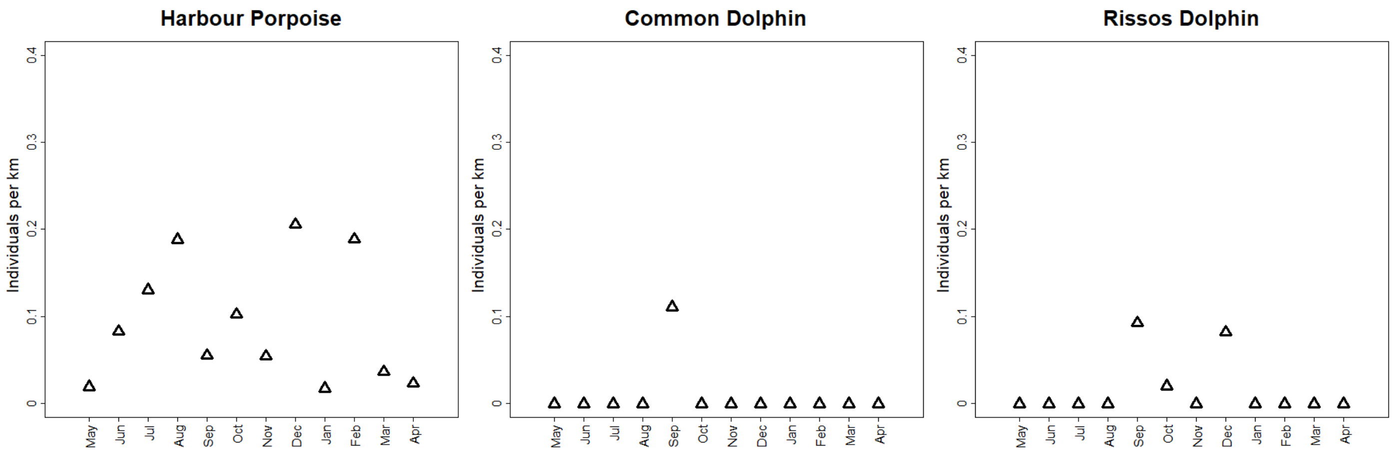


FIGURE 3.11: DENSITY ESTIMATES (+/- STANDARD ERROR) OF MARINE MAMMALS IN SURVEY A FROM MAY 2022 TO APRIL 2023.

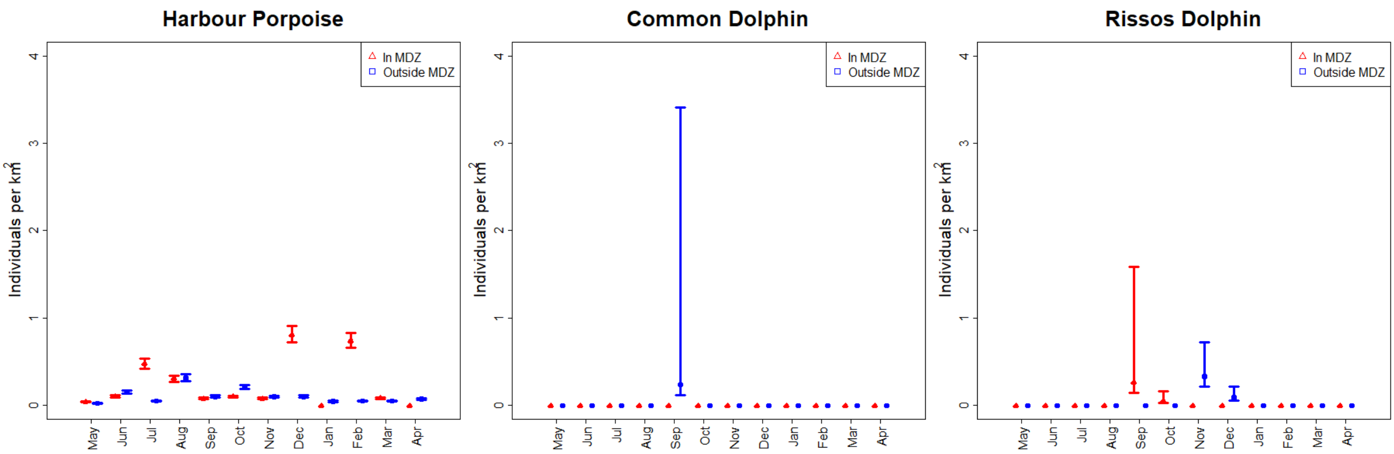


TABLE 3.16: THE SAMPLE SIZE (NUMBER OF SIGHTINGS), RATE, COVARIATES (AND ASSOCIATED SLOPES), COEFFICIENT OF VARIATION AND AIC SCORE OF CANDIDATE MODELS FOR SURVEY B HARBOUR PORPOISE DETECTION FUNCTION.

Sample size	Rate	Covariates	CV	AIC	Slope
28	Half Normal	Sea State	0.14	328.38	-0.57
28	Hazard	Sea State	0.42	329.17	-1.29
28	Hazard	None	0.31	334.22	0.00
28	Half Normal	None	0.12	334.26	0.00

TABLE 3.17: THE SAMPLE SIZE (NUMBER OF SIGHTINGS), RATE, COVARIATES (AND ASSOCIATED SLOPES), COEFFICIENT OF VARIATION AND AIC SCORE OF CANDIDATE MODELS FOR SURVEY B DOLPHIN (COMMON DOLPHIN AND RISSO'S DOLPHIN) DETECTION FUNCTION.

Sample size	Rate	Covariates	CV	AIC	Slope
5	Hazard	None	0.01	67.63	0.00
5	Half Normal	None	0.47	67.84	0.00
5	Half Normal	Sea State	0.58	69.13	-0.64
5	Hazard	Sea State	0.00	75.08	0.94

TABLE 3.18: G(0) ESTIMATES FOR HARBOUR PORPOISE SHOWING ASSOCIATED STANDARD ERROR (SE) AND COEFFICIENT OF VARIANCE (CV) ALONGSIDE SUMMARIES OF SIGHTNGS FROM PRIMARY AND INDEPENDENT OBSERVERS.

g(0)	0.84
SE	0.08
CV	0.09
Sightings by Primary Observer	23
Sightings by Independent Observer	17
Sightings by Both Observers	12

TABLE 3.19: OUTPUTS FROM DETECTION FUNCTIONS FOR HARBOUR PORPOISE IN SURVEY B FROM MAY 2022 TO APRIL 2023 SHOWING ESTIMATED STRIP WIDTH (*ESW*), COEFFICIENT OF VARIATION IN *ESW* (CV), PROPORTION OF 1-MINUTE SECTIONS WITH ANIMAL ENCOUNTERS (PR), THE ESTIMATED AREA EFFECTIVELY SEARCHED (KM^2), THE NUMBER OF ANIMALS ENCOUNTERED (IND) AND THE ESTIMATED DENSITY OF ANIMALS (IND KM^2) PER MONTH FOR INSIDE AND OUTSIDE OF THE MDZ AND ACROSS THE SITE.

Date	Zone	*esw*	CV	Pr	Km^2	Count	Ind Km^2
14/06/2022	MDZ	0.25	0.10	0.00	4.01	0	0.00
	Non-MDZ	0.22	0.11	0.01	8.27	1	0.12
08/07/2022	MDZ	0.12	0.22	0.02	3.64	1	0.27
	Non-MDZ	0.11	0.22	0.01	7.84	2	0.25
10/08/2022	MDZ	0.25	0.10	0.05	8.53	3	0.35
	Non-MDZ	0.26	0.10	0.13	7.53	7	0.93
20/09/2022	MDZ	0.10	0.24	0.00	1.68	0	0.00
	Non-MDZ	0.07	0.35	0.00	2.50	0	0.00
20/10/2022	MDZ	0.11	0.24	0.04	3.23	3	0.93
	Non-MDZ	0.11	0.23	0.04	3.25	7	2.15
22/11/2022	MDZ	0.12	0.20	0.06	2.94	2	0.68
	Non-MDZ	0.15	0.17	0.03	5.17	2	0.39
02/12/2022	MDZ	0.11	0.22	0.06	2.41	2	0.83
	Non-MDZ	0.13	0.19	0.02	4.79	1	0.21
27/01/2023	MDZ	0.27	0.09	0.00	4.05	0	0.00
	Non-MDZ	0.27	0.09	0.00	8.81	0	0.00
04/03/2023	MDZ	0.17	0.15	0.06	3.35	6	1.79
	Non-MDZ	0.16	0.16	0.00	5.23	0	0.00
27/03/2023	MDZ	0.24	0.10	0.03	6.39	1	0.16
	Non-MDZ	0.24	0.10	0.00	8.41	0	0.00
07/04/2023	MDZ	0.14	0.18	0.00	3.87	0	0.00
	Non-MDZ	0.17	0.15	0.00	4.15	0	0.00
MDZ	**Mean**	**0.17**	**0.17**	**0.03**	**4.01**	**1.64**	**0.46**
	Median	**0.14**	**0.18**	**0.03**	**3.64**	**1.00**	**0.27**
Non-MDZ	**Mean**	**0.17**	**0.17**	**0.02**	**6.00**	**1.82**	**0.37**
	Median	**0.16**	**0.16**	**0.01**	**5.23**	**1.00**	**0.12**

Table 3.20: Outputs from detection functions for Common Dolphin in survey B from May 2022 to April 2023 showing estimated strip width (*esw*), coefficient of variation in *esw* (CV), proportion of 1-minute sections with animal encounters (Pr), the estimated area effectively searched (Km²), the number of animals encountered (Ind) and the estimated density of animals (Ind km²) per month for inside and outside of the MDZ and across the site.

Date	Zone	*esw*	CV	Pr	Km²	Count	Ind Km²
14/06/2022	MDZ	0.49	0.02	0.00	4.26	0	0.00
	Non-MDZ	0.49	0.02	0.00	15.15	0	0.00
08/07/2022	MDZ	0.49	0.02	0.00	15.09	0	0.00
	Non-MDZ	0.49	0.02	0.00	33.11	0	0.00
10/08/2022	MDZ	0.49	0.02	0.00	15.56	0	0.00
	Non-MDZ	0.49	0.02	0.00	12.47	0	0.00
20/09/2022	MDZ	0.49	0.02	0.04	8.20	2	0.24
	Non-MDZ	0.49	0.02	0.03	17.74	13	0.73
20/10/2022	MDZ	0.49	0.02	0.02	14.41	16	1.11
	Non-MDZ	0.49	0.02	0.00	13.58	0	0.00
22/11/2022	MDZ	0.49	0.02	0.00	10.91	0	0.00
	Non-MDZ	0.49	0.02	0.00	16.46	0	0.00
02/12/2022	MDZ	0.49	0.02	0.00	9.65	0	0.00
	Non-MDZ	0.49	0.02	0.00	17.60	0	0.00
27/01/2023	MDZ	0.49	0.02	0.00	7.33	0	0.00
	Non-MDZ	0.49	0.02	0.00	15.95	0	0.00
04/03/2023	MDZ	0.49	0.02	0.00	8.85	0	0.00
	Non-MDZ	0.49	0.02	0.00	16.07	0	0.00
27/03/2023	MDZ	0.49	0.02	0.00	12.10	0	0.00
	Non-MDZ	0.49	0.02	0.00	16.40	0	0.00
07/04/2023	MDZ	0.49	0.02	0.00	12.83	0	0.00
	Non-MDZ	0.49	0.02	0.00	11.36	0	0.00
MDZ	**Mean**	**0.49**	**0.02**	**0.01**	**10.83**	**1.64**	**0.12**
	Median	**0.49**	**0.02**	**0.00**	**10.91**	**0.00**	**0.00**
Non-MDZ	**Mean**	**0.49**	**0.02**	**0.00**	**16.90**	**1.18**	**0.07**
	Median	**0.49**	**0.02**	**0.00**	**16.07**	**0.00**	**0.00**

TABLE 3.21: OUTPUTS FROM DETECTION FUNCTIONS FOR RISSOS DOLPHIN IN SURVEY B FROM MAY 2022 TO APRIL 2023 SHOWING ESTIMATED STRIP WIDTH (*ESW*), COEFFICIENT OF VARIATION IN *ESW* (CV), PROPORTION OF 1-MINUTE SECTIONS WITH ANIMAL ENCOUNTERS (PR), THE ESTIMATED AREA EFFECTIVELY SEARCHED (KM^2), THE NUMBER OF ANIMALS ENCOUNTERED (IND) AND THE ESTIMATED DENSITY OF ANIMALS (IND KM^2) PER MONTH FOR INSIDE AND OUTSIDE OF THE MDZ AND ACROSS THE SITE.

Date	Zone	*esw*	CV	Pr	Km²	Count	Ind Km²
14/06/2022	MDZ	0.49	0.02	0.00	4.26	0	0.00
	Non-MDZ	0.49	0.02	0.00	15.15	0	0.00
08/07/2022	MDZ	0.49	0.02	0.00	15.09	0	0.00
	Non-MDZ	0.49	0.02	0.00	33.11	0	0.00
10/08/2022	MDZ	0.49	0.02	0.00	15.56	0	0.00
	Non-MDZ	0.49	0.02	0.00	12.47	0	0.00
20/09/2022	MDZ	0.49	0.02	0.00	8.20	0	0.00
	Non-MDZ	0.49	0.02	0.02	17.74	3	0.17
20/10/2022	MDZ	0.49	0.02	0.00	14.41	0	0.00
	Non-MDZ	0.49	0.02	0.00	13.58	0	0.00
22/11/2022	MDZ	0.49	0.02	0.00	10.91	0	0.00
	Non-MDZ	0.49	0.02	0.00	16.46	0	0.00
02/12/2022	MDZ	0.49	0.02	0.00	9.65	0	0.00
	Non-MDZ	0.49	0.02	0.00	17.60	0	0.00
27/01/2023	MDZ	0.49	0.02	0.00	7.33	0	0.00
	Non-MDZ	0.49	0.02	0.00	15.95	0	0.00
04/03/2023	MDZ	0.49	0.02	0.00	8.85	0	0.00
	Non-MDZ	0.49	0.02	0.00	16.07	0	0.00
27/03/2023	MDZ	0.49	0.02	0.00	12.10	0	0.00
	Non-MDZ	0.49	0.02	0.00	16.40	0	0.00
07/04/2023	MDZ	0.49	0.02	0.00	12.83	0	0.00
	Non-MDZ	0.49	0.02	0.00	11.36	0	0.00
MDZ	**Mean**	**0.49**	**0.02**	**0.00**	**10.83**	**0.00**	**0.00**
	Median	**0.49**	**0.02**	**0.00**	**10.91**	**0.00**	**0.00**
Non-MDZ	**Mean**	**0.49**	**0.02**	**0.00**	**16.90**	**0.27**	**0.02**
	Median	**0.49**	**0.02**	**0.00**	**16.07**	**0.00**	**0.00**

FIGURE 3.12: ENCOUNTER RATES OF MARINE MAMMALS IN SURVEY B FROM MAY 2022 TO APRIL 2023.

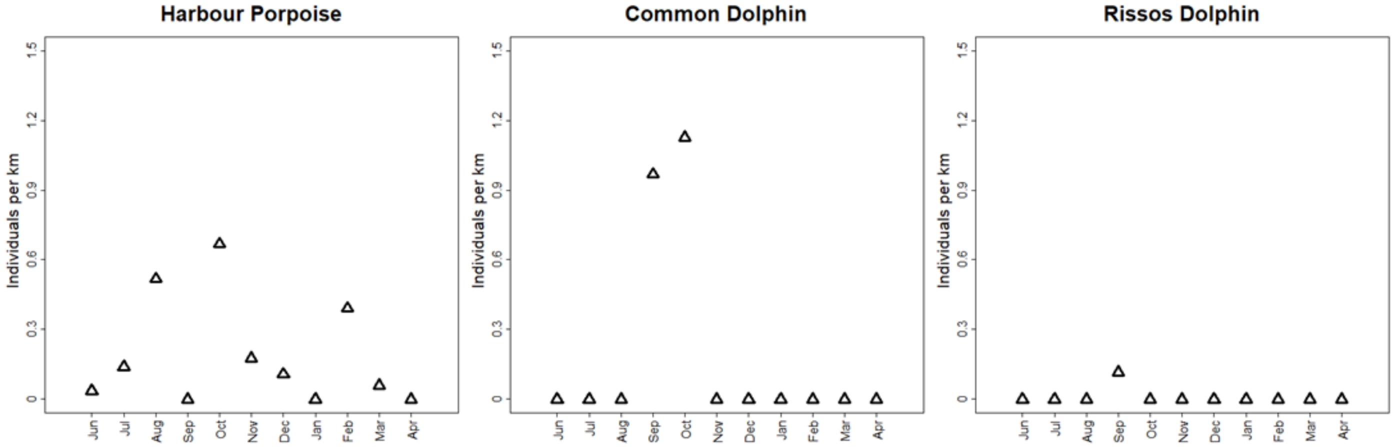


FIGURE 3.13: DENSITY ESTIMATES (+/- STANDARD ERROR) OF MARINE MAMMALS IN SURVEY B FROM MAY 2022 TO APRIL 2023.

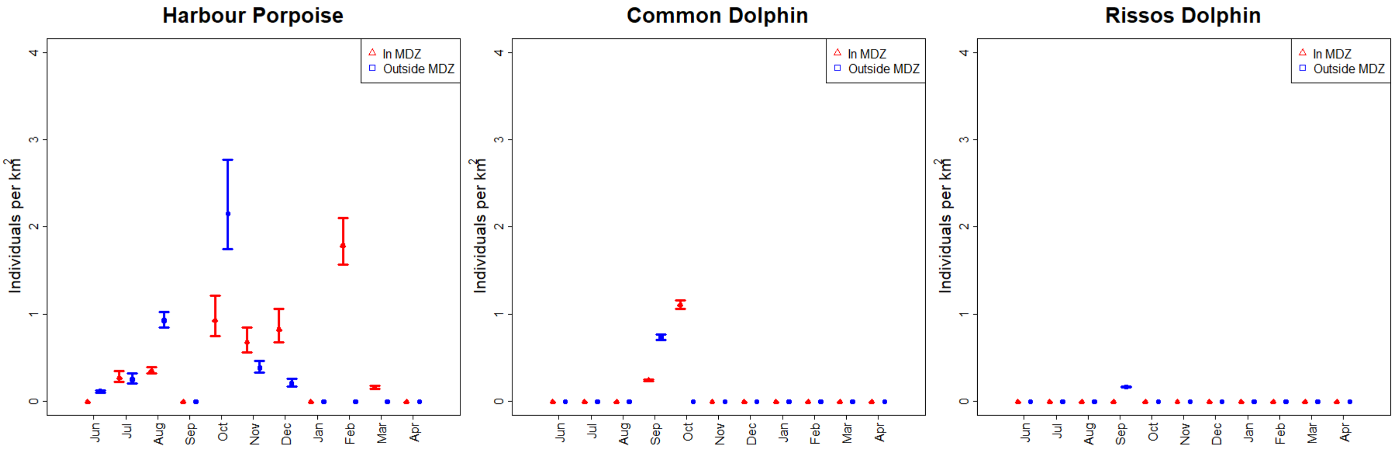
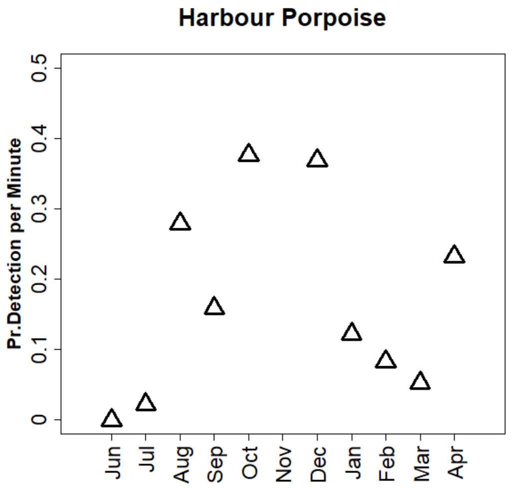


FIGURE 3.14: PROPORTION OF MINUTES WITH MARINE MAMMAL ACOUSTIC DETECTIONS FROM MAY 2022 TO APRIL 2023.



4 Discussion

4.1 General Aims

Understanding spatial and temporal variation in diving animals (marine mammals and seabirds) occupancy of tidal stream environments helps assess impacts of tidal stream turbines (Waggitt and Scott 2014). This project used boat-based surveys at monthly intervals to understand diving animals (*Alcidae*, Manx shearwater, marine mammals) spatial and temporal occupancy of the MDZ in western Anglesey, UK. This interim report focusses on data and analyses estimating variations in densities between areas (within versus outwith MDZ) and variation in densities amongst months between May 2022 and April 2023.

4.2 Seasonal Patterns

4.2.1 Seabirds

Known seasonal movements of seabirds were broadly demonstrated. Manx shearwaters perform trans-equatorial migrations, arriving in the northern hemisphere in spring and departing for southern hemispheres in autumn (Guilford *et al* 2009). Manx shearwaters are commonly encountered in large flocks, presumably forming after group foraging events, and drifting for considerable distances (Guilford *et al* 2008). These migratory and foraging behaviours explain why Manx shearwater encounters were constrained to summer, with estimated densities either extremely small or large. The MDZ occurs alongside an Important *Alcidae* colony at South Stack. *Alcidae* commonly accumulate in large groups alongside breeding colonies in summer months, either preening or resting (Nettleship and Birkhead 1985). These colonial behaviours explain why *Alcidae* encounters peaked between May and October 2022, coinciding with the breeding season. Similar patterns in *Alcidae* encounters amongst months were recorded in the Natural Power surveys (Morlais 2019). The densities of common guillemots were generally higher than razorbills, mirroring differences in the regional and local populations of these species (Mitchell *et al* 2004, WP5). Interestingly however, the highest densities of razorbills occurred in the post-breeding season, when they also considerably outnumbered common guillemot in the area. Intensive surveys in July 2022 (Morlais 2022) and Natural Power surveys in 2016-18 (Morlais 2019) also recorded high densities of razorbill in July and/or August, suggesting this is an important post-breeding location for razorbill.

4.2.2 Marine Mammals

Known seasonal movements of cetaceans were also demonstrated. Common and Risso's dolphin move into north Wales during summer and autumn (Evans and Waggitt 2023), and encounters and estimated densities reaffirmed this knowledge. As expected from wide-ranging and group-living animals, these species were not sighted every month, but moderate estimated densities occurred when they were present. Harbour porpoises occur in north Wales across seasons, and seasonal patterns in occurrence are subtle (Evans and Waggitt 2023). Encounters and estimated densities suggested larger numbers of harbour porpoise in the MDZ during autumn and winter months. However, moderate encounter rates and estimated densities also occurred in some summer months, showing that many harbour porpoise occupy the MDZ across seasons. Seasonal variation in harbour porpoise occupancy is not reported from the SEACAMS2 surveys (Veneruso *et al* 2019); however, systematic seasonal variation in site-use is absent in the Natural Power surveys (Morlais 2019), As Passive Acoustic Monitoring (PAM) approaches can provide better temporal coverage, it is suggested that seasonal occupancy patterns in harbour porpoise are considered alongside findings from complementary Work Packages (WP1).

4.3 Focal MDZ Occupancy

4.3.1 Seabirds

Estimated densities of seabirds were broadly similar within and outwith the focal MDZ. *Alcidae* sometimes drift with surface currents whilst resting or feeding (Bennison *et al* 2019, Cooper *et al* 2018, Falch 2021). As mentioned above, Manx shearwater show similar drifting-behaviour following foraging activity (Guilford *et al* 2008). This drifting-behaviour could explain why certain locations within the MDZ were not targeted, with animals being dispersed relatively homogenously within the study site.

4.3.2 Marine Mammals

Whilst no consistent patterns in space-use occurred, the highest densities of harbour porpoise were seen within the MDZ. Harbour porpoise commonly associate with prominent hydrodynamic features in tidal stream environments including shear-lines and eddies originating from interactions between topography and strong currents. (Benjamins *et al* 2015) In a relevant example, shore-based observations in northern Anglesey found harbour porpoise strongly associating with shear-lines originating from the South Stack headland (Waggitt *et al* 2018). As these shear-lines occur inshore, these associations may explain the higher densities in the MDZ.

4.4 Densities

4.4.1 Seabirds

Comparisons of common guillemot and razorbill densities (individuals per km^2) in this study (2022-23) to those in the Natural Power surveys (2016-18) (Morlais 2019) revealed notable differences in some seasons. In the main *Alcidae* breeding season (May-July) densities of common guillemot were broadly similar in 2016-18 (3.93 to 46.93) and 2022 (5.56 to 31.58); densities of razorbill were also similar in 2016-18 (0.18 to 4.90) and 2022 (1.26 to 4.71). However, in the *Alcidae* post-breeding season (August-September), densities of common guillemot were considerably smaller (2.30-9.52) in 2016-18 than 2022 (6.70-37.29), whereas densities of razorbill were extremely smaller in 2016-18 (0.00-8.88) than 2022 (5.17-28.09). Manx shearwater densities were not presented by Natural Power, so comparisons cannot be made. Several methodological and ecological factors could explain discrepancies between 2016-18 and 2022:

- **Conditions***:* The Natural Power surveys targeted periods when Sea State <= 3 was expected, based upon guidelines from Camphuysen *et al* 2004. This culminated in 90% of surveys being performed in Sea State <= 2 and 40% being performed in Sea State <= 1. To increase detectability of animals, these surveys aimed to perform most surveys in Sea State <=1. This culminated in 90% of surveys being performed in Sea State <= 2 but 58% being performed in Sea State <= 1. Therefore, the WP11 surveys were often performed in better conditions than the Natural Power surveys, which presumably culminates in higher detections of animals on the water. Including sea state in 'Distance' analyses partially accounts for these differences. Whilst sea state was included in analyses here, it is unclear whether it was included in Natural Power analysis.
- **Observer Coverage:** The Natural Power observer team recorded seabirds on one side of the vessel, whereas WP11 observer team recorded seabirds on both sides of the vessel. The observation platform on the Seekat C has unobstructed views of port and starboard, allowing observer teams to cover 180^o ahead of the vessel. When high densities of *Alcidae* were anticipated (i.e., summer months), two observers were used to ensure that neither were overburdened. *Alcidae* commonly occur in small and dense groups at-sea, culminating in a heterogeneous distribution. These behavioural tendencies are particularly prevalent in summer months,

where *Alcidae* accumulate in large groups alongside breeding colonies (Nettleship and Birkhead 1985). Covering both sides should increase the likelihood of detecting these groups on the water.

- **Survey Coverage:** To accommodate Survey A and B, this project performed fewer transects than the Natural Power project. In practice, the area covered remained similar – whilst the distances covered was (approximately) halved, the *esw* was doubled as observers scanned both port and starboard. However, it is known that animals accumulate at hydrodynamic features (e.g., shear-lines and upwellings) in tidal stream environments (Waggitt *et al* 2016). Therefore, animal densities could depend upon whether selected transects covered a used or unused hydrodynamic feature within the study area.
- **Short-Term Variation**: Animal densities could differ considerably amongst and within days. This variation could be systematic and associated with tidal and daylight cycles; it could also be intermittent and associated with oceanographical and meteorological conditions. The intensive surveys accompanying monthly surveys revealed considerable variation in animal numbers in the MDZ across 3 consecutive days in July 2022 (Morlais 2022). The notable differences between densities recorded in 2016-2018 and 2022 occurred in the post-breeding season (August – September). During this season, *Alcidae* are no longer constrained to the breeding colony, and presumably move in response to environmental conditions and/or prey resources. Consequently, densities in the post-breeding season could have greater short-term variation, depending upon whether surveys coincide with preferable conditions or aggregative events.

When considering the methodological and ecological explanations for differences between 2016-2018 and 2022, short-term variation seems the most plausible explanation for these differences. Differences associated with short-term variation are difficult to overcome in analyses. However, with regards to methodological differences: (1) surveys used identical transect routes, (2) since 27/07/2022, observers have recorded whether seabirds on the water were detected on port or starboard. Therefore, amalgamating datasets from current and Natural Power projects and performing directly comparable analyses is possible. For example, appropriately subsetting transects and sides (port or starboard) from the WP11 surveys. These analyses will be presented in the final report.

4.4.1 Marine Mammals

Comparisons of harbour porpoise densities in Survey A (2022-23) to Natural Power surveys (2016-18) revealed no systematic difference in animal densities. Densities of harbour porpoise were predominately <0.5 animals per km^2 in 2016-18, and also predominantly < 0.5 animals per km^2 in 2022-23. Similar comparisons between Survey B and SEACAMS2 surveys (2015-16) were not possible because the latter did not present monthly variations in animal densities. However, average densities between 0.714 and 0.852 animals per km^2 across months in 2016-18 were higher than the average densities of 0.37 and 0.46 in 2022-23. Investigation into differences between periods requires inspection of densities per survey and estimated *esw* from the SEACAMS2 surveys.

4.5 Evaluation and Recommendations

Both Survey A and Survey B were generally performed per calendar month, and mainly performed in good conditions. However, some compromises were needed to meet these objectives. An evaluation of the approaches is provided below, accompanied with recommendations for future applications.

1. **Conditions:** The representativeness of surveys is dependent on conditions, with detection rates of marine mammals (Evans and Hammond 2004) and seabirds (Camphuysen *et al* 2004) declining with increasing sea state. Therefore, a main objective was to perform most surveys in sea state <= 1. With 58% performed in these conditions, the project met these primary objectives. Having locally based observers and crew with experience of surveying the MDZ and at-sea operations within the region was essential to this success. Nevertheless, despite this experience, observers and crew did misjudge conditions on one-occasion, cumulating in an abandoned survey on 09/09/2022. Whilst Royal Society for the Protection of Birds (RSPB) wardens at South Stack could be consulted before leaving Amlwch Port, it is difficult to assess conditions from their elevated location or ensure that staff members are contactable in early morning / out-of-hours. Therefore, eliminating the risk of abandoning survey is problematic. The demands for sea state <= 1 led to a

survey not being performed in February 2023, although a replacement survey was performed soon afterwards on 04/03/2023. It is believed that the benefits of performing surveys in good weather conditions outweigh those of performing a single survey per calendar month. A continued emphasis on surveying in reasonable sea states is encouraged, which is achieved by using locally based observers and crew with appropriate experience.

2. **Coverage:** To facilitate comparisons with previous surveys by Natural Power and SEACAMS2, this project replicated their general approaches. However, to achieve these objectives, it was decided to reduce the number of transects performed, allowing both surveys to be completed in 1 day. At the beginning of the project, these compromises were required because the Seekat C represented the only suitable vessel in the region, and constraints incurred by weather conditions and vessel availability. However, particularly when accommodating echosounder surveys (see Annex), performing Survey A and Survey B on the same day place considerable stress on scientific crew and reduces survey coverage. Having another suitable vessel in the region would enable Survey A and Survey B to be performed separately, increases coverage, and reducing stress on observers and crew. It is recommended that alternative vessels are approached and encouraged to construct suitable observation platforms (i.e., appropriate height, comfort, and shelter) for surveys.

4.6 EMMP Indicators and Questions

By measuring animal densities within and outwith the MDZ, the outputs provided by this project have several applications in EMMP indicators and questions. However, some considerations are needed when applying these outputs. The applications and considerations are discussed below.

- **Changes in behaviour / site-use following installations (I1, 12 and Q2):** Comparison of animal densities from surveys performed before and following installations can potentially reveal changes in the temporal or spatial occupancy of the MDZ. The interpretation of absolute differences must consider short-term variation in animal densities, which are likely to reduce statistical power to detect changes and/or produce spurious conclusions (Maclean *et al* 2013). However, the animal densities in this work package provide insights into seasonality and space-use, helping design and develop approaches to increase statistical power and prevent spurious conclusions.
- **Validation of ERM and CRM (I9):** Animal densities help parameterise ERM and CRM estimating interactions between seabirds / marine mammals and turbine blades (SNH 2016). However, these interactions are influenced by diving behaviour around installations (Waggitt and Scott 2014). the likelihood of diving is not considered in the existing ERM/CRM (Morlais 2020). The South Stack breeding colony will strongly influence the behaviour of *Alcidae* in the MDZ. For instance, *Alcidae* alongside colonies are primarily engaged in resting and maintenance (i.e., bathing and preening) activities during breeding seasons, whereas high intraspecific competition could also encourage animals to forage further afield during these periods (Gaston 2007). Therefore, despite large numbers of *Alcidae* in the breeding season, it seems likely that animals are rarely foraging in the MDZ. Because animals are observed for a relatively short-time during boat-based surveys, recording behaviour is challenging. It is recommended that animal densities from this work package are combined with behavioural information from complementary work packages (WP5, WP12), with animal densities amended based upon the likelihood of animals diving within the MDZ.

4.7 Future Reports

The following data and analyses from additional activities (Section 2.2.2) will be included the Final Report:

1. Spatial and temporal variation in animal densities in Survey A from 2016-2018 and 2022-2024.
2. Spatial and temporal variation in animal densities in Survey B from 2022-2024.
3. Spatial and temporal variation in prey availability from monthly surveys in 2023-2024.
4. Within and amongst-day variation in animal densities in intensive surveys from 2022-2024.
5. Within and amongst-day variation in prey availability in intensive surveys from 2023-2024.
6. Impacts of survey design on the statistical power to detect changes in animal densities.

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6 Annex

PARTICIPANTS

Name	**Role**	**Organisation**
James Waggitt	Project Lead	Bangor University
Eleanor Falch	Project Support	Bangor University
Peter Evans	Observer Team Leader	Sea Watch Foundation
Jack Egerton	Echosounder practitioner	Echology ltd.
Jon Shaw	Vessel owner, skipper, and crew coordinator	SeeKat Marine Charters

INFORMATION COLLECTED DURING SURVEYS

Seabirds

For seabirds, the following approaches were taken:

- All seabird species were recorded whether in flight or on the water within the 300m strip width.
- Birds were detected by the naked eye, and binoculars used to confirm species when necessary.
- Birds in flight within the 300m strip width were recorded at 1 min intervals (i.e. the 'snapshot method) and the following details recorded:
    - Time
    - Species
    - Number of individuals
    - Behaviour
        - Flying (Fly), individual was continuously flying in one direction
        - Searching (Search), individual was changing direction or circling
        - Diving (Div), individual was seen diving
    - Direction of flight
- Birds on the water were recorded continuously as individuals drew level with the bow of the boat and the following details recorded:
    - Time
    - Species
    - Number of individuals
    - Side of vessel (port or starboard)
    - Behaviour
        - Sitting (Sit), individual was sitting on the surface
        - Diving (Div), individual was seen diving before responding to the boat
        - Feeding (Feed), individual was seen with food
    - Distance band
        - A (0-50m)
        - B (50-100m)
        - C (100-200m)
        - D (200-300m)
        - E (300m+) not in transect
- Vessel speed was maintained as close to 10 knots as possible (range 9.3-10.7 knots) due to variation in local sea conditions and current speeds.

Marine Mammals

For marine mammals, the following data was collected:

- Time
- GPS position
- Species
- Number
- Distance (estimated in m)
- Angle from observer (using angle board mounted in front of observers)
- Behaviour
  - Surfacing (SURF) individual seen surfacing, but no specific behaviour viewed
  - Normal swim (NS) individual is moving at an average pace
  - Fast swim (FS) individual is moving at a fast pace
  - Slow swim (SS) individual is moving at a slow pace
  - Leap (LEAP) individual breaches the water
  - Feed (FEED) individual is changing direction quickly and making fast movements
  - Bow riding (BOWR) individual swims at the side or front of the boat
  - Bottling (BOT) in seals, individual is seen hanging vertically with head at the surface

VESSEL SPECIFICATION

Vessel specification of the Seekat C is provided at the following link:

http://www.seekatcharters.co.uk/Seekat_Specification.pdf

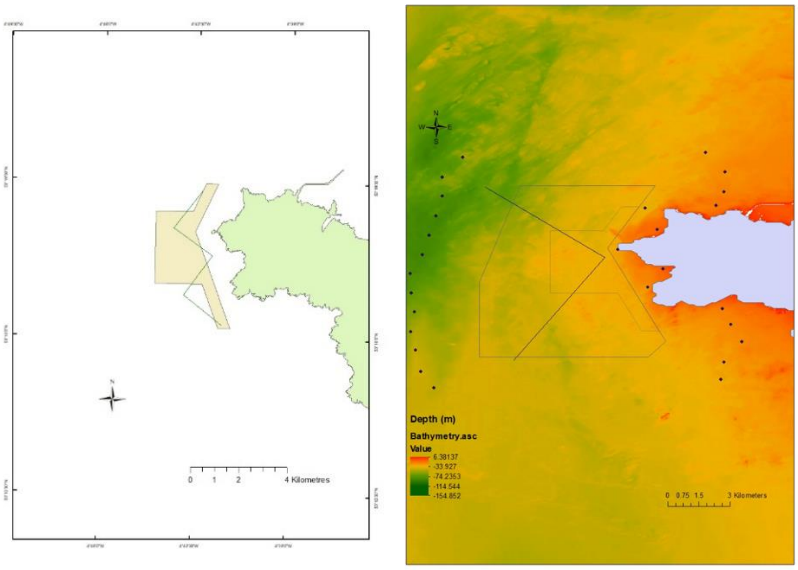
ADDITIONAL SURVEYS

Monthly surveys following the approaches in this report have been continued since April 2023. An additional 6 surveys have been performed. Summaries of sightings from 4 surveys are provided below.

Intensive surveys have been performed in July 2022, May 2023, June 2023, and September 2023. These surveys use the zigzag transect design shown below and occurred within the focal MDZ (where installations are planned). Intensive surveys were performed over 3 consecutive days within discrete seasons, with transects are repeated as many times as possible within working hours. These surveys focus on capturing within and amongst day variation in animals' site-use. Such variation could be associated with tidal or daylight cycles, or inherent stochasticity associated with animal movement. Summaries of sightings are provided below, and outputs from September 2022 were presented in the Interim Report.

Echosounder surveys have complemented both the monthly and intensive surveys since March 2023. These surveys focus on estimating school prevalence and distribution in the site, helping explain spatial or temporal variation in seabird or marine mammal site-use. A Biosonics DTX echosounder operating at 200khz is used. Because the echosounder is pole-mounted the vessel is constrained to 5kt, which is unsuitable for observation and hydrophone surveys. Therefore, separate transects are performed alongside those for seabirds and marine mammals. In monthly surveys, the transect design is shown below. In intensive surveys, these transects occur between the start and endpoints of the zigzag below.

TRANSECTS FOR INTENSIVE SURVEYS (LEFT) AND ECHOSOUNDER SURVEYS (RIGHT)



COUNTS OF ALL SEABIRDS IN THE MONTHLY SURVEYS FROM MARCH 2022 TO APRIL 2023

Date	Arctic Tern	Black Guillemot	Black Headed Gull	Common Guillemot	Common Gull	Common Scoter	Common Tern	Cormorant	Fulmar	Great Northern Diver	Greater Black Backed Gull	Herring Gull	Kittiwake	Lesser Black Backed Gull	Manx Shearwater	Northern Gannet	Puffin	Razorbill	Sandwich Tern	Shag	Total
15/05/2022	9			717			23	2				8	7	1	408	16	5	96			1292
14/06/2022	1	1		182								20	7		3	3	1	47	2		267
08/07/2022	42		1	437	9		2					20	13		271	5	2	64	1	1	868
10/08/2022				254				1			1	99	13	1	232	2		435		3	1041
20/09/2022				479							1	147			1	3		83			714
20/10/2022				148								11	1					4		2	166
22/11/2022			3	58							1	16			1			23		1	103
02/12/2022				28		18					4	17						24			91
27/01/2023				143						1		4	3					7		1	159
04/03/2023				251	4	7						16	1			1		45			325
27/03/2023				106							3	13	4		2	2	2	32		2	166
07/04/2023				11					2			19	5		6	1		16		1	61
Total	52	1	4	2814	13	25	25	3	2	1	10	390	54	2	924	33	10	876	3	11	5253

COUNTS OF ALL SEABIRDS IN THE MONTHLY SURVEYS FROM MAY 2023 TO SEPTEMBER 2023

Date	Arctic Tern	Common Guillemot	Common Gull	Common Tern	Cormorant	Fulmar	Greater Black Backed Gull	Herring Gull	Kittiwake	Large Auk	Manx Shearwater	Northern Gannet	Puffin	Razorbill	Sandwich Tern	Shag	Total
May	2	652		2		2	1	28	10		1021	5		107		14	1844
Jun	4	535		8		3	1	24	21		431	23	2	103		2	1157
Jul		165			1		2	58	12	115	103	10		52		4	522
Aug		55	5	6		1	3	16	17		56	17		29	1		206
Sep		141					4	7	4		14	7		22	5		204
Total	6	1548	5	16	1	6	11	133	64	115	1625	62	2	313	6	20	3933

COUNTS OF ALL SEABIRDS IN THE INTENSIVE SURVEYS FROM JULY 2022 TO SEPTEMBER 2023

Date	Arctic Tern	Black Headed Gull	Common Guillemot	Common Gull	Common Scoter	Common Tern	Cormorant	Fulmar	Greater Black Backed Gull	Herring Gull	Kittiwake	Large Auk	Lesser Black Backed Gull	Manx Shearwater	Northern Gannet	Puffin	Razorbill	Sandwich Tern	Shag	Total
27/07/2022			26		16			4	8	49	14			132	14	1	91	9	5	369
28/07/2022		9	73				1	1	2	36	21	5	1	17	6	1	240		5	418
29/07/2022		4	266	3		1			2	50	24			114	16	4	852	2	9	1347
01/05/2023			191					3		23	9	22		9	1	2	40		1	301
02/05/2023			1056					6	2	72	2	43		7	9		137		1	1335
03/05/2023			917					4	1	14	1	190		10	5	2	175			1319
12/06/2023			2321	3		1	1	3	7	151	30	412		90	26	14	356			3415
14/06/2023			1463	152				3	4	475	38	546		11	9	5	342			3048
15/06/2023	1		1903					4	1	143	391	1468		7	1	9	360		2	4290
01/09/2023			24	2	1				6	3	7			10	5					58
02/09/2023			7		30	1			15	73	1			4	5		2		1	139
04/09/2023		9	30						5	22	12			10	15		1			104
Total	1	22	8277	160	47	3	2	28	53	1111	554	2686	1	421	112	38	2596	11	24	16143

COUNTS OF ALL MARINE MAMMALS IN THE MONTHLY SURVEYS FROM MARCH 2022 TO APRIL 2023

Date	Common Dolphin	Dolphin Species	Grey Seal	Harbour Porpoise	Risso's Dolphin	Total
15/05/2022			1	2		3
14/06/2022			1	5		6
08/07/2022			1	10		11
10/08/2022				19		19
20/09/2022	21		1	3	8	33
20/10/2022	16		3	15	1	35
22/11/2022			2	8	15	25
02/12/2022		4		13	4	21
27/01/2023				1		1
04/03/2023				15		15
27/03/2023				3		3
07/04/2023			1	1		2
Total	37	4	10	95	28	174

COUNTS OF ALL MARINE MAMMALS IN THE MONTHLY SURVEYS FROM MAY 2023 TO SEPTEMBER 2023

Date	**Common Dolphin**	**Grey Seal**	**Harbour Porpoise**	**Risso's Dolphin**	**Total**
May		1	9		10
June		1	2	9	12
July	5		9	3	17
August	8	1	7	26	42
September	16	2	27	10	55
Total	29	5	54	48	136

COUNTS OF ALL MARINE MAMMALS IN THE INTENSIVE SURVEYS FROM JULY 2022 TO SEPTEMBER 2023

Date	Common Dolphin	Grey Seal	Harbour Porpoise	Risso's Dolphin	Total
27/07/2022		4	6		10
28/07/2022	8		6		14
29/07/2022			26		26
01/05/2023					0
02/05/2023		1	1		2
03/05/2023		2	7		9
12/06/2023		1	2		3
14/06/2023					0
15/06/2023			1		1
01/09/2023		1	9		10
02/09/2023		1	8		9
04/09/2023	12	2	37	12	63
Total	20	12	103	12	148