Chapter 6: Recommendations for high resolution digital video aerial surveys in the U.S.

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Chapter 6 Highlights

Recommendations for conducting high resolution digital video aerial surveys in the U.S.

Context[1]

High resolution digital video aerial surveys are one of several different survey methodologies for quantifying animal densities. Digital aerial approaches were developed in Europe, but this study represented the first broad-scale application of these technologies in North America. This novel approach to wildlife surveying presents several challenges, which can be addressed through management, technological advances, or analytical approaches.

Study goal/objectives

Present advantages and challenges of high resolution digital video aerial surveying, and provide management, technology, and analysis recommendations for addressing these challenges in order to advance this method as an option in broad-scale surveying.

Highlights

- We compare the advantages and challenges of boat, visual aerial, and digital aerial survey methods.
- We recommend that future application of digital video aerial surveys in the U.S. include the continued development of standardized data formats, as well as transparent data management and QA/QC protocols.
- This technology continues to be improved. Advances in camera resolution, GPS integration, and performance in poor weather are important for the application of this technology.
- There are tradeoffs between ground spatial resolution (GSR) of video and the ground coverage (e.g., strip width) of transects. For the camera technology used in this study, we recommend a minimum ground spatial resolution (GSR) of 2 cm.
- Digital aerial survey data are not distance-biased, unlike visual survey approaches from both boats and aircraft. However, there may be other sources of detection bias for these data, and this question has remained largely unexamined in Europe to date. It will be important to examine this issue, and if necessary, develop detectability and availability metrics for digital aerial survey data.

Implications

High resolution digital aerial surveying has largely replaced other survey approaches for offshore wind energy development in Europe. With recent and continuing technological advances, digital aerial surveying could be a cost effective, time-efficient and repeatable option for performing broad-scale surveys to inform siting and permitting of offshore wind energy development in North America.

[1] For more detailed context for this chapter, please see the introduction to Part II of this report.

Abstract

High resolution digital video aerial surveys were conducted in the mid-Atlantic U.S. in 2012-2014, using two twin-engined Cessnas outfitted with four super high-resolution cameras. As a result of these survey efforts, we have significant experience with the advantages and challenges of digital video aerial survey approaches. Digital aerial surveys are a useful approach to many situations because they are safe, can be conducted both pre- and post-construction, and are efficient for covering large survey areas. In this chapter, we present management, technology and analysis recommendations for consideration in future high resolution video aerial surveys if implemented as a survey method in North American offshore wind development.

Overview

The optimal approach for quantifying animal densities, both temporally and spatially, is dependent on project goals and the extent of the geographical area in question, among other factors. In recent years, digital aerial survey approaches have become commonly used methods in planning and assessing offshore wind energy development in Europe (Buckland et al. 2012). Comparing different offshore wildlife survey approaches, there are clear advantages and disadvantages to each method (Table 6-1). Boat-based surveys, for example, are known to cause disturbance to wildlife, are not generally repeatable pre- and post-construction, and have lower detections of submerged marine animals (i.e., sea turtles, rays and sharks) than either visual aerial or, in particular, digital aerial approaches (Normandeau Associates Inc. 2013; Chapter 14). Although not investigated in our study, traditional low-flying aerial surveys with visual observers are less safe than digital aerial surveys, are also known to cause disturbance, and are not repeatable post-construction, all due to the low altitude required to visually detect marine wildlife. Unlike observer-based approaches, digital aerial surveys are repeatable post-construction, and the data produced is auditable. However, digital aerial surveys are dependent on video quality and atmospheric conditions, have limited strip width, unknown detection bias (though no distance bias in detections, unlike boat and visual aerial surveys), and require greater technological infrastructure for video data management and storage.

High resolution digital video aerial surveys in this study were conducted in 2012-2014 by HiDef Aerial Surveying, Ltd., using two twin-engined Cessnas outfitted with four super high-resolution cameras. Fifteen surveys were flown at 610 m (2,000 ft) over a 13,245 km^2 study area (Chapter 3). Wildlife observed in the digital video footage was identified to the lowest taxonomic level (Chapter 4) and georeferenced. Additional data were also collected (e.g., direction of movement) or calculated (e.g., flight height), according to HiDef's standard protocols (Hatch et al. 2013).

As a result of these survey efforts, we have substantial experience with the advantages and challenges of digital video aerial survey approaches. Barring significant technical and legal advancements in the civilian use of drones, digital aerial surveys may be the most useful survey approach to many situations in the marine environment, because they are safe, can be conducted both pre- and post-construction, and are efficient for covering large survey areas. They have largely replaced other survey approaches for offshore wind energy development in Europe for these reasons. However, there are challenges to this approach as well. Some of these are inherent to the methodology, such as the inability to collect detailed behavioral data. Many challenges of digital video aerial surveys, however, are due primarily to the relative novelty of the method, and can be addressed through management, technological advances, or analytical approaches. We outline some of these possibilities here, with the intent of advancing the understanding and broad-scale use of this approach in North America.

Recommendations

Management recommendations

Flights

When planning digital aerial surveys over large geographic areas, prior consideration should be given to the frequency of naval and air traffic in the area that may impede or cancel planned survey flights. In addition, aerial surveying companies and pilots should maintain flexibility to conduct surveys at the first window of opportunity in case long periods of poor weather conditions develop that would prevent flying. If necessary, multiple planes should be used to complete surveys in brief time windows.

Data standards

We recommend working with federal, state, and private partners involved with at-sea survey data to develop a set of standard data fields and outputs to insure wide acceptance and use. This is a critical step in helping with future data aggregation and analysis. Given that this method is in its infancy in the U.S., it is important to develop these standards early, before many surveys have been conducted. We recommend consultation with managers of the two largest federal databases, the USFWS Northwest Atlantic Seabird Catalog (formerly the Avian Seabird Compendium) and the USGS North Pacific Seabird Pelagic Bird Database, to develop these standards with a view towards final deposition into these databases.

Object tracking

A unique identifier should be applied to each object observed in the video, and this identifier should be maintained throughout all data management and processing activities during the course of a study, including object location, object identification, audits, georeferencing, and flight height estimation. This will help with quality assurance and quality control (QA/QC) processes, and allow the tracking of individual records throughout data management and analysis efforts.

Detailed QA/QC process

We also suggest that a publicly available QA/QC process is developed for the video data. This guiding document should include methods for object detection, as well as identification and final data processing. We developed a data management and QA/QC protocol for BRI's responsibilities during this study (Chapter 4) that could provide the basis for a larger protocol and improve data standardization between studies.

Technology recommendations

Ground spatial resolution

We recommend a minimum ground spatial resolution (GSR) of 2 cm for all aerial video surveys. Two cm GSR digital aerial surveying had higher identification rates for scoters and higher detection of aquatic animals when compared with 3 cm GSR (Chapter 5). While the 3 cm GSR allowed for a wider recorded strip width, video quality (clarity and color accuracy) was substantially lower, leading to poor identification rates (Table 6-2) and longer times required to make identifications. In the UK, HiDef has achieved 90% identification rates with 0.5 GSR (HiDef 2011), and a recent trial of a different digital aerial survey technology in the United States achieved higher identification rates for 1.5 GSR, compared to 2cm GSR (Normandeau Associates, Inc. 2013). While there is a tradeoff between GSR and strip width (and, thus, ground coverage of surveys), we believe that in many cases, it is worth considering the prioritization of GSR when designing studies to meet project goals. It should be noted, however, that recent technological advances in high resolution digital video camera systems have increased the strip width, as well as substantially improving identification rates beyond what is reported here, while keeping other survey characteristics constant (Webb and Hawkins 2013, HiDef unpubl. data).

Improve camera response in poor weather

Poor weather, such as low cloud and fog, may have been a factor in detection rates and identification rates of animals, particularly during winter surveys. Some animals behave very differently during adverse weather conditions, however, and may even change flight heights (Shamoun-Baranes et al 2006), emphasizing the importance of better data collection under these conditions. Predictive models of distribution and abundance are also hampered by variable (and unquantified) variation in detection and identification rates between surveys, possibly due to weather.

Night-time imagery

Currently, there are no surveys capturing data at night, which leaves a gap in our understanding of behaviors of marine fauna. There is evidence that animals make directed movements at night, and increasing knowledge of these movements would improve our understanding of animals in the offshore environment. Improvements in thermal and/or low light imaging should allow data collection at night or at least extend imagery later at night and earlier in the morning.

Improved color fidelity, clarity, and contrast in video

We recommend continued advances in video quality for surveys. Video technology used during these surveys at times suffered from poor color fidelity, clarity, and contrast, making it difficult to identify some animals to species. Recent advances in digital camera and optical technology have clearly improved video quality (Webb and Hawkins 2013), but need to be deployed in the United States to take advantage of these benefits. The improvement in quality should help improve identification rates, as well as sex and age determinations. This may be particularly useful for particular taxa, such as loons and small turtles, which were difficult to identify consistently in the mid-Atlantic.

Standardization of video file types

This survey used a proprietary video file type that was not viewable by most video review programs. While there may be reasons to develop such proprietary file types, we do not believe it is in the best interest of broadening our understanding of digital video systems or transparency in data, because data cannot be distributed and reviewed without specialized software. We recommend that a standardized file format be adopted, and, if necessary, an open-source video review software package be developed, in order to allow anyone to review such imagery and support further development and enhancements of such a product.

Integrated GPS and camera sensor data

The importance of GPS positioning linked to aerial video data is paramount and must be tightly integrated into the video frame data. Much time and effort was spent post-processing video and GPS data to generate proper effort data for aerial observation data. We recommend that camera systems have an array of sensors on board to capture plane height, camera orientation (compass direction), camera down angle, zoom, sensor resolution, and other metrics necessary to calculating exact frame position on the ground. On-board processing should calculate exact field of view and spatial position during capture, and this data should be encoded in the video frame so that location information can be easily extracted and used for analysis. We also highly recommend an integrated backup GPS system that takes over in case of failure, and provides clear warning to pilots when systems are down, so that flights are not conducted without recording spatial data.

Improved parallax algorithm

HiDef uses the principle of parallax to determine flight heights for flying birds and bats (Hatch et al. 2013). Flight heights were reported in categories – 0-20 m, 20-50 m, 50-100 m, 100-200 m, and 200+ m. For the purposes of informing siting and permitting of marine wind turbines (with yet to be determined turbine design) and to properly assess collision risks, we recommend the use of narrower, more precise flight height ranges for future surveys, where possible.

Analysis recommendations

Develop detection and availability metrics

We were unable to derive true estimates of abundance from the aerial video data due to the way it is currently collected and processed. Boat surveys use distance sampling methods (Buckland 2001; Buckland et al. 2005) to estimate detection bias related to distance to observer. Using distance sampling allows for calculation of corrected abundance values which are then comparable with other surveys, times, and conditions. Video aerial surveys assume 100% detection across the video screen, which seems reasonable given the camera angle and relatively narrow strip width. Currently, however, they do not incorporate other potential sources of detection bias, such as variations in weather and image quality, or observer bias. We recommend that additional methods be developed to allow estimation of detection relative to changing atmospheric conditions (for example, the development and use of a metric for image quality that can be applied to all video data). Further research is needed to develop a suitable method for this. Inter-observer and inter-survey bias in detections and species identifications could be examined using a double observer approach during video analysis. This approach would be relatively straightforward to incorporate into existing audit protocols for object location and species identification.

To date, there is no way to calculate depth and visibility for submerged animals in digital aerial surveys. Flying over fixed points in the study area and using known objects of different sizes placed at different depths, measured under varying water turbidity and sea state conditions (Pollock et al. 2006), could provide a maximum depth of visibility under varying conditions and potentially maximum depths at which identifying marks and coloration disappear.

Given the greatly increased flight speeds of the aerial video, there is less time for diving animals to appear at the surface in the frame, potentially resulting in a lower availability for detection. This availability bias is also a common issue in other types of surveys (Thomson 2013). To offset this availability bias, which varies with season, region, depth, and temperature for some marine animals (Thomson 2013), it may be possible to use diving rates for some species based on behavioral and telemetry studies to obtain a better estimate of availability, since we know exactly the time and space covered by video (Thomson 2013; Southall et al 2005).

Additional comparison studies

We were able to conduct a targeted comparison between boat and high resolution digital video aerial surveys (Chapter 13), but were limited to survey overlap of one day. Conditions change throughout the year, and video technologies are continuing to improve, so it would be useful to perform a number of overlapping survey runs to develop a more comprehensive and rigorous comparison and continue to improve our understanding of how best to integrate data developed using these different survey methods. Recent comparison efforts in Europe (Burt et al. 2009; Burt et al. 2010; Buckland et al. 2012; Webb and Hawkins 2013) have added to our understanding of the capabilities different survey approaches, and additional exploration of this topic in North America will be essential for establishing digital approaches in North America and integrating new survey datasets with those generated using traditional methods (Chapter 13). Furthermore, an analysis comparing results of the various digital aerial survey methods and technologies currently in existence would be helpful for determining exactly how these methods compare. The sole study to conduct this type of comparison (Thaxter and Burton 2009) is now outdated, due to recent advances in digital technologies. It is particularly important to conduct comparison studies in North America for taxa that have remained largely unexamined in similar studies to date, either because they do not occur frequently in European waters (e.g., sea turtles and some North American cetaceans), or because the North American populations exhibit different morphological or behavioral characteristics than European populations (e.g., loons in the mid-Atlantic study area; Chapters 5 and 16).

Conclusions

Cost effective, time-efficient, repeatable survey methods are a priority for siting (i.e., baseline studies) and permitting (i.e., pre- and post-construction wildlife studies) of offshore wind energy development. Normandeau Associates, Inc. (2013) found that their digital aerial surveys were cost effective for areas >149 km^2. With technological advances in camera resolution and improvements in aircraft fuel efficiency, digital aerial surveying will continue to improve in cost-effectiveness, accuracy, and efficiency. Digital aerial surveys are also flown at much higher altitudes than visual aerial surveys, which provides several advantages; they are repeatable for direct comparisons pre- and post- construction (because flights are conducted above turbine height), they cause no discernible disturbance for most wildlife, and they are much safer for pilots and biologists. However, there are also limitations to digital aerial surveys. To ensure the success of digital aerial survey methods in the United States, wildlife managers and holders of historical databases must reach a consensus on the methods for image analysis and data incorporation. Additional comparison surveys using the latest technology should also be conducted. Some challenges, like the lack of detailed behavioral data compared to what can be collected from boat surveys (Normandeau Associates, Inc. 2013), are probably inherent to the survey method. Others can and should be addressed through adjustments to technology, management processes, or analytical approaches as this survey method is refined.

Literature cited

Buckland, S.T. 2001. Introduction to Distance Sampling: Estimating Abundance of Biological Populations. New York: Oxford University Press.

Buckland, S.T., Anderson, D.R., Burnham, K.P. & Laake, J.L. 2005. Distance sampling: Wiley Online Library

Buckland, S.T., Burt, M.L., Rexstad, E.A., Mellor, M., Williams, A.E. & Woodward, R. 2012. Aerial surveys of seabirds: the advent of digital methods. Journal of Applied Ecology 49: 960-967.

Burt, M.L., Rexstad, E., & Buckland, S.T. 2009. Comparison of Visual and Digital Aerial Survey Results of Avian Abundance for Round 3, Norfolk Region. COWRIE STANDBIRD-09, COWRIE Ltd. 40 pp.

Burt, M.L., Rexstad, E. & Buckland, S.T. 2010. Comparison of Design- and Model-Based Estimates of Seabird Abundance Derived from Visual, Digital Still Transects and Digital Video Aerial Surveys in Carmarthen Bay. COWRIE-STANDBIRD-09. COWRIE Ltd. 30pp.

Hatch, S.K., Connelly, E.E., Divoll, T.J., Stenhouse, I.J. & Williams, K.A. 2013. Offshore observations of eastern red bats (Lasiurus borealis) in the Mid-Atlantic United States using multiple survey methods. PLoS ONE 8(12): e83803.

HiDef. 2011. “HiDef announce world leading 0.5 GSD video survey capability”, June 15,2011, www.hidefsurveying.co.uk/latest-news/hidef-announce-world-leading-05cm-gsd-video-survey-capability.html

Normandeau Associates, Inc. 2013. High-Resolution Aerial Imaging Surveys of Marine Birds, Mammals, and Turtles on the US Atlantic Outer Continental Shelf—Utility Assessment, Methodology Recommendations, and Implementation Tools. Report Prepared under BOEM Contract M10PC00099. U.S. Department of the Interior Bureau of Ocean Energy Management. 378 pp. www.data.boem.gov/PI/PDFImages/ESPIS/5/5272.pdf.

Pollock, K.H., Marsh, H.D., Lawler, I.R. & Alldredge, M.W. 2006. Estimating animal abundance in heterogeneous environments: An application to aerial surveys for dugongs. Journal of Wildlife Management 70 (1): 255-262.

Shamoun-Baranes, J., van Loon, E., van Gasteren, H., van Belle, J., Bouten, W. & Buurma, L. 2006. A comparative analysis of the influence of weather on the flight altitudes of birds. Bulletin of the American Meteorological Society 87(1): 47–61. http://doi.org/10.1175/BAMS-87-1-47

Southall, E.J., Sims, D.W., Metcalfe, J.D., Doyle, J.I., Fanshawe, S., Lacey, C., Shrimpton, J., Solandt, J.-L. & Speedie, C.D. 2005. Spatial Distribution Patterns of Basking Sharks on the European Shelf: Preliminary Comparison of Satellite-Tag Geolocation, Survey and Public Sightings Data. Journal of the Marine Biological Association of the UK 85 (05): 1083. doi:10.1017/S0025315405012129.

Thaxter C.B., Burton, N.H.K. 2009. High Definition Imagery for Surveying Seabirds and Marine Mammals: A Review of Recent Trials and Development of Protocols. COWRIE BTO Wshop-09 report to COWRIE Ltd., London. 30pp.

Thomson, J.A., Cooper, A.B., Burkholder, D.A., Heithaus, M.R. & Dill, L.M. 2013. Correcting for heterogeneous availability bias in surveys of long-diving marine turtles. Biological Conservation 165: 154-161. doi:10.1016/j.biocon.2013.06.005.

Webb, A., Hawkins, K. 2013. Race Bank Offshore Wind Farm: comparison survey between aerial and boat-based surveys. Report to Centrica Renewable Energy Limited. Document no. RB-D-EV-075-0076-000000-047. HiDef Aerial Surveying, Ltd., Cleator Moor, Cumbria. 49pp.

Table 6-1. Comparison of common survey approaches for marine wildlife

	Advantages	Challenges
Visual Aerial Surveys	• Fast survey pace • Can record both in and outside the strip width • Higher identification rates	• Safety issues related to low flight height • Observer biases • Not repeatable pre- and post- construction • Not auditable • Disturbance to animals • Detection rates affected by ambient conditions and distance from observer
Boat Surveys	• Can record both in and outside the strip width • Higher identification rates • Behavioral details can be seen • Comparable with historic datasets	• Observer biases • Not repeatable pre- and post- construction • Not auditable • Disturbance (attraction and displacement) to animals • Detection rates affected by ambient conditions and distance from observer • Slow survey pace
Digital Aerial Surveys	• Fast survey pace • Archivable • Auditable (Observer identification variability, false negatives and observer biases can be identified and alleviated through audits and QA/QC processes) • Ability to obtain replicable flight height estimates • Minimal disturbance to animals • Repeatable pre- and post- construction • Technology will continue to improve	• Image quality is affected by atmospheric conditions • Low identification rates for some taxonomic groups • Detection and identification rates are dependent on video quality • Strip width is limited (controlled by camera resolution and plane altitude)

Table 6-2. Comparison of 2 cm vs. 3 cm GSR video data from the March, May and June 2012 surveys in the mid-Atlantic study area. The percentage of birds that were not identified to the species level for 2cm GSR was 53%, while the percentage of birds not identified to species in 3cm GSR was 74%.

Statistic	2 cm GSR	3 cm GSR
Percentage of all birds from each resolution that were not identified to species (excluding scoters)*	53%	74%
Percentage of all loons from each resolution that were not identified to species	43%	79%
Percentage of all gulls and terns from each resolution that were not identified to species	67%	87%
Percentage of the sea turtles from each resolution that were not classifiable to species (e.g., all SMTU)	61%	88%
Percentage of the marine mammals from each resolution that were not classifiable to species (e.g., all unknown cetacean, unknown dolphin)	18%	50%
Percentage of the sharks and rays from each resolution that were not classifiable to species	10%	78%
Disagreement rate among observers during audits (as percentage of all biota audited; includes only May and June data)	7%	12%
Percentage of all animals not identified to species from each resolution**	53%	81%

* Excluded because scoters occurred disproportionately in 3 cm footage.

**Does not include scoters and gannets (species with high identification rates despite GSR)