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Full Scale Trial of High Definition Video Survey for Offshore Windfarm Sites

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Executive Summary

Following from an initial investigation into the use of High Definition HD video for aerial waterbird survey undertaken in August 2007, this paper presents the findings of a full scale trial of the technique. The trial was carried out at the Shell Flats area off Blackpool, and aimed to satisfy five objectives. The outcome of this trial is assessed against its objectives as follows:

Demonstrate the ability of the technique to reliably survey the more sensitive species of waterbird, such as common scoter or red throated diver.

A large number of common scoter were encountered. When observed from 600m, the birds showed no signs of awareness of the aircraft. Indeed, Blackpool air traffic control notified the survey aircraft of several other aircraft in the vicinity at a similar altitude, and even required that the survey be halted at one point to make way for a large jet. If aircraft at this altitude disturb birds then a revision of survey methodology at areas near large airports would be required. When flying at 210m, the birds were clearly aware of the aircraft, but the vast majority remained on the water at the point of encounter. Only a very small number of birds were observed in the air or taking flight. It appears that if the survey altitude is kept at 270m or more, Scoter will not take flight as a result of the survey aircraft. It is therefore recommended that 270m be adopted in future as the minimum survey altitude.

Compare the output of the technique with data from other surveys to provide insight into the performance of the technique.

Some comparison has been made with historic data from the 2004/5 surveys undertaken for BERR (formerly the DTI) and with four datasets generated by WWT between 2004 and 2007. These show very good agreement in terms of the spatial distribution of birds, with the same key feeding locations and seasonal behaviours identified across all data sets. Comparison of overall population reveals that our estimated population (7000 birds) is somewhat less than those from the WWT surveys (15000-16000). However, this is not seen as a reason for concern, partly as there are good reasons to expect the estimate to be lower in our case, and also because the way in which we have analysed the WWT data is likely to be generating an over-estimate of the population. It is proposed that consistency of the data, the quality of the video and the relative statistical simplicity of our method, coupled with its intrinsic advantages for surveying built windfarms justify its use along side existing techniques as a mainstream tool for environmental data gathering and analysis.

To undertake a trial on a statistically significant scale, to demonstrate the consistency of the technique and the usefulness of the data.

An area of 226 sq. km has been surveyed at a coverage density of 12%. A total of 823 birds were observed, 785 of which were 'on transect' with a further 38 observed between transects. This provides a suitably large observed population for statistical analysis. The format of the data permits straightforward population and distribution analysis by well established statistical methods. A particular benefit is the ability to perform local rather than global statistical normalisation, which could potentially increase the power of local population variation analysis. While this is particularly relevant to species which form localised clusters around static features such as cockle beds, in principle the scale of analysis can be varied to suit the distribution and behaviour of any species. In particular, it will be relevant in the future to tune the scale of analysis to the scale of a given windfarm in order to assess the likelihood that a significant alteration in bird population and/or distribution has occurred. Investigation of the potential performance of such a technique will be explored further using methods comparable to those described in Ref. 8.

Demonstrate the feasibility of an aeroplane rather than a helicopter as the survey vehicle.

As expected, the aeroplane was well suited to the task, providing a more stable platform, a quieter more comfortable environment for the operators, using less fuel, and costing significantly less per hour (excluding international ferry flights). Unlike visual observer methods,

a large number of twin engine aircraft are suitable for this form of surveying, and can be put into service with only minor interior modifications.

To test the technical refinements proposed as a result of the first trial.

The recommended techniques for control of focus, image size and contrast were implemented and found to result in a significant improvement in video quality overall. In particular setting of contrast for bright whites rather than midtones was found to be highly beneficial. Control of focus still presents some difficulties over flat seas, and focus would preferably be capable of being fixed in a dedicated survey aircraft. Similarly, zoom and camera attitude could be locked without an adverse impact on the survey quality, which would considerably reduce the burden on the operator. Indeed, this would probably be a necessity for a multi-camera system controlled by a single operator.

The target image width of 30m metres identified during the first trial was found to be pessimistic; the increased image quality resulting from the other technical refinements was sufficient to enable an increase of image width to 40m while still maintaining an overall improvement in quality. This adjustment confers a 30% increase in coverage rate.

Glossary

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

Acronyms

HD – High Definition

JNCC – Joint Nature Conservation Committee

Units

1. Introduction

Windfarm developers are obliged by law to undertake pre and post-construction surveys of the seabird population at and in the vicinity of proposed windfarm sites. The two standard tools for these surveys are aerial and ship-based surveys (Ref. 1). Of these two, aerial surveys are the more affordable, although the data generated is generally less rich than that from boat based surveys, and provide the most suitable means for gathering contemporaneous data on a large area due the limited speed of boats.

In a previous COWRIE study (Ref. 2), HiDef Aerial Surveying Ltd. investigated the feasibility of applying high definition video technology to seabird surveys through a small scale trial. This trial demonstrated the technical feasibility of the process; however, it also identified several technical and environmental limitations with the system as trialled and proposed techniques for mitigating these. These issues were as follows:

Technical:

- Difficulty in setting and maintaining accurate focus during transect
- Overexposure of white and grey birds
- Difficulty in accurately maintaining a transect heading in a helicopter
- Lack of range of helicopter
- Loss of fine detail due to motion blur

Environmental:

- System not tested against the more sensitive species
- Location and limited physical scale of trial did not enable a view to be formed on the statistical quality of the data.

In order to address these limitations and provide confidence in the technique as a practical tool for windfarm survey, HiDef developed a specification for a more detailed trial in consultation with JNCC and the birds subgroup of the COWRIE Environment Technical Working Group. This trial was then implemented by HiDef, with funding from COWRIE’s R&D Budget. The objective of this report is to record and analyse the output from this trial.

1.1 Objectives

The objectives of the full scale trial were as follows:

- To demonstrate the ability of the technique to reliably survey the more sensitive species of waterbird, such as Common Scoter or red throated diver.
- To compare the output of the technique with data from other surveys to provide insight into the performance of the technique.
- To undertake a trial on a statistically significant scale, to demonstrate the consistency of the technique and the usefulness of the data.
- To test the technical refinements proposed as a result of the first trial.
- To demonstrate the feasibility of an aeroplane rather than a helicopter as the survey vehicle.

2. HD Video Aerial Survey Technique

The survey technique employed during this full scale trial was derived from the recommended technique identified as a result of the first trial. A description of the experience leading to the selection of this method can be found in Ref. 2. The following sections describe the technique applied and the specification of the survey, as implemented.

2.1 Equipment

Airframe

The aircraft selected for the trial was a Diamond DA-42 MPP multipurpose aerial survey plane. This aircraft is purpose built for aerial filming and survey applications, and was the only available platform capable of deploying high-definition video equipment similar to that used in the first trial.

The relevant variant of the DA-42 MPP is currently undergoing certification in Europe. As a result, only the pre-certification test aircraft itself was available for the trial, necessitating relocation of the plane from Austria to the UK and back again, immediately prior to and following the survey.

The DA-42 has numerous advantages over the helicopter used in the first trial: the overall cost of the plane for three days (1 day survey and 2 ferry flights) was comparable to the cost of the helicopter for a single day. The plane is significantly more stable in flight than the helicopter, providing greater pointing accuracy for the camera. Finally, the plane consumes significantly less fuel than a helicopter, conferring greater range and reducing the carbon footprint.

Figure 1 – The Diamond DA42 MPP test plane

Camera

The camera employed for this trial was a Cineflex gyroscopically stabilised HD media system, with very comparable performance to the Gyron system employed in the first trial. This permits completely free movement of the camera allowing any point beneath the horizon to be filmed. Figure 1 shows the camera system located on the nose of the aircraft. As with the Gyron, the system has not been designed to be held at a fixed orientation, and orientation control relies on user judgement, based on visual feedback from the video. The optical system within the Cineflex is identical to that in the Gyron, and the intrinsic image quality of the two systems is therefore identical.

Recording

Recording was onto digital tape, using essentially the same system employed during the first trial. The tape recorders use a high-quality data compression algorithm to increase the quantity of video that can be stored on each tape. Although this does result in a small loss of quality relative to the raw data, the previous survey had demonstrated that this was not significant enough to materially affect detection or recognition of the birds.

One of the recommendations of the previous trial was to use an uncompressed 10-bit format to maximise contrast head-room, and thereby minimise the risk of overexposure. While this may indeed provide

GPS

The on-board GPS navigation system was used to control the survey pattern. The system provides a large colour monitor displaying a live update of the planes location relative to the track line. This proved vastly superior to the waypoint system used in the first trial, resulting in an apparent position accuracy of the plane relative to the track of around 30m for much of the survey.

2.2 Survey Specification

The survey was undertaken at the Shell Flats area off Blackpool on the 14th of March 2008. Due to strong headwinds, the aircraft was unable to complete the journey from Austria to the UK on the 13th, and was therefore unavailable to initiate the survey until approximately midday on the 14th. This necessitated splitting the survey across two days, as there was insufficient light remaining on the 14th to complete the survey in a single pass. In order to maximise the probability of a suitable weather window on the second day, the survey was relocated from the site of the London Array to Shell Flats.

The survey area comprised a rectangular box approximately 20km by 10km, covering the majority of the shallow water at Shell Flats. Figure 2 shows the survey pattern: the 19 red tracks indicate transects completed on day 1, and the 17 green transects indicate those completed on day 2[1].

The nominal specification of the survey was for a fixed speed over the water of 100 knots, with the camera fixed in a forward orientation and looking down at an angle of 30 degrees from vertical. Image width was to be maintained between 30m and 40m at all times. The separation between tracks was approximately 300m, to give a minimum coverage of 10% (minimum area to be observed was 36x0.03kmx20km = 21.6kmsq, or 10.8% of the target area). The target altitude for the survey was 600m; however, low cloud on day 2 forced the aircraft down to 210m in order to maintain visibility.

[1] In the case of boat surveys, it is standard practice to repeat the last transect of the preceding day when splitting a survey across multiple days. This would have been advantageous here, particularly since it is beneficial to conduct a ‘dry run’ transect prior to commencing each days survey. It is recommended that this approach be adopted in future.

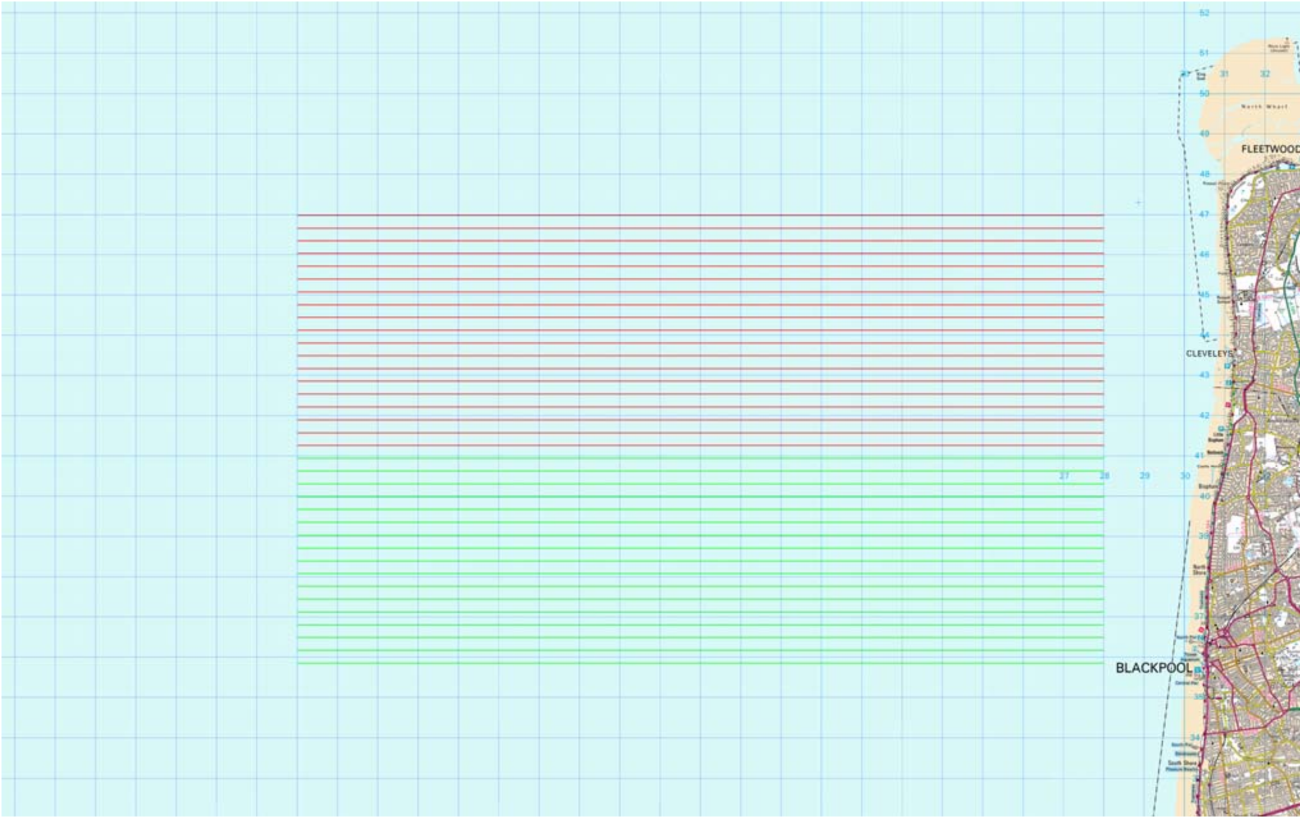

Figure 2 – A map of the survey area showing the transect pattern. Red transects were flown on day 1 green transects on day 2.

2.3 Comparison with Conventional Surveys

The development of this basic specification for aerial surveys and the reasons for selecting the various parameters are described in more detail in Ref. 2. However, for clarity we present here a brief summary of the differences between our technique and the conventional technique described in Ref. 1.

Coverage:

With a video method, any area of sea that is recorded is assumed to have been perfectly observed, i.e. no birds are missed within the field of view of the camera. However, due to the size of the frame, it is impractical to attempt to cover the whole area and a sampling approach is taken instead. In this survey we aimed to achieve at least 10% coverage, which would be expected to provide sufficient observations to produce a suitably accurate estimate of the population of scoter.

It is frequently suggested that visual surveys provide 100% coverage; were this the case, the number of birds observed during a survey would be the precise number present and there would be no need to compensate for missed birds using techniques such as distance sampling (Ref. 4,5). By comparing total observations with estimated populations, it is possible to infer an estimated coverage for an individual species at a specific location on a particular day. As an example, the 2004/5 DTi waterbirds report (Ref. 3) records that in Period 4 (10 Feb – 11 Mar) 9021 common scoter were observed in the area from Morecambe Bay to North Liverpool bay denoted NW4. The estimated population of scoter for the same period was 26012, suggesting a nominal 'coverage' of 34.7%. A similar exercise for red throated diver in the TH1 area in Period 3 (1 Jan – 9 Feb) yields an estimated coverage of 19.6%.

However, the objective is not to achieve 'coverage' but to provide a population estimate with the best possible confidence interval. The quoted 95% upper and lower confidence bounds for the estimate of common scoter population mentioned above are 11,258 (-67%) and 47,391 (+80%) respectively. These bounds are wider than would have been the case if 34.7% of the area had been surveyed using a video technique, as additional uncertainty is incorporated into the system through estimation of flock numbers and the fitting of a multi-parametric model to the data. A bootstrap technique for estimating 95% confidence intervals for our data is currently under development and is not available for direct comparison. However, a resampling technique for estimating the variation of the number of observed birds estimates that the 95% confidence intervals on this figure generates upper and lower 95% bounds of 694 and 899 scoter about a mean of 794, i.e. +/-13%. Although this interval does not bear direct comparison with confidence intervals of a population estimate, it does represent the dominant contributor to the uncertainty of our estimate.

Transects:

Visual observer based studies use a pattern of straight transects separated by 2km, which has been identified as a safe distance to avoid double counting (Ref. 1). Double counting should not be an issue in general for video techniques, as the field of view is precisely controlled and the inter-transect separation is sufficient that even large deviations from the planned transect are unlikely to result in overlaps. However, it should be noted that where this does happen, the kernel density estimator described later treats the situation appropriately. The second issue which places a minimum separation on visual observer surveys is bird flushing; the transects must be sufficiently far apart so that any flushed birds do not find their way into the next transect.

In the case of the present video survey, transect width has been reduced to 300m, which increases the amount of time the aircraft spends in the air on each survey relative to visual observer systems. However, a multi-camera system would enable several 40m wide 'mini transects' to be sampled simultaneously while the plane flies a single transect on a conventional pattern.

Speed and Altitude:

Airspeed is effectively equivalent for visual and video surveys; in the latter case, camera sensitivity and resolution are the limiting factor and is likely that cameras will be available in the future that enable an increase in airspeed. Altitude in our method is selected to avoid disturbing the birds, while in visual surveys it is chosen to avoid flushing birds before they have been counted. In the case of video surveys, altitude has no statistical effect on the data (provided birds are not flushed) as lens focal length is adapted to give the desired field of view regardless of height. The only trade off is image quality, particularly contrast and available light, which decreases for longer lenses and therefore greater altitude.

Sampling:

Sampling with video methods is trivially simple: if an area is 'looked at' by the camera then any birds present will be seen. The survey area is therefore divided into areas that are perfectly observed and areas which are unobserved. There is no requirement to measure the inclination of the birds at each observation, partly because the information is not useful as distance sampling techniques are not applied, but also because it is a fixed, pre-determined constant for each camera.

3. Data Gathering

3.1 System Performance

The Diamond DA-42 MPP provided a significantly more stable platform than the helicopter, resulting in significantly more consistent camera orientation. Some image motion remained due to small alterations in attitude while following the transect. These motions are relatively small and at their worst result in shifts of a few tens of metres from the nominal transect location.

As with the Gyron system, the Cineflex is designed to be controlled by continual operator feedback based on the image. The survey parameters dictate a very rapidly moving image, and this makes control of the camera, particularly orientation, difficult. The operator's consistency increased rapidly with familiarity, and was helped by the presence of full attitude indication, which was not available in the first trial. However, constant monitoring and adjustment of camera orientation, combined with the other duties makes operating the camera a tiring task, and a fixed orientation camera would be a significant improvement on the present system, particularly since the space available in the rear of the aircraft effectively prevents the operators duty being shared among more than one individual.

In the initial trial, techniques for controlling focus and contrast were proposed, and these were applied from the outset of the present trial. On the first day, focus control once again proved difficult, due to the lack of sharp features on the flat sea. Nevertheless, the majority of the video from the first day was at or close to sharp focus. On the second day, whitecaps were present providing a visual cue to check focus. While none of the data was so badly affected by focus that birds could not be detected or recognised, a method of locking the focus once set would be a significant enhancement to the system.

Following the experience with the first trial, the exposure was set intentionally low so that white birds would not be overexposed. The shutter speed was set at 1/1000 secs for the majority of the survey, the fastest available on the camera, and a small amount of gain was then used brighten the image if required. This setup was found to completely eliminate motion blur, and provided a well exposed image in the vast majority of cases. Towards the end of day 1, loss of light forced a decrease in shutter speed to 1/500 secs, which did not result in a perceptible loss of quality and enabled the survey to continue for a further two transects.

A particular problem encountered during the first trial was the difficulty of following transects accurately using only waypoints loaded into the GPS system. The GPS equipment installed within the DA-42 was far better suited to survey applications, with the ability to display tracklines as well as waypoints. This, combines with a large colour display, enabled the pilot to track the transects with an accuracy of 30m or better for much of the survey.

3.2 Performance of Video Equipment

The experience of the video system during this trial was very similar to that gained during the initial trial in August 07. Technically, the system is more than able to meet the image quality requirements for detecting and classifying birds. Once again, some difficulty was experienced in operating the system under survey conditions; however, the overall quality of the data was greatly improved by following the recommendations identified during the initial trial. In particular, the contrast and focus were generally much better as a result of intentionally under-exposing and focussing at the beginning of each transect.

Focus Control

However, focus was occasionally lost during a transect and regaining correct focus proved difficult in the absence of any sharp features; this was a particular problem on day 1, where the calm sea lacked any high contrast features. Despite these difficulties, video quality was sufficient to enable classification of detected birds throughout. In future, it would be preferable to be able to set the focus to a pre determined value based on the survey altitude and then lock it in place.

Contrast Control

Further to the recommendations identified during the first trial, a waveform monitor was used to inspect the brightness histogram periodically during the trial. This provided a more reliable way of ensuring that no clipping of bright-whites was occurring. In future, this task could be readily automated, as it effectively amounts to replacing the standard auto-exposure function with one that emphasises correct exposure of bright whites.

Orientation Control

The operator’s skill in controlling the orientation of the camera increased substantially during the course of the trial. As recommended following the first trial, full altitude-azimuth indication helped with camera control. However, the need to continually check these indicators along with focus and contrast makes operating the camera a demanding task, and it would be preferable in future to lock the outer gimbal of the camera system to remove this burden from the operator. Cineflex have confirmed that this is a readily achievable modification of the system.

Exposure

A challenge that was encountered on both days of this trial, but not during the initial trial, was low light. On day one a halt was called to the survey at approximately 16:30, due to low light. Camera gain was used to compensate for low light; however, this also increases electronic noise. The final transect of the day was completed with high gain and an increased exposure time of 1/500th of a second rather than 1/1000th of a second; this increased the amount of available light with only a very slight increase in motion blur, and resulted in acceptable data quality (see the images of auks in section 5.2). It is recommended that in future surveys, increasing exposure to 1/500th of a second be used in preference to camera gain.

White Balance

A further modification to the video parameters was to alter the white balance to make best use of the available light under conditions of low cloud and light mist. This results in a skewing of the overall colour of the recorded data towards the blue. In principal, this blue cast could be removed in post-processing, but was found not to affect the ability of an observer to recognise birds, with the exception of the distinction between black-backed and herring gulls. The data was therefore left in its original form, but the reader should be aware that the bright blue colour of the sea in many of the following images does not reflect the true colour of the sea during the survey. Figure 3 provides an illustration of the colour balance. In future, however, it is recommended that data be gathered in as close to true colour as possible, as the difficulty experienced with identifying gulls in this trial could conceivably extend to other species.

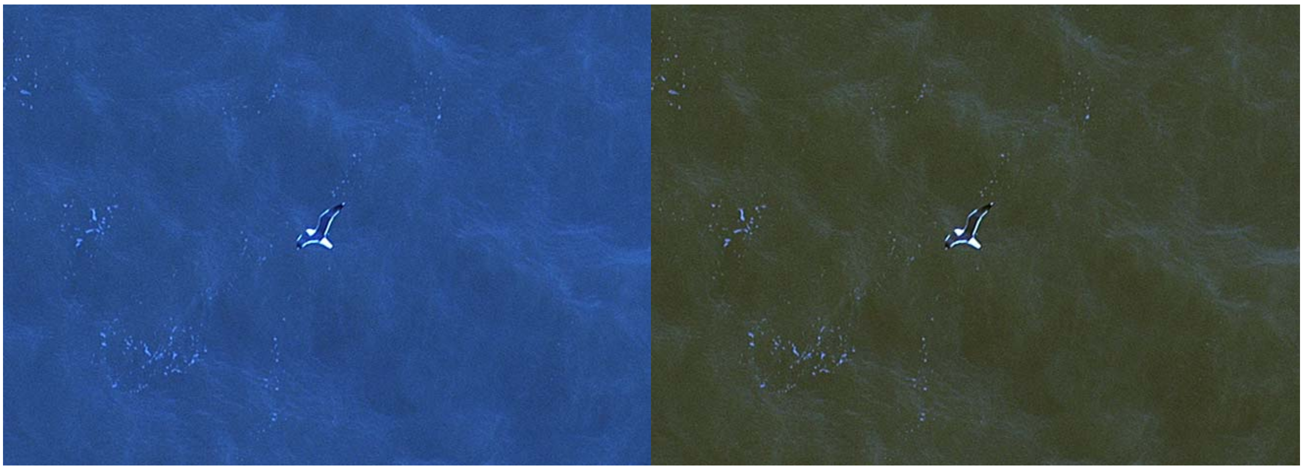

Figure 3 - Examples of pre (left) and post (right) colour corrected video frames. Despite the significant increase in the amplitude of the blue component of the image, recognition was generally unaffected.

Image Width

The final aspect that required manual intervention was image width. The initial trial identified 30m as a suitable target width that would provide sufficient detail to recognise even small birds under adverse imaging conditions. Image width is determined by a combination of aircraft altitude and camera lens focal length. Although the aircraft is capable of maintaining a fixed altitude, the Cineflex system provides no mechanism to fix lens focal length. Instead, focal length is manually determined by the user by judging the apparent speed of the video; when travelling at 100 knots the correct focal length results in an image speed that carries objects across the frame in a little under half a second.

Control of focal length proved quite difficult on the first day of the survey, when the absence of whitecaps made estimation of the image speed difficult. On the first day, average image width was 43m with a standard deviation of 9.6m, with minimum and maximum widths of 27 and 64m respectively. The bias therefore seems to have been towards wider frames when visual cues of image speed were fewer. On the second day, average image width was close to target at 32m with a standard deviation of 5m. However, it should also be noted that the only on-transect auks recorded during the trial were observed with an image width of 46m, (over 50% more than the original recommendation), but gave images somewhat clearer than those from the initial trial. This suggests that when focus and contrast are adequately controlled, 30m is an excessively pessimistic target image width. It is recommended that future surveys adopt a target image width of 40m, rising to 45m if image width control tolerances can be improved (e.g. by fixing focal length).

In general, the video system proved able to maintain a sufficient level of detail and consistency. For large scale application, however, it would be highly desirable to fix or automate as many of the variables as possible to improve consistency and reduce burden on the operator. In particular, it would be desirable to fix camera orientation and lens focal length.

4. Impact on Birds

A key objective of this trial was to assess the impact of the technique on one or more of the more sensitive species, such as Common Scoter or red throated divers. As described previously, the aircraft altitude was varied between the first and second days of the survey, due to a lowering of the cloud base. Data on day1 was gathered from an altitude of 600m, while data from day 2 was gathered from an altitude of 210m. Although forced by weather conditions, this change in altitude allows an interesting comparison of bird behaviour under different survey conditions.

A total of 760 Common Scoter were observed, 318 on day 1 and 442 on day 2. On both days the vast majority were sitting on the water. However, some notable differences in behaviour of the Common Scoter were identified between the two days.

On day 2, while very few airborne birds were observed, the majority of birds did appear to be actively propelling themselves through the water, in a direction that was approximately the same as the direction of the aircraft. This indicates that the birds were at least aware of the aircraft when flying at this altitude. However, only one group of birds was actually observed to take flight as a result of the aircraft, and even within this group not all of the individuals in the group took flight. Although the observed disturbance was minor, the possibility cannot be ruled out that birds were taking off after being observed sitting on the water and subsequently being flushed onto a neighbouring transect.

On day 1, however, while flying at 600m the birds were encountered at apparently randomly distributed orientations, relatively few birds had clearly distinguishable heads and almost no birds had visible feet. This suggests that the vast majority of birds encountered on day1 were in a state of rest. This strongly suggests that the birds were either oblivious or indifferent to the presence of the plane at an altitude of 600m.

These observations can be used to derive a lower operating limit for the video survey technique. The distance between the birds and the plane at the point of observation was approximately 240m (due to the effects of looking forwards at an angle of 30 degrees). Accordingly, it seems likely that had the altitude of the plane been well over 240m almost no birds would have taken flight. It is therefore proposed that 270m be adopted as an absolute lower limit for video survey of areas in which Common Scoter are anticipated. A similar exercise could be used to establish the operating limits for other species, such as Divers (sp. Gavia). No disturbance to any of the other observed species was noted. It is therefore recommended that 600m be adopted as the default survey altitude, with 270m as a lower ceiling when cloud base is below 600m.

5. Data Analysis

5.1 Bird Detection and Location

A total of five hours data was gathered in the form of raw video. The video was downloaded to the hard disk of a desktop computer for review, taking up 225Gb of storage space. For archival, the video can either be stored on its original cassettes (of which 8 were used) or saved onto a single digitial data archival cassette, which are currently available in sizes up to 800Gb.

Each transect was reviewed by at least two independent reviewers, one an experienced surveyor, the other(s) novice. In this instance, reviewers recorded only species and location; in future it would be straightforward to add additional columns to the data record sheets to record information such as flight direction, gender, behaviour etc. The video also provides a potentially useful record of polution, and it might be useful in future to mark up areas with particularly large amounts of rubbish as a measure of water quality.

In general, agreement between the reviewers was very high with just a handful of discrepancies. In the case of such discrepancies, the expert reviewer was found to be correct in almost all cases. However, the most notable distinction between novice and experienced observers was the speed with which the data was reviewed; the experienced observer was able to review the data in real time, whereas the novices took over ten hours to review the same footage.

A total of 823 birds were observed, 785 of which were 'on transect' with a further 38 observed between transects. Of the 785 on transect birds, 760 were Common Scoter, 19 were gulls, 4 were auks (either guillemots or razor bills), 1 was an eider, and 1 was either a cormorant or shag.

Bird observations were recorded in clusters with associated video timecode, i.e. if a group of birds were observed simultaneously, a single record ascribing a particular timecode (and therefore location) and species and number to the group was generated. Clusters were not allowed to span more than one second, to maximise accuracy of location. Note that the definition of a cluster is rather arbitrary in this application and is simply a device for making data management more straightforward by reducing the total number of records. The concept of a cluster used here is not the same as an observation of a group in visual surveys, as we generate a definitive count, not an estimate of the number of birds; also, we may well only see part of such a group if it is partially out of frame. The ability to slow down or pause the video allowed each cluster to be counted exactly. Figure 4 shows the locations of all observed bird clusters

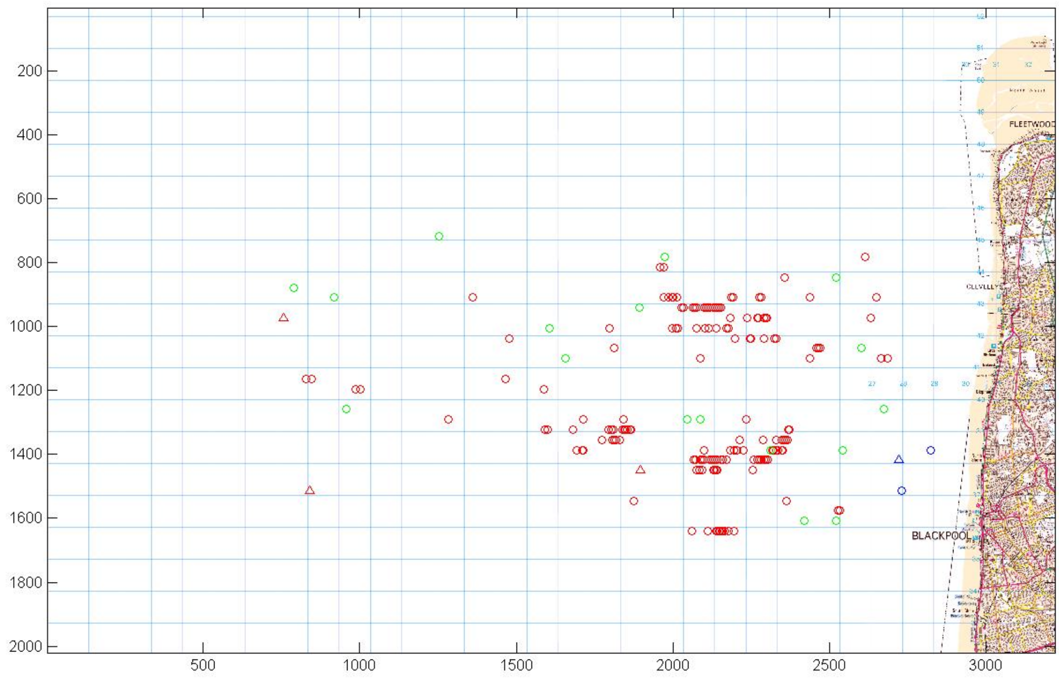

Figure 4 – Bird cluster locations. Red circles: Common Scoter. Green circles: gulls. Red triangles; auks. Blue circles: eider. Blue triangles: phalacrocorax.

5.2 Bird Classification

Overall, image quality was significantly improved relative to the first trial, and there were few cases in which classification was in doubt. The main difficulty was in differentiating between herring gulls and black back gulls where the video was over-exposed. Common Scoter, auks, cormorant / shag, and were all identified without ambiguity. A large amount of man-made debris was observed, and a very small number of these objects could be confused with birds. In most cases, they could be differentiated by close scrutiny of the margin of the object, which usually revealed objects to be largely submerged.

Auks:

In Common with previous surveys of the area (Ref. 3), only a small number of auks were observed and these were generally found in the deep water at the western extremity of the survey area. Figure 5 shows a close-up of a pair of auks, encountered late on day 1, from a height of 600m, as light was beginning to fade; note that the low light required camera gain to compensate resulting in the ‘speckled’ background. Note that the speckle is varies randomly between frames, and is therefore less distracting in the video than in a still image.

In comparison with the slightly overexposed and blurred images gained in the first trial, this image gives significantly greater confidence in identification. Additionally, the birds were far easier to detect. The frame width at the point that this image was captured was 46m, significantly greater than the recommended width identified as suitable for auks during the first trial. It is therefore proposed that the target image width be increased in future trials.

Figure 5 – A pair of auks observed under low light conditions from a height of 600m.

Gulls:

The majority of gulls were encountered in flight, making both detection and observation straightforward. Figure 6 shows a comparison of higher quality gull images from the present trial (left) and the initial trial (right). The substantial increase in quality results from application of the recommended camera technique proposed following the first trial. Note that there is still room for improvement; the left hand image would have been further improved by reducing the exposure. Dynamic exposure control for bright-whites would be s significant benefit for future surveys.

Figure 6 – comparison of higher quality images of gulls from the present trial (left) and the first trial (right). A marked increase in quality results from following the recommended technique identified during the first trial.

Phalacrocorax

A single example of a shag or cormorant was observed, shown below in Figure 7. Note that the height of the bird can easily be estimated from its reflection in the water; its wingtip almost touches the water in this frame.

Figure 7 – The single example of a cormorant or shag observed during the trial.

Eider

Two individuals were recorded during the trial, both males, One of these was recorded just off transect. Both images suffer a little from over exposure, again highlighting the potential benefit of an auto-exposure feature based on bright whites only. Nevertheless, both birds are readily recognisable.

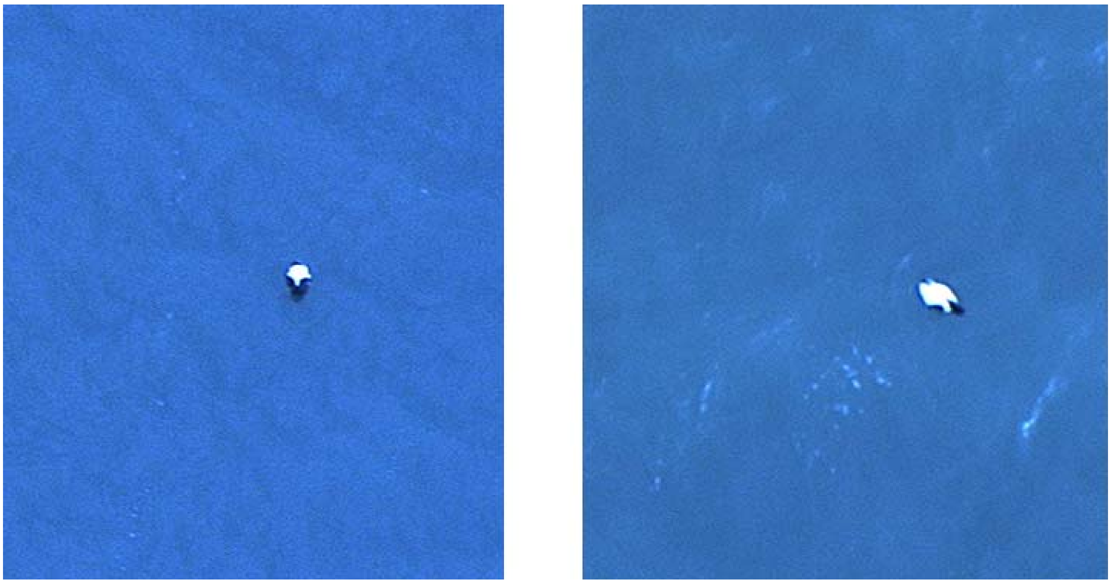

Figure 8 – Still images of the two Eider drakes observed during the trial.

Common Scoter

As described previously, the vast majority of the Scoter were observed sitting on the water, although many of those observed from the lower altitude of 210m were seen to be swimming away from the plane. Figure 9 shows a typical still frame of a cluster of Scoter in which this behaviour can be observed. Note that feet can be observed through the water and that some individuals appear to have light beaks, potentially suggesting gender.

A small number of Scoter were observed in flight. Some of these images initially caused some confusion, as areas of the wings appear light grey or even white, which would not be expected from Common Scoter. In fact these features were dark grey and had been lightened as a result of the exposure settings of the camera; this suggests that some experience of the performance of the system is required for reliable identification. It also demonstrates that the camera system is able to differentiate between subtly different shades of grey, when appropriate exposure settings are chosen.

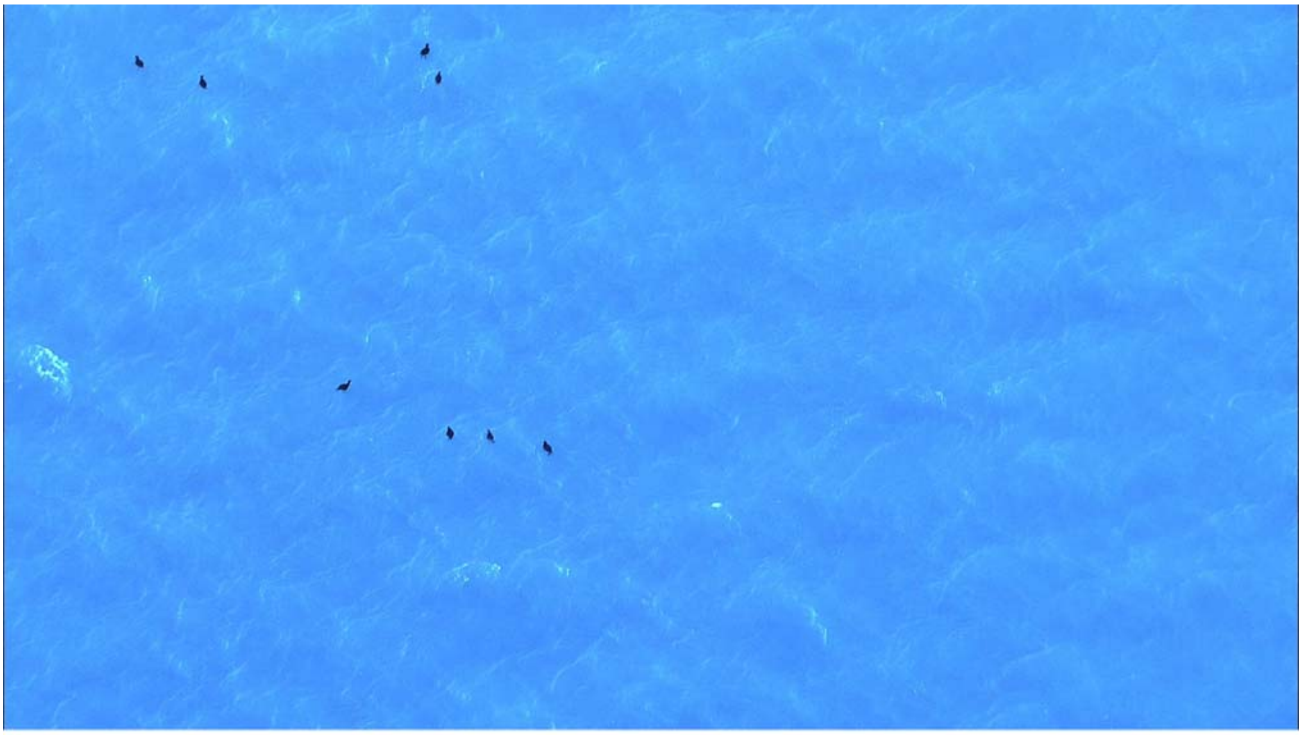

Figure 9 – A typical image frame from day 2 showing Common Scoter swimming away from the aircraft. Details such as submerged feet and apparent colouration of the beak are visible on some birds. Note that this image has not been colour corrected.

5.3 Statistical Analysis

Statistical analysis of the data is straightforward. Unlike other survey methods, all birds within the observation area are detected, so there is no need to compensate for detection rate using technique such as those employed by the Distance package (Refs. 4, 5). A simple total population estimate can be made simply by scaling observations according to the proportion of the area that was observed. Because transect location and width can fluctuate locally, the analysis is most accurate if carried out locally using a kernel density estimation method (Refs. 6, 7, and summarised below) and then summed over the area of interest; this is particularly important when looking at species which are aggregated locally, as the transect width over the dense areas will have a disproportionate impact on the estimate, which will not be modelled accurately using the simple 'count and divide by coverage approach.

Kernel Density Estimation

The ability to detect and quantify localised fluctuations in bird population is highly desirable if the data is to be used for its intended purpose of monitoring the impact of individual windfarms on bird populations. In the case of visual observer data, the standard method of localised analysis has been to divide the surveyed area into a grid of 2km squares centred on the transects. Each square therefore contains a 2km stretch of a single transect, and the observations can simply be aggregated for each square to generate a 'pixelated' map of bird density. In our case, we can generate a proportional measure by summing the birds observed in any given 2km square and dividing by the proportion of that square that was imaged. However, 2km 'pixels' provide a relatively coarse data-set for analysis; the spatial extent of many clusters of scoter, for example, appears to be around the 2km mark (see Figs 10 and 12). The exact location of a grid with respect to a cluster could therefore have the effect of either concentrating the birds into a single square or splitting them between as many as four, quadrupling the apparent area of the cluster.

It is therefore preferable to avoid local analysis on a fixed grid and to define a continuous representation of the data. Kernel Density estimation is a straightforward technique that enables this approach. Consider the example, described above, of analysing our data using a 2km square window. There is no reason to centre the square on a transect as each square will contain multiple transects anyway; we could therefore generate an estimate of the density at each point in space by centering the window on that point, summing the birds within in it and dividing by the observed area within it. In this case, the sampling window is referred to as a 'kernel' and the resulting density is referred to as a *kernel density estimate*. This can be evaluated at any point, and it is therefore possible to generate continuously varying density estimates, such as those shown in Figure 10. Note that this is not the same as simply interpolating between the two kilometre grid samples; such a technique would still suffer the limitations of the grid itself.

The kernel used here is not a 2km square window. Square kernels have two undesirable properties: first, they are sharp edged which can generate spurious sharp edges in the density estimate as large clusters suddenly enter and leave the window; second, because they are not 'round' the orientation of a cluster with respect to the survey grid will have a significant impact on its shape. For these reasons we prefer to use Gaussian (bell-curve) windows instead. These are 'round' and provide a weighting for each data point that rises smoothly with proximity to the analysis point, rather than simply switching data points on and off.

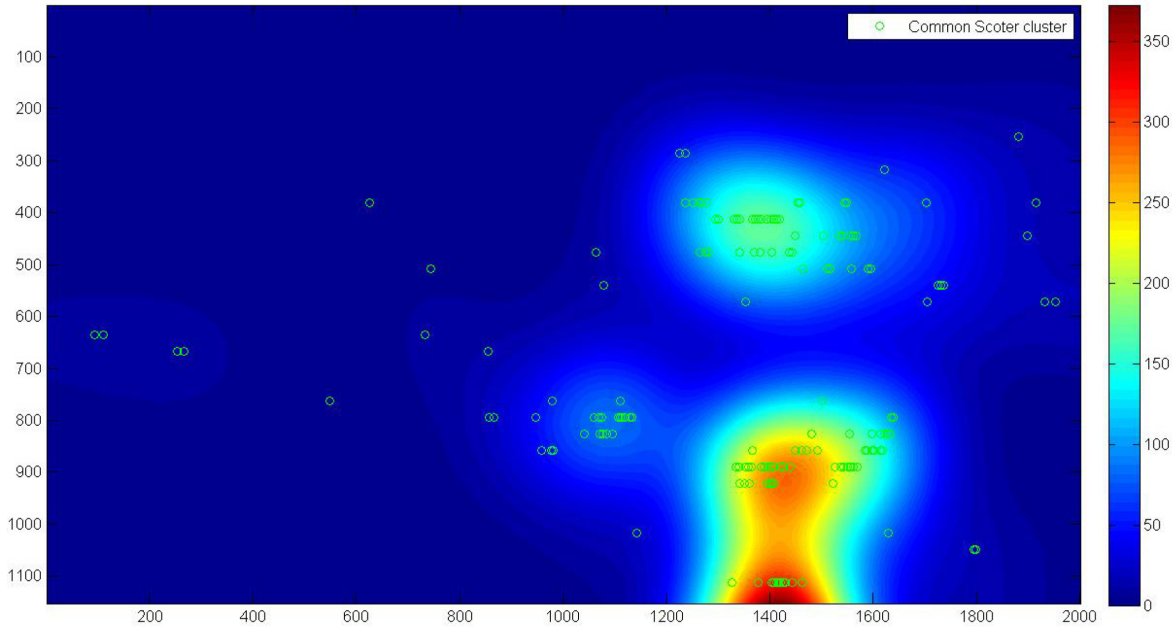

Figure 10 – Spatial variations in Common Scoter density recorded during the trial, estimated using a kernel regression technique. Units are birds per square km.

Figure 10 shows a density map for Common Scoter, the only species present in sufficient numbers to enable a meaningful analysis. The kernel used was a Gaussian with standard deviation of 1km, giving approximately the same scale of analysis as the 2km square blocks that have previously been used to represent bird populations (Ref. 3). The most likely total population according to this analysis is approximately 7000 individuals within this 200 sq km region.

It should be noted that this particular scheme is not being proposed as the most appropriate for analysing bird data, but simply as an illustrative example of the local rather than global statistical analysis that this type of data readily lends itself to. The ability to generate statistically normalised data at relatively fine spatial scales is potentially a significant advantage when searching data for changes in distribution, and may be of some use in overcoming the relative weakness of existing data in monitoring local population fluctuations (Ref. 8).

5.4 Comparison with Previous Surveys

The data gathered during the trial has been compared against historical data from aerial surveys undertaken during the 2004/2005 season by WWT on behalf of BERR (then DTI) (Ref. 3), and a second set provided by WWT comprising raw counts taken from varying months over the 2004-2007 period.

BERR 2004/5 Data

This data is taken directly from the 2004/5 BERR Waterbirds report. The data is presented as aggregated counts and population estimates, and as counts aggregated over a 2km square grid. The former two types of information refer to a larger areas than the present survey and so cannot be compared directly. The grid data can be compared. However, only approximate values for each square are provided, and the values describe raw counts not population estimates. It is therefore only possible to compare the distributions (i.e. relative magnitudes of each square) and not the actual numbers of birds in each square.

Figure 11 shows five population density maps for Common Scoter; each map consists of a 10 by 6 array of 2km square blocks, with lighter blocks representing higher concentrations of birds. The top left map is the data gathered during this trial, the other four are the results of surveys during the four winter survey periods. The centre image on the bottom row corresponds to period four, the same period in which our trial was completed.

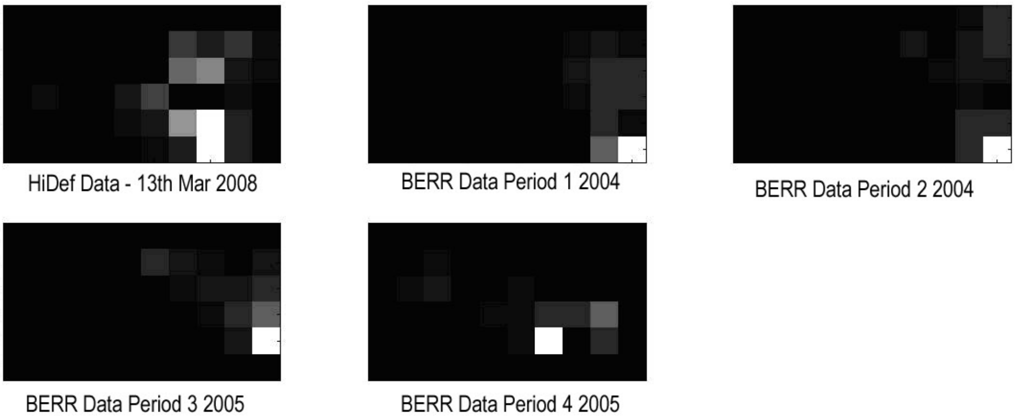

Figure 11 – maps showing the variation of Scoter density within 2km square blocks. Top left: our data. Others: data for periods 1-4 2004/05, from DTI waterbirds report (Ref. 3).

Some commonalities can be identified across the maps: all maps show a concentrated population in the south eastern corner (the two period four maps show this concentration in the same location), and all but one of the maps shows a less numerous, more distributed cluster to the north and west of the first.

It is also interesting to note that the DTI report notes a general trend of Common Scoter populations to drift away from shore toward the end of the winter season, a property that has been attributed to exhaustion of food supply in shallower waters. This trend can apparently be observed in Figure 11, in which the greatest concentration of Scoter occurs in the shallowest (right-most) waters in periods 1-3, and then apparently shifts 4km away from shore in period 4, both in the case of the 2004/5 survey and in the case of our data.

WWT 2004-2007 Data

A second set of data was provided by WWT. This consisted of Excell files listing all observations for the whole area over a number of surveys. These were filtered by bird type and location to produce lists of common scoter observed within the footprint of the present survey. For each year the latest winter survey was taken for analysis, yielding four data sets that are as comparable as possible with the data set generated during the trial.

In order to be able to compare the data sets as fairly as possible, the raw observations were processed using a kernel density estimation scheme to approximate the local density. Unlike our data, the WWT data is banded, with detection rate varying as a function of band. In order to apply a kernel density technique it is therefore necessary to estimate the detection probability in each band. This was done simply by assuming that the density in each band is constant on average, and that all birds in the densest band are detected. Surprisingly, band B (second closest to aircraft) was found to contain significantly more birds than band A, with a very high repeatability across surveys. This band was therefore assumed to be fully detected, and normalisation factors were derived and applied to bands A and C so that all three bands had equivalent densities. Band D proved to be very sparse and was not used for the analysis. The normalised data was then processed using exactly the same technique as our data, but with transects revised to reflect the locations and widths of bands A, B and C only. While this analysis is relatively crude, in that it doesn't model the varying detectability of groups of different sizes as is the case with Distance 5.0 (Ref. 4, 5), it does enable an approximate local analysis.

Figure 12 shows the results of this process. The data are again very comparable in terms of distribution, showing a single large concentration, usually with one or more secondary clusters, and a tendency for the main cluster to drift into deeper water toward the end of the season. In this instance, it is possible in principle to compare the populations across the surveys. This yields an estimate of approximately 7000 birds for our survey and 16000, 17000, 13000 and 17000 for the 2007, 2006, 2005 and 2004 WWT surveys respectively.

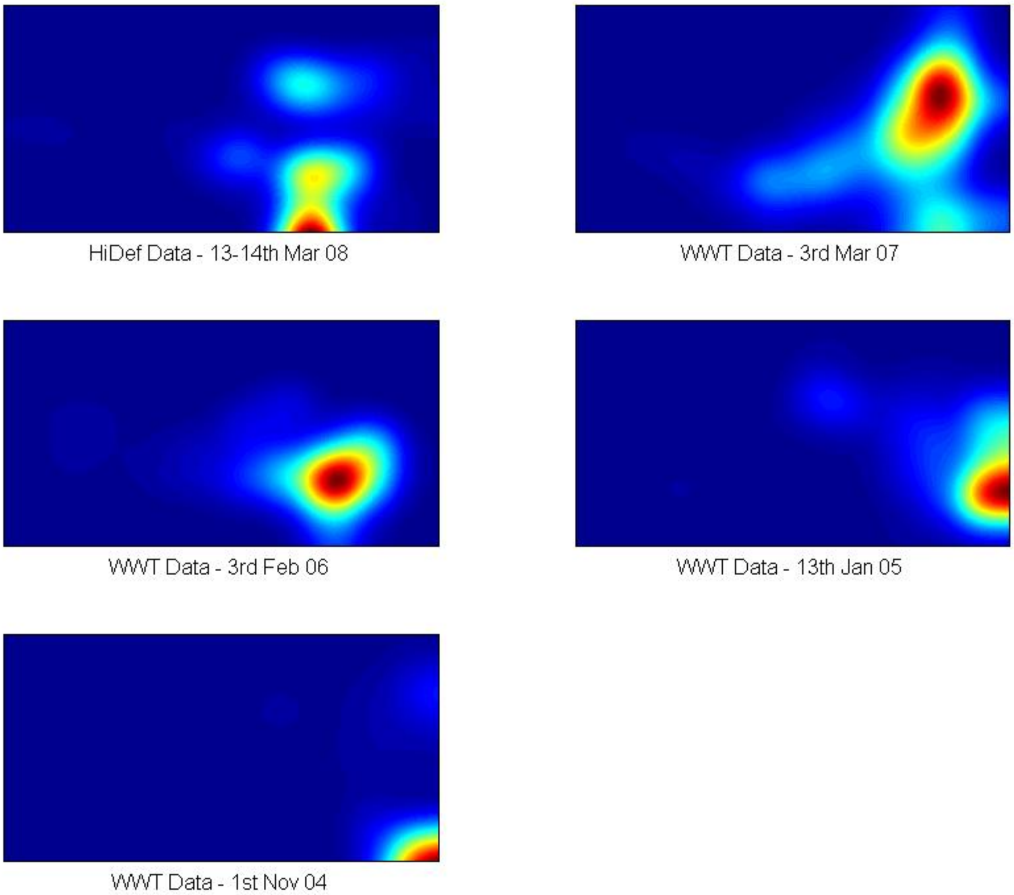

Figure 12 – Scoter distribution estimated using kernel regression for the data generated during the present trial (top left) and one WWT data set from each of the last four years. WWT data sets were selected to be as close as possible to mid March.

The WWT surveys would therefore appear to have consistently detected a greater number of birds than appear to have been present during this trial. There are several potential contributing factors to this phenomenon. First, our survey was very late in the season, actually falling outside the survey period as defined Ref. 3. This and inter-annual variation may explain some of the difference.

Second, the densest cluster of scoter in our survey actually occurs on the very margin of the survey area, and one could therefore speculate that a significant cluster of birds was present just outside the area. Although this is also apparently the case for two of the WWT surveys, scrutiny of the un-cropped data sets reveals that in these cases the majority of the birds are within the survey area; the shape of the clusters near the edge of the map is a function of the kernel density estimation method, which does tend to assume that clusters at edges continue or even increase beyond the edge. In future it is recommended that the margins of the data are ignored up to a thickness equivalent to the scale of analysis. In this instance, such a crop cannot be performed as it would delete most areas of interest.

Another potential reason for the discrepancy is the way in which we have normalised the WWT observation bands. The standard assumption made by distance sampling methods is that all birds at zero distance from the aircraft are detected and that the detection function drops monotonically with distance (i.e. it has no peaks other than at zero distance). This is apparently not the case for common scoter, but it is not clear from the data why this should be, and it is therefore unclear how it should be compensated for. One possibility is that scoter are displaced from band A into band B as a result of flushing. In this case the true detection factor for band B is effectively greater than unit (more birds are seen than would have been there had the survey not taken place). Since we have taken the detection function in band B to be unity this would result in a potentially significant overestimate.

6. Discussion

A full scale trial of the high definition video bird survey technique, initially described in Ref. 2, was undertaken at Shell Flats on the 13th and 14th of March 2008. The basic technique, adapted to an aeroplane rather than a helicopter, and with the refinements recommended following the initial trial has been shown to provide a consistently high quality raw data set on which to base an analysis of the bird population. Although the method as deployed in this trial requires denser transects and therefore greater effort from the aircraft, other recommendations from the first trial, such as multiple camera systems and super-high definition cameras have the potential to bring the survey effort in line with current techniques.

A feature of particular interest that has been verified during the trial is the ability to survey more sensitive species such as common scoter without disturbing them (when flying at 600m) or without flushing them (when flying above 270m). This feature, combined with the simple form of the statistics and the ability to survey over built windfarms makes the technique a potentially very powerful addition to the suite of tools currently available for bird population monitoring.

The simple statistical methods employed to analyse the bird distribution in this trial may have the potential to increase the sensitivity and robustness of the analysis of multi-year data sets by removing the dependence on arbitrary features such as grid location, and by enabling statistically robust estimators to be applied at a local rather than semi-global level.

The agreement between our results and historic results appears to be very good in terms of the spatial distribution. Although some difference was found between our population estimate and previous estimates, the size of the difference, and the number of potential reasons for it does not suggest that it should be any cause for concern when applying the video survey technique.

Taking into account the consistency of the technique during the trial, across two days with varied weather conditions, and the compatibility of the results with previous data, it is proposed that the technique is now ready to be applied on a wide scale alongside the existing methodologies.

7. Recommendations

1. HiDef and the birds subgroup of the COWRIE Environment Technical Working Group should work together to produce and formally agree a COWRIE Methodology for video surveys.

2. A further study should investigate the assessment of long term population analysis using Kernel density estimates.

Technical Recommendations:

1. Focus and camera orientation should preferably be locked in future to ease the burden on the operator.

2. Exposure increase up to 1/500th of a second should be used in preference to electronic gain in low light conditions.

3. True colour should be used wherever possible, even at the expense of image sharpness and noise.

4. Target image width should be 40m for 2000 pixel wide video images.

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