Offshore Wind Evidence + Change Programme

Interim Report on the Suitability of Laser Range Finders for Land-based Observations of Manx Shearwater Flight Heights

ProcBe WP3 Deliverable 3.2

THE CROWN ESTATE

Contents

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EXECUTIVE SUMMARY

This report builds on the outcomes of D3.1, which covered a feasibility study of Laser Range Finder (LRF) work to ascertain seabird flight heights as well as a calibration study to ascertain the precision and accuracy of the two main LRFs we intended to use in Year 1 of the ProcBe project. The LRF work to collect flight height data on Manx Shearwaters (MSW) and storm petrels is intended to complement the work of Work Packages 1 and 2 that are collecting flight height data on these species using tagging devices on individuals from a range of sites.

A successful calibration trial (involving testing LRFs against objects of known height and a drone) at the start of the year allowed us to train fieldworkers and gave valuable information on the limitations of the two main devices. As a result of this trial, land-based fieldwork was determined to be practically achievable for the summer of 2024.

Fieldwork at two principal sites demonstrated that calibrating land-based heights, including observer height, was challenging at times due to difficulties in acquiring an accurate height above sea level at all times. However, we developed a new LRF methodology for calibrating bird flight heights above sea level collected on land, using objects on the sea surface at a range of distances.

We determined the limitations of both devices getting 'real world' data, compared with findings from the earlier calibration trial. The Nikon LRF appeared to be most effective out to 100m distance, with declining accuracy and precision beyond this distance. The Vector LRF appeared to be most effective out to 100m, but also collected reasonable data out to 100-300m distance. The calibration trial in March 2024 using the Vector pointed to a marginal but consistent under-estimate of flight height (<1.0m) under 300m, although this requires further testing. Overall, the Vector was found to be more accurate and precise than the Nikon.

We collected 79 records of MSW flight height in Phase 1 (May 2024) and 137 in Phase 2 (July/August 2024). While this is not sufficient data to calculate flight height distributions currently, the Year 1 data collection provides a proof of concept, demonstrates the feasibility of collecting reliable land-based data within defined distances, and allows us to make recommendations as to the feasibility and focus of future boat-based data collection. Opportunistic boat-based data collected in Year 1 indicated birds flew much closer to the observer during vessel-based surveys than land-based surveys. We anticipate that boat-based work in Year 2 will eliminate some of the problems encountered in Year 1 due to: 1) a new LRF model with increased range becoming available to the project, 2) birds being closer to the observer (and therefore LRF) than earlier land-based restricted observations, and 3) reduced need to calibrate with objects on the sea surface, due to known height above sea level.

1. Introduction

This project was initiated in response to a funding call by the Offshore Wind Evidence and Change programme which is funded by The Crown Estate. This programme seeks to support the growth of the offshore wind industry and the UK's net zero ambitions by funding research projects that contribute a wide-ranging base of data and evidence to resolve gaps in evidence and understanding of cumulative impacts on protected seabird populations, a high-level priority of the OWEC programme.

Work Package 3 (WP3), from the beginning, was a relatively experimental work package. We could only find one record of Manx Shearwater flight height previously calculated using a Laser Range Finder (LRF) (Harwood *et al.* 2018). Consequently, we decided that Year 1 of fieldwork would work on trialling the two most probably successful LRFs and include a calibration trial at the outset to ascertain how reliable these two main devices would be. We also limited fieldwork to land-based work in Year 1, in order to refine the methods to be used throughout the rest of the project, and to keep costs down (versus more expensive boat-based work) while troubleshooting any problems encountered.

Laser rangefinders use a laser beam to measure the distance from the observer to a target, and in some cases have been incorporated into binoculars and can measure distance, angle of inclination, altitude, azimuth (i.e. the horizontal angle or direction of a compass bearing) and direction (Cole *et al.* 2019; Thaxter *et al.* 2016).

An additional factor to consider was that only two LRF options were available to us at that time: a cheaper Nikon model (Nikon Forestry Pro II) and an older Vector model (Leica Vector 1500) which was lent to the project by Dr. Emily Shephard (University of Swansea), as the new Vector model (the Vector X, which has considerably greater range) was not available at that time. The limitations and strengths of each device were described in detail in D3.1; however, in summary, the Nikon was relatively accurate at shorter (i.e. <100m) distances, but with variable precision and limited in its distance range to get fixes on birds. The Vector performed better at longer distances (up to c. 300m), but results from the field trial also indicated that at greater distances flight heights may be underestimated by potentially a few metres (more on this discussed later).

The purpose of Year 1 fieldwork using LRFs was to establish a proof of concept and undertake 'real world' trials of the devices that had been tested in the Calibration Trial earlier in the year. Given the experimental nature of WP3, it was decided to trial land-based observations only in Year 1, and then if these proved successful, to roll out boat-based (and more land-based) observations in Years 2 and 3 of the project.

As Year 1 was quite experimental, we trialled a range of approaches and 'ground-truthed' our work in several ways. These approaches were developed in the field and so methods changed and evolved as we found our feet within the fieldwork. Hence, the results presented in this Deliverable are done so with various caveats and 'lessons learned' for future years of fieldwork.

2. Methods

2.1 Locations of Fieldwork

The fieldwork in Year 1 was carried out in two main periods. Phase 1 was undertaken on Copeland Islands, Northern Ireland in May 2024. Phase 2 was conducted in July/August 2024 and across two sites – Strumblehead, Wales and Copeland Islands, Northern Ireland. These two sites were selected, alongside the times of year, based on exploration of potential sites and seasons in D3.1 – the Feasibility Study for WP3[1].

It was decided in Year 1 to focus on data collection for MSW as these are larger birds, and so we were more likely to have success in gathering data from them using the LRFs. MSW are also far more accessible for land-based observations, as they are more likely to be sighted closer to shore than storm petrel.

Fieldwork comprised of a two-member team surveying across a week period in each site (i.e. one week at Copeland Islands in May in Phase 1, followed by a second week at Strumblehead, Wales in July directly followed by a third week at Copeland Islands in August during Phase 2). In order to be reactive to the conditions we found in the field, throughout the course of each week we adjusted the times that we took observations to the times when most birds were passing near the observation points, to make the best use of the time available. This also enabled us to test the devices in a range of weather conditions including low-light conditions and high/low cloud cover.

We also opportunistically gathered MSW flight height data on one crossing of the Fishguard to Rosslare ferry, in transiting between Strumblehead to Copeland field sites. This was not part of the initial fieldwork survey plan, but despite this we gathered useful data and so this has also been included in this report for context and to aid in future decision-making for Year 2 fieldwork.

2.2 Measuring and calibrating bird flight heights

LRFs were used to measure the height of flying birds relative to the observer's eye-level (i.e. H_{record} as shown in **Error! Reference source not found.**). Therefore, to ascertain bird flight heights relative to sea level (**Error! Reference source not found.**, H_{flight}), these LRF measured height records needed to be calibrated to account for the observer's eye height above sea level.

Across the two land-based data collection periods, two potential methods of collecting calibration data were trialled. First, the calibration value was measured "directly" as the total height difference between the observer's eye-level and the sea-surface, measuring tide-height relative to a jetty used as the observation point directly using a 'plumb line' (i.e. a weighted measuring tape from which we could manually read the height above sea level) (Figure 1a). However, not all observations can be made from viewpoints where tide height can be directly measured so easily. Therefore, a second method was also trialled, where calibration data were collected 'indirectly' using a LRF, measuring the height difference between the observer eye-level and an object on the sea surface (e.g. a buoy, rock, or bird; Figure 1b). In theory,

[1] 2024, JNCC, ProcBe, Observational Bird Behaviour Data Collection (WP3) | Marine Data Exchange

assuming little error in values recorded by the LRF devices, these two methods of collecting calibration data should produce equal or similar values.

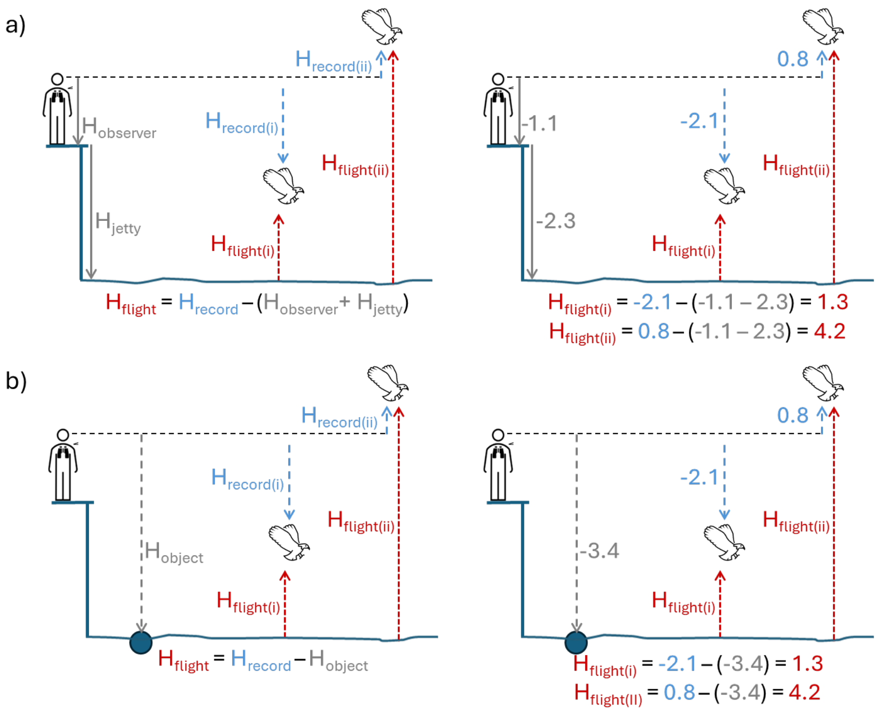

Figure 1. Calibration of LRF measured bird height data to estimate flight heights. LRF measures bird flight height relative to the eye-level of the observer, and so values must be adjusted to account for the observer's height above sea level.

Height and calibration data were collected across both Phase 1 and Phase 2 of the field trial.

While methods were refined during Phase 2 of the field trial to record multiple readings per calibration event in most instances (**Error! Reference source not found.**a) (thereby allowing calculation of an average calibration value to minimise impacts of potentially spurious readings), during Phase 1, often a single measure was made per calibration event (**Error! Reference source not found.**a).

Furthermore, bird height and calibration data were generally not collected at exactly the same time due to practical constraints (**Error! Reference source not found.**, **Error! Reference source not found.**). More typically, calibration data were collected intermittently during surveys (**Error! Reference source not found.**a, **Error! Reference source not found.**a). Therefore, flight height data were typically calibrated using the calibration value measured from the nearest timepoint that matched observer and device of the bird flight record. Multiple calibration measurements were taken throughout the periods of observation to account for changing observer height above sea level, as a result of the tidal cycle.

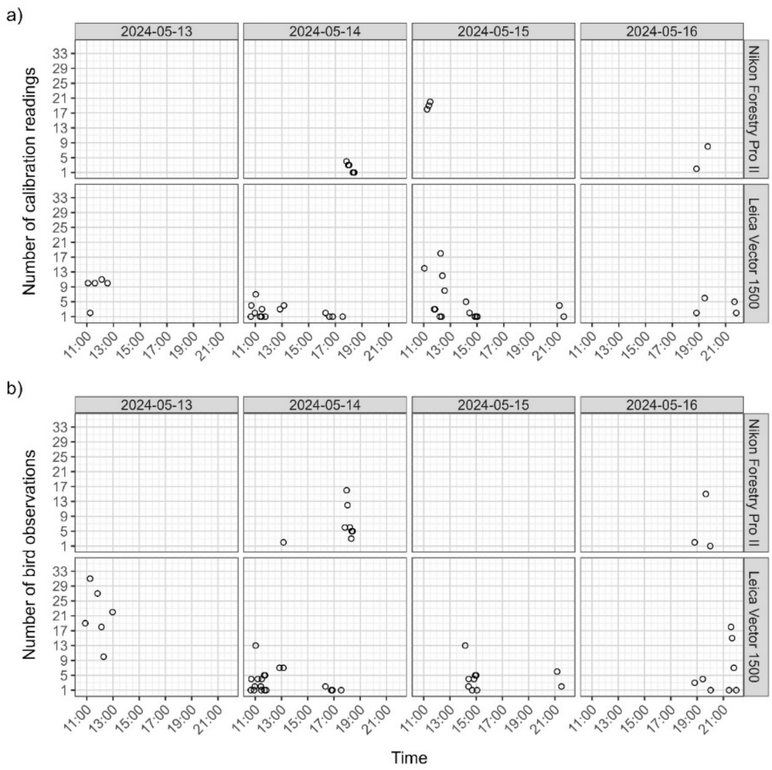

Figure 2. Timing and number of a) calibration and b) bird height data collected using two laser range finders (Nikon Forestry Pro II and Leica Vector 1500) during data collection Phase 1.

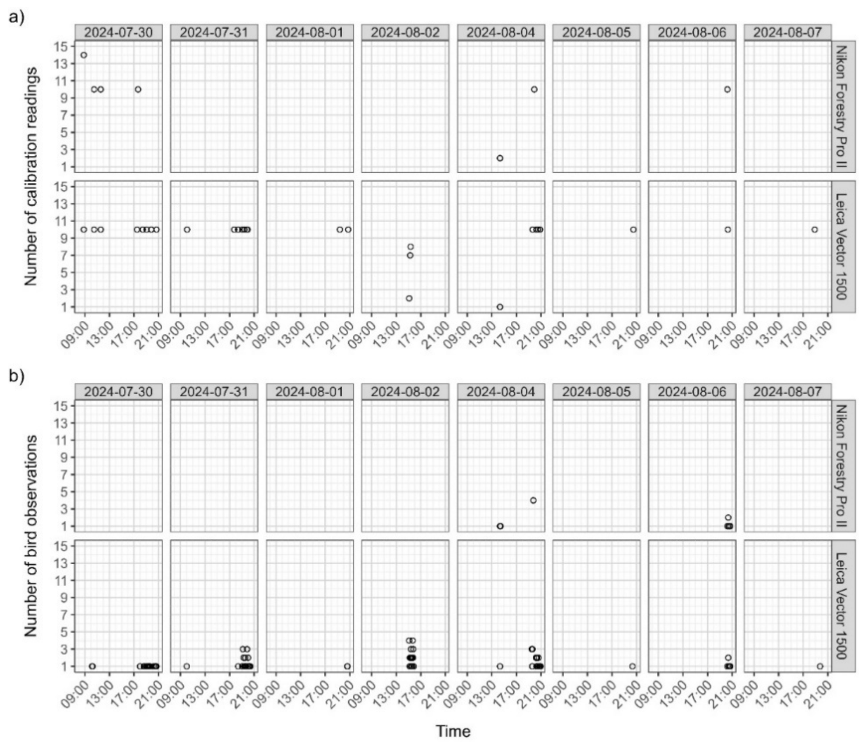

Figure 3. Timing and number of a) calibration and b) bird height data collected using two laser range finders (Nikon Forestry Pro II and Leica Vector 1500) during data collection Phase 2.

Figures 2 and 3 show the spread of calibration events across the periods of collecting bird flight height data. At this stage the team were still trialling methods to calibrate height above sea level, so some of these data points represent birds other than MSW, in order to give a larger dataset of points with which to work. In particular, 22% (n = 79 out of 358) of the bird flight height observations during Phase 1 were of MSW, but the majority (96%) of bird observations in Figure 3 represent MSW (n=137 out of 142). As the 'indirect' method developed, we determined to take 10 fixes using the LRF on objects on the sea surface for each calibrated time point and use an average of the values to represent the observer's height above sea level.

2.3 Calibration data from Phase 1

On Days 1 and 3, calibration data were collected by both calibration methods ('direct' and 'indirect', Figure 1). However, 'direct' calibration data on Day 1 were collected alongside each bird observation (rather than at intermittent time points across the survey period, as per subsequent days), while the repeated 'indirect' calibration measures were recorded at four timepoints across the survey period (Figure 2a). Bird observations from Day 1 were therefore calibrated using the concurrently recorded 'direct' calibration measurements.

In contrast to Day 1 data, 'direct' calibration data on Day 3 were collected prior to all bird observations (Figure 2) and were therefore considered unsuitable for calibrating bird flight heights. Bird height observations were therefore calibrated using 'indirect' calibration data, with bird height observations calibrated using the nearest comparable calibration datapoint. The 'direct' calibration data collected on Day 3 could, however, still be used to assess the accuracy of the LRF for measuring relative height difference between the observer and the water's surface. On Days 2 and 4, only 'indirect' calibration data were collected, and bird height observations were calibrated using the nearest comparable calibration datapoint. Across Days 2-4, all but one of the 79 Manx Shearwater height observations made were calibrated to a calibration record within 30 minutes (time difference between observation and matched calibration: min = 0 minutes, max = 36 minutes, mean = 2.24 minutes, median = 0 minutes)".

In total 245 calibration objects were measured during Phase 1 (Figure 2): 80 using the Nikon (33%) and 165 using the Vector (67%). This difference in sample size between the devices was not by design, but instead resulting from practical constraints found when using the Nikon, with greater success found in recording flight height data for birds with the Vector, which was also reflected by the sample sizes for bird height data collected (of 285 bird height observations, ~80% were made with the Vector vs. ~20% with the Nikon). While having a smaller sample size for the Nikon may increase uncertainty when comparing between the two devices, the proportion of calibration vs height readings are broadly similar. Furthermore, the timings of the calibration and height records within device types are similar, which is more important for establishing a reliable calibration of flight height estimates.

2.4 Calibration data from Phase 2

Across all surveys during Phase 2, relative sea surface-observer height calibration data were solely collected with the LRFs on objects on the water's surface (i.e. 'indirect' calibration method). Objects were primarily buoys on the water's surface, but calibrations were also recorded on other objects such as rocks and birds on the water surface, or on white water on the water surface itself, in the case of the data collected on the Fishguard-Rosslare ferry (the latter because there were few buoys and reflective backscatter from certain types of white water seemed to be enough to get a fix). In general, multiple readings were made consecutively on each object per timepoint (**Error! Reference source not found.**a; mean =

9.2 fixes, min = 1, max = 14), allowing calculation of an average object height to be used for calibration. Bird height observations were calibrated using the nearest comparable calibration datapoint, with all but two of the 137 Manx Shearwater height observations made calibrated to a calibration record within 30 minutes (time difference between observation and matched calibration: min = 0 minutes, max = 53 minutes, mean = 9.88 minutes, median = 7 minutes).

2.5 Assessment of calibration data

The accuracy of 'indirect' LRF-collected calibration data can be assessed by comparing 'direct' and 'indirect' calibration data collected during Day 1 Phase 1 (Nikon: n = 47, Vector: n = 103). Here, if measures of height difference between the observer and the water surface were measured accurately by the LRFs, then 'indirect' and 'direct' height measurements should be equal. However, these two measures often did not agree (Figure 4), with 'indirect' LRF measures frequently overestimating or underestimating the vertical distance between the observer and the water surface. Furthermore, measurement discrepancies were not trivial, with differences of 2m+ between the two calibration methods (i.e. 'direct' versus 'indirect') frequently observed (29.8% of Nikon records, 16.5% of Vector records). While errors in Nikon recorded measures had a relatively even split between over and underestimates (mean difference = -0.2m), records made by the Vector generally tended to underestimate heights (mean difference = -1.19), suggesting that flight height data calibrated with Vector-recorded calibration values could be negatively biased (i.e. suggesting lower flight heights).

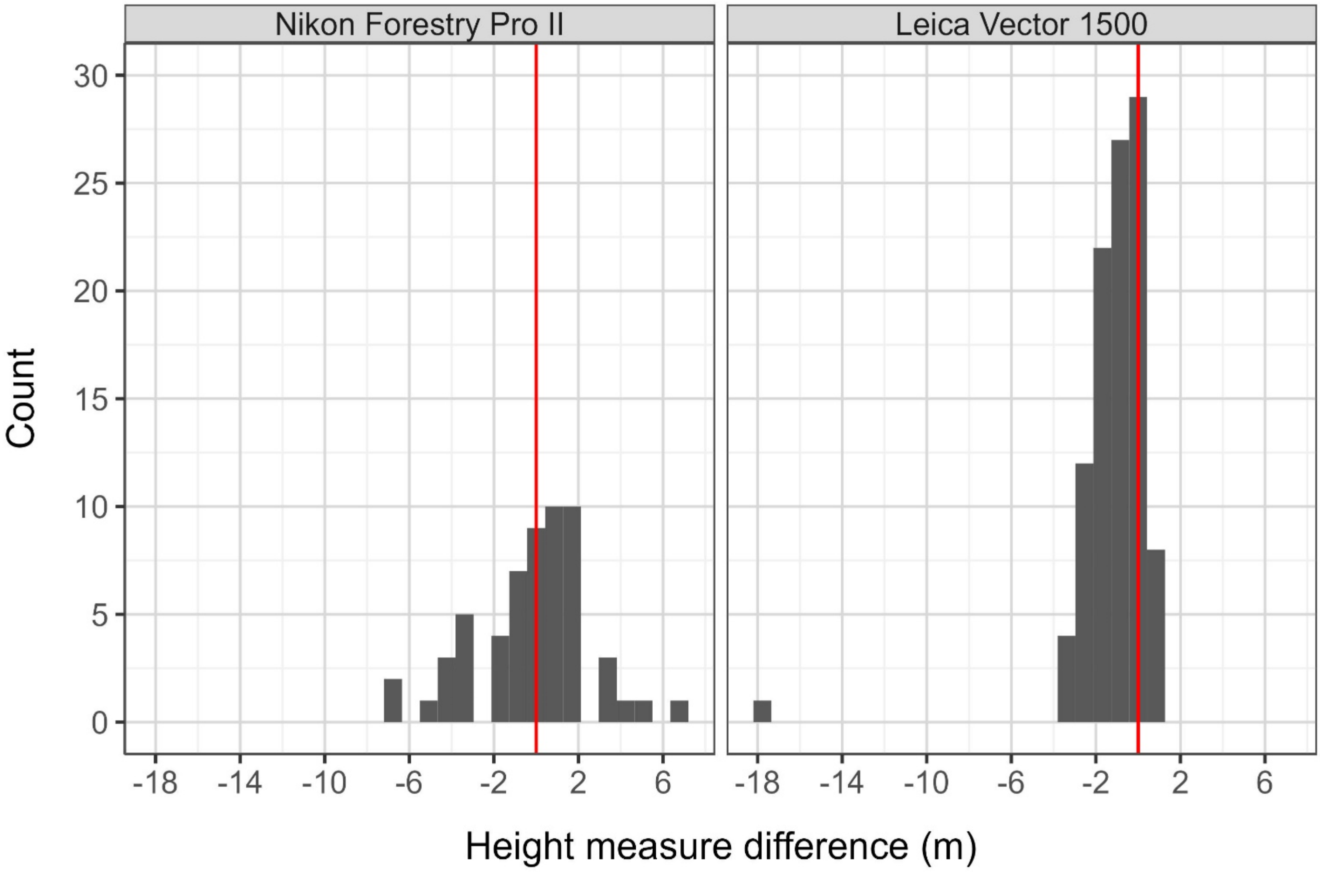

Figure 4. Difference between 'direct' and 'indirect' measured estimates of height difference between the observer and the water surface across two LRF devices (panels) during Phase 1 data collection. If calibration values agreed between the two methods, the height measure difference should centre around zero (red vertical line). Negative values indicate where 'indirect' LRF measures overestimated the calibration value, and positive values indicated where 'indirect' LRF measures underestimated the calibration value.

However, it should be noted that, from the outset, the survey design was not undertaken with the express purpose of comparing the 'direct' and 'indirect' methods of calibrating to sea surface level. This work was undertaken opportunistically, as our methods developed in the field, and so there was not systematic testing of this technique. The 'direct' method of calibration was also quite crude (using a 'plumb line') and so in itself subject to some error. These aspects should be considered when planning fieldwork for Year 2. Should we undertake any land-based fieldwork in Year 2, we would endeavour to undertake a more systematic trialling of 'direct' and 'indirect' comparison of methods.

2.6 Assessing measurement error with increasing horizontal distance

For both devices, height measurement errors are comparatively minor at shorter distances from the observer, with both recording measurements with a relatively higher degree of precision and accuracy (**Error! Reference source not found.**). However, the accuracy and precision of height difference values measured by 'indirect' and 'direct' calibration methods generally decreased with increasing distance between the observer and calibration object. In contrast to the results of D3.1 (Feasibility Study), which demonstrated that the Vector was accurate to <1m out to over 300m, the results from the opportunistic 'direct' and 'indirect' comparison work in Phase 1 points to the accuracy being somewhat less than this – in the region of 2m at 300m (Figure 5). The results for the Nikon indicated that accuracy was in the region of ±1m only at around 100m distance. Beyond this, at approximately 300m for example, accuracy dropped to around ±6m (Figure 5).

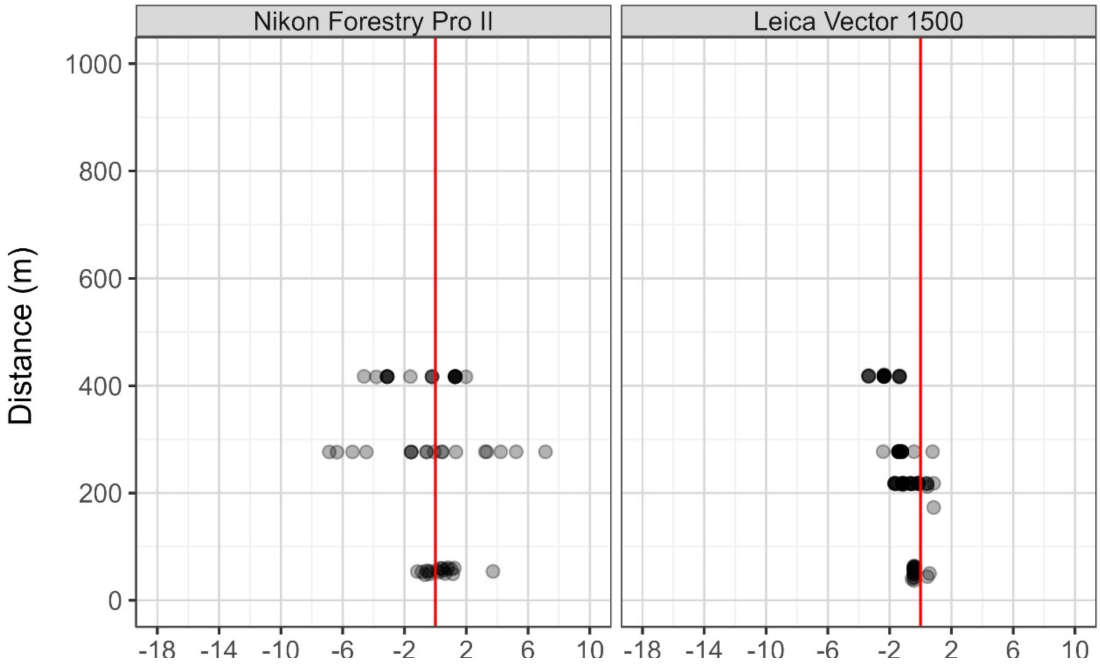

Figure 5. Error in LRF height measurement with distance between the observer and the calibration object during Phase 1 data collection. If calibration values agreed between the two methods, the height measure difference should centre around zero (red vertical line). Negative values indicate where 'indirect' LRF measures overestimated the calibration value, and positive values indicated where 'indirect' LRF measures underestimated the calibration value.

Moreover, the study indicated that distance to the calibration object may be an important factor to consider when determining the reliability of 'indirect' calibration measures recorded by the LRFs. It would appear advisable to calibrate sea level using objects on the sea surface at a range of distances, for example, if we've now demonstrated that the Vector is most effective out to 200-300m distance, then calibrated objects should also be done within these range of distances, rather than always on objects closer into the observer.

2.7 Assessing the impact of weather on flight height

Measures of wind (speed and angle) and bird flight direction were recorded so that potential impacts of wind on flight heights could be assessed. An anemometer (Kestrel 5000) was set up within a few metres of the LRF observations at each time of data collection, with observations being taken every 15-30 minutes.

However, during Phase 1, wind speed measurements were considered unreliable, and so were not considered further. Furthermore, bird flight direction was not recorded, and so no assessment of the potential impact of wind direction could be made.

During Phase 2, weather data were assigned to flight height observations based on weather records from the nearest timepoint. While wind direction was measured in degrees to true north, bird flight was recorded on a coarser level, as an 8-point compass point (i.e. N, NE, E, SE, S, SW, W, NW). Therefore, to assess potential impacts of wind direction, relative wind directions to bird flight was measured as an 8-point difference from bird flight direction. A value of zero would indicate that a bird was travelling in the same direction as the wind (e.g. bird flying north in a southerly wind), a value of four would indicate that the individual was flying cross-wind (e.g. bird flying north in an easterly wind), and a value of eight would indicate that the bird was flying into the prevailing wind (e.g. bird flying north in a northerly wind). The potential impacts of wind speed on calibrated flight heights were assessed with a general linear model. Distance was also included as a continuous covariate in this model to control for some potential biases that may occur with greater distance between the bird and observer.

3. Results

3.1 Phase 1: Copeland May 2024

During Phase 1, 79 records of flying MSW were recorded for their height and distance. While 'direct' calibration data were collected on Day 1, no MSW were observed on this day, therefore all MSW flight heights from Phase 1 were calibrated using 'indirect' calibration data.

Firstly, there was a clear pattern of decreasing calibrated flight height with increasing distance from the observer for heights recorded by the Vector (Figure 6). It is unknown whether this pattern represents any biological basis. It is possible that MSW fly higher as they approach closer to land where they nest, but it seems unlikely from general observation of the birds' behaviour by the observers at the time, particularly given the land at Copeland is not particularly high. Alternatively, it is possibly indicative that LRF height values may be increasingly biased downwards with increasing distance. It is also worth noting that very few records of birds at larger distances (>500m) were made using the Nikon (this device known to struggle to fix on objects at greater distances), therefore it remains unclear whether this bias is consistent across both devices at the greater distance ranges.

Secondly, a substantial proportion of calibrated flight heights were negative, particularly for those collected with the Vector (Figure 6). However, presuming no measurement error associated with the LRFs, all calibrated flight heights should be positive (i.e. above the water surface).

The accuracy and precision of height measurements may in practice differ between observers. However, only Observer 1 collected data using the Nikon in Phase 1 and so no assessment of observer effects can be made for this phase of data collection. Both observers collected data with the Vector, but preliminary inspection does not indicate substantial differences between observers (Figure 6).

It should be noted that, over time, our experience as observers improved throughout the study period, and we got a better understanding, intuitively, of how the devices were performing. Figure 6 includes many data points out beyond 600m for the Vector, but much of these were collected in the earlier part of the study period. Over time, we realised that the devices were reporting spurious readings at much greater distances and felt that any data points beyond this range were unlikely to be meaningful and were more likely the result of a random 'hit' off a faraway wave or cloud (although all these data points have been included in Figure 6 for completeness). In future, we feel a better approach will be truncate the data from a particular point, beyond which the calibration data indicates results may become spurious.

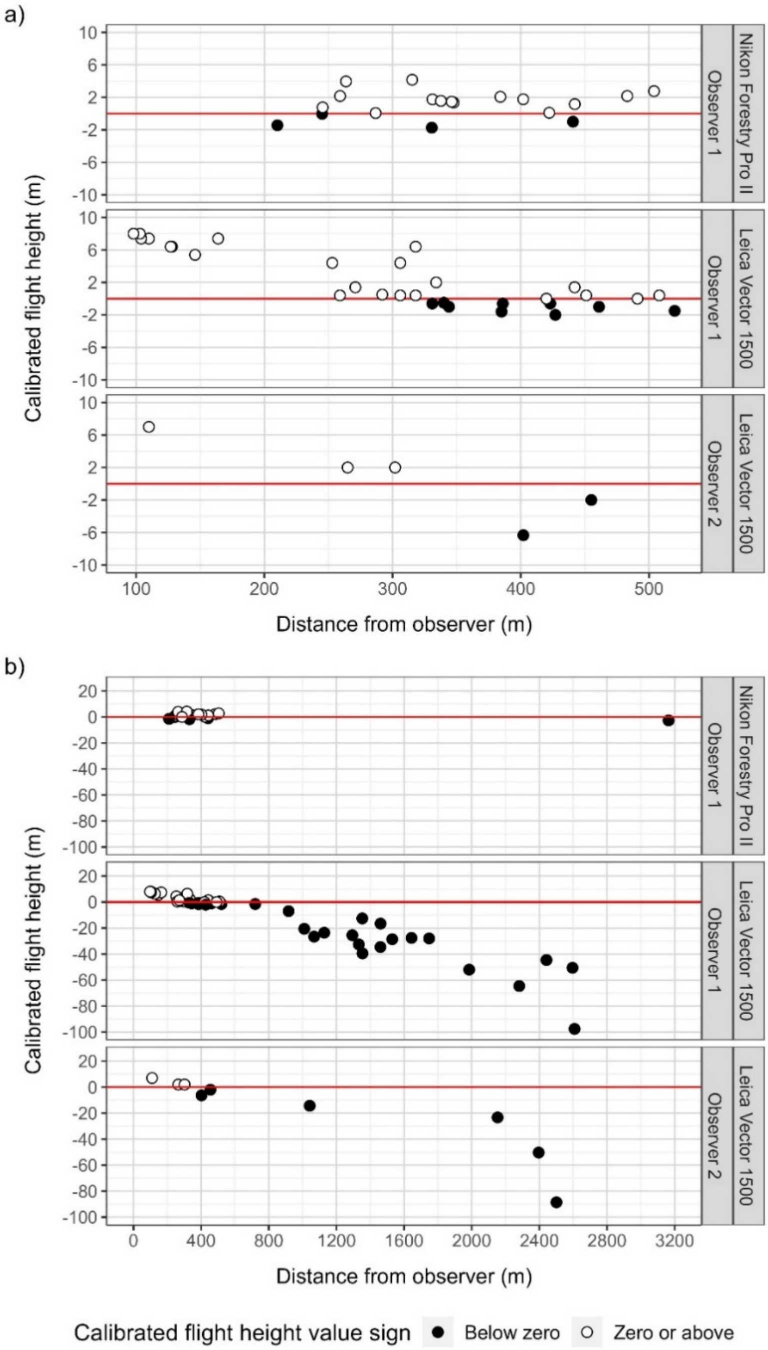

Figure 6. Phase 1 calibrated MSW flight height estimates of a) individuals recorded within 700m of the observer, and b) all individuals recorded across the range of LRF recorded bird distances from the observer. Observations were recorded by two observers using two LRF devices (Nikon Forestry Pro II and Leica Vector 1500). The red horizontal line illustrates a calibrated flight height equal to zero, indicating the bird would be flying at the water surface.

3.2 Phase 2: Strumblehead and Copeland July/August 2024

During Phase 2, 137 records of flying MSW were recorded for their height and distance. Similarly to that found in Phase 1, there was a clear pattern of decreasing calibrated flight height with increasing distance from the observer, and a substantial proportion of calibrated flight heights were negative (Figure 7). As only Observer 1 collected data using the Nikon[2], observer effects could not be assessed; however preliminary inspection of data collected with the Vector does not indicate substantial differences in recorded flight heights between observers. Figure 7 clearly shows the varying distances of bird observations with site, with the Fishguard-Rosslare ferry demonstrating the closest range of observations, followed by Copeland and then Strumblehead. A considerable amount of data was observed on the ferry at distances under 200m with the Vector.

[2] This was due to practical constraints in the field, but this will be addressed in Years 2 and 3 of data collection, with both observers using both devices to address any bias issues.

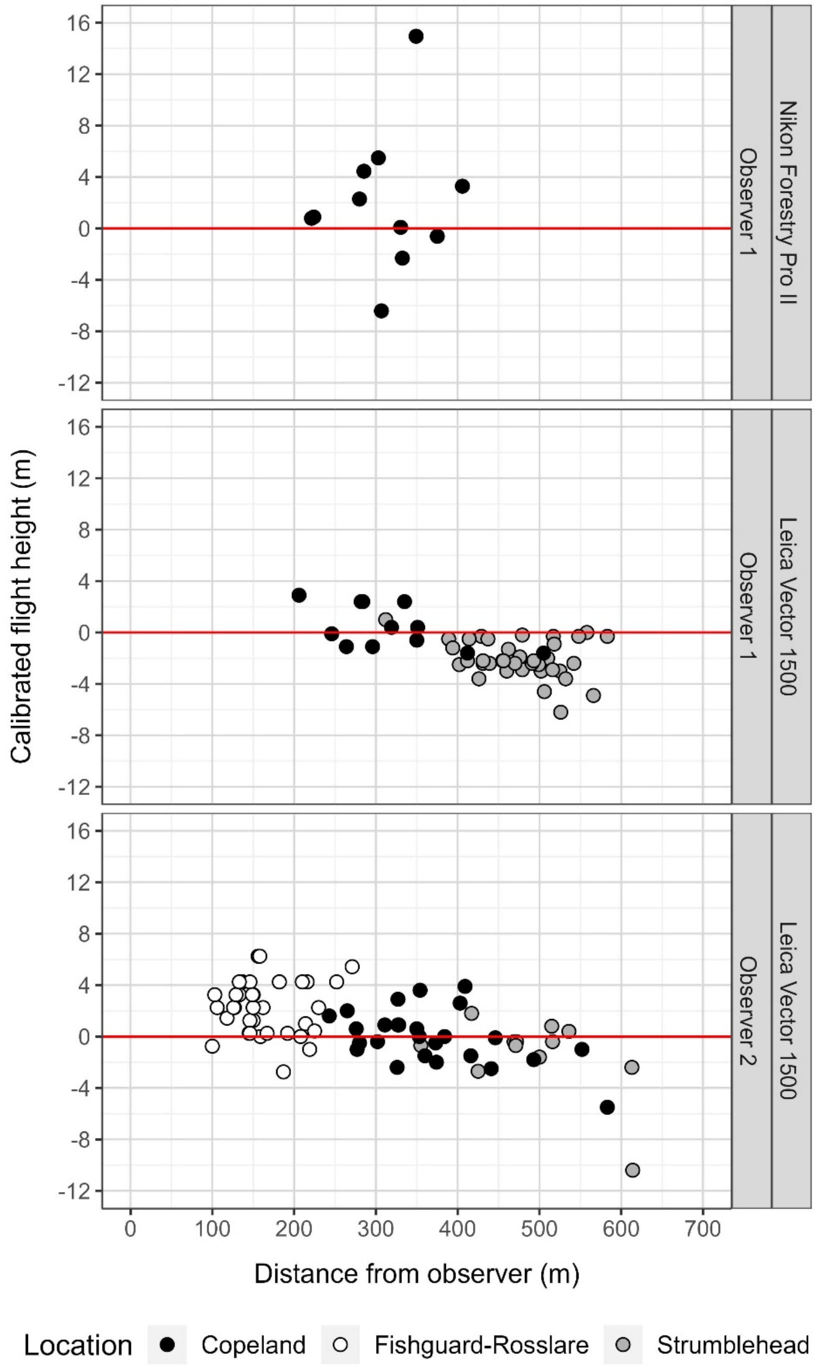

Figure 7. Phase 2 calibrated MSW flight height estimates across the range of LRF recorded bird distances from the observer, recorded by two observers across three locations (coloured points: Copeland, Fishguard-Rosslare and Strumblehead) using two LRF devices (Nikon Forestry Pro II and Leica Vector 1500). The red horizontal line illustrates a calibrated flight height equal to zero, indicating the bird would be flying at the water surface.

3.3 Phase 2 Weather conditions and Flight Height Data

While there was insufficient data collected with the Nikon to assess impacts of weather (Figure 8 a&c), initial examination of weather data collected alongside the Vector suggested a weak positive association between MSW calibrated flight heights and wind speed (Figure 8). A general linear model testing the relationship between calibrated flight heights and wind speed, whilst controlling for the potentially confounding effect of observation distance (m) indicated a positive but non-significant correlation (Table 1).

Additional data over a wider range of wind speeds is required to fully explore the potential relationship between flight heights and wind speed (during Year 1 fieldwork the range was only between 0 m/s and 4.1 m/s).

Furthermore, while it was not considered appropriate to model the relationship between calibrated flight heights and relative flight-wind direction (due to lack of data), there does appear to be a slight positive relationship, indicating that MSW may fly higher when flying into the prevailing wind. This is an aspect that could be tested further with future data collection. Both elements will be examined further in future years of data collection, but the explanatory power is not currently sufficient to draw any firm conclusions.

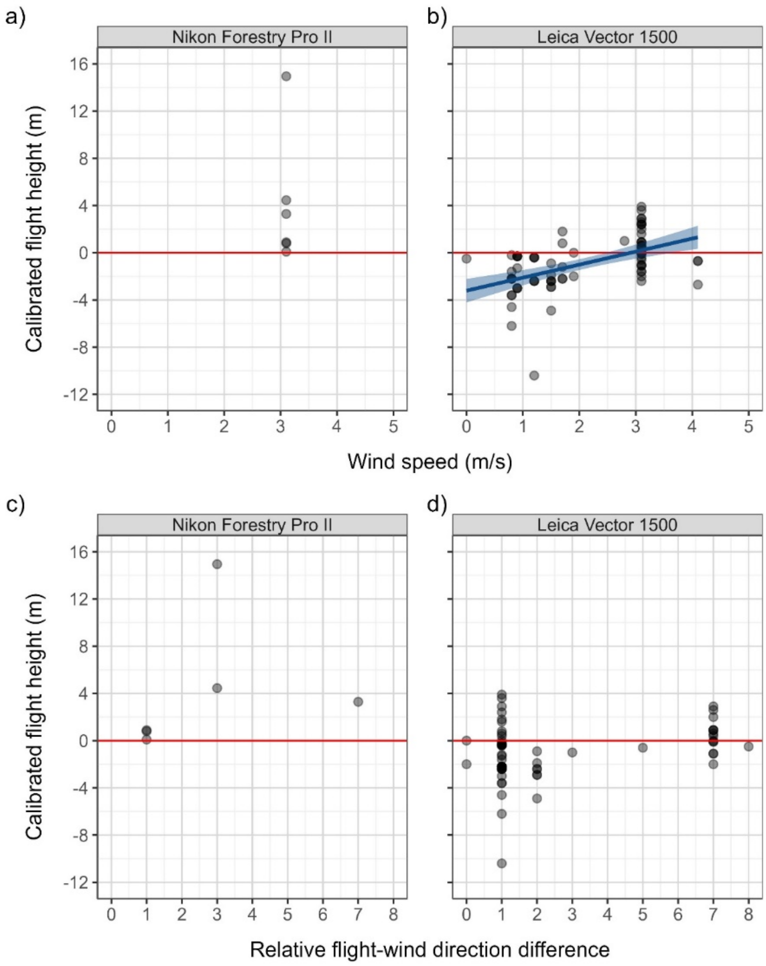

Figure 8. Relationship between Manx Shearwater calibrated flight heights (m) and wind speed (m/s) (a & b) and wind direction relative to bird flight direction (°) (c & d) in Phase 2. C & d) Value of 0 suggests that the individual was travelling in the same direction as the prevailing wind, and a value of 8 indicates the individual was flying into the prevailing wind.

Table 1. Parameters of linear model assessing relationship between calibrated Max Shearwater flight heights and wind speed (m/s), controlling for the potentially confounding impacts of observation distance (m) (data only includes that collected with the Vector; number of observations: 75; adjusted R^2 = 0.36).

Fixed effects	Estimate	S.E.	t-value	p-value
(Intercept)	2.94	1.75	1.68	0.10
Wind speed	0.40	0.28	1.43	0.16
Distance	-0.01	0.00	-3.65	<0.01

4. Discussion

Results from the March calibration trial indicated that the measurements recorded by the LRFs, the Nikon in particular, became increasingly unreliable as distance and height difference between the observer and object increased. However, the range of distances tested during the calibration trials were often substantially lower than those observed (and recorded) for MSW in the field. While the calibration trials typically tested distances of up 100m from the observer for the Nikon, and then 300m for the Vector, distances recorded for birds with the Nikon were generally between ~200-500m, and with the Vector typically 100-600m away (Figures 6 & 7). Therefore, since we have no comparable calibration data, we should be wary of observations made at distances over c. 300m in the Year 1 data.

Data from both the calibration trial and the field trial indicate that Nikon data collected within 100m of the observer is generally accurate. However, deviance from the true height value (generally within 2m) tends to be slightly wider than that of the Vector at similar distances (generally within 1m). Comparisons of 'direct' versus 'indirect' calibration data collected from the field trial currently indicate that Nikon collected 100-300m from the observer is not highly reliable, producing estimated flight heights that substantially deviate from the true height value.

Data from both the calibration trial and the field trial indicate that Vector data collected within 100m of the observer is generally reliable, and data collected 100-300m from the observer may be relatively reliable, although analyses from the calibration trial indicated that the Vector may generally slightly underestimate height (but only in the region of ~1m).

While the Vector appears to be able to acquire data out to greater distances, its accuracy does come into question. Given that the March calibration trial was unable to get results beyond distances of 300m, and so we don't have comparable calibration data at further distances, makes it difficult to reliably determine a specific cut off point beyond which we wouldn't trust the data. However, it may be appropriate to, in future, include data within 500m in analyses, but to thoroughly examine it for signs of discrepancies, and it may be more robust to limit data to the first 300m to draw conclusions from.

Given the issues observed in the field with reduced data accuracy and precision with increasing distance , there would be merit in running a further calibration trial using an UAV, as in the Feasibility Study D3.1, but with a focus on increasing the horizontal distances if possible, and with less focus on vertical height bands, as it did not appear that as many of these were required by the 'in the field' scenarios as were assessed in the calibration trial. The new trial could refine what we think are the approximate limits of the devices and allow more appropriate calibration data to be collected (although recognising the limitations of the LRF fixes on the UAV in the original study). The focus of the new calibration trial would be predominantly to test the new devices that we hope will be available to the study for Year 2 (at this stage the new Vector X model), but we could refine the scope and revisit testing of the Nikon and Vector Leica 1500 at the same time, as a backup in case we are unable to source new, stronger devices for Year 2.

It is extremely promising that the opportunistic boat-based data, collected this year on the Fishguard-Rosslare ferry, demonstrated typical MSW observations being in the 100-200m band for this route across the Irish Sea. This would fall within the reliable range of the Vector model we currently have and is likely to be well within the capabilities of any future Vector X model, if we are able to secure one. The fact that this observation platform points towards much closer distances than the land-based observations so far, means that the Nikon will also be more likely to provide useful results in future, compared with what has been indicated by the land-based use of this device in Year 1. We are mindful though that the move to boat-based fieldwork in Year 2 will pose new challenges, with the need to account for swell height in calibrating the data and arriving at accurate flight height estimations, for example.

5. Conclusions

We had a successful calibration trial at the start of the season, which allowed us to train up some fieldworkers and gave valuable information on limitations of the two main devices.

Land-based fieldwork was determined to be practically achievable, but with some challenges. Calibrating the land-based height, including observer height, in order to calibrate the LRF bird height values, was challenging at times. We developed a new method of calibrating bird flight heights using LRFs, by frequently recording objects on the sea surface, as a means of adjusting for the birds' height above sea level.

We determined the limitations of both devices getting 'real world' data, as opposed to elements determined through the earlier calibration trial. It appeared that data using the Nikon was effective out to around 100m, possibly a bit more. The Vector was effective at collecting bird data up to 100m, and relatively well from 100-300m, but beyond that became more spurious. At greater distances it may be that the Vector increasingly underestimates flight heights.

It may be that some of these problems are reduced in future boat-based work, where it may be easier to establish with greater accuracy observer height above sea level, and so the correction factor to flight height given by the LRFs will have greater certainty. We are also hopeful that boat-based platforms will allow us to decrease the distance to observed individuals, and so bring the range of the current devices into more reliable distances.

Finally, our aim is that future years of study will allow us to; undertake more refined calibration trials, increase sample sizes of data collected, expand data collection to the other species of interest, and acquire improved technology to extend our range of acquiring data.

6. Next steps

We intend to proceed with boat-based fieldwork, given that there is a proven methodology for collecting flight height data using LRFs.

We plan to undertake a further (shorter) calibration trial for a number of reasons;

To get data on calibration at greater distances if possible (rather than increasing height bands). While the initial trial collected data out to further distances wherever possible, there were some time constraints, and also the environmental conditions may have made it harder to get readings at greater distances, due to background cloud conditions, moisture in the air, etc. We would hope that a change in environmental conditions on the day of testing, may produce slightly different results to the first calibration trial.

To further explore the potential for observer effects as this was not sufficiently explored in the first calibration trial due to lack of time.

To explore the error associated with angle of inclination and if possible using negative angles (the object being at a lower altitude than the observer).

We plan to acquire a new LRF model (either Vector X or PLRF from Safran manufacturers) both of which are newer models to the older Vector model used in this first field season. We anticipate the accuracy and distance range of the device will be improved, and we can test this at the next calibration trial.

We plan to roll out boat-based LRF work for both MSW and storm petrels next summer, given the successful trial of the LRFs in this first field season, and the acquisition of a clearer understanding of the methodological and logistical constraints from Year 1. Given our experience on the Fishguard-Rosslare ferry (data shown in Figure 7) we have a proven method for getting data from ferries/boats, and it would appear that boat-based data on MSW flight heights was possible to acquire at much closer distances than on land.

For the purposes of Year 2 data collection, we are recommending the following steps:

1. Continue as planned with Scilly fieldwork and boat-based charter to get flight height data on storm petrels (for which there has been no previous data), based on the proof of concept of the land-based work, as well as the data collected on the Fishguard-Rosslare ferry.
2. Continue as planned with Mallaig-Small Isles/Lochboisdale ferries (permission already granted for 2025 and 2026 field seasons) to collect flight height data on MSW in far greater abundance than was collected in Year 1 (sample sizes are currently too small to robustly calculate flight height distributions, and needs a greater focus on closer distances to ensure greater accuracy of readings).
3. Switch land-based work at Strumblehead and Copeland to boat-based work out of Wales. This would involve approaching the two ferry companies that work out of Pembrokeshire (Irish Ferries and Stena Line) to request vessel access to get flight height data on MSW in the Irish and Celtic Seas. This would involve several weeks of fieldwork in Pembrokeshire, focusing on getting vessel access from either ferry company. The plan would be to get as much data as possible from the ferries, particularly on bad weather days, when the birds are most likely to be flying highest, and then on days when the weather is so bad the ferries might not run, this survey

effort would be turned to Strumblehead, as per the methodology for Year 1 (thus making the best use of staff and financial resources for this year's field season).

7. References

Harwood, A.J., Perrow, M.R. and Berridge, R.J., 2018. Use of an optical rangefinder to assess the reliability of seabird flight heights from boat-based surveyors: implications for collision risk at offshore wind farms. *Journal of Field Ornithology*, *89*(4), pp.372-383.