2018 FINAL REPORT

MIGRATION AND STOPOVER ECOLOGY OF SORAS AND VIRGINIA RAILS AT PATUXENT RIVER PARK-JUG BAY NATURAL AREA USING AUTOMATED TELEMETRY TRACKING SYSTEMS

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INTRODUCTION

A secretive marsh bird, the Sora (*Porzana carolina*) begins its fall migration in late summer arriving from northern breeding ranges to Atlantic coastal marshes. Their arrival to the Jug Bay portion of the middle Patuxent River correlates with the fall maturation of Wild Rice (*Zizania aquatica*). The Soras weave through the dense vegetation of the marsh to forage for fallen rice seeds in the mud[1]. The seeds are high in carbohydrates and are nutrient dense allowing the Soras to quickly accumulate enough body fat to complete their migration south; thus making Jug Bay an important stopover habitat for this species' migration. Historically, Soras were abundant on the Patuxent River. In the 1800s and early 1900s, they were a popular game bird, hunted in incredibly high numbers using a special push boat and shotguns. Their popularity as a game bird has since then declined along with their abundance on the Patuxent. Greg Kearns, Park Naturalist II at Patuxent River Park – The Maryland-National Park and Planning Commission and Michael Haramis of Patuxent Wildlife Research Center-USGS, conducted banding and telemetry studies of the rails from 1993-1999[2]. They discovered a sharp decline in the population in 1999 that was correlated to the overgrazing of rice by resident Canada geese[3] as well as a strong El Niño season in 1998, which altered the jet streams to an abnormal westerly flow. After Greg and his team spent 16 years directing the restoration of the rice stands in Jug Bay, the banding and telemetry study of soras was revived as a result of receiving the Cove Point Natural Heritage Trust grant.

The Virginia rail (*Rallus limicola*) shares the same habitat as the Sora, but prefers slightly higher and drier areas of the marsh and their shorter toes reflect this[1]. Their longer beak is geared more toward consuming invertebrates and not seeds like the wild rice seed the Sora prefers[1]. Soras concentrate here in much higher numbers accordingly, often outnumbering the Virginia rail at least 5:1. The Virginia rail can adapt to a wider variety of habitats such as brackish and salt marshes as well as tolerate a colder climate[1]. They arrive later and tend to stay later than the sora, often found over wintering here unlike the Soras that have mostly departed by late November. They tend to breed here whereas the Soras breed as far North as the Northwest Territories of Canada[1].

This study began in August 2017 incorporating the use of an automated telemetry tracking network called Motus (meaning "movement" in Latin) operated by Bird Studies Canada. The Motus network contains over 638 receiver stations in the Americas (874 worldwide) that provide access to tracking stations in eastern North America, Central and South America as well as some in the Caribbean Islands[4] and Bermuda where we recently installed this system in August 2019. This widespread international connection supplies the capability to track the full cycle migration of individual birds. We erected the first two inland tracking stations in Maryland, one at Patuxent River Park in Upper Marlboro, the other at Newtowne Neck State Park in Compton. These two stations detect the rails fitted with transmitters as they leave their stopover habitat to head further south for winter and possibly their return in the spring. Conjointly, the system collects detection information on other species studied using the Motus system that fly by our tracking stations. The transmitters are on the same 166 MHz frequency with individual digital coding to delineate each individual bird and species.

Research on these species is motivated by the population's decline both nationally and locally, the decline in their use of the Patuxent River as a stopover habitat, the lack of information about rail stopover ecology and migration, and the need for better management and conservation of these secretive species. The goals of this study are to discover 1) where the migrant rails originate and what is their ultimate destination? 2) How long does it take them to migrate and how fast do they fly? 3) How long do they stay in this region on the Patuxent River? 4) How does the population fluctuate from year to year? 5) What is the survival and life expectancy for this species? 6) Do they travel in family groups at night or individually? 7) Can we justify our current field sexing methods using body measurements to a 95% accuracy? 8) How important are the freshwater tidal wetlands of Jug Bay as a migratory stopover habitat and source of wild rice as a major migration food? 9) How are the rails effected by climate change and El Nino years?

MATERIALS

Grant Expenditures

44 Lotek Nano tag Transmitters	$9,925.31
Annual Deployment Fee for MOTUS tracking system	$2,050
Feather DNA Testing for soras	$1,524.69
Total	$13,500

Park Expenditures

Trapping Equipment	Previously purchased
Banding supplies	previously purchased
5 Audio Lure Sound Systems	$425
2 Wildlife Research Assistants hourly pay	$19,200
1 3 element Yagi Antennas	$150
1 5 element Yagi Antennas	$200
1 100' Low loss cables	$150
Feather DNA Testing for soras	$1,336.31
SRX800 Handheld Lotek Receiver	$2,800
Total	$25,261.31

METHODS

This project was a continuation of the one that we began in the summer of 2017. With the installation of the Motus tracking system already complete from the previous year and using the guidance of biologist Dave Brinker from Maryland Department of Natural Resources, the preliminary work was able to begin mid-June. The research assistants constructed traps and assisted installing five new trap sites for a total of 11 trapping sites in the marsh to capture the rails following the methods and protocols used by Greg Kearns (Park Naturalist II, Patuxent River Park) and Michael Haramis (Biologist, USGS) in the 1990s[2]. Greg Kearns supervised the team of two research assistants in the preliminary and day to day work for the research project, as he has numerous years of experience in the research of both Sora and Virginia rails. Once the birds were captured they were banded and various data was collected from each individual. Birds that matched the proper criteria were fitted with transmitters and released back into the marsh near their individual capture sites. The plan was to track their movements over the next 12 months utilizing the Motus network. The Motus receiver stations provide continuous data collection for which there is no current end date[4]. The trapping and banding efforts using Cove Point Natural Heritage Trust funds ended on November 10, 2018. In addition to radio-telemetry we introduced DNA sexing to the project to assess the sexing method used by our research team to try to achieve 95% accuracy.

The Motus tracking system- No new Motus tracking receiver stations were erected during the 2018 project. The two current stations were managed and improved by installing software updates, decreasing our SensorGnomes signal to noise ratio, and the rearrangement of the Yagi antennas mounted on the towers. The software update is a routine update that is downloaded and installed into the SensorGnome's Raspberry Pi computer. The update corrects bugs and improves systems operation[5]. The signal to noise ratio for pulses was reduced to increase the SensorGnome detection range by approximately 26%[5]. At the Patuxent River Park receiver station the directional orientation of the nine element Yagi antennas were altered to increase the probability of detecting a radio tagged rail from our project in migratory departure flight. One of the four nine-element Yagi antennas mounted on top of the receiving station towers was replaced by two four-element Yagi antennas, one on a horizontal axis and the other on a vertical axis located approximately 8 feet up on the tower, in hopes to increase the likeliness of detection. At the Newtowne Neck State Park receiver station one of the four nine-element Yagi antennas mounted on top of the receiver station tower was replaced by three four-element Yagi antennas, all in the horizontal plane to maximize detection of birds in flight.

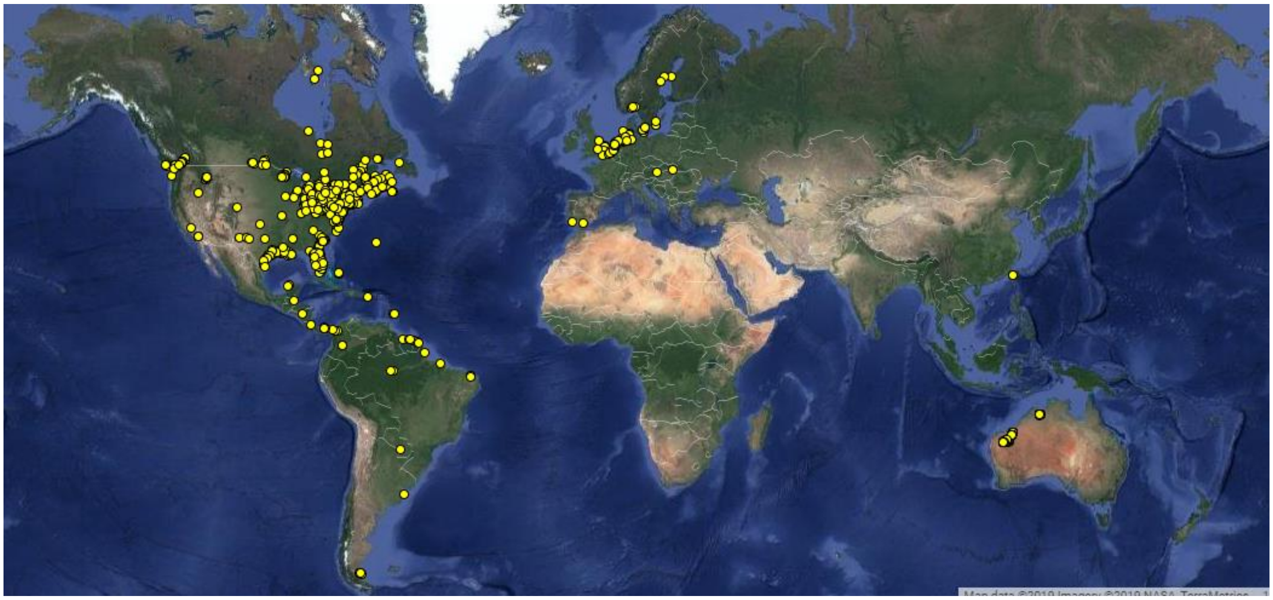


Fig 1. Map showing locations of currently active receiving stations in the Motus network[4].

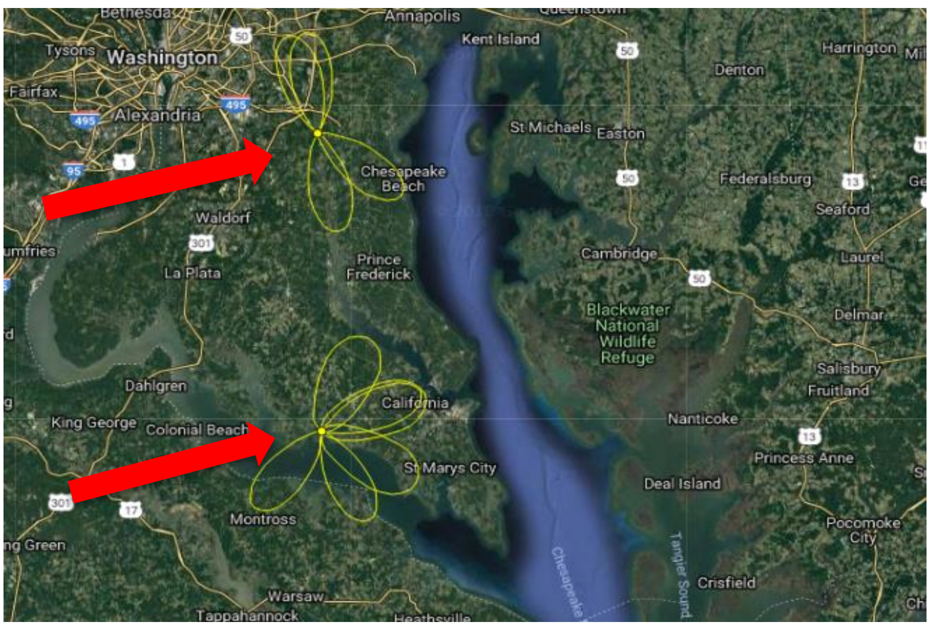
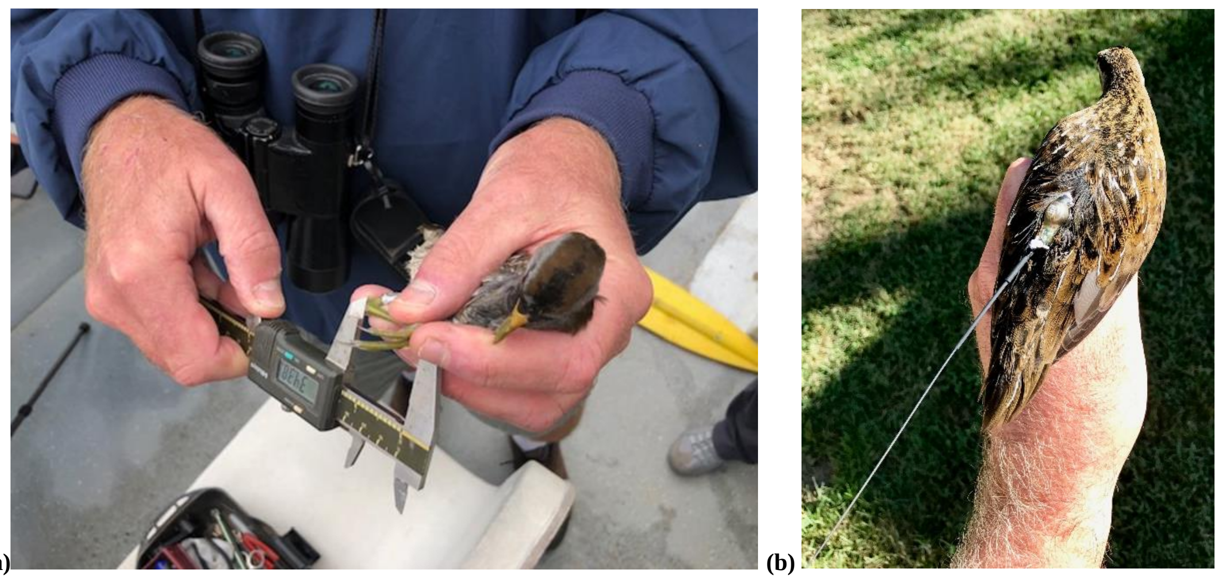


Fig 2. Map showing the detection radius and location of the two tracking stations erected in 2017 (signaled by red arrows).

Trapping and banding- Capture techniques were developed during the previous work in the 1990s based on Seth Low Clover Leaf Traps[6]. The traps were constructed using 2.5 cm mesh galvanized wire. Drift fence from standard 2.5cm mesh, 46cm high poultry wire. Ramped funnels were constructed from 1.3cm mesh hardware cloth. Catch boxes constructed of 1.3cm mesh. Vinyl coated wire is preferred to create the longest lasting and sturdy traps. The length of each trap line varied based on marsh topography, typically they consisted of two to three cloverleaf traps evenly spaced along 46+m of drift fence with a repeating audio lure system (audio unit, battery, solar charging panel, 2 speakers) located centrally between the traps[6]. Seven of the twelve audio lures included a playback of both Sora and Virginia rail calls. The track includes 40 seconds of Sora calls ("Keek", "Kerwee", and "Whinny") and 20 seconds of Virginia rail calls ("Kiddick" and grunts) playing a one minute on, one minute off cycle[6]. Five of the twelve audio lures included a playback of Sora, Virginia rail, Black rail, King rail, Yellow rail and Clapper rail calls playing on a one minute on, one minute off cycle. All of the audio units are equipped with a 24 hour timing circuit to provide programmable turn on capability for the next day. Once captured, measurements for culmen, tarsus, toe, and body mass were recorded as well as age and sex (Fig.3a). Age was determined by the fall plumage and eye color[1]. Sex was estimated by a series of body measurements[2] and some plumage characteristics. Each individual was banded with a United States Geological Survey – Bird Banding Laboratory metal butt-end leg band, and designated individuals with a body mass of ≥80g were fitted with a transmitter (Fig.3b), and a random sample of over 100 individuals had blood samples taken for DNA testing.



(a) **(b)**

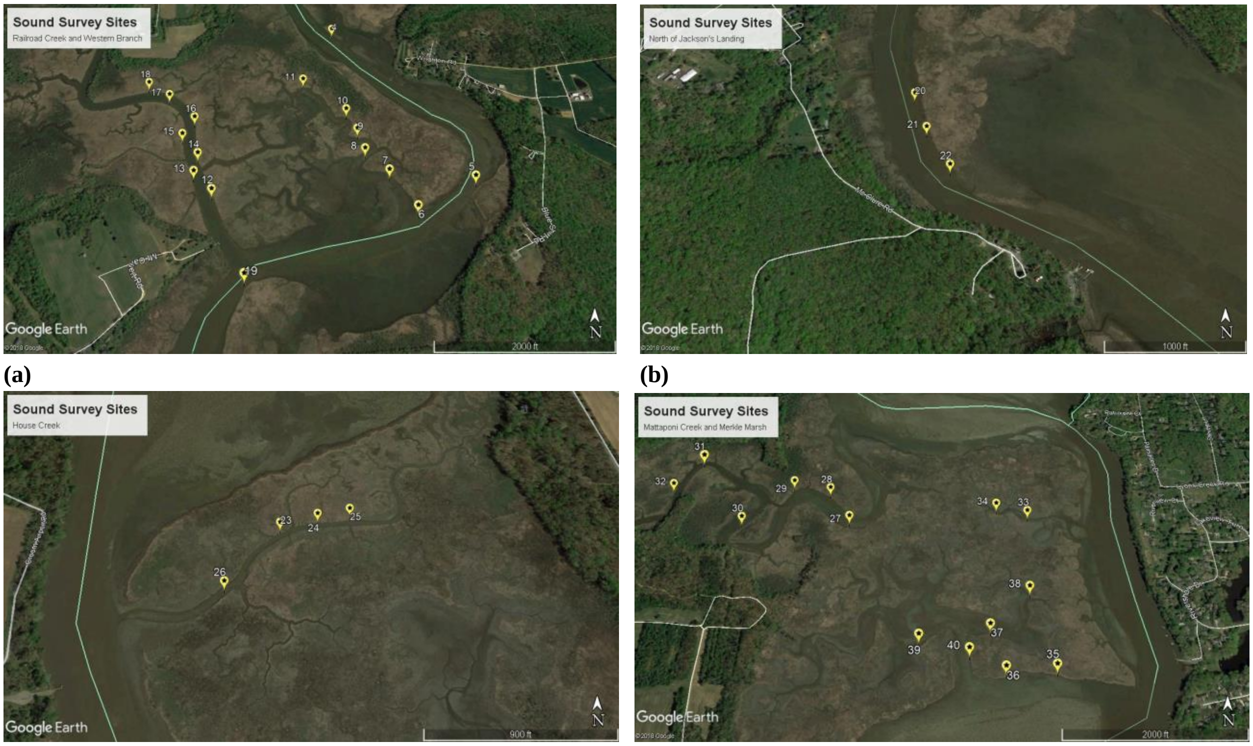
Figure 3a & 3b. (a) Image of a Sora fitted with a transmitter. (b) Image of researcher, Greg Kearns, taking a measurement of the tarsus length on a Sora.

*Uploading detection data***-** Each SensorGnome has a microchip that must be pulled to copy the detection data onto a computer. This data from each receiving station must be uploaded to the Motus.org site to be deciphered. The summary of the detection results can be seen on your projects profile and is emailed to the project lead. There is more in-depth data available on the website under the project name "Sora Migration (#172)". The site provides receiver detection tables, maps and timelines that keep record of any transmitter detections from each receiver station, as well as, tables, maps and timelines of all of our transmitters and their associated detections on any receiver station in the Motus system. These tables and figures are regularly monitored to track the progress of deployed transmitters, and the functionality of the receiver stations. However, all data analysis must be done using the program R for statistical computing and graphics. The data from each receiver and/or all the projects' specific transmitters can be downloaded from the website and uploaded in R. In this program, data cleaning is performed to filter and remove false positive detections and further data analysis is conducted to create graphs and figures following the guidance of The Motus R Book[7].

SRX800 Hand-held Receiver – This mobile receiver was purchased and provided to us by Chesapeake Bay National Estuarine Research Reserve – Maryland DNR and is capable of tracking any transmitters used in the Motus system. The SRX was used in this project to test the performance of our transmitters before deployment, to keep record of the exact location radio tagged rails were in relation to where they were released, to establish presence and/or absence, to monitor the behavior of the rails before migration departure, and to track the time and direction of departure from Patuxent River Park - Jug Bay Natural Area. The SRX allowed us to test the sensitivity of our receiver stations by comparison. The receiver was connected to either a three-element or five-element Yagi antenna. The SRX800 has the capability to log data, including tag ID number, gain, and signal strength.

From October 12th to December 4th, the receiver was used to locate radio tagged rails near release sites a minimum of once a week. When time was not a constraint, the receiver was used at each trap site, and the antenna was rotated across 360 degrees at least four times to ensure that any transmitters in range would not be missed as there are varied pulse rates. There are 14 transmitters with an 11.3 sec pulse rate, 15 transmitters with a 12.7 sec pulse rate and 15 transmitters with a 5.3 sec pulse rate. When time was a constraint, the receiver was used at four different locations, rather than each of the 11 trap site locations. These locations included, trap site 2, trap site 3, between trap sites 9 through 11, and between trap sites 4 through 8. For each transmitter, location (in reference to trap site number) and highest signal strength at each location, were recorded and analyzed. Essentially we tracked the "home" ranges and length of stay of the tagged rails while in their migratory stopover habitat.

Sound Site Surveys - 40 sites were surveyed, across a distance of five miles of the Patuxent River. Sites were selected based on vegetation preferences of soras for habitat and diet, which includes cattails, wild rice, and tear-thumb[1]. Sound surveys were conducted seven times on an almost weekly basis between September 6th and October 26th. Five of the sound surveys were conducted at sunrise, while the other two were conducted just before sunset. At each sound survey site three "Kerwee" calls and three "Whinny" calls were played, as well as, three paddle slaps across the water to illicit a response. A period of silence followed each to listen for responding rails.



(a) **(b)**

(c) **(d)**

Figure 4(a-d). Satellite imagery from Google Earth displaying locations of the 40 sound survey sites around Jug Bay used for this study. Sites are located North of Jackson's Landing, Western Branch, Railroad Creek, House Creek, Mattaponi Creek and Merkle Marsh.

DNA sampling – To justify our current field sexing techniques to a 95% accuracy or create more accurate field sexing methods, blood samples were taken as a non-lethal method to determine the sex of the rails. The goal was to collect 100 DNA samples total, 25 from each age-sex group (AHY = after hatch year and HY = hatch year birds, based on fall plumage) (25 AHY-M, 25 AHY-F, 25 HY-M, and 25 HY-F). To extract DNA samples from the rails the less invasive method of nail clipping was used[8]. One nail from the middle toe of the banded (right) leg of an individual bird was disinfected using a Q-tip soaked in rubbing alcohol to remove any foreign DNA. The nail was then clipped just enough to nick the vein (usually 2/3 of the distance from the root of the nail) using sanitized nail clippers. A few drops of blood were then rubbed onto the DNA Sample Card provided by the DDC Veterinary Company[8]. The card was then placed in a sealed container to allow the sample to dry for 60 to 90 minutes and remain protected from bacterial or fungal growth before placing into a properly labeled re-sealable plastic bag. All researchers participating in the DNA sampling were wearing sanitary gloves that were changed after each bird to prevent cross-contamination. A powder blood coagulant, Wonder Dust, was used after collecting the blood sample to quickly clot the bleeding and prevent infection. DNA samples were then packaged and sent to DDC Veterinary in Ohio. DDC Veterinary tests DNA using methods based on Griffith's method published in 1998[9]. Unlike humans where the sex chromosomes are XX for female and XY for male, bird sex chromosomes are WZ for females and ZZ for males. Using a Polymerase Chain Reaction, DDC Veterinary can detect the presence of a single CHD-Z band in male DNA samples and a second, distinctive CHD-W band in female DNA samples[9]. A Head shot picture was taken of all blood sampled birds to see if plumage characteristics had a recognizable pattern to distinguish sex.

RESULTS

Migrant Sora rail population of the Jug Bay marsh on the Patuxent River, 2018- A total of 238 individual Soras were captured between the dates of August 17th and November 10th. A total of 43 Virginia rails were captured between those dates. In comparison, in fall 2017 we captured 190 individual Soras and 21 Virginia rails.

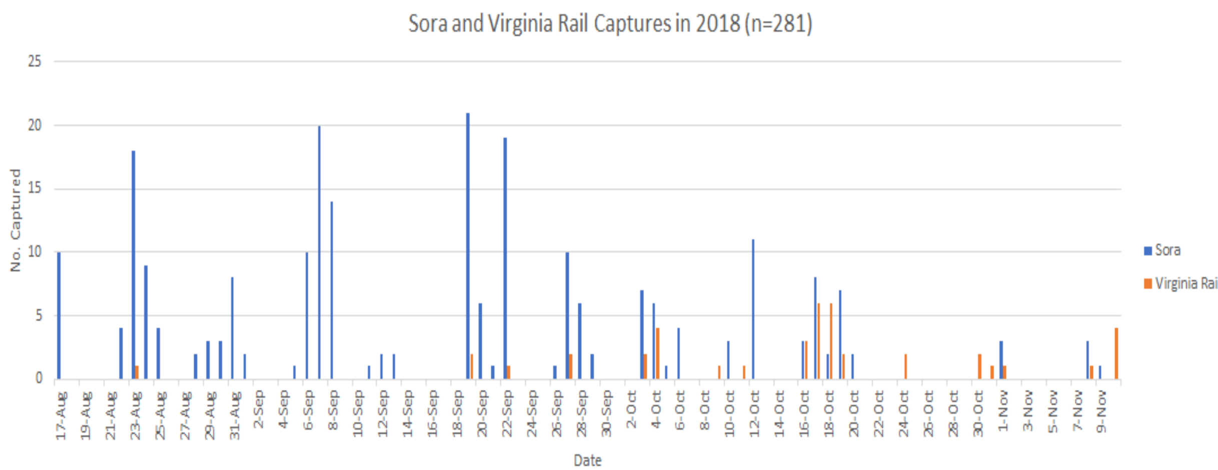


Figure 5. Total number of Sora and Virginia rails captured during the trapping and banding period. Sora captures peak in early September and taper off in mid-October, whereas Virginia rails peak in mid-October. Sora captures outnumber Virginia rail captures by 11:2(#Sora=238, #Virginia=43).

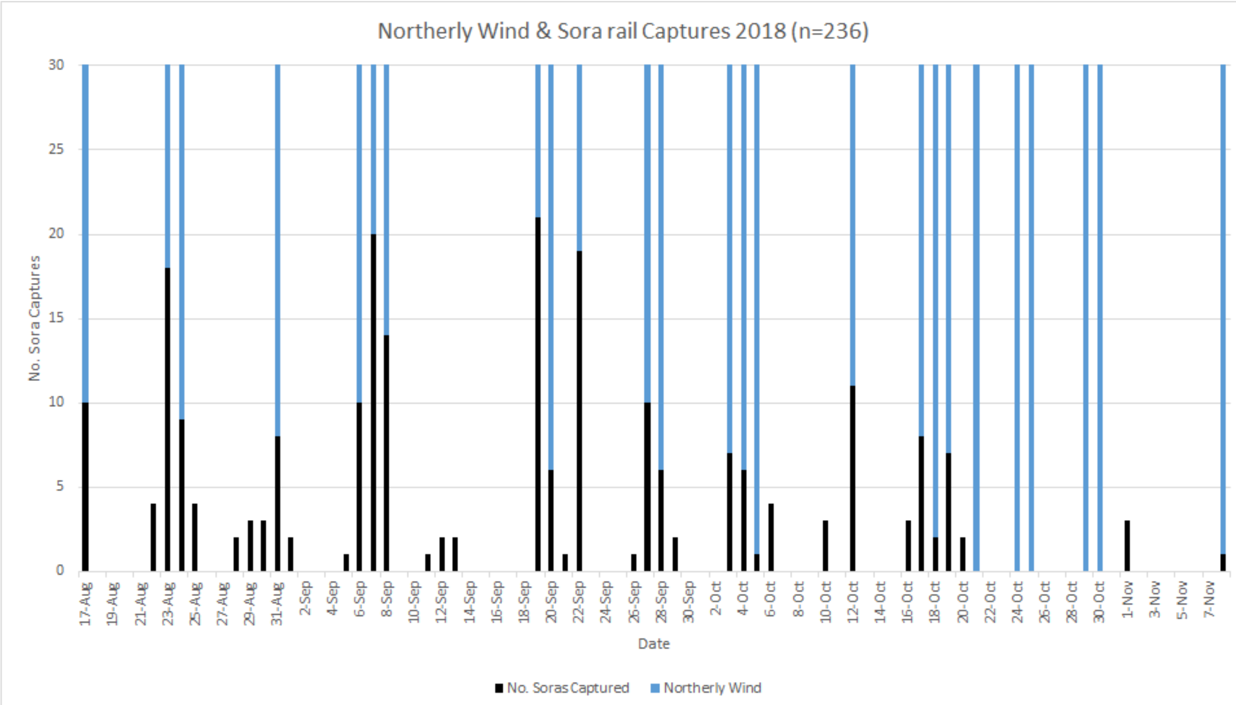


Figure 6. The occurrence of northerly cold fronts (≥ 5mph) in relation to Sora capture success in fall 2018. The northerly cold fronts bring flights of migrant Soras to the marsh in late August through September, resulting in a higher capture of birds during these fronts. The audio lure set to turn on just before sunrise to intensify capture rate. The capture success decreases mid-October as the Soras use the northerly cold fronts to migrate farther South.

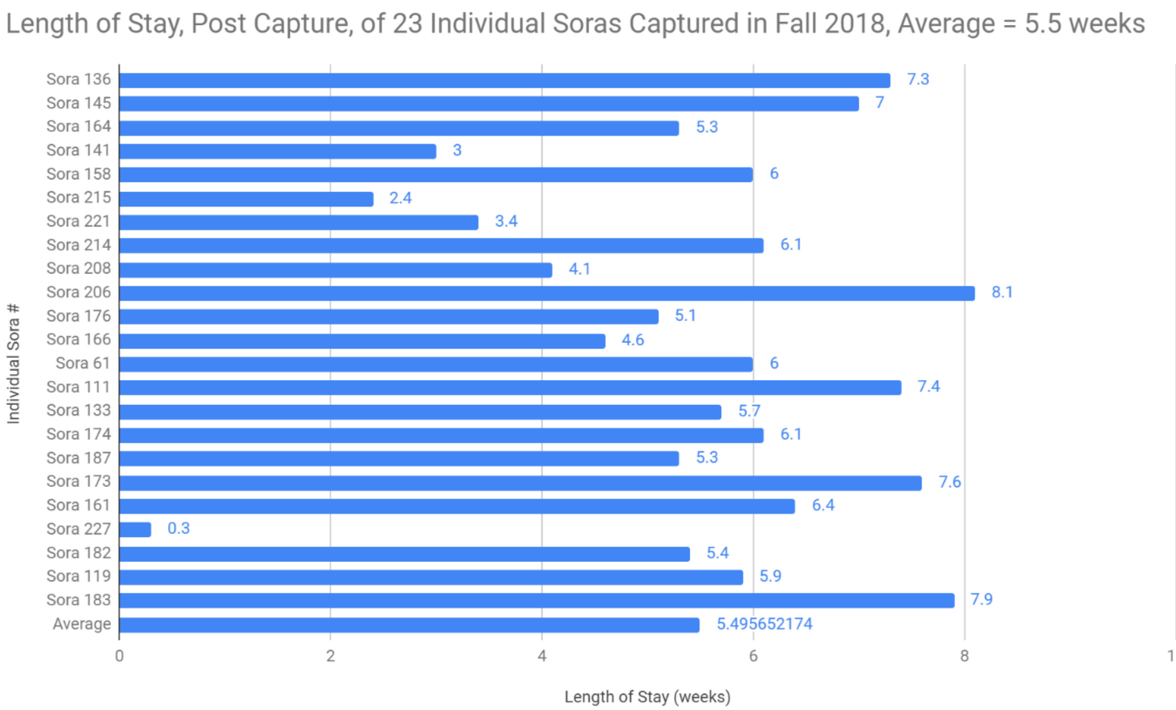
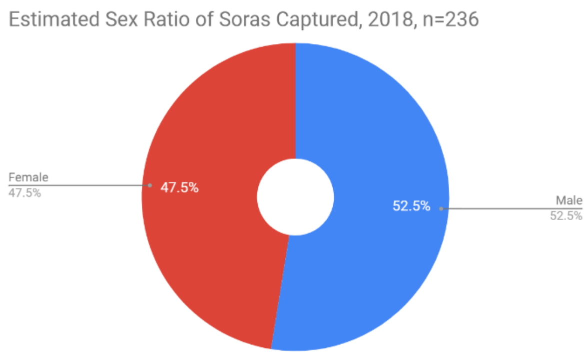
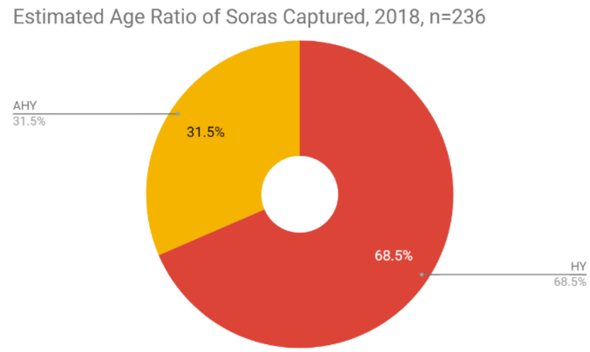


Figure 7. This bar chart displays the duration of stay (weeks) from the time of capture to the time of departure from the Jug Bay Marsh for 23 individual soras captured in the fall of 2018. These individuals were fitted with radio transmitters allowing us to track and record departure date. The average length of stay at 5.5 weeks.



(a)



(b)

Figure 8a & 8b. The age and sex ratios of the Sora rails captured in 2018. Age and sex determined in the field is based on fall plumage and body measurements, making it subject to error particularly in the hatch year birds. The sex ratio is about 1:1. The hatch year birds outnumber adults by about 3:1.

DNA Sexing- To test the accuracy of current field sexing techniques we collected a total of 108 blood samples from 29 After Hatch Year-Males (AHY-M), 18 After Hatch Year-Females (AHY-F), 30 Hatch Year – Males (HY-M), and 31 Hatch Year- Females (HY-F). There was limited collection of female AHY soras due to availability of those individuals. Soras were sexed based on current field sexing techniques which utilize the notion that males are generally larger in measurements[1] (weight, culmen, toe, and tarsus). In addition, current field sexing techniques indicate that males and females differ in physical features. Males having a chrome-yellow bill color versus females having an olive-green bill color and males frequently having an isolated auricular patch, while females more frequently have a connected auricular patch.

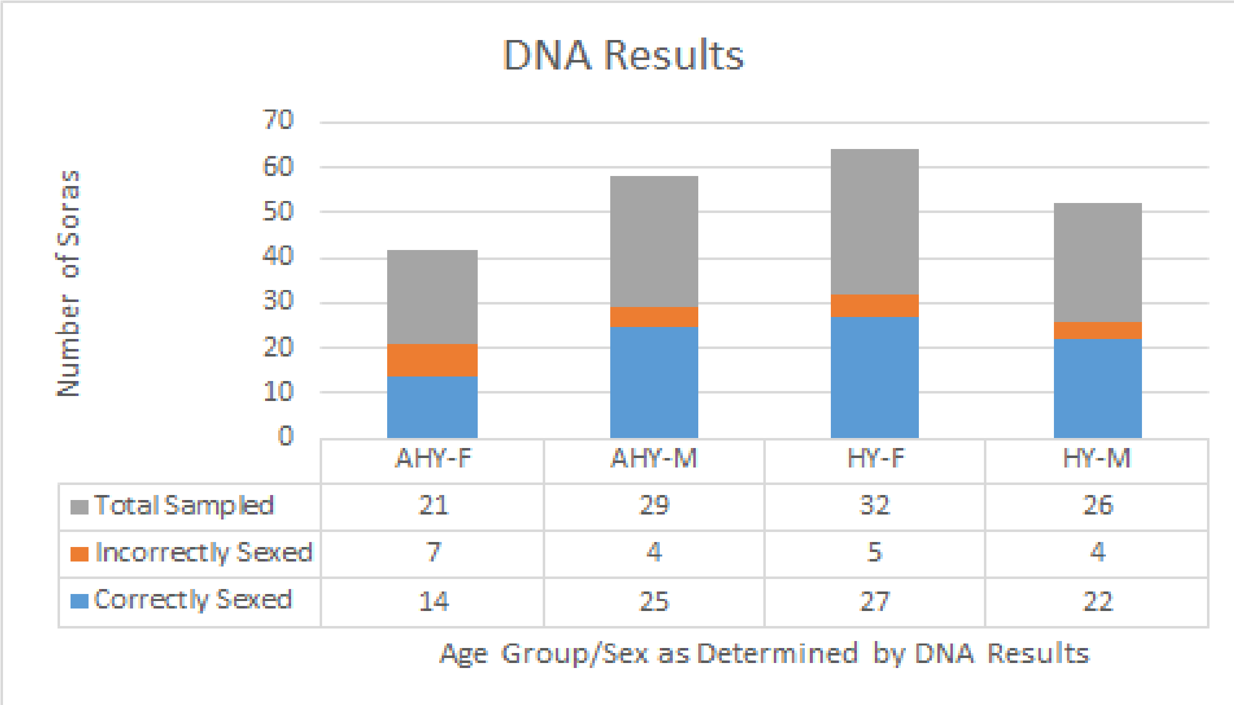


Figure 9. DNA sample results of Soras displaying total sampled sorted by age and sex. Correctly versus incorrectly sexed refers to whether or not its sex based on current field sexing methods was proven correct or incorrect by DNA sample results.

Male	Culmen (mm)	Tarsus (mm)	Toe (mm)	Weight (g)
Average:	20.83	34.35	35.93	71.93
Minimum:	19.5	30.5	31.4	55
Maximum:	23.4	37.3	39	105

Female	Culmen (mm)	Tarsus (mm)	Toe (mm)	Weight (g)
Average:	19.18	32.33	33.75	65.17
Minimum:	17.1	30.1	31	50
Maximum:	21.4	34.5	35.8	95

Table 1. DNA sample results of Soras, including average, minimum, and maximum of different measurements for each sex.

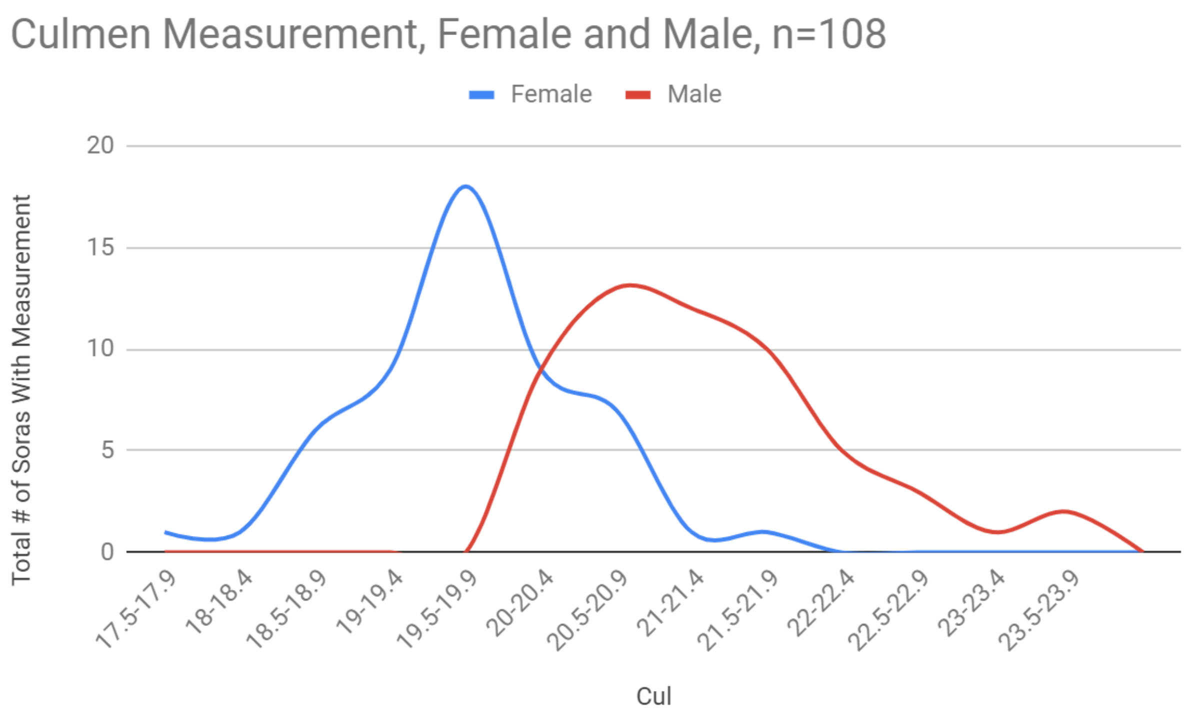


Figure 10. Sora culmen measurements of 55 males and 53 females that had been sexed using DNA sampling methods. Females show a peak at 19.5-19.9mm. Males peak at about 20.9-21.0mm.

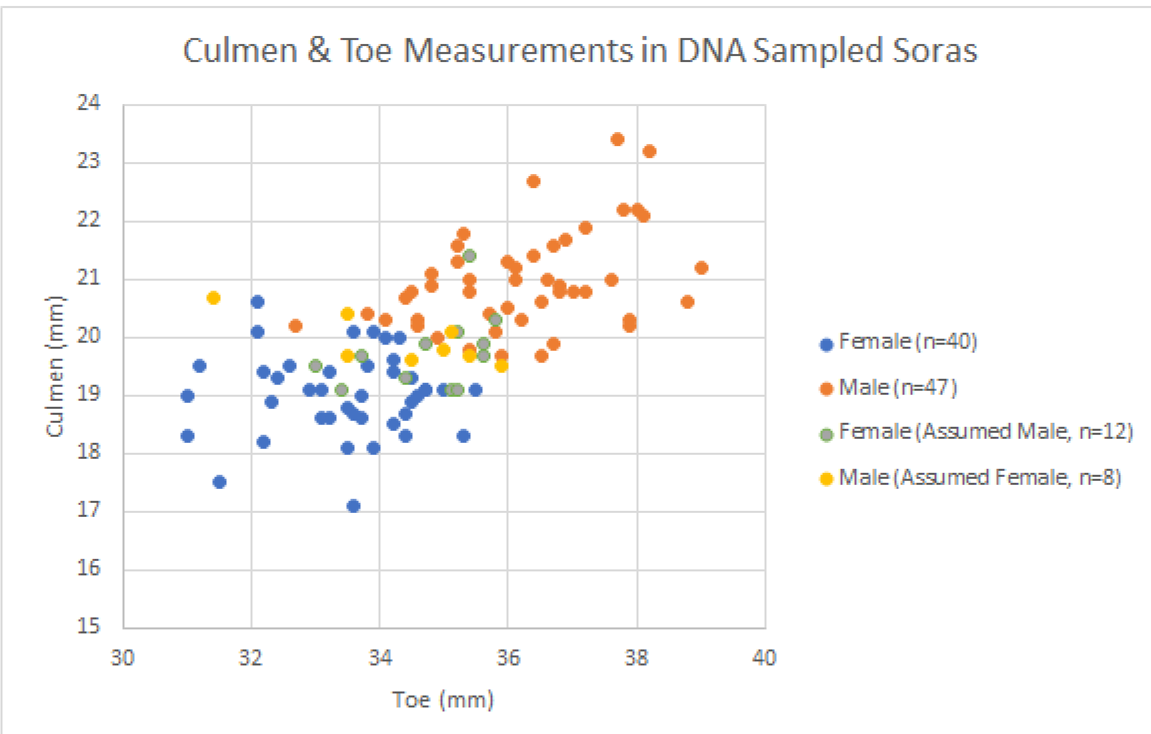


Figure 11. Scatter plot of culmen measurements versus toe measurements in DNA sample Soras, showing how accurate current field sexing techniques are.

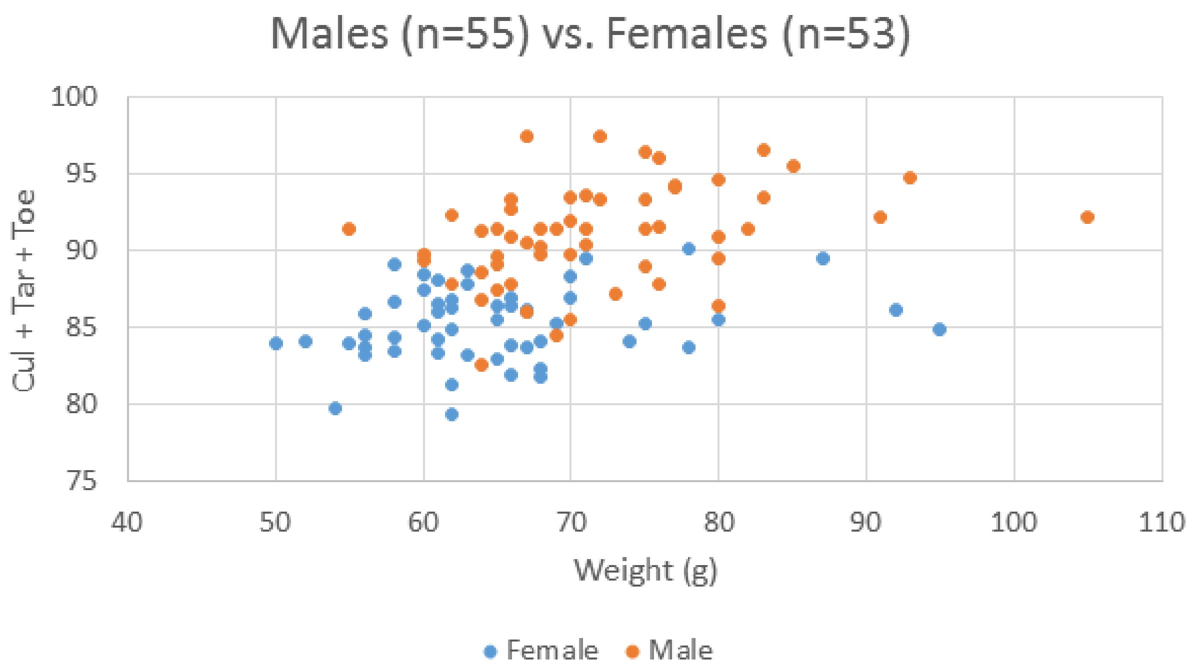


Figure 12. Scatter plot of combined (culmen, tarsus, toe) measurements versus weight for comparison of male and female Sora body measurements.

Sound surveys- Overall the surveys yielded 355 individual responses. Sites 23 through 40 yielded twice as many individual responses as sites 1 through 22, for 230 responses versus 125 responses. The maximum number of rails heard per one survey was 146 on 9/26/2018. The maximum number of rails heard per site was 28 at site 23.

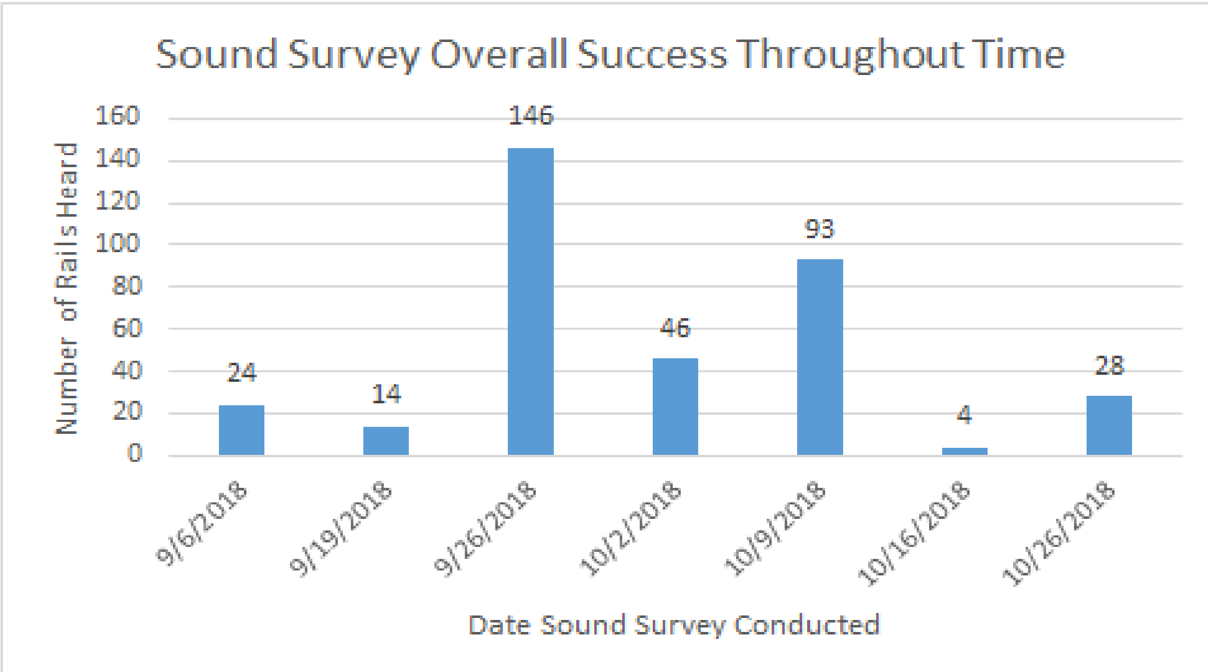


Figure 13. Number of Sora and Virginia rails heard during each sound survey.

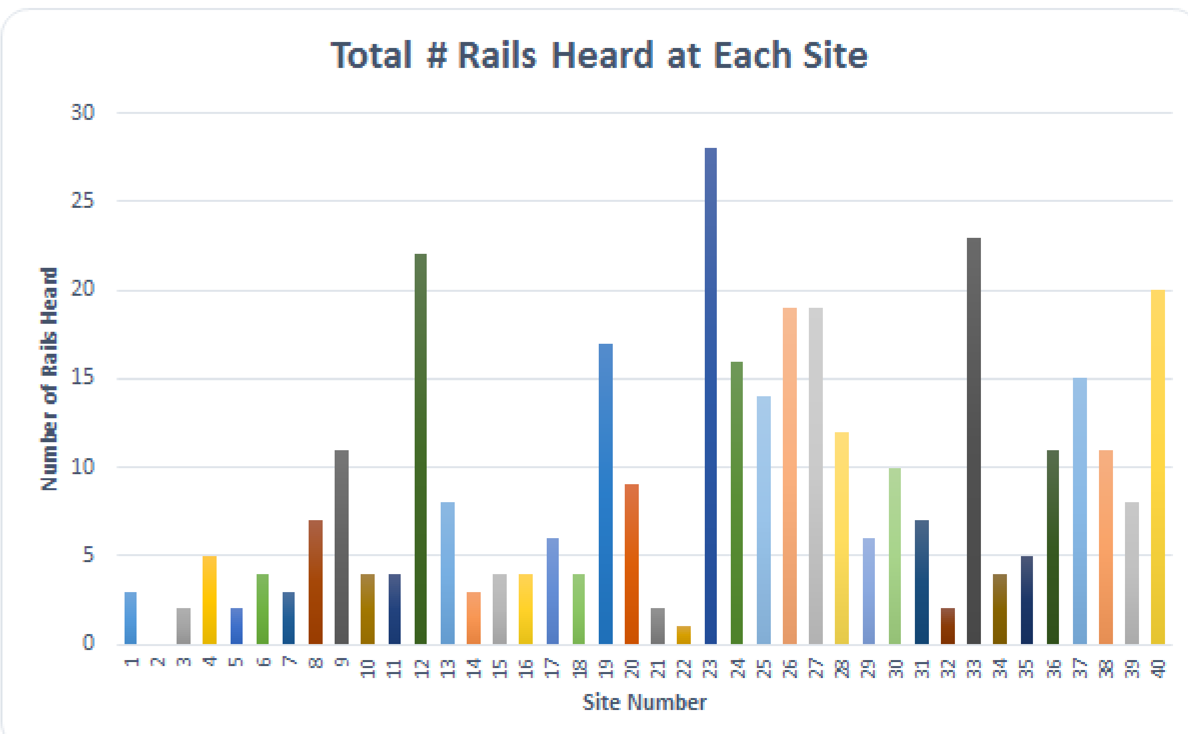
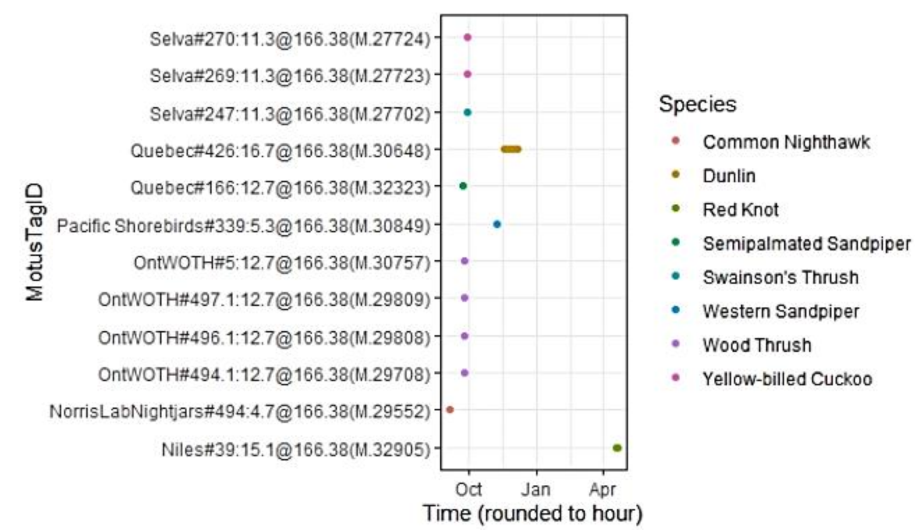


Figure 14. The total number of Sora and Virginia rails heard at each site across all seven sound survey days.

MOTUS receiver station detection data from Patuxent River Park and Newtowne Neck State Park- Receiving stations in the western hemisphere of the system collect detection information on any species studied using transmitters that are on the same 166 MHz frequency that fly within the detection range of that tracking station. Each transmitter is assigned unique digital coding to delineate each individual bird and species.

(a)



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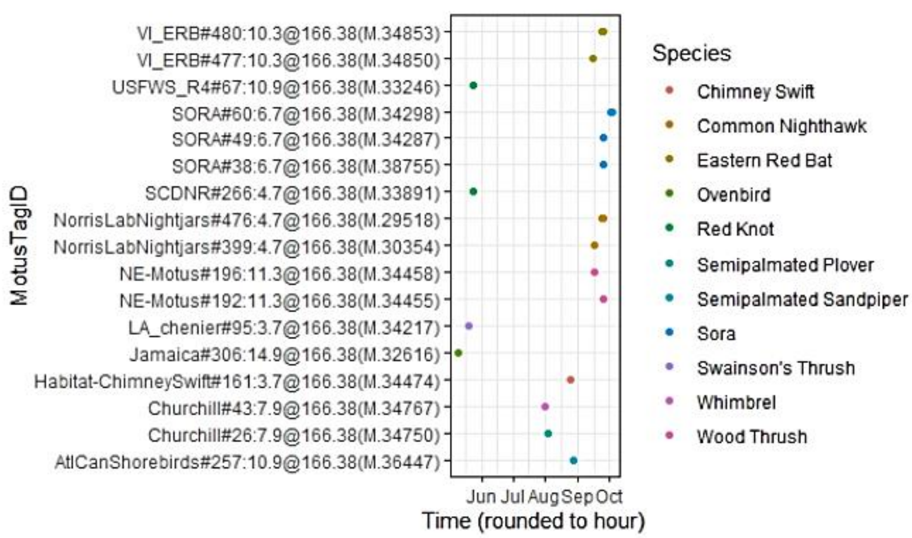


Figure 15a & 15b. Species detected by (a) Patuxent River Park receiving station and (b) Newtowne Neck State Park receiving station in 2018.

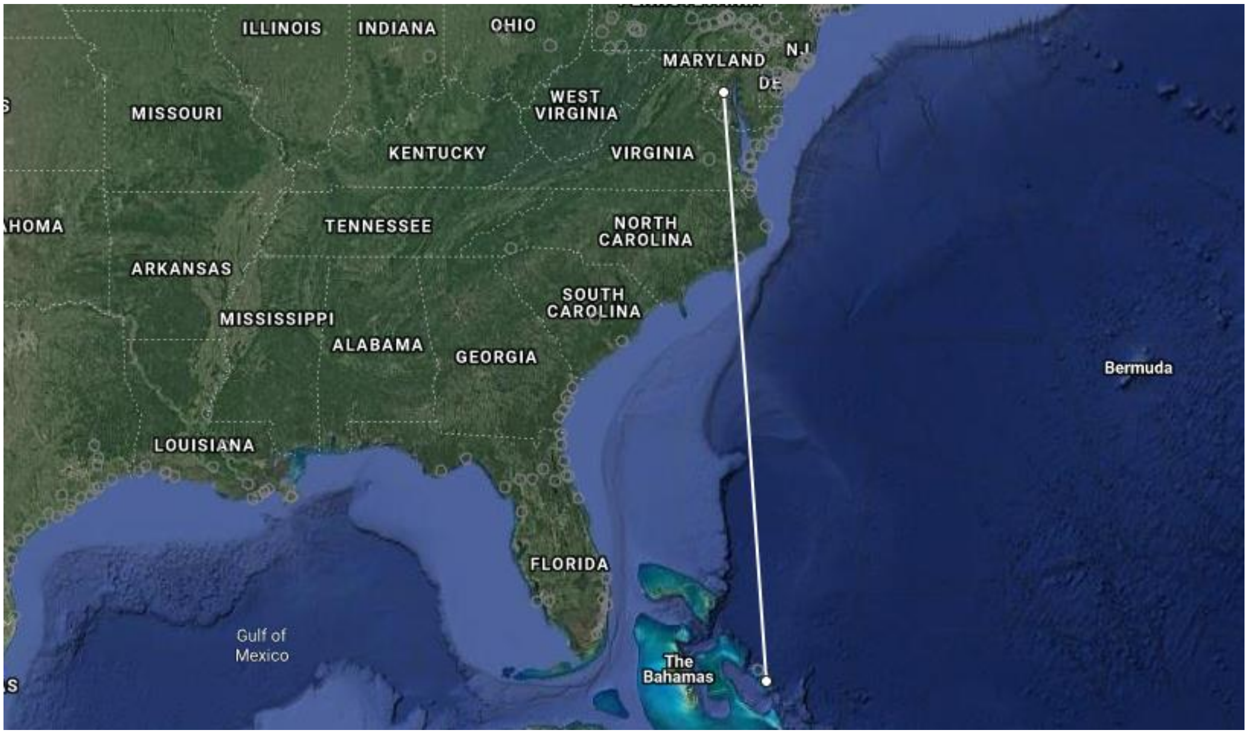
MOTUS Detection Data of Migrant Sora & Virginia rails- Access to detection data is dependent on the frequency each receiver station's data is uploaded. This may result in delayed results up to several months. Results shown below are preliminary and basic data accessed through our projects profile on the Motus website. Further, more detailed, data analysis is currently being processed through R. This will take more time to accomplish and produce.

Table 2. Record of deployed transmitters from year 2018 that have had successful migration detections, thus far, using the Motus automated tracking system. Listed below are transmitters that have been detected departing Patuxent River Park (PRP). Some were detected at this projects second tower located at Newtowne Neck State Park (approx.38miles South of PRP). There are ten transmitters that have been detected even farther South (orange highlight). See figures 17 & 18 for exemplary migrations of transmitters #116 and #351.

Transmitter #	Hours On	Pulse Rate	Sora #	Band #	Age/Sex	Date Captured	Departure Date	Departure time	Length of Stay (days)	Weeks
83	12hrs	12.7 sec	Sora 136	1412-08765	AHY-F	9/20/2018	11/10/2018	6:06 PM	51	7.3
86	12hrs	12.7 sec	Sora 145	1412-08773	AHY-M	9/22/2018	11/10/2018	6:15 PM	49	7
87	12hrs	12.7 sec	Sora 164	1412-08794	AHY-M	9/27/2018	11/3/2018	7:48 PM	37	5.3
95	12hrs	12.7 sec	Sora 141	1412-08770	AHY-M	9/21/2018	10/12/2018	7:50 PM	21	3
98	12hrs	12.7 sec	Sora 158	1412-08788	EHY-M	9/22/2018	11/3/2018	8:05 PM	42	6
102	12hrs	12.7 sec	Sora 215	1412-08858	AHY-F	10/17/2018	11/3/2018	7:39 PM	17	2.4
105	12hrs	12.7 sec	Sora 221	1412-08868	AHY-M	10/17/2018	11/10/2018	6:22 PM	24	3.4
106	12hrs	12.7 sec	Sora 214	1412-08856	LHY-F	10/16/2018	11/28/2018	5:55 PM	43	6.1
108	12hrs	12.7 sec	Sora 208	1412-08848	MHY-M	10/12/2018	11/10/2018	6:15 PM	29	4.1
112	12hrs	12.7 sec	Sora 206	1412-08846	EHY-M	10/12/2018	12/7/2018	6:15 PM	57	8.1
114	12hrs	12.7 sec	Sora 176	1412-08808	MHY-M	9/28/2018	11/3/2018	7:47 PM	36	5.1
116	12hrs	12.7 sec	Sora 166	1412-08797	AHY-M	9/27/2018	10/29/2018	7:30 PM	32	4.6
135	24hrs	11.3 sec	Sora 61	1412-05786	EHY-M	8/31/2018	10/12/2018	7:30 PM	42	6
137	24hrs	11.3 sec	Sora 111	1412-08736	AHY-M	9/12/2018	11/3/2018	7:53 PM	52	7.4
138	24hrs	11.3 sec	Sora 133	1412-08760	AHY-M	9/19/2018	10/29/2018	8:19 PM	40	5.7
140	24hrs	11.3 sec	Sora 174	1412-08806	AHY-F	9/28/2018	11/10/2018	6:13 PM	43	6.1
141	24hrs	11.3 sec	Sora 187	1412-08822	AHY-M	10/4/2018	11/10/2018	6:20 PM	37	5.3
142	24hrs	11.3 sec	Sora 173	1412-08805	MHY-M	9/28/2018	11/20/2018	8:45 PM	53	7.6
340	12hrs	5.3 sec	Sora 161	1412-08791	AHY-M	9/26/2018	11/10/2018	5:58 PM	45	6.4
342	12hrs	5.3 sec	Sora 227	1412-08883	AHY-M	10/19/2018	10/21/2018	8:15 PM	2	0.3
349	12hrs	5.3 sec	Sora 182	1412-08815	AHY-M	10/3/2018	11/10/2018	6:10 PM	38	5.4
351	12hrs	5.3 sec	Sora 119	1412-08744	AHY-M	10/4/2018	11/14/2018	9:15 PM	41	5.9

353	12hrs	5.3 sec	Sora 183	1412-08816	LHY-M	10/3/2018	11/27/2018	6:25 PM	55	7.9

(a)



(b)

Chart uses UTC time on the X-axis, starting at midnight UTC on the left.

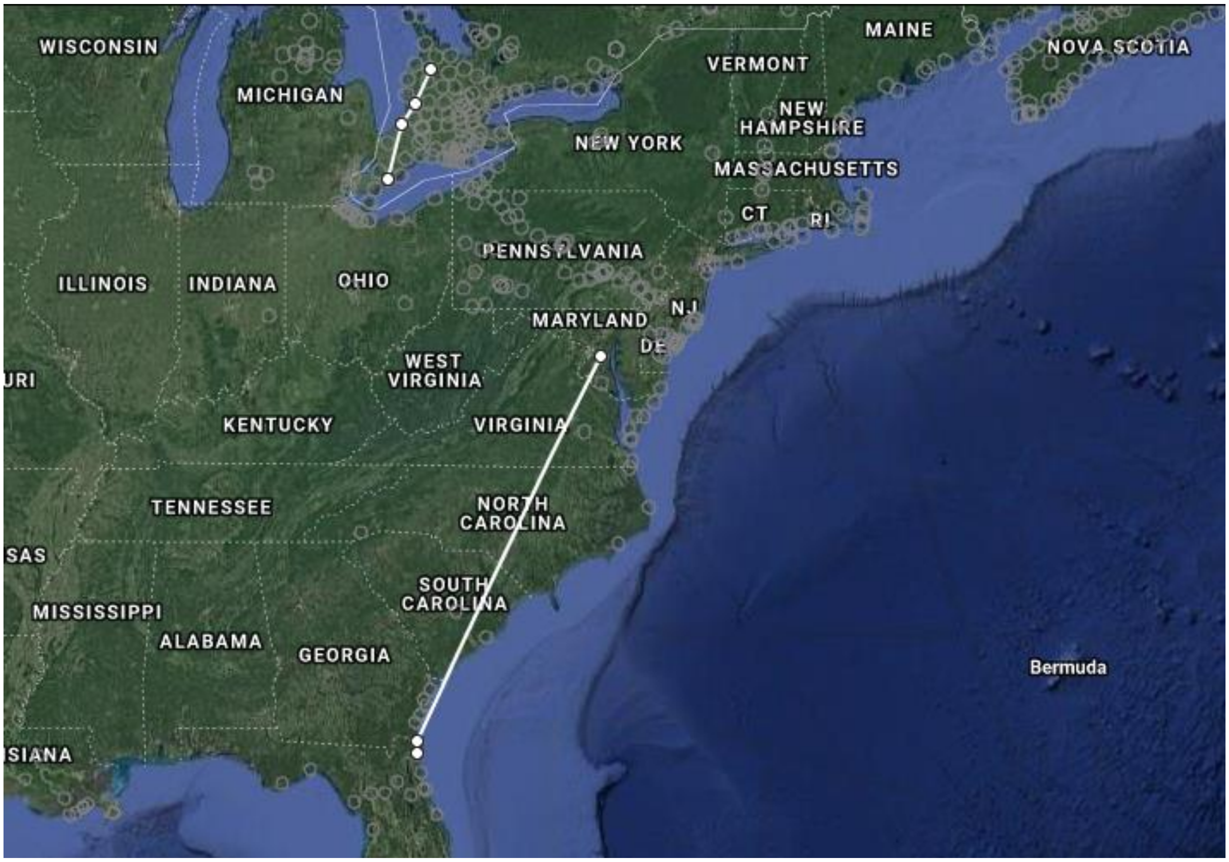
Show detections in: a table | a timeline | a map

Receiver deployments

SG-5304RPI3AAED - Patuxent River Park (ID# 4272) - detections of this tag by this receiver
Lotek-D000594 - Knowles Tower (ID# 4700) - detections of this tag by this receiver

Figure 16a & 16b. Tag detections in (a) satellite map and (b) timeline format for Sora#166, Transmitter#116. The transmitter is active 24 hours a day. The chart uses UTC time. To calculate UTC time to EST subtract 4 hours or 5 hours for daylight savings. The Sora was last detected at Patuxent River Park around 7:40 PM(EST) on 10/29/18, then it was detected on 10/30/18 at Knowles Tower, Cat Island, Bahamas from 3:03 PM to 3:10 PM(EST) traveling a distance of 997.94 miles in 19hr22min57s (~51.57 mph). Note the travel path line on the map is not reflective of the actual movement of the bird.

(a)

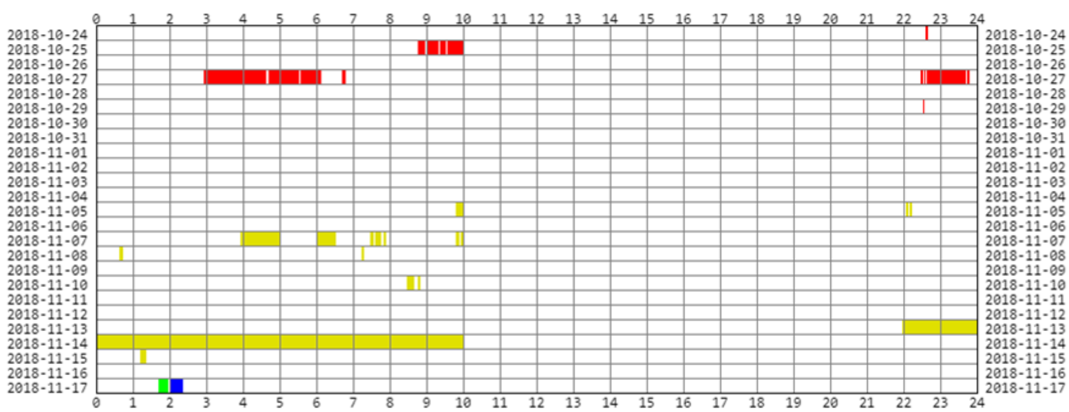


(b)

Chart uses UTC time on the X-axis, starting at midnight UTC on the left.

Show detections in: a table | a timeline | a map

2018 - 2019



2018 - 2019

Receiver deployments

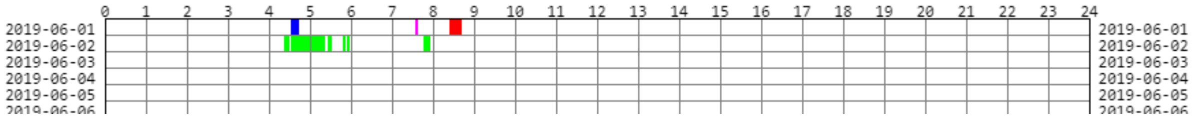
- SG-5304RPI3AAED - Patuxent River Park (ID# 4272) - detections of this tag by this receiver
- Lotek-D000604 - Ft. Clinch (ID# 4702) - detections of this tag by this receiver
- Lotek-D000606 - Little Talbot (ID# 4705) - detections of this tag by this receiver
- SG-5304RPI3AAED - Patuxent River Park (ID# 5016) - detections of this tag by this receiver

(c)

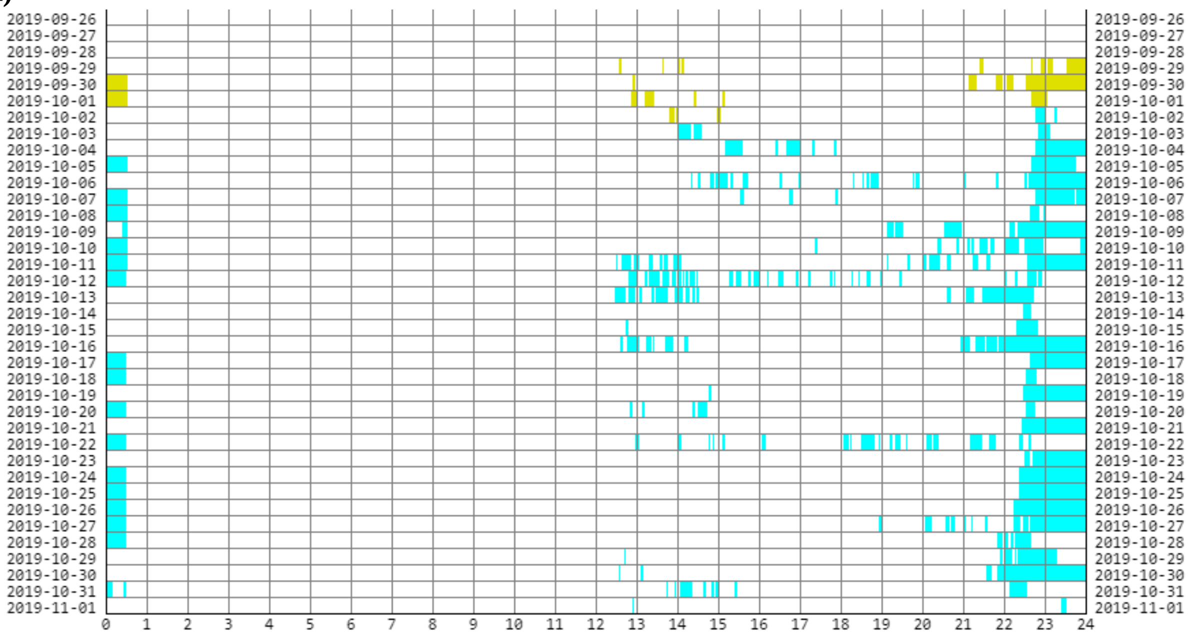
Chart uses UTC time on the X-axis, starting at midnight UTC on the left.

Show detections in: a table | a timeline | a map

2018 - 2019



(d)



2018 - 2019

Receiver deployments

- SG-4000BBBK8230 - Hullet_Provincial_Wildlife_Area2 (ID# 3974) - detections of this tag by this receiver
- SG-5113BBBK0408 - Chesley (ID# 3985) - detections of this tag by this receiver
- SG-4002BBBK1580 - Merlin (ID# 4041) - detections of this tag by this receiver
- SG-5304RPI3AAED - Patuxent River Park (ID# 5042) - detections of this tag by this receiver
- SG-5304RPI3AAED - Patuxent River Park (ID# 5721) - detections of this tag by this receiver
- SG-5113BBBK0333 - Pinery_Provincial_Park (ID# 5756) - detections of this tag by this receiver

Figure 17 (a-d). Tag detections in (a) satellite map format and (b-d) timeline format for Sora#119, Transmitter#351. The transmitter is active at night for 12 hours from around 6:00 PM to 6:00 AM (EST). The chart uses UTC time. To calculate UTC time to EST subtract 4 hours or 5 hours for daylight savings. This detection data represents a full year's migration of this individual. The bird is detected migrating south (b) from Patuxent River Park, Maryland to Florida (Ft. Clinch, Little Talbot) on November 16, 2018 then is (c) detected in Canada (Merlin, Pinery Provincial Park, Hullet Provincial Wildlife Area, Chesley) on June 1 – June 2, 2019 then (d) detected again at Patuxent River Park, Maryland from September 29 to November 1, 2019.

(a) 

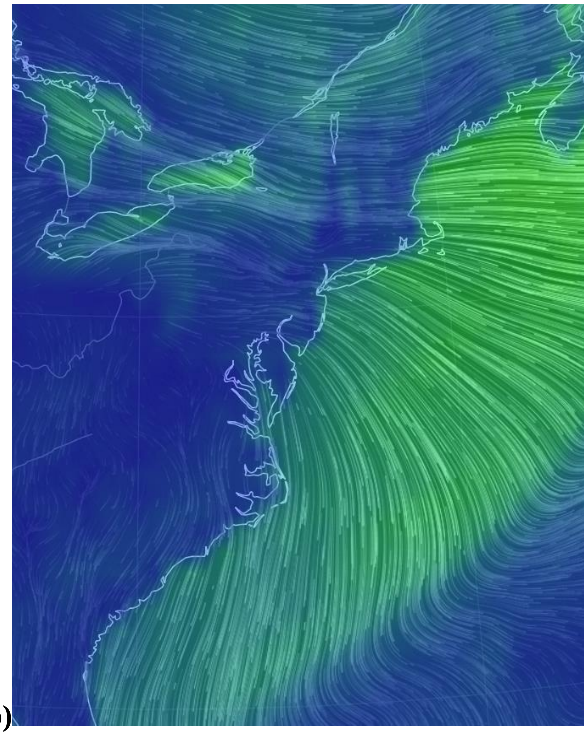
(b) 

Figure 18a & 18b. (a) Wind map from 11/10 at 5:41 PM(EST) from weather application, named WillyWeather, showing the current wind speed, gust speed, and direction. (b) Wind map from 11/10 at 7:00 PM (EST) from https://earth.nullschool.net/ showing favorable northerly circulation from New England, down the coast through the Chesapeake Bay and being northeasterly towards along the southern U.S. coast. This illustrates the perfect clockwise circulation of a high pressure system moving into the east coast creating ideal conditions for Sora migration. Eight individual soras fitted with transmitters departed from Patuxent River Park on this night between 5:58 PM and 6:22 PM(EST).

By-catch- Below is a table displaying the approximate number of captures per species. We did not band, tag, or measure any by-catch. The approximate number represents the number of times that species was caught through the duration of the study.

Table 3. By-Catch, 2018

Species	Approximate Number
Marsh Wren, *Cistothorus palustris*	4
Common Yellowthroat, *Geothlypis trichas*	15
Song Sparrow, *Melospiza melodia*	21
Swamp Sparrow, *Melospiza georgiana*	77

Red-winged Blackbird, *Agelaius phoeniceus*	6
Rice Rat, *Oryzomys palustris*	37
Muskrat, *Ondatra zibethicus*	1
Fish sp. unknown	272
Northern snakehead, *Channa argus*	7
American Eel, *Anguilla rostrata*	1
Frog sp. unknown	2
Mud Turtle, *Kinosternon subrubrum*	31
Musk Turtle, *Sternotherus odoratus*	18
Painted Turtle, *Chrysemys picta*	2
Northern Watersnake, *Nerodia sipedon*	41
Atlantic Blue Crab, *Callinectes sapidus*	5
Red Swamp Crayfish, *Procambarus clarkii*	105
Total	**645**

DISCUSSION

The project results indicate promise of acquiring new knowledge on the migration and stopover ecology of Sora and Virginia rails. As the project's migration data expands over time via the Motus tracking system, the technology is improved and enhanced, and the seasonal trapping and banding is continued into future years, we will obtain the much needed information on this secretive marsh bird. This information will help to establish efficient management and conservation of the rails as well as many other species that utilize the same habitat. This scientific research will also be published for the methodology and knowledge to be shared. Some of our questions will remain unanswered until at least next year and possibly further in the future, however there is insight provided by the current results.

The rails migrate to this portion of the Patuxent River during the fall and stay for roughly four to eight weeks, averaging a five and half week length of stay (Fig.7). The Soras arrive in late August – early September and start to depart in mid-October – mid-November (Fig.5). The Virginia rails arrive in late September and start to depart in early December (Fig.5). Capture success increased following the occurrence of northerly cold fronts that brought flights of birds into the marsh in early fall (Fig.6). Capture success then decreased following the occurrence of northerly cold fronts in mid-October (Fig.6) and the first occurrences of frost in early November. The rails are small-bodied flap-fliers that travel great distances in one night[2] (≥750km) on fat reserves acquired at their stopover habitat. We learned this from the previous telemetry study conducted in the late 1990s[2]. The rails depart in the evening when the winds are of northerly direction (Fig.18) and the stars are at least 50% visible[2]. We have successfully tracked 23 radio-tagged soras leaving Patuxent River Park in the fall of 2018, nine of which we detected on our second tower at Newtowne Neck State Park and ten have been detected south of the Chesapeake Bay (Table 2). For this report, the two most thrilling migrations are displayed. One Sora departed at 7:40 PM (EST) from Patuxent River Park in Upper Marlboro on October 29 and arrived at Knowles Tower, Cat Island, Bahamas at 3:03 PM (EST) on October 30 (Fig.16). The ground travel speed between these two locations was approximately 51.57 mph. The individual flew over night and into the next day a distance of 997.94 miles in 19 hours 22 minutes and 57 seconds. In previous work, we documented birds achieving speeds as high as 70 mph under ideal wind conditions, but the average was around 45 mph [2]. The speed throughout the duration of the flight likely fluctuates depending on the strength and direction of the tail wind and the altitude the bird is flying at (Fig.18). Detection data for a full year's migration was obtained for Sora #119, transmitter #351 (Fig.17). The individual was fitted with transmitter #351 at Patuxent River Park, Maryland on October 4, 2018 and was detected migrating south to Florida in mid-November. Then #351 was discovered in the Great Lakes region of Canada during the first week of June 2019. This bird was then detected again at Patuxent River Park, Maryland from September 29 to November 1, 2019. There are gaps in the timeline (Fig.17b-d), which results in a fragmented migration movement line (Fig.17a). The fragmentation is caused by a defect in the transmitters programming, as well as, a lack of receiving stations on the inland side of the Atlantic flyway. The transmitter was programmed to be active for twelve hours (6:00 PM (EST) to 6:00 AM (EST)) and off for twelve hours. Somehow the programming was altered during the summer of 2019 to turn the transmitter on at 8:00 AM (EST) and off at 8:00 PM (EST) decreasing the probability of detection significantly as soras are nighttime migrants. We eliminated this issue by ordering transmitters that are on for 24 hours to be used in the fall of 2019. As stated before, we are dependent on researchers of other Motus tracking stations to upload their data from the field to the website where we have access to it. Additionally, it takes time to clean and analyze the data through the R statistical computing and graphics program.

Soras are primarily ground-based birds, except for migration purposes or escaping predators[1]. They take advantage of the northerly winds that come down from Canada along the east coast as jet streams alter into a fall pattern. According to our hypothesis, the high-pressure wind system will likely cause a curved clockwise flight path that pushes them out over the Atlantic Ocean and then wind from the Northeast pushes birds back towards the southeast coast of the United States (Fig.18). If the wind was too strong or pushed a bird too far out over the ocean, its fat reserves could deplete and it would need to find the nearest possible land or else settle in the ocean, which would be a certain death. This would explain the reported findings of Soras in Bermuda every year, approximately 600 miles from the nearest land in North Carolina. This species migration is dependent on wind, weather, and fat reserves. An incident of a hurricane, a strong El Nino year, and/or a lack of adequate stopover habitat with proper food resources can have major impacts on the Sora population from year to year. We saw in the 1998-1999 seasons a major collapse between the two years, most likely because of the strongest El Nino ever recorded in 1998. This altered the normal jet stream patterns to a westerly flow, which would carry birds far offshore from a safe overland route. The freshwater tidal wetlands of Jug Bay contain the largest standing population of wild rice in the state of Maryland and is vital to the success of the rails' migration in the fall. The rice is their primary high carbohydrate seed source that allows them to accumulate high lipid fat reserves that sustain them for the length of this migration, possibly thousands of miles[2]. Considering the 1998 El Nino season with the dramatic decline of the wild rice in Jug Bay helps explain the disastrous collapse in the rail populations in the 1999 and 2000 fall migration seasons[3], from which it appears they have never fully recovered.

The handheld SRX receiver acquired for the 2018 year allowed us to track and monitor the locations of the radio tagged rails for their duration of stay in the Jug Bay marsh (Fig.7). This proved useful in determining the locations of all the transmitters in the marsh in relation to where the trap sites are located and where individuals were released. Due to the greater sensitivity of the handheld receiver in comparison to the Motus receiver tower we were able to track and record the exact times of departure for many individuals as well as behaviors that displayed Zugungruhe (migratory restlessness). These behaviors include the individual radio tagged bird climbing up and down in the vegetation to reorient to star patterns or for roosting behavior causing high fluctuations in the signal strength, and a few individuals were witnessed performing "test" flights in which they flew up to circle around and then go back down into the vegetation. This information can be used to create "home" ranges of these individuals while in their stopover habitat, and was used to record avian Zugungruhe behavior, and detect departure times that were not recorded by the Motus receiving stations. Lastly, we were able to recover two transmitters from the marsh using the SRX800. One of these was able to be re-deployed on a different individual, while the other was kept for receiver operation testing.

The Sound surveys overall yielded 355 individual responses (Fig.13-14). Sites 23 through 40, yielded twice as many individual responses as sites 1 through 22 (Fig.4), for a total of 230 responses versus 125 responses. Sites 23-40 were not located near our trappings sites, so those particular rails were not exposed to their calls on repeat 5 days outs of the week, thus were likely more responsive to the calls played during sound surveys (Fig.4). However, it is possible that their numbers may have been higher in Mattaponi Creek, House Creek, and Merkle Marsh. The goal of the sound surveys was to learn the approximate population density of these areas using a non-invasive method. Vegetation of each site was recorded to be able to analyze if there was a site preference. From the data acquired during sound surveys, it appears that Sora population peaked around September 26th, with 146 individuals being heard (Fig.13). We learned that more studies are needed to see what influences the rails to be more vocal and responsive some mornings and/or evenings versus others. We believe time of day, wind speed, lighting, tides, temperature, and number of individuals occupying a space, all impact the number of responses heard.

The goal of the DNA testing to determine sex was to prove our current field sexing techniques as 95% accurate. Due to the cost of DNA testing we focused this portion of the study on the Sora, while saving the samples of the Virginia rails for later testing when funding is adequate. Based on current field sexing techniques, of the 108 soras that were sexed through blood sampling, 80.56% (n=87) of the soras were accurately sexed (Fig.9). There is overlap in measurements between male and female soras, even in culmen (Fig.10) and toe length measurements (Fig.11), those of which appear to be more distinctly separated than other measurements such as tarsus length (Table 1). There are several outliers in the sample, which skew the data (Fig.11, 12). For example, the stray male in figure 11, which had a well below average male toe length. There are some factors that may not be suitable to use in our sexing method due to the time of year we are trapping these rails. When they are here in the fall, they are here to gain weight to continue their migration. Therefore, weight is not as reliable of a characteristic to determine sexual dimorphism during migration because depending on when the rail arrived and when it was trapped the weight of either sex is changing and has too much overlap or variation (Fig.12). Plumage as a characteristic to determine sex may not be a reliable factor either due to it being outside their breeding period and therefore not the definitive adult plumage. Further analysis of the blood sample data and plumage photography needs to be done in order to create a method of 95% accuracy between both sexes. To develop a method of 95% accuracy for at least 80% of the sample population, leaving the other 20% recorded as unknown (or sampled for DNA testing) would also be adequate. Past developments of field sexing techniques for other bird species, such as for California Clapper Rails[10], Sanderlings[11], Laughing Gulls[12], and *Pygoscelis* Penguins[13], suggest using statistical analysis methods, such as discriminant function analysis, t-test, and classification functions to create a method of 95% accuracy for sexing bird species. For example, the discriminant function analysis, will scientifically show how successful culmen and toe length are in discriminating males versus females. Future utilization of such statistical programs, such as SAS and R, is necessary to create a formula of 95% accuracy to sex soras.

The project resulted in significant information on not only rails in the Jug Bay marsh. The trapping and banding methods produced a variety of “by-catch” (Table.3) which highlights the diversity of life that exists in the marsh habitat. This also displays existence of invasive species and when combined with previous and future years results may present a pattern. Additionally, the wildlife tracking receiving stations produced by this project detected numerous migratory species including sandpipers, thrushes, common nighthawks, red knots, an eastern red bat and more (Fig. 15). These stations will continue to collect this type of detection data that will provide a greater understanding of the differing species that migrate through the Patuxent River Corridor proving exactly how vital the area and habitat is.

Additional information will advance our knowledge as Motus detection data is received through the year, and further data analysis is conducted in R. Trapping, and banding will resume in the fall of 2019 in which a large sample of birds will be fitted with transmitters and more details on local population size will be obtained. Next year we would like to focus more attention on the telemetry aspect of the study. The Motus system technology is advancing and improving as is our understanding of the system and the data analysis. We hope to continue this project and publish our findings in the near future. At this time we have some information that will likely answer many of our questions upon further analysis, questions including 1) where do they originate and what is their ultimate destination? 2) How long does it take them to migrate? 3) How does the population fluctuate from year to year? 4) What is the survival and life expectancy for this species? 5) Do they travel in family groups or individually? 6) What are other important stopover habitats along the way? 7) Can we justify our current field sexing methods using body measurements to a 95% accuracy? 8) How important are the freshwater tidal wetlands of Jug Bay as a migratory stopover habitat and source of rice as a major migration food? 9) How are the rails effected by climate change and El Nino years?

Our mission, combined with our status as a National Estuarine Research Reserve under NOAA, is to acquire and protect land while encouraging scientific research from institutions and universities. Just as importantly, we provide environmental education to the public on such matters. One of the long term goals we have in conjunction with Maryland Department of Natural Resources and Maryland Ornithological Society is to designate Jug Bay as a nationally known Bird Observatory and this project complements that goal. Jug Bay is already recognized by Maryland DNR and National Audubon Society as an Important Bird Area (IBA) with more than 310 species recorded. Multiple publications could be created from this work and contribute to the future preservation of numerous species of birds that utilize this valuable wetland habitat.

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