Video Article

A Video Surveillance System to Monitor Breeding Colonies of Common Terns (*Sterna Hirundo*)

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Abstract

Many waterbird populations have faced declines over the last century, including the common tern (*Sterna hirundo*), a waterbird species with a widespread breeding distribution, that has been recently listed as endangered in some habitats of its range. Waterbird monitoring programs exist to track populations through time; however, some of the more intensive approaches require entering colonies and can be disruptive to nesting populations. This paper describes a protocol that utilizes a minimally invasive surveillance system to continuously monitor common tern nesting behavior in typical ground-nesting colonies. The video monitoring system utilizes wireless cameras focused on individual nests as well as over the colony as a whole, and allows for observation without entering the colony. The video system is powered with several 12 V car batteries that are continuously recharged using solar panels. Footage is recorded using a digital video recorder (DVR) connected to a hard drive, which can be replaced when full. The DVR may be placed outside of the colony to reduce disturbance. In this study, 3,624 h of footage recorded over 63 days in weather conditions ranging from 12.8 °C to 35.0 °C produced 3,006 h (83%) of usable behavioral data. The types of data retrieved from the recorded video can vary; we used it to detect external disturbances and measure nesting behavior during incubation. Although the protocol detailed here was designed for ground-nesting waterbirds, the principal system could easily be modified to accommodate alternative scenarios, such as colonial arboreal nesting species, making it widely applicable to a variety of research needs.

Video Link

The video component of this article can be found at https://www.jove.com/video/57928/

Introduction

Common terns (*Sterna hirundo*, hereafter COTE), a waterbird species with a widespread breeding distribution, have become a flagship example of the need for conservation and monitoring programs[1]. Once harvested to near extirpation for the millinery trade, federal legislation in the 1900s enabled populations to rebound. However, declining population trends in the Chesapeake Bay have prompted increased concern over COTE, in addition to many other waterbirds[2]. COTE are currently listed as a Maryland state endangered species due to reductions in both breeding numbers and active breeding colonies[3]. Stressors including flooding and washouts of breeding sites[4,5,6], anthropogenic disturbance, competition/predation with gulls[7,8], and predation by great horned owls (*Bubo virginianus*) and red foxes (*Vulpes vulpes*)[9,10], are believed to have contributed to current population declines; however, the relative contributions of individual stressors are not known. Understanding stressors associated with different stages of the breeding cycle, such as incubation, post-hatch, and fledging success are important but can be intensive and include frequent surveys that require entry into the nesting colony[11]. Such monitoring techniques can be disruptive to tern populations, and in some cases may result in nest abandonment and/or reductions in reproductive success[12,13,14].

While the impact of researchers on common terns is well documented, intensive monitoring can impact a number of additional ground-nesting colonial species, such as short tailed shearwaters (*Puffinus tenuirostris*)[15], common eiders (*Somateria mollissima*)[16], black skimmers (*Rynchops niger*)[17], and Fiordland crested penguins (*Eudyptes pachyrhynchus*)[18]. For instance, a study on short tailed shearwaters found that monitoring intensity had an inverse relationship on hatching success, and can exacerbate population declines. These examples illustrate the increasing need to reduce disturbance while maintaining comprehensive monitoring programs. With the video system outlined in this paper, we aimed to obtain information on nest attentiveness and observation of predators in a manner that would reduce the physical presence of humans within the colony.

Our study was located at the Paul S. Sarbanes Ecosystem Restoration Project at Poplar Island (38°46′01″N, 76°22′54″W, hereafter Poplar Island), one of the few known nesting sites for COTE in Maryland. Ongoing monitoring programs on Poplar Island have identified consistent nesting by COTE, albeit with variable levels of success depending on presence of avian or mammalian predators[19,20]. Due to these factors, Poplar Island was identified as an ideal location to conduct this study.

While the ability to monitor waterbird populations with video technology has clear benefits to the species under observation[21,22], a number of technical considerations must be taken into account when implementing such an approach. For instance, video resolution must be sufficient to identify items of interest to the researcher, such as food items, nest markings, or colored leg bands for individual identification. Additionally, the physical components must be durable enough to withstand both weather events and wildlife interactions. Wireless security cameras were chosen due to their high definition picture quality, color display with wireless and infrared capabilities, outdoor durability, and overall cost effectiveness[23].

The objective of this study was to design a video monitoring system that would allow for the remote observation of a ground-nesting colonial species while causing minimal disturbance to those individuals and the colony. This paper outlines the specific video system used to collect data.

Protocol

1. Pre-Field Preparation of the Video Monitoring System

Note: This includes the steps necessary to prepare the solar panels, battery system, cameras and staking system for construction at the field site.

1. To begin set-up of the solar panels and battery system, cut and solder 20 copper insulated 10 American wire gauge (AWG) wires (10 positive, 10 negative), attaching ring terminals when necessary.
    1. Cut six negative (black) and six positive (red) wires approximately 2 ft. long, stripping between 1/4 in. and 1/2 in. from each end.
    2. Cut four negative (black) and four positive (red) wires approximately 4 ft. long, stripping between 1/4 in. and 1/2 in. from each end.
    3. Add a thin layer of solder to one end of two negative and two positive 2 ft. wires, and both ends of all 4 ft. wires.
    Note: Soldering helps to prevent the exposed metal from splitting in the charge controller, enabling the wires to be reused more readily while ensuring optimal conductivity. However, this step is not necessary.
    4. Attach 3/8 in. ring terminals to the non-soldered ends of the positive 2 ft. wires and 5/16 in. ring terminals to the non-soldered ends of the negative 2 ft. wires.
        1. To attach the ring terminals, feed the stripped wire through the yellow tubes until the exposed metal reaches the edge but does not stick out.

2. Label the four solar panels C1, DVR1, DVR2, and DVR3 respectively and attach the appropriate wires.
    1. For panels C1 and DVR2, attach one set of 4 ft. positive and negative wires to the respective positive and negative ends on the solar panel using winged wire connectors. Cap open ends of wires with additional winged wire connectors for transport.
    2. For panel DVR1, attach two sets of 4 ft. positive and negative wires to the respective positive and negative ends on the solar panel using winged wire connectors. Cap open ends of wires with additional winged wire connectors for transport. Panel DVR3 does not need any additional wire attachments.
    3. Tape all loose wires to the back of the solar panels for transport.

3. To prepare the solar panels for staking, attach a 50 ft. long piece of rope to each side of the back of the solar panels by sliding the rope through the provided holes until the midpoint of the rope reaches the hole. For added precaution and to reduce wear, wrap duct tape around the edges of rope that come into contact with the solar panel; there should be eight pieces of rope total.
    1. Tape all loose rope to the back of the solar panel for transport.

4. Begin set-up of the battery system by attaching the charge controller to an 18-gallon plastic bin.
    1. Drill four holes 1/4 in. in diameter, 1 in. from the top, centered lengthwise, and attach using the screws included in the system. Repeat this step for a second plastic bin; label the first bin “Camera system” and the second, “DVR system”.
    2. Leave one positive and one negative 2 ft. wire with ring terminals in the “Camera system” bin and three positive and three negative 2 ft. wires with ring terminals in the “DVR system” bin.

5. Attach the DVR to a 1/4 in. thick 1 ft. x 2 ft. plywood sheet using Velcro sticky back tape strips and place the plywood in the “DVR system” bin for transport.
6. Charge six 12 V dry cell Absorbent Glass Mat (AGM) car batteries with a battery charger by attaching the positive clip to the positive terminal on the car battery and the negative clip to the negative terminal on the car battery and plugging the battery charger in to an outlet.
7. Attach wires to the charge controllers to prepare the battery system for field use.
    1. Attach one set of one side soldered, one side ring terminal 2 ft. wires (hereafter referred to as OSS/OSR wire) to the charge controller in the “Camera system” bin by loosening the screws labeled "Battery +” and “Battery –” on the charge controller and sliding the soldered end of each wire into the left side of its corresponding slot. Positive wires attach to the positive (+) slot and negative wires attach to the negative (-) slot.
    2. Tighten the screws and ensure both wires are secured. Repeat steps 1.7.1 and 1.7.2 for the charge controller in the “DVR system” bin.
    Note: CAUTION: Make sure there is no bare metal sticking out of the bottom of the charge controller as this has the potential to short and disrupt the system. If this occurs, complete replacement of the charge controller will be necessary.

3. In the “DVR system” bin, attach the 12 V male DC adapter with positive and negative wires and two male DC power plugs to the charge controller by loosening the screws labeled “Load +” and “Load –” on the charge controller and sliding the corresponding positive and negative wires into the left side of each slot. There should be one positive wire from the 12 V male DC power adapter and one positive wire from each of the male DC power plugs in the “Load +” slot and one negative wire from the 12 V male DC power adapter and one negative wire from each of the male DC power plugs in the “Load –” slot.
    1. Tape loose wires to the plastic box for transport. After tightening the screws, make sure the connection is secure to ensure that none of the wires fall out of the charge controller.

4. Repeat step 1.7.3 with only the two male DC power plugs, not the 12 V male DC adapter, in the “Camera system” bin. There should be two positive and two negative wires in the corresponding slots on the charge controller.
   Note: The wires on the two male DC power plugs can be soldered together, positive to positive and negative to negative, to reduce the number of loose wires in the charge controller.
5. Connect two 4 port DC power splitters (one female to four male) to the two male DC power plugs in the “Camera system” bin. Repeat this step for the two male DC power plugs in the “DVR system” bin.

8. Prepare the cameras for field use.
   1. Attach a wireless HD camera to a 1.5 ft. 2x4 board (or a 2x4 wood stake) using the provided screws. Cut the board opposite the mounted camera into a V pattern to ensure easier staking. Repeat with four more cameras.
   2. Attach one wireless HD camera to a 5 ft. long 2x4 board (see 1.8.1 for instructions) using screws. This will serve as the colony camera.
   3. Label each wireless HD camera with its counterpart receiver. Place the five cameras attached to 1.5 ft. boards in the “Camera system” bin for transport and all six camera receivers in the “DVR system” bin for transport. The remaining camera will be carried separately.
   4. Bundle six 50 ft. Bayonet Neill–Concelman (BNC) extension cables with duct tape for transport and place in the “Camera system” bin.

9. Prepare the staking system for field use.
   1. Drill one hole in the center of each of the two sides furthest from one another on the sawhorse (size of hole differs based on type of eye bolts used). Repeat for the remaining three sawhorses, for a total of eight.
   2. Attach eye bolts, nuts, and washers to each of the holes in the following pattern: eyebolt, nut, washer, sawhorse, washer, nut, with the eyebolt facing outward.
   3. Loosely attach 9-22 mm hose clamps to each of the eye bolts.

2. Construction of the Video Monitoring System in the Field

Note: This includes the steps necessary to secure the staking system, wire the battery system and solar panels, connect the DVR system and set up the cameras.

1. To secure the staking system, begin by determining the placement of the camera and DVR systems. The camera system should be far enough from the nests to reduce disturbance but within the range of the BNC extension cables.
2. Secure sawhorses to the ground using a metal rebar staking system.
   1. Place one sawhorse and the “Camera system” bin at the designated camera system location. Place the remaining three sawhorses and “DVR system” bin adjacent to one another at the designated DVR system location.
   2. Ensure that the sawhorses are oriented for maximum sun exposure.
   3. Drive two 5 ft. rebar 1-2 ft. into the ground using a post driver. Make sure that the rebar is spaced to match the distance between the eye bolts on the sawhorse. Repeat for each sawhorse, ensuring that the rebar is stable.
   4. Lift each sawhorse over the rebar pairs and slide the ring clamps through the rebar on both sides. Tighten the ring clamps.

3. Secure the solar panels to the sawhorses.
   1. Place solar panel C1 on the sawhorse at the designated camera system location and panels DVR 1, 2, and 3 on the three sawhorses at the designated DVR system location at the optimum angle for maximum sun exposure (angle depends on latitude and season). Place panels DVR 1, 2, and 3 in order.
   2. Drive two 6 in. nails (or tent stakes, depending on the substrate) into the ground in front of each solar panel to prevent sliding. There should be eight nails total.
   3. Drive two 6 in. nails (or tent stakes, depending on the substrate) into the ground at an approximate 45° from the back of the solar panels and secure the loose ends of rope from the back of the solar panel to the nails. Adjacent rope can attach to the same nail for a total of four nails for the DVR system and two for the Camera system.

4. Place the “Camera system” bin near panel C1 and the “DVR system” bin near panel DVR1.
5. To wire the battery system, remove any loose items from both bins and place two 12 V dry cell AGM car batteries in the “Camera system” bin and four 12 V dry cell AGM car batteries in the “DVR system” bin. When placing the batteries, ensure the negative terminal is always facing the same direction.
   Note: A third battery may be added to the “Camera system” bin if the system is not maintaining an optimal charge during operations.
   1. Wire the two 12 V dry cell AGM car batteries in the “Camera system” bin in parallel.
      1. Attach the 3/8 in. ring terminals from the positive, 2 ft. wire to each of the two positive battery terminals on the 12 V dry cell AGM car batteries. Repeat this step with the negative 2 ft. wire with 5/16 in. ring terminals and the negative battery terminals.
      2. Attach the OSS/OSR wire from the charge controller to a positive battery terminal. Repeat this step with the negative OSS/OSR wire and the negative battery terminal on the opposite battery.

   2. Wire the four 12 V dry cell AGM car batteries in the “DVR system” bin in parallel (**Figure 2**).

1. Make sure that the four 12 V dry cell AGM car batteries are oriented in a 2x2 fashion. When looking into the bin, the side of the bin where the charge controller is attached is considered the top. As a result, the batteries in this 2x2 pattern will be labeled top left (TL), top right (TR), bottom left (BL) and bottom right (BR).
2. Attach one 3/8 in. ring terminal from the positive 2 ft. wire to the positive battery terminal on battery TR and the other 3/8 in. ring terminal from this same wire to the positive battery terminal on battery BR. Repeat this step with the 5/16 in. ring terminal from the negative 2 ft. wire to the negative battery terminals on the respective batteries.
3. Attach one 3/8 in. ring terminal from the positive 2 ft. wire to the positive battery terminal on battery TL and the other 3/8 in. ring terminal from this same wire to the positive battery terminal on battery BL. Repeat this step with the 5/16 in. ring terminal from the negative 2 ft. wire to the negative battery terminals on the respective batteries.
4. Attach one 3/8 in. ring terminal from the positive 2 ft. wire to the positive battery terminal on battery BL and the other 3/8 in. ring terminal from this same wire to the positive battery terminal on battery BR. Repeat this step with the 5/16 in. ring terminal from the negative 2 ft. wire to the negative battery terminals on the respective batteries.
5. Attach the OSS/OSR wire from the charge controller to a positive battery terminal. Repeat this step with the negative OSS/OSR wire and the negative battery terminal of a different battery.

6. Connect the solar panel wires to the charge controller, attaching positive connections together and negative connections together.
    1. Connect one positive and one negative wire from DVR2 to the respective positive and negative wires on DVR3 using the winged wire connectors on panel DVR3. Connect one positive and one negative wire from DVR1 to the respective positive and negative wires on DVR2 using the winged wire connectors on panel DVR2.
    2. Connect the remaining positive and negative wires from DVR1 to the charge controller in the “DVR system” bin by loosening the screws labeled “Solar +” and “Solar –” on the charge controller and sliding each wire into the left side of its corresponding slot. Tighten the screws and ensure both wires are secure.
    3. Repeat step 2.6.2 for C1 and the charge controller in the “Camera system” bin.
    Note: CAUTION: Make sure that the positive and negative ends of wire do not touch during this step, as this has the potential to short and disrupt the system (see 1.7.2 for additional note).
    4. Discard any winged wire connectors leftover from transport and tape all winged wire connections with weatherproof electrical tape.
    5. Check to make sure both the white and green lights (solar and battery power, respectively) are on in both charge controllers. This ensures the system is operational and has a full charge.
    Note: The system will not function optimally without a full charge. If the battery power light is not green (yellow or red), either disconnect the batteries and recharge them or allow the solar panels to charge the batteries for several hours before proceeding.

7. Connect the DVR system to the receivers and program settings.
    1. Place the wooden plywood with the attached DVR on top of the four 12 V dry cell AGM car batteries in the “DVR system” bin.
    2. Connect the female DC power plug on each receiver to each of the male DC power plugs on the two 4 port DC power splitters.
    3. Connect one of the male DC power plugs from one of the two 4 port DC power splitters to the port labeled “DC12V” on the DVR. Secure the remaining male DC power plug with weatherproof electrical tape.
    4. Connect the yellow BNC connector on each receiver to six of the eight ports labeled “Video In” on the DVR.
    5. Securely tape each receiver to the sides of the “DVR system” bin with duct tape. Receivers should be spaced at least 4 in. apart to reduce signal interference.
    Note: Extreme temperature fluctuations may cause the tape to be ineffective so ensuring proper hold is crucial to preventing footage loss.
    6. To program the DVR settings, connect the 12 V male DC adapter from the charge controller to the yellow AV port on the display monitor and the HDMI cable from the display monitor to the HDMI port on the DVR. Press the power button on both the DVR and the display monitor to ensure the system is working.
    7. Attach the provided computer mouse to the USB port on the DVR; this allows the display monitor to be programmed with the appropriate settings, including the correct date and time (factory settings can be retained for the remaining setting options) Once the settings are adjusted, remove the computer mouse.

8. Set up the cameras in the field.
    1. Place all cameras in marked locations at the nesting site and drive each stake into the ground with a mallet. While driving the stakes in, hold the camera in one hand to prevent possible damage to the camera or loosening of the screws and ensure that each stake is stable before proceeding.
    2. String out one BNC extension cable to each of the six camera locations with the male DC port end at the cameras and the female port end at the “Camera system” bin, and make sure to avoid hitting other nests with the cable.
    3. Plug each BNC extension cable into the corresponding camera female port and use weatherproof electrical tape to seal all connections.
    4. Seal the yellow video ports on both sides of the BNC extension cables with weatherproof electrical tape.
    5. Connect the six BNC extension cables to each of the four port DC power splitters in the “Camera system” bin.

9. Place the lid on the “Camera system” bin and secure with a bungee cord.
10. Return to the DVR system and check the display monitor to view the live footage. Ensure that the videos on the display monitor are clear and accurate and make adjustments to camera placement if necessary.
11. Place the lid on the “DVR system” bin and secure with a bungee cord.

3. Review the Video Footage.

1. Remove the hard drive from the DVR in the field by unplugging both the data and power Serial Advanced Technology Attachments (SATA) from the hard drive. If data collection is ongoing, replace the hard drive with a different one.
Note: Removing the hard drive will reset the settings on the DVR system. To reset them, repeat steps 2.7.6 and 2.7.7.

2. Set up the video review devices.
    1. Plug the DVR into a power source with the provided power cable.
    Note: If video monitoring is still in progress, footage can be reviewed using a different DVR from the one established in the field. This would require purchasing a second DVR.
    2. Connect the DVR to a computer monitor by attaching an HDMI cable to the respective HDMI port on both devices. If HDMI cables are not available, VGA cables can be used to connect the DVR to a computer monitor.
    3. Connect the hard drive to the DVR system by plugging in both the data and power SATA cables. Once connected, set the hard drive in the DVR box and close the lid.
    4. Attach the provided computer mouse to the USB port on the DVR. This allows interaction with the program on the monitor.
    5. Turn on both the monitor and DVR. This should cause the system logo to appear while the system is initializing.

3. As a blue pop up box will appear, right click the mouse anywhere outside of the pop up box to close it. A screen should appear with nine rectangles, eight of which should display the system logo in the center.
4. Right click anywhere on the screen. A pop-up box will appear with the following options: View 1, View 4, View 8, View 9, Pan/Tilt/Zoom, Camera Setting, Info, Sequence, Disable Beep, Search, Manual, and Main Menu.
5. Click **Search**. A blue pop-up box will appear titled, “System Login”.
6. As the system will generate the automatic username (admin) and password (000000), enter the password in the provided field using the on-screen keyboard and click **OK**. The username and password can be changed at any time within the settings.
Note: A screen will appear with a long rectangle at the bottom and a calendar on the right; dates with recorded footage will be highlighted in bright blue; all other dates will appear dark blue. Click the date of the video to be reviewed. Once clicked, the bottom of the screen will change to show recorded footage for the day in yellow.
7. As the DVR records footage for all six cameras on six separate channels, press the single grey rectangle under the calendar to review footage from one camera at a time. This causes a pull down menu to appear with a list of channel numbers; select the appropriate channel.
8. To view the footage, press the play button (triangle pointing right). To skip to a specific time on the video, click on the appropriate time on the recorded footage rectangle at the bottom of the screen.
9. To play faster than real time speed, press the fast-forward button (double triangles pointing right). Each click will speed the footage up by 1x speed; footage can be viewed up to 4x speed before the fifth click returns the footage to a normal playing time.
10. To pause the footage, press the pause button (two parallel lines). This will save the place in the footage but stop the playback.
11. In order to switch footage, press the stop button (square); this will reset the footage and display. Once the main display is black, the calendar and channel pull down menu can be clicked to change the footage.
12. To close the program, stop the footage and right click anywhere on the screen. This will cause the program to return to the main screen of 9 rectangles. Power off the monitor and DVR system.

Representative Results

The implementation of this video monitoring protocol will result in continuous datasets of footage from five waterbird nests at close range and one set of footage of the entire colony from an elevated vantage point. A successful use of this system will minimize time where the footage is out of range or displaying a poor-quality image and will maximize time where the footage is of high quality (**Figure 2**; **Figure 3**). Cameras were installed on Poplar Island over the summer 2017 on nests with one egg because adult terns do not begin attending their nest regularly until a complete clutch (2-4 eggs) is laid[24]. Installation time averaged between 1-2 h, including both time inside the colony setting up the "Camera system" bin and time outside the colony setting up the "DVR system" bin. By installing the camera monitoring system prior to regular nest attendance, adult terns were given time to acclimate.

The fully functional electronic system resulted in the collection of 3,120 h of footage from 8 nests and 504 h of footage from one colony camera (**Table 1**). The nest count is more than five in this case because cameras with failed or successfully hatched nests were removed and reused for re-nesting attempts later in the season. Footage was recorded over 63 days in weather conditions ranging from 55 °F to 95 °F. Of these 3,624 h of footage, 3,006 h (83%) of footage contained usable data and 618 h (17%) of footage was out of range. Because the DVR system has a 2 TB capacity, the hard drive was replaced every 10 days. Signal interference was the primary cause of signal loss, though reduced charge on batteries and camera interference also contributed in small amounts. Footage obtained was sufficient to differentiate food items and nest markings, but insufficient to read numbers on the size 2 metal USGS bands. Behaviors such as feeding, incubation, nest maintenance, and preening were observed by adults on the nest level cameras and flocking and disturbance were observed by adults on the colony camera.

	Total Footage (h)	**Total Nests**	**Season Length (Days)**	**Lost Footage (h)**	**Usable Footage (h)**	**Percent of Footage Usable (%)**
Ground Nest Cameras	3120	8	63	508.52	2611.48	83.7
Colony Cameras	504	1	63	109.82	394.18	78.2

Table 1: Overall video footage collection data for the 2017 nesting season. The following data was recorded during the 2017 common tern nesting season on Poplar Island in the Chesapeake Bay, Maryland.

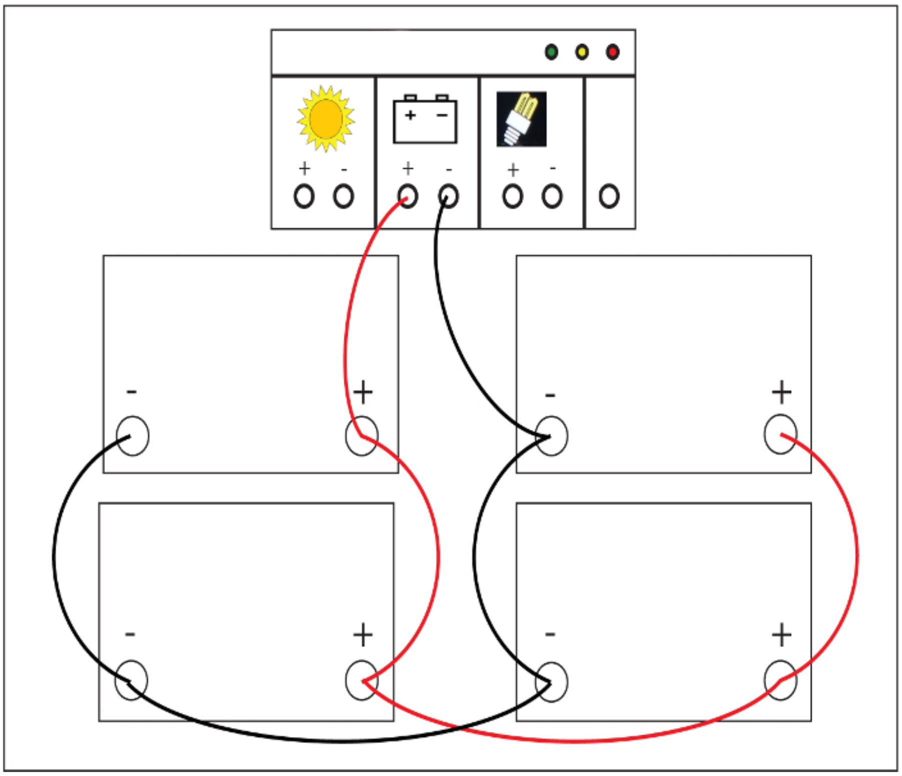

Figure 1: Schematic of Parallel Battery Wiring System. A simplified diagram depicting the parallel wiring structure for the DVR system. The charge controller is depicted at the top with four car batteries forming a 2x2 pattern below. Please click here to view a larger version of this figure.

Figure 2: Visual representation of video footage quality. A. High quality imagery with no signal interference. **B.** Poor quality imagery with lines denoting signal interference. **C.** Out of range imagery denoting lost footage. A successful use of this system will maximize high quality footage and minimize both poor quality and out of range imagery outcomes. Note that B was captured from a separate trial location as opposed to A and C, which were captured on Poplar Island. Please click here to view a larger version of this figure.

Figure 3: Visual representation of video image from colony camera. Example of high quality imagery from the colony camera on Poplar Island. Please click here to view a larger version of this figure.

Discussion

Monitoring waterbirds can be disruptive, and investigator disturbance while monitoring waterbirds has been linked to nest abandonment and decreases in reproductive success[12,13,14]. The protocol presented here offers a minimally invasive monitoring approach that allows researchers to establish and document the nesting behavior of ground-nesting waterbirds through continuous video footage.

Because this approach is minimally invasive, it requires a significant amount of initial labor to ensure the system operates smoothly when no researchers are present. One concern for researchers attempting to utilize this method is the maintenance of power required to charge the car batteries. The system presented here utilizes three solar panels for the DVR system and one solar panel for the camera system; however, maximum power output on solar panels varies based on latitude and time of year due to changes in day length and angle of the sun's path. We recommend testing all equipment prior to field use and verifying the correct angle for maximum sun exposure based on the location. There are several nonacademic user-friendly online sources to assist in determining optimal angle[25,26]. This test should occur in an area comparable to the intended site without impacting the target species. If the test run indicates that more power is necessary, the methods can be altered to add an additional solar panel to either the DVR or Camera systems.

During the initial establishment of this protocol, we encountered a number of challenges that required additional consideration and scrutiny. One such challenge was the maintenance of signal strength. The display monitor would consistently read either "out of range" or present data with a lot of noise for a number of cameras, demonstrating either a loss of signal or signal interference. Once we were confident the camera system was within range of the receivers and there were no objects obstructing the sightline, we began troubleshooting for alternative causes of signal interference. The biggest source of signal interference proved to be the placement of the receivers with respect to one another. According to the manufacturer, the receivers must be placed at least 4 in. away from one another to reduce interference[27]. If this is implemented and signal interference is still occurring, or there are too many objects obstructing the sightline, then receivers can be mounted to tall pipes in an effort to raise them above potential sources of signal obstruction. Alternatively, the wireless cameras could be replaced with wired cameras to ensure a strong connectivity. However, this would require a different cable system.

Additional considerations include weatherproofing all connections, ensuring the stability of the cameras and confirming receivers are properly secured. This system is constructed outside, and sand as well as moisture may enter the connections and cause corrosion. Protecting all connections with waterproof electrical tape will reduce the amount of corrosion and increase the longevity of the system. Along with sand and moisture, wildlife can also impact the system's longevity. During the establishment of this protocol, great horned owls were seen knocking cameras over multiple times, and COTE were often seen sitting on the colony camera, actions which can lead to data loss and damaged equipment. To reduce wildlife interactions, we recommend verifying the solidity of the camera placement in the ground prior to initializing the experiment. One possible adjustment could be the addition of rebar to the wooden camera stakes. Temperature may also have a significant impact on this system. Extreme temperatures can weaken the duct tape securing the receivers and may cause them to fall to the bottom of the container, resulting in lost footage. As a result, we recommend ensuring a strong receiver placement prior to deployment of the system. If extreme temperatures are common and/or a more secure attachment is needed, alternative attachment methods, such as a bracket system attaching each receiver to the bins, can be used. However, this would require more tools, labor and cost to establish.

This video monitoring protocol is limited in both location and monitoring potential. The staking system described here has been successfully tested on both sandy and semi-rocky terrain; however, it may be hard to set up on certain substrates such as rocky outcrops. This limits the potential use of the system to specific terrain. To bypass this problem, alternative staking methods suitable to the target terrain can be developed for the principal system, giving it a broader location potential. The monitoring potential is also limited by the finite scope of the infrared camera at night. Although this system utilizes a colony camera to see more of the colony than what is visible from the nest level, the infrared light does not fully extend across the colony and it is difficult to distinguish more than shapes outside the light range. As a result, the colony camera is very limited in its ability to provide insight into predation and overall colony patterns at night without the addition of external infrared lighting systems.

While the system described herein is for ground-nesting waterbirds, the principal system can be altered for other species, making it widely applicable to documenting the behavior of many target species. For example, for species that lay one egg, such as the Laysan albatross, researchers would need to install the system at nests at the time of nest construction to ensure the system is established prior to regular nest attendance. It is also critical to assess the target species tolerance towards the camera equipment before setting up the system, as this could limit effectiveness. This method enables researchers to collect data remotely with minimal disturbance and will allow researchers to continue documenting common tern nesting patterns and to expand remote monitoring efforts to many other species. It is our hope that this development can be utilized among the research and management communities to not only improve data collection, but also to reduce the impacts monitoring efforts have on the species we aim to protect.

Disclosures

The authors have nothing to disclose.

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