Chapter 13: Integrating novel and historical survey methods: a comparison of standardized boat-based and digital video aerial surveys for marine wildlife in the United States

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Chapter 13 Highlights

A standardized comparison of boat-based and digital video aerial surveys for marine wildlife

Context[1]

All field survey methods have strengths and weaknesses and understanding the nuances of a new method can be challenging. Recent advances in aerial survey methods in Europe use digital video and photography to collect distribution and abundance data for wildlife in the offshore environment. In Part II of this report, we discuss the first broad-scale application of high resolution digital video aerial surveys in North America. Part III of this report focuses on the use of standardized boat-based surveys with distance estimation, a well-established method of obtaining density data for wildlife. In Part IV, we focus on comparing and integrating data from these two survey approaches. With the help of project collaborators (HiDef Aerial Surveying, Ltd. and the City University of New York), BRI conducted an experimental comparison of boat-based survey and high resolution video aerial survey methods in 2013. A more general comparison of the two methods (using two full two years of survey data, but with boat and aerial surveys conducted at different times and locations), is presented in Chapter 14.

Study goal/objectives

We compare two alternative survey methods for assessing the distribution and abundance of wildlife offshore, and explore specific challenges faced in implementing digital video surveys in the U.S.

Highlights

- Compared results from simultaneous boat-based and digital video aerial surveys on transects off the mid-Atlantic coast of the U.S., using experimentally controlled methods.
- Most taxa were identified to species more often from the boat than in the video aerial data. An exception was scoters (*Melanitta* spp.), which were more often identified to species from the air.
- Northern Gannets (*Morus bassanus*) showed no significant effect of disturbance from the survey vessel, but 21% fewer scoters were observed in areas recently surveyed by the boat.
- Abundance estimates using boat data were higher than those from aerial data, likely in part because boat data were corrected for distance bias, as well as the poorer spatial coverage and greater velocity of the plane in this particular study.

Implications

These two methods each have complementary strengths and notable weaknesses, and the optimal survey approach will vary based on location, species, and study goals. Despite a short-term displacement of some species by the survey vessel, boats will continue to provide a useful survey platform. The archivable and auditable nature of the digital survey data may be attractive to developers and regulators, particularly as the limitations of this method are ameliorated by technological advances.

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

Abstract

Introducing a novel field methodology based on advancing technology can be desirable when it improves the quality of data or simplifies data collection methods, but it can also complicate assessment of long-term changes to habitats or populations. Though it has recently become a common survey methodology for offshore wind energy development in Europe, surveying offshore wildlife distributions using high resolution videography is a new technique in North America. To assess its effectiveness and experimentally compare the results of this survey method with traditional boat-based surveys, we conducted a boat-based survey off the coast of Virginia in 2013, while a survey aircraft using high resolution video repeatedly flew the same transect lines over the same time period. Rates of species identification varied widely between survey methods; boat-based observers were better able to identify most animals to species level than were aerial video reviewers, with the exception of scoters (*Melanitta* spp.), a sea duck family. Though Northern Gannets (*Morus bassanus*) did not appear to be displaced by the survey vessel, an estimated 21% fewer scoters were observed in the aerial survey of a given transect segment after the boat had passed through it, suggesting substantial disturbance to surveyed populations of this species. Population size was estimated for scoters and Northern Gannets from both survey platforms; these estimates were reasonably well-correlated for scoters (Spearman's correlation =0.68), but were not well-correlated by location for Northern Gannets. The inexact temporal overlap between methodologies, due to differing survey speeds, likely contributed to this poor correlation for highly mobile Northern Gannets. For both scoters and Northern Gannets, population size estimates developed from the boat data were higher than aerial estimates in almost all locations; differences may have been partially related to the poorer spatial coverage and greater velocity of the plane in this study.

Boat-based surveys and digital aerial methods have complementary strengths, and also both have notable weaknesses; the optimal survey approach will vary based on location, species, and study goals. Several weaknesses of the digital aerial surveys used in this comparison (low availability for highly mobile species, poor species identification rates for some taxa, and a lack of analytical methods for addressing detection bias) could be ameliorated by technological or analytical advances in this field. This study provides key comparative data for integrating digital video aerial approaches into the suite of survey methodologies used in North America, and maintaining continuous historical records on seabird and marine mammal distributions and abundance.

Introduction

Introducing a new field technique into an established discipline requires identifying the technique's advantages (and disadvantages) relative to more established methods, developing appropriate analytical approaches, and determining how best to integrate newly collected information with existing bodies of historical data. Though it is often desirable to introduce new methods that can improve data quality or simplify data collection, this presents a particular challenge for maintaining long-term datasets that can be used to track population- or landscape-level changes in the environment. Based on the efficiencies of cost on a broad scale, for example, it has been suggested that digital methods could largely replace visual surveys for offshore wildlife (Buckland et al. 2012). Understanding the nuances of a new method can be extremely challenging, however, as can acceptance of new methods and the integration of data collected via new methodologies into existing, long-running bodies of knowledge.

Gathering accurate information on the abundance and distribution of marine wildlife in space and time is increasingly necessary to assess the effects of environmental and ecological stressors on marine ecosystems, and to inform marine spatial planning and conservation efforts. Estimating spatial patterns in relative abundance in the offshore environment can be difficult, as these systems are extremely dynamic, animals tend to show high degrees of spatial autocorrelation or aggregative behaviors, and surveys are logistically challenging and more expensive than terrestrial equivalents. In the past century, offshore distributional surveys have mostly been carried out by direct visual observation of wildlife from boats or aircraft. Standardized methods using strip or line transects are common for monitoring marine species on both boat-based surveys (Tasker et al. 1984, Camphuysen and Garthe 2004, Camphuysen et al. 2004, Gjerdrum et al. 2012) and aerial surveys (Camphuysen et al. 2004, Certain and Bretagnolle 2008), and have been refined over the last few decades to achieve more accurate estimates of population size (Buckland et al. 1993, Buckland et al. 2001, Strindberg and Buckland 2004, Certain and Bretagnolle 2008, Evans and Hammond 2004, Kaschner et al. 2012).

In this study, we compare a new technique for monitoring offshore animals in North America, high resolution digital video aerial surveys (also "digital video aerial surveys"), to a more traditional approach. Digital aerial surveys using video and stills have been developed and successfully deployed in Europe to assess marine wildlife populations in relation to offshore wind energy development (e.g., Groom et al. 2013, Buckland et al. 2012). Very little work has been published comparing these new surveys to traditional distance sampling methods of aerial survey in that region, and results regarding the precision and magnitude of resulting relative abundance estimates are contradictory (Burt et al. 2009, Buckland et al. 2012, Webb and Hawkins unpubl. data). Such work is particularly important for species thought to be most vulnerable to offshore wind energy development; European vulnerability assessments for seabirds have prioritized several taxa that are also present in North America, including loons (*Gavia* spp.), scoters (*Melanitta* spp.), and Northern Gannets (*Morus bassanus*; Garthe and Huppöp 2004, Furness et al. 2013).

In the western hemisphere, we have no significant prior experience with this method, particularly with how detection rates, identification rates, and estimates of population size may differ between digital video aerial surveys and more traditional survey methods. The only published study to use the technique on a broad scale in the western hemisphere described an offshore movement of bats in 2012 (Hatch et al. 2013). The only relevant comparison of survey methods that has occurred to date in the United States employed a methodology for digital aerial surveys that has not been used elsewhere (Normandeau Associates, Inc., 2013), and varied in several ways from the approach presented in this study. Thus, this technique is new for North American species, and studies comparing it to traditional techniques in the peer-reviewed literature across the globe have been few and limited in scope. Such work must be taxonomically specific, as different survey strip widths and speeds can interact with animal movement behavior (primarily through the process of availability to the survey) to create species-specific bias in detection rates (Certain and Bretagnolle 2008, Spear et al. 2004).

There are some distinct advantages to high resolution digital surveys over their more traditional counterparts (Buckland et al. 2012) that could cause researchers to switch to these methods consistently in the Americas. First, they are considered safer than traditional aerial surveys, with plane speeds above 100 knots (185 km/hr) and survey altitudes above 500 m (as compared to common flight altitudes for visual aerial surveys, which can range from 60-180 m; Camphuysen et al. 2004, Certain and Bretagnolle 2008). Second, their comparatively high survey altitude limits disturbance on the wildlife being surveyed, unlike both boat-based and traditional aerial surveys (Mosbech and Boertmann 1999, Schwemmer et al. 2011). Aerial surveys also do not attract wildlife being surveyed, a phenomenon that could bias abundance estimates from boat-based surveys for certain species, such as scavenging seabirds (e.g., Hyrenbach 2001, Votier et al. 2013). Third, these surveys can be cost effective at large spatial scales, so much so that digital aerial surveys are expected to largely replace visual surveys, by either boat or aircraft, in the offshore environment around the U.K. and other western European countries (Buckland et al. 2012). Fourth, a digital record of all surveys is kept so that they can be reanalyzed or reassessed at later points in time, which may be of particular importance for phased infrastructure development scenarios or for species with changes to their conservation status. But such advantages come with potential trade-offs for digital video aerial surveys, including a relatively narrow and defined strip width and thus more variable encounter rate (Burt et al. 2009), decreased detection or identification rates for some taxa, less detailed behavioral information, and infrastructure challenges associated with the management of large quantities of video data (though it should be noted that recent technological advances have increased strip width and identification rates substantially; Webb and Hawkins 2013).

To better understand the application of digital video aerial surveys generally, and the specific challenges faced in implementing the technique in North America, we compared results from simultaneous boat-based and digital video aerial surveys on transects off the mid-Atlantic coast of the U.S., using experimentally controlled methods. Due to the survey design used in this comparison, we were also able to examine evidence of disturbance by the survey boat. For taxa with sufficient observations, we compared identification rates and population size estimates between the two methods. This comparison provides the first information of its kind for North America, improves our understanding of the relative utility of boat and video aerial surveys, and will assist in integrating data derived from new survey technologies into historical databases. Such integration of new and traditional methodologies is essential in order to maintain consistent data on marine wildlife distributions and relative abundance, and enable detection of long-term trends.

Methods

The comparison survey was conducted on March 22, 2013, off the coast of Virginia, USA (Figure 13-1). Two parallel transects were located 10 km apart and between 5.5 and 64.6 km from shore (5.3-36.9 m water depth). Total combined transect distance was 109.6 km. Weather conditions were conducive to surveys using both platforms, with light winds and no low cloud cover, mist, or fog.

Boat-based survey

The boat-based survey was carried out by the City University of New York and the Biodiversity Research Institute, with experienced observers working from the deck of a 17 m long charter vessel. The survey was conducted in “passing mode”, where the vessel stayed on a predetermined transect line and at a constant survey speed (10 knots, 18.5 km/h), except when avoiding other vessel traffic or complying with National Marine Fisheries Service (NMFS) rules about approaching marine mammals. This method was largely compliant with European Seabirds At Sea (ESAS; Camphuysen et al. 2004) and Eastern Canadian Seabirds at Sea (ECSAS; Gjerdrum et al. 2012) standards for boat-based surveys and was comparable to many other boat-based surveys conducted in the United States and elsewhere.

During surveys, teams of two observers alternated two-hour observation periods and used line transect methods to observe and record animals. The two observers were stationed on the flying bridge in most circumstances, and moved to the pilot house when wind speeds increased to the point that salt spray could damage the computer used to record observations. A continuous watch was maintained by one observer, who counted all animals within at least a 300 m bow-to-beam arc to one side of the boat. The second observer recorded the observations on a laptop computer and also watched outside the strip transect for cetaceans and sea turtles. Each record included data on species identification, number of animals present, behavior, radial distance from the boat and degree of the animal’s angle to the bow of the boat (from the location of first detection), direction of movement, and, where possible and appropriate, age and plumage/molt state. The second observer was consulted in cases of uncertain identifications. Radial distance and angle data allowed for the use of detection functions to estimate densities (Buckland et al. 2001). The computer program dLOG3, specifically designed for seabird and marine mammal surveying (Ford 2009), was linked to a GPS and used to record the vessel track; location data were recorded approximately every 5 seconds, and each animal observation was individually georeferenced. Sea state was recorded hourly using the Beaufort Wind Force Scale.

Digital video aerial survey

The aerial survey was carried out by HiDef Aerial Surveying, Limited, a technology development company based in the United Kingdom. The survey was conducted from a multi-engine Cessna 300 series aircraft equipped with the company’s first generation camera system, consisting of four super high resolution digital video cameras facing forward or backward (depending upon time of day, to reduce glare) at 30-45° from vertical, in a specially designed and patented air frame secured to the lower fuselage. Surveys were flown at an average speed of 250 km/h and 610 m above sea level, according to standard protocols (Hatch et al. 2013). The four cameras were set to 2 cm Ground Spatial Resolution

(GSR) and had non-overlapping 50 m strip widths, for a total strip width of 200 m. Cameras captured up to 15 frames per second. At one second intervals, position data for the aircraft were captured on a Garmin GPSMap 296 (Garmin International, Inc., Olathe, KS) receiver with differential GPS enabled to give 1 m precision for each position. Due to the height at which surveys were flown, there was little risk of affecting the behavior of animals at or near the water's surface, and no permits were required from the National Marine Fisheries Service (NMFS). Flights complied with all Federal Aviation Administration (FAA) regulations. Recorded images were stored on heavy duty disk drives or solid state recording devices for subsequent review and analysis.

Digital video data were manually reviewed to identify segments containing objects (including wildlife, boats, etc.), in line with HiDef's typical quality control procedures (Chapter 4). The review process was audited by experienced staff using a 20% blind sampling audit methodology. Once this process was complete, video footage was examined by trained biologists to identify objects to the lowest possible taxonomic level (either species or species grouping). Observers used a three tiered system to rate certainty in their identifications (Hatch et al. 2013). Twenty percent of object identifications were independently reviewed to determine the rate of agreement among analysts; a third reviewer examined all objects for which the original analyst and the second reviewer disagreed. Completed analysis provided data on the number of target organisms in the video, the species or species grouping of organisms, the approximate flight height for flying animals (after Hatch et al. 2013), and geospatial data for all biota.

Comparing survey types

Due to the difference in survey speeds between the two platforms, when the plane reached the end of the first transect line (after passing directly over the boat), it turned around and repeated the transect in the opposite direction. In all, the plane travelled the length of each transect six times in the time it took the boat to traverse it once, and these replicates were treated as replicates of the same transect in analysis. Given the distance between transects, and the narrow strip width involved, the likelihood of animals moving between transects (and the risk of double-counting individuals) was considered negligible in aerial surveys. While the boat moved between transects, the plane landed to refuel, and then repeated the process on the second transect. In total, the plane surveyed for three hours and 35 minutes (9:15-11:15 a.m. and 1:10-2:45 p.m.), while the boat surveyed for six hours and 54 minutes (8:45 a.m.-3:39 p.m.). While exact spatial and temporal overlap between the two survey types was not possible, except on twelve brief occasions when the plane was directly above the boat, the close spatial and temporal proximity afforded by this design allowed the boat and aerial surveys to sample approximately the same population of animals over the same time period.

To compile boat and aerial datasets for analysis, objects identified with >50% confidence in the aerial dataset were included at the specified identification, while objects identified with <50% confidence were considered at the next lowest taxonomic level (e.g., a "possible Black Scoter," *Melanitta americana,* became an "Unidentified Scoter" for analysis purposes; Hatch et al. 2013). Boat-based surveys had no confidence rankings for identifications, and all observations were taken at 100% certainty.

Species identification rates: all taxa

We used the raw counts from each survey to examine identification rates derived from the two survey platforms (Appendix 13A). Within each family (Alcidae, Anatidae, Gaviidae, Laridae, Sulidae, and Delphinidae), the proportion of observations in which animals were identified to the species level (e.g., "Common Loon", *Gavia immer*) vs. the group level (e.g., "unidentified loon sp.") was compared between survey methods.

Population size estimates derived from boat vs. aerial surveys: scoters and gannets

Survey transects were divided into 2.5 km segments for analysis (*n* = 25; Figure 13-1). For each segment, we developed estimates of population size for the two species groups with sufficient data for analysis: scoters (including Black Scoters; Surf Scoters, *Melanitta perspicillata*; and unidentified scoters) and Northern Gannets. Boat-based survey estimates of total number of individuals per segment were developed using the 'distsamp' function in Package 'unmarked' in the R Statistical Environment (Royle et al. 2004, Fiske and Chandler 2011, R Core Team 2014). Distance bands were set to 0-50 m, 50-100 m, 100-200 m, 200-300 m, 300-500 m, and 500-800 m. Wind speed (m/s) from a nearby weather station (Figure 13-1) and visibility (a categorical variable recorded by boat observers) were used as covariates to detection. No covariates to abundance were included in the model, as there was insufficient data to parameterize the model to this degree.

For video aerial surveys, it was unclear whether there was a variable like distance from observer that affected detection. Analysis of digital aerial survey data in the published and gray literature has acknowledged variable encounter rates, due to diving animals and clumped distributions, but has generally assumed perfect detection (e.g., Burt et al. 2009, Buckland et al. 2012). Thus, to quantify variance within the raw aerial survey data in an initial analysis, we used the six aerial replicates to bootstrap segment-level estimates of average numbers of individuals per segment; 500,000 simulations were run in package 'bootstrap' in R (Tibshirani and Leisch 1993). While this approach provided error estimates, it did not allow for explicit estimation of detectability. Prior to comparisons of segment-level population size estimates between survey methods, all estimates were standardized to density/km^2 to eliminate the effect of differences in effort (e.g., strip width or effective strip width) between survey platforms.

Disturbance to wildlife populations from the survey vessel: scoters and gannets

In addition to estimating abundance (or variance around counts in the case of aerial data), we conducted a separate analysis for the same two species groups (scoters and Northern Gannets) focused on the effect of disturbance on raw count data. We specified a generalized linear mixed model (using package 'lme4' in R version 1.1-7; Bates et al. 2014) that assumed a Poisson distribution for raw aerial survey counts and used a Laplace approximation to calculate likelihood. A negative binomial distribution was also examined, but did not improve model fit (likely because of limited zero-inflation in the data). Segment was included as a random effect to control for unidentified spatial variation. Wind speed and survey replicate (categorical) were added to the model as fixed effects; wind speed was averaged for each segment of each replicate. A categorical 'disturbance' variable was also added to the model; each replicate of a given segment was categorized as 'disturbed' if the survey boat had passed through it <1 hr prior to the passage of the plane, or 'undisturbed' if the boat had not yet entered the segment or had passed through the segment >1 hr prior to the plane. A single model with all abovementioned covariates was tested in this analysis and the importance of boat disturbance for influencing counts (either negatively or positively) was evaluated by a z-test of the parameter estimate from the model.

Results

A total of 3,484 birds and aquatic animals were observed from the boat's single replicate of the two transects. During the six aerial survey replicates, a total of 2,711 birds and aquatic animals were observed (Figure 13-2), with an average of 451 (±75 SE) animals observed per replicate. The six aerial surveys allowed us to estimate coefficients of variation (CV) for each species group in each transect segment. Scoters had the lowest CV at 0.35; Northern Gannets had a CV of 0.58; and loons had the highest level of variation between replicates, at 0.69.

Species identification rates: all taxa

Rates of identification to species varied by taxon and by survey platform. Overall, 11.6% of observations from the boat were at the species level, due to the large number of unidentified scoters in the boat-based survey; 45.7% of observations were identified to species from the aerial survey (Figure 13-2). Excluding scoters, observations from the boat were identified to species 100% of the time, while 51.2% of aerial observations were identified to species (Figure 13-2). Two auks (Alcidae) were observed in the aerial survey, but were not identified to species; none were observed from the boat (Figure 13-3). Video reviewers also had difficulty identifying gulls and loons to species (with identification rates of 16.7% and 0%, respectively), though 100% of observations from these families were identified to species by boat observers (Figure 13-3). In addition, 3.1% of aerial observations were not identified to the family level (i.e., were classified as "unidentified birds" or unidentified aquatic animals). Both survey platforms proved efficient in identifying Northern Gannets to species (100% identification rate in both surveys) and delphinids (81.8% identification to species from the air, and 100% from the boat).

Population size estimates derived from boat vs. aerial survey methods: scoters and gannets

Population size estimates for scoters were much larger for nearshore segments than for areas farther offshore, particularly for segments near the mouth of Chesapeake Bay. Northern Gannets were more evenly distributed across the study area, and were present in much smaller numbers. In almost all cases, modeled population size estimates using boat data were higher than aerial estimates for the same locations (Figure 13-4). Boat and aerial estimates of scoter relative abundance were correlated by segment (Spearman's correlation = 0.68), but Northern Gannet abundance estimates were not well correlated between the two survey platforms (Spearman's Rho = 0.17; Figure 13-4).

Disturbance to wildlife populations from the survey vessel: scoters and gannets

Ten percent more Northern Gannets were observed in 'disturbed' segments than 'undisturbed' segments in the aerial footage, though the effect was not statistically significant (Beta = 0.09; 95% CIs: -0.332, 0.519, $z = 0.43$, $p = 0.66$). Scoters showed a significantly negative relationship to disturbance, with 21% fewer scoters present in 'disturbed' segments (Beta = -0.23; 95% CIs: -0.289, -0.117, $z = -4.2$, $p < 0.0001$).

Discussion

The traditional boat-based survey method and the high resolution digital video aerial survey method each had clear strengths and weaknesses, with overall counts and identification rates varying considerably by taxon as well as survey platform. Abundance estimates derived from both survey platforms were much higher for scoters located in segments near the mouth of Chesapeake Bay, and were well-correlated between the two survey platforms. Northern Gannets were more widely dispersed across the study area, but relative abundance estimates between the two survey platforms were less well correlated for this species. The boat provided better species identification capabilities for many species groups than did the aerial video, but the boat also caused substantial disturbance for some taxa, potentially complicating both identification efforts and abundance estimation for scoters, the most abundant species group in the survey. Digital video aerial surveys, on the other hand, are considered to be less affected by observer biases than visual surveys (Normandeau Associates, Inc. 2013). In their assessment of a slightly different digital aerial technology in North America, Normandeau Associates, Inc. (2013) concluded that “aerial high-resolution digital imaging is likely to produce superior animal detection, density calculation, and taxonomic identification accuracy compared with conventional visual observer surveys from either boat or aircraft.” While not all of these predictions were borne out by our results in this study, there are distinct advantages to high resolution digital surveys over their more traditional counterparts (Buckland et al. 2012) that could encourage the widespread adoption of these methods in the Americas, particularly with further technological and analytical advances.

Identification rates: all taxa

We found substantial differences in species identification rates between the two survey platforms. One observer participated in both the boat-based survey and video review for this comparison study, and two of the other three video reviewers participated in previous boat-based surveys in the region. Rather than inter-observer differences, we suggest that the disparity in species identification rates was partially due to differences in the quality assurance protocols that are applied to the two datasets. Observational data collected from the boat are not replicable, and the near-instantaneous species identifications required of observers can seldom be verified after the fact. The exhaustive quality assurance and audit protocol followed by aerial video reviewers, as well as characteristics inherent to the video review process itself (such as the use of multiple levels of “certainty” criteria in identifications), ultimately lead to fewer definitive identifications than do observational approaches. This is not to discount the differences in observation acuity between the two survey types; video aerial surveys have lower fidelity than the human eye, and do not allow for extended observation periods, which can facilitate the incorporation of behavior into identification protocols. As a result, the likelihood of identifying certain individuals to species in the video is almost certainly lower than from the boat. However, it is also a clear recognition of the inherent uncertainty in the identification process, which can be difficult to account for in unrecorded visual surveys. This uncertainty is generally under-recognized or ignored, as it can be difficult to measure, but in some cases species misclassification in visual surveys may actually lead to less reliable density estimates than classifying animals as “unknown” (Conn et al. 2013), as was more frequently done in digital aerial surveys in this study. Identification rates in digital aerial surveys have also continued to improve with technological advances in the field; a new generation of cameras is now being used in Europe, which have much higher resolution and enhanced color rendition, with improved identification rates as a result (95% on average; A. Webb pers. comm.).

Northern Gannets and delphinids were highly identifiable using both survey methods, due to their large size and distinctive coloration. Scoters were the one taxonomic group in this study for which identification to species was significantly easier from the aerial video than from the boat, and we suggest that this may be partly due to the effects of disturbance from the survey vessel. Previous studies (as well as this study) have found that scoters and other sea ducks show variable flush distances by species, as well as variable recovery times to pre-disturbance behaviors or locations (Schwemmer et al. 2011, Mosbech and Boertmann 1999). We suggest that the low rate of identification of scoters to species from the boat in our study was largely due to the fact that 84% of scoters were observed >300 m from the boat; in fact, over 70% were in the 500-800 m distance band, and it can be difficult to differentiate species at this distance. The larger rafts of scoters in this survey were located close to shore, beyond the end of our survey transects; however, disturbance from the boat likely also affected the distance at which scoters were observed.

In contrast, all loons (Gaviidae) in this comparison study were identified to species by boat observers, and none were identified to species in the aerial video. This difficulty in differentiating loon species has not occurred to the same degree in digital aerial surveys in Europe to date (Hexter 2009). There is a substantial overlap in body size among loon populations using the mid-Atlantic coast of the United States during winter, however (Gray et al. 2014, Barr et al. 2000), which often prevented video aerial observers from distinguishing the two species. Offshore wind energy development in Europe is known to have caused displacement of Red-throated Loons (*Gavia stellata,* one of the few species for which consistent post-construction effects have been seen at multiple project sites; Halley and Hopshaug 2007, Petersen and Fox 2007, Langston 2013). As Red-throated Loons are a species of interest to U.S. regulatory agencies (USFWS 2008), the inability of aerial video data to reliably differentiate Red-throated Loons from Common Loons was a shortcoming of this survey approach in this study. Where both survey types are coincident, using the boat-based data to inform aerial species identification could provide an analytical solution to this problem in the future (Chapter 16; Johnston et al. 2014). Recent advances in camera technology would likely also ameliorate the issue to an extent.

Correlations in relative abundance estimates between survey platforms: scoters and gannets

Relative abundance estimates for scoters were well-correlated between the two survey platforms, but less well correlated for Northern Gannets. Since Northern Gannets were highly identifiable to species and scoters to genus using both survey methods, identification bias appears to be an unlikely explanation for these differences. Gannet attraction to the survey vessel is a possibility, as this species is known to change behaviors relative to fishing boats from up to 11 km away (Votier et al. 2010, Bodey et al. 2014), but no statistically significant attraction to the boat was observed during this study. We suspect that there were three main factors at work that led to this difference: (1) during non-breeding periods and in daylight hours, Northern Gannets are generally observed in flight, and are highly mobile (Mowbray 2002), (2) exact temporal and spatial overlap between survey methodologies was not possible, due to substantial differences in survey speed, and (3) the study design utilized in this comparison yielded relatively low encounter rates for Northern Gannets in the aerial survey. Due to the species' mobility and the inexact temporal overlap between methodologies, it is likely that individuals were observed in slightly different locations between the boat and aerial surveys, particularly for aerial replicates that were conducted well before or well after the boat's passage through a given segment. In addition, the aerial transect strip width is narrower than the effective strip width for the boat-based survey (which is intended to have a minimum of 300 m, but for gannets and ducks was estimated to be between 379 and 571 m in this study). At the low density transect spacing in this study, it seems likely that aerial surveys were simply inconsistent at observing highly mobile species (such as Northern Gannets) between replicates. A similar issue has been found for highly mobile gull species using digital aerial survey approaches in the United Kingdom (Burt et al. 2010). Encounter rate variability has been noted to affect precision in abundance estimates in digital aerial surveys in the North Sea, and previous studies have recommended careful survey design, including high transect densities for digital aerial surveys, to reduce uncertainty and ensure sufficient statistical power to detect change (Burt et al. 2009, Buckland et al. 2012). This type of availability bias was likely less of an issue for scoters in this study, which were observed in large, more geographically stable aggregations. This same issue of availability, however, explains why distance-corrected boat-based estimates of seabird population size were consistently higher than bootstrapped aerial estimates for the same locations. Newer generations of camera systems have increased the strip width for aerial surveys from 200 m to 500 m to help address this issue (Webb and Hawkins 2013).

Disturbance from the survey vessel: scoters and gannets

We expected that animal distributions could be disturbed by the boat survey vessel, as displacement by and attraction to survey vessels has the potential to bias estimates of population size made using a boat-based platform (Buckland et al. 2012). The boat did appear to affect distributions of scoters in the short term. A displacement effect has been observed in other studies of scoters, and the degree of geographic or temporal displacement appears to vary by species (Schwemmer et al. 2011, Mosbech and Boertmann 1999). This has the potential to lower detection rates of scoters and could negatively bias estimates of scoter population size, though we saw no clear evidence of such in this study. However, boat disturbance probably did play a role in the poor species identification rates for scoters. Northern Gannets showed no significant attraction or displacement in this study, though they are known to be attracted to fishing vessels under some circumstances (Votier et al. 2010). Attraction is possible for other taxa observed in this study as well, including dolphins, which were infrequently observed but were more common in the boat-based survey than in any single aerial replicate.

The future of offshore wildlife surveys

The best methodological approach for studies of offshore wildlife will depend on the specific characteristics of each study area and project goals (Camphuysen et al. 2004), and may involve a combination of complementary survey methods. Digital aerial survey approaches have largely replaced visual aerial surveys for offshore wind energy research in Europe, as they are safer to conduct than visual aerial surveys, reduce or eliminate disturbance to wildlife as compared to visual aerial or boat survey approaches, and produce archivable data, which allows for a robust quality assurance and audit process. Boat-based surveys also have methodological strengths, including excellent (although generally unverifiable) identification rates for most species, and the ability to obtain more detailed behavioral data than is possible with digital aerial approaches. Detection bias is a known issue for boat-based surveys, but it is also an issue that is relatively well understood, and can be addressed in part with established analytical approaches (Buckland et al. 2001).

While digital aerial approaches were developed in Europe, this application of these technologies in North America demonstrates clear avenues for additional research and development. The species composition of ecological communities in the western Atlantic varies considerably in some cases from what is present in the North and Baltic Seas. Early indications suggest that digital aerial surveys may have distinct advantages over visual aerial or visual boat surveys for sea turtles, for example, a taxon of considerable interest in North America but one that rarely occurs in Europe (Chapters 14 and 15, Normandeau Associates, Inc., 2013). Even pan-Atlantic species may possess different characteristics in North America than in Europe, as evidenced by the large range of body sizes for Common Loons that winter in the mid-Atlantic United States (Gray et al. 2014, Barr et al. 2000), and the resulting difficulty in differentiating Red-throated Loons and Common Loons by body size in aerial video in this study. Additional exploration of species identification capabilities—for example, by conducting test flights over known-species flocks—could aid the future application of this technology in the U.S.

In addition, there is a need to further the development of analytical approaches for digital aerial surveys. Because the cameras are pointed down towards the water's surface, digital aerial surveys avoid the common problem of distance bias; but, to date, other types of detection bias have not been addressed for digital aerial surveys. Further examination of detection rates (in relation to taxon, weather, sea state, time of day, and other factors) could be a fruitful avenue for methodological development. Existing audit processes for object location in aerial video could be easily modified to incorporate a double observer approach and lead to more statistically rigorous, accurate, and reliable estimates of abundance for North American populations.

There will continue to be a role for boat surveys in North America, as they can provide more detailed information on behaviors (and in some cases, species identifications), and can be cost-effective in smaller geographic areas, particularly close to shore. However, at the proposed geographic scale of offshore wind energy build out in the United States (USDOE 2011), it will also be essential to explore more efficient survey alternatives. The key will be to successfully integrate data from these newer survey platforms, in order to ensure compatibility among future studies, maintain a continuous historical record, and enable the assessment of long-term changes in wildlife distributions and abundance. Boat survey data from historical databases such as the Compendium of Avian Information, maintained by the U.S. Fish and Wildlife Service, are being used to assess baseline wildlife distributions (O'Connell et al. 2009, Kinlan et al. 2012), but those baselines will only be relevant for assessing future change if they can be interpreted in combination with data derived from more recent, technologically advanced approaches. This issue has remained largely unaddressed in European studies to date, in part due to the low precision of early abundance estimates developed from digital approaches (Burt et al. 2010). The technology has advanced dramatically in recent years, however, and the development of calibration factors will be essential to ensure comparability between survey datasets and facilitate the deployment of this technology in North America.

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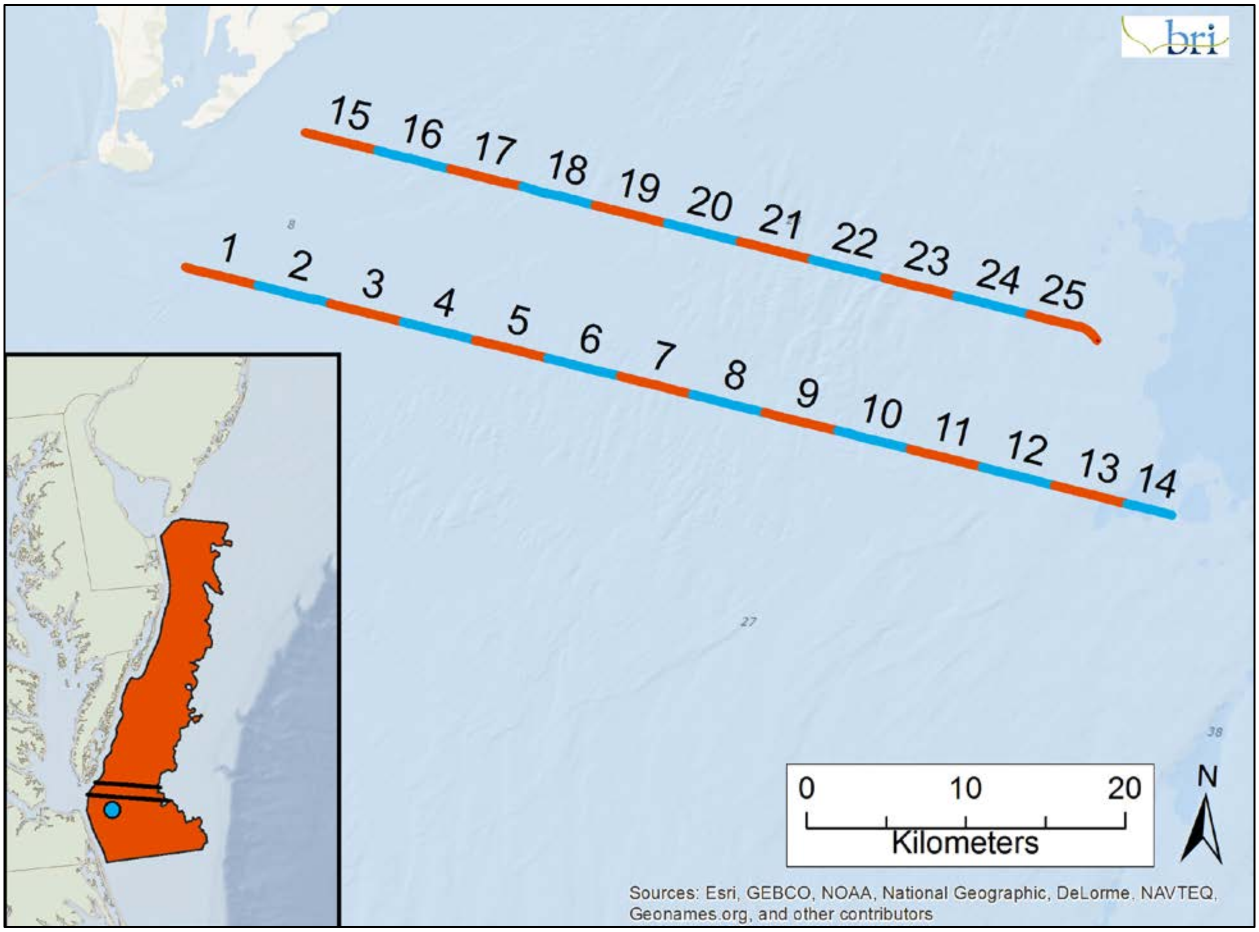
Figures



Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors

Figure 13-1. The comparison study occurred on two transects, 5-66 km offshore of Virginia. Transects were subdivided into 25 segments 2.5 km long. The inset map shows the broader project study area, the two transect strips (in black), and the location of the Chesapeake Light weather station (blue circle).

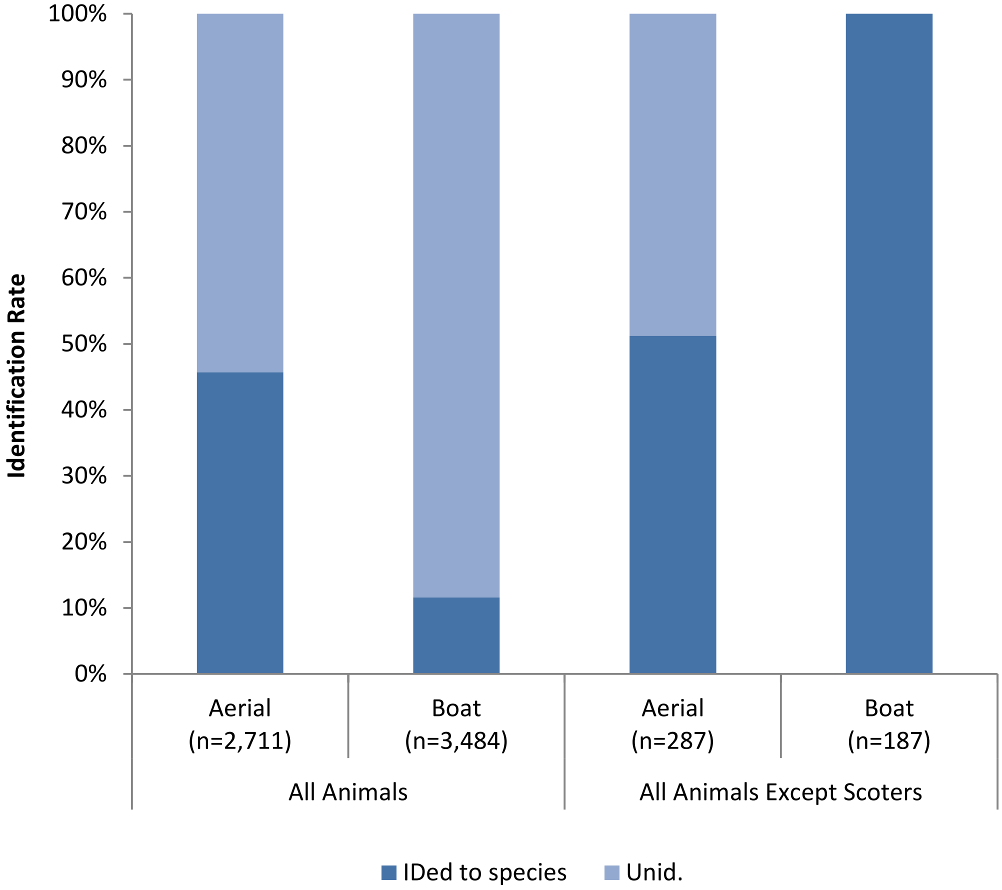


Figure 13-2. Rate of identification for all animals (with and without scoters) in the boat and digital video aerial surveys. Sample sizes are noted below each category.

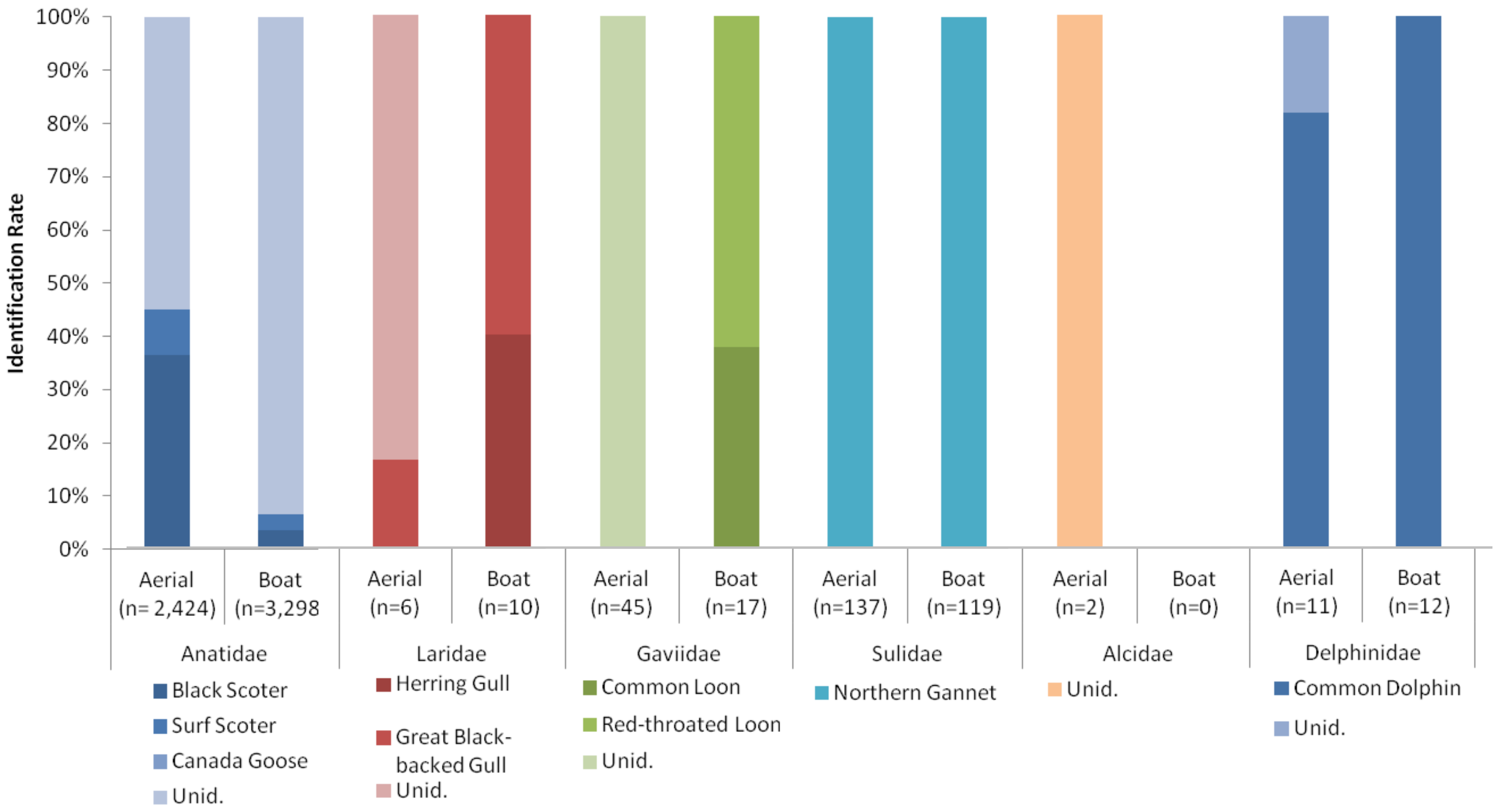


Figure 13-3. Rate of identification for animal groups for the boat and aerial surveys. Sample sizes and species included in counts are noted for each category.

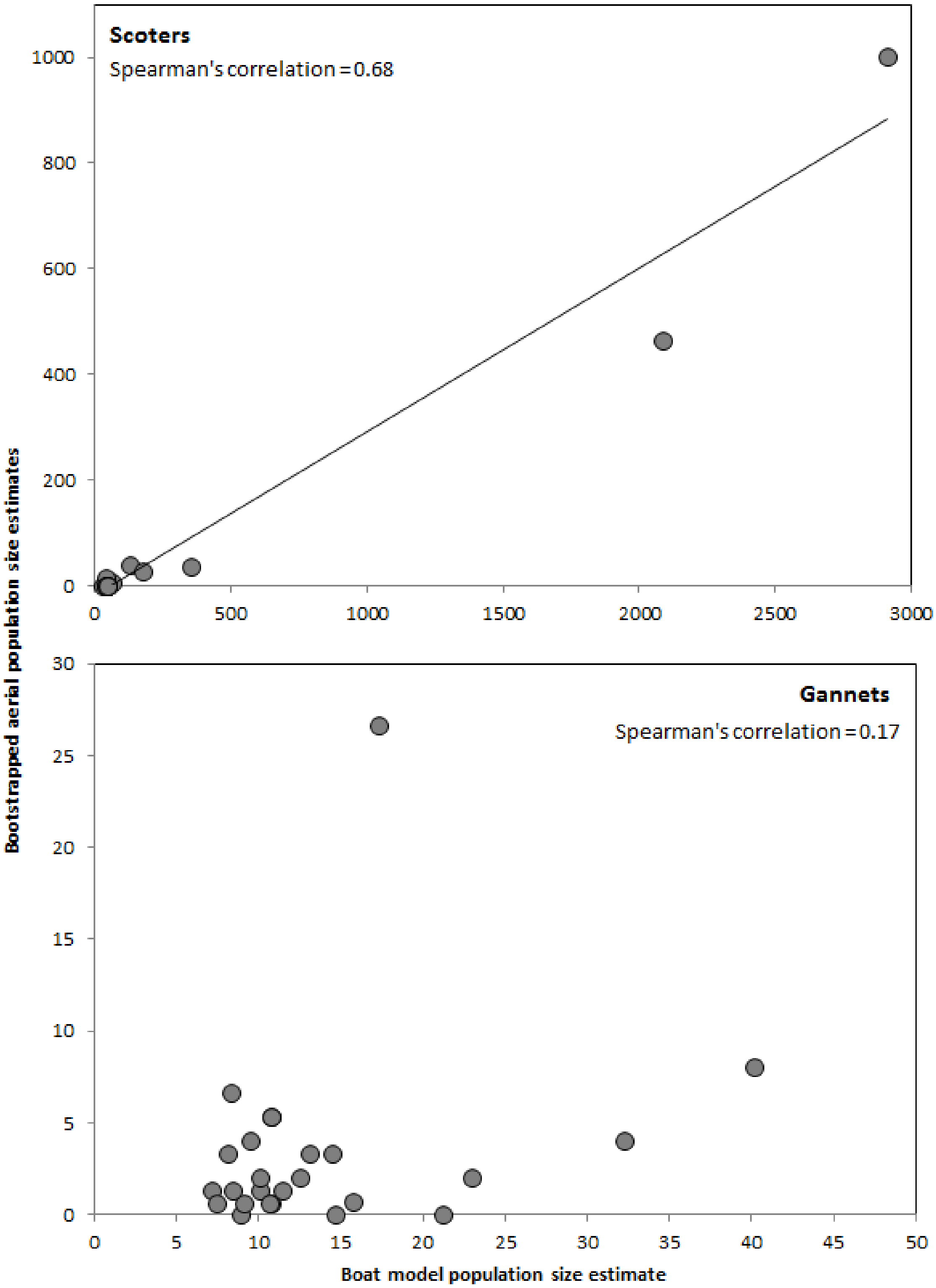


Figure 13-4. Correlations between boat model population size estimates and bootstrapped aerial survey population size estimates, by transect segment, for scoters and Northern Gannets.

Supplementary material

Appendix 13A.

Table 13A-1. **Boat-based and digital aerial survey counts of wildlife by transect segment and family.** All six aerial replicates are included in counts. Counts are not corrected for transect strip width.

Segment	Alcidae		Anatidae		Delphinidae		Gaviidae		Laridae		Sulidae		Unidentified birds		Unidentified aquatic animals	
	Aerial (all reps.)	Boat	Aerial (all reps.)	Boat	Aerial (all reps.)	Boat	Aerial (all reps.)	Boat	Aerial (all reps.)	Boat	Aerial (all reps.)	Boat	Aerial (all reps.)	Boat	Aerial (all reps.)	Boat
1	1	0	707	1,246	0	0	5	7	1	0	46	6	9	0	0	0
2	0	0	1,520	1,732	0	0	2	8	1	2	9	2	17	0	0	0
3	0	0	56	178	0	0	2	3	2	0	6	6	7	0	0	0
4	0	0	12	17	0	0	3	6	0	1	1	2	4	0	0	0
5	0	0	0	0	0	0	2	4	1	0	8	2	5	0	0	0
6	0	0	0	0	0	0	2	0	0	1	0	5	0	0	0	0
7	0	0	0	0	0	0	1	1	0	2	5	5	2	0	0	0
8	0	0	0	0	1	0	1	1	0	0	6	3	3	0	4	0
9	0	0	0	0	0	4	1	2	0	0	2	5	1	0	0	0
10	0	0	0	0	0	0	0	1	0	0	2	0	1	0	0	0
11	0	0	0	0	0	0	3	1	0	0	3	6	1	0	0	0
12	0	0	0	0	0	0	2	0	1	0	1	1	2	0	2	0
13	0	0	0	0	1	1	4	1	0	1	7	8	1	0	1	0
14	0	0	0	0	0	0	4	1	0	0	13	32	1	0	0	0
15	0	0	63	47	0	0	1	3	0	1	5	0	5	0	0	0
16	1	1	41	71	0	0	2	1	0	1	10	1	4	1	0	1
17	0	0	22	7	0	0	3	1	0	0	1	8	4	0	0	0
18	0	0	1	0	0	0	2	2	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	2	0	0	0	2	2	9	0	0	0
20	0	0	0	0	0	0	0	2	0	1	3	2	0	0	0	0
21	0	0	0	0	1	0	1	0	0	0	1	1	0	0	0	0
22	0	0	0	0	7	3	1	0	0	0	1	2	2	0	0	0
23	0	0	0	0	0	0	1	0	0	0	0	6	0	0	0	0
24	0	0	0	0	1	2	0	0	0	0	3	12	0	0	0	0
25	0	0	2	0	0	2	0	0	0	0	2	3	1	0	0	0
Totals	**2**	**1**	**2,424**	**3,298**	**11**	**12**	**45**	**45**	**6**	**10**	**137**	**120**	**79**	**1**	**7**	**1**