2020 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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GREG KEARNS
Park Naturalist
Patuxent River Park
The Maryland – National Capital Park and Planning Commission

KATHERINE DAMI & MOLLY JANC
2020 – Research Assistants

INTRODUCTION

The Sora (*Porzana carolina*), is a secretive marsh bird that 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 and shot 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 observed 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 likely altered the jet streams to an abnormal offshore westerly flow. After Greg and his team spent 18 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 and new Motus tracking technology became available.

The Virginia rail (*Rallus limicola*) shares the same habitat as the Sora, and is the secondary focus of our study. Virginia rails prefer slightly higher and drier areas of the marsh and their shorter toes reflect this[1]. Their longer beak is adapted for consuming invertebrates in the mud rather than seeds like the Wild Rice the shorter-billed Sora prefers. Soras concentrate here in much higher numbers accordingly, often outnumbering the Virginia rail at least 10:1. 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 nest here whereas the Soras nest from Pennsylvania to as far 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 1,010 receivers worldwide that provide access to tracking stations in eastern North America, Central and South America, Europe, Australia, as well as some in the Caribbean Islands and Bermuda. 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 the automated tracking stations called Sensor Gnome and Sensor station. All Motus transmitters are on the same 166 MHz frequency with a unique digital code to delineate each individual bird and species. This way all researchers can benefit from each other's Motus tracking systems.

Research on the Sora is motivated by the population decline both nationally and locally, the decrease 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 affected by climate change and El Niño years?

MATERIALS

Grant Expenditures

28 Lotek Nanotag Transmitters	$6,116.40
Total	$6,116.40

Park Expenditures

Trapping Equipment	Previously purchased
Banding Supplies	Previously purchased
Handheld Lotek Receiver	Previously purchased
1 3 Element Yagi Antenna	Previously purchased
1 5 Element Yagi Antenna	Previously purchased
3 Audio Lure Sound Systems	$200.00
2 Wildlife Research Assistants Hourly Pay	$19,200.00
Annual Deployment Fee for Motus Tracking System	$1,856.00
Blood DNA Testing for 72 Rails	$1,200.00
Lotek Nanotag Transmitter Shipping and Surcharge	$146.00
Total	$22,602.00

Table 1. A breakdown of grant and park expenditures for the year 2020. The grant money covered most of the cost of the 28 Lotek Nanotag transmitters purchased. The rest of the fees for the purchase and other associated expenses were covered by the park.

METHODS

The work this year was a continuation of the Sora project that began in the summer of 2017. With the installation of the Motus tracking system already complete and using the guidance of biologist and Motus expert Dave Brinker from Maryland Department of Natural Resources, the preliminary work was able to begin in July of 2020. The research assistants installed and reestablished existing trap sites for a total of 10 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 600+ days (the expected battery life of the transmitter) utilizing the Motus network. This will be the longest span of time we have tracked the migration since the beginning of the project, almost twice the length of previous transmitter life. 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 6, 2020, though tracking efforts continued for another month. We will collect data from other Motus station detections for the rest of the battery life, likely into 2022. In addition to radio-telemetry we introduced DNA sexing to the project to assess the field sexing method used by our research team to try to achieve 95% accuracy.

The Motus tracking system- New Motus tracking receiver stations were erected during the 2019 project. The two new stations are located at the Patuxent Research Refuge in Laurel, Maryland and on Trunk Island, Bermuda in cooperation with US Fish and Wildlife (USFWS) and Bermuda Aquarium Museum and Zoo (BAMZ), respectively. These projects were funded by Maryland Ornithological Society and by the JES Avanti Foundation, respectively. The goal was to further expand our coverage for detection of migrant Soras which are known to overwinter in Bermuda and to include Patuxent Research Refuge to demonstrate for the public the value of the Motus Network. The original two stations in Maryland were improved by installing software updates, decreasing our SensorGnomes signal to noise ratio (increases sensitivity), and the rearrangement of the Yagi antennas mounted on the towers. The software update is a routine upgrade that is downloaded and installed into the SensorGnome's Raspberry Pi computer. The update corrects bugs and improves systems operation[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 from the Jug Bay marshes.

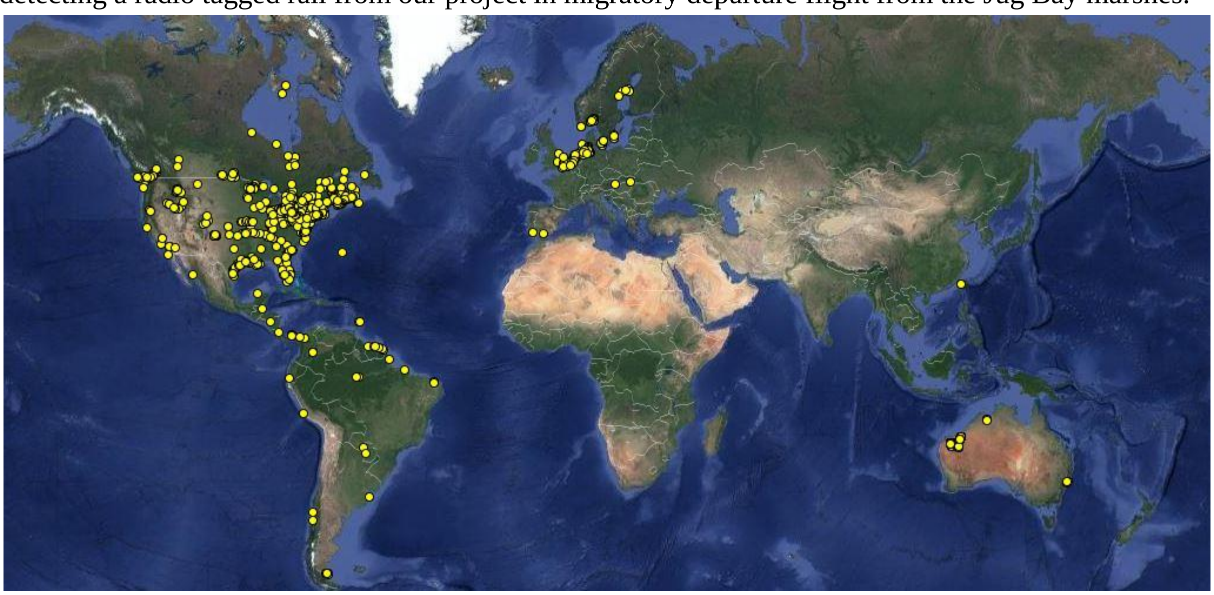


Figure 1. Map showing locations of currently active receiving stations in the Motus network

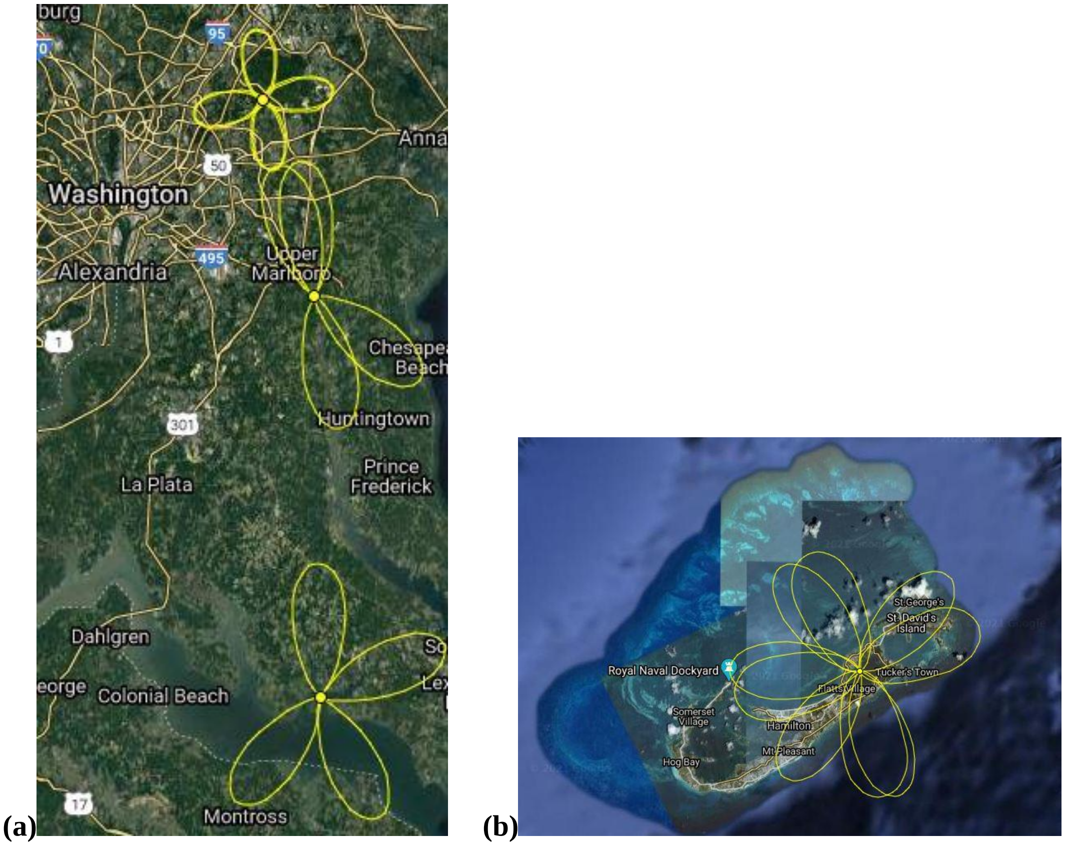


Figure 2. Map showing the detection radius and location of the four Motus tracking stations erected between 2017 and 2019. (Yellow flower petals represent antenna ranges for the following stations, from top to bottom are : (2a) Patuxent Research Refuge USFWS, Patuxent River Park M-NCPPC, Newtowne Neck State Park MD-DNR, and (2b) Trunk Island, Bermuda, BAMZ)

Trapping and banding- Capture techniques were developed during the previous work of Kearns and Haramis in the 1990s[2] based on Seth Low Clover-Leaf Traps. 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 approximately 30 to 40 meters of drift fence with an electronic digital audio lure system (audio unit, battery, solar charging panel, a speaker) located centrally between the traps[6]. Seven of the ten 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].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, body mass and fat score 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 morphometric body measurements[2] and some plumage characteristics. Each individual was banded with a United States Geological Survey aluminum alloy metal butt-end leg band, and designated individuals with a body mass of ≥60g were fitted with a transmitter (Fig.3b), and a group of over 70 individuals had blood samples taken for DNA testing in 2020. This DNA testing was to compliment the 110 samples collected in 2018 to further increase the validity of our morphometric model.

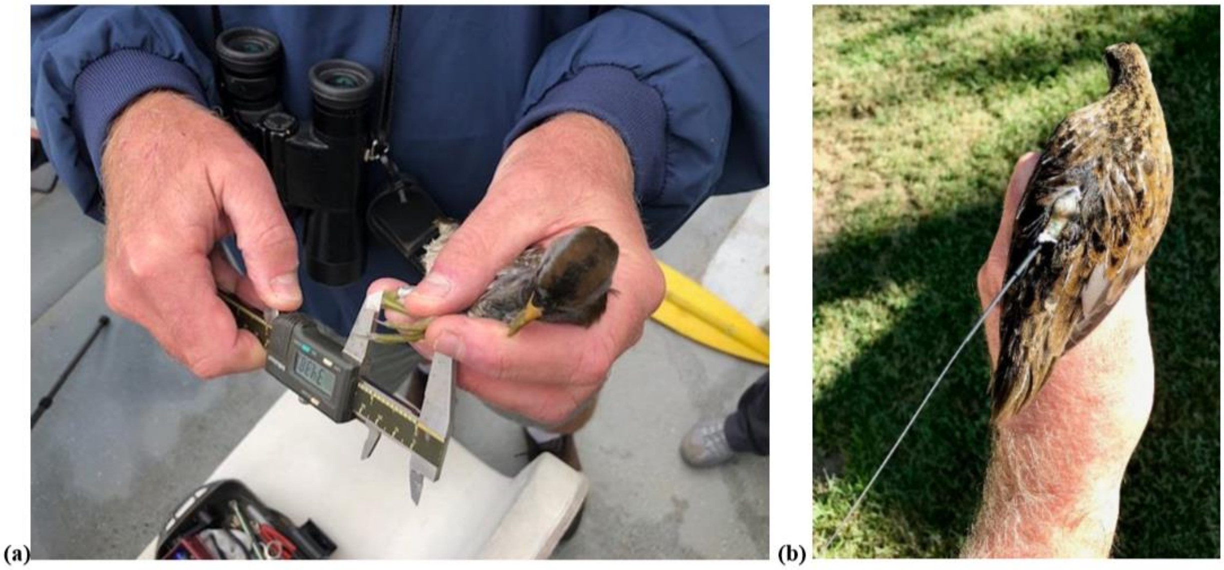


Figure 3a & 3b. (a) Image of researcher, Greg Kearns, taking a measurement of the tarsus length on a Sora. (b) Image of a Sora fitted with a transmitter exposed for the photo.

Uploading detection data- Each SensorGnome has a microSD card that must be removed to copy the detection data onto a computer. This data from each station must be uploaded to the Motus.org site to be deciphered. The summary of the detection results can be seen on “your project’s profile” and is emailed to the project leader. 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, data analysis is often 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.

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 of radio tagged rails 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. In 2020 we deployed twenty two transmitters with an every 9.7 second pulse rate and twenty seven transmitters with an every 12.9 second pulse rate. When time was a constraint, the receiver was used at four different locations, rather than each of the 10 trap sites.. These locations included, trap site 2, trap site 3, between trap sites 9 through 11, and between trap sites 5 through 8. For each transmitter, location (in reference to trap site number) and highest signal strength at each location, were recorded and analyzed. By doing this we tracked the "home" ranges and length of stay of the tagged rails while in their migratory stopover habitat. We were also able to determine if the transmitter was still affixed to the bird or if it had succumbed to a predator.

Sound Site Surveys - Forty 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]. A general vegetation composition survey was recorded at each site. Sound surveys were conducted six times on a weekly basis between September 8th and October 20th. All of the sound surveys were conducted during the first 3 hours from sunrise. At each sound survey site three "Kerwee" calls and three "Whinny" calls were played, as well as three paddle slaps across the water to elicit a response. A period of silence followed each to listen for responding rails. This was the same protocol used in 2018 and 2019 sound surveys for comparison of responses to estimate general density.

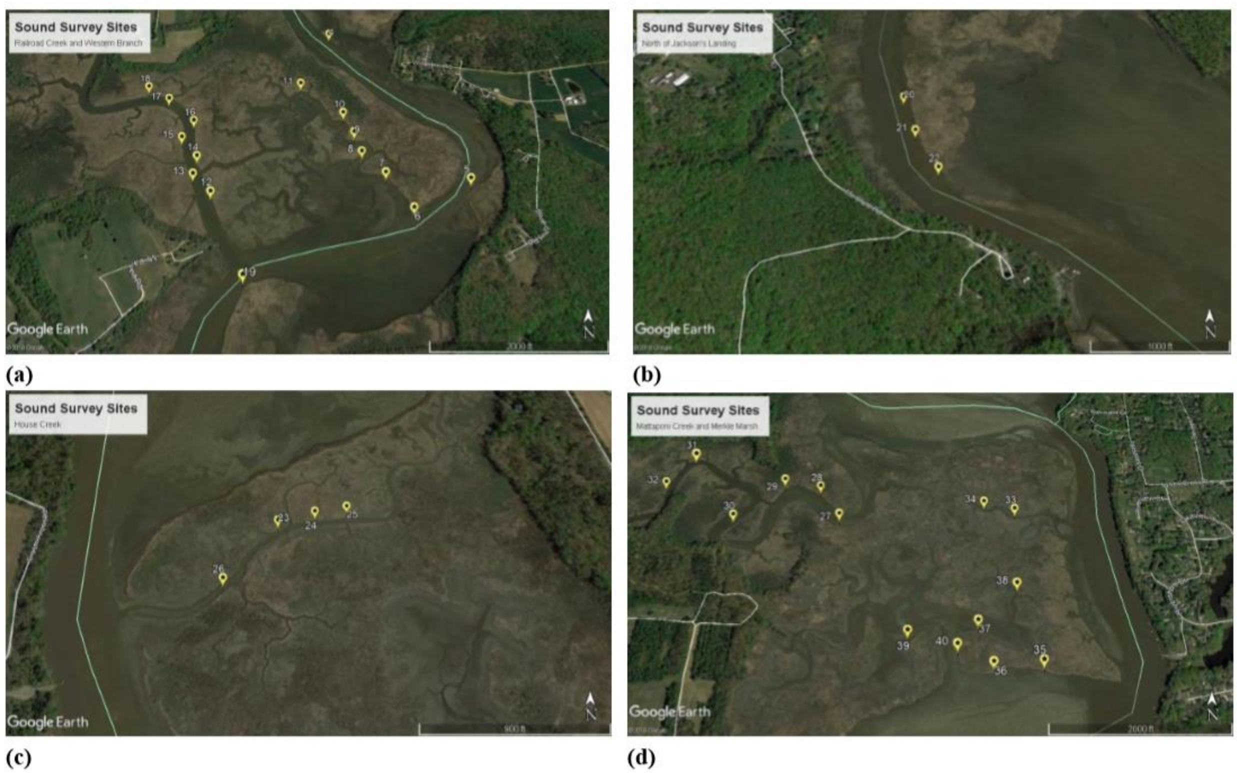


Figure 4(a-d). Satellite imagery from Google Earth displaying locations of the 40 sound survey sites around Jug Bay used for this study. Sites are located at (a) Western Branch and Railroad Creek, (b) North of Jackson's Landing, (c) House Creek, (d) Mattaponi Creek, Weir Creek, and Merkle Marsh.

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. In 2018, 108 Soras were randomly sampled. In 2020, 72 Soras were selectively chosen to be sampled because there was interest in investigating the overlap area in greater detail, between males and females. High and low ends of the measurement spectrum were established in prior years. The focus in 2020 was on the overlap birds, which are more difficult to distinguish sex even with measurements. To extract DNA samples from the rails, a non-invasive method of nail clipping was used. One nail from the middle toe of the banded (right) leg of an individual bird was disinfected using a cotton swab soaked in isopropyl alcohol to remove any foreign DNA or contaminants. 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 applied to 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 (Fig. 5) was taken of all blood sampled birds to see if plumage characteristics such as presence or absence of an auricular patch, bill color and shape had a recognizable pattern to distinguish sex.

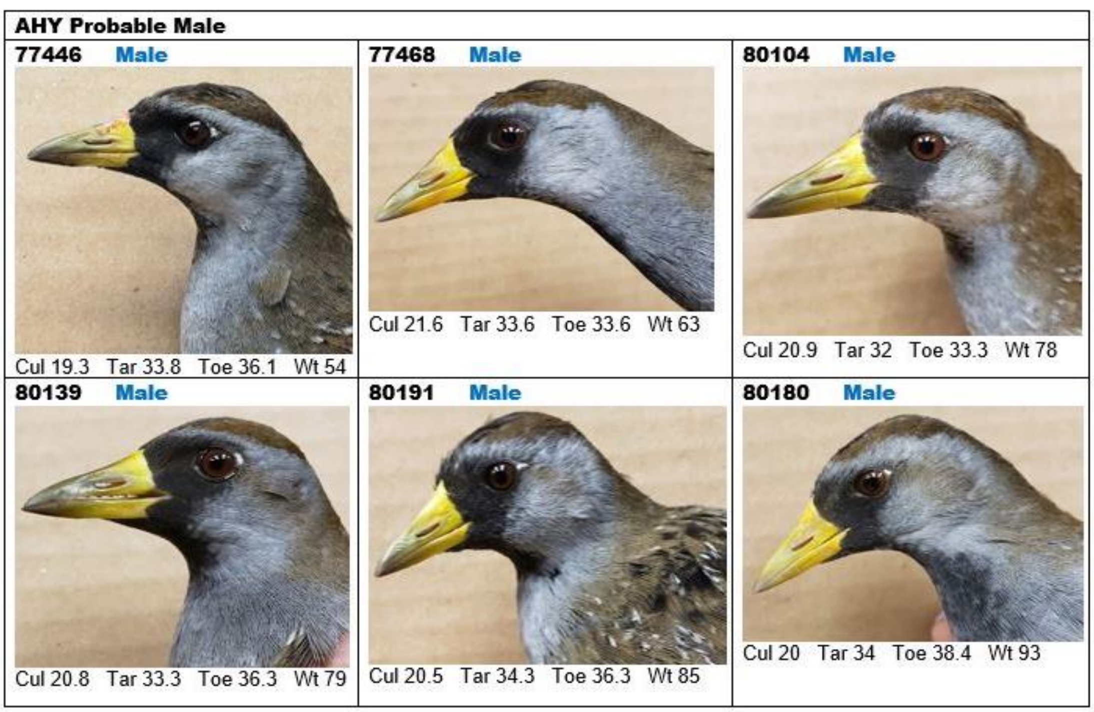
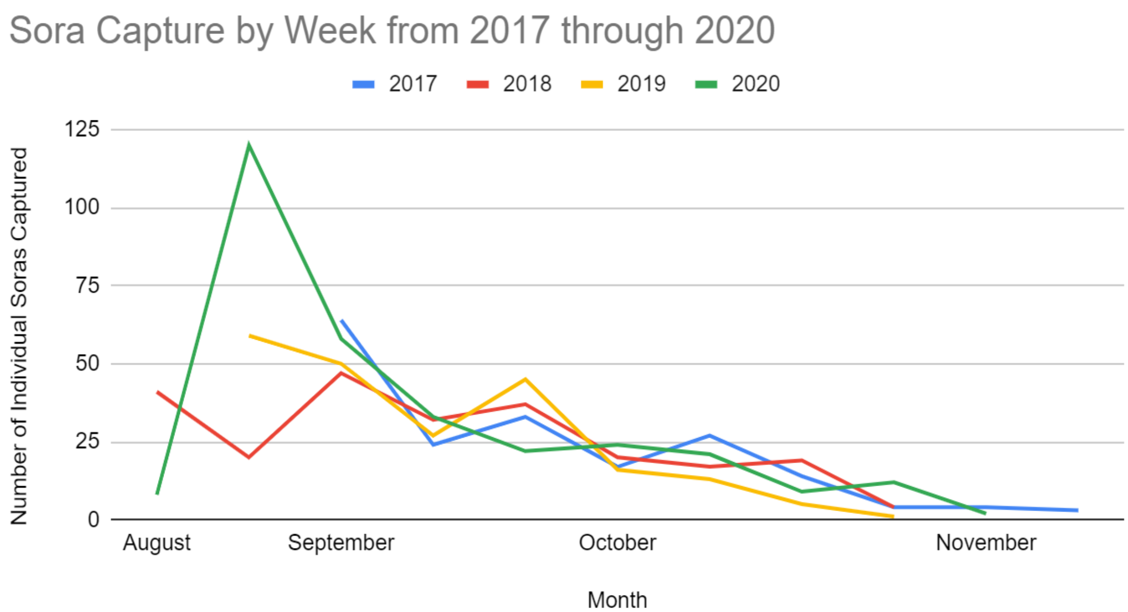


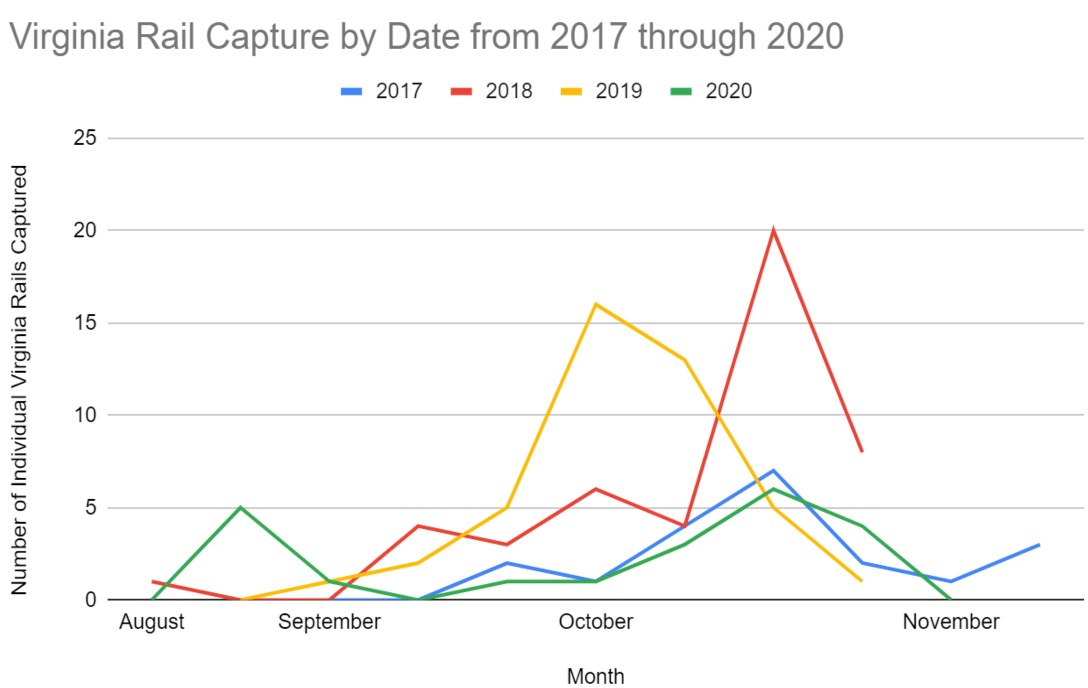
Figure 5. Example of Sora "mugshot" page used to compare and contrast physical characteristics.

RESULTS

Migrant Sora rail population of the Jug Bay marsh on the Patuxent River, 2020- A total of 309 individual Soras were captured between the dates of August 20th and November 6th. A total of 21 Virginia rails were captured between those dates. For comparison, in Fall of 2019 we captured 216 individual Soras and 40 Virginia rails. This year's Sora capture was the highest total number since the study began in 2017.



(a)



(b)

Figure 6a & 6b. Total number of (a)Sora rails and (b)Virginia rails captured during the past 4 Fall seasons of trapping and banding by year. 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 15:1 (#Sora=309, #Virginia=21).

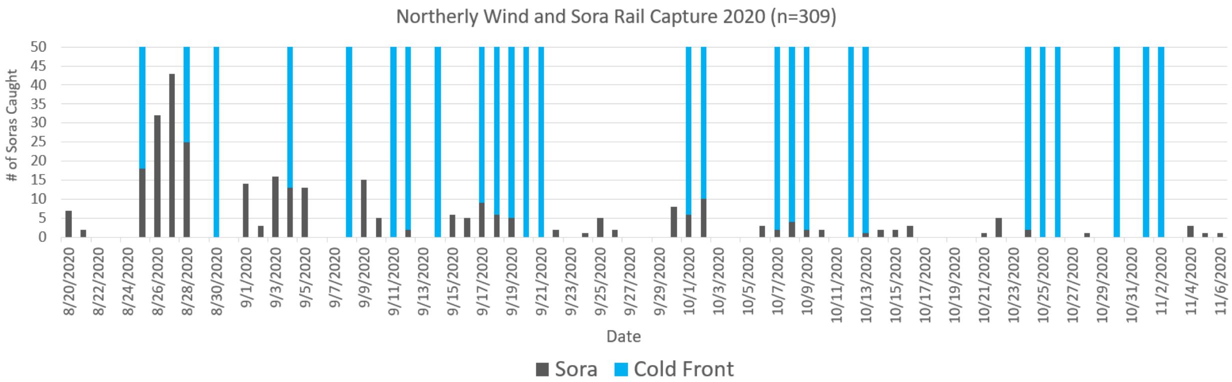


Figure 7. The occurrence of northerly cold fronts (≥ 10mph) in relation to Sora capture success in Fall 2020. The northerly cold fronts bring flights of migrant Soras to the marsh in late August through September, usually resulting in a higher capture of birds during or just after these fronts. The audio lure is set to turn on just before sunrise to increase capture rate. The capture success is high in late August to mid-September. It decreases at the start of October as the Soras begin to use the northerly cold fronts to migrate further South.

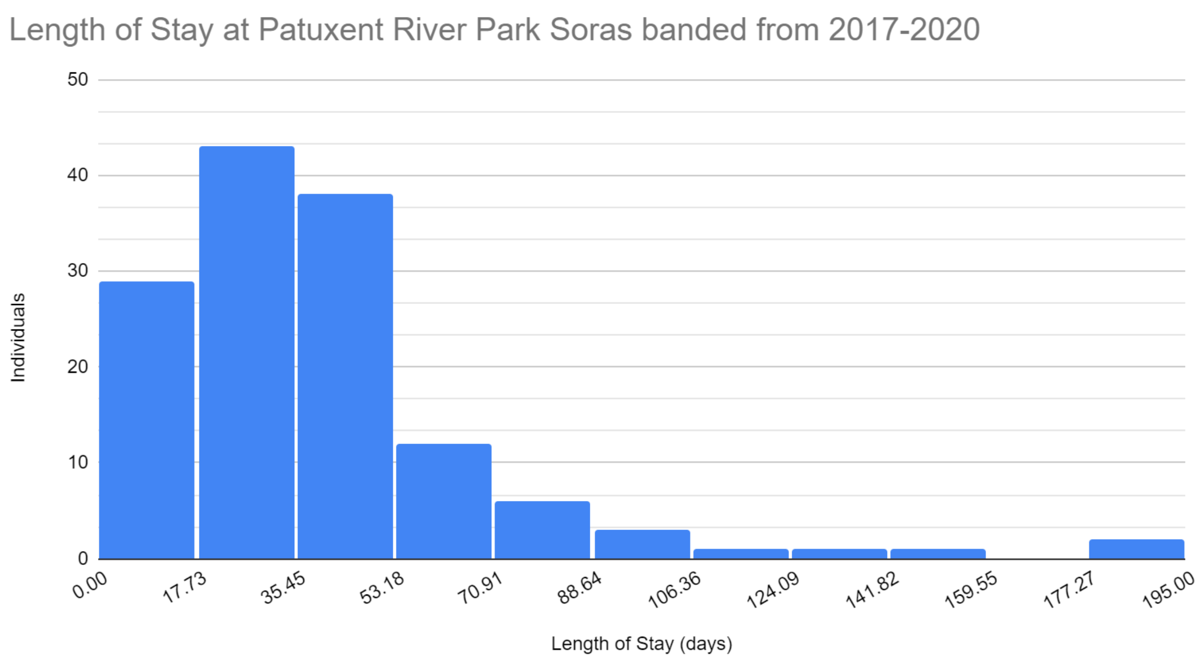
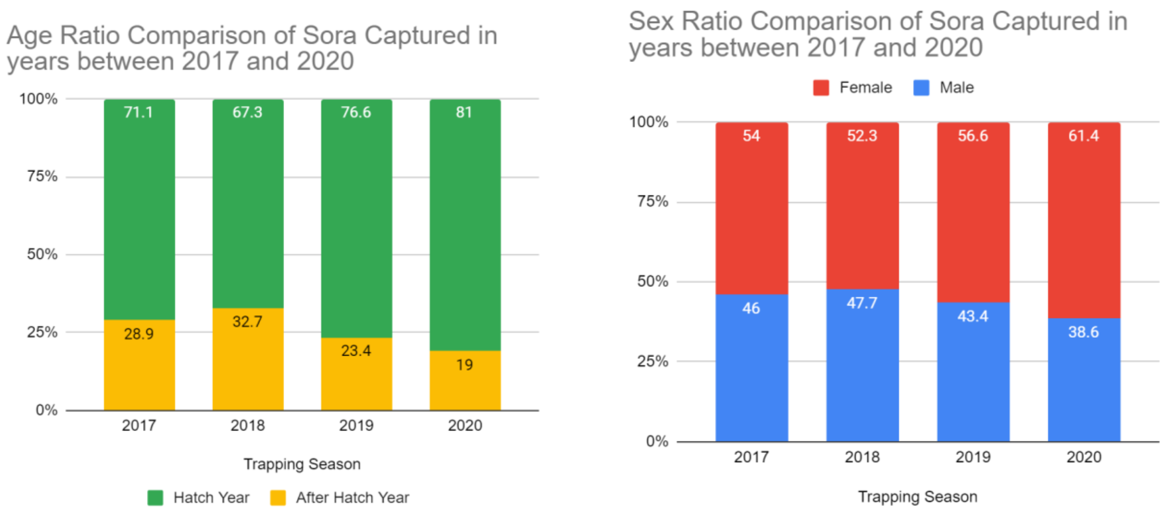


Figure 8. Estimated length of stay in days of transmitter fitted Soras banded between 2017 and 2020.



(a) **(b)**

Figure 9a & 9b. The age and sex ratios of the Sora rails captured over the past 4 years. Age and sex determined in the field is based on Fall plumage and morphometric body measurements, making some error possible, particularly in the hatch year birds. The sex ratio is typically close to 1:1. The hatch year birds outnumbered adults by about 2.5:1 in 2017, 2:1 in 2018, 3.3:1 in 2019 and 4.3:1 in 2020.

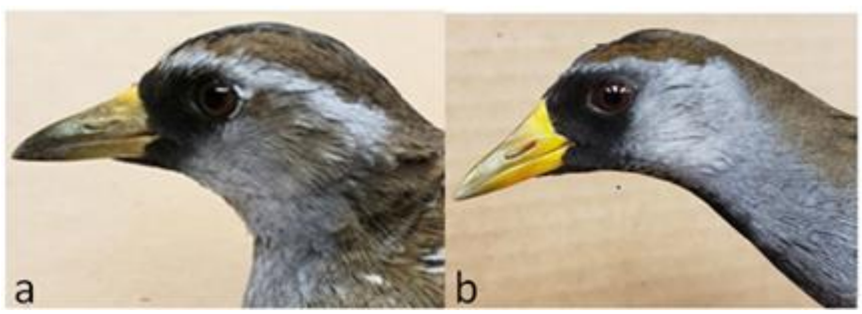


Figure 10a & 10b. Pictures showing the difference between typical female and male appearance. (a) AHY-F displaying a characteristic dull green bill, a smaller culmen height, a dipped slope of the forehead where it meets the bill, and a more distinct and connected auricular patch (AP). (b) AHY-M displaying a characteristic brighter yellow bill, a taller culmen height, a straight slope of the forehead where it meets the bill (canvasback-like), and a less distinct and unconnected or absent AP.

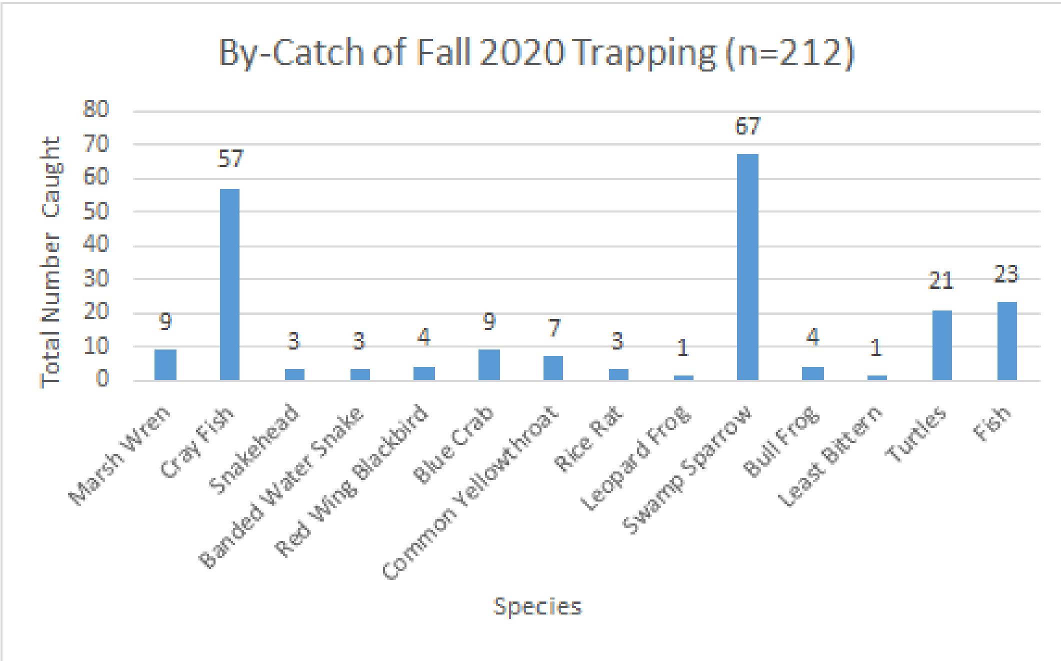


Figure 11. Graph of multiple species By-Catch in Seth Low clover leaf traps for the Fall 2020 trapping season

DNA Sexing- To test the accuracy of current field sexing techniques we collected a total of 180 blood samples from 37 After Hatch Year-Males (AHY-M), 30 After Hatch Year-Females (AHY-F), 55 Hatch Year-Males (HY-M), and 58 Hatch Year-Females (HY-F). The Soras sex was determine based on current field 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. AHY Males predominantly have a chrome-yellow bill color versus females that often have an olive-green bill color and males frequently have an isolated auricular patch, while females more frequently have a connected auricular patch.

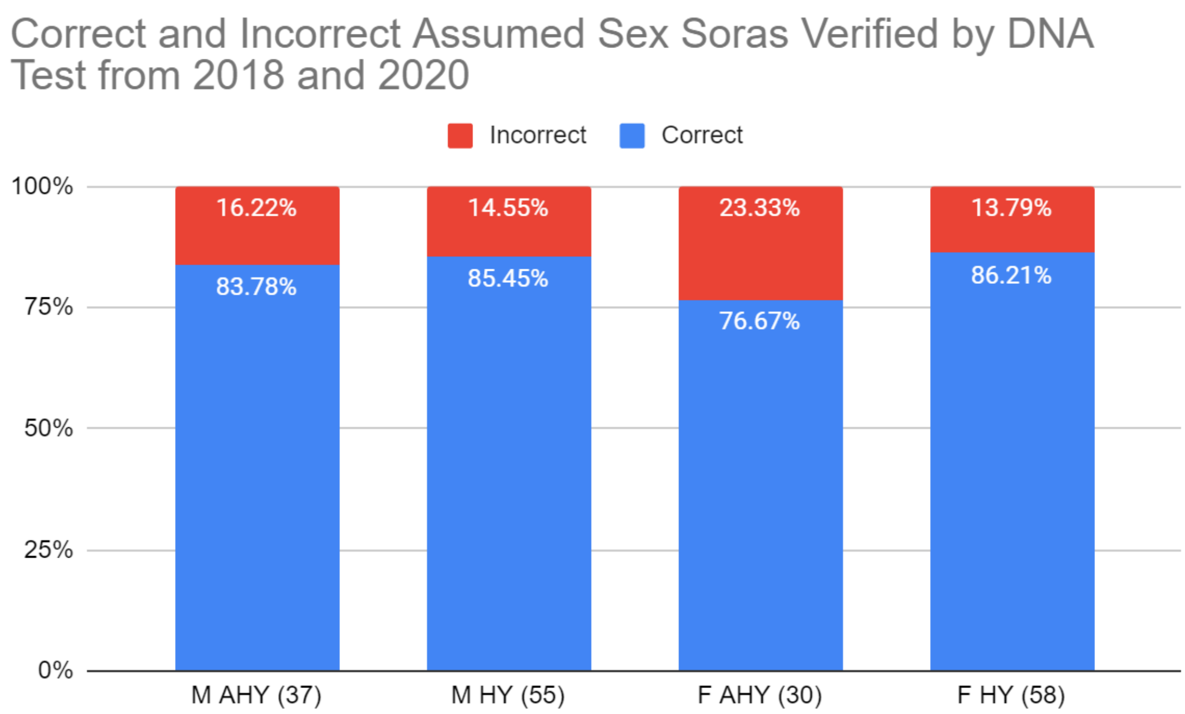


Figure 12. DNA sample results of Soras displaying total sampled, sorted by age and sex. Correctly versus incorrectly refers to whether or not the assumed sex in the field could be accurately verified by DNA results.

Male	Culmen (mm)	Tarsus (mm)	Toe (mm)	Weight (g)
Average	20.5	34.1	35.8	73.1
Minimum	18.4	30.2	31.4	51
Maximum	23.4	37.3	39	107
Female	Culmen (mm)	Tarsus (mm)	Toe (mm)	Weight (g)
Average	19.0	32.3	33.8	63.5
Minimum	17.1	29.7	31	44
Maximum	21.4	34.5	37.2	95

Table 2. DNA sample results of Soras, including average, minimum, and maximum of different measurements for each sex.

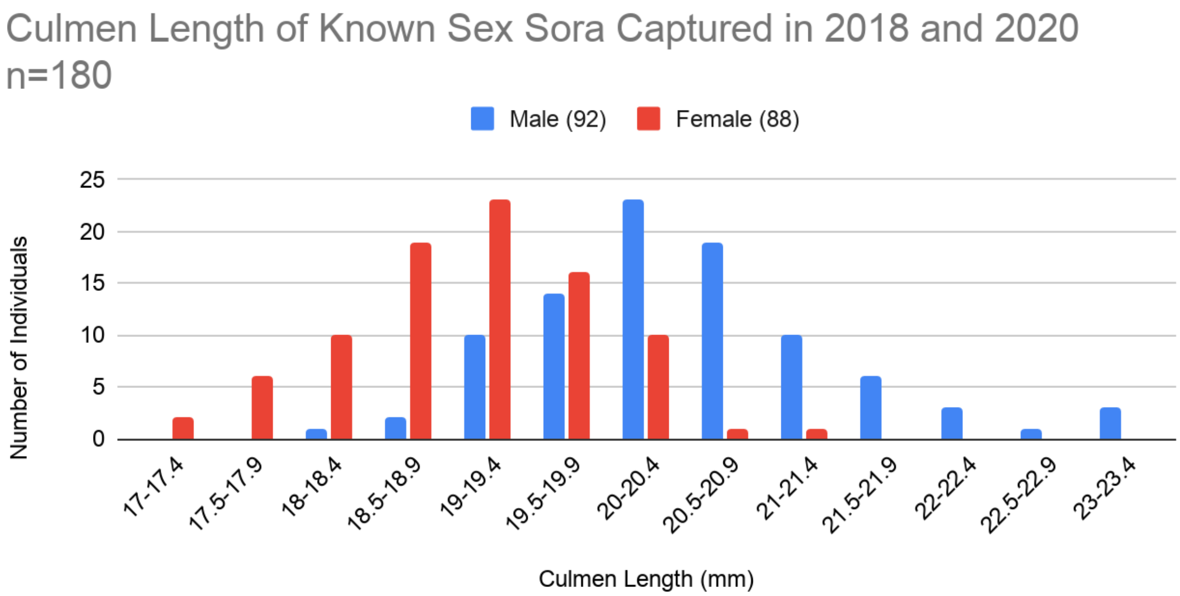


Figure 13. Sora culmen measurements of 92 males and 88 females that had been sexed using DNA sampling methods in 2018 and 2020. Females show a peak average at 19.0-19.4mm. Males peak average at about 20.0-20.4mm.

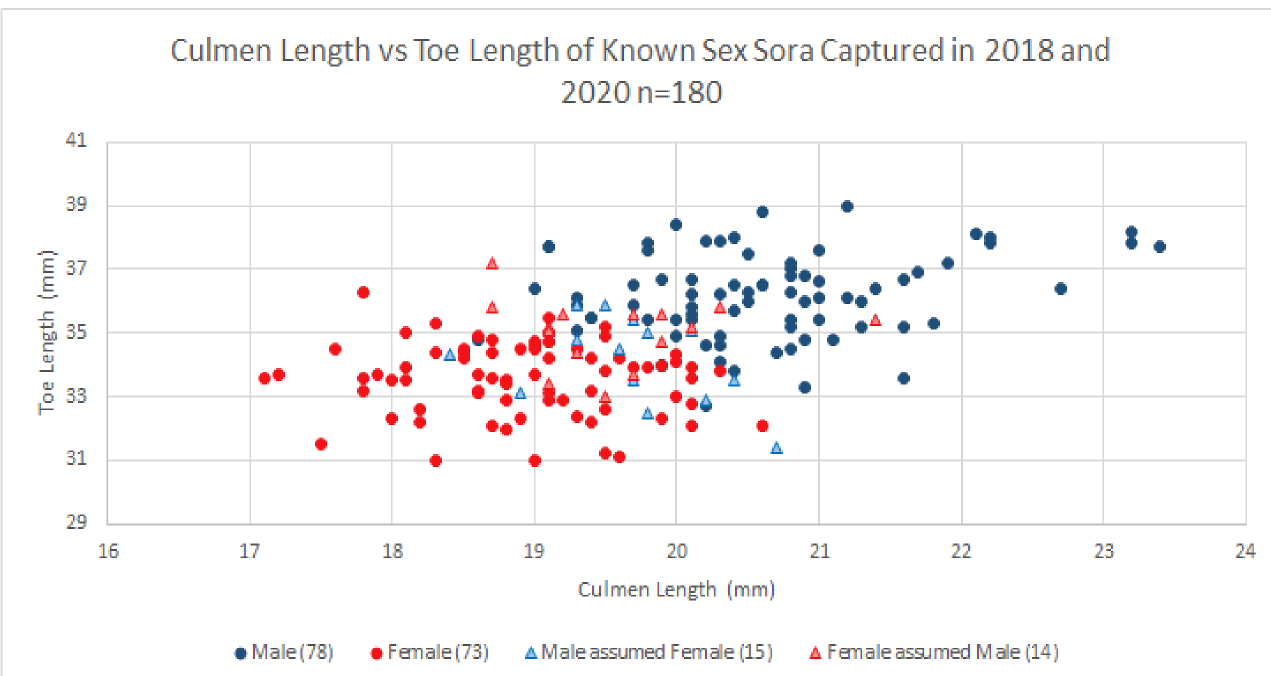


Figure 14. Scatter plot of culmen measurements versus toe measurements in DNA sample Soras collected in 2018 and 2020, showing how accurate current field sexing techniques are.

Sound surveys- Overall, the 2020 surveys yielded 975 individual responses over all five sound survey days. Our top sites this year were sites 23, 26, and 33. The maximum number of rails heard per one survey was 206 on 9/24/20. In 2018, our best sound survey was on 9/26/18 with 146 individual responses total at all locations. In 2020, the maximum rails heard per site was 19 at site 26.

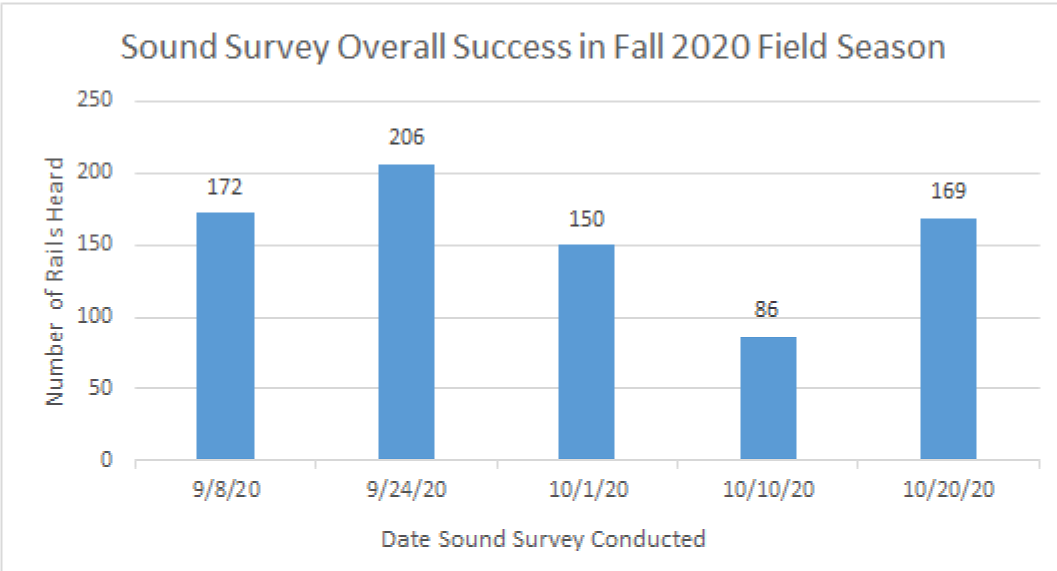


Figure 15. Number of Soras heard during each sound survey.

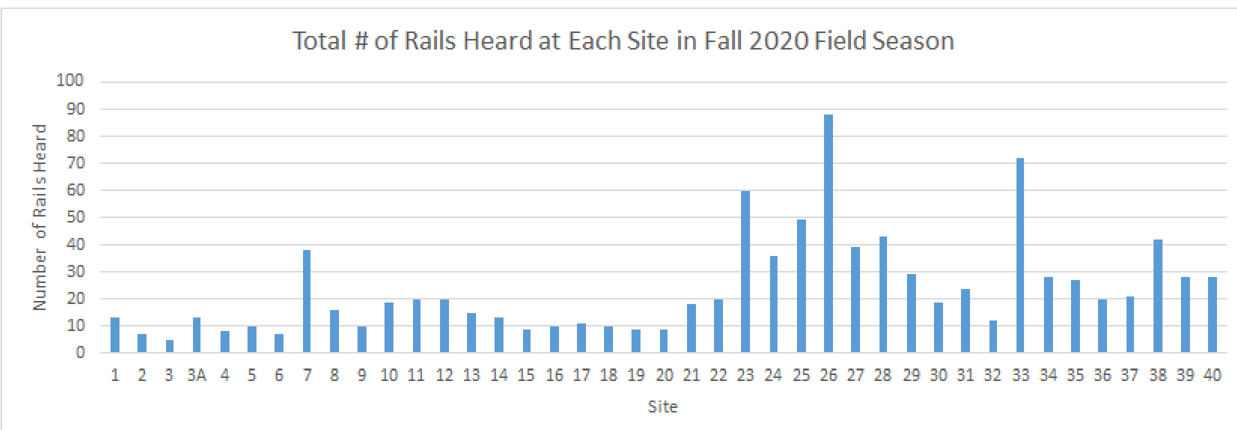


Figure 16. The total number of Soras heard at each site across all five sound survey days.

Motus receiver station detection data from Patuxent River Park, Newtowne Neck, Patuxent Research Refuge & Trunk Island Bermuda- 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.

Species	PRP	NTN	PRR	TIB	Individuals Detected between all 4 Towers
Am Kestrel		2			2
Am Pipit	1	3			4
Am Woodcock	2	1			3
Bicknell's Thrush	5				5
Blackpoll Warbler	3		1		3
Chimney Swift	2				2
Common Nighthawk		1			1
Common Tern	3				3
Eastern Red Bat		1			1
Peregrine Falcon		1			1
Red Knot				1	1
Ruddy Turnstone		1			1
Rusty Blackbird	2	6			7
Semipalmated Plover	1				1
Swainsons Thrush		1			1
Vira		1			1
White-Rumped Sandpiper				2	2
White-throated Sparrow	1	1			2
Wood Thrush	3	2	1		3
Yellow-rumped Warbler		3			3

Table 3. Species detected by Patuxent River Park (PRP), Newtowne Neck (NTN), Patuxent Research Refuge (PRP) & Trunk Island Bermuda (TIB) from 2017 through 2020

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. R and R Studio, a statistics program is used to filter out false hits from real data. This will take more time to accomplish and produce.

Transmitter #	Hours On	Pulse Rates	Capture Date	Departure Date from PRP	Sora #	Band #	Age	Sex
440	24	12.5	9/1/2020	9/18/2020	138	77412	EHY	M
395	24	9.7	9/4/2020	9/19/2020	172	77445	MHY	M
464	24	12.5	9/10/2020	10/1/2020	213	77486	LHY	M
476	24	12.5	9/1/2020	10/2/2020	140	77414	EHY	M
393	24	9.7	8/28/2020	10/3/2020	113	66788	MHY	M
467	24	12.5	8/25/2020	10/13/2020	15	58289	AHY	M
470	24	12.5	8/27/2020	10/13/2020	86	66762	MHY	M
469	24	12.5	8/26/2020	10/14/2020	42	66717	EHY	M
509	24	9.7	10/15/2020	10/15/2020	300	80180	AHY	M
475	24	12.5	8/27/2020	10/24/2020	103	66778	MHY	M
477	24	12.5	8/28/2020	10/25/2020	110	66785	AHY	F
401	24	9.7	9/9/2020	10/28/2020	204	77477	MHY	M
433	24	12.5	10/1/2020	10/30/2020	269	80141	AHY	M
431	24	12.5	9/18/2020	11/1/2020	239	80111	AHY	F
430	24	12.5	10/7/2020	11/2/2020	288	80161	AHY	M
438	24	12.5	9/18/2020	11/2/2020	237	80109	AHY	M
436	24	12.5	9/30/2020	11/13/2020	267	80139	AHY	M
508	24	9.7	9/30/2020	11/17/2020	260	80132	AHY	M
514	24	12.5	10/2/2020	11/23/2020	275	80147	AHY	F
466	24	12.5	8/25/2020	12/6/2020	17	58291	AHY	M

Table 4. Record of deployed transmitters from 2020 that have had successful migration detections thus far using the Motus automated tracking system. Listed above are 20 transmitters that have been detected on Patuxent River Park (PRP) and at least one other tower. Some were detected at this project's second tower located at Newtowne Neck State Park (approx. 38miles South of PRP).

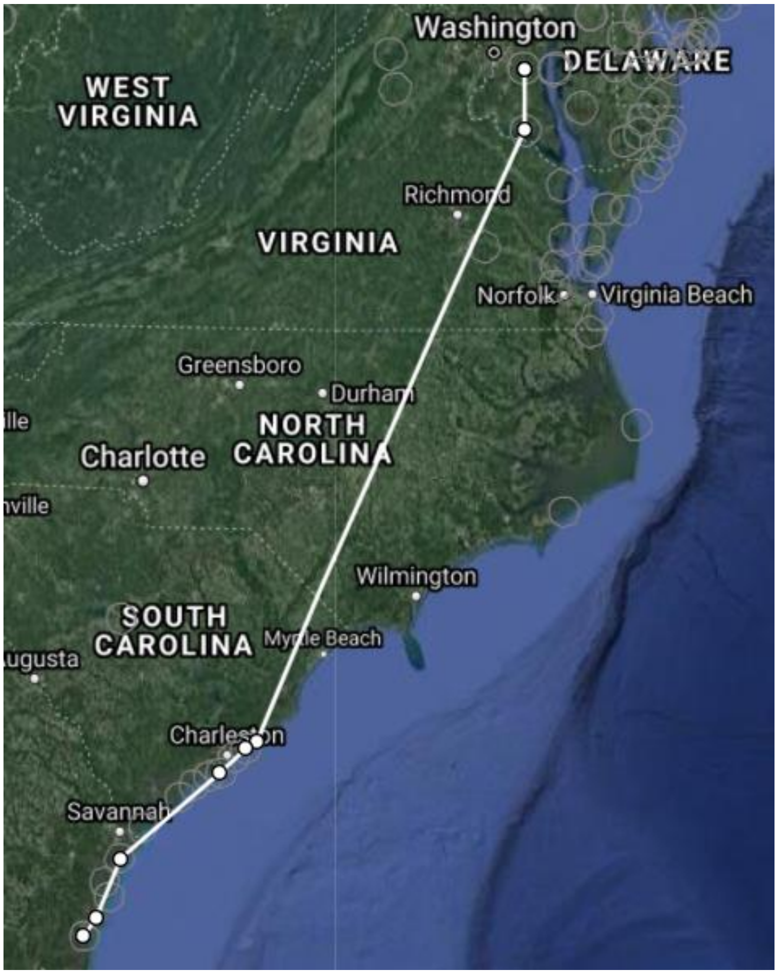
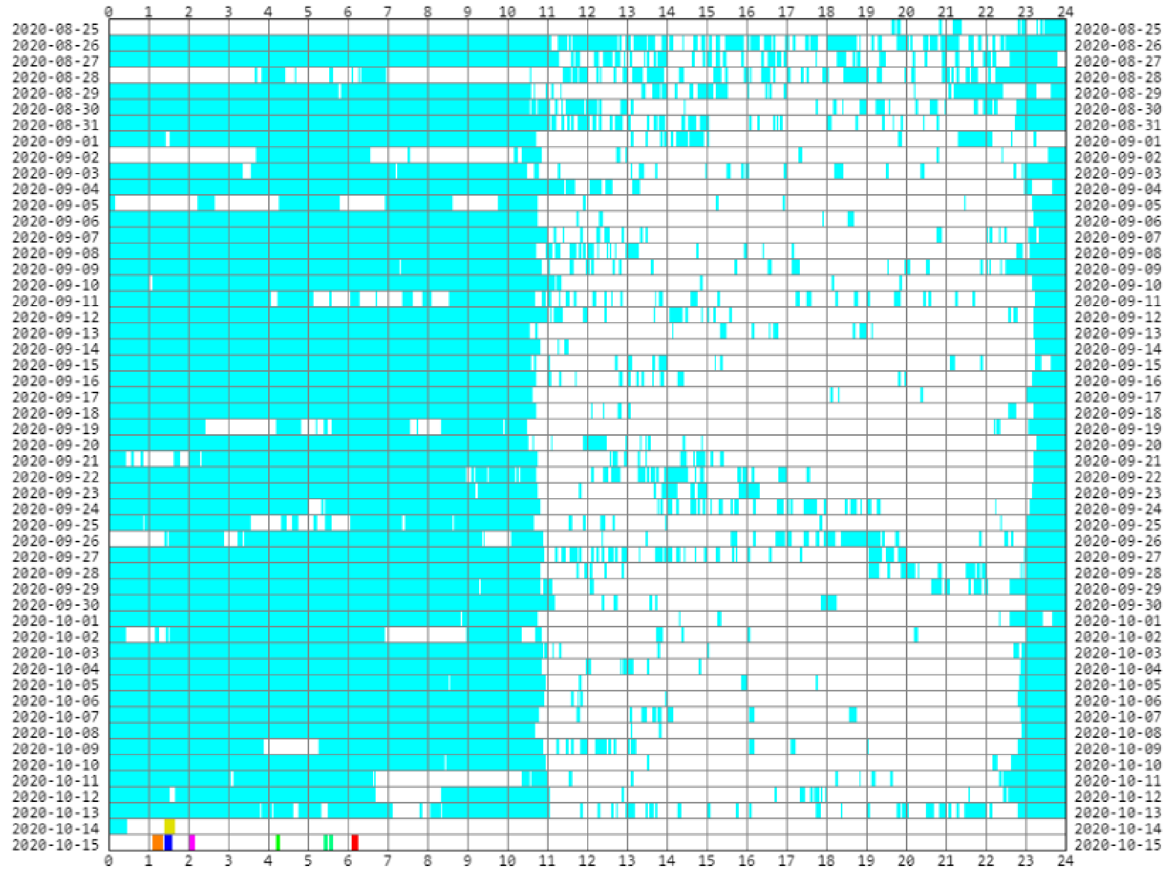


Figure 17. Tag detections in satellite map for Sora Transmitter #467. The Sora went from Patuxent River Park, where it was banded, to Newtowne Neck on the night of 10/13/20. The following night of 10/14/20 and early morning of 10/15/20 ,the Sora was picked up on 3 South Carolina towers and 3 Georgia towers. Note the travel path line on the map is not reflective of the actual movement of the bird.



Receiver deployments

- SG-1215BBBK1769 - GA_DNR_DOCK (ID# 3944) - detections of this tag by this receiver
- SG-422BRPI3D99D - GA_OSS_DOCK (ID# 5111) - detections of this tag by this receiver
- SG-329ERPI3DD60 - Dewees Island, SC (ID# 5237) - detections of this tag by this receiver
- SG-E290RPI34AAE - Newtowne Neck (ID# 5720) - detections of this tag by this receiver
- SG-5304RPI3AAED - Patuxent River Park (ID# 5721) - detections of this tag by this receiver
- SG-9085RPI3AFC4 - Little Bear (ID# 7237) - detections of this tag by this receiver
- SG-4381RPI38232 - Bulls Island, Cape Romain NWR, SC (ID# 7306) - detections of this tag by this receiver
- SG-E87DRPI3BD87 - GA_SSI_DOCK (ID# 7311) - detections of this tag by this receiver

Figure 18. Tag detections in timeline format for Sora Transmitter #467. The transmitter is active 24 hours a day. The chart uses UTC time. To calculate UTC time to EST subtract 4 hours. During daylight saving time subtract 5 hours. The Sora was last detected at Patuxent River Park (PRP) around 8:25pm (EST) on 10/13/20, then it was detected at Newtowne Neck, our project's second tower about 38 miles South of PRP, 58 minutes later indicating a minimum average speed of at least 59km/h(37mph). The following night of 10/14/20 and early morning of 10/15/20 ,the Sora was picked up on 3 South Carolina towers (Dewees Island, Little Bear, and Bulls Island) and 3 Georgia towers (GA_DNR_DOCK, GA_OSS_DOCK, GA_SSI_DOCK).

Figure 19. Tag detections in satellite map format for Sora Transmitter #508. The Sora was last detected at Patuxent River Park, where it was banded, on 11/17/20. Then it was detected at Pelican Island NWR (FL) later that day. About two weeks later on the night of 12/1/20, the Sora was picked up at Hobe Sound NWR (FL) and Loxahatchee NWR (FL). Note the travel path line on the map is not reflective of the actual movement of the bird.

Figure 20. Tag detections in timeline format for Sora Transmitter #508. 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 (PRP) around 6:30pm (EST) on 11/17/20, then it was detected at Pelican Island NWR (FL) about 17 hours later indicating a minimum average speed of at least 74km/h (46mph). About two weeks later on the night of 12/1/20, the Sora was picked up at Hobe Sound NWR (FL) and Loxahatchee NWR (FL).

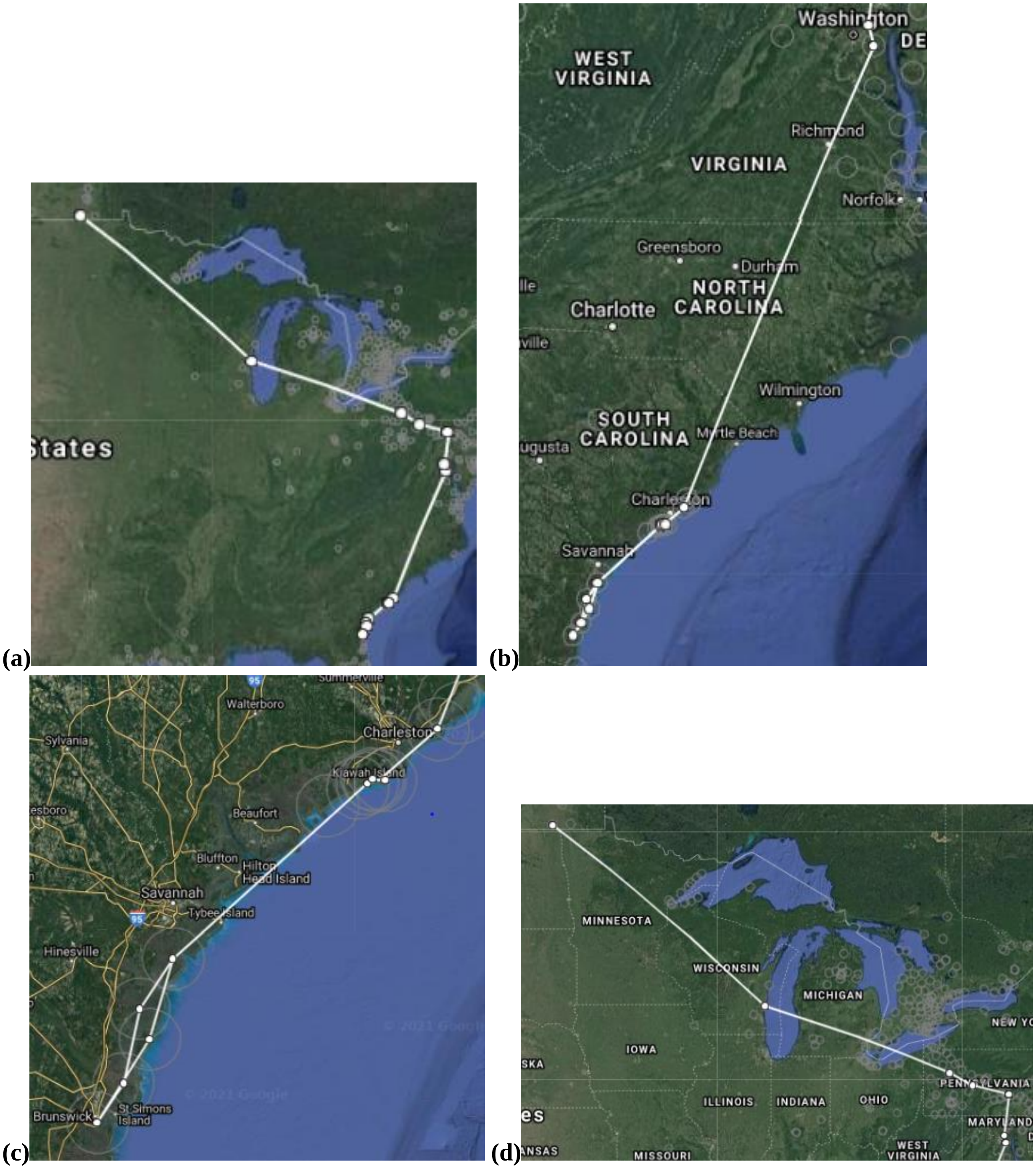
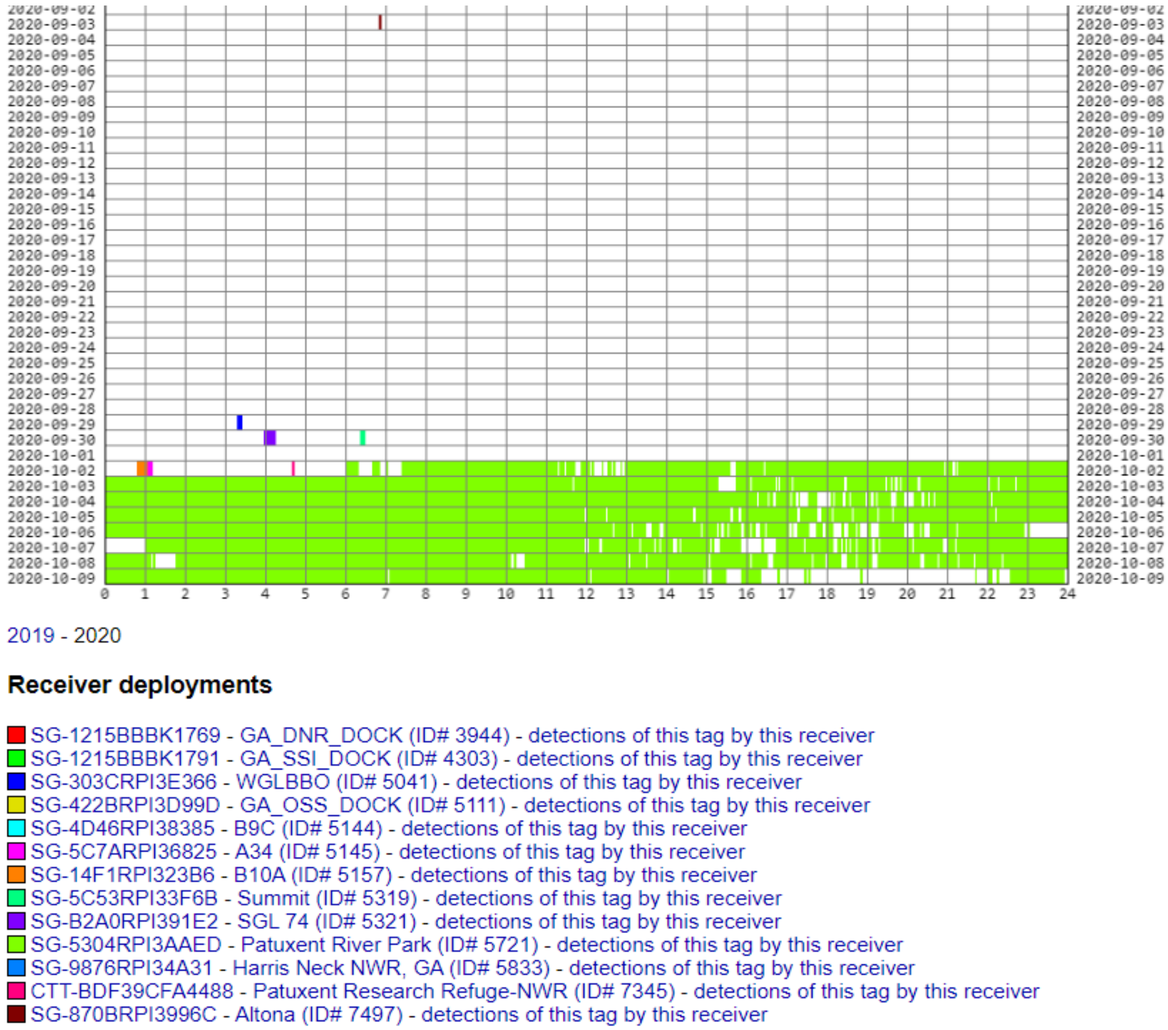


Figure 21. Tag detections in (a-d) satellite map format for Sora Transmitter #59 affixed in 2019. This track shows a Fall 2019 (b), Spring 2020(c), and Fall 2020 (d) migration. Fall 2019 migration is from Patuxent River Park (MD) on 10/4/19 to its last hit on GA_DNR_DOCK (GA) on 10/6/19. Spring 2020 migration is from GA_DNR_DOCK (GA) on 3/18/20 to its last hit at GA_OSS_DOCK (GA) on 3/18/20. Fall 2020 migration is from Altona on 9/3/20 to its last hit back at Patuxent River Park on 10/2/2020. Note the travel path line on the map is not reflective of the actual movement of the bird.


2019 - 2020
Receiver deployments
SG-1215BBBK1769 - GA_DNR_DOCK (ID# 3944) - detections of this tag by this receiver
SG-3021RPI2BBB8 - Blackbeard Island NWR, GA (ID# 4622) - detections of this tag by this receiver
SG-5304RPI3AAED - Patuxent River Park (ID# 5042) - detections of this tag by this receiver
SG-422BRPI3D99D - GA_OSS_DOCK (ID# 5111) - detections of this tag by this receiver
SG-329ERPI3DD60 - Dewees Island, SC (ID# 5237) - detections of this tag by this receiver
SG-CEB1RPI3C0D0 - The Sanctuary (ID# 5493) - detections of this tag by this receiver
SG-2013BB000060 - Marsh Island (ID# 5505) - detections of this tag by this receiver
SG-9085RPI3AFC4 - Little Bear (ID# 5599) - detections of this tag by this receiver
SG-5304RPI3AAED - Patuxent River Park (ID# 5721) - detections of this tag by this receiver
2020-03-18
2020-03-19

(a)

(b)



(c)

Figure 22 (a-c). Tag detections in (a-c) timeline format for Sora Transmitter #59 affixed in 2019. 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. This track shows a Fall 2019 (a), Spring 2020(b), and Fall 2020 (c) migration. Fall 2019 migration is from Patuxent River Park (MD) at about 8:55pm on 10/4/19 to its last hit on GA_DNR_DOCK (GA) at about 4:05am on 10/6/19. Spring 2020 migration is from GA_DNR_DOCK (GA) at about 3:50am on 3/18/20 to its last hit at GA_OSS_DOCK (GA) at about 5:05am on 3/18/20. Fall 2020 migration is from Altona at about 2:50am on 9/3/20 to its last hit back at Patuxent River Park at about 2:00am on 10/2/2020. The transmitter's battery ran out on the night on 10/9/20.

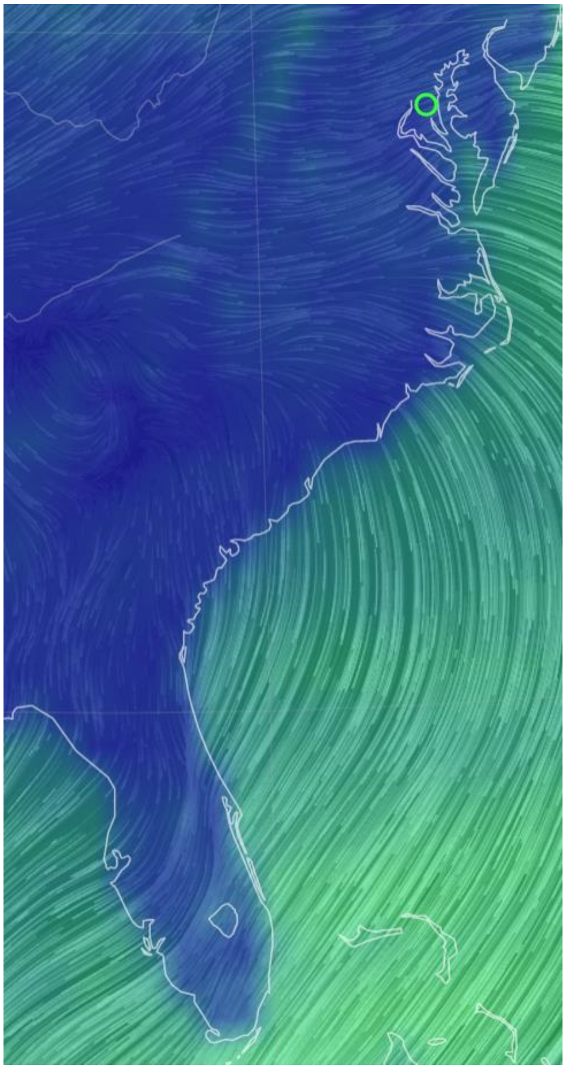


Figure 23. Wind map from 11/2/20 at 7:00pm (EST) from https://earth.nullschool.net/ showing favorable North Easterly circulation from Patuxent River Park (green circle) down the coast through the Chesapeake Bay to Florida. This illustrates the perfect clockwise circulation of a high pressure system moving into the East coast creating the ideal conditions for Sora migration. Six individual Soras fitted with transmitters departed from Patuxent River Park on this night.

DISCUSSION

The project results are a demonstration of previously unknown information on the migration and stopover ecology of Sora and Virginia rails. As the project's migration data has expanded over time via the Motus tracking system, the technology, methodology and accuracy has improved. Seasonal trapping and banding was vital for the acquisition of the much needed data on this secretive marsh bird. This information will help to establish efficient wetland 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

Fall 2021 and Spring 2022 and possibly further in the future, depending on the project end date. However, there is significant insight provided by the current results.

We had 43 successful transmitters out of 53 total deployed transmitters in the Fall 2020 field season. Successful transmitters are those that remained affixed to the bird. Out of those 43, twenty have already been hit on other towers beside Patuxent River Park (Table 4). We recovered ten transmitters from the marsh that had fallen off the Sora using the SRX hand held receiver. Out of these 10 finds, 6 were thought to be predation and 4 likely just fell off the Sora. We reattached 4 of these recovered transmitters, but they also were unsuccessful and 2 of them were likely predations. We plan to deploy all of these recovered transmitters in the Spring of 2021.

The rails migrate to this portion of the Patuxent River during the Fall and stay for roughly four to eight weeks, averaging 35 days of about 5 weeks length of stay (Fig.8). The Soras arrive in late August – early September and the majority of birds depart in mid-October to mid-November (Fig.6a). The Virginia rails arrive in late September and start to depart in early December though some overwinter (Fig.6b). Capture success increased following the occurrence of northerly cold fronts that brought nocturnal flights of birds into the marsh in early Fall (Fig.7). Capture success then decreased following the occurrence of northerly cold fronts in mid-October (Fig.7) and the first occurrences of frost in early November. The rails are small-bodied flap-fliers that travel great distances in one night on fat reserves acquired at their stopover habitat. We have documented distances as long as 1600km in just over 19 hours of nonstop flight from Jug Bay to the Bahama Islands at an average speed of 83km/h. The rails depart in the evening when the winds are from a northerly or north-west direction (Fig. 23) a rising barometric pressure, and the stars are visible due to a 50% or less cloud cover. This preference for visible star patterns indicates their use for navigational direction. For this report we displayed the three most interesting migrations, 2 transmitters deployed in 2020 (Fig. 17,18, 19, and 20) and one deployed in 2019 (Fig. 21 and Fig. 22).

One Sora with transmitter 467 (Fig. 17) departed at about 8:25pm (EST) from Patuxent River Park in Upper Marlboro on October 13th and was detected on our project's second tower, Newtowne Neck about 38 miles South of PRP, 58 minutes later indicating a minimum average speed of at least 59km/h (37mph). The following night of 10/14/20 and early morning of 10/15/20 ,the Sora was picked up at Bulls Island Cape Romain NWR (SC), Dewees Island (SC), Little Bear (SC), GA_OSS_DOCK (GA), GA_SSI_DOCK (GA), and then GA_DNR_DOCK (GA). This bird shows a very comprehensive Fall migration from Maryland to Southeast Georgia.

Another Sora with transmitter 508 (Fig. 17 and Fig. 18) departed at Patuxent River Park around 6:30pm (EST) on 11/17/20. It was detected at Pelican Island NWR (FL) about 17 hours later indicating a minimum average speed of at least 74km/h(46mph). About two weeks later on the night of 12/1/20, the Sora was picked up at Hobe Sound NWR (FL) and Loxahatchee NWR (FL). We speculate that unlike transmitter 467, this bird was swept farther off the coast and came back inland to Florida which would result in no detections in South Carolina and Georgia like transmitter 467.

One of the best tracks we have observed from our project was from a Sora with transmitter 59 that was deployed in 2019. Motus detected migration tracks for Fall 2019, Spring 2020, and Fall 2020 seasons. The Fall 2019 migration began with a departure from Patuxent River Park (MD) at about 8:55pm on 10/4/19. The bird was detected on 4 other towers in South Carolina and 2 in Georgia before it's last detection on GA_DNR_DOCK (GA) at about 4:05am on 10/6/19. The Spring 2020 migration began at GA_DNR_DOCK (GA) at about 3:50am on 3/18/20. It was detected at 2 other Georgia towers before its last detection at GA_OSS_DOCK (GA) at about 5:05am. The Fall 2020 migration starts from Manitoba, Canada at about 2:50am on 9/3/20 to Wisconsin at about 11:15pm on 9/28/20, 25 days later. The bird was detected on 3 Pennsylvania towers before it went past one of our project's other towers at Patuxent Research Refuge in Laurel, Maryland at 12:40am on 10/2/20. Its last detection was back at Patuxent River Park at about 2:00am on 10/2/20. The transmitter's battery expired on the night of 10/9/20. The transmitter lasted 24 days past its 383 day life expectancy. This data represents a complete migration cycle including Fall, Spring, and Fall again. It returned to the same trap location in the Jug Bay marshes on the Patuxent River where it was originally captured in 2019. This further reinforces migration site fidelity and the value of Jug Bay as an important stop-over habitat for Soras and other species.

Soras are primarily ground-based birds, except for migration purposes or escaping predators. They take advantage of the northerly winds that arrive 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 Soras out over the Atlantic Ocean. Then, wind from the Northeast pushes them back towards the southeast coast of the United States (Fig. 23). If the wind was too strong or pushed a bird too far out over the ocean, its fat reserves could deplete so that it would need to find the nearest possible land or else settle in the ocean, which would mean certain death. This would explain the reported findings of Soras in Bermuda every year, approximately 600 miles from the nearest land in North Carolina. Occasionally when they have adequate body fat and the jet stream winds are favorable, Soras have been carried across the ocean to locations such as Great Britain and Norway. This species migration is dependent on wind, weather, and fat reserves all coming together in perfect synchronization . An incident of a hurricane, a strong El Niño 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 in the number of Soras captured between the two years, most likely because of the strongest El Niño ever recorded in 1998. This altered the normal jet stream patterns to a more 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 serves as the 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]. The 1998 El Niño season and the dramatic decline of the Wild Rice due to overgrazing by resident Canada Geese (*Branta canadensis*)[3] in Jug Bay, helps explain the disastrous collapse in the rail populations in the 1999 and 2000 fall migration seasons, from which it appears they have never fully recovered. The capture of sora declined from almost 1,300 individuals captured in 1998 to about 300 in 1999 with no change in trapping effort[3]. We believe many of the birds left the Jug Bay marshes in less than ideal body fat condition to complete the full migration, especially given the abnormal westerly flow of winds mentioned above. Not being in prime condition upon departure and being pushed eastward from their normal course south could have led to their demise over the open Atlantic Ocean upon depletion of fat supply.

The handheld SRX800 receiver allowed us to track and monitor the locations of the radio tagged rails for their duration of stay in the Jug Bay marsh. 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. It also aided in recovery of transmitters that had fallen off the Soras or were lost due to predation. Due to the greater sensitivity and more directional ability of the handheld receiver in comparison to the fixed Motus receiver tower, we were able to track and record the exact times of departure for many individuals as well as behaviors that displayed Zugunruhe (migratory restlessness). These behaviors include the individual radio tagged birds climbing up and down in the vegetation at night to reorient to star patterns or for roosting behavior, causing high fluctuations in the signal strength (as can be seen in Figure 18). The vegetation absorbs signal during the day while they forage at ground level but at night when they are roosting higher, the signal escapes with less interference from the dense marsh grasses. A few individuals were witnessed performing “test or directional reorientation” flights in which they flew for several minutes above the marsh, circling around and then returning into the vegetation. This information was used to record avian Zugunruhe behavior and detect departure times that were not recorded by the Motus receiving stations.

The goal of the sound surveys is to determine the approximate population density of these areas using a non-invasive method and investigate when their migration population peaks. The sound surveys overall yielded 975 individual responses over all five sound survey days (Fig.15-16). Our best sites were 23, 26, and 33. Site 23 and 26 are both located on House Creek, and Site 33 is located on Weir Creek (Fig. 4). Sites 23-40 were not located near our trapping sites, so those particular rails were not exposed to digital electronic call playback 5 days out of the week, and thus were likely more responsive to the calls played during sound surveys (Fig.4). However, it is possible that their numbers may have actually been higher in Mattaponi Creek, House Creek, Weir Creek, and Merkle Marsh. From the data acquired during sound surveys, it appears that Sora population peaked around September 24th, with 206 individuals being heard on the sound survey that day (Fig.15). Our data also indicates a likely rise in population density from previous years. In 2018, our surveys yielded only 355 individual responses over seven sound survey days, while in 2020, our surveys yielded 975 individual responses over five sound survey days. We believe time of day, wind speed, lighting, tides, temperature, all impact the number of responses heard as well.

The goal of the DNA testing to determine sex was to prove our current field sexing techniques as 95% accurate and create a morphometric model of Sora for other researchers to utilize. Due to the cost of DNA testing we focused this portion of the study on the Sora. Based on current field sexing techniques, of the 180 Soras that were sexed through blood sampling in 2018 and 2020, 83.78% of M-AHY, 85.45% of M-HY, 76.6% of F-AHY and 86.21% of F-HY Soras were accurately sexed (Fig.12). Generally in the field a culmen length of 19mm or larger, a tarsus length of 33mm or larger and a toe length of 35mm or larger were declared male. However, there is often overlap in measurements between male and female Soras in culmen, tarsus, and toe length measurements as can be seen in our preliminary analysis (Fig.13, 14). There are several outliers in the sample, which skew the data (Fig.13, 14). For example, the stray female in figure 14, which had a well above average culmen length of 21.4mm when the average for females is 19.0mm (table 2).

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 arrive in the Fall, they are here to gain weight to continue their migration. Therefore weight nor fat score is a reliable characteristic to determine sexual dimorphism during migration because weight and fat score depend heavily on arrival and capture date. These parameters of either sex are subject to drastic change due to preparation for migration and have significant overlap or variation. In 2018, we determined that 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. As a result in 2020, we mainly focused on blood sampling individuals who had measurements within the overlap area of male and female averages determined in 2018 to help create a more accurate method of sex determination. 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 differentiating males from 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 more than just the rails in the Jug Bay marsh. The trapping and banding methods produced a variety of "by-catch" (Fig. 11) which highlights the diversity of life that exists in the marsh habitat. This also displays the existence of invasive species such as the Northern Snakehead (*Channa argus*) 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 among others (Table 3). 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 how vital the area and habitat is.

Additional information will advance our knowledge as more Motus detection data is received throughout the year, and further data analysis is conducted in R. 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 for 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 wild rice as a major migration food? 9) How are the rails affected by climate change and El Niño 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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