Determination of Fishing Gear Density and the Potential Overlap with Endangered Large Whales in Maine

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Final Report

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Project Description and Summary

Gear Research

DMR completed three gear surveys (2005, 2006, and 2008) prior to this award to establish and track the baseline gear configurations (amount of gear on a string, etc.) and density in different areas seasonally. Past surveys concentrated on federal license holders (2006) and were conducted prior to the ALWTRP regulations in 2008. These surveys proved useful in models aimed at determining areas of importance with regards to entanglement risk and were used to draft alternative proposals to the Final Rule. Under this award, DMR undertook additional survey initiatives to update the baseline characterizations of the fisheries and perform further analyses of the information received to update models and assist in efforts to quantify entanglement risk and target regulations aimed at reducing the risk of entanglement in vertical lines. This included two types of fishery characterization methods: fishery dependent and fishery independent.

The fishery dependent methods included sending Annual Logs out to all license holders with their license renewal materials for the 2009 fishing year. These logs had over a 35% return rate (conservative estimate because it does not remove latent licenses from the pool of respondents) and asked respondents to document the maximum number of traps and vertical lines fished per month, fishing zone and distance from shore. Additionally, a more in-depth gear survey was also mailed to all license holders for the 2009 fishing season. These surveys had a 10% return rate and documented the configurations of gear fished in different areas and months, as well as types of ropes used and typical fishing practices. Both of these surveys are being used in models that identify co-occurrence of whales and gear or entanglement risk by area and season and aid in identifying areas and seasons for the Draft Environmental Impact Statement for vertical line regulations due out in 2013.

It was determined that a method to assess the density of vertical lines in regulated state waters independent of voluntary industry surveys was needed. To this end, two projects were undertaken to determine the density of vertical lines using transect lines: aerial and boat-based surveys. Aerial surveys were flown with near 100% coverage of the non-exempt state waters in either November of 2010 or June of 2011. Each transect line was only covered once due to cost concerns. In an effort to get better temporal resolution, boat-based surveys were conducted year round along similar transect lines and the density and locations of buoys were documented by hand throughout the non-exempt state waters. Both datasets were interpolated using kriging spatial analysis techniques to determine seasonal densities of vertical lines and compared to numbers extrapolated from the fishery dependent surveys.

An additional gear research project was completed under this award to document the operational feasibility of potential gear modifications. Various configurations of knotted and spliced vertical lines simulating “weak top rope” were tested for breaking strength and all determined to be above the 1,100-pound threshold that was sought for a vertical line that would prevent most entanglements.

Large Whale Habitat Research

Right whale distribution and behavior in the coastal waters of Maine can be hard to study. There are not predictable aggregations of whales in this part of their range as they use the region to transit between larger feeding grounds in southern New England in the spring and the Bay of Fundy in the late summer and fall. Instead, DMR decided to partner with collaborators at Cornell University's Bioacoustic Research Program and Allied Whale at the College of the Atlantic to undertake a passive acoustic monitoring program. Deployments included ten buoys inside of regulated state waters in the fall of 2010 and four in the offshore region of Outer Fall/Jordan Basin year round from October 2009 through May 2011. The inshore buoys have been analyzed for the weekly presence of right whale and fin whale calls (and humpback whales opportunistically), with additional more in-depth daily call rates assessed for a subset of three buoys. The results of the Outer Fall study were largely contained within the master's thesis work of Jacqueline Bort at the College of the Atlantic and shows potential evidence for this area to be an important breeding habitat for right whales in the winter months.

The large amount of passive acoustic data that was gathered throughout this period was also used to characterize the ambient noise field in the offshore habitat. This will be used to compare to other important right whale habitats and will serve as a baseline for assessing potential impacts of shipping and other anthropogenic uses of this region.

Gear Research

Fishery Dependent Gear Surveys

Two methods were employed to collect two types of data. First, annual logs (provided in final report for NA09NMF4520418) were mailed to all commercial lobster license holders with their license renewal materials in October of 2009 (roughly 6,100 individuals). DMR received over 2,100 responses from active fishermen, which were successfully recorded into a database. The raw data from these surveys were made available to the NMFS sub-contractor, Industrial Economics (IEC) to replace the gear surveys as the primary dataset used to inform the risk co-occurrence model created for the Atlantic Large Whale Take Reduction Team.

The second initiative was the comprehensive gear survey (provided in final report for NA09NMF4520418). Surveys were mailed to the entire lobster (roughly 6,100) and gillnet (roughly 300) industries. DMR received just over 700 surveys from the lobster industry and 50 from the gillnet industry. The databases used to record this information have been provided to IEC, for use in the co-occurrence model.

Additional information was collected through collaboration with other DMR programs, including licenses and trap tags sold through the Licensing program and individual landings by month from 100% dealer reporting to the Landings program. Variations of this information was provided to IEC, as well as being used in DMR's own baseline calculations for the number of vertical lines by month in different areas of the coast. Calculations included corrections to track the active participants in the fishery by month and accounted for latency when the data was scaled up to estimate the baseline amount of gear for the whole population of lobstermen. Summaries for

each survey, calculated densities of vertical lines, gear configurations fished and other information about gear use that was compiled is available in the report provided in Appendix I.

Fishery Independent Buoy Density Surveys

Aerial Gear Density Surveys

DMR partnered with Kappa Mapping in Bangor, Maine to develop a flight and analysis plan for mapping all non-exempt state waters for the density of buoys and therefore vertical lines (Figure 1). This area was chosen because state waters represent the majority of the lobster fishery in Maine and additional regulations imposed in this area will have the biggest impact on the fishery. High resolution aerial photography was taken in stereo from a height of 3,960 feet above the water, using strict weather and sea surface guidelines, such as low sunlight and therefore glare, calm winds and therefore minimal surface water chop, and at low or slack tides so buoys that were not pulled underwater and missed. Images were matched up on a computer screen and viewed using three dimensional glasses to classify buoys in each image as "certain", "probable" or "possible". The buoy locations and determinations were then digitized into ArcGIS format for delivery to DMR (Figure 2). The original project was set up to take place during the peak fishery in this area, September through November, since it was too expensive to sample the entire area using this method more than once. All analysis work done by DMR used only buoys that were characterized by Kappa Mapping as "certain" or "probable".

Several changes were made to this project as it progressed. The aerial survey team had a hard time during the original study period finding days that met the strict conditions outlined above. The flight height was set so that 100% of the area would be covered by digital images in stereo. However, the flight team could not obtain a work day in which the cloud ceiling was above the height set for the flight and therefore no digital images could be taken. DMR worked with Kappa to re-evaluate these criteria and decided to change the flight height so that some flights could take place. This resulted in gaps of coverage for small areas between every transect line flown. It was determined that interpolation techniques could be used during data analysis to account for gear that occurred in these holes. Due to these delays, only Lobster Management Zones E, F, G, and parts of C and D were completed before gear started moving out of the area. The remaining zones were put off until the spring fishery began, which in most cases, is not very different from the fall densities in those particular months. The remaining flight lines in A, B, C and parts of D were flown in June of 2011.

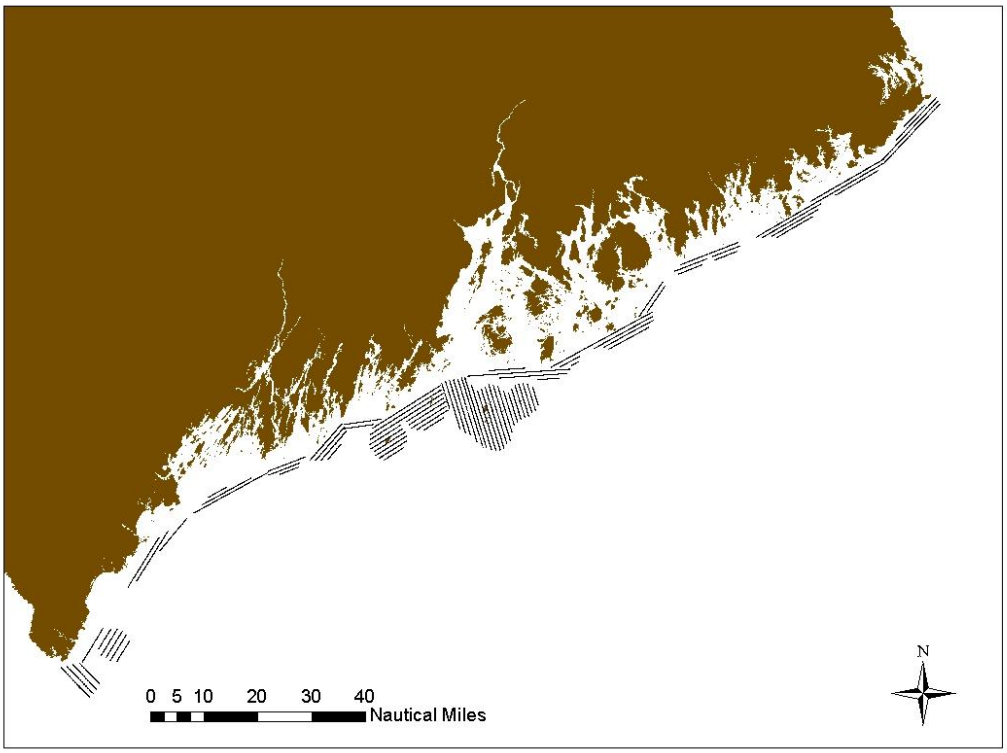


Figure 1. Aerial survey flight lines used to sample the non-exempt portion of state waters in November 2010 and June 2011.

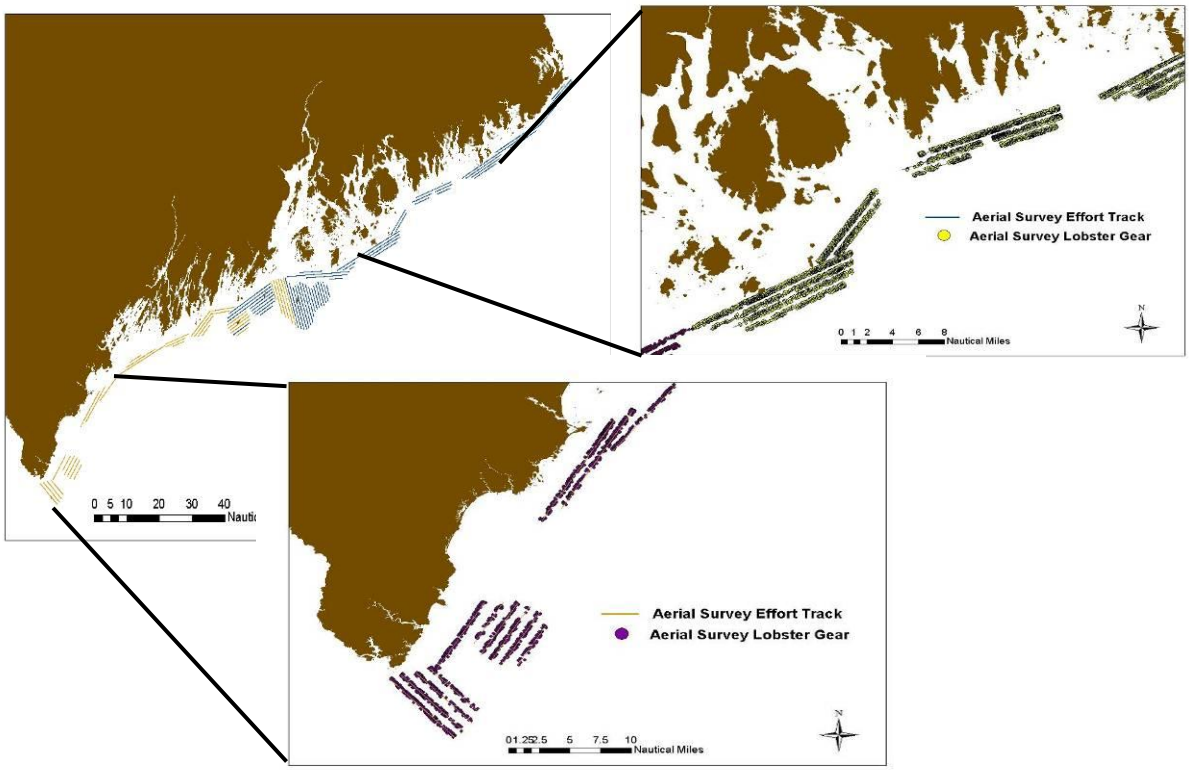


Figure 2. Sample buoy locations digitized from images taken during aerial survey flights.

Boat-based Gear Density Surveys

Due to the cost of the aerial surveys above, they were only performed enough to provide coverage for each transect line once during high use fishing seasons in the study area. Boat-based surveys were created to count vertical lines year-round as a way to increase temporal coverage and document how density changes throughout the season. A pilot project in 2010 performed through the collaboration with Allied Whale/College of the Atlantic served as the basis on which the methods utilized in the boat-based portion of the study were developed. Lobster vessels were contracted through the GOMLF and used to conduct the surveys along the same sampling lines used for the aerial surveys (lines used were randomly selected with no line being able to be sampled twice in a row). Vessels ranged in size from 25-42 feet in length and ran at speeds of 10-15 knots. Observers, placed on the port side of each boat, entered the location of all buoys sighted within 100 meters of the boat using Logger software, a laptop and a handheld GPS unit. Surveys were conducted for a year (Sept. 2010 through Sept. 2011) twice per month in each of three areas (Downeast, Midcoast, and Southern), except January through March, which decreased to one sampling trip in each area per month. After each trip, the locations of all of the recorded buoys were mapped in ArcGIS, in addition to transect survey effort completed (Figures 3-5).

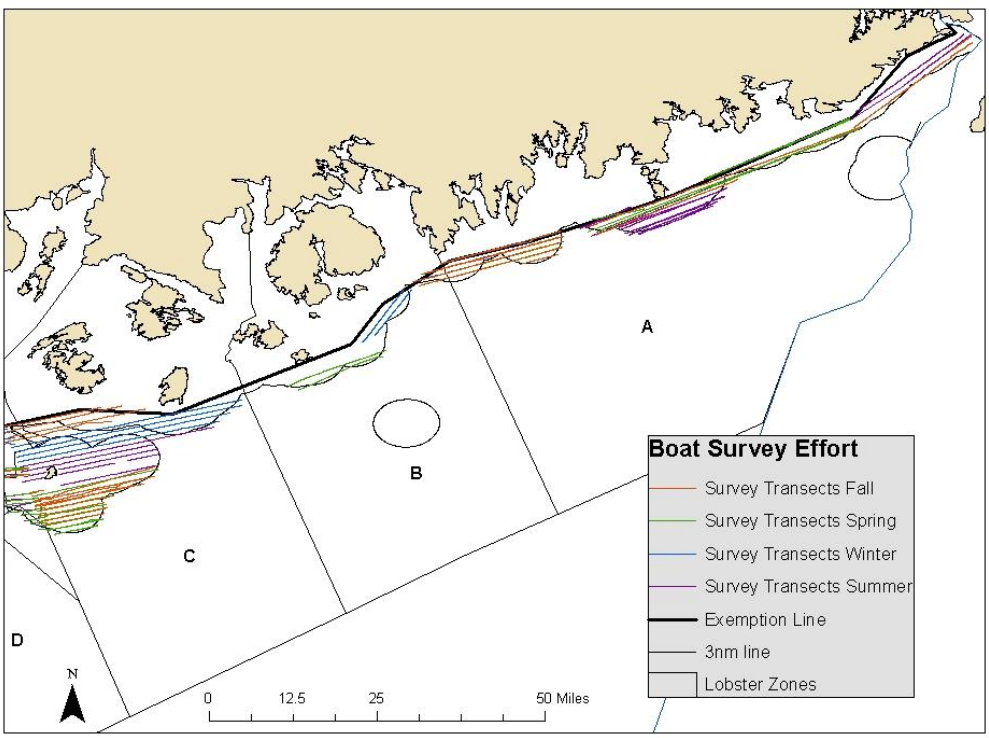


Figure 3. Boat-based survey transects completed by season in Lobster Management Zones A-C.

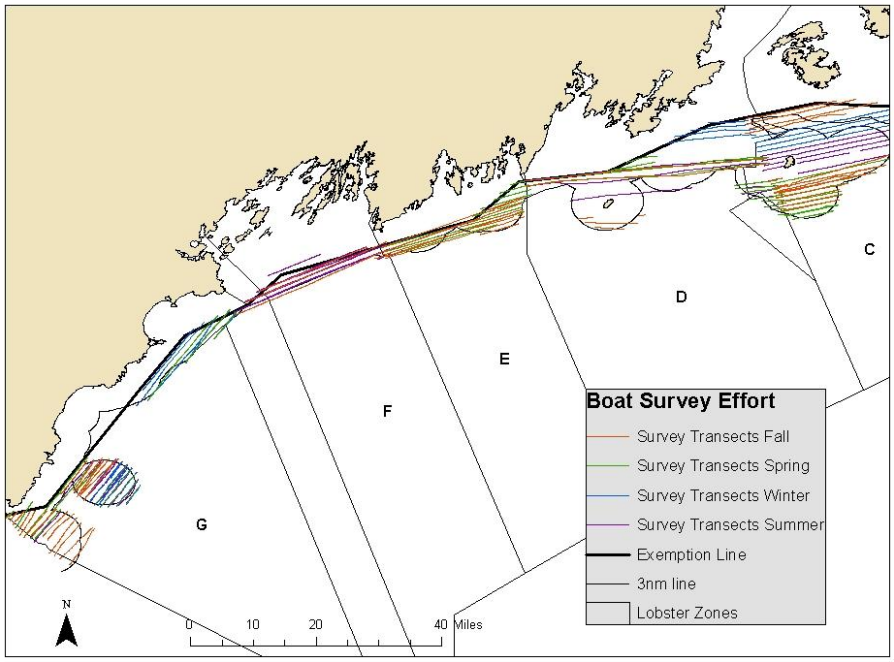


Figure 4. Boat-based survey transects completed by season in Lobster Management Zones D-G.

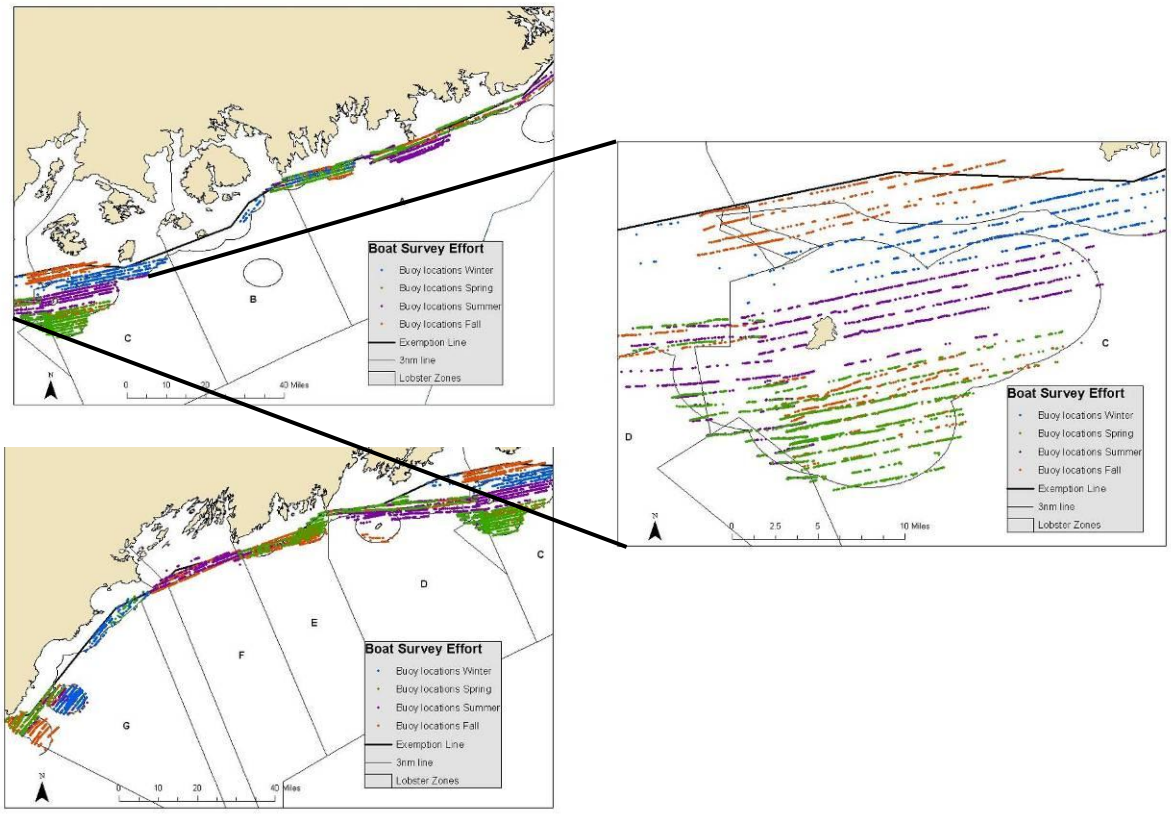


Figure 5. An example of buoy locations recorded on boat-based transects coded by season.

Data Analysis

Both the aerial and boat-based surveys were handled the same for post data collection analysis. Each dataset was mapped in ArcGIS and overlaid with a grid of 1x1 mile squares (Figure 6). For each grid cell in the study area, the sum of the buoys counted in that cell was divided by the amount of effort completed in that cell to create a measure of buoy density. These data were imported into spatial analysis software called "Surfer" to get an estimate of the density of buoys in areas not sampled by the surveys. The geostatistical interpolation method, kriging, was used to estimate the pattern of gear density, creating and filling in a grid from the available point measurements. The data were fitted using a linear variogram model with no drift or nugget effect. The kriging algorithm was used to estimate the value of the density at points other than those that were sampled, thereby providing a map that extends over the entire grid area. An initial grid surface was made with the original latitudes and longitudes and density values of the 1 x 1 mile grid. Values for the center of each grid cell, plus two additional grid points between each were estimated. This yields a uniform grid by which a density estimate exists for each point. The values that are predicted are the result of a weighted average of the sampled values and are dependent upon the distance between the target and sample locations. The weighted average comes from the application of $z = \sum a_i x_i$ where z is the estimated value, a_i is the weight that is applied to variable x and $\sum a_i = 1$ (Matheron 1963). Weights are chosen so that the error associated with the predictor is less than for any other linear sum (Cressie 1990). The function of the distance between the sampled variables is a semi-variogram, which is assumed to be direction nonspecific. The semi-variogram chosen here was the linear model.

A nugget effect, or sampling error, can be used in the kriging algorithm for correctional purposes. A higher nugget effect makes kriging more of a smoothing interpolator, meaning there is less confidence in the resulting surface (Keckler 1995). No nugget effect was used here. The interpolated surface was exported back into ArcGIS and mapped for display and comparative purposes (Figures 7-12). The data were pooled seasonally to increase coverage and an average density for each Lobster Management Zone was calculated. These data were presented at the ALWTRT meeting in January 2012 and at the Maine Fishermen's Forum in March 2012.

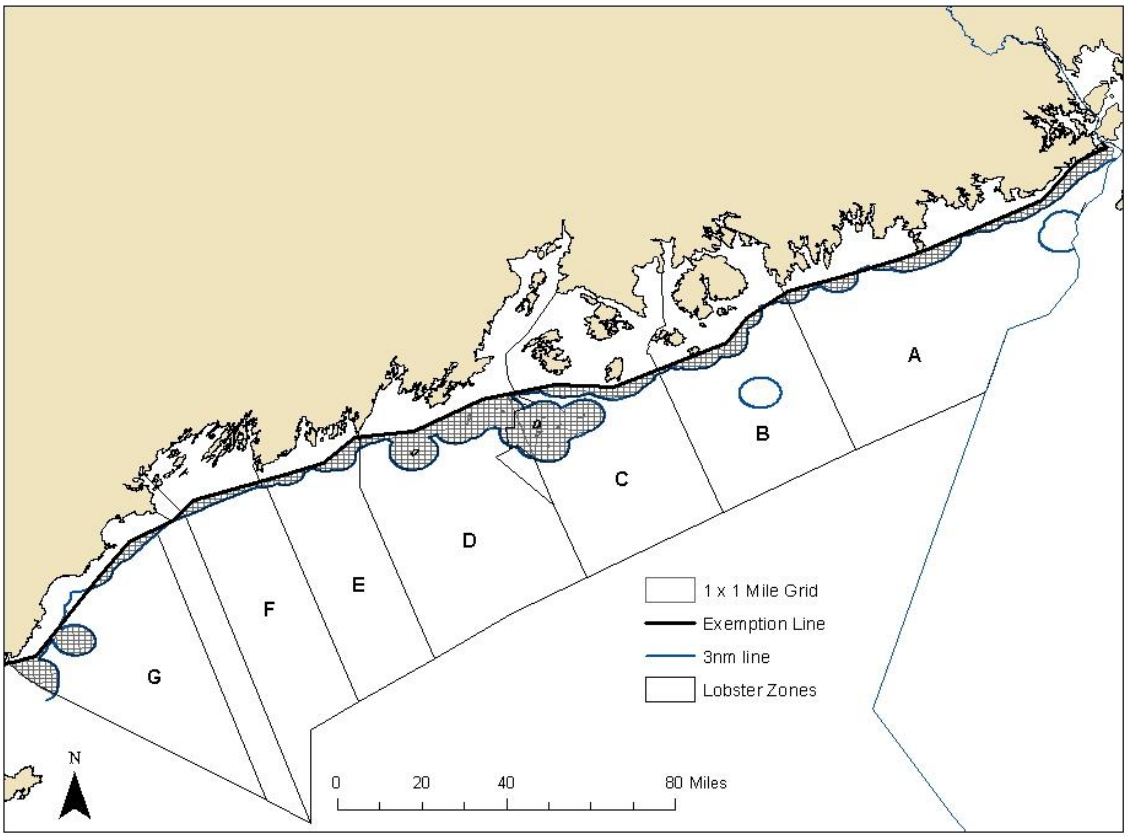


Figure 6. The 1x1 mile grid applied across the study area allowed for a calculation of the corrected density of buoys per unit effort. This was a common calculation that could be used for both methods and make the data collected on the aerial and boat-based surveys comparable.

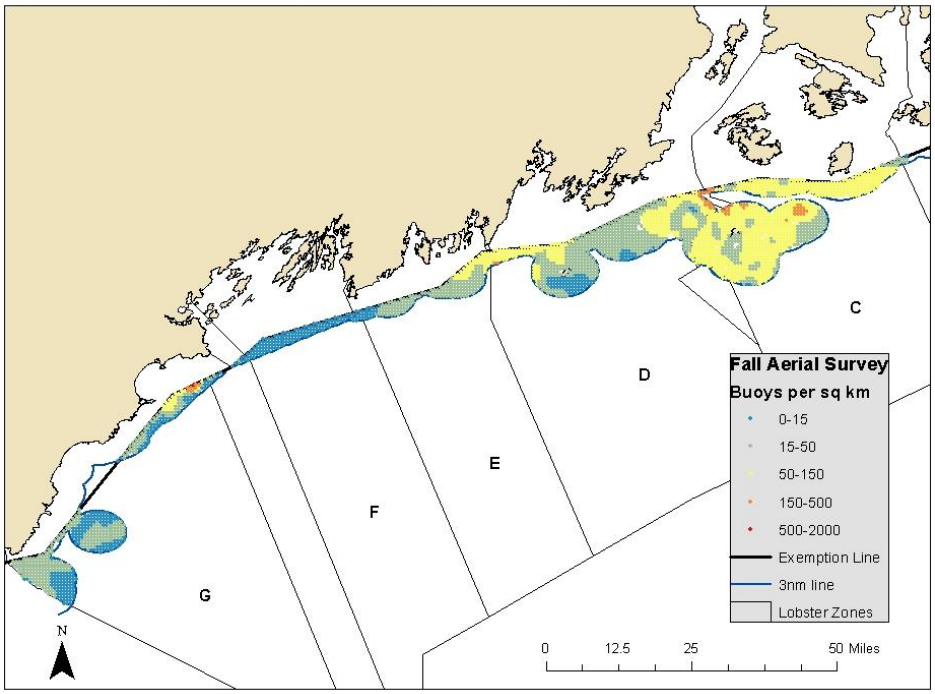


Figure 7. The interpolated density of vertical lines in the fall as recorded by aerial surveys performed in Nov.

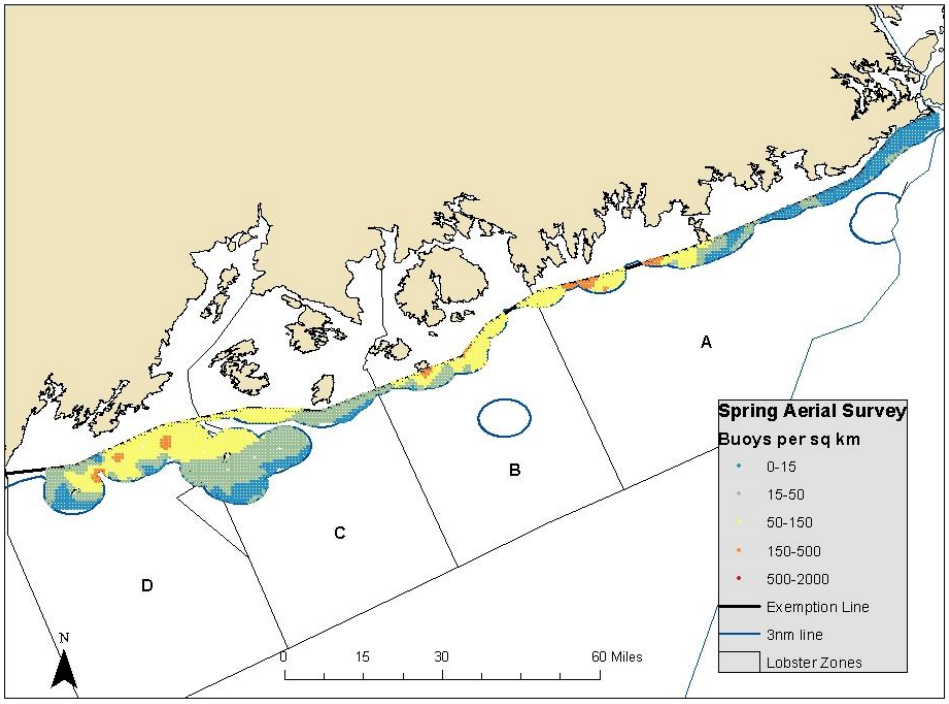


Figure 8. The interpolated density of vertical lines in the spring as recorded by aerial surveys performed in June.

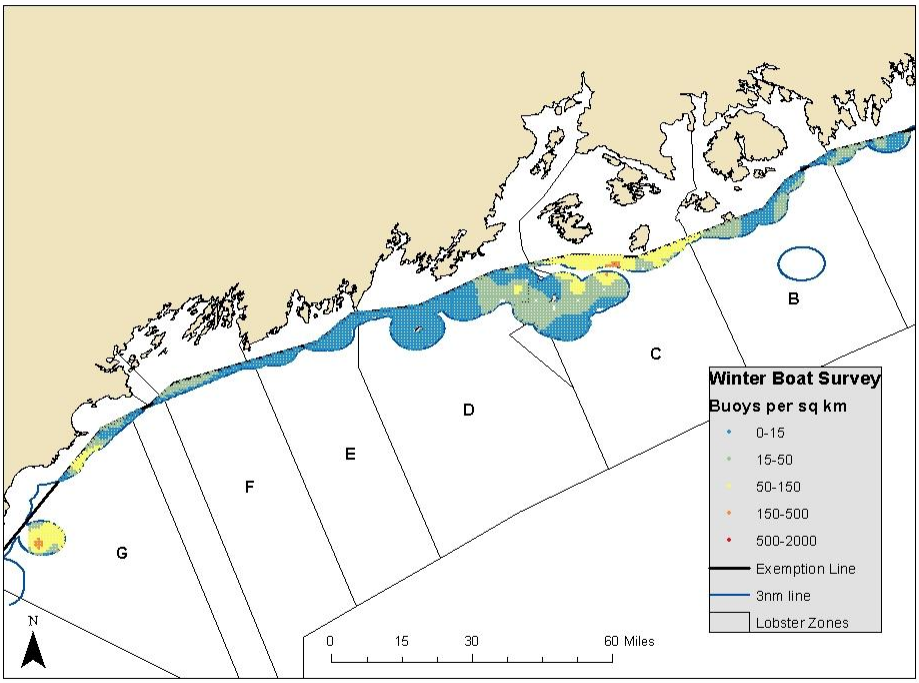


Figure 9. The interpolated density of vertical lines in the winter as recorded by boat surveys Jan-March.

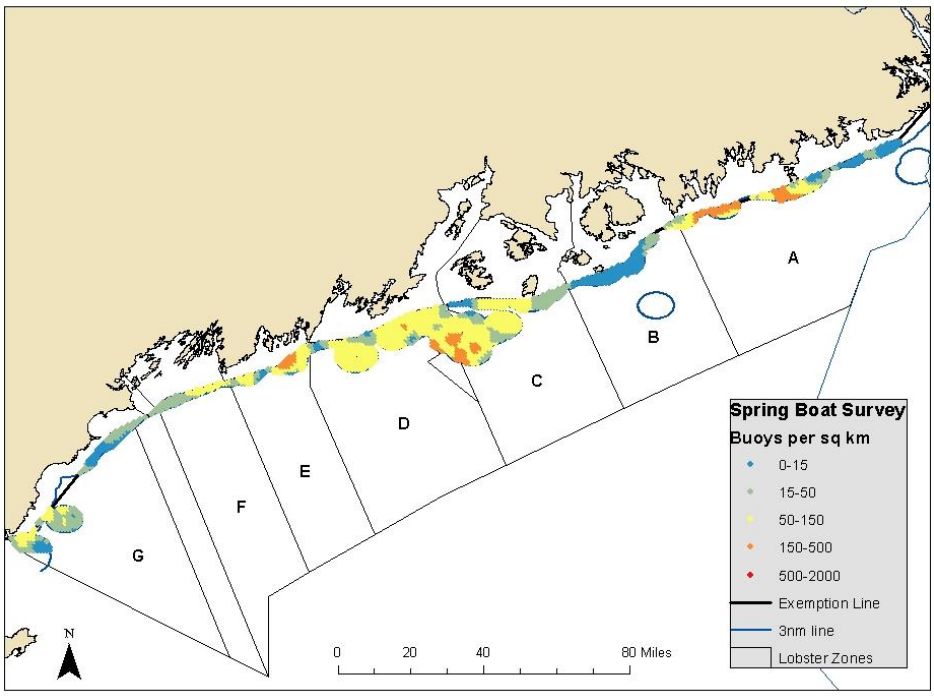


Figure 10. The interpolated density of vertical lines in the spring as recorded by boat surveys April-June.

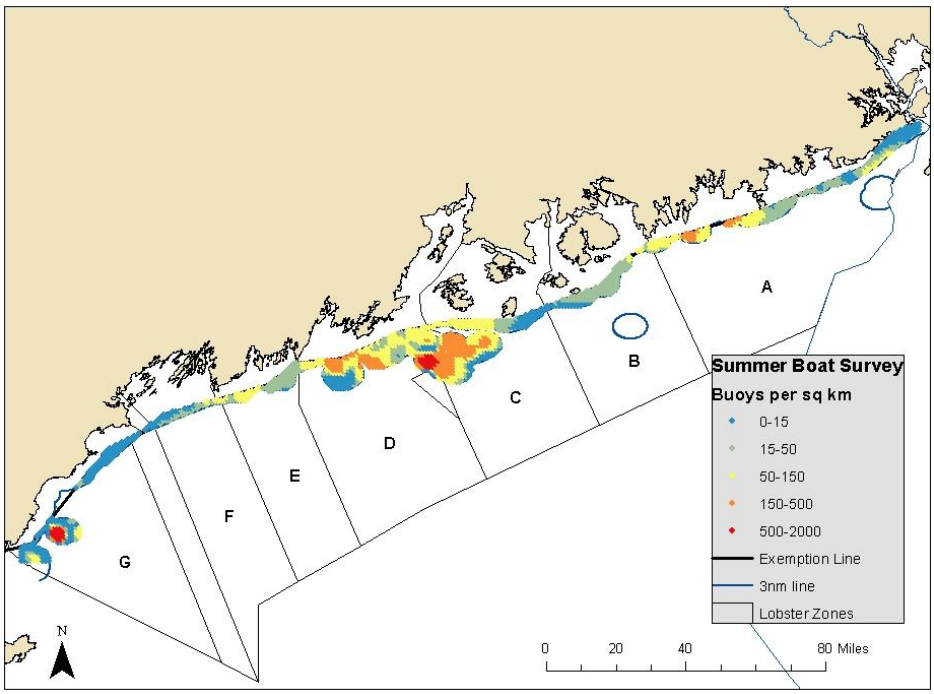


Figure 11. The interpolated density of vertical lines in the summer as recorded by boat surveys July-Sept.

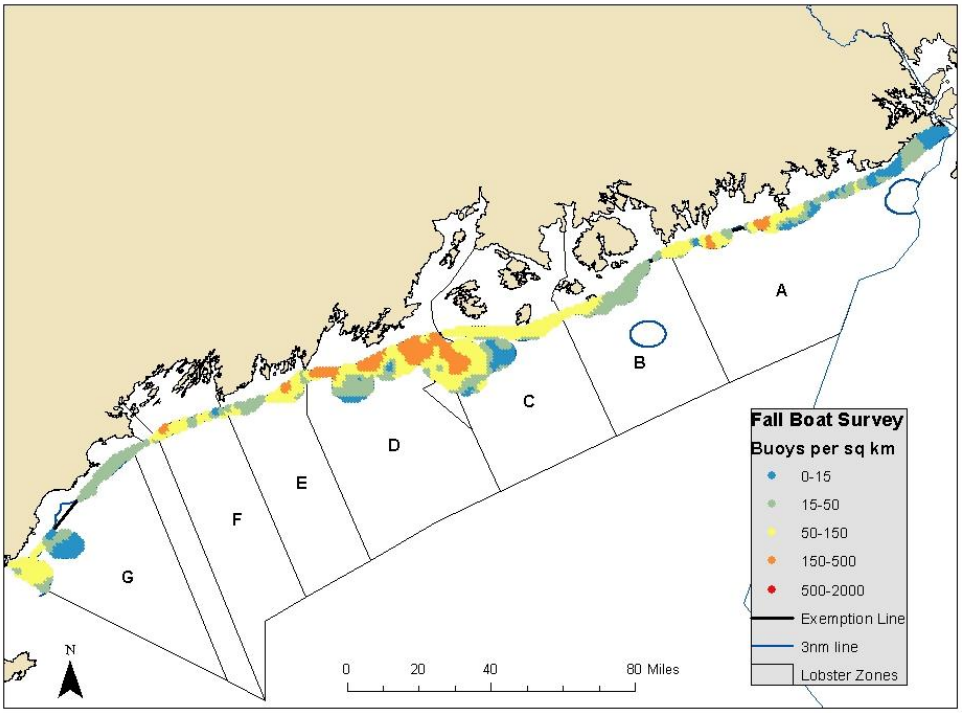


Figure 12. The interpolated density of vertical lines in the fall as recorded by boat surveys Oct-Dec.

Method Comparisons

DMR wanted to look at each method for characterizing the lobster fishery and calculating the density of vertical lines in a given area. Because the data was collected differently in each method, and was voluntary and somewhat qualitative in the two dependent surveys, they were not compared using statistical methods. However, DMR staff was able to calculate the density of vertical lines in a given area by month using the same units so that the trends can be compared visually side by side for each Lobster Management Zone (Figures 13-19). Each method has certain advantages and disadvantages. Dependent methods as they were done, without at least a sub-set being mandatory, will have a bias based on who in the population is more likely to report their fishing habits. These surveys also assume a degree of honesty from the fishermen that send them back without a real way to audit the results. However, the Annual Logs had a very high return rate due to the survey's simplicity and inclusion with annual license renewal materials. The longer Gear Surveys were helpful because they include the actual configurations of traps set by fishermen and how those configurations trend spatially and temporally. The fishery independent methods are able to collect data without reliance on the industry to report. Both, however, are prohibitively expensive to collect the quantity of data that is required to estimate the density of gear. It is DMR's recommendation that future monitoring programs rely more heavily on the Annual Log model and work towards making at least part of the reporting population mandatory reporters. The differences in documentation methods shown below by Lobster Management Zone are likely due to the number of and differences in reporting population for the zone in the fishery dependent surveys (gear surveys and annul logs), as well as interpolation artifacts in the boat surveys where effort may have been low and the smoothing algorithms applied trends across areas not sampled.

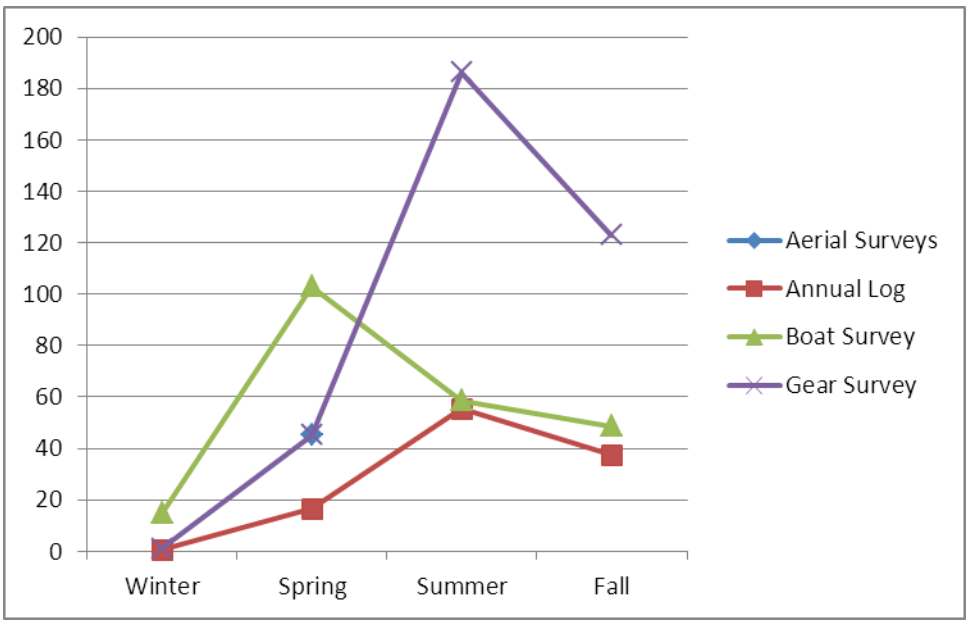


Figure 13. Comparison of Lobster Management Zone A fishery characterication methods using density of vertical lines per square kilometer in regulated state waters by season. The caculation of gear density varies within a single season depending on the sampling method (density goes between just under 60 vertical lines/km^2 and over 180 vertical lines/km^2 in the summer).

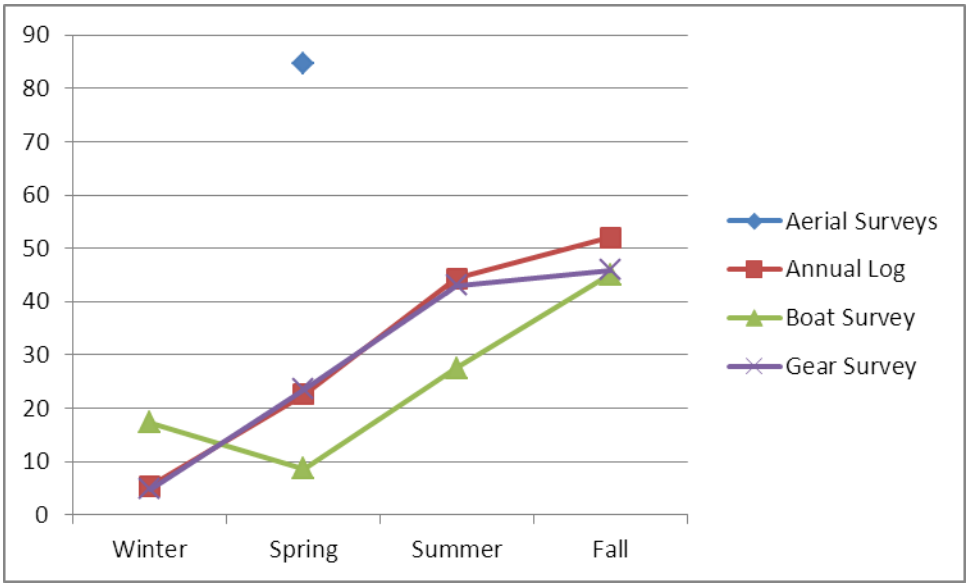


Figure 14. Comparison of Lobster Management Zone B fishery characterication methods using density of vertical lines per square kilometer in regulated state waters by season. Both of the fishery dependent surveys track closely in Zone B with Boat Surveys estimating a slightly lower density. The spring aerial survey estimates of higher density than any other method.

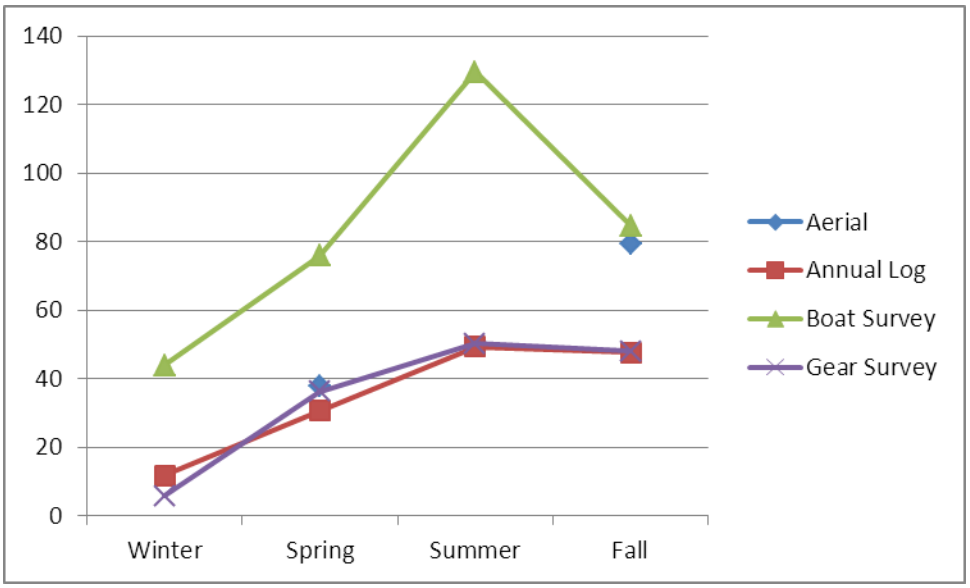


Figure 15. Comparison of Lobster Management Zone C fishery characterication methods using density of vertical lines per square kilometer in regulated state waters by season. The fishery dependent methods track closely in Zone C with both the boat and aerial surveys estimating higher densities of gear throughout the year.

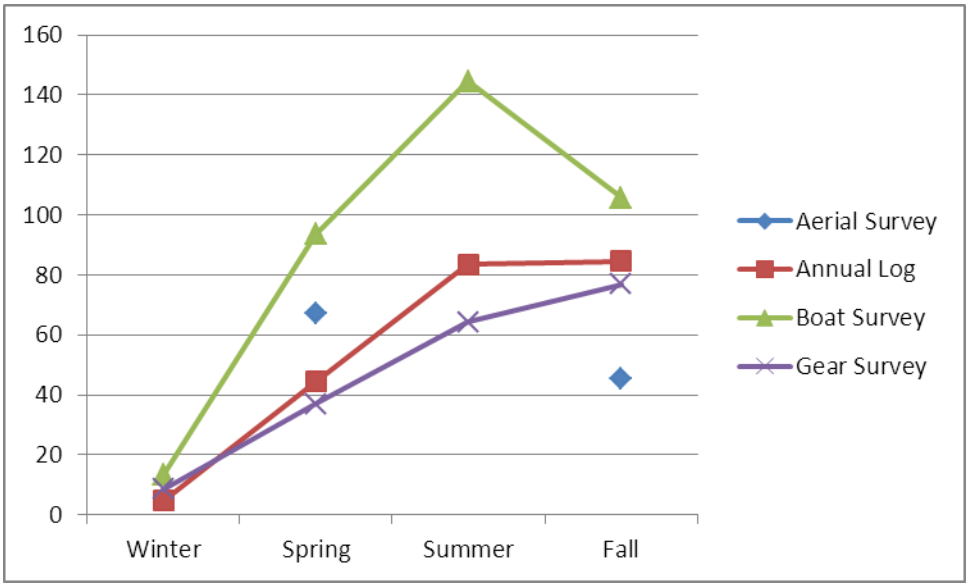


Figure 16. Comparison of Lobster Management Zone D fishery characterication methods using density of vertical lines per square kilometer in regulated state waters by season. The fishery dependent methods track fairly closely in Zone D, along with aerial survey estimations. Boat surveys estimate density at a higher rate.

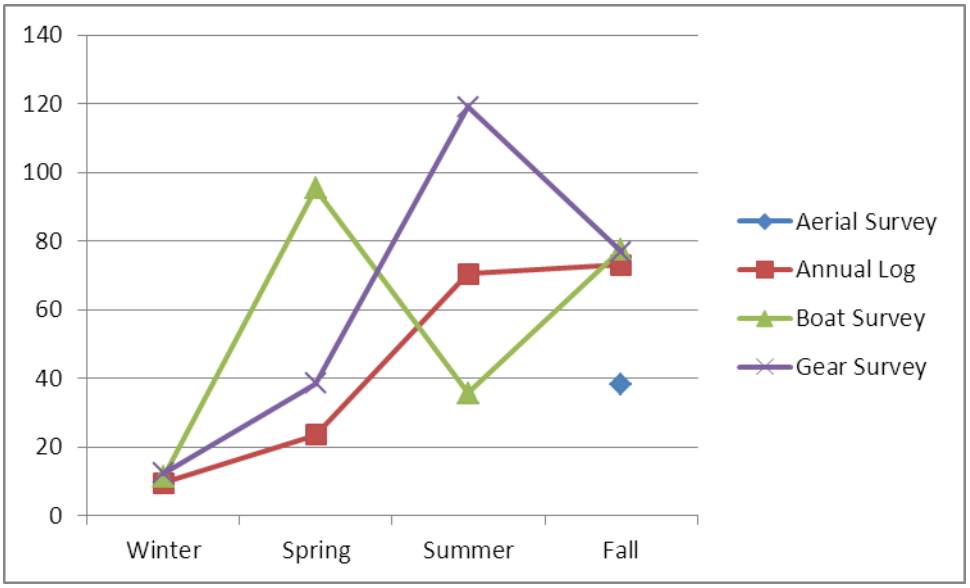


Figure 17. Comparison of Lobster Management Zone E fishery characterication methods using density of vertical lines per square kilometer in regulated state waters by season. In Zone E all methods show slightly different trends in density over the course of the year.

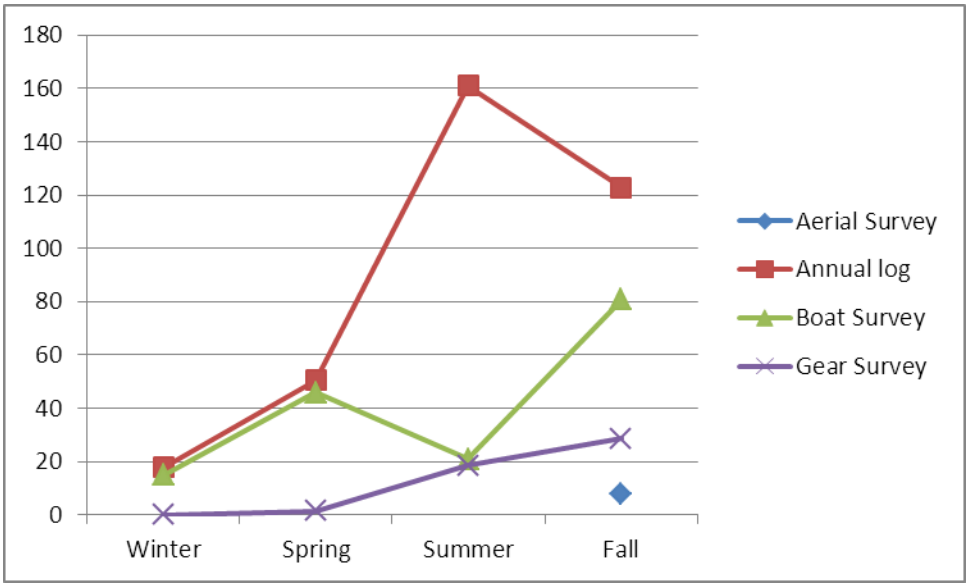


Figure 18. Comparison of Lobster Management Zone F fishery characterication methods using density of vertical lines per square kilometer in regulated state waters by season. In Zone F, the fishery dependent methods exibit almost opposite trends in density in the summer and fall, while the gear and aerial surveys both estimate lower densities of gear.

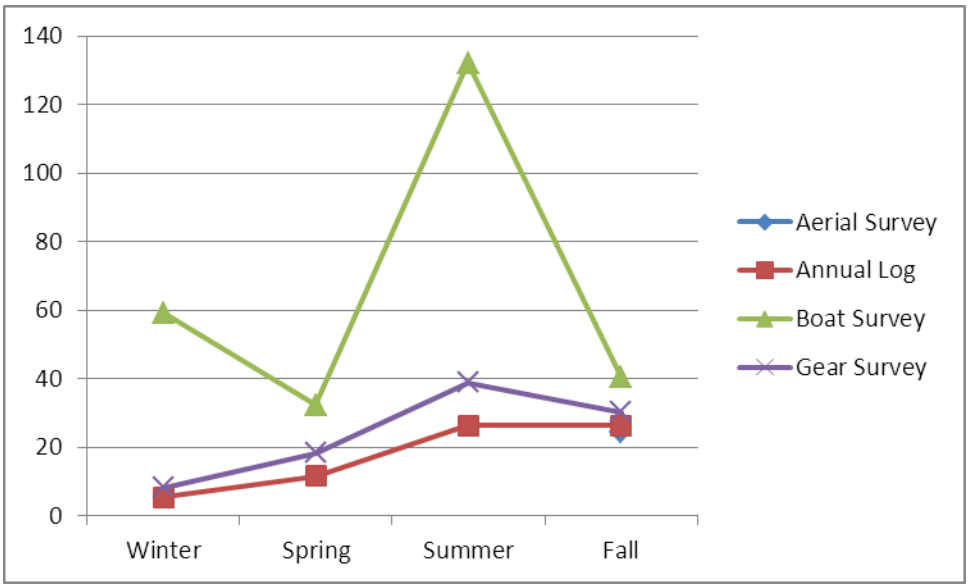


Figure 19. Comparison of Lobster Management Zone G fishery characterication methods using density of vertical lines per square kilometer in regulated state waters by season. The fishery dependent survey methods track closely in Zone G along with the aerial survey in the fall. The boat survey estimates a higher gear density, especially in the summer.

Weak Top Rope Breaking Strength Tests

DMR partnered with co-investigators at the GOMLF to initiate and complete an experiment on the breaking strengths of different configurations of vertical lines with weak top ropes. DMR heard support for the idea of a weak top rope throughout the state scoping meetings that were

held in the summer of 2011; however, there was no data to determine if the ideas being suggested would result in a conservation benefit. Many fishermen said that they were willing to tie or splice 11/32 line into the upper 1/3 of their vertical lines to make the overall vertical line less than 1,100 pounds breaking strength, a strength that has been preliminarily shown to result in serious injury or mortality for fewer right whales of all age classes. Thirteen configurations of vertical lines were constructed using the most commonly used diameter lines, 7/16" and 3/8". Ten of each configuration was broken through a contracted company called Southwest Ocean Technologies. No configurations tried by the experiment resulted in a breaking strength of less than 1,100 pounds and therefore could not be pursued (Table 1).

Table 1. Results of the weak top rope experiment. Thirteen different configurations were tested, including solid or straight lines of each diameter, as well as ropes with 11/32" rope knotted or spliced into the top 1/3 of the line. The average breaking strength is lower for lines knotted together than for splices, but this is contrary to the best practice of having knotless lines. The lines with 11/32" lines spliced in did reduce the breaking strength when compared to a straight line of that diameter, but were not significantly lower than the straight breaking strength of 11/32" sink line.

ID #	Rope Config	Rope Type	Diameter	AVG break strength	% strength reduction	% strength retained
1	Solid line	Sink	3/8	4203		
2	Solid line	Float	3/8	3636		
3	Solid line	Sink	7/16	4109		
4	Solid line	Float	7/16	4304		
5	Solid line	Sink	11/32	2592		
6	Spliced*	Float	3/8	2573	29%	71%
7	Spliced*	Sink	3/8	2573	39%	61%
8	Spliced*	Float	7/16	2477	42%	58%
9	Spliced*	Sink	7/16	2622	36%	64%
10	Knotted*	Float	3/8	1582	56%	44%
11	Knotted*	Sink	3/8	1614	62%	38%
12	Knotted*	Float	7/16	1740	60%	40%
13	Knotted*	Sink	7/16	1710	58%	42%

Lobster Conferences

Collaborators at the Gulf of Maine Lobster Foundation put together two lobster conferences for this award. The topic chosen for the workshops was the upcoming vertical line risk reduction measures coming through the Atlantic Large Whale Take Reduction Team. The first conference was held in York, Maine in April and included members of the fishing community, DMR staff, NMFS representatives, and two whale biologists. This meeting served to begin brainstorming for what could feasibly be included in a vertical line risk reduction proposal submitted by DMR. The summary of this meeting is attached in Appendix II. It should be noted that there are no specific comments given in the document, but instead summaries of ideas that were discussed around the table. It is the DMR and GOMLF's joint opinion that in an effort to maintain an open dialogue with fishermen that their specific comments not be individualized in the record of the meeting. Participants were told at the beginning of this meeting that all of their comments would only be presented in summary form and that names would not be used. DMR and the GOMLF would like to keep to this promise. If NMFS still needs additional information from these

workshops please feel free to contact project leads directly. Comments recorded about right whale biology, habitat use, entanglement trends and scarification rates were made by the two whale biologists in attendance, Scott Kraus and Charles Mayo. These statements were not independently verified and simply reflect the direction of the conversation during the meeting. DMR and the GOMLF feel that this conference served as a great starting place for discussions at information and scoping meetings that were held through the spring and summer by both DMR and NMFS. The second conference was held in Rockport in September to wrap up the last thoughts and ideas heard over the summer and discuss the levels of line reductions that were achieved by the different scenarios presented. There is no summary for this meeting, however the results are reflected in what is included in Maine's Vertical Line Risk Reduction Proposal that was submitted to NMFS at the end of September. For more information please see the attached report from the GOMLF in Appendix II.

Large Whale Habitat Research

Passive Acoustic Monitoring

This effort aimed at documenting potential habitat use by right, humpback and fin whales in several different habitats across the coastal waters of Maine. All DMR buoy deployments and completed analyses are listed below in Table 2.

Table 2. Summary of all deployments by location, dates, and analyses completed. An assessment of the weekly presence/absence for right whale upcalls and fin whale pulses (and humpbacks opportunistically) was completed for all buoys. Buoys at Petit Manan, Matinicus Island and Boothbay Harbor were analyzed for daily right whale upcalls and gunshots. Ambient noise levels were calculated for 2 buoys in the Jordan Basin/Outer Fall region. Buoys 66, 134, 182, and 223 were deployed and analyzed by College of the Atlantic. The entire results were presented in the final report for grant # NA09NMF4520418. Buoys 151 and 148 in the Jordan Basin/Outer Fall region were assessed in depth in a master's thesis by Jaqueline Bort at the College of the Atlantic. Additional analyses that DMR plans to accomplish in the next year, outside of this grant's funding, includes ambient noise evaluation for all 10 inshore buoys. If time, funding, and staffing allows, DMR would like to complete daily right whale detection for all remaining buoys (inshore buoys being the priority). An assessment of humpback presence in the weeks not opportunistically sampled would be an additional useful analysis but is not one that DMR has plans to complete at this time.

Buoy ID	Location	Deployment date	Retrieval date	Weekly presence/absence	Daily right whale calls (D)	Ambient noise (A)	Additional analyses
168	York	Jul-10	Oct-10	X			
66	Mount Desert Rock	Jul-10	Oct-10	X			COA*
134	Mount Desert Rock	Jul-10	Oct-10	X			COA*
182	Mount Desert Rock	Jul-10	Oct-10	X			COA*
223	Mount Desert Rock	Jul-10	Oct-10	X			COA*
74	Monhegan	Sep-10	Dec-10	X			D,A
96	Petit Manan	Sep-10	Dec-10	X	X		A
135	Seal Island	Sep-10	Dec-10	X			D,A
136	York	Sep-10	Jan-11	X			D,A
143	Lubec	Sep-10	Jan-11	X			A
165	Portland	Sep-10	Dec-10	X			D,A
166	Jonesport	Sep-10	Dec-10	X			D,A
171	Swans Island	Sep-10	Dec-10	X			D,A
215	Matinicus	Sep-10	Dec-10	X	X		A
216	Boothbay	Sep-10	Jan-11	X	X		A
151	Jordan Basin	Oct-09	May-10	X			Thesis**
148	Jordan Basin	Jun-10	Oct-10	X			Thesis**
149	Jordan Basin	Oct-10	May-11	X		X	
197	Jordan Basin	Oct-10	May-11	X		X	

* An in-depth analysis was completed by the College of the Atlantic and submitted with the final report for grant # NA09NMF4520418

** Complete analysis of these buoys was accomplished as a master's thesis by Jaqueline Bort at the College of the Atlantic

The results will be published in a follow up manuscript

Analyses to be completed

First, the potential right whale breeding habitat in the Outer Fall region has been monitored by DMR and Allied Whale near continuously from October of 2009 through May of 2011 (partially funded under this award). The results of the first year of this study were completed as a part of Jacqueline Bort's master's thesis through the College of the Atlantic, which is included in Appendix III. The second stage of that project, two additional buoys deployed from October 2010 until May 2011, has been assessed by collaborators at Cornell's Bioacoustic Research Program for the weekly presence of right whale upcalls, fin whale pulses, and opportunistic humpback whale calls (see *Acoustic Automatic Detection Methods* below). The results of these analyses are available in Appendix IV. The extra eight months of data supports the seasonal results outlined in Bort's thesis, with an increase in the rate of upcalls being noted from November through January (the potential breeding season in this area). Additional analyses are required to look more in depth at daily call rates and the ratios between upcalls and different types of calls, such as gunshots. This was not completed before the termination of this grant. Copies of all of the acoustic data are being supplied to NMFS so that others can work on the data as is possible. Additionally, an extra study was accomplished by a student at the College of the Atlantic entitled "Seasonal occurrence of sei whales (*Balaenoptera borealis*) in the Gulf of Maine: An examination using passive acoustic monitoring of the Outer Fall region" as a part of a senior project. The resulting report is attached in Appendix V.

DMR also deployed ten pop-up buoys throughout regulated state waters from September through December of 2010, with the exception of the buoy off the coast of York, which was deployed in July of that year for an additional three months of data in that location (Figure 20). The timing of this deployment was meant to overlap the peak fishing season of the study area.

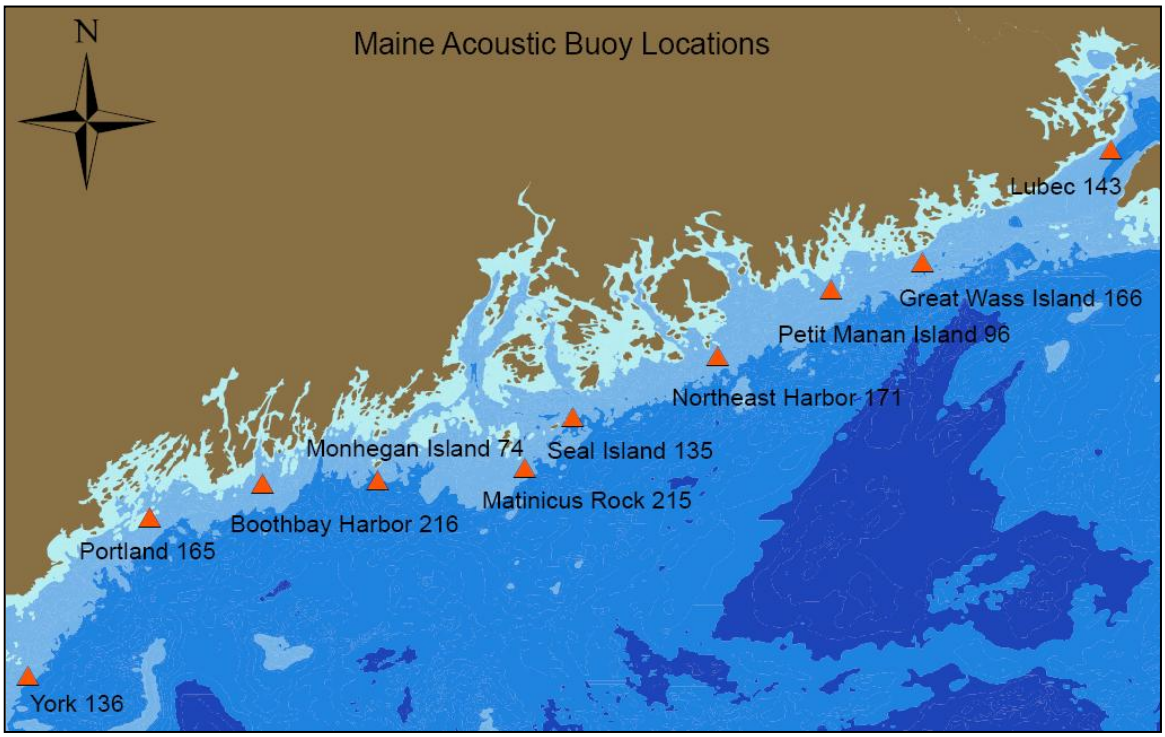


Figure 20. Deployment locations (and buoy number) of the ten pop-up acoustic buoys deployed inside of Maine regulated state waters. All buoys were deployed from Sept. through Dec. of 2010, with the exception of the York buoy (136), which was deployed three months earlier in July.

Weekly detections of right whale upcalls and fin whale pulses (humpbacks were recorded opportunistically) were also completed on these buoys according to the methods described below (Figures 21 and 22; Appendix IV). Every buoy had at least one week that contained a right whale upcall. The buoys farther downeast, such as Lubec, Jonesport, Petit Manan, tend to have calls earlier in the listening period while calls in the southern and western portion of the state tended to record calls more towards the end of the listening period. This is consistent with the expected migration pattern of right whales this time of year.

Right Whales

Buoy	**Date**															
	Sept	Oct					Nov				Dec				Jan	
Lubec	x	x	x	x	x											
Jonesport					x		x									
Petit Manan		x				x		x		x		x				
Northeast Harbor			x	x		x	x	x	x	x						
Seal Island					x			x	x	x	x					
Matinicus Island			x	x	x	x	x	x	x	x	x					
Monhegan Island	x															
Boothbay Harbor			x	x				x						x		
Portland					x		x			x	x		x			
York	x				x		x	x	x	x	x	x	x	x	x	

Fin Whales

Buoy	**Date**															
	Sept	Oct					Nov				Dec				Jan	
Lubec			x	x	x	x	x	x	x	x			x			x
Jonesport	x		x	x	x				x		x					
Petit Manan	x	x		x	x	x			x		x					
Northeast Harbor						x			x	x						
Seal Island					x				x	x						
Matinicus Island		x	x	x				x	x	x	x					
Monhegan Island	x	x	x	x	x	x	x		x	x			x			
Boothbay Harbor				x	x	x				x			x		x	x
Portland		x		x	x	x				x		x		x		
York		x	x	x	x	x			x	x	x	x		x	x	x

Humpback Whales

Buoy	**Date**															
	Sept	Oct					Nov				Dec				Jan	
Lubec						x		x			x	x	x	x		x
Jonesport			x			x			x	x			x			
Petit Manan	x	x		x		x	x		x	x		x				
Northeast Harbor						x	x	x	x	x	x					
Seal Island		x				x	x			x	x					
Matinicus Island	x			x			x		x	x		x				
Monhegan Island												x	x			
Boothbay Harbor		x			x		x			x	x	x	x	x	x	x
Portland	x	x	x	x	x	x	x	x	x	x	x		x	x	x	
York					x			x	x	x	x	x	x	x	x	

retreived
detection

Figure 21. The above tables document the weeks with detections for all three large whale species by buoy location; right whales at the top, fin whales in the middle and humpback whales at the bottom. In general, the buoys are listed with the most north/eastern buoy at the top and the most west/southern buoy at the bottom. The red indicates when the buoy was retrieved and therefore data was no longer available. Yellow cells with an "x in them indicate detections. There were no buoy locations that didn't have at least one week of detections for all three species. Right whales indicate a progression down the coast that mirror their departure from the Bay of Fundy region and movement to the middle of the Gulf of Maine and southern portions of Maine. The Matinicus buoy had one of the highest number of consecutive weeks with right whale detections. The pattern for fin whales is less obvious. Fin whales are present throughout most of the coast in October and the second half of November. Humpback whales appear to be more abundant off the coast of Maine in November and December, with the Portland buoy logging detections for this species in all but one week of recording.

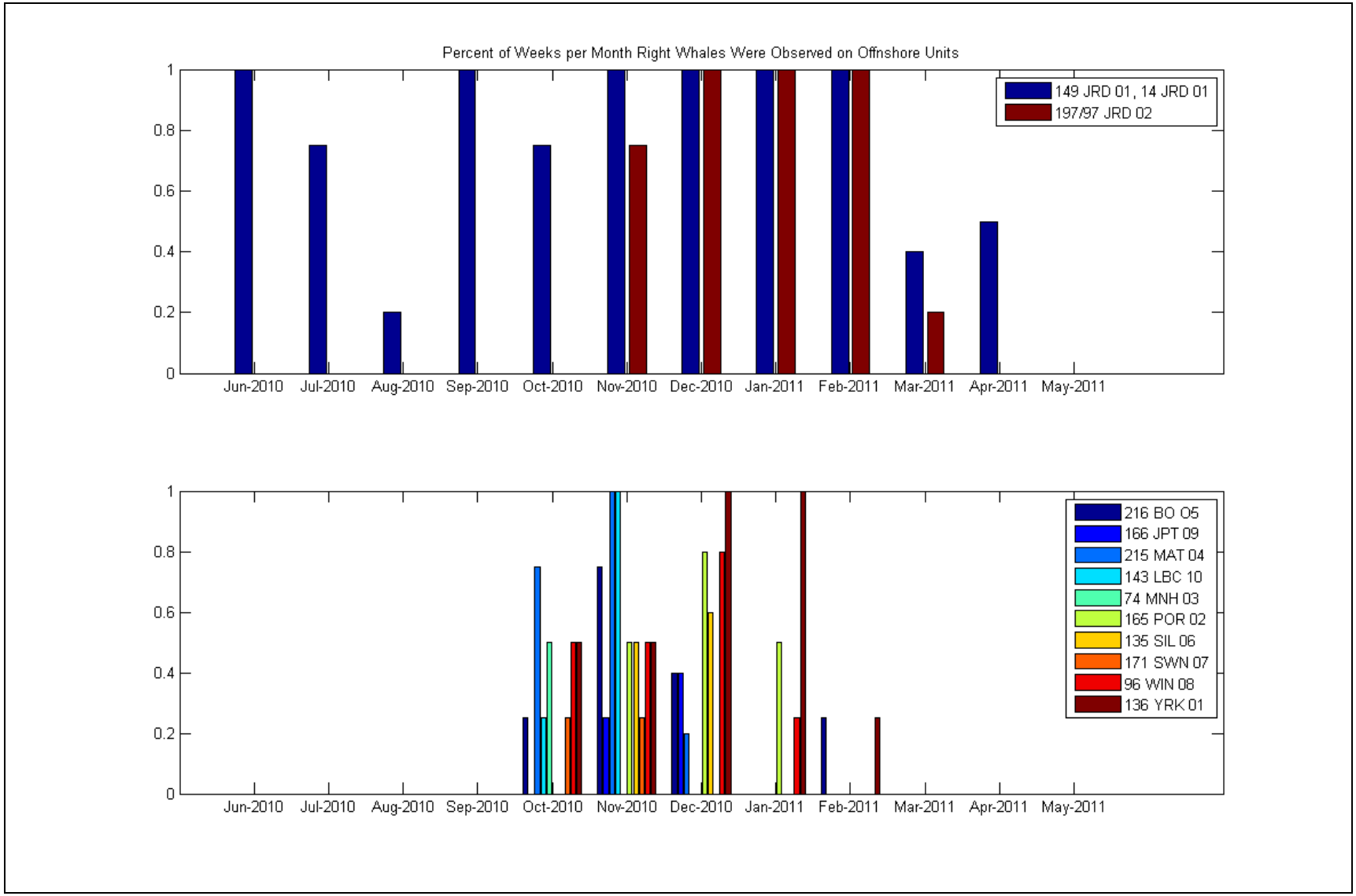


Figure 22. The percent of weeks in a month that right whales were present on Outer Fall (upper chart) and inshore (lower chart) buoys.

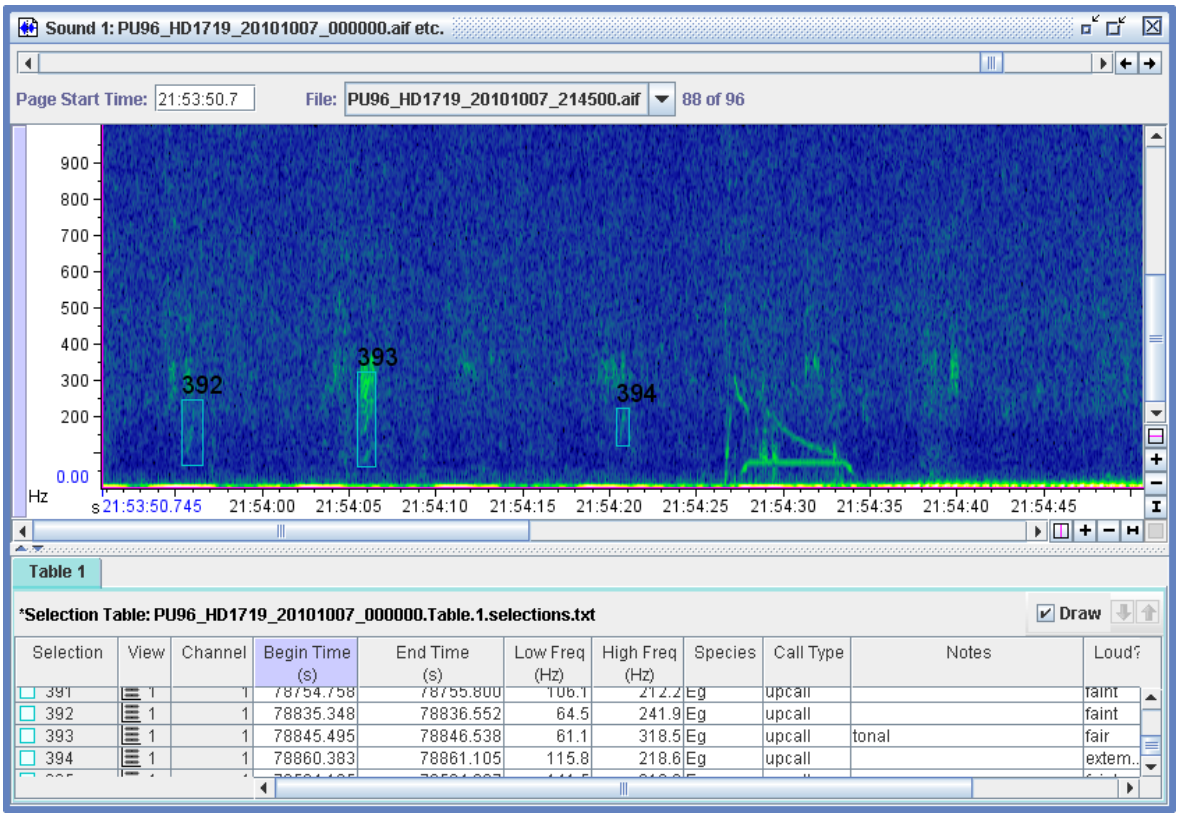
Since these buoys were single deployments, no localization was able to be done and therefore, it is unknown exactly where a call came from or how many animals were making calls at a given site. It cannot be determined if the calls were coming from regulated state waters, federal waters, or inside the exemption area. However, DMR was able to use the data on weekly presence/absence of right whales obtained from Cornell University to take a more in depth look at right whale calls on three of the ten inshore buoys (the rest were not completed due to time constraints but could be in the future when resources allow). The buoy deployed off of Matinicus was chosen as the first priority because it had the most weeks with positive right whale calls. The other two buoys, Boothbay Harbor and Petit Manan, were chosen to get a spatial spread across the coast. The dataset provided by Cornell University was used to narrow the scope of data that needed to be hand-browsed, only weeks with positive upcall detections were used in the analyses. All weeks with detections were hand-browsed in Raven Acoustic Analysis Software and all right whale upcalls and gunshots were tagged, recorded, and graded on a scale of loudness and therefore possible proximity to the hydrophone (raw data can be found in Appendix VI). The classification scheme is shown below in Table 3 and includes scales for both call amplitude and ambient noise levels. Calls classified as "close" had to meet the criteria of being excellent amplitude with low or fair ambient noise levels, or fair amplitude with low ambient noise levels. This is not a measure of how close the call actually is to the hydrophone but was one way of assessing the relative proximity or quality of the call. All determinations were done by a single technician for consistency of results.

Table 3. Scale and classification system used for the determination of how far or close a call may have been to the hydrophone.

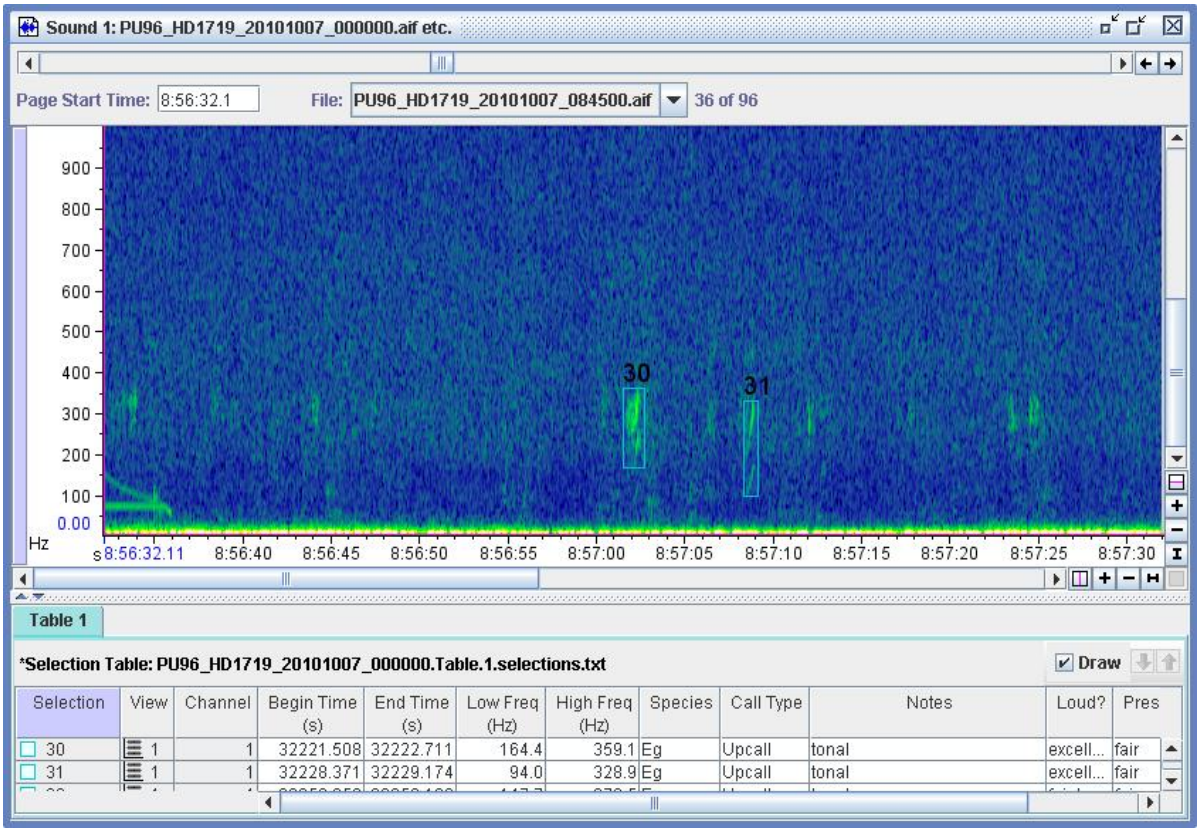
Scale for amplitude and ambient:	
Call Amplitude	Ambient Noise Level
extremely faint	high
faint	fair
fair	low
excellent	
Call distance classification	
close distance:	
low ambient-excellent and fair amplitude	
fair ambient-excellent amplitude	
far distance:	
low ambient-faint, extremely faint amplitude	
fair ambient-fair, faint, extremely faint amplitude	
high ambient-excellent, fair, faint, extremely faint amplitude	

The occurrence of an unfamiliar variation of the right whale upcall is also noted in the data and call rate calculations were completed both with and without including these calls. The "tonal" upcall is similar to the traditional right whale upcall but is different enough that it prompted investigation and help from other analysts at NMFS and the Cornell University Bioacoustics Research Program. In the end a definitive species and call type remained uncertain, but the call's frequency range, rhythm and surrounding call types make it likely attributable to the right whale. However, this variation is not backed by empirical proof and may be from either a unique

signaler, a different species of whale altogether, or may be a unique enough call that cannot be classified as the well documented right whale upcall (personal communication Genevieve Davis Northeast Regional Science Center). Therefore, these calls are listed separately in the tables ("tonal" calls) and the call rate for each day was calculated both with and without this call included. In the image below, logs 392 and 394 are classic right whale upcalls, while 393 is the "tonal" call in question above.



Another example of the "tonal" upcall is below in both logs 30 and 31:



Right Whale Call Rate/Gear Density Overlap

In an effort to determine the relative overlap between right whales and lobster fishing gear, the average call rate for each of the three buoys with fine scale assessments was multiplied by the average density of vertical lines for the same area using the boat-based gear density interpolations. To accomplish this, a five mile buffer (a conservative estimate for the listening range of a buoy) was established around each deployment site (Figure 23). The interpolated values for the number of vertical lines per square kilometer that intersected the buffered area were selected using ArcGIS software and averaged before being multiplied by the respective average hourly call rate (Figure 24). While the units have no meaning as far as absolute assessment of entanglement risk, the numbers relative to each other show trends for higher and lower rates of encounter, whether from a high call rate (a proxy for right whale density, although the number of calling whales cannot be discerned) or a high density of fishing gear. Ideally, this method will be applied to all ten sites for a more complete understanding of potential trouble spots for entanglement risk during this particular time of the year. The first step of determining gear density for each buffered region has been completed (Figure 25).

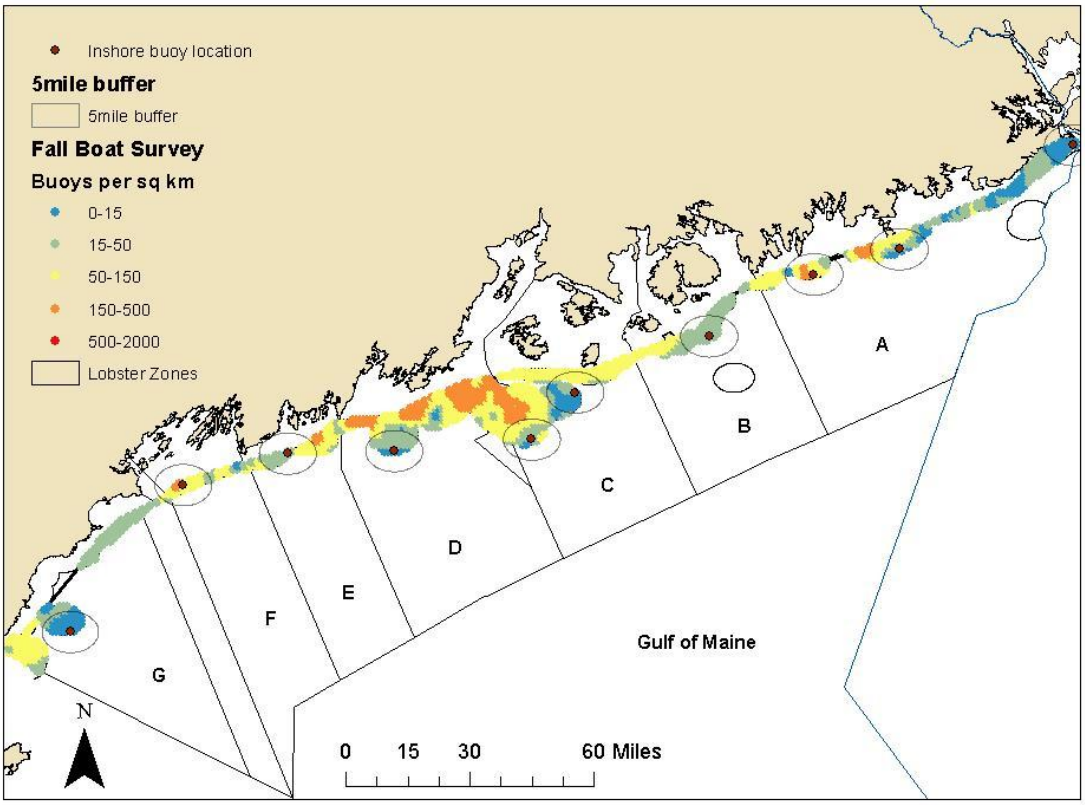


Figure 23. The locations of the pop-up buoys are shown as red circles with a five mile buffer surrounding each one. In the background are the interpolated data points estimating gear density in the regulated state waters for this same time period.

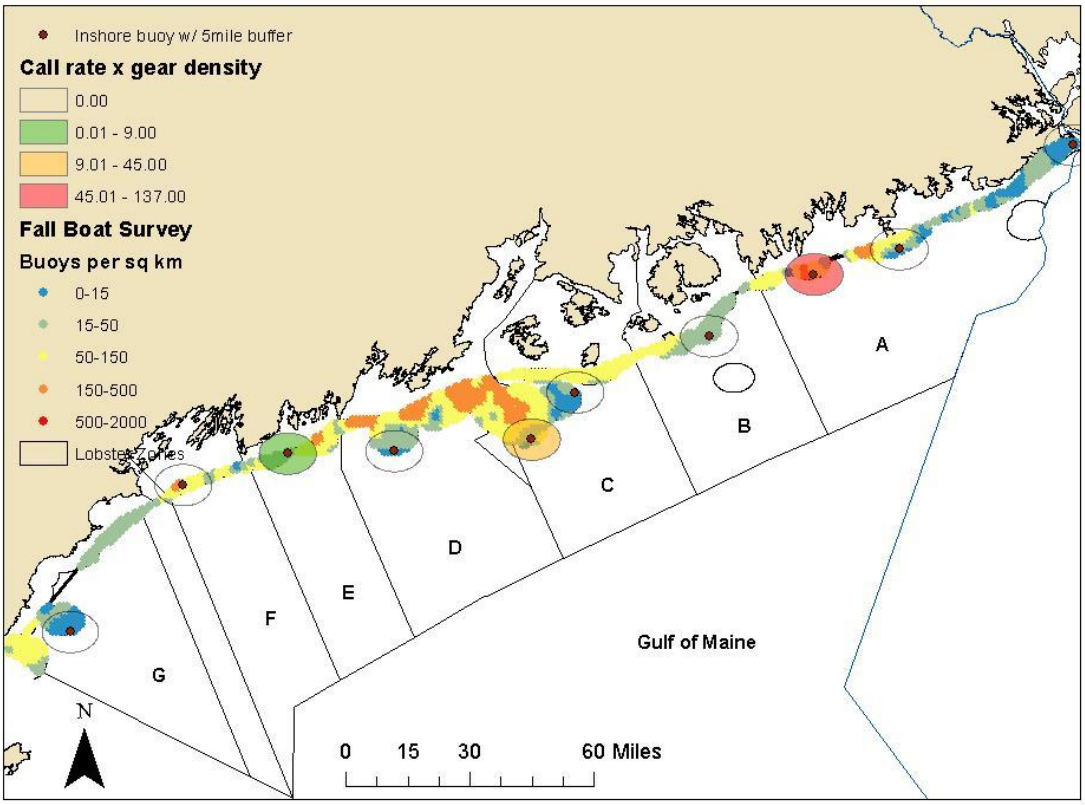


Figure 24. The rate of overlap between vertical line density (buoys per square kilometer) and the average daily call rate for right whale upcalls. The units are meaningless but when compared to each other it can be noted that the offshore site near Matinicus Island has a moderate overlap rate with both moderate amounts of gear and right whale upcalls. Petit Manan has the highest of the three with both the highest call rate and second densest gear estimation. While Boothbay Harbor has a moderate amount of gear to contribute to its overlap score, the low right whale call rate does not make it stand out as a potential site for increased entanglement risk.

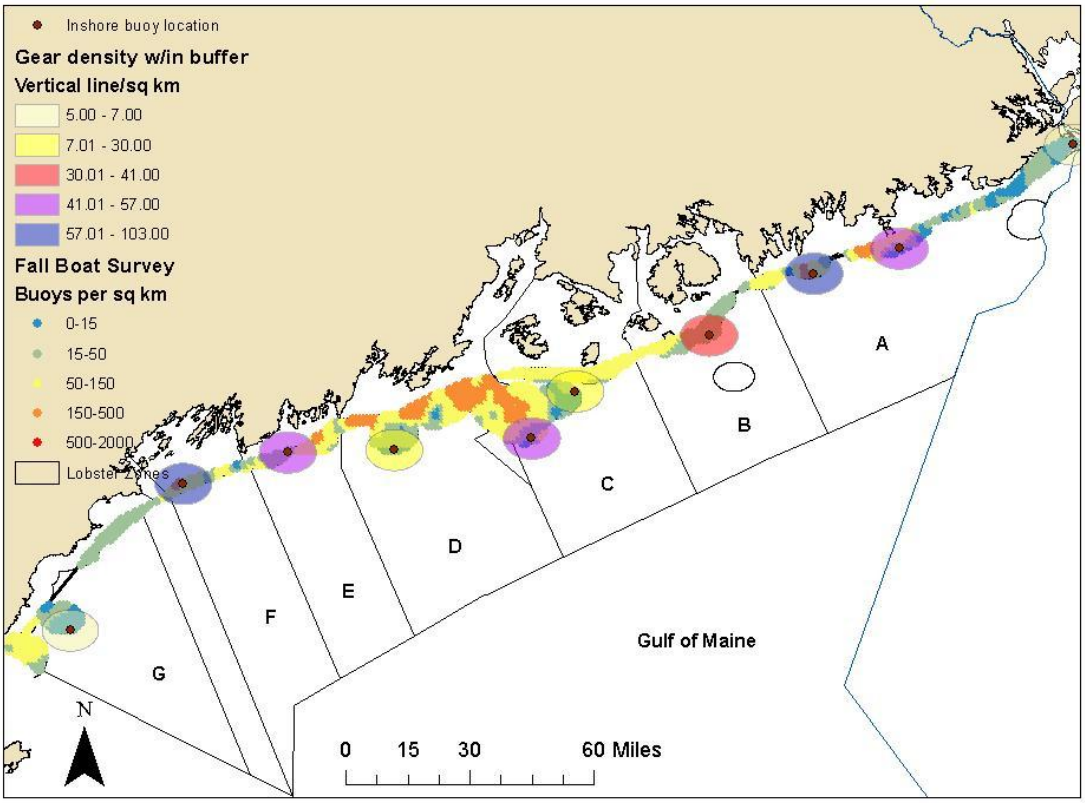


Figure 25. The average gear density (buoys per square kilometer) for each of the buffered acoustic deployment sites. The two highest locations were Petit Manan and Portland, with sites off of Jonesport, Matinicus Island, and Boothbay Harbor falling into the next highest category. The lowest gear sites for this time of year were Lubce and York at either end of the coast.

Acoustic Automatic Detection Methods

Through a collaboration between DMR and staff at Cornell University, analysts at the Bioacoustics Research Program processed data from all acoustic buoy deployments in a standardized manner using their automated detectors for right whale upcalls and fin whale pulses, while recording humpback whales opportunistically. Only call types (right whale upcalls and fin whale pulses) with previously documented auto-detectors were included in the complete analysis to save time and keep costs within the allowable budget. The remaining calls (humpbacks) were documented opportunistically as auto-detected calls were validated through the hand-browsing process. The un-browsed portions of the dataset are identified and can be added to the analysis when time and funding allows or made available to other researchers for specific projects. The above analysis included weekly presence/absence detections. This method was chosen to concentrate on the seasonal occurrence of whales at the different listening sites and to create a manageable format for pairing the data with the density of fishing gear in relevant areas. The number of detections was not determined to be a priority at this time without being able to determine the number of individuals calling. Because this is a broad brush

approach to take a first look at where future research should concentrate, many of the more in-depth and nuanced analyses were not given priority until the need for them could be assessed.

Given the enormous amount of data collected by the Marine Autonomous Recording Units (MARUs), the timely and efficient completion of detection analysis depended on a statistical approach and evaluation of the detection process. Detecting the occurrence of right whale up-calls on each MARU was accomplished using a multi-stage process (Urazghildiiev 2009; Urazghildiiev and Clark 2006; Urazghildiiev and Clark 2007 a and b).

The first step in the detection process consisted of running automatic right whale call detection algorithms on data from each MARU, with a particular emphasis on up-calls (Urazghildiiev 2009; Urazghildiiev and Clark 2006; Urazghildiiev and Clark 2007 a, b). It is important to note that a detection process will not detect every possible right whale call (i.e., missed detections) and will include detections that are not right whale calls (i.e., false alarms). It is known from previous research that area-specific noise conditions affect missed detection and false alarm rates (Dugan et al. 2010 a, b; Urazghildiiev et al. 2009). Additionally, a matched-filter detection algorithm (following Mellinger and Clark 2000) was used to automatically detect the 20 Hz pulses produced by fin whales.

Therefore, the initial step in the analysis process was to statistically determine the relationship between missed detections and false alarms as a function of the detection threshold. In the first analysis stage, a sub-sample consisting of *ca*. 10% of the MARU data was processed by the customized, Matlab-based right whale detector/recognizer program, ISRAT (Urazghildiiev and Clark, 2006, 2007a, 2007b; Urazghildiiev et al. 2009) using a series of different detection thresholds. All potential right whale up-calls automatically detected by ISRAT for each of the different threshold settings was screened by experts and all detected sounds that were not right whale calls were removed and recorded. These results were then used to calculate relative operating characteristic (ROC) curves following the procedures in Urazghildiiev and Clark (2007a, 2007b) and Urazghildiiev et al. (2009), and from these, threshold levels and detection parameter settings were selected to yield consistent detection probability and false alarm probability values across the full MARU dataset. The challenge here is to find a balance between the detection probability and the false alarm probability values, such that one has a good chance of detecting most of the calls, but does not have to spend large amounts of time screening out the false detections.

In the second analysis stage, Cornell used the ROC analysis to determine an optimal detection threshold for each of the MARU datasets, and the automatic detection process was run on all MARU acoustic data using these optimized parameters. The resultant set contained an expected number of false detections. These were removed and recorded by a team of analysts with expertise in whale sounds.

During the second stage of the right whale call detection analysis while expert analysts were screening and removing false call detections, they opportunistically noted the occurrence of songs from humpback whales on the same time scale resolution. This was a relatively easy and rapid process because a) the songs of humpback whales are easily distinguished and quite obvious and fall within separate frequency bandwidths (humpback: 50-1000Hz), and b) the analyst is already visually screening through the data and so does not need to spend extra time

scrolling through the data for humpback songs. To determine the weekly presence/absence of right and fin whale calls, analysts suspended the validation process after the first agreed upon detection of each species. The days that were assessed through the hand-browsing validation process were tracked, along with auto-detected and hand validated calls. Tables of the resulting weekly assessments for each buoy can be found in Appendix IV.

There were no buoys deployed that did not have at least one week with right whale detections. Because the buoys were not set in location arrays, it will not be possible to tell where (or in what management area) these calls originated or how many individuals to which they can be attributed. The data included details the inshore results for all three species, right, humpback and fin whales. The offshore data only details right whale detections. Fin whales were detected in every week recorded using the offshore buoys and humpbacks were detected in every week that could be opportunistically searched. A summary of deployments, analyses completed, and future plans is included in Appendix IV following the weekly summarization tables.

Ambient Noise Characterization

The determination of ambient noise levels became a priority within the Large Whale Conservation Program at DMR due to expanding needs for ocean planning initiatives that include ocean energy (wind and tidal) permitting and monitoring. Several of the acoustic buoys deployed through this program coincide with areas that have been identified as potential wind development sites, in addition to the buoys that have been deployed in the Outer Fall/Jordan Basin region, which may be a high importance habitat for right whales. The determination of ambient noise in the latter location is the first documentation of baseline levels of underwater noise here and will be useful in making comparisons with publications from other documented right whale habitats, such as the Bay of Fundy and Cape Cod Bay. There are several uses and applications for these data that could affect multiple industries, including fishing and ocean energy. A scientific paper is being drafted to publish these baseline data. A report is included in Appendix VII. The results of these analyses will also be used in conjunction with Automatic Identification System data obtained for another grant funded through the Maine Outdoor Heritage Fund.

Work to be Completed

There is still some work being completed on interpretation of results and preparation of manuscripts for peer-reviewed publication, including ambient noise classifications and fishery characterization methods. Additional fine scale data analysis will continue to take place as is feasible with time and funding constraints, including hand-browsing to verify detections, note gunshots, and calculate call rates on the rest of the inshore buoys and the remaining deployment of Outer Fall buoys. A graduate student at the College of the Atlantic will be analyzing the remaining Outer Fall buoy data over the course of the next year for right whales. Copies of all of the raw data are being provided to NMFS as well.

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