National Fish and Wildlife Foundation
Final Programmatic Report

Project Name and Number: Whales Ships & Gear II (2006-0093-09)

Recipient Organization/Agency: _Virginia Aquarium Foundation

Recipient Contact: _Susan Barco_____

Recipient E-mail: sgbarco@virginiaaquarium.com_____

Recipient Web Address: ___www.virginiaaquairum.com_____

1) Summary

This project was supported by four funding sources. We originally received a grant from the National Fish and Wildlife Foundation (NFWF) through the Commonwealth of Virginia Department of Game and Inland Fisheries. We matched that funding with an equal amount from the Virginia Aquarium Foundation's Batten Research Endowment. The original proposal requested funds for both a vessel-based ship characterization study and a simultaneous whale and fishing gear survey. We were funded for the ship characterization study and chose to conduct the study from a shore-based platform on the top floor of a hotel. By using the shore-based platform instead of the vessel, we were able to man the surveys from the originally proposed 24 hours per month to 40 hours per month.

2) Introduction

The Virginia Aquarium & Marine Science Center sought funding support to collect baseline data on large vessel traffic entering and departing the Chesapeake Bay. Data collection was planned to include numbers and types of vessels and their speeds at varying distances from port. Fortunately, due to the timing of the funding support for this project and the passage of the Ship Strike Rule, the project actually straddled the December 2008 implementation date allowing for a pre and post Ship Strike Rule comparison. To characterize vessel traffic, this project utilized a recently implemented technology called AIS (Automated Identification System). AIS is a vessel-based tracking system that provides real-time data on vessel movements. It allows us to collect and archive vessel information including ship type, vessel identifications, dimensions, positions, and speed using a land-based receiver. This project also utilized a RADAR (Radio Detection and Ranging) system to collect and archive track data on all vessels over 65 feet, including military vessels and other vessels not transmitting AIS data.

3) Methods

Data Collection

This is the first study to simultaneously collect and analyze vessel traffic data using both AIS and RADAR. Our shore-based survey platform was located on the 17th floor of an oceanfront hotel in Virginia Beach VA. AIS data were collected passively using a RadarPlus AIS receiver (SM161RG-2) with GPS attached to a 2-bay dipole Omnidirectional AIS antenna which was mounted approximately 50m above sea level on the hotel roof. The received data were downloaded from the AIS receiver directly to a Dell Precision (M4300) laptop through a serial port. The laptop had a 2.00GHz processor, 120GB hard drive and 8MB RAM. The AIS download cable was split and also run through a B&B Electronics RS232 data converter, and then attached to data port two on a Furuno 1954C RADAR unit with a ARP11 (Automatic RADAR Plotting) card. The ARP11 card has mini-ARP functionality which includes a 10-target auto plotter that automatically acquired vessels within 2.5nm of an area 45 degrees on either side of the vessel heading and tracks manually acquired radar targets, calculating their courses and speeds. Therefore we did not use the mini-ARP auto acquire function limited for this project. The manual ARP function was capable of

tracking up to 16nm from the RADAR antenna. Full ARP was not available for RADAR units in our budget range. Running the AIS signal to the RADAR unit allowed the observer to determine which targets appearing on the RADAR screen were transmitting AIS and which were not. The RADAR unit had a Furuno heading sensor, GPS antenna and four foot wide open array antenna. The antenna was mounted on the hotel roof adjacent to the VHF antenna. The RADAR unit ran on AC power and was operated using a TrippLite (PR25) 25amp power supply. The data from the RADAR unit was downloaded into the laptop via USB cable from data port one (Figure 1).

We surveyed for five consecutive days each month for one year. Observers completed a Coast Guard-approved RADAR observer course prior to the initiation of surveys. During each survey, AIS data were continually downloaded. The RADAR data stream originated from targets that were manually acquired by observers. During daylight hours, an observer would continually monitor the RADAR screen and visually scan the ocean. When a target appeared on the RADAR screen, the observer would determine if it was broadcasting an AIS signal by looking at the shape of the target. Targets broadcasting AIS had a triangle around the target. If a target was not broadcasting AIS and was of sufficient size (determined either by size of target on RADAR or by size of vessel seen by visual scanning), we manually acquired it with ARP11 which started data download from the RADAR unit. Once a target was acquired, a circle surrounded it on the RADAR screen (Figure 2). We attempted to track only large vessels, but often could not see the target before acquiring it. Once we acquired a target, we recorded the date and time of acquisition and attempted to identify the vessel. When an acquired target was in visual range, we used a Nikon (Prostaff 16) 48X65mm spotting scope fitted with a Vixen Piggyback ¼" -20 fine adjustment unit mounted on a tripod to observe the vessel. When possible, we took pictures of each vessel using a Nikon Coolpix (4600) attached to the spotting scope using a Nikon 16-48X digiscope adapter. If visibility allowed, we would record the vessel's hull number and/or name. Once a target was identified, we assigned it a ship type code (Table 2). If we acquired a target and upon visual scanning it was obviously less than 65ft (19.8 m), we scored the track as an error. Vessels that we never observed (due to visibility) or could not categorize were assigned an 'unknown ship' code.

We used SiiTech AIS Server v3.6.191 (http://www.siitech.com) to collect AIS and ARP11 messages. The server automatically redistributed, decoded, and stored records in a Microsoft SQL Server™ 2005 database. In addition, the server continually calculated the positions of the RADAR acquired vessel by using the range and bearing from the radar unit location. The AIS Server automatically created a new SQL database for each survey month. AIS data were received in two data streams, one with ship ID number and continually changing position (ship position data) and one with one set of data per ship ID with information about the size, draft and cargo of the vessel (ship static data). Thus, any misidentification or mistakes in the AIS static data were due to AIS coding on the part of the vessel operator. Each database contained two raw data tables: (1) a table with all ship position information from AIS and ARP11 messages (Table 3), and (2) a table with static messages from AIS records (Table 4). We manually entered the static RADAR data into a third SQL table in the same database where automated AIS messages were redistributed (Table 5).

Data Processing & Analyses

We used Microsoft SQL Server™ 2005 queries to perform Quality Assurance/Quality Control (QAQC) to: (1) delete location errors from the AIS ship position table, (2) assign a unique ID to all RADAR targets based on time and date acquired, (3) separate AIS and RADAR records into individual tables, (4) assign text ship type names to all numerically coded AIS ship type reports, (5) delete all records from RADAR targets acquired in error, and (6) calculate whether vessels were inbound or outbound.

After conducting QAQC on each month's data, we exported the tables into an ESRI file Geodatabase, and loaded them into ESRI® ArcMap™ 9.3. Based on the origin position at the COLREGS line in Chesapeake

Bay (published in the Federal Register notice of the Ship Strike Rule), we used the ArcGIS "buffer" tool to create two semi-circular zones extending seaward from the defined point of origin (37°00'36.9"N , 075°57'50.5"W): (1) 0-20nm (the Seasonal Management Area) and (2) >20-30nm.

We created multiple ArcGIS models in order to efficiently process each month of survey data into GIS format (Figure 3). We processed seven data manipulation steps using the first model, described as follows: 1) joined the "ship static" table to the "ship position" table; 2) displayed and exported the X Y data from tables in Geographic Coordinate System (GCS) World Geodetic Survey 1984 (WGS 1984); 3) projected the data to North American Datum (NAD 1983) Universal Transverse Mercator(UTM) Zone 18 North; 4) used the ArcGIS "intersect" tool to join the ship position feature with the semi-circular zones in order to identify in which zone each record occurred; 5) used the ArcGIS "clip" tool to remove all points with outside of semi-circular zones; 6) created a new field containing a concatenation of a ship's unique ID number ("MMSI") and each position point's "receive date"; 7) calculated the decimal time for each record, (Figure 4).

We used the ET GeoWizards 9.9 "convert point to polyline" tool to connect the vector points to line representations. We used the newly created "MMSI-Receive Date" field as the unique identifier and the "Decimal Time" field to order the positions. Each polyline feature was then joined with the original point table to attach the original attributes to each of the polylines. Each polyline represented one unique transit. We calculated the linear kilometers of each transit using the ArcGIS "calculate geometry" tool.

Two ArcGIS models were used (one for RADAR data and one for AIS) to create uniform attribute fields for each month of data. We combined all the months into yearly datasets for both RADAR and AIS using ET GeoWizards 9.9 "merge" tool for the point and line representations of the tracks. We removed records from all vessels traveling <0.5kt or >30.0kt to eliminate stationary targets and high speed outliers that were often data input errors. In order to correct the AIS data to match RADAR effort, we used decimal time to select AIS records collected during RADAR surveying time periods. We used the corrected AIS dataset when comparing AIS records to RADAR records. The results and maps are based on five final features: (1) all AIS lines, (2) all AIS points, (3) AIS lines corrected for effort, (4) AIS points corrected for effort, (5) RADAR lines, and (6) RADAR points.

We used the ArcGIS Spatial Analyst "density" function to create density grids of tracklines with various attributes, using a 1500 meter search radius and 200 meter resolution. We visualized the results using ArcGIS' "geometrical interval" method to distribute the range of values into ten classes. We created density maps for transits of all AIS vessels ≥ 65 feet (19.8m) in length, and seasonal. The same procedure was used to create density maps of AIS and RADAR transits for each of the four seasons. For the seasonal analyses we defined "Winter" as January - March, "Spring" as April- June, "Summer" as July-September, and "Fall" as October-December.

In order to investigate vessel speed, we used ArcGIS Spatial Analyst "neighborhood statistics" tool to calculate the average speed over ground (SOG) in knots of vessels within a 500 meter radius of a 200 meter cell. Two grids were created representing time periods "before" (Apr-Nov 2008) and "after" (Jan-Mar 2009) the implementation date of the Ship Strike Reduction Rule. Separate grids were created for data inside the seasonal management area (SMA), and data located 10 nm outside the SMA. We used the ArcGIS "manual" classification method to visualize the grids into five groups of mean SOG: less ≤8; >8-10; >10-12; >12-15; and >15 knots. Cell counts were calculated for each mean speed classification group to represent spatial and temporal changes in ship speeds. In addition to the spatial analyses, we used the tabular records to calculate mean speeds of vessel locations inside and outside the SMA, before and after the Ship Strike Rule for both AIS and RADAR data.

4) Results

a) Outputs

The south Chesapeake Bay entrance lane is defined by a row of buoys, beginning with the Chesapeake Bay (CB) buoy south of the bay mouth indicating the inbound and outbound lanes for large vessels (Figure 4). Large, deep draft vessels must approach Chesapeake Bay from the south. The north lane, for smaller, shallower draft vessels is defined by a single buoy (NCA buoy). Both lanes converge at the Chesapeake Bay Junction (CBJ) buoy where harbor pilots are picked up and dropped off. The two entrance lanes are referred to as the Chesapeake Bay approach. Once inside Chesapeake Bay, vessels move into the Thimble Shoals channel to the port of Hampton Roads and to various military installations or into the Baltimore channel to the port of Baltimore and other smaller ports inland. The seasonal management area (SMA) described in the Ship Strike Rule extends 20nm offshore of the ocean/bay interface defined by a point (37°00'36.9"N , 075°57'50.5"W) on the COLREGS line.

Vessel Demographics

We recorded over $2.6X10^6$ records of data with ship position information during the entire survey period (April 2008-March 2009). Each record represented one point on the map. There were 1181 hours of AIS data collection and 540 hours of RADAR data collection for a monthly mean of 98 and 45 hours for AIS and RADAR respectively. After QAQC, we analyzed $2.46X10^6$ records of data where errors and vessels less than 65feet in length were removed and all transits inland of the COLREGS line were removed. These point records represented 1411 transits by vessels broadcasting AIS for a total of 69,606km of track line, and vessels acquired with the RADAR unit represented a total of 506 transits for a total of 8,702km of track line. AIS data resulted in 1.2 transits per hour and RADAR resulted in 0.9 transits per hour (Table 6; Figure 5). For these and other results, we are reporting number of vessel transits. The number of transits does not reflect the number of unique vessels, since an individual vessel may have been tracked multiple times during the survey.

When AIS effort was corrected to match RADAR effort, the AIS data contained 499 transits with 25,270km of track line representing 0.9 vessels per hour. Thus, when effort was equalized, AIS data represented only 49.7% of the total large vessel transits observed, and transits per hour were equal for corrected AIS and RADAR data. This was likely an underestimate because we could not verify the length of all vessels acquired by RADAR, and we may have acquired some vessels <65 ft. When we eliminated all transits in those categories that most likely contained some smaller vessels ("fishing" and "unknown") from the RADAR results, the proportion of vessels captured by RADAR was reduced to 33.4% (236 of 706). Thus, we believe that use of AIS alone in the Chesapeake Bay approach would capture between 49% and 67% of the large vessel traffic using the area. When examining track line distance by AIS versus RADAR methodology, RADAR vessels represented only 25.6% of the track line distance. The disparity between number of transits and distance of track was due to the limitation of the RADAR ARP11 unit which was only able to track vessels to 16nm from the survey platform. In contrast, most AIS vessels were tracked through the 30nm study area.

Comparing AIS and RADAR when AIS effort was corrected, we recorded more inbound vessels using AIS (n=276 of 499; 55%) and more outbound vessels with RADAR (n=327 of 506; 58%; see Table 6). The greater number of outbound transits in the RADAR data was probably due in part to our ability to detect vessels on RADAR >10nm inland, giving us a considerably larger detection zone for outbound vessels than for inbound ones. Another explanation could be our choice to survey using the RADAR during daylight may mean that we captured some military and fishing vessels leaving port in the morning and missed them returning to port in the evening.

Vessel Location

With good weather conditions, we were able to collect AIS broadcast data from vessels more than 40nm offshore and occasionally more than 100nm from shore. The RADAR unit we acquired did not detect vessels more than 20nm from the survey platform and the ARP11 card could not acquire a target at a distance of more than 16nm. Thus, we collected data from a much larger area using AIS than RADAR (Figure 6). More powerful RADAR and antenna units with full ARP capability cost substantially more and are considerably larger than the portable unit we used for this study. Future studies will require the use of a RADAR unit with full ARP capability and a larger target acquisition range in order for RADAR survey ranges to be comparable with AIS.

`Density maps were created from the track lines of vessels (Figure 7). The density pattern of vessels recorded using AIS was different from that recorded using RADAR (Figure 8). There was a very discrete pattern for AIS vessels that corresponded with the shipping lanes. RADAR vessels, on the other hand, were more spread out and displayed less predictable patterns covering a large area outside of the shipping lanes. Where there was an obvious area of low vessel density near the Chesapeake Light Tower (36°54'35" N 75°42'35" W) in the AIS data, that area was heavily used by military vessels captured in the RADAR data.

A density analysis including both AIS and RADAR data shows relatively little space without vessel traffic within 30nm of the Chesapeake Bay COLREGS line (Figure 9). The density pattern for AIS vessels changes from the inshore SMA area to offshore of the SMA. Outside the SMA (and outside of the shipping lanes), ships spread out dramatically covering all areas of the coastal ocean. A question to protected resources managers would be: if speed were not a factor, does the risk to whales change if vessel traffic is concentrated in discrete areas of higher density traffic (shipping lanes) versus exponentially larger areas of lower density. This is exactly the type of question that should be considered when conducting future marine spatial planning.

Vessel Seasonality

Winter was the season with the fewest vessel transits for both data collection methods (23.8% AIS; 17.0% RADAR), though it was not a substantial decrease when compared with other seasons in the AIS data (see Table 6). Spring, summer and fall were similar for AIS data (24.2%, 25.7%, 26.3% respectively), but fall (31.4%) had considerably more vessel transits recorded by RADAR than spring and summer (26.5%, 25.1%, respectively). This was likely due to an increase in fishing activity in the fall, especially by the menhaden fleet whose vessels are all $\geq$65ft. Overall, differences in vessel density among seasons were negligible (Figure 10). Higher density in the fall, west of the primary shipping lane, was most likely due to fishing effort.

Vessel type

When examining vessel type data, we reported vessel type for AIS transits based on the AIS codes received and for RADAR transits based on visual scanning and photography. More than two thirds of the vessel transits recorded using AIS were cargo vessels (68%; n=337; see Table 6; Figure 11). Other common vessel types included tankers (n=70; 14%) and tugs, both under tow and alone (n=55, 11%). Military vessels represented only 2% (n=9) of the AIS transits. Other vessels not required to use AIS in the data set were federal law enforcement (USCG) and research (NOAA) vessels (n=16). Twenty-six percent of the transits tracked using RADAR were categorized as “unknown,” primarily due to poor

visibility (Figure 12). Excluding unknown vessels, military vessels comprised 47% (n=179) of the vessels we identified, followed by fishing (32%; n=120) and federal law enforcement (USCG) vessels (10%, n=38). There were several commercial cargo, tanker and tug vessels (n=13) in the RADAR data set.

Vessel Speed

We investigated vessel speed using the point data and the neighborhood analyses described in the *Methods* section. We then compared the spatial distribution of mean speed by vessel type for the three most frequent vessel categories for both AIS and RADAR. Vessel traffic patterns for cargo, tanker and tugs collected using AIS exhibited similar spatial, but different, speed distributions (Figure 13). Among the AIS vessel types, tugs exhibited the slowest mean speeds with most traffic (73%) 10kt or less (Figure 14). Tankers were also relatively slow with only 5% of traffic greater than 12kt. Cargo vessels were significantly faster than both tankers and tugs with >90% more than 10kt and 46% greater than 12kt.

For military, unknown and fishing vessel data collected using RADAR, there were no distinct differences in vessel traffic patterns among the three categories. This was true for both spatial distribution and speed patterns (Figure 15 and 16). There were, however, subtle spatial differences between military and fishing traffic. Outside of the shipping lanes, military traffic utilized to the area east (offshore) of the lanes and fishing vessels had a distinct bi-modal coastal distribution north and south (inshore) of each shipping lane. The dispersed spatial pattern of the RADAR vessel traffic seen in the density analyses appears to be due to both military and fishing vessel traffic. Both types of vessels occurred well outside of the shipping lanes within the SMA.

Seasonal Management Area & Speed Restrictions

In the SMA, speed was restricted to a maximum of 10kt for commercial vessels ≥65ft on 8 Dec 2008. This occurred during a survey period, and we eliminated that survey from the seasonal management area analyses. Thus, excluding December data, we report eight months of data before speed restrictions and three months after. We analyzed the vessel speed data in two ways to investigate the response of vessel traffic to the Ship Strike Ruling. Nearly all of the AIS vessel data (95%) consisted of vessels that were required to restrict their speed under these regulations. When we calculated mean speed over ground (mean speed) for all records in the vector point feature, mean speed before the restrictions (April-Nov 2008), was 11.4kt (±4.6) inside the SMA and 13.3kt (±5.3) outside the SMA.

In the raster grids (Figure 17), before the speed restrictions 57% of cells had mean speeds >10kt in the SMA and 82% were greater than 10kt outside the SMA (Figure 18). After the restrictions (Jan-Mar 2009), 52% of cells had mean speeds great than 10kt inside the SMA and 82% were greater outside the SMA. Ideally, if all ships were complying with the rule, the percentage of cells with speeds >10kt in the SMA after the restrictions should be approaching zero. The cell counts of raster grid data suggest that inside the SMA, there was a negligible change in amount of time vessels travelled at 10kt or less. For vessels travelling over 10kt, there was a trend toward speed reduction with proportionately more cells in the 10-12kt range after the restrictions than before. This apparent speed reduction inside the SMA is evident in the spatial analyses (Figure 178), where the difference in speeds before and after the restriction is defined by the SMA boundary.

Both before and after the SMA, AIS vessels exhibited greater speeds while outbound than inbound (Figure 19). The slower inbound speeds were most likely due to a ship's need to slow while inbound to pick up a harbor pilot. Pilots often leave outbound ships inshore of the SMA, therefore no speed reduction to drop off a pilot was obvious for outbound vessels inside the SMA. There was an obvious

reduction in speed in the shipping lanes, which represents the primary speed reduction in the entire SMA due to the high density of vessels in the lanes (See Figure 9). In general, vessels were clearly slowing down, but not all vessels were complying with the mandatory speed limit of the Ship Strike Rule. The speed restrictions had no significant effect on the cell counts calculated from the data outside the SMA for vessels transmitting AIS.

Speed restrictions had no effect on RADAR vessels, most of which were not required to comply with the regulations. In fact, the proportion of the SMA area with speeds above 15kt increased from 11% before the regulations to 26% after (Figure 20). Spatially, the highest speeds were not confined to the shipping lanes as they were in the AIS data, nor was there any predictable speed pattern (Figure 21).

b) Post-project Outcomes

To date there are no Post Project outcomes as we have just completed data analyses. We will share these data with NOAA and the US Coast Guard in hopes that there will be enforcement associated with the Ship Strike Rule in the near future.

5) Discussion & Adaptive Management

a) Lessons Learned and Transferability

i) This project brings into question the use of AIS data as an accurate representation of large vessel traffic in coastal regions of the United States. In Virginia, during daylight hours, AIS data represent a maximum of two thirds, and, as little as one half, of the large vessel (≥65 feet) traffic in the Chesapeake Bay approach.

ii) Spatial analysis was necessary to accurately evaluate compliance over the entire study area. Using tablature data alone, the mean speeds of AIS vessels inside the SMA were greater that 10kt before the Ship Strike Rule was enacted (11.4kts ±5.1) and were <10kt (9.5k ±3.5kt) after the restrictions. Spatial analyses of these data allowed us to examine speed behavior in each grid area, eliminating the error associated with an overrepresentation of records from relatively slow moving vessels. Without utilizing spatial analysis, one could draw the conclusion that vessels were complying with the speed restriction. Because ships change speeds during a transit and AIS speed records are skewed by the greater number of speed points for slower vessels, spatial analysis increases the accuracy of speed averages by capturing the data in a spatial environment. This project raises numerous questions about vessel traffic patterns, vessel speeds and risk to whales. A lack of data about whale presence hinders right whale management (Fujwara & Caswell, 2001). Habitat analysis and tracking data have shown that the right whales, migrating through the mid Atlantic, utilize a significantly larger area than the current 20nm seasonal management area (Schick, et al., 2009). However, there is a definite need for more detailed whale presence data in the mid-Atlantic area. Without data on whale presence, it is nearly impossible to answer questions about the level of risk that the vessel traffic patterns present. This project does show that if whales are present outside the 20nm boundary, then the risk to them will not decrease as a result of the ship strike ruling.

iii) In the future, we need to assess RADAR vessel traffic during all hours in order to better compare it to AIS traffic. In 2007, Virginia ports were listed as the third highest port on the US Atlantic coast for vessel calls (USDOT 2008). This research will use a more powerful full ARPA unit in order to collect non-AIS ship position data farther from the survey platform. Without knowledge of seasonal whale distribution, the risk to whales and the effectiveness of the ship strike mitigation strategies, with or without a Ship Strike Rule, remain unclear.

b) Dissemination

i) *We have presented portions of this project at 3 scientific meeting and have an abstract accepted at the SMM Biennial in Oct 2009.*

ii) *We are preparing a manuscript for submission from the final report. We expect to submit the MS by Jan 2010 and would prefer that our final report by protected until that time.*

c) NFWF Adaptive Management

i) *We had several different NFWF Grant administrators during this project. I don't think you can control that but it was confusing.*

6) References

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7)

We are preparing a manuscript for submission from the final report. We expect to submit the MS by Jan 2010 and would prefer that our final report by protected until that time.

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Approved: Susan G Barco Date: 28 Aug 2009

Signature

Susan G. Barco, Senior Scientist

Print name and title