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Trial High Definition Video Survey of Seabirds

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Executive Summary

This report describes the method, output and learning from a trial of a high-definition video survey technique for census of seabirds and windfarm sites. The technique utilises a gyroscopically stabilised camera mount to eliminate aircraft vibration enabling the use of high magnification lenses. This in turn enables the helicopter to fly at a significant distance from the birds, while still maintaining sufficient image quality to identify them and assess certain aspects of their behaviour. The video is coupled with a GPS logging system that associates a geographical location with each video frame, enabling subsequent statistical analysis of the spatial distribution of birds. The general findings of the trial are as follows:

- The system provides sufficient detail to enable reliable identification of birds in most cases.
- Altitudes in excess of 1km are feasible; cloud-base would typically be the limiting factor.
- Although this survey was not carried out over an existing windfarm, the altitude and image quality demonstrate that it directly applicable to windfarm survey.
- Despite higher wind speeds than would be tolerated on a conventional survey, it was possible to conclude that all birds had been observed on most transects with a high degree of confidence.
- To ensure recognition of smaller species, image width must be fixed at around 30m, which is substantially smaller than the zone in which it is assumed conventional surveys have a 100% detection rate.
- Transects must therefore be significantly closer than is the case during conventional surveys.
- Some difficulties were encountered in operating the video equipment in the manner required by the trial and an approach that minimises these effects has been identified.
- Technical refinements to improve quality and reduce cost have been identified, which it may be appropriate to test in a second survey.

The use of video provides a permanent record of the survey, which confers the advantage of 'auditability' of survey data. It also enables subsequent re-use data for other purposes, such as monitoring of non-windfarm human impacts or marine mammal activity; indeed the video provides a complete record of all visible aspects of the condition of an area of water on a given day.

While the mode of operation of the equipment for survey purposes poses significant challenges not normally encountered in aerial filming, the potential of the technique is largely as anticipated. The trial successfully identified a range of birds from a variety of families and species, including auks, gulls, gannets, and shags. Despite the relatively small scope of the survey, these birds demonstrate the ability of the technique to cope with a range of bird sizes, plumages and behaviours. The GPS data enabled an approximate location to be allocated to each bird, revealing anticipated patterns in their spatial distribution.

The coverage rate of the technique during the survey was found to be approximately 20 sq. km per hour. A significant proportion of survey time was spent on manoeuvring due to the small size of the survey area, and it is anticipated that a very significant increase in coverage rate would be found for larger survey areas.

Several technical difficulties encountered during the survey reduced image quality when compared with the theoretical optimum. Nevertheless, bird identification was straightforward in most cases, even when the image quality was poor. This was enabled by the ability of an experienced observer to recognise a bird by size and wing motion. It was also found that consistency of appearance across multiple frames was the strongest visual clue for detecting

sitting birds. It is therefore concluded that video has significant advantages over still images as a survey medium in this application.

Appropriate measures to eliminate or mitigate each of the technical difficulties encountered have been identified, and it is anticipated that future trials will show a significant increase in both image quality and statistical robustness of data analysis. In particular, logging camera orientation and providing visual aids to facilitate camera control will be a great advantage in future.

At this stage, while qualitative comparisons have been made, it is not possible to make a quantitative comparison in terms of accuracy and cost between the high definition video method and either the plane or ship based survey techniques. This cost/benefit analysis will be required in future to ensure adoption of the most appropriate survey techniques for census of seabirds at windfarm sites.

It is therefore recommended that a further trial be undertaken, to run alongside a conventional survey of a windfarm site. This would both enable a direct comparison of techniques to be made, and provide the opportunity to test technical refinements identified as a result of this survey.

Glossary

High Definition – an enhanced resolution video, giving a resolution of 1080x1920 pixels (approximately 2.1 mega-pixels)

Gimbals – a mechanical device for holding an enclosed object in place while enabling it to rotate freely

Acronyms

HD – High Definition Video

GPS – Global Positioning System

1. Introduction

The UK's shallow coastal waters provide a key component of the habitat of several species of marine birds. For many species, the UK breeding population accounts for the majority of the European population. The shallow waters required by many species are also favoured as potential windfarm sites; there is therefore a need to understand the distribution of marine birds over potential windfarm sites, and to monitor and assess the impact of the construction and operation of windfarms on local marine bird populations.

Numerous survey techniques for monitoring marine birds from boats and aircraft have been developed and applied throughout the world. However, the effects of the many survey parameters on the outcome are considerable and remain only partially understood (Ref. 1). Further, most survey techniques depend on statistical techniques to construct un-biased estimates of population density (Ref. 3); these rely on assumptions which are known, or suspected, to be violated in practice for common survey techniques under some circumstances (Ref. 4). It is a key feature of the method described in this report that these assumptions are generally not violated, and that a visual record of the survey is retained enabling any interested party to convince themselves, retrospectively, of the integrity of the survey data.

COWRIE has recognised the need to develop standardised survey practices to promote consistency and quality of gathered data. In order to achieve this goal, the Marine Bird Survey Methodologies Project was established in 2003. Phase 1 of this project, which was completed in May 2004, has reviewed existing methods to identify good practice and provide guidance for future surveys. This review found that, while aerial techniques were the most cost effective way to undertake surveys on the necessary spatial scale, there are numerous technical shortcomings of the technique (Ref. 1). In particular, the potential use of digital imaging methods to augment the technique was proposed as a way to overcome some of these shortcomings.

1.1 Objective

HiDef Aerial Surveying Limited has developed a helicopter-deployed high definition digital imaging survey technique for monitoring marine bird populations at potential or actual windfarm sites. HiDef approached COWRIE with a proposal to undertake a trial of the technique to assess its performance. The purpose of this document is to describe practical experience of this technique gained during this trial.

The objective of the trial was to investigate whether the technique provides the anticipated advantages over conventional surveys, which include:

- Decreased cost through more efficient use of expert observers and the ability to cover a greater area in a given flying time.
- Fully auditable outputs, based on recorded HD video footage of all birds included in the survey.
- Greater ease of deployment within existing windfarms, due to the ability to fly considerably higher than would be the case in a conventional survey.
- Increased accuracy through reduction of subjective elements, such as counting of large groups or classification of poorly observed birds.
- Potential reduction in disturbance of birds by increasing aircraft altitude.

2. HD Video Aerial Survey Technique

Currently, surveying is performed either by flying expert visual observers over the area of interest, or by locating visual observers on a boat. In the case of plane surveys, proximity to the birds is required to enable reliable identification of species, which restricts aircraft altitude to around 250ft. Because of the proximity of the craft to the birds, observer induced disturbance becomes a problem; to minimise the effects of noise (and reduce cost), light planes are preferred to helicopters. Flight speed is determined by trading off various conflicting factors; accuracy of counting and identification improve with slower speeds, while area covered per unit time and ability to count disturbed birds before they can react improve with faster speeds. In practice, observations are imperfect, and statistical correction techniques must be used to allow for the difficulty of correctly detecting and identifying birds at a distance.

The technique described in this trial report seeks to overcome many of these limitations by deploying a High Definition video system from a helicopter. The camera is gyroscopically stabilised, so that long focal length (high magnification) lenses can be employed, without the aircraft vibrations causing image degradation. This in turn enables the helicopter to fly at altitudes in excess of 1km, effectively eliminating any disturbance of the birds.

Additionally, the HD recorder is equipped with a GPS receiver, enabling precise location, date, time, and velocity and a reasonably precise measure of altitude[1] to be embedded in each frame. This makes the raw video a fully self contained archive of the survey, so that the data can be retained and re-evaluated at any time following the survey.

2.1 Survey Protocol

A range of survey protocols were considered. The camera stabilisation mount has tilt, pan and roll functions, enabling full control over the camera field of view from within the helicopter. A survey area can therefore be covered either by physically moving the helicopter over the area with the camera fixed, by keeping the helicopter stationary while sweeping the area with the camera, or by some combination of the two. Dry runs (unrecorded) of three possible survey techniques were made to assess their practicality. These were:

Camera fixed straight down (or with slight inclination) while helicopter flies straight transects at 100 knots.

Camera sweeps from side to side while helicopter flies straight transects at 100 knots.

Helicopter hovers while camera sweeps out a rectangular area directly beneath the helicopter using both pan and tilt functions.

The two characteristics of interest for these survey techniques are coverage rate, the area of sea surveyed per unit time, and reliability, the extent to which the technique is repeatable, essentially determined by simplicity.

The stationary helicopter technique is hard to apply in practice, partly because the pan-tilt controls make sweeping a regular grid with the camera difficult, and because the range of viewing angles introduces problems with focus and glare on bright days.

The combination technique of ‘nodding’ the camera from left to right while flying forward at a reduced speed was found to be more usable than the stationary helicopter technique, but significantly more difficult to control than the stationary camera technique. The slower speed of

[1] The accuracy of GPS for altitude is significantly less than that of horizontal measurements, nominally around 100 ft in good conditions. Nevertheless, GPS and barometric altitude were found to agree closely throughout this survey, and the GPS altitude of the landing site agreed exactly with the OS height above sea level, suggesting that a clear view of well position satellites was available during this survey.

the helicopter also makes maintaining approximately constant velocity more difficult. Nevertheless, this technique has some advantages in terms of consistency of coverage, which will be described in more detail later.

The fixed camera technique is simplest as it minimises the effort needed to control the camera, and generally results in higher quality images since it reduces the need to adapt focus. When flying at 100 knots with a sufficiently high magnification to enable recognition of smaller birds, and a video frame rate of 24 frames per second, any given point will only appear in around 10 frames, i.e. less than half a second of video. Despite the brevity of each bird sighting, it was found that these ten frames were typically sufficient to provide a strong impression of bird behaviour, or to enable recognition of wing motion during flight. Therefore, it is considered that this technique achieves the maximum feasible frame rate and therefore the maximum coverage rate.

2.3 Survey Specification

The trial survey was undertaken at St. Bees, West Cumbria, on the 6th of August 2007. The time and location were selected to ensure that a variety of birds would be present, providing a challenge to the system representative of a variety of environments that might be found in the vicinity of windfarm sites. The fixed camera technique described above was adopted and the survey area was sampled along eight parallel transects, running from West to East. Each transect was between 3 and 4 kilometres long, with 500m separation between transects. These transects are considerably closer together than might be used for a conventional plane based survey, as the visible width of each transect is reduced. This is due to the narrow field of view of a camera relative to a human observer who is able to take in most of a scene.

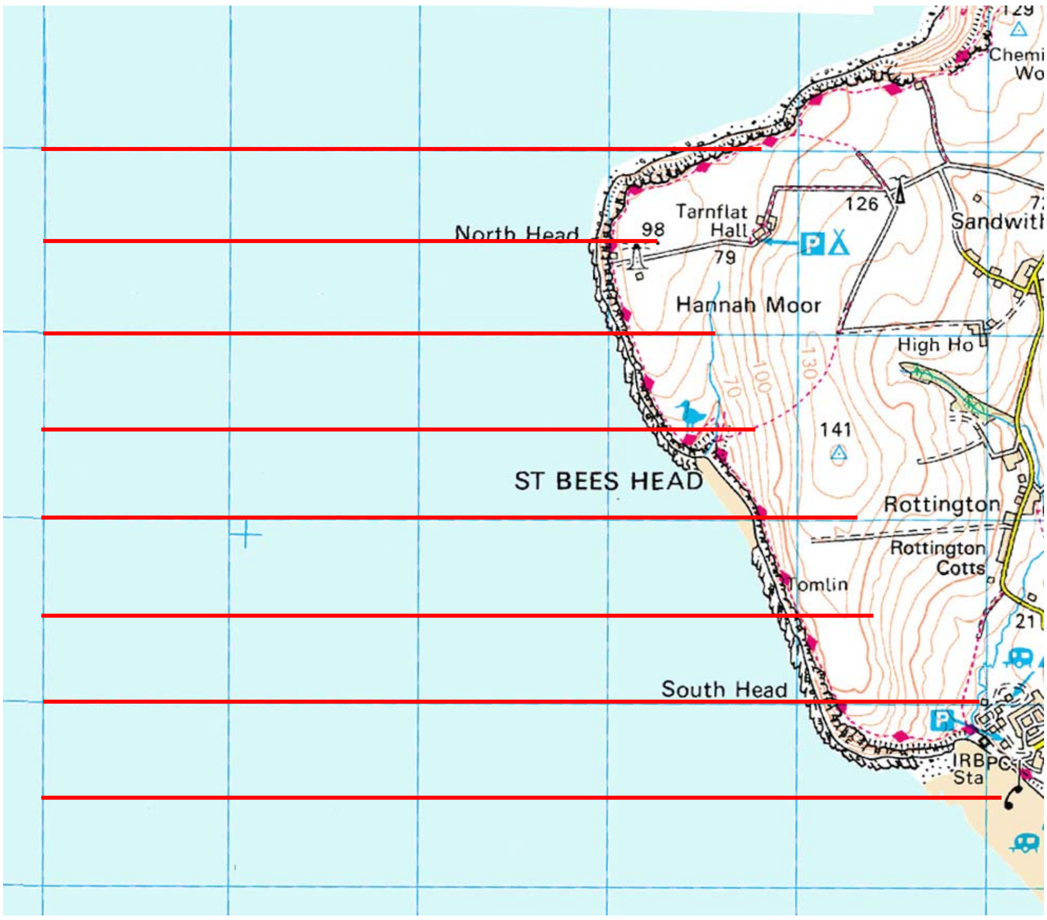

Figure 1 – Survey transects (red) superimposed on map of St. Bees head (1km grid). © Crown copyright 2006. All rights reserved. Licence number WL10221.

3. Data Gathering

3.1 Helicopter Performance

A GPS unit was used to guide the helicopter. The start and end points of each transect were loaded into the GPS unit as waypoints. To minimise manoeuvring time, the direction of flight on each transect was alternated. Figure 2 shows the plan projection of the track followed by the helicopter during the survey.

The survey took approximately 30 minutes to complete, giving a coverage rate of approximately 20 sq. km per hour. Parameters such as altitude and magnification were varied between runs, in order to identify the best settings, and one additional North-South transect was performed; these experimental aspects significantly increased the duration of the survey. Note also that the length of the GPS track corresponding to manoeuvring at the end of each transect varies between 3 and four kilometres. Since manoeuvring is also slower, the overheads associated with manoeuvring for small survey areas actually dominate the length (and therefore the cost) of the survey.

Weather conditions during the trial were quite challenging; the wind speed was higher than preferred for sea bird surveys, at around Force 5. A large number of white horses were present, with significant patches of foam, making detection of birds challenging. Large patches of broken cloud with bases varying from 2500ft to 3000ft effectively prevented higher altitude transects and resulted in a mix of bright sun and shade. The white horses and foam were easy to distinguish from birds during playback, and are not considered to present a major challenge; direct sun, however, may present a challenge for certain camera orientations, but could be avoided simply by altering either camera orientation or transect orientation.

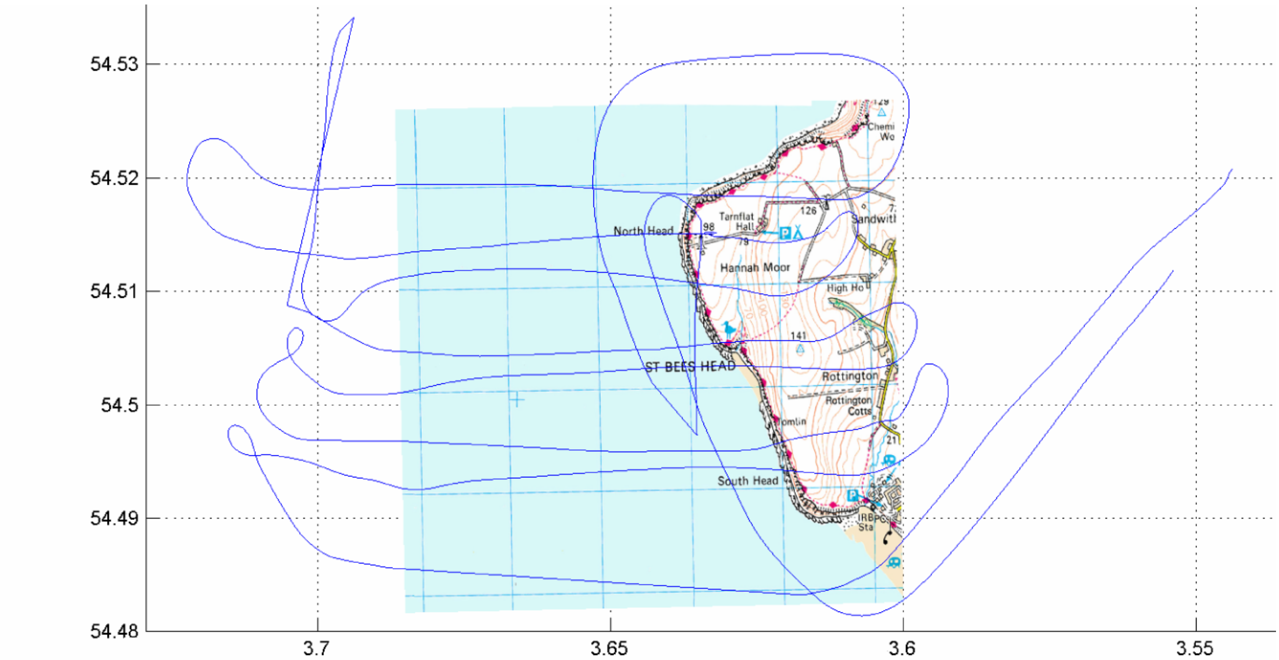

Figure 2 – Plan projection of helicopter path during survey onto map of the survey area. Coordinates are degree latitude / longitude. Note that the vertical travel during manoeuvring between transects 5 & 6 was an experiment with North-South Transects; data gathered on this transect has not been used in the trial.

In practice, the same survey could be carried out in significantly less time, if parameters were kept constant and longer transects were flown, decreasing the proportion of time spent manoeuvring. Speed over the water during the survey averaged at 180kph when travelling from West to East and 126kph when travelling East to West (the difference is due to on-shore wind-speed), giving a mean speed of 153kph. Average manoeuvring time was a little over two minutes. These figures can be used to estimate survey times for larger grids. For example, a 10km by 5km grid sampled at the same density used in the survey would require five manoeuvres, taking 10 minutes, and a total length of 50 km, taking 30 minutes to cover. The total time required to cover this 50 square kilometre area is therefore 40 minutes, giving a coverage rate of 75 square kilometres per hour. The efficiency increased even further for longer transects. The proportion of the survey area that is actually imaged with the fixed camera technique is approximately 6%, which is half the proportion that is accurately observed during conventional aerial surveys (Ref. 1). It may therefore be appropriate in future to reduce transect separation to raise the proportion of area imaged. Another option for future surveys would be the use of a super-high-definition camera, which is discussed in detail in Section 6.

Some difficulty was experienced keeping the helicopter on-track between way points. Figure 2 shows that pairs of tracks appear to be 'squeezed' together. This is partly due to the effects of rounding lat/long coordinates of waypoints to facilitate entry into the GPS system, but has been exacerbated by deviation of the helicopter from the GPS transects. This may be due to the wind strength and direction or other factors. Although this is not a fundamental problem for this survey, more even coverage would be preferable, and it is expected that the problem would be worse for longer transects. It is therefore proposed that future surveys should use multiple waypoints on each transect, at around a 1km separation, or other GPS navigational aids to maintain position control.

3.2 Performance of Video Equipment

The video system comprises two main components: the camera itself, mounted in a gyroscopically stabilised gimbals; and the recorder system comprising a digital recorder capable of storing uncompressed (highest quality) full contrast depth video, and a backup digital tape recorder, capable of recording a greater quantity of compressed, reduced contrast video. The camera gimbals is mounted in front of the cockpit and has an almost completely unrestricted view of the sea.

3.2.1 Recording and Exposure

Although all items of equipment have been extensively field tested, an equipment fault prevented the use of the digital recorder. As result a slight reduction in video quality was caused. In particular a reduction in dynamic range (contrast) was caused resulting in some difficulties balancing the contrast of the recorded images. This fault was coincidental and was not caused as a result of the survey.

Nevertheless, the digital tape recorder was found to have an acceptable image quality for the application. The most significant difficulty was with image contrast; as a result of the loss of contrast in the signal, the decision was taken to set the exposure such that full use was made of the available contrast range. It is was not possible to find a stationary bird to set the contrast, so open water was used as a guide instead; unfortunately, the relative brightness of white plumage was underestimated by this technique, resulting in overexposure and resulting loss of detail for many birds. In future, it would be preferable to err on the side of caution and risk under-exposure, rather than lose major details through over-exposure. This would be facilitated by use of the digital recorder, as the greater colour depth minimises the side effects of under-exposure.

3.2.2 Camera Orientation

The main difficulty found when operating the equipment is that it is much harder to read the visual cues that indicate the orientation of the camera. This is partly due to the fact that the sea is relatively featureless, but the most significant source of difficulty is the speed of the image through the frame; any given point will typically be on screen for around half a second. This makes orientation and interpretation of the moving image in real time extremely difficult (although it is straightforward when reviewing the data in slow-motion). As a result of this, the camera was occasionally found to be pointing off-transect, resulting in image location errors. To overcome this issue in future surveys, HiDef are developing a system to provide a visual indication of camera position, facilitating camera control, and a position logger to enable accurate location of all images regardless of camera pose.

After exposure, the next most significant characteristics affecting image quality were motion blur and focus. The worst motion blur observed was relatively minor and only occurred when travelling at very high speeds. However, it would be preferable in future to use 1/1000 second exposure time rather than 1/500 second as used in this trial; as contrast also needs to be reduced, there is no-image quality penalty with the shorter exposure time. Focus control is affected by the same problems that complicate orientation control. To make focus easier, it is recommended that in future each transect begin with a near hover to enable initial set up of focus and orientation. Focus problems can also be alleviated by maximising depth of focus; this can be achieved either by decreasing altitude and lens focal length together or by decreasing aperture. For future surveys, it is recommended that a shorter lens be used and that the survey altitude be restricted to the lower ranges (see the following section for a discussion of altitude). This increases the depth of field, facilitating focus, reduces atmospheric hazing, and reduces image location errors. Although a large amount of light was available during the survey, it would be possible to achieve the desired exposure time in significantly lower light conditions by increasing the aperture at the expense of depth of field; using the shorter lens also increases the feasibility of lower light applications.

The focal length required at a given height is determined by the visibility of the birds: the ideal focal length is the shortest (lowest magnification) that provides sufficient detail to recognise all observed birds. This was set empirically during the survey; on review of the data, it was possible to calculate the width of the image

In summary the specific recommendations for improving data quality identified as a result of this trial are as follows:

- Use an exposure time of 1/1000 sec or less, to minimise motion blur.
- Use full colour depth, uncompressed recording to maintain quality and maximise leeway with contrast setting.
- Use a slightly lower than necessary contrast setting, as birds are often brighter than their surroundings.
- Fly at 400m altitude or as the low as altitude possible without disturbing the birds, to enable use of shorter focal length lenses.
- Log camera attitude, and provide visual indicators to facilitate camera control.

4. Impact on Birds

Helicopter altitude was gradually increased throughout the survey, in order to provide data to optimise future surveys. The altitude was held approximately constant on each transects, but increased in steps of between 100 and 200 metres between transects. The lowest altitude flown was around 400m, and the highest was over 1km.

Although assessment of the impact on birds from the helicopter itself is difficult, there was no indication that the birds were affected by its presence. A large proportion of the observed birds were sitting rather than flying, suggesting that they were comfortable with the presence of the helicopter immediately above. Indeed, no change in bird behaviour was observed, either from the video, or by visual inspection from the cockpit. Due to the limited size of this trial, this needs to be tested on more volatile species during winter, as the species present during the summer and post-breeding season are not particularly prone to disturbance. However, it is also worth noting that this system has been used extensively for wildlife filming, including seabirds, specifically because it has a well established track record of being able to film from a sufficient distance to avoid disturbance of sensitive species.

The prevalent view of the use of helicopters for surveys of seabirds is that the increased noise and downdrafts, when compared with a plane, are highly disturbing to the birds. It would appear that the discrepancy between this view and the experience gained during this trial is due to altitude. Conventional survey techniques relying on visual observation typically use altitudes of around 80m (Ref. 1), which is at most 20% of the altitude used in this survey, and as little as

8% of the highest altitude used. As noise and down draft drop off rapidly with distance, the amplitude of sound reaching the ground from a craft at 1km altitude will be less than 1% of the amplitude experienced from the same vehicle travelling at 80m. The disturbance of a helicopter at 1km altitude should therefore be expected to be significantly lower than of a plane at 80m.

5. Data Analysis

A total of 35 minutes of footage was recorded. This included time spent manoeuvring and setting up equipment, which could not be used for survey purposes due to either insufficient detail or uncertain camera direction. Of the remaining footage, 11½ minutes corresponds to the transects, and was used as the basis for analysis of the performance of the technique. An additional 1 minute and 20 seconds was shot over the cliff, to increase the total number of birds seen, to provide an additional test of the image quality.

The image data gathered during the trial amounts to a total of 88 Gb of video, using a high quality data compression package. Although this is a large quantity of data by current standards (it would take approximately 19 DVD's to store), digital tape based data archive systems are already able to accommodate up to 800Gb per tape, enabling each tape to hold around four hours of survey data.

5.1 Bird Detection and Location

The first stage in the processing was initial review of the footage to identify frames with individual birds, which were then passed to an expert[2] for identification. The video was played back slower than real-time, but fast enough to clearly see the motion of objects within the frame. Airborne birds were immediately obvious due their movement against the background. Sitting birds were harder to detect, but were detectable by their colouration and the fact their appearance does not change across several frames, while wave features do; this demonstrates significant value in using video, rather than still images, to survey seabirds over water. Several extraneous objects were also observed, both organic and man-made, and in all cases were easy to distinguish from birds. It was generally also possible to classify these objects as either natural or man-made, suggesting that this technique can also be used to monitor aspects of human impact on the marine environment.

This phase of the survey is actually the most time consuming; because the data has to be viewed at less than real time, each minute of footage can take as long as five minutes to search through. However, it should be emphasised that this task can be carried out by a technician with no special training. It is hoped in future that this component of the survey can be dramatically accelerated in future by using automated search algorithms to rule out most of the frames showing open water, leaving only a few to be checked manually.

An observation time and location were associated with each detected bird by recording the GPS time and location of the frame in which the bird appeared closest to the centre of the frame. These locations are shown if Figure 3; each dot represents the location of the helicopter at the moment a bird passed through the field of view of the camera. For clarity, groups of birds spotted simultaneously are denoted by single dots.

As discussed in Section 3.3, the nature of the survey made control of camera orientation difficult. However, as camera orientation was held constant during each transect, it was possible to infer the camera orientation from the location of the inland features captured at the beginning or end of each transect. This information was then combined with the GPS helicopter location to infer the physical location of the patch of sea shown in each frame. In the case of transects where the camera was pointed ahead of the helicopter, it was found that the difference between helicopter location and frame location was as much as 1km. The ability to observe birds at a significant distance ahead of the helicopter further reduces the risk of bird disturbance, when compared with visual surveys in which the birds are not seen until in the immediate vicinity of the aircraft.

[2] Brian Little, MBE

Figure 4 shows the bird locations corresponding to the helicopter locations shown in Figure 3, generated using the positional correction method described above. Note that the overall effect of the corrections is to cluster the birds more tightly around the headland than would have been inferred from helicopter location alone. This is compatible with casual visual observations made during the survey.

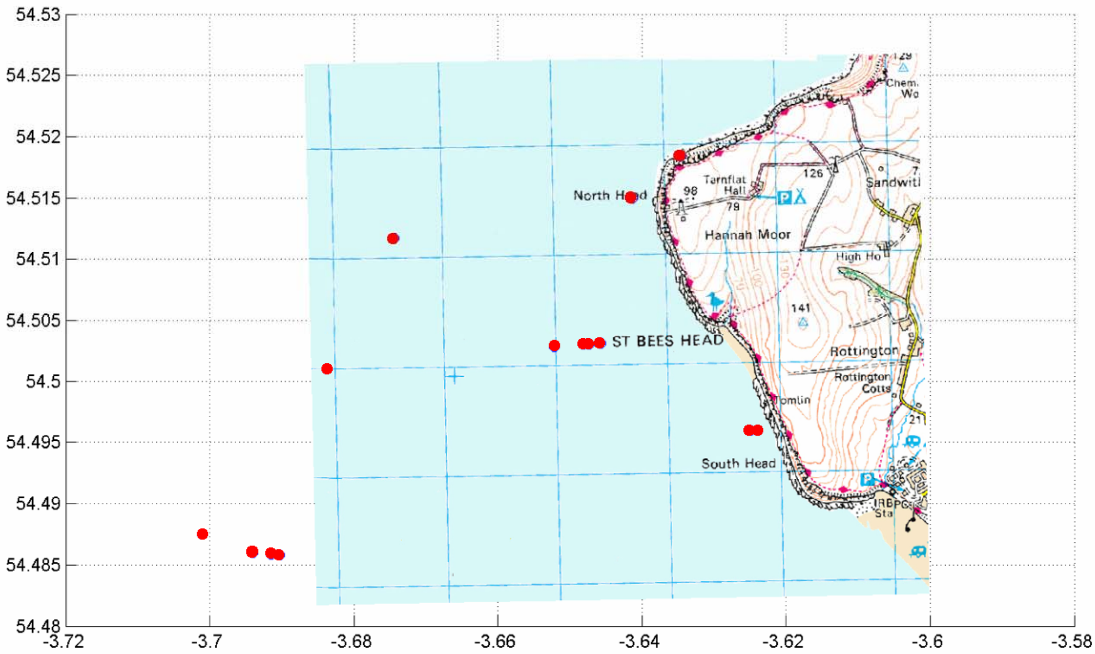

Figure 3 – Helicopter location (red dots) at times of bird detection. Some circles correspond to multiple detections.

The technique described above relies on the assumption that the camera orientation is constant on each transects, and requires visual features of known location to work. Neither of these will be the case for long transects over open water, and it is therefore considered essential for validity of the results of future surveys that the camera orientation logging equipment proposed in Section 3.3 be adopted.

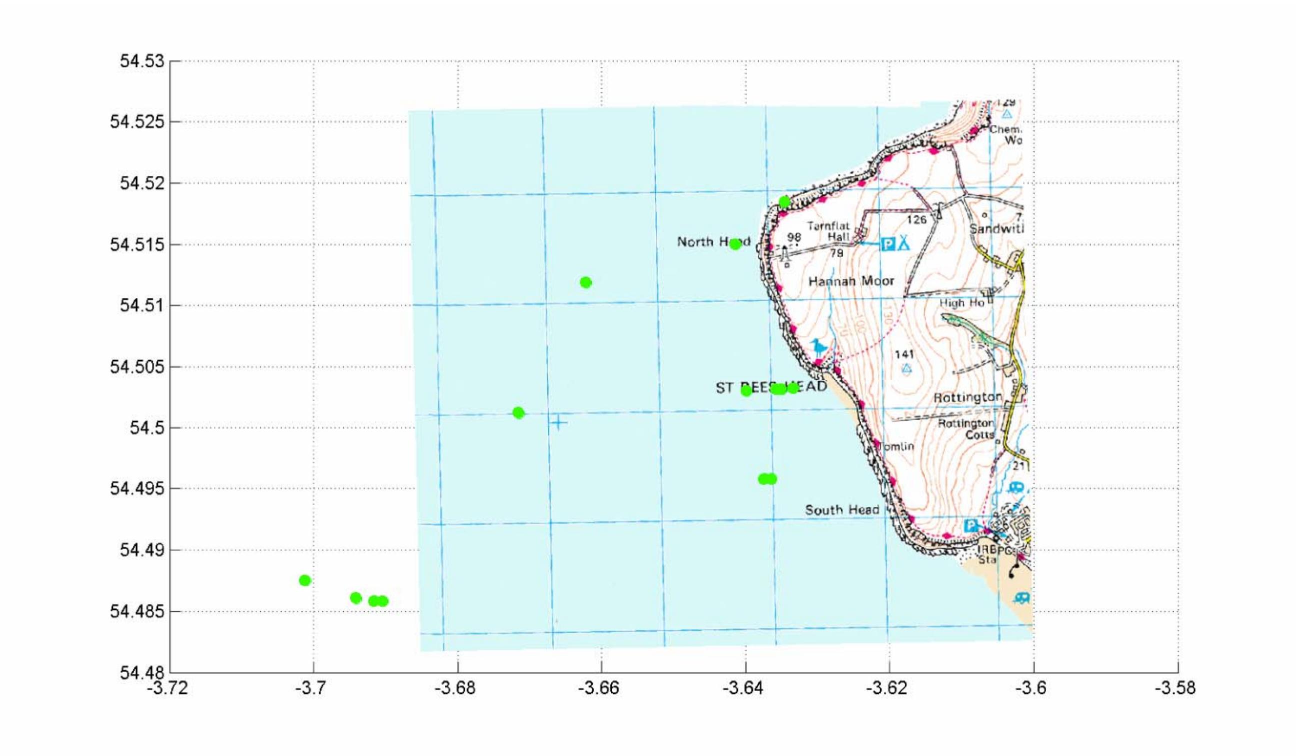

Figure 4 – Inferred bird locations (green dots). © Crown copyright 2006. All rights reserved. Licence number WL10221.

5.2 Bird Classification

The frames containing birds were reviewed by an experienced ornithologist to formally identify the species of each bird. In general, despite the significant loss of image quality due to the technical difficulties described in section 3.3, birds were able to be identified with a high degree of confidence. Birds observed in flight were particularly easy to identify, as each bird is in the frame for long enough to enable the 'shape' of its wing-beats to be recognized. Sitting birds were generally harder to classify. Additionally, it has also been possible to estimate the size of each bird by comparing the known GPS velocity to the apparent velocity through the frame of the video. However, this technique is dependent on knowledge of the orientation of the camera, and must therefore be treated with some caution for the purposes of this trial. Future work will focus on validating and improving the robustness of this technique.

The survey over open water identified four groups of birds: auks (probably guillemots), gannets, kittiwakes, and herring gulls. In addition, a sweep over the cliff itself captured a single shag. Figure 5 shows the spatial distribution of identified birds; the survey provides sufficient information to identify patterns of behaviour, such as the concentration of gulls around the colonies at St. Bees North Head, and the clustering of Guillemots approximately four kilometres out from the South Head. The ability to recognise individuals from each of these species is discussed in detail below.

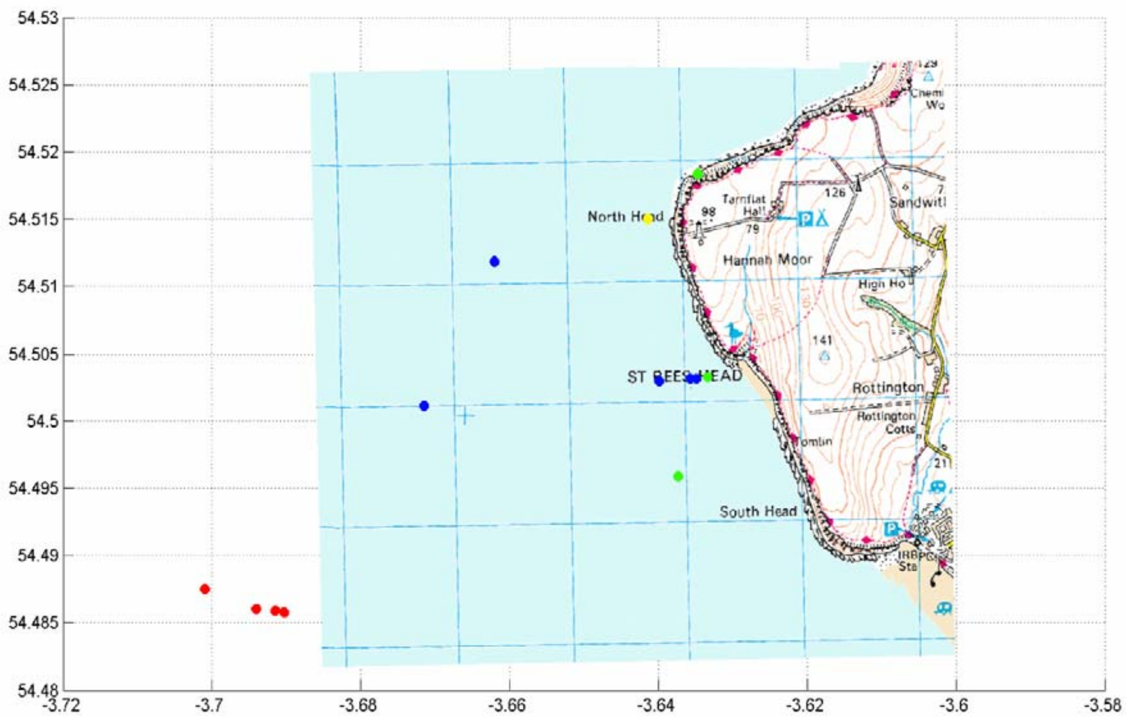

Figure 7 – Spatial locations of birds by type, showing strong spatial clustering compatible with expected bird behaviour. Red circles: Guillemots. Blue circles: Kittiwakes. Green circles: Herring Gulls. Yellow circle: Gannets.

Auks:

A total of eleven auks were observed during the trial, all of them sitting on the water within a small area of sea. Ten appeared to be grouped in pairs; Figure 6 shows an indicative frame containing two pairs of auks. Overexposure of the images destroyed a lot of detail that could have been potentially useful for identification, particularly plumage colour which would give greater confidence in differentiation between razorbills and guillemots. Nevertheless, plumage coloration on some of the individuals suggested that they were guillemots rather than razorbills. In each pair, one individual appeared lighter than the other, suggesting that these are immature guillemots protected by the male parent. The birds were measured using the velocity comparison technique, and found to be of the order of 35cm length, which is compatible with guillemots and razorbills, and suggests that they are not smaller auks, i.e. puffins.

Figure 6 – A challenging image. This frame contains two pairs of auks, highlighted with red ellipses. The yellow line under each pair represents 1m, estimated using image velocity. Individual birds are therefore approximately 35 cm long, tail to head.

Gannets:

A single group of three gannets were briefly observed flying in close proximity to each other. The group passed through one corner of the frame, so the possibility that there were more than three birds in the group cannot be ruled out. As the largest birds that would be expected in a survey over British waters, gannets are relatively easy targets to identify. The black wingtips are clearly defined and the mode of flight and silhouette are easily recognised.

Gulls

Both kittiwakes and herring gulls were observed during the trial, along with an airborne bird that was probably a juvenile herring gull, but may possibly have been a lesser black-backed gull, and a sitting bird that was probably a herring gull but may also have been a Fulmar Petrel. Airborne kittiwakes and herring gulls were easily distinguished by their size and wing movements and in some cases by colour of their wingtips. Image quality of gulls was often poor due to over-exposure and motion blur; however, firm identification was nevertheless possible in the majority of cases, and it is anticipated that the technical solutions for these problems, described in section 3.3, would significantly improve the data quality. Indeed, the footage taken over the cliff, which is well focussed and exposed, shows a dramatic increase in image quality. Figure 8 shows a comparison between a typical image of a gull over water, compared with one from the immediate vicinity of the cliff. Both images have been blown up to the same extent; despite the fact that the gull near the cliff was smaller in the image, due to a wider lens setting, the level of detail is considerably better, as a result of the increased ease of focussing and exposure setting, near to the static landmarks of the cliff. Nevertheless, this image still shows compression artefacts, and it is anticipated that further improvements in quality are possible.

Figure 7 – a still frame showing three gannets (lower right corner), one almost completely off frame. In addition to their location, it is also possible to infer direction of flight; in this case, approximately NE, parallel with the coast.

Figure 8 – comparison of still images of gulls. Left: a gull image taken over open water, affected by poor focus, overexposure and motion blur. Right: a gull image taken in the immediate proximity of the cliff; note that, although smaller on frame, this image is significantly more detailed. In both cases, however, identification was possible.

Shags

A single shag was observed during the pass over the cliffs. This bird was immediately recognisable as either a cormorant or a shag. The discriminating between cormorants and shags is possible on the basis of overall size and the shape of the neck. Note that there is sufficient detail to pick out the birds feet in this image.

Figure 9 – A shag observed in close proximity to the cliff. Its size and shape, particularly of its neck, enable it to be differentiated from the similar cormorant.

5.3 Statistical Analysis

In principle, the survey technique employed in this trial provides all necessary information to undertake statistical analysis of the spatial distribution of birds by type. This essentially consists of a map of all locations observed and locations for each bird identified. This in turn enables application of a wide range of statistical tools.

The key technical challenge is accurately establishing the width of the field of view of the camera. This is complicated in the present survey, by the fact that the camera orientation is unknown and can only be roughly estimated, and that camera roll sometimes prevents the full frame width from being utilised. These have been estimated for a number of isolated instants in the present analysis using the cliff edge based camera angle estimate and image velocity length estimate techniques described above. In all cases, the frame width was found to be between approximately 30 and 34m.

An example analysis was undertaken, based on the assumption that the frame width was 32m at all times and that the effects of roll are negligible. A kernel regression technique (Ref. 2) was then used to estimate the density of Guillemots and Kittiwakes; a Gaussian kernel of approximately 1km width (s.d. of 400m) was used (i.e. sufficiently large to straddle two neighbouring transects). The resulting estimated distributions are shown in Figure 10. The estimated peak density of Guillemots was 303 birds per sq. km, while the peak density of Kittiwakes was 43 birds per sq. km. These results can easily be verified by hand calculation; for example, the 11 Guillemots observed all occur within a 1km strip 32m wide, i.e. an area of 0.032 square km. Dividing 11 by 0.032 yields a density estimate of 343 birds per sq. km. This analysis is effectively equivalent to normal distance sampling in the trivial case of a known distance-detection function (i.e. 100% detection within a certain distance of the transect and nothing beyond).

In principle, these maps can be used to estimate the total number of birds present. In the present case, the estimates are 88 Kittiwakes and 707 Guillemots. While the number of Kittiwakes may be plausible, the number of Guillemots certainly seems high – the likely reason for this is that the cluster of birds is significantly smaller than the separation between tracks, so that the likely size of the cluster is over-estimated. This is reflected in relatively high uncertainties for the figures. The appropriate way to avoid this would be to reduce transect separation where tight clusters of birds are anticipated.

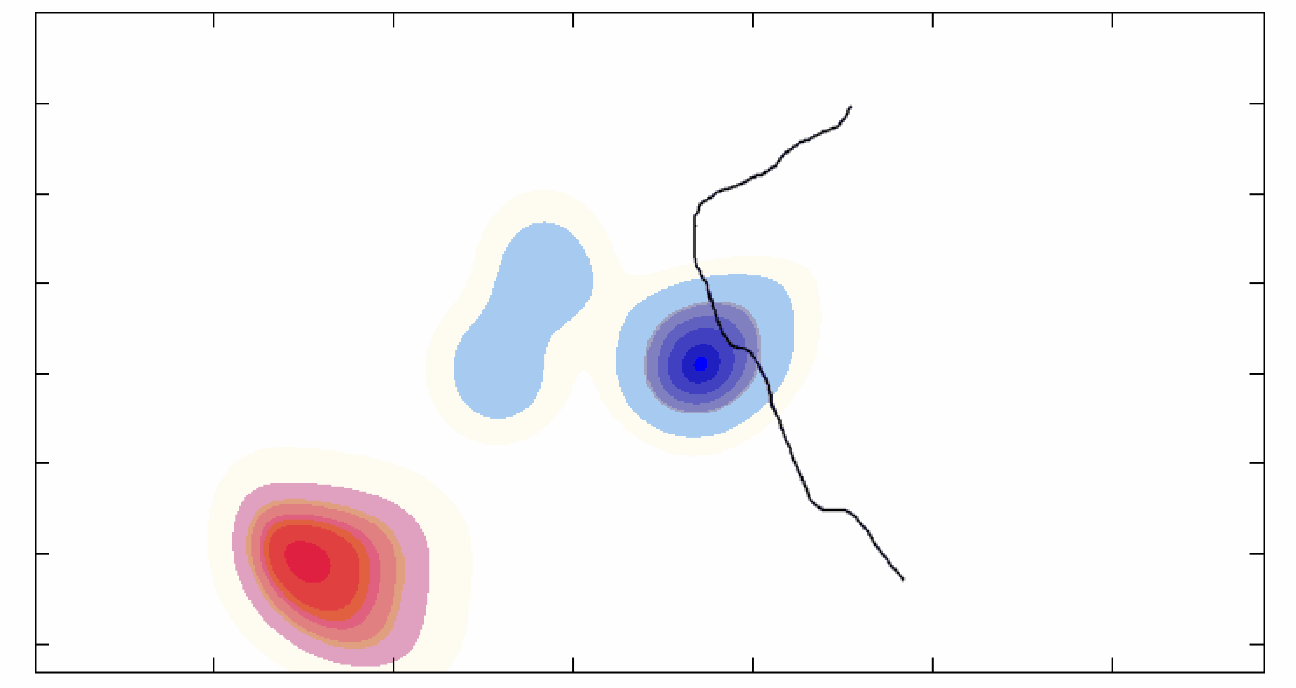

Figure 10 – Estimated densities of Guillemots (red) and Kittiwakes, superimposed on the profile of the headland. Saturated red would correspond to a local density of 350 Guillemots per square kilometre, while saturated blue would correspond to a local density of 50 Kittiwakes per square kilometres.

6. Discussion

A single limited-scope trial of a high definition video survey technique for seabird census has been undertaken. The trial surveyed a 12 sq km area of sea of St. Bees head in Cumbria, on the 6th of August 2007, where a variety of seabirds were anticipated to be present. The following general findings have been made:

The system provides sufficient detail to enable reliable identification of birds in most cases.

Altitudes in excess of 1km are feasible; cloud-base would typically be the limiting factor.

Although this survey was not carried out over an existing windfarm, the altitude and image quality demonstrate that it could be directly applicable to windfarm survey.

Despite higher wind speeds than would be tolerated on a conventional survey, it was possible to conclude that all birds had been observed on most transects with a high degree of confidence.

To ensure recognition of smaller species, image width must be fixed at around 30m.

Transects must therefore be significantly closer than is the case during conventional surveys.

Some difficulties were encountered in operating the video equipment in the manner required by the trial and an approach that minimises these effects has been identified.

Technical refinements to improve quality and reduce cost have been identified, which it may be appropriate to test in a second survey.

Despite several respects in which the quality of the video could have been improved, a significant number of birds of several different species were detected and successfully identified. It is therefore considered that the trial has demonstrated the feasibility of the technique as a practical tool for surveys.

Although more thorough testing on sensitive species is required, the experience gained during this trial supports the hypothesis that a relatively high-flying helicopter does not disturb seabirds. It should also be noted that if disturbance of birds remains an issue, there is still significant scope for reducing impact, either by use of a plane or by increase in altitude to the theoretical maximum of 1 mile. The video quality in this survey was found to be sufficient to assess bird behaviour, including direction of flight, while bird wing motion provides a strong cue for identification that would not be available in still image surveys.

The coverage rate achieved during the survey was 20 sq. km per hour. The coverage rate has been found to increase with longer transects, with significantly coverage rates in excess of 70 sq. km per hour feasible for larger survey areas. However, future surveys would also benefit from increased sampling density, potentially reducing coverage rate. Where significant areas must be covered, significant cost savings can be made by employing a plane, increasing speed and by using super high definition video equipment enabling doubling of the transect width to around 60m.

The reduction in video quality experienced during the survey was due partly to equipment malfunction, but the most significant impact was the difficulty of manipulating the equipment. It is anticipated that the measures described in Section 3.3 will make a substantial improvement in data quality in future trials.

There are numerous technical refinements of the technique which can be envisaged. Accurate logging of camera direction will potentially enable better measurements; in addition to size, flight direction, velocity and height above water might also be estimated from the parallax effect. Perhaps the most promising innovation for large surveys would be an automatic bird detection system to accelerate the data review process; combined with plane-deployed super-high-definition video, this could result is substantially reduced survey costs and programmes.

6.1 Comparison with Existing Techniques

A detailed comparison with other surveys is not possible at this stage in the development of the technique, as a typical windfarm site survey will differ from the present trial in respect of the area to be surveyed and the number and species of birds present. Nevertheless, certain general comparisons can be made, particularly with plane based surveys.

One of the most significant points of comparison is survey cost; this is largely determined by survey duration, and is therefore well represented by coverage rate. As discussed in Section 3.1, coverage rate is determined by airspeed & manoeuvring time, features of the aircraft, and transect separation, a feature of the technique.

Helicopter airspeeds of up to 180 km/hr were found to be workable in the present trial, which are directly comparable to typical aircraft speeds (Ref. 1). The maximum speed achievable with a helicopter survey is 220 km/hr; this was not tested during this trial, but is expected to be feasible without a significant reduction in quality, particularly if higher frame rates are used. It is expected that manoeuvring time is significantly less for helicopters than planes, due to their significantly greater agility. This may be a significant benefit for small survey area, e.g. within a windfarm footprint, as a significant proportion of time is spent manoeuvring. In the future it may be possible to increase airspeed by using Super-HD to increase the number of pixels in the image; if the depth of a frame were ~2500 pixels rather than ~1000 pixels, a bird would stay in-frame for over twice as long for a given speed or, conversely, would be in-frame for an equal amount of time if the airspeed were doubled. The limitations to this approach with the present technique are that helicopters cannot achieve the necessary speed, and that very short exposures would be required to prevent motion blur.

The second factor influencing coverage rate is the distance between transects. The determining factor in deciding transect separation is the desired confidence interval in the population density estimates resulting from the survey. Clearly, improved confidence is always desirable, but for the purposes of this report we are only concerned with the relative confidences of the video and conventional survey approaches. The confidence interval of the video technique is driven purely by the number of birds observed, with confidence increasing as the number of observations, and therefore the number of transects increase.

Conventional surveys employ distance sampling techniques to account for missed birds at some distance from the aircraft (Ref. 3); these techniques assume that all birds within a certain distance of the aircraft are observed, and use the count in this ‘fully-observed’ region to estimate the number of birds that were missed in other regions. The confidence of the distance sampling estimates also increase with increasing numbers of observations; the ability to spot birds outside the central ‘fully-observed’ counting band therefore adds confidence. However, as fewer birds are detected in these bands, the increase in confidence is not as good as would be achieved by undertaking an exhaustive fully-observed survey, and it would therefore be incorrect to assert that conventional surveys achieve 100% coverage in a statistically meaningful sense. Furthermore, the confidence in conventional survey results is reduced by estimating uncertainties associated with the detection probability function and clustering probability functions (Ref. 3); these counteract some of the benefits gained from counting birds outside of the fully-observed strip, further reducing the effective coverage of the survey.

The result of these effects is that, while the confidence in a particular survey can be estimated, it is hard to say *a priori* what survey parameters should be used to obtain equivalence in confidence between the two survey techniques, as confidence is effected by the performance of the technique on the day (e.g. visibility, sea state) and by the actual density of birds; future work will attempt to address this issue through consideration of real datasets.

A potentially more fundamental limit of the accuracy of the distance sampling techniques, however, is the reliance on the assumption that no birds are missed within the central ‘fully observed’ strip. If this assumption is not accurate, the resulting error in the number of birds observed in the central strip is propagated to the other strips, resulting in underestimation of the bird population. This does not affect the confidence estimate, which is also based on the assumption of perfect observation, and so confidence estimates can be misleading in circumstances where birds in the central band are missed. Although a quantitative measure of the count rate in the central strip is challenging, anecdotal evidence from observers suggest that confidence in achieving 100% for some species in some conditions is low (Ref. 4). It is a significant advantage of the video technique that it removes time pressure from the observer, enabling careful detection and identification of small and/or cryptic birds.

Although it is not possible to define a video survey technique that will always match the confidence of a given distance sampling technique, on consideration of the above it is possible to say that the performance of distance sampling techniques is likely to be dominated by the performance of detection in the central band. We therefore propose to adopt the rule of thumb that the coverage of a video survey should be at least equal to the coverage of the ‘fully-observed’ region in a conventional survey – typically 12% (Ref. 1). With the standard HD camera equipment used in this trial, the width of the image is significantly narrower than the fully observed view band from a conventional survey (30m and 240m respectively); This results in a need for around eight times as many transects to cover a given area. The density used in this trial was only around four times as great as that used in a conventional survey, hence the recommendation to further reduce transect separation to 250m. As transects get close to each other, the care taken when controlling the helicopter course must increase, to prevent transect overlap. It is possible using GPS data to identify any transects that do come too close to each other and eliminate these sections; the cost of transect overlap is therefore a loss of data, rather than statistical invalidity.

In order to reduce the cost, it is recommended that the camera should be mounted on a plane for larger surveys, and that super-high definition cameras are used to give a strip width of around 75m. As discussed above, the air speed could also be significantly increased: in the best case, the overall coverage rate would rise by a factor of 6 as a result of the combined effects of increasing strip width and airspeed, bringing the airtime and associated cost of video based surveys down to the approximately the same level as those of conventional surveys. There are also cost savings associated with the technique as a result of decreased manpower. The two ornithologists with specialist training required for conventional survey techniques are replaced by a single equipment-operator in the aircraft, while on the ground the straightforward bird detection task is performed by a technician, with a single ornithologist (with no additional training required) classifying the detected birds only, rather than the reviewing whole video. For sparse bird populations this results in a large reduction in effort on the part of the ornithologist.

The combined effects of the decreased transect separation and increased airframe-cost makes helicopter deployment of standard HD video more expensive than the method described above. However, the helicopter-mounted format remains a powerful tool for surveying small and/or inaccessible areas, such as windfarm footprints or cliffs, which cannot be reliably surveyed using conventional techniques.

Data quality should also be a deciding factor in selecting a survey technique. The robustness of the HD video technique to subjective errors has been demonstrated; the ability to replay video as desired and even seek second opinions where necessary eliminates the need to make snap decisions for difficult sightings. Furthermore, there is clearly scope to improve image quality in future surveys. Although not relevant to this trial, one advantage of the HD video approach is to count large numbers of birds very accurately, rather than relying on estimates which are liable both to be inaccurate and to vary between observers. Additionally, the ability to archive the video enables review of any aspect of the survey at any time, by any interested party. This is likely to prove a useful tool for convincing windfarm stakeholders of the validity of any trends observed across time. It is also important to gain a more accurate impression of bird behaviour due, in part, to the ability to observe the birds without disturbing them, but also due to the ability to measure properties such as direction of flight, which are very difficult for a human observer to assess from within a moving vehicle.

Finally, there are a variety of other practical advantages to the HD video technique. The technique is apparently applicable in a greater range of weather conditions; for example the breaking waves encountered in the trial did not represent a challenge, whereas it is recommended that plane surveys are not undertaken in these conditions (Ref. 1). There is no need for specialist training of ornithologists in survey protocol, and a significant portion of the task (bird detection) requires no special skills and may well be readily automated. Last, but not least, is the ability conferred by the relatively high altitude to survey directly over constructed windfarms without altering survey technique.

7. Recommendations

It is recommended that future high definition video trials adopt the survey strategy defined here, consisting of flying straight transects at between 250 and 500m separation, with a speed over water of approximately 150km/hr. Focal length should be selected to give an image width of approximately 30m. Technical recommendations for maintaining image quality are recorded in Section 3.3.

Although general comparisons may be drawn between the HD video survey technique and other techniques, it has not been possible to make a direct quantitative comparison, either in terms of quality, cost or duration, with a ship or plane based survey of an actual windfarm site. It is therefore recommended that a further trial be undertaken, consisting of duplication of a plane based survey to enable such a comparison to be made. In particular, it would be valuable to trial the technique within a windfarm, where problems with conventional plane based surveys may affect their validity. The trial time and location should also be selected to ensure the presence of some of the more sensitive species, such as wintering ducks and geese. Such a trial would also enable demonstration of the technical refinements identified as a result of the present trial. The potential to use super-high-definition equipment and/or a plane to perform the survey should also be investigated.

Finally, it is recommended that further investigative work be undertaken to assess the potential for automated video analysis to further decrease the cost, duration and subjectivity of surveys, and to increase the amount of data available on individual birds.

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