Using radar data to evaluate seabird abundance and habitat use at the Fundy Ocean Research Centre for Energy site near Parrsboro, NS

Project #: 300-223

Final Report for April 1 to September 30, 2018

Recipient: Acadia University

Author: Jacob Walker

Project Lead: Dr. Philip Taylor

Submitted: September 28, 2018

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EXECUTIVE SUMMARY

Radar scans from an open-array Furuno marine radar at the Fundy Ocean Research Centre for Energy (FORCE) site were assessed to determine if the data could be used to monitor seabird activity at the site. The radar unit was installed to monitor the surface of the water in the Minas Passage, to determine flow rates and turbulence at the site. Radar scans from the site have been archived since 2015 in SQLite and .jpg formats, and have somewhat less resolution than the raw radar data. The archived radar scans in .jpg format were subsampled and converted into five-minute long clips, and analysed using the radR program in the R statistical programming language. After filtering out areas with persistent interference due to waves on the surface of the water, bird targets were successfully tracked using tracking algorithms in the radR program. Clips from a wide range of dates, tidal stages, and times of day were analysed to characterize seabird use at the site over four years. A general additive model was used to simultaneously account for the effects of wave clutter, date, tidal stage, time of day, and wind speed and direction on the number of bird tracks detected. The results showed a clear seasonal pattern, with few bird tracks detected in winter, peaks during spring and fall migration, and a period of high activity during the summer. Effects of time of day and tidal stage were complex, and intertwined, as the effect of tidal stage on the number of bird tracks detected was dependent on the time of day and vice versa. The effect of wind speed and direction indicated that strong southwest or southeast winds produce higher numbers of bird tracks at the site, but strong winds from other directions produce fewer bird tracks. Recommendations were made for future use of radar monitoring at the site, and for how the data from this study could be used to modify the sampling regime of observer-based seabird surveys.

INTRODUCTION

The Fundy Ocean Research Centre for Energy (herafter FORCE) is a demonstration site for in-stream tidal turbines in the Minas Passage, located west of Parrsboro, NS. To date, three turbines have been installed at the FORCE site, though no more than one have been deployed at any time (FORCE 2018). The Environmental Effects Monitoring Program (hereafter EEMP) was initiated in 2009 to monitor any effects of the turbines on the local ecosystem (FORCE 2018). Seabirds are one guild that have been selected for monitoring by the EEMP. Monthly observer-based seabird surveys have been conducted at the site from 2016 to present to determine species composition, habitat use, and effects of turbine placement at the site (FORCE 2018). To complement the observer-based seabird surveys, radar data from the FORCE site were analysed in this study to determine patterns of seabird use in relation to season, tidal cycle, time of day, and weather.

An open-array Furuno marine radar unit has been operating nearly continuously at the FORCE site since 2015. The radar was deployed to monitor the flow of water and turbulence at the FORCE site, however bird targets were also evident on the scans. The radar scans have been archived in two formats, initially in SQLite databases, and more recently in .jpg format. The raw radar scans were converted to .jpgs to save storage space, but in doing so some resolution was likely lost in the compression process. The primary objective of this study was to determine to what extent the existing radar data could be used to monitor seabirds at the FORCE site.

OBJECTIVES

To determine appropriate methodology for extracting bird targets from the radar scans archived in .jpg format from the radar unit at the FORCE site.

To provide a comprehensive analysis of bird use at the FORCE site, summarized by time of day, tidal cycle, and season.

METHODOLOGY

Data Processing

An open array Furuno marine radar unit was installed at the FORCE site in January 2015 to monitor tidal flow in the Minas Passage at the following coordinates (Latitude 45.3714°, Longitude -64.4029°). Scans from this radar unit were archived in SQLite databases until November 2015, and subsequent scans were and continue to be archived in .jpg format. Archived scans were acquired from John Brzustowski on several external hard drives. Analysis of scans was performed using radR program in the R statistical computing language (Taylor et al. 2010, R Core Team 2016). The radR program does not read in scans in either SQLite or .jpg formats, so scans were converted into .mp4 clips of 5-minute duration using the program FFmpeg, which could then be read into radR (FFmpeg Developers 2016). The scope of the project allowed for scans archived in .jpg format to be analysed in this study, but not those archived in SQLite databases. When splicing the .jpg scans into .mp4 clips, FFmpeg settings included a frame rate of 0.46 frames per second, the libx264 codec, and a pad of 1 black pixel (pad=1876:1866:0:0:black) on the side to make the dimensions in an even number of pixels.

Radar data in .jpg format were available between Nov 17, 2015 and July 2, 2016, and between May 22, 2017 and April 11, 2018. The hard drive containing scans between July 2016 and May 2017 was not obtained. Though radar data presently continue to be archived at the FORCE site, .jpgs were converted to .mp4s on Apr 11, 2018, hence the end date. The available radar data were subsampled to obtain 5-minute clips from four times of day (sunrise, three hours after sunrise [morning], three hours before sunset [afternoon], and sunset) thought to represent diurnal sea bird activity at the site. Clips from these four times of day were taken from one day per week throughout the year, and were selected from the day of that week that had the lowest average wind speed during diurnal hours. While the effects of wind and wind direction were of interest on sea bird use, it was clear after initially processing numerous clips from randomly selected days that the birds were not readily detectable over the waves when it was windy. Historic weather data were obtained for the Parrsboro, NS weather station from the Environment and Climate Change Canada website (http://climate.weather.gc.ca/climate_data/) to determine days with little wind and precipitation, and for use in the data analysis. Dates with >5mm of precipitation were not considered due to the difficulty in filtering rain or snow from of the radar data. By selecting clips from these four times of day and the range of dates, it also ensured that each stage of the tidal cycle would have adequate representation. Tide predictions were calculated for Cape Sharp using the following website: tides.mobilegeographics.com. Based on the above criteria, 305 clips were created and processed (some of the time periods were missing data on some days), though only 294 clips contained usable data due to radar malfunctions, fog, or other unknown reasons.

Each clip was read into radR using the video plugin, and processed using the radR settings shown in Appendix 1. The settings were selected after much trial and error specifically to reduce the effects of interference from waves on the surface of the water. Radar scans from the FORCE site are collected with an open-array antenna which records data in two dimensions, range and bearing, so objects detected at all altitudes are combined in a single plane. Additionally, the radar unit at the FORCE site was set up to intentionally detect the surface of the water, so there is significant amount of wave interference on most clips. The declutter plugin in radR was used to eliminate areas with persistent wave interference, which varied in each clip depending on wind speed, wind direction, and tidal stage. A separate clutter map was created for each clip, and was used to filter out waves on that clip and saved for use in the analysis. Additionally, the radar data were filtered to include only blips from within four kilometres of the radar, as there was an increasing amount of noise beyond that range.

Once the most problematic areas with persistent waves were removed from each clip, it was possible to use the tracker plug-in in radR to track flights of individual birds. The multi-frame correspondence algorithm was used, with the settings shown in Appendix 1, and the resulting tracks were saved in a .csv file. Finding appropriate settings that tracked birds effectively without producing unwanted tracks using blips from waves and other clutter was a difficult task, and the optimum settings found were a balance between the false positive and false negative tracks. The optimum settings were identified, however the process could not be fully automated due to excessive noise from the surface of the water, and manual corrections for false positive and false negative tracks were necessary. Specifically, each clip was watched as it was processed using the declutter, tracker, and blip trails (displays blips from previous scans in a different colour to help visualize tracks) plugins. The tracker plugin displays tracks it identifies by drawing a line through them on the plot of the radar scans. Tracks arising from clutter (false positives) were identified and deleted, and the beginning and endpoints of visible tracks not picked up by the tracking algorithm were recorded. An example of a clip being processed in radR is included in a separate .gif file as Appendix 2. Tracks are displayed in orange and blip-trails in green.

Data Analysis

Average velocities and bearings were calculated for tracks recorded by the tracking algorithm in radR. Tracks with average velocities below 20 kilometers per hour (kph) and bearings between 100 and 125 degrees or between 280 and 295 degrees were considered to be objects floating with the tides, and were removed from the other track data prior to further analysis. To determine the effects of date, time of day, and tidal stage on bird activity in the area, a general additive model was created using the package mgcv in R (Wood 2011). The number of tracks on a clip was the response variable, and predictor variables included a circular smoothed term for Julian day, the size of the wave clutter file (in Kilobytes), an interaction between tidal stage (factor with six levels) and time of day (factor with four levels), and an interaction between wind speed (hourly average kph from time of clip) and wind direction (factor with nine levels). The size of the clutter file from the declutter plugin is representative of the amount of wave clutter on each clip, so this term was used to account for the amount of interference from waves. The tidal stages used are as follows: High (one hour before to one hour after high tide), High Falling (one hour after high tide to mid tide), Low Falling (mid tide to one hour before low tide), Low (one hour before to one hour after low tide), Low Rising (one hour after low tide to mid tide), and High Rising (mid tide to one hour before high tide). The factor for wind direction included the directions: N, NE, E, SE, S, SW, W, NW, and a level for calm for which no wind direction was specified. A negative binomial distribution was used for the model as the counts of tracks were overdispersed, and the model fit much better than it did with a Poisson or quasi-Poisson distribution. Predicted values were calculated using the model to aid in interpretation of plots, and used the average amount of clutter, wind speeds of 0, 5, 10, 15, and 20 kph, and the full range of values for other variables. Data from multiple years were included in the model, however there was insufficient overlap in dates between years to model separate year effects.

RESULTS

Number of tracks

Bird flights were detected on 233 of the 294 (79%) clips processed. Most of the clips lacking birds had high levels of wave interference, however there were several clips from calm days that also lacked birds. A total of 12,753 tracks from birds were recorded, with an average of 54.84 tracks per clip on clips where at least one track was detected. Of the 12,753 tracks detected, 10,928 were identified by the tracking algorithm in radR and an additional 1,825 (14%) were detected manually. The maximum number of tracks detected on a clip was 628. The raw number of tracks detected by date is depicted in Figure 1, however these numbers are not corrected for the amount of clutter, wind, tide, or any other variables considered. An additional 1005 tracks were detected that were considered to be floating objects (Figure 2). While some of these tracks could have been birds sitting on the surface of the water, we have no way to distinguish them from other floating objects. Birds were detected up to the range cut-off of four kilometers, however there appeared to be a decrease in detection probability at ranges over one kilometer (Figure 3). Beginning and end points of tracks were plotted to determine core areas of bird activity, but the only clear pattern indicated that the area of water between Black Rock and the small inlet west of the FORCE site was heavily used (Figure 4). Similar plots were also examined with tracks separated by time of day and tide, but none of these plots indicated a pattern different from the overall pattern, and are not depicted.

Effects of date, time, tide, and wind

The general additive model considered the effects of multiple explanatory variables simultaneously, including the effects of wave interference, to enable interpretation of the effects of each variable separately after the effects of the other variables had been accounted for. The model converged with an adjusted R^2 of 0.347 and 65% of the deviance explained, and all terms including the interactions were statistically significant at $\alpha = 0.05$ (Table 1). Estimates of parametric coefficients are shown in Table 2. The term for clutter is the most explanatory, which was expected due to the strong influence of wave interference on the ability to isolate tracks from birds. The smoothed term for date was highly explanatory ($\chi^2_8 = 234$, $P < 0.0001$), and predicted values for the effect of date are shown in Figure 5. It was clear from the model, and the raw data, that there are very few bird tracks in the winter, and that the number of tracks increases markedly in March (Figures 1 and 5). An influx of spring migrants begins in March and peaks in late May, followed by a period of high activity in summer. There is another peak in late summer and early fall depicting fall migrants, which gradually tails off as winter approaches. A violin plot of track velocities by month helps document the presence of migrants, which should have higher track velocities than resident or breeding birds (Figure 6). Velocities are highest in March and April when many sea birds are migrating, and nearly bimodal in May when both migrant and breeding birds are present. Velocities in the summer are generally low, but increase again in the fall.

The effects of time of day, tide, and wind were not as easily interpretable due to the complex nature of the system involving multiple species of birds and their behaviours related to tidal cycles, times of day, and weather patterns. Two 2^{nd} order interactions were modeled, both of which proved to be statistically significant, however these still likely downplay the complexity of the system. The interactions are most easily interpreted by plots of predicted values. Figure 7 depicts the interaction between time of day and tidal stage, and Figure 8 illustrates the interaction between wind speed and wind direction. The interaction between time of day and tidal stage indicates that bird species behave differently each day depending on the timing of the tides. A high tide in the afternoon, falling tide in the morning, or a low tide at sunset seem to produce the highest number of tracks (Figure 7). Strong winds from the SW or SE produce large numbers of bird tracks, but winds from due S or other directions do not have the same effect (Figure 8).

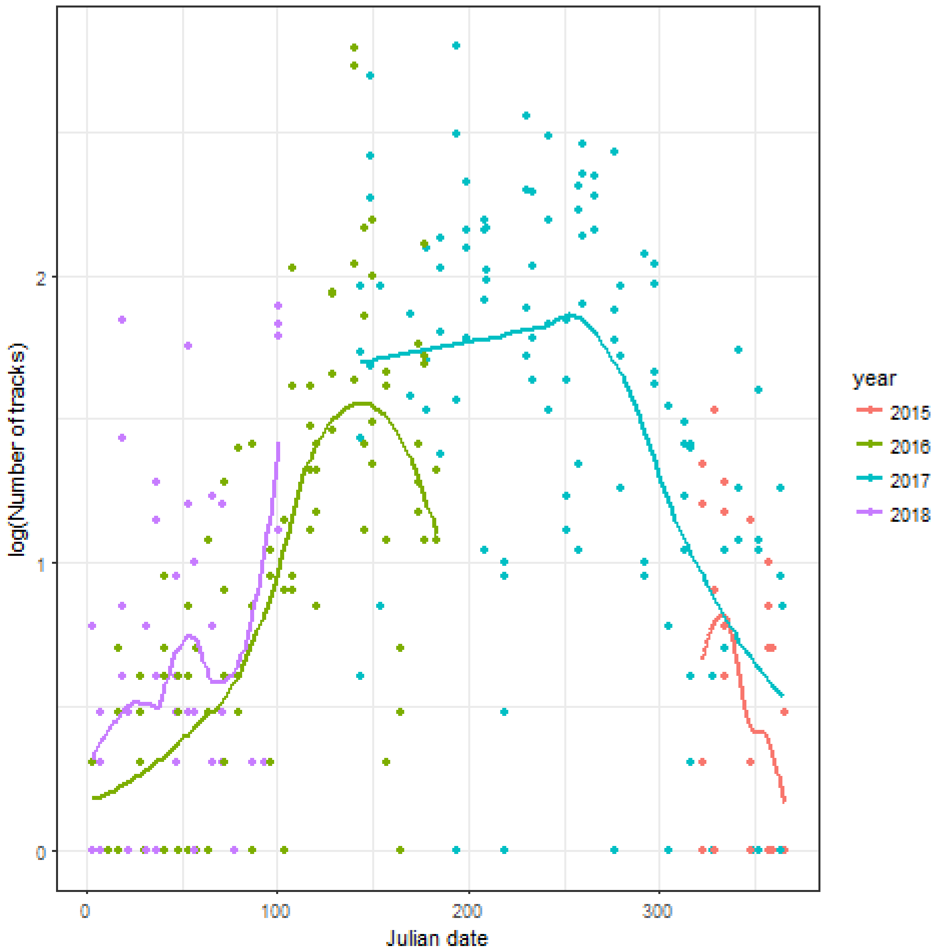

Figure 1. The number of tracks (log_{10} scale) detected on each five-minute clip, by Julian date, including a separate smooth for each year.

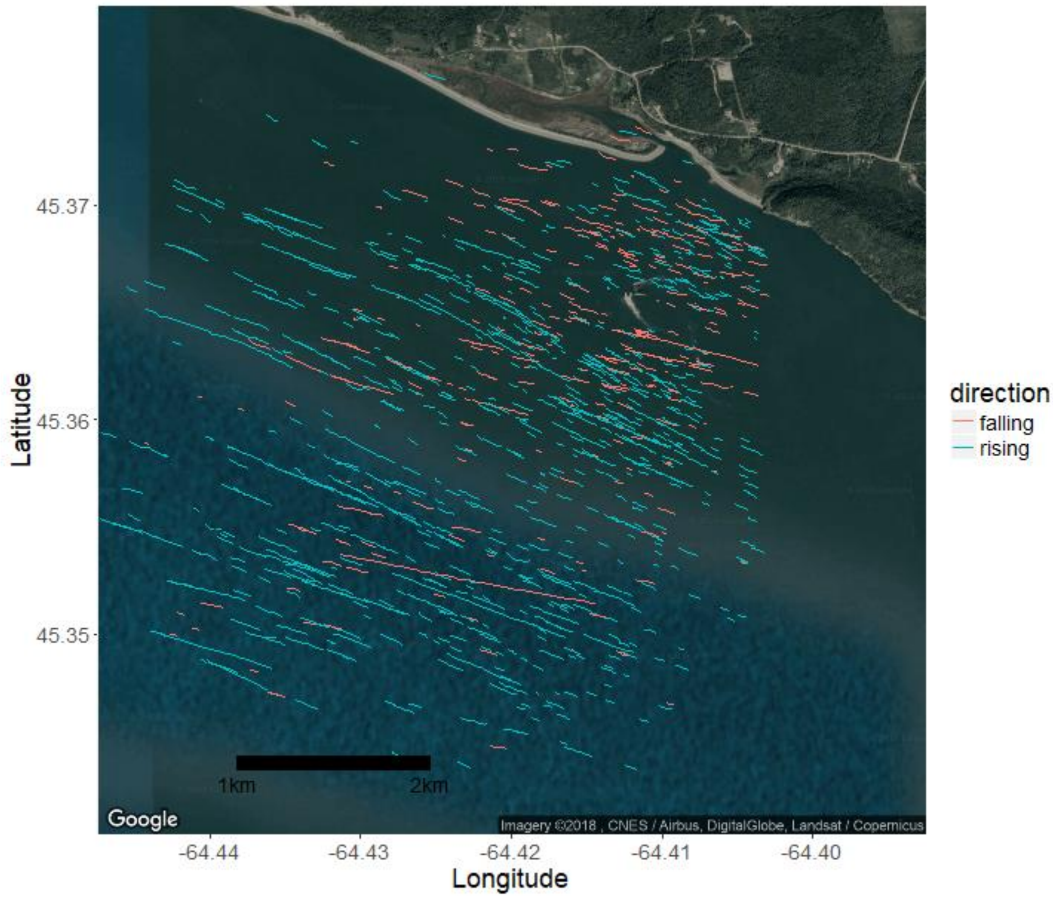

Figure 2. Map of tracks classified as floating objects, separated by tidal direction.

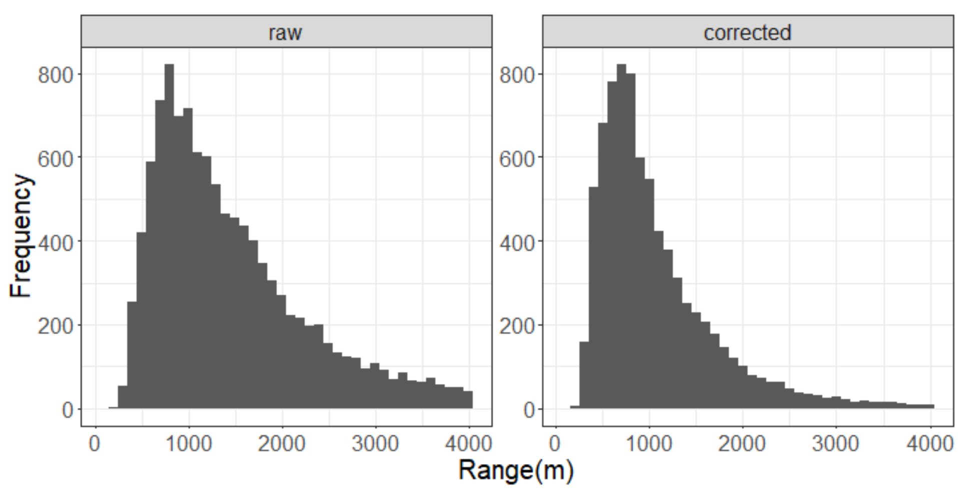

Figure 3. Histogram of the number of tracks detected by range. The left panel is the raw number of tracks and the right panel is corrected for the area sampled, which increases with range.

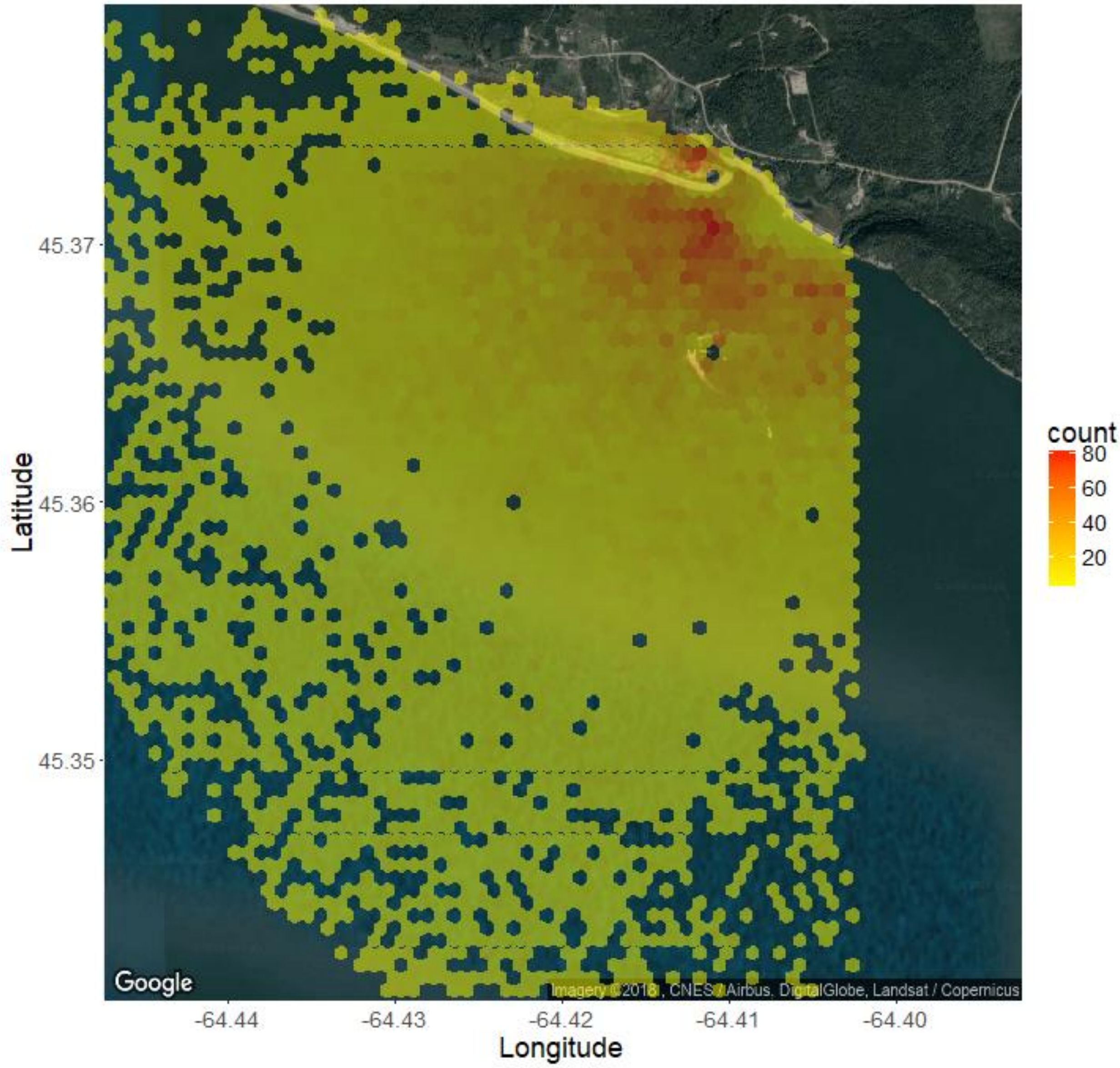

Figure 4. Map showing density of beginning and end points of bird tracks detected by the radar. The colors represent the number of tracks in each hexagonal bin.

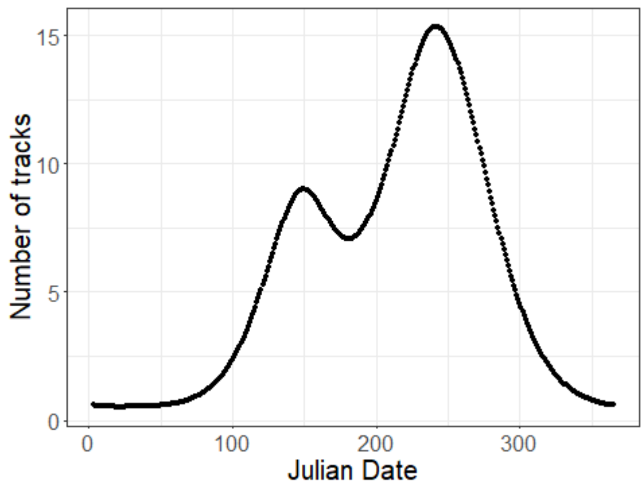

Figure 5. Predicted values from the general additive model for number of tracks by Julian date. The y-axis ticks are arbitrary, and based on the levels of the other variables in the model, but the relative effect of date remains constant. In this case, the levels of the other variables were: an average amount wave interference, at sunrise, at high tide, and with a north wind of 10kph.

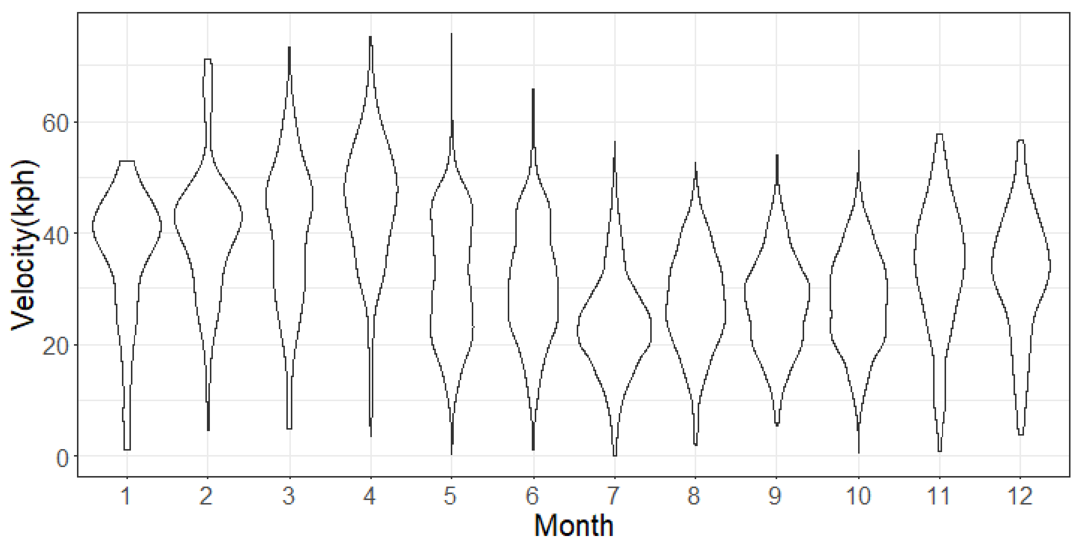

Figure 6. Violin plot showing histograms of track velocities by month.

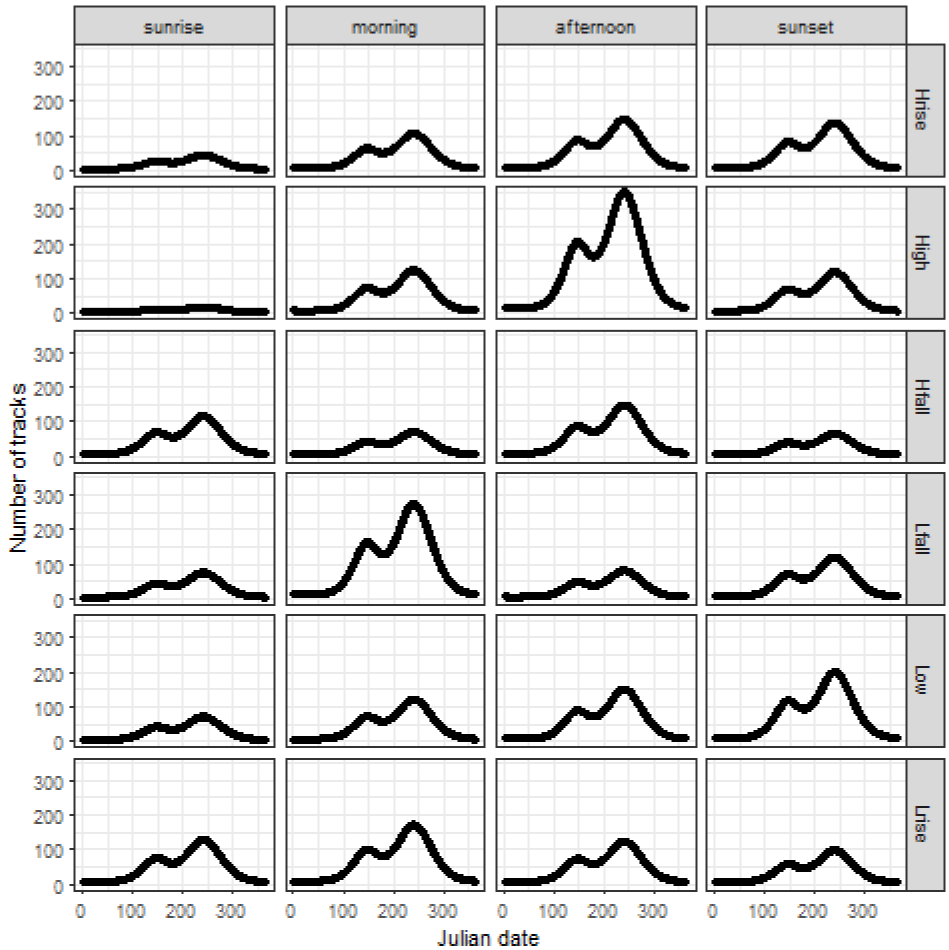

Figure 7. Interaction plot showing the number of tracks by Julian date for each combination of tidal stage and time of day.

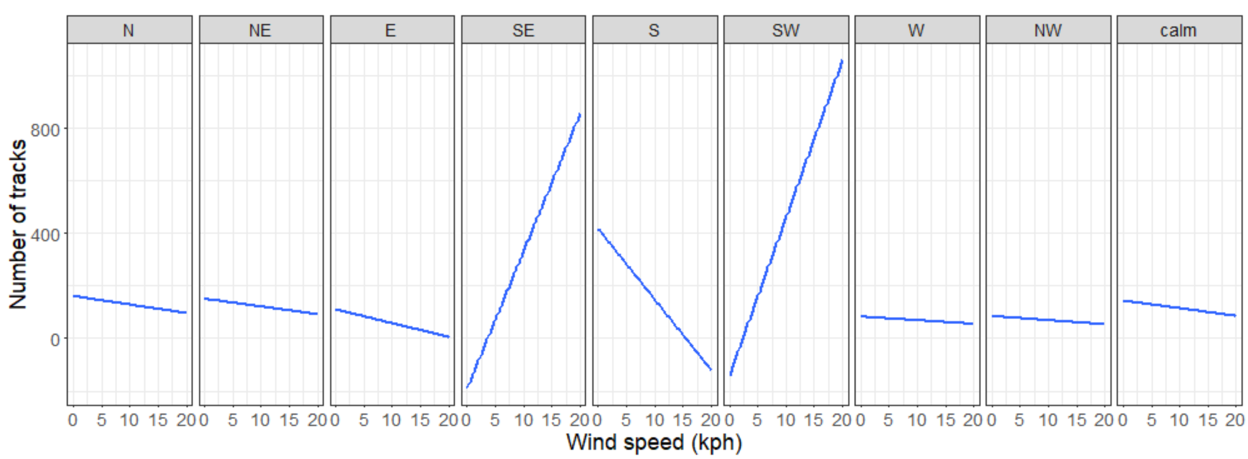

Figure 8. Interaction plot showing the how the effect of wind speed varies with wind direction.

Table 1. Anova table from the general additive model showing the degrees of freedom, $\chi 2$ value, and *P* value for each term in the model.

Term	df	χ^2	*P*
time	3	18.0542	0.0004
tide	5	12.4602	0.0290
clutter	1	88.1319	<0.0001
wind direction	8	18.6458	0.0169
wind speed	1	0.4858	0.4858
time:tide	15	30.3152	0.0108
wind speed:wind direction	7	14.8963	0.0374

Table 2. Parameter coefficients from the general additive model, with their standard errors (se), t values, and P values. Statistically significant parameters at a =0.05 are shown in bold font.

Parameter	Coefficient	se	*t*	*P*
intercept	**2.9352**	**0.6941**	**4.2289**	**<0.0001**
timemorning	**2.0641**	**0.7109**	**2.9034**	**0.0037**
timeafternoon	**3.1177**	**0.7407**	**4.2089**	**<0.0001**
timesunset	**2.0184**	**0.7107**	**2.8401**	**0.0045**
tideHfall	**1.9951**	**0.6996**	**2.8519**	**0.0043**
tideHrise	1.0004	0.7312	1.3681	0.1713
tideLfall	**1.5555**	**0.7029**	**2.2130**	**0.0269**
tideLow	1.5029	0.7798	1.9272	0.0540
tideLrise	**2.1051**	**0.7137**	**2.9495**	**0.0032**
clutter	**-0.0058**	**0.0006**	**-9.3879**	**<0.0001**
wdirNE	-0.0651	0.6154	-0.1058	0.9157
wdirE	-0.2742	0.6033	-0.4545	0.6495
wdirSE	**-2.7550**	**0.8200**	**-3.3599**	**0.0008**
wdirS	1.3517	0.9275	1.4574	0.1450
wdirSW	-1.2065	0.7299	-1.653	0.0983
wdirW	-0.6717	0.4410	-1.523	0.1278
wdirNW	-0.6456	0.5930	-1.0887	0.2763
wdircalm	-0.1167	0.3634	-0.3212	0.7480
windkph	-0.0255	0.0366	-0.697	0.4858
timemorning:tideHfall	**-2.5862**	**0.8680**	**-2.9796**	**0.0029**
timeafternoon:tideHfall	**-2.8656**	**0.8404**	**-3.4097**	**0.0007**
timesunset:tideHfall	**-2.6125**	**0.8834**	**-2.9574**	**0.0031**
timemorning:tideHrise	-1.1587	0.8762	-1.3225	0.1860
timeafternoon:tideHrise	**-1.8739**	**0.8939**	**-2.0962**	**0.0361**
timesunset:tideHrise	-0.8499	0.8867	-0.9585	0.3378
timemorning:tideLfall	-0.7446	0.8614	-0.8644	0.3874
timeafternoon:tideLfall	**-3.0377**	**0.8833**	**-3.4391**	**0.0006**

Parameter	Coefficient	se	*t*	*P*
timesunset:tideLfall	-1.5359	0.8341	-1.8415	0.0656
timemorning:tideLow	-1.5117	0.9050	-1.6703	0.0949
timeafternoon:tideLow	**-2.3483**	**0.9385**	**-2.5021**	**0.0123**
timesunset:tideLow	-0.9676	0.9364	-1.0332	0.3015
timemorning:tideLrise	**-1.7710**	**0.8549**	**-2.0716**	**0.0383**
timeafternoon:tideLrise	**-3.1605**	**0.8746**	**-3.6137**	**0.0003**
timesunset:tideLrise	**-2.3006**	**0.8645**	**-2.6611**	**0.0078**
wdirNE:windkph	0.0008	0.0899	0.0091	0.9928
wdirE:windkph	-0.0763	0.0931	-0.8198	0.4123
wdirSE:windkph	**0.2615**	**0.0993**	**2.6334**	**0.0085**
wdirS:windkph	-0.3510	0.1992	-1.7615	0.0781
wdirSW:windkph	0.1905	0.1037	1.8378	0.0661
wdirW:windkph	0.0052	0.0530	0.0989	0.9212
wdirNW:windkph	0.0025	0.0751	0.0339	0.9730
wdircalm:windkph	0	0	NA	NA

CONCLUSIONS

Data from the radar unit installed at the FORCE site to monitor currents, waves, and turbulence can be used to effectively monitor bird movements at the site, with some limitations. Bird targets were detected at ranges of at least up to four kilometers from the site. There was some evidence that fewer birds were detected as range increased, however if birds were selectively using areas closer to shore as indicated by the observer-based seabird surveys, it would confound this result. Interference from waves on the surface of the water are a major impediment to the identification of bird tracks, but methods were developed to eliminate areas with persistent wave clutter to enable tracking of birds in other parts of the study area. As a consequence, however, any birds using areas with persistent waves could not be isolated and tracked by the radar. It may be possible to develop algorithms to filter out wave interference while retaining blips from birds flying over the water, but this was beyond the scope of this project. Models using the radar data were corrected for the area obscured by wave interference, but the highly variable level of interference precluded an in-depth analysis of habitat use at the site.

The tracking algorithm in radR successfully tracked many of the birds present, though missed approximately 14% of the total based on manual estimates. Relaxing the settings of the tracking algorithm, such as allowing faster average velocities, allowing larger changes in bearing, or allowing more scans to be missing blips from the tracked target effectively reduced the number of bird tracks missed by the algorithm, but resulted in many spurious tracks consisting of wave clutter. Additionally, the tracking algorithm sometimes assigned multiple tracks to the same bird, which happened if the bird changed velocities, turned abruptly, or disappeared from the radar by passing behind a wave or by passing through an area filtered out by the declutter plugin. Also, any birds that landed and then later took off would be assigned a new track. As a consequence, the number of tracks presented in the results should not be interpreted as the number of birds detected during a five minute clip, but as a record of activity that should be reflective of and proportional to the number of birds present.

The results clearly show a seasonal pattern of activity at the site across years. There are very few birds present at the site during the winter, and peaks of activity during spring and fall migration are obvious. Bird activity at the site during the summer months is much higher than during the winter. There was no clear pattern of how birds use the site at different tidal cycles or times of day, though it was clear that both tidal stage and time of day do have effects on the number of bird flights at the site. This is likely due to the multitude of species that use the site which varies by season. Adding a seasonal component to the interaction between time of day and tidal stage might tease out some of these differences, but the added complexity would require an enormous quantity of data and would be difficult to interpret. The interaction between wind speed and direction matched our expectations, showing that strong SW winds blow seabirds into the inner Bay of Fundy, and strong SE winds aligned with the shorelines of the Minas Passage increased the number of birds present. There is likely a seasonal component to this interaction as well, but adding another variable to this interaction would increase the complexity of the model markedly. Many of the clips with numerous tracks come from the summer months, so the effects of the interactions between time of day and tide and between wind speed and direction may be driven by the dominant species present then, namely gulls and cormorants (FORCE 2018).

One major limitation of the radar data is that it is difficult or impossible to determine the species of birds tracked by the radar. It may be possible to differentiate some species based on the size of the blips and speed of the tracks, but there will always be a need for observer-based surveys to accurately determine species composition, and how different species utilize the site. The radar data largely agreed with the observer-based seabird surveys in terms of seasonal peaks in activity, however the radar data indicate higher levels of activity in the summer than the observer based surveys (FORCE 2018, Figures 1 and 3). Additionally, radar data from multiple years indicated that there were large quantities of birds present at the site in late May. To date, none of the observer-based surveys have been conducted in late May, so these large flights of birds have not been recorded by the monitoring program. Future observer-based monitoring should continue, and should use the results of this radar study as a guideline for scheduling survey dates so they coincide with periods of peak activity. Weather should be considered when scheduling these surveys, since SE and SW winds can have marked effects on the number of tracks detected.

RECOMMENDATIONS

Effective monitoring of sea birds using radar is inextricably dependent on filtering wave-clutter from the data. Many sea birds fly at low altitudes, often in the troughs of waves, so there is no effective way to detect sea birds without also detecting the surface of the water. To specifically monitor birds, data from a dish antenna may be easier to analyze and interpret than those from and open array antenna since the scans and data are recorded in three dimensions, including altitude. This would likely facilitate the separation of bird targets from waves, but would require running a separate radar unit specifically to monitor birds. Classifying tracks to species would still be nearly as difficult as with an open array antenna, but there would be additional information from the scans that could be used.

If bird monitoring via radar is to continue but using data from an open array antenna, the next advancement would be to develop an algorithm for detecting birds in sectors of the radar sweep with wave clutter. For the tracking algorithms to work effectively, the blips from waves will need to be removed while retaining those of the birds above the waves. This will be a complex and difficult task, especially considering that it is not possible to visually discern the blips from birds from the background noise with the human eye on the radR display. If wave clutter can be effectively filtered out, it would be possible to automate the processing of the radar data. This would provide a nearly complete record of bird activity at the site since 2015, allowing full analyses of inter-annual variability more detailed analyses of variation by weather, tide, and time of day. Additionally, modifications to the radR code should be made to allow .jpg files to be read into the program directly, so that .jpgs do not need to be spliced into videos prior to analysis. This modification would not only save time and computing power, but would preserve time stamp information included in the .jpg files.

Determining effects of a bottom-mounted turbine on sea birds at the FORCE site is very complex, especially due to the variation in sea bird abundance and behaviour by season, tidal stage, time of day, and weather. Each species of sea bird may need to be considered separately, since they use the site in different ways and are present at different times of year and under different weather conditions. Risk to birds would likely be restricted to diving species, though some species may be deterred from using the site by increased waves, noise, or turbulence. Some species could change their feeding patterns if there is an effect on fish or invertebrate species caused by the turbine. Detecting such varied effects in an already highly variable system will require careful thought as to which species are of interest and what the potential effects of a turbine might be.

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APPENDIX 1. TABLE OF radR SETTINGS USED FOR PROCESSING DATA

Plugin	Setting	Value
Video	frame rate	0.46 frames/sec
	image width	1876 pixels
	image height	1866 pixels
	x offset	-936 pixels
	y offset	-273 pixels
	scale	4.8 m/pixel
Antenna	angle of beam above rotaion	0 degrees
	horizontal aperture of beam	1 degree
	vertical aperture of beam	1 degree
	bearing offset	0 degrees
	elevation	10 metres
	true range of first sample	0 metres
	latitude	45.4 degrees
	longitude	-64.4 degrees
	rotation axis	90 degrees
	tilt	0 degrees
Blip processing	noise cutoff	0
	find blips	on
	learning scans	15
	update stats every scan	on
	exclude stats from blip update	on
	old stats weighting	0.95
	hot score threshold high	2.5
	hot score threshold low	-128
	samples per cell	4
	pulses per cell	4
	blips extend diagonally	off
	blip centroids by area not intensity	off
	filter blips	on
	min blip samples	8
	max blip samples	5000
	min blip area	150
	max blip area	20000
	min angular span	1
	max angular span	-1
	min radial span	1
	max radial span	-1

Plugin	Setting	Value
Blip processing	filter by logical expression	on
	logical expression	int > 0.08 & sqrt(x^2 + y^2)<4000 & 2*aspan>rspan
Declutter	blip cutoff for mean occupancy rate	0.03
Tracker controls	minimum number of blips required for a track	4
	maximum speed of tracked objects	80 kph
	minimum number of blips before track is plotted	4
	how long to retain plots of complete tracks	300
Multiframe correspondence controls	number of scans to backtrack over in building tracks	4
	weight of directional coherence vs proximity to prediction	0.64
	maximum gain for a blip to join a track (log units)	19
	small penalty for blips missing from tracks (gain units)	0