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Thousands of Images and the Big Picture: Site-specific Long-term and Seasonal Bird Assessments Using Wildlife Camera Trapping and Automated Object Counting in Remote Locations

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Abstract. Reliable assessment of long-term bird utilization and relative abundance remains a challenge on active airfields. The costs and data reliability compound for remote airfield locations. Recent improvements in wildlife camera trapping techniques and image processing, however, holds the promise of effective long-term, low-cost, and semi-automated monitoring. This paper presents the preliminary results of baseline monitoring of a 23-hectare retention pond at Marine Corps Air Station Iwakuni/ Kintaiyako Airport in Yamaguchi Prefecture, Japan. Using an array of wildlife cameras, we captured images of the pond every 30 minutes throughout the day and night. Images were then processed using machine learning techniques to provide counts of objects automatically identified as birds on the pond surface, with each count time stamped. The intent is to provide BASH stakeholders with site-specific seasonal and long-term trend information, assess efficacy of deterrent strategies, and relieve or reduce monitoring efforts for on-airfield BASH technicians so they can focus on deterrence. Although this paper focuses on the level of effort to deploy a camera-based monitoring system at a remote location and the analysis of large numbers of images, we discuss a number of recommendations to improve the utility of the field data, such as: (1) pairing of cameras with acoustic recorders, (2) cellular/satellite image uploads for further data integration, and (3) camera orientation and settings in the field to move from bird counts to actual species identifications.

I work as a contractor for the Navy at Marine Corps Air Instalation Iwakuni. It is in Japan in Yamaguchi Prefecture if you are familiar with the region at all. It is located on the Seto Sea which is between two of the major islands in Japan and creates a major migratory funnel if you will through the migration season (Slide 2).There are also numerous other factors that contribute to the installation risk profile. We completed the wildlife hazard assessment for the installation last year (2018) and we identified a number of major aggregating features that tend to concentrate birds for one reason or another.

One of those places is the north retention pond (NRP). It is a large retention pond that is very close to the takeoff area of the runway. It is just to the west of the runway. What we are starting to do now is to monitor the efficacy of the BASH team interventions that have recently come on-line there and monitor the efficacy of an acoustic deterrent that we have going on right now too. In addition, we want to compare what we have done through the monitoring studies through the wildlife hazard assessment with another round of monitoring, but we also want to use wildlife cameras for in-depth surveys and that is what this presentation is primarily about.

The north retention pond is a very important spot that we are focusing on (Slide 3). It is a 54 acre (22 ha) retention pond. It is adjacent to the take-off area. It is a foraging area for large numbers of birds – very high-risk species like our cormorants, herons, egrets, hawks, Ospreys – it attracts Black-eared Kites which is like a vulture-niche type of bird. It comes in and will eat up some fish that have died in the pond and such like that.

The pond itself has a variety of depths. There are exposed mudflats when the water-level is low. The are deep water habitats where you get a nice mix of fish when the water levels are high. It is a seasonal water level too. In the winter the water level is low and in the summer, during the agricultural irrigation season the water level is quite high because of the outflows from agricultural sites.

It is an important part of the network of bird movements on the installation. Here is just a few pictures of what we have at the NRP (Slide 4). Mudflats you see, there is a large carp here, maybe 2.5 feet long. There is another carcass that Black Kites have worked to the bone. At one time there was Phragmites forming some nice reed habitat; that since has been removed. That is no longer present in the mudflats, but the mudflats do provide some nice habitat.

For a close-up picture (Slide 5), here is our Osprey, cormorants and this here is one of our most challenging birds -- the Black-eared Kite, and Spot-billed Ducks and different waterbirds. Part of the wildlife hazard assessment is to – what we want to do is to construct some conceptual ecological models of different bird species groups (Slide 6). Mainly we want to highlight the importance of this square here. There are a lot of vectors that go to the NRP for raptors and for waterbirds. So if we can break that linkage and deny habitat in those areas we want to test ways to do that.

Here is just a general view of the assemblage of birds throughout the season (Slide 7). It is typically what we might see in North America. Your red line is your raptors coming in for migrations and your grebes and ducks have a high peak in your normal migration season that you might see pretty much anywhere. The idea is to develop whatever is happening on the base now, with the BASH team or whatever deterrent technology that is being deployed out there is to flatten these lines and lower them down.

What do we want to do at Bird Strike 2019 (Slide 8)? We want to provide an overview of the risk profile at the installation. We have done that already. We want to present field methods for monitoring remote locations using our index and wildlife cameras. We have a number of them out there right now. We want to go through the overview of the methodology that we are using to count birds in the thousands of images that we are collecting. We are going to go through the methods that do this in a semi-autonomous way using a software platform called MatLab. Is anyone familiar with that software platform?

Here is just a basic overview of the wildlife cameras (Slide 9). We are using Reconyx cameras. Are you familiar with Reconyx cameras? Those are our go to cameras for our projects. Great quality. We are capturing images every 30 minutes. It is just on a time lapse so later we can go back in and sample out different time intervals of that if we want, but you can never add once you selected a too far interval, but we can always subtract if we need to. These cameras are deployed in a way to capture different habitats of the NRP and to see what we can do to build some index surveys. Slide 10 is just another picture of our camera deployment.

Slide 11shows where the magic happens. This is our BASH shed. We use a workspace that we have availability to at the installation. These are wildlife cameras. I think they are kind of cute. Yes, here is a picture of them. They are ballasted at the bottom with 25 kg of gravel just to weigh them down. There is a daddy longlegs deterrent on top. The last thing we want to do is to put something out there to count birds that attracts birds to perch on. You can buy these with the cameras – it is just a pole mount for Reconyx cameras, but you can also make those in a pinch with some butterfly nuts and bolts and stuff.

This is our first camera that we have (Slide 12). It is looking out onto a wide area of the NRP. This is in some high water. When this goes down, this area is a nice spot of mudflats. This is our second camera (Slide 13). This is in a narrow section of the pond. It focuses on a very shallow area – predominantly shallow area of the pond. And this is a third camera that we have in one of the airfield ditches that collects water (Slide 14). One of the great things the installation is doing for removing the freshwater habitat that accumulates at the pond.

So we are doing a project in Japan and I thought it would be appropriate to have some Japanese cartoons in it (Slide 15). What are we going to do with all these pictures? This is a problem. We have one picture every 30 minutes. That is 48 pictures per day. Three cameras. That is a lot of pictures. In fact this guy does the math, it is 51,840 pictures over the course of the monitoring year. What do we do with that? Sometimes you have to look for the mother of invention. Necessity is the mother of invention, right? This is the mother of invention in this allegory. There actually is a Manga cartoon called "maternity ward" (Slide 16). You can buy volumes of it and I have. It is really funny.

How do we do it? What is our tool? That is when we have to look at our tools. MatLab (Slide 17). Some of you are familiar with it some of you are not. If you are not, it is a platform to analyze data, algorithms, you can do images, image analysis. It involves the processing of images into fundamental components to extract meaningful information. The image analysis can include tasks such as finding shapes, detecting edges, removing noise, counting objects – that is what we are doing – calculating statistics for texture analysis – maybe in a remote sensing type of scenario.

It is a broad term – image analysis – that covers a range of techniques that can fit into some sub-categories. We actually practice a lot of these. There is image enhancement, image segmentation to isolate regions and objects of interest and noise removal – the stuff that you don't want using some kind of filtering morphological filter. There is region analysis to extract statistical data.

MatLab is so cool if you get into it because there are these function lists that are just ready to go. You can display boundaries. You can detect shapes, edges, gradients and homogeneous blocks. We are using all of those tools within the MatLab platform to analyze each one of these in a way that does it rapidly in a large data set.

I am going to go through broadly the steps. I have committed to writing just a short paper that will have some code in it, but I wasn't going to show code in a Powerpoint slide because that is not right. Your first step – you need some way to read images and MatLab has a great programing block you just point to some directories and it will load all the images in (Slide 18). The second step is to convert these images to a gray-scale image. That is important because now you are starting to define the image as something that is manageable. Then you can adjust the image intensity and then you move on to determining the background. Once you determine the background you can subtract that background so you are finding the items of interest. Then you can convert that image into what we call a binary image or define pixels for different kinds of blocks so you can count those collections of pixels. What we also did is we eliminated any blobs that were blurring our region of view. That is a standard practice when you are counting things in MatLab just so you are not over-counting or under-counting. There is a programming block just to drop in to trace the boundaries of what you are identifying and then you need to correct for any overlapping blobs that you teased out so you can count those as multiple birds instead of just one bird. Then you separate those blobs out – it is called segmentation and then you run a count algorithm and your output per image has a count assigned to it.

If that was just what MatLab was used for that would be very limited capability of the program. There are lots more programming blocks that you can use. One of them is machine learning where you can create a semi-autonomous way of counting all these birds in the image so that you can process lots of images and train it to do better each time. It is an iterative process.

I highlighted these first three steps in green (Slide 19) because if you have done this process in the previous slide, you have done these three steps already. You figured out a way to tell MatLab what to process. You preprocessed the images and you derived the features using the preprocessed images counting the features. Now we get into these red steps for the machine learning part of MatLab. The robust part of MatLab. Step 4 is you train the models using birds counted in Step 3. So you are saying basically – I will show you an example in a second – maybe the program has counted a reflective pixel that is not a bird so you don't want to count that, you need to tell MatLab not to count that. And the following steps are to iterate again and then you are finding this best fit where you are comparing the manual count where you know the number of birds on the image with your output. You are just continuously training the algorithm to do that and MatLab has a very sequential way of doing that. And then just for best practices you want to track those iterations so you could rerun the whole dataset so you are not comparing apples to oranges – version 1 of counting method versus version 2 of counting method. Are you still with me?

Let's look at a picture (Slide 20). These circles with lines – some of these are birds and some of these are not birds. For the sake of expediency I have labeled the ones that are birds. Now some of these blobs will overlap so you need in those steps that we went over you need to tell MatLab to not count multiple blobs as birds. When I run the first iteration of MatLab I get 12 birds, but if you count the birds there are really actually only 9. There are a couple of items here – some reflective pixel areas that are really from this tower – they are counted as birds. We want to tell MatLab not to count those. It will learn not to count those based on its position and just different ways to tease out the pixels from the background image. So using the machine learning steps you iterate and you get closer to the actual count. Then you can apply this model to many of the other pictures and still iterate. Here is another photo that is in an earlier part of the day (Slide 21). This is at dawn in the morning – 6:30 in the morning. Again we have the same problem. Here is an interesting one with overlapping blobs that we need to make sure we can train this to not count as one giant bird – Godzilla bird.

What are our next steps (Slide 22)? We have more data to collect. We have eight more months of collecting photos. We are re-iterating with what we have and tuning it as we go as we collect data. Then finally, towards the end when we have a great collection of photos we will be able to process it quickly. We would like to have these in lots of places too. You can also integrate these with other information possibly using the power of MatLab for predictive modeling. There are data sets that you can integrate in. Tidal flows that have a great influence from what we have seen being out there – currents of birds on the installation. Low tide – the mudflats are exposed in the surrounding waters outside the installation. High tide comes in and birds have nowhere to go. Where do they come? North pond and other places on the installation. There is other information you can integrate in that does nicely with other program modules in the software. We also want to just continue to fine-tune the field methods that would aid in the image processing steps.

I will go back to this photo real quick (Slide 20). Maybe positioning this camera in a better way where we are not getting reflection. Maybe over here going this way or orientate the camera in some way where we are reducing areas where we might have errors even when we can re-iterate those out it is just an extra step of identification. That is a consideration if you are ever doing a large collection of images with wildlife cameras that are time stamped - to greatly consider your position at different times of the day, different times of the season.

We are demonstrating a semi-autonomous approach for processing time-lapse camera-trap photos (Slide 23). It has a capacity to reduce the monitoring burden of people on site. It won't ever replace humans because all this counts is birds. It doesn't count different species of birds. We are not there yet. I am not there yet. There might be some other technology out there that can do that, but that is certainly not in my capabilities as the MatLab person, or what I have seen in the software for birds at distance. If they are closer, sure, there are some algorithms you can plug into to identify species. But at a distance, that is a tough road to plough. What we wanted to do was show that this could be a cost effective approach, not to inventory birds, but to have index surveys. The purpose of an index survey, especially out in a place where it is hard to get to, you can't be there all the time, with index surveys with the robot collecting images over and over and over again is that you can gauge success of BASH interventions and programs like that, or figure out what is going on across the airfield in terms of where the birds are moving at different times of day. The power of MatLab (I am not a salesman for MatLab, there are other ways to do it), the power of that is you can tease that information out.

I want to thank the people that are working on the installation. We have personnel from Iwakuni and the CNIT (?) BASH program and I have worked with MatLab technical support to develop some algorithms too.

Parting thoughts (slide 24). You know BASH, I am always impressed with these conferences because it is an entrepreneurial activity. Is anyone actively working on airfields? You guys are out there working the problem, you are figuring it out. You are like Matt Damon and the Martians sometimes – you have to deal with what you have and [inaudible]. What I want to convey is that most of those innovations in the BASH world happen from you guys out on the airfield just thinking about things. You are up at night. How can we do it better? It can also happen that new tools at night through a computer screen, That is just where we are at with technology. There have been more presentations here than I think at any other BASH conference in terms of looking at data and these two entrepreneurial thoughts on the airfield and off the airfield I think can translate to some good results eventually.

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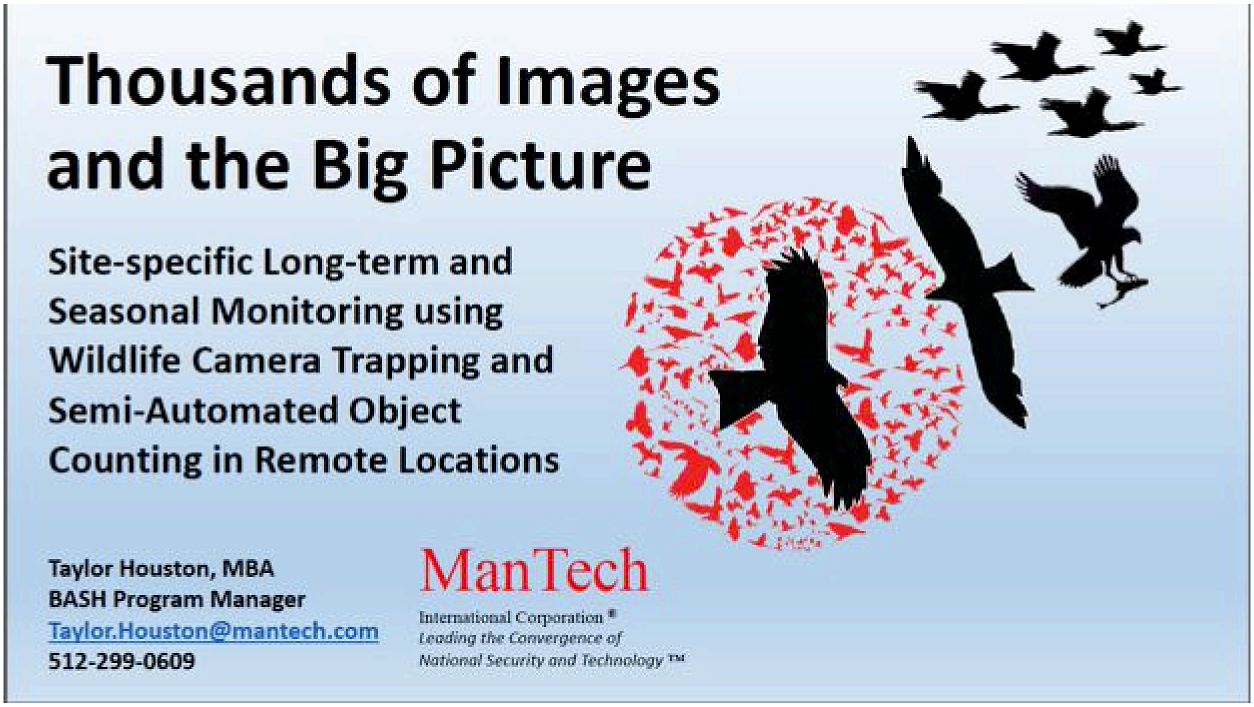

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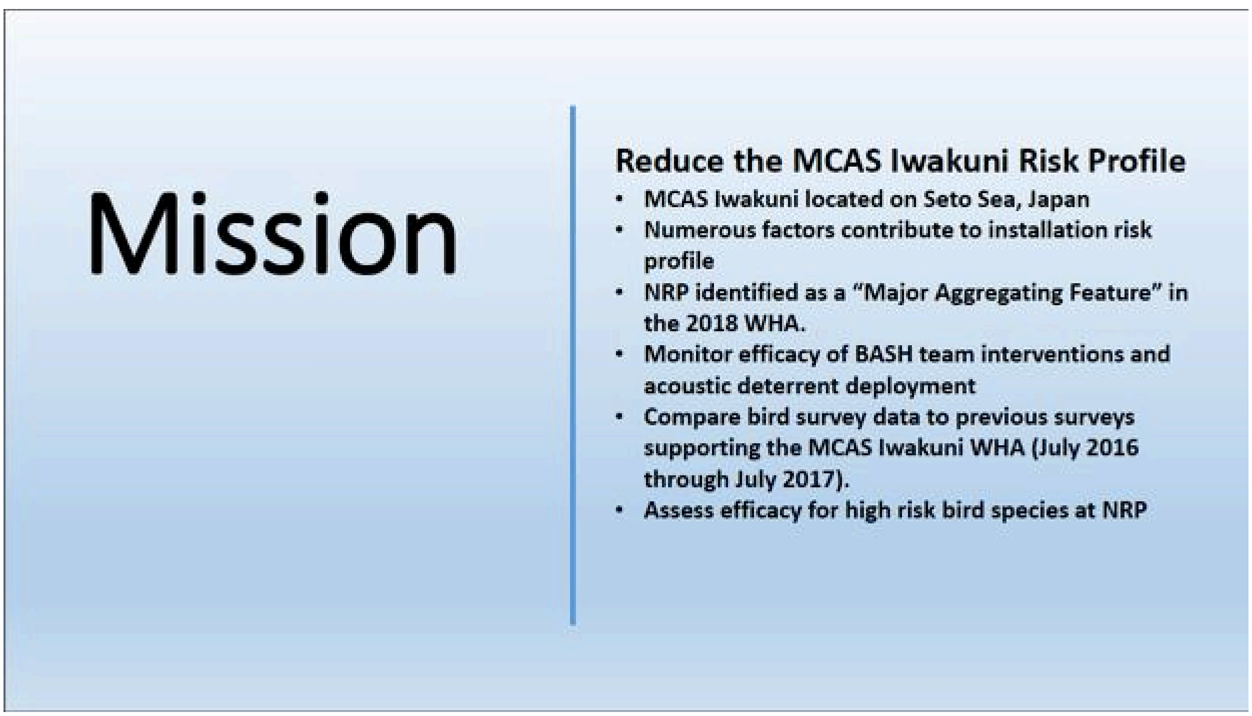

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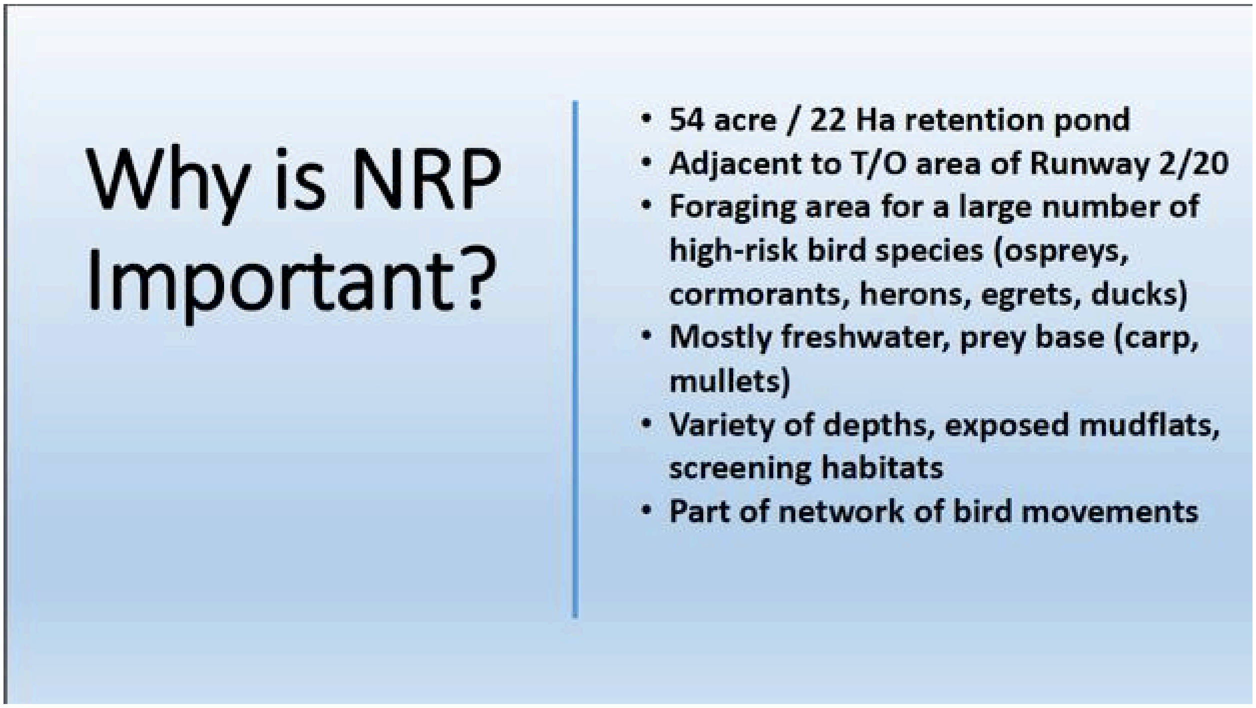

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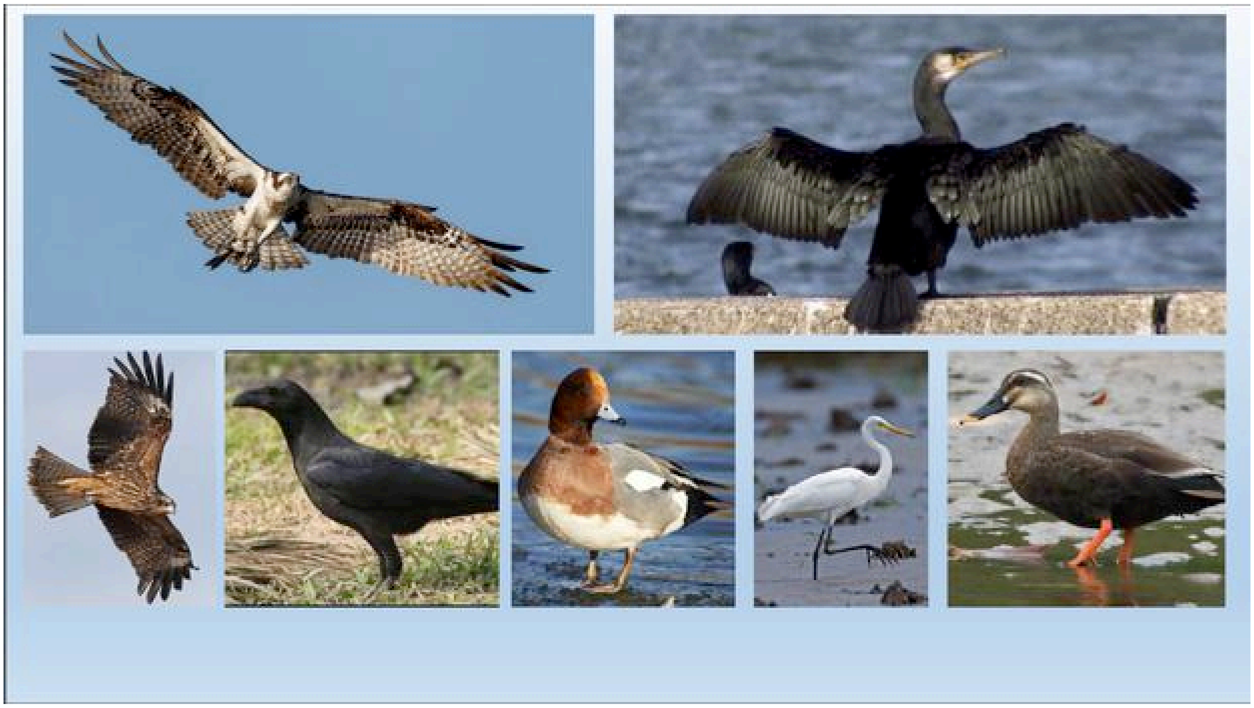

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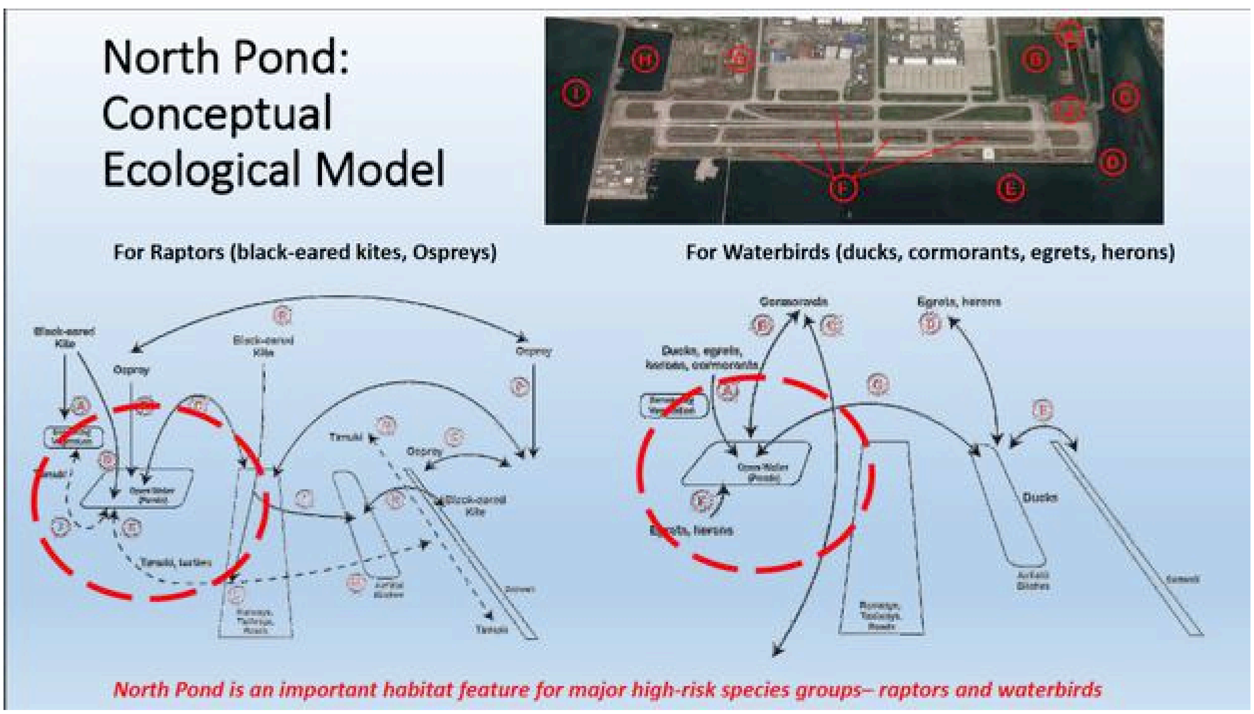

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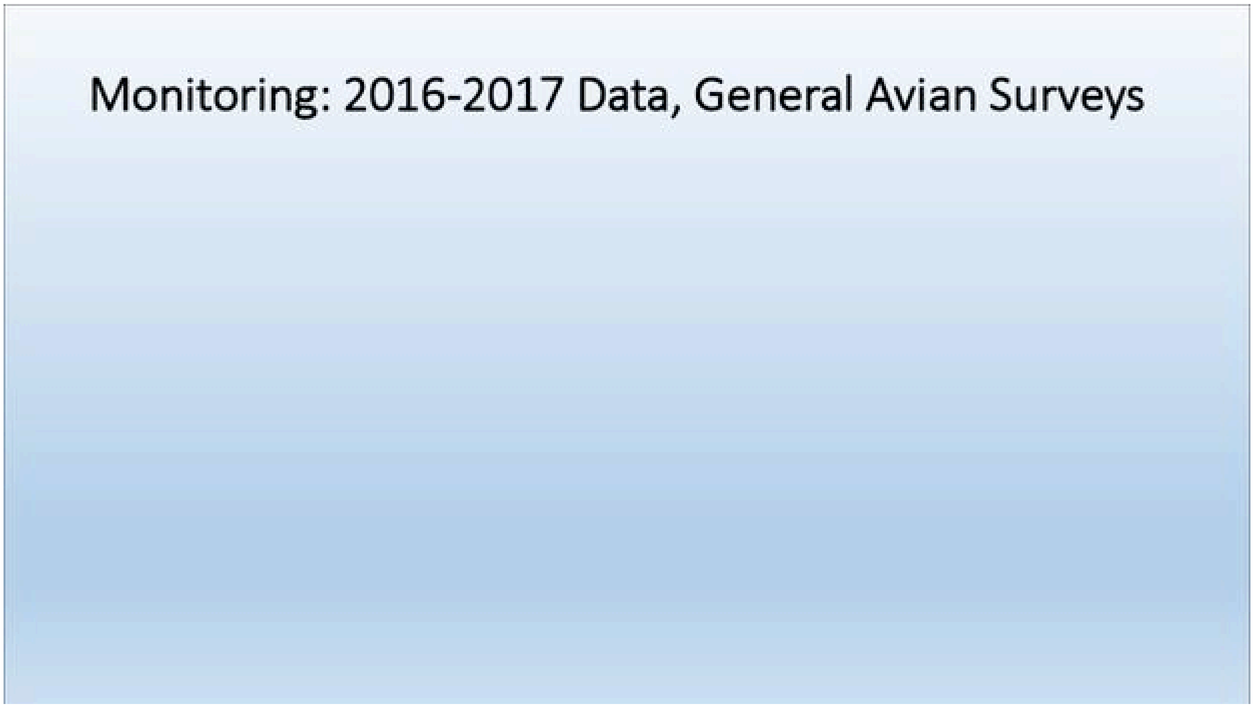

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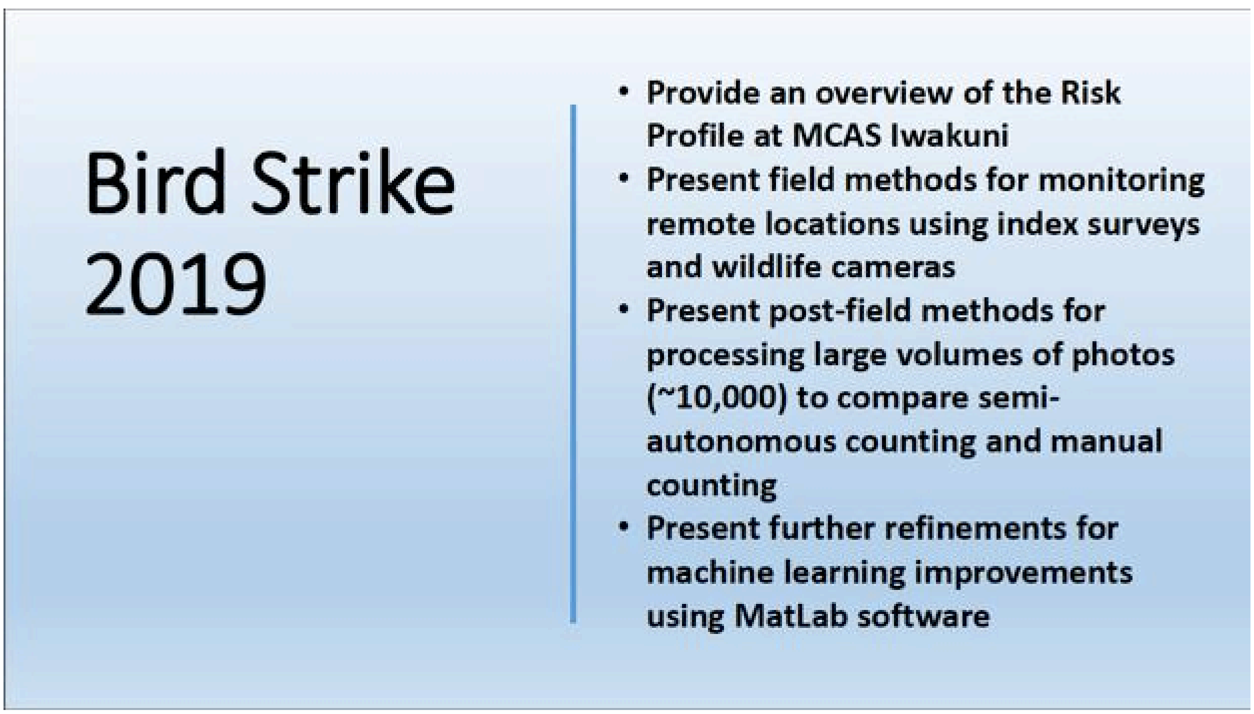

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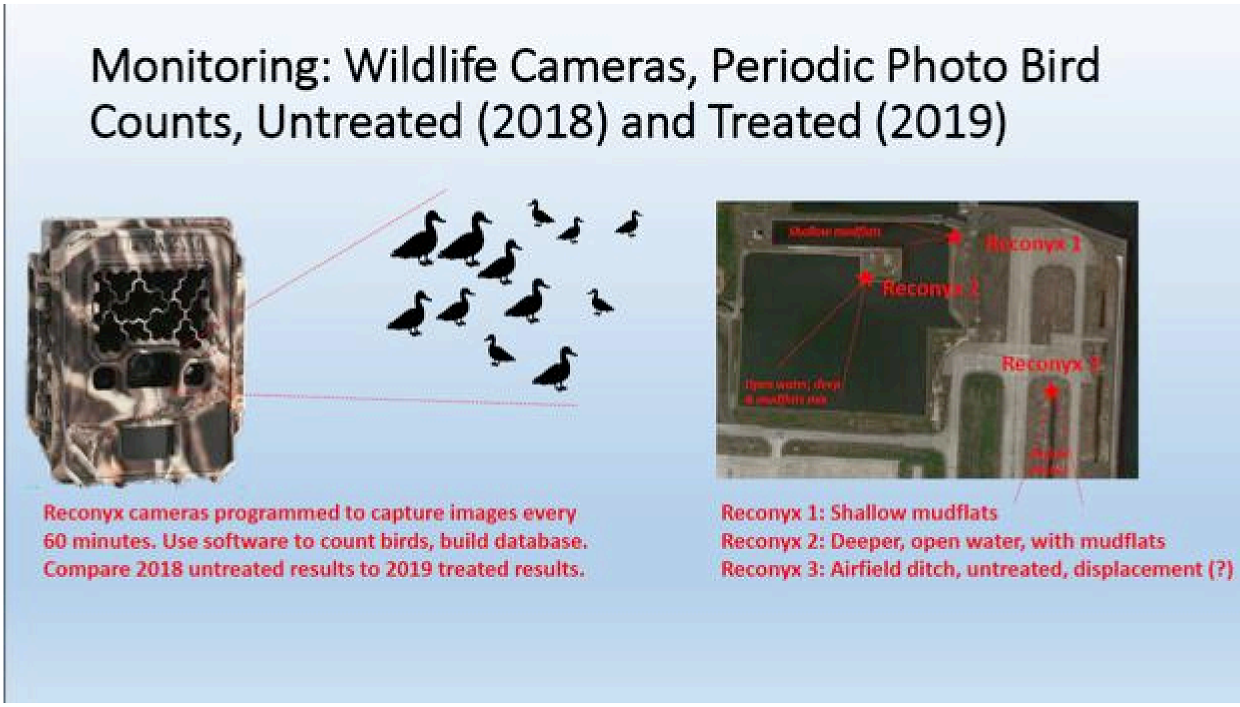

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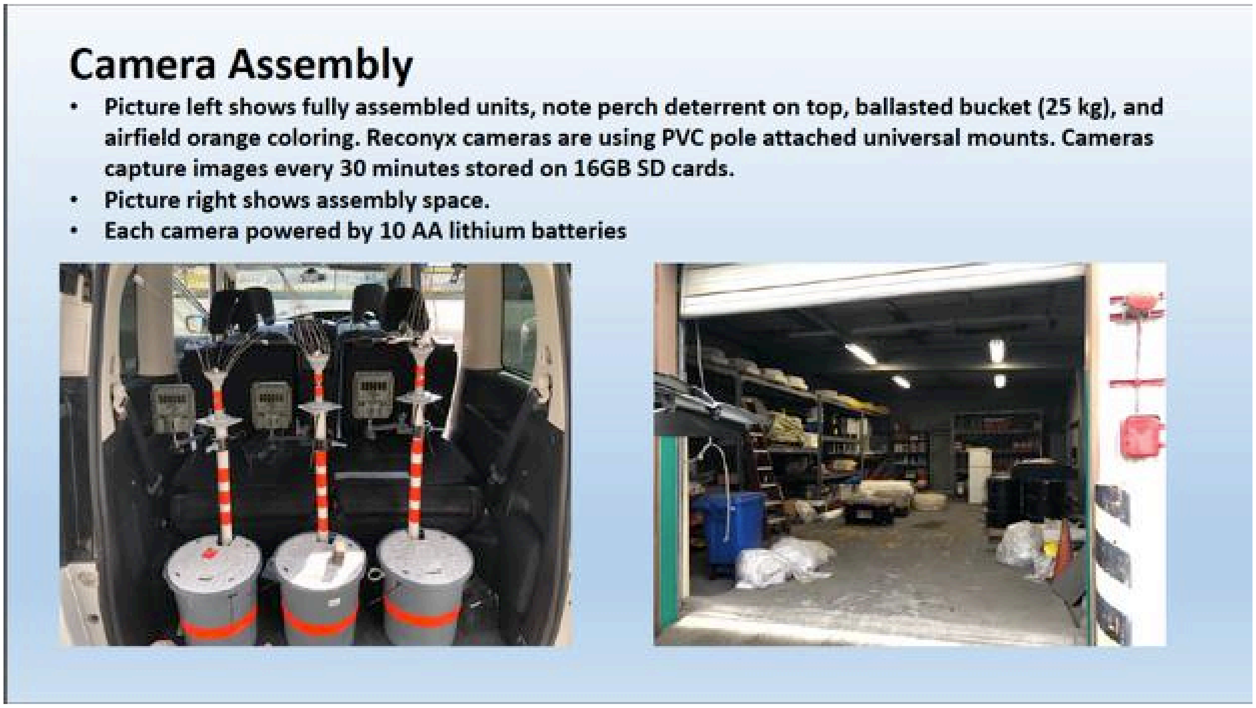

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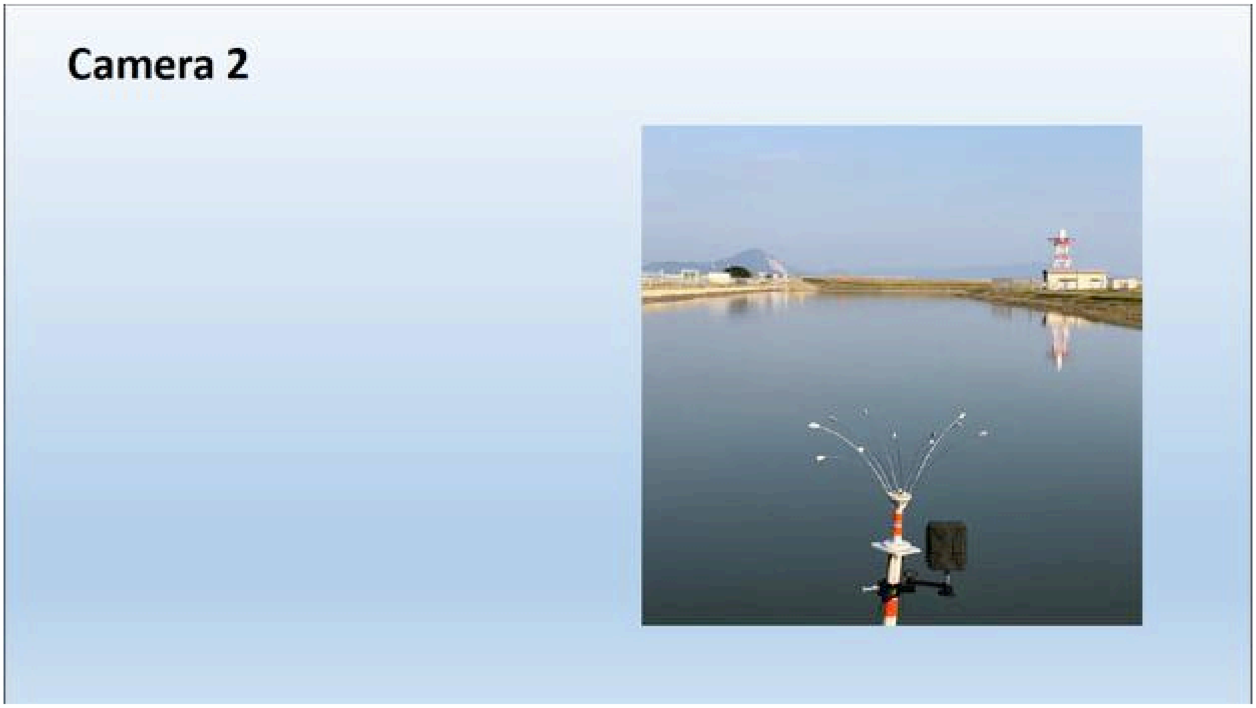

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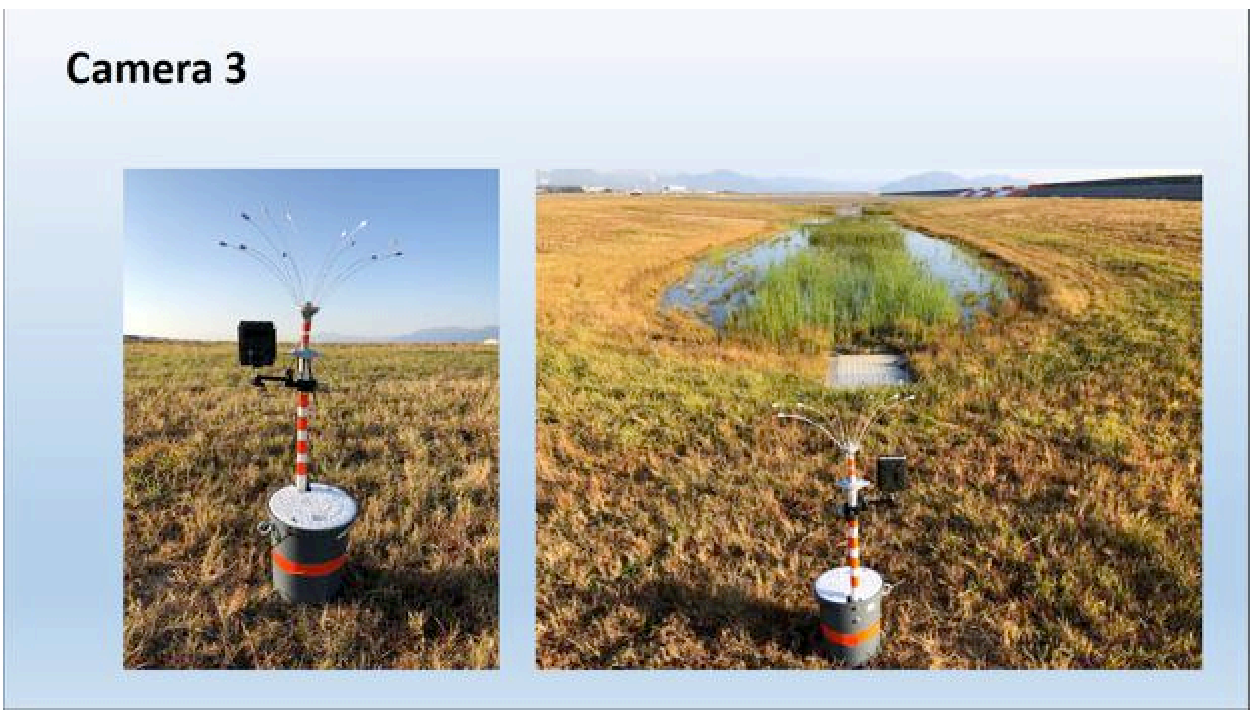

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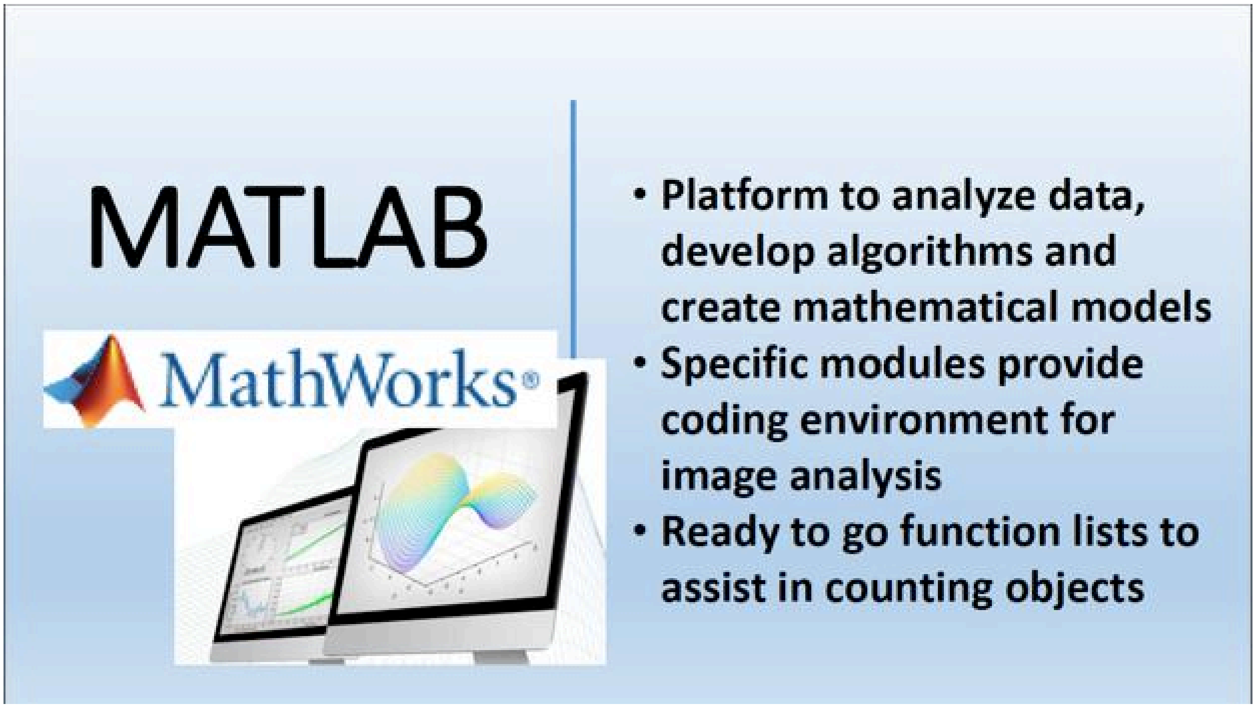

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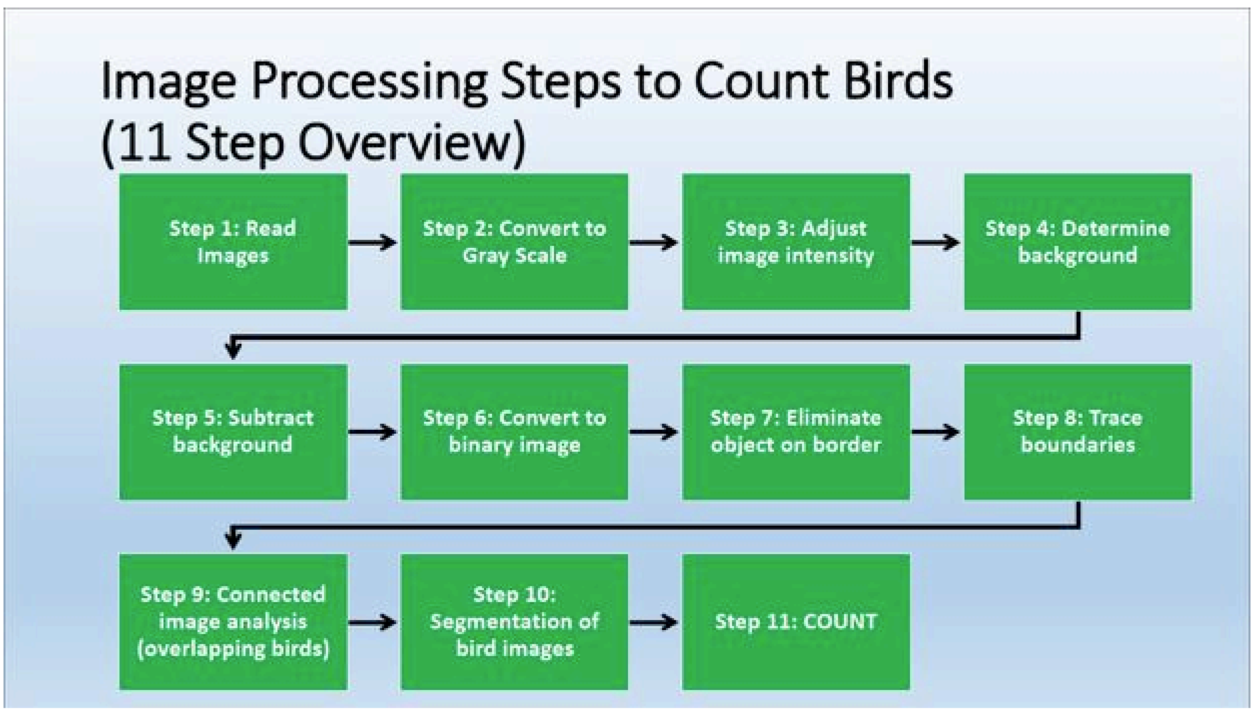

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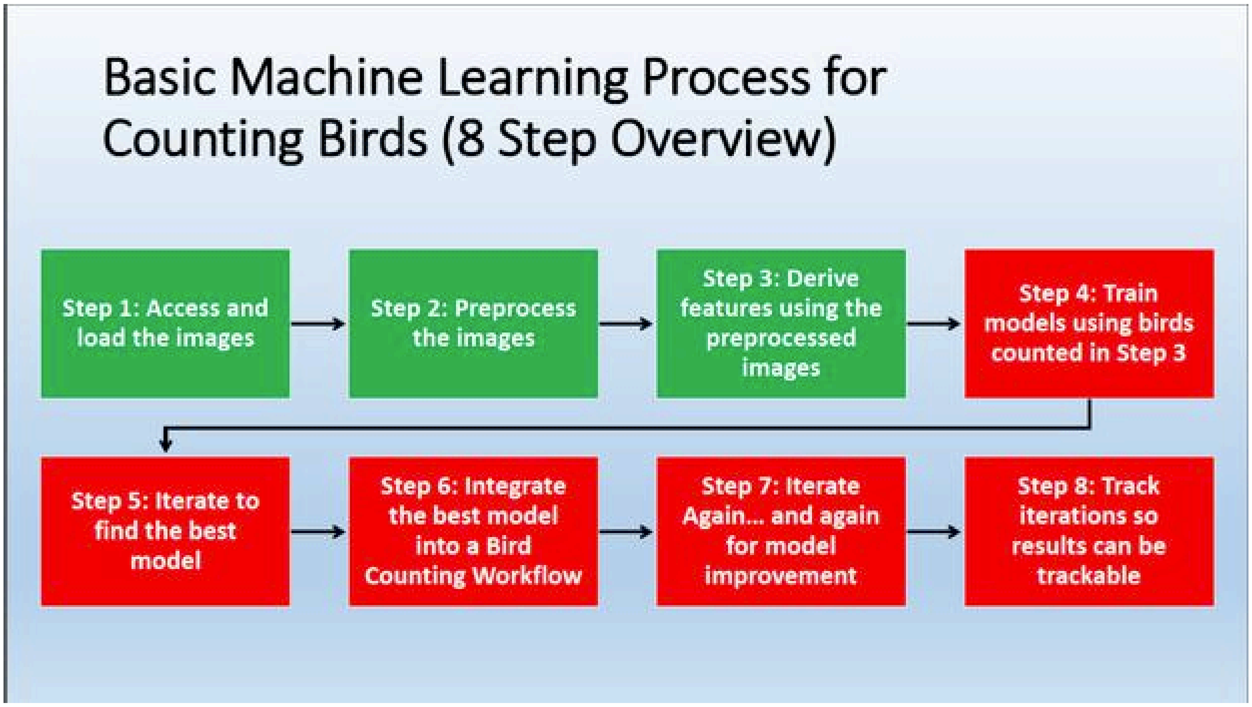

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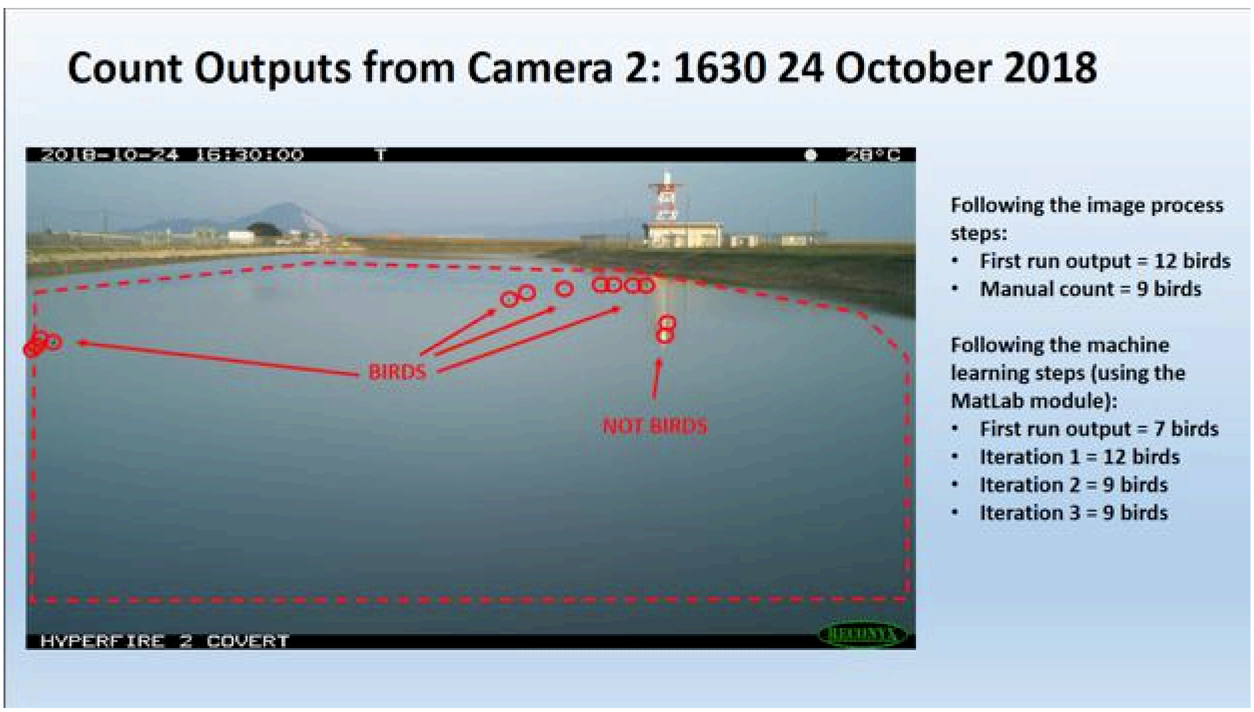

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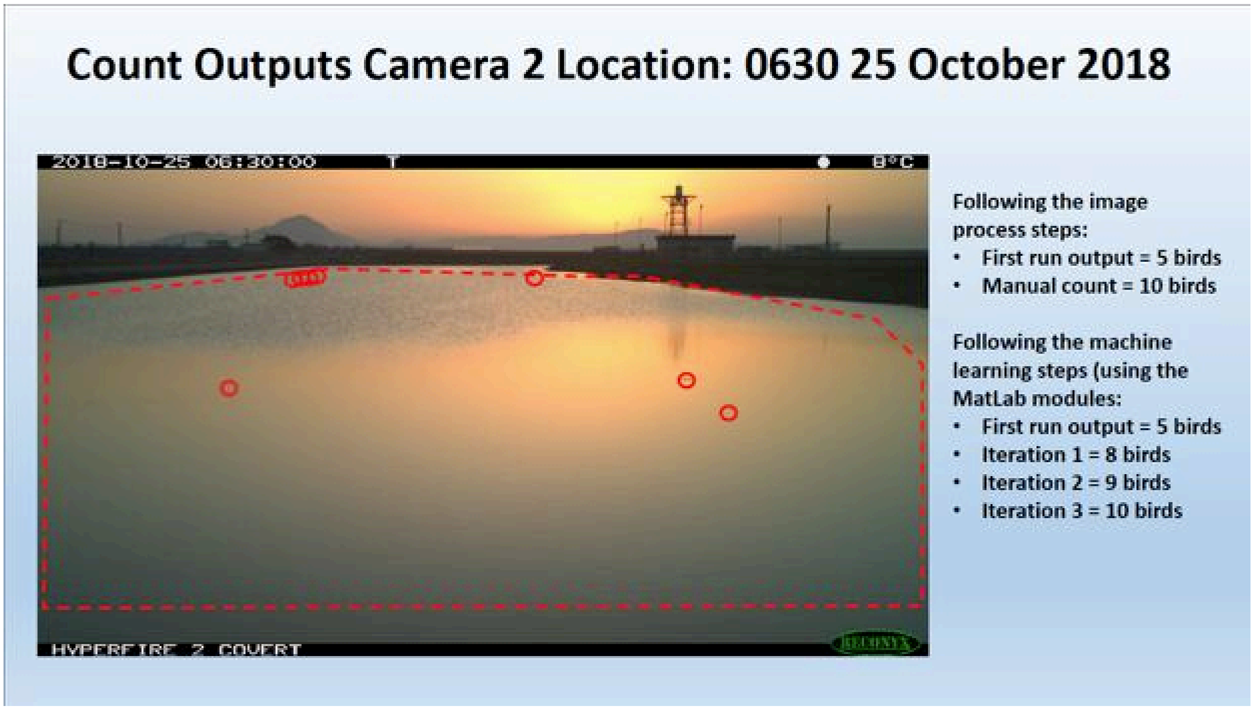

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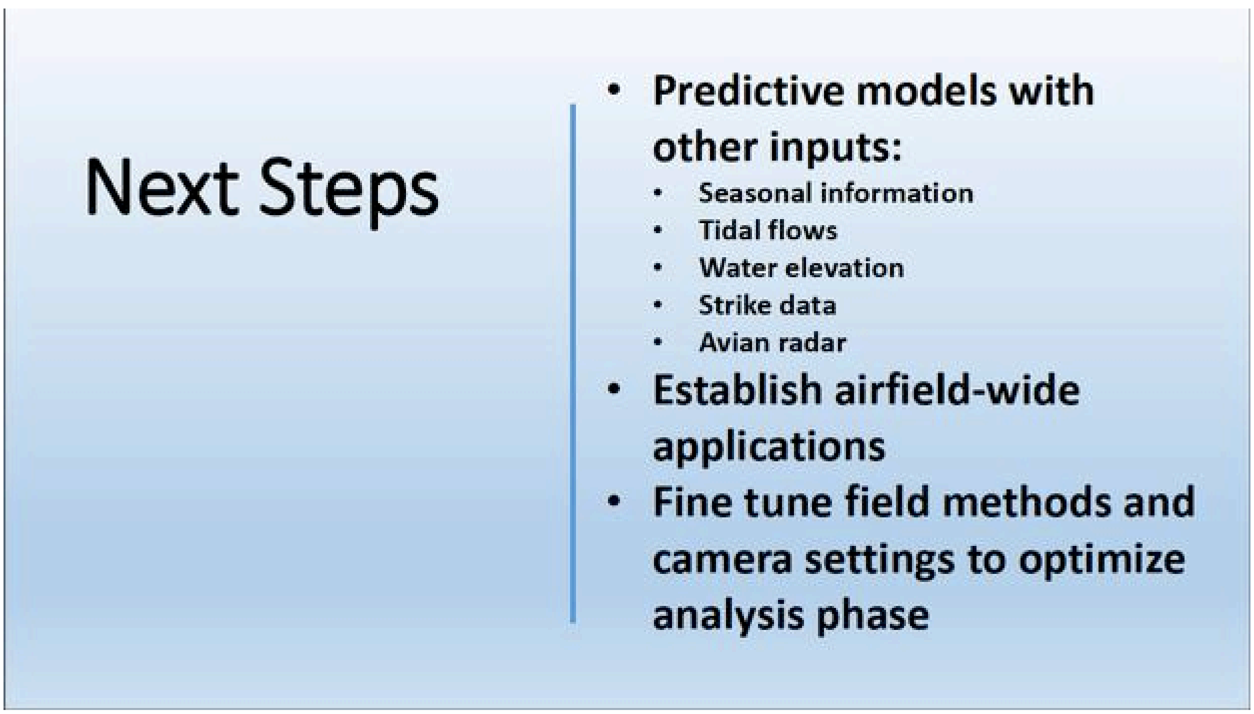

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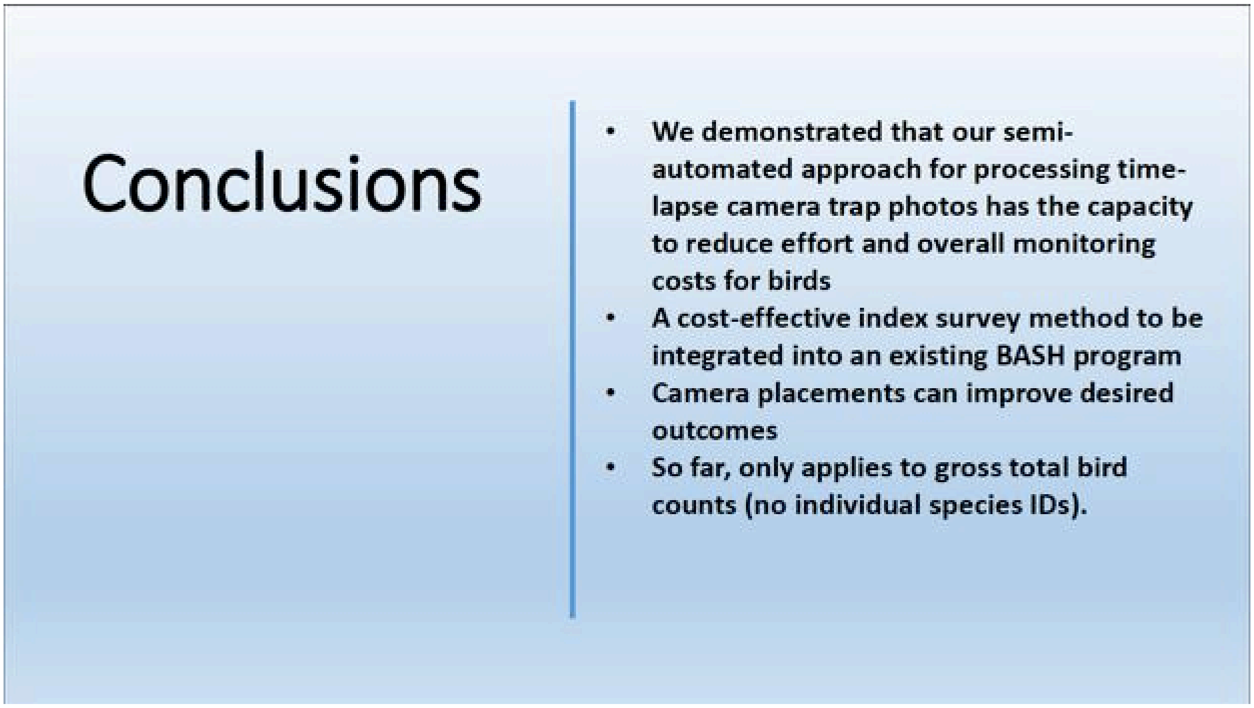

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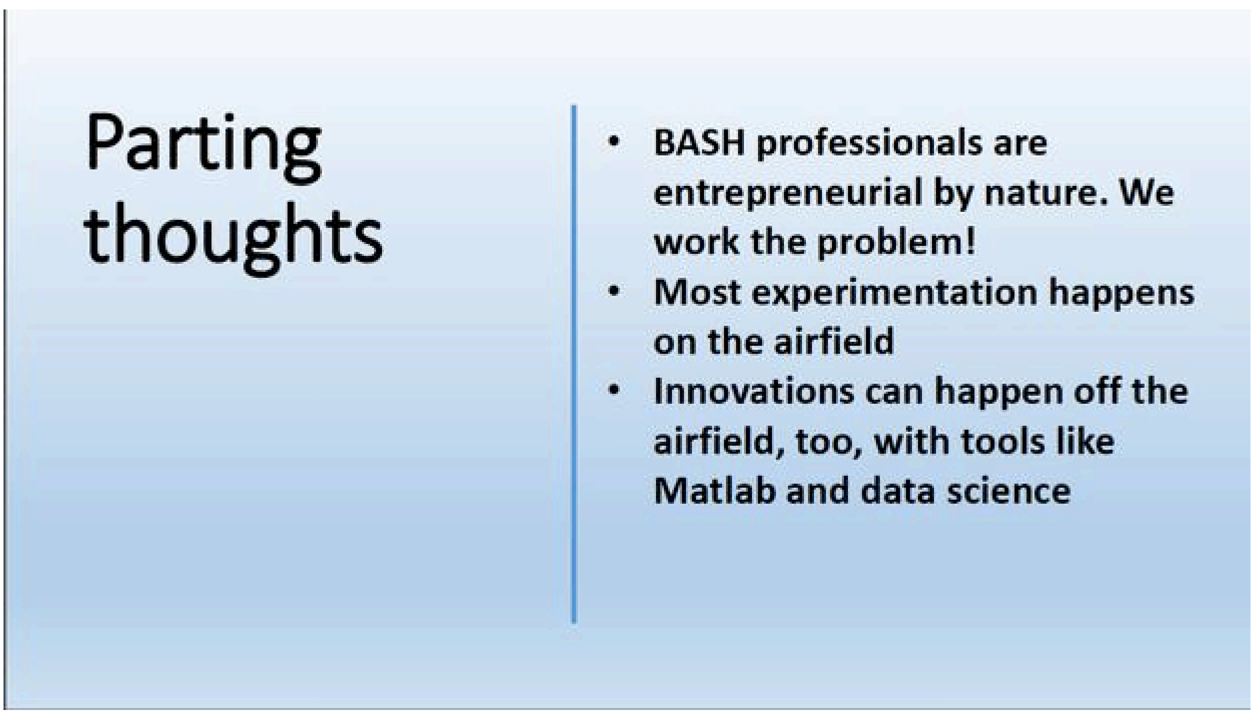

Slide 24


Domo Arigato!
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