USING PLANET LABS IMAGERY TO TRACK CARIBOU: A PILOT STUDY

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ABSTRACT

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Using satellite imagery from an earth imaging company called Planet Labs, this study aimed to see whether Woodland Caribou (*Rangifer tarandus caribou*) could be tracked through a disturbance path left by migrating herds. To examine the efficacy of this procedure, evaluations were based upon whether this process could be equally or more efficient/effective in terms of tracking and costs than telemetry collaring methods. For comparison, the Ontario Ministry of Natural Resources and Forestry caribou collar telemetry data was obtained from the Natural Heritage Information Center. This data was compared with satellite imagery from Planet Lab's 5-meter resolution RapidEye Satellites. To accomplish this, imagery for four areas was obtained for prior to the caribou's arrival and for the timestamped arrival of the caribou. Change detections were run on these four areas that all conclusively resulted in not being able to track caribou through disturbance patterns using the RapidEye 5m resolution imagery. Although the caribou could not be tracked with the 5m resolution future research could examine the concept with 3m or 80cm resolution imagery from Planet if newer telemetry data ever becomes available.

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ACKNOWLEDGEMENTS

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INTRODUCTION

The monitoring of wildlife is a key part of management practices that conserve many species (Lindenmayer *et at.* 2012). The data collected from this monitoring can give crucial information on details such as habitats or population dynamics that can assist in managing for species persistence. At this day in time, there are many species that require proper management in order to survive in this increasingly anthropogenically disturbed world. This study focuses on the Boreal Woodland Caribou (*Rangifer tarandus caribou*) in Ontario that are currently listed as threatened under the Endangered Species Act.

Although all caribou in Ontario are considered to be Woodland Caribou, they are further broken into two types. The first is the Forest-dwelling Woodland Caribou that live year-round in the boreal forest and are the type that is most at risk. There are also the Forest-tundra Woodland Caribou that live in the far north of Ontario and are not at as much risk. (OMNRF 2009). Between the two types there is little difference other than location and herding behaviour, with the Forest-tundra Caribou forming larger herds and migrating longer distances. In general, the Woodland Caribou have massive home ranges of anywhere from 200 to 4,000 sq. km. in comparison to about 40 sq. km for moose (OMNRF 2009). All of the Woodland Caribou in Ontario winter in the Boreal forest; which although is large, much of the forest is naturally in an unsuitable condition for caribou at a given time. Over time, within their large home ranges, the caribou habitat is a shifting configuration of large patches of their ideal mature forest ecotype (OMNRF 2009).

Being an Endangered species means that the caribou, as well as their shifting necessary habitat, must be constantly monitored. As well as being monitored by the Ontario Ministry of Natural Resources there is interest from other resource-based industries. This is because if a group of caribou were to show up in a forest management zone then all operations there would come to a stop. With the need to know where the caribou are comes the cost of monitoring them. Multiple methods have been used over the years, all of which require time, money, and people. With the high prices of current methods, it opens up the possibility of finding new alternative methods of wildlife monitoring. This Thesis will focus on the possibility of one of these new potential methods; an Earth imaging company called Planet Labs. This company uses hundreds of small dove satellites to fully image the Earth every day, with some areas even being done up to twice in a day. Using satellite imagery would remove the lengthy and expensive process of tracking down caribou in helicopters and tranquillizing them so telemetry collars can be attached. It also eliminates the risk of the collar falling off or not working properly that wastes time, money, and effort.

This study seeks to determine whether Planet Labs Imagery can be an equally or more cost effective method as well as if it can be effective at tracking caribou populations than telemetry collaring methods. Since the caribou in the far north of Ontario tend to travel in larger herds in more open areas their telemetry data will be focused on most heavily. This is because they will cause the most disturbance and will provide the best results when compared with the Planet Labs Satellite imagery. It can then be determined how effective this method of wildlife monitoring will be.

LITERATURE REVIEW

AERIAL REMOTE SENSING

In the past decade or so, unmanned aerial vehicle (UAV) technologies have significantly advanced and can now be used for a variety of purposes. More specifically for their possible uses in the collection of scientific data and sampling (Watts *et al.* 2012). These UAVs are becoming increasingly more available and inexpensive to the public sector, making them a safer and more cost-effective option over manned aircraft flights (Gonzalez *et al.* 2016). The software for UAVs are evolving just as quickly and can autonomously perform flight paths and acquire geo-referenced sensor data (Gonzalez *et al.* 2016). The user also has the ability to break from the flight paths to examine anything they might come across more closely, the UAV can then be returned to its flight path when the user is satisfied. Despite the benefits of the UAV technologies, there are some issues, such as UAV flight regulations and in many cases extensive post-processing that can negate any convenience or time savings compared to traditional survey methods (Gonzalez *et al.* 2016). However, UAVs do provide a good platform for wildlife monitoring and management in many situations.

All existing wildlife monitoring techniques will have their downsides, especially in terms of time and convenience, but monitoring must continue and is crucial especially for threatened populations (Gonzalez *et al.* 2016). UAVs save time in the field and can be more accurate compared to conventional methods such as on foot or recording from an aircraft (Van Gemert *et al.* 2015). One major issue with UAVs in wildlife monitoring identified by both Gonzalaz (2016) and Van Gemert (2015) is the post-processing efforts required. However, Van Gemert evaluated automatic object detection techniques that could offer a possible solution for wildlife conservation tasks (Gonzalez *et al.* 2016). The main objectives for this technique focused on two conservation tasks; animal detection and animal counting (Van Gemert *et al.* 2015). The results showed that object-based detection techniques are not without their flaws but have promise for future improvement (Van Gemert *et al.* 2015). The issue was further addressed by Gonzalez in 2016, where a UAV equipped with a thermal imager and a video processing pipeline for automated detection, classification and tracking of wildlife populations in a forest setting for population estimates.

PHOTO TRAPS

Automatically triggered cameras taking photos and videos of passing animals has become a widely used tool across the globe. This method is commonly used to study medium to large mammals and sometimes birds (Rovero *et al*. 2013). This is because they are easily caught by the camera traps and can also usually be identified without troubles. In the past decade or so, camera trapping has become much more affordable and readily available to the public and for scientific uses that are in part due to increased use by sport hunters (Rowcliffe & Carbone 2008). This now mainstream tool can be utilized for a variety of conservation and ecological purposes. Some of which include species inventories, abundance estimations, population dynamics, and even the possible discovery of new species (Rowcliffe & Carbone 2008).

Many factors can affect the suitability of a camera model and its performance for a given site or purpose. The Primary consideration is the aim of the study but also aspects such as the target species, trapping site, and climate (Rovero et al. 2013). There are many study designs that exist for using camera traps to monitor wildlife utilize varying camera types/features, placement and number of sites, and study durations (Rovero et al. 2013). Despite the many options, there are four commonly used study designs that researchers tend to use. The first design is for general faunal detection and inventory. The goal of this method is to maximize the capture of clear images containing as many species as possible to create a complete species list for the area. The second commonly used design is an occupancy study that determines the area that is occupied by a species or individuals of a species. In this case, researchers are looking to determine the abundance of the species rather than richness. Another common design is the capture-mark-recapture which is used to determine density and abundance estimates. For this model to be effective, the target species must be individually identifiable, either by distinct fur patterns or artificial marks. There is also the random encounter model that aims to estimate the density of species that cannot be individually identified as in the capture mark recapture design. It is based on the likelihood of an animal passing through a camera's detection zone (Rovero et al. 2013).

The integration of camera trap studies has been beneficial to globally monitoring biodiversity, as well as generating reliable detection of elusive wildlife species (Burton *et al*. 2015). Camera traps owe their increased use to relatively low cost, ease of use, and promising results from many studies. They are now an integral part of wildlife monitoring; however, they have their limitations. Although these camera traps can produce large amounts of data there is no quick way to analyze it. When the data collection outpaces sampling designs and statistical analysis it can convey a false sense of progress to wildlife managers (Burton *et al*. 2015). As with any other type of wildlife surveys, camera traps are vulnerable to sampling error. The most common error of the camera traps is imperfect detection where individuals present in the sample area go undetected (Burton *et al*. 2015). On the other hand, overdetection can also be a problem for camera traps. Many of these studies are focused on finding elusive species and they must maximize their capture rate. To increase captures sites are often baited to attract the target species. This baiting can skew the data by increasing the number of individuals in the area and even draw them to areas that they may not normally frequent (Rowcliffe & Carbone 2008). Despite any limitations to camera traps, they are still an effective tool for wildlife surveys. They hold the potential to produce ground-breaking data and bring about analytical innovation to process the results in new ways. In the case of Caribou monitoring, camera traps may have their place in plot samples or small studies. However, the possibility of large scale caribou monitoring would not be reasonable due to cost, extensive data processing, and inaccessibility to many areas.

MONITORING OF UNGULATE SPECIES

It is important in conservation to have accurate population estimates as well as knowledge of when and where a species will be and what they will be doing. To monitor a species at a population level, models can be used to determine vital rates. This can be extremely variable depending on the population being monitored, especially when it applies to small, declining, or endangered populations (Johnson *et al.* 2010). The species of interest also plays a role in how it is monitored. For example, large ungulates such as moose or caribou have a higher risk associated as larger body size is inherently more vulnerable to harvest and other natural or human threats (Mills 2013). Because of this, ungulate species must have accurate data pertaining to the size, density, and structure of the population.

As counting the entire population is often unrealistic, sample plots using aerial censuses in open areas and drive censuses in closed/heavily forested areas are used (Morellet *et al*. 2007). Aerial studies from a helicopter or fixed-wing aircraft are commonly used however as good as they can be, they are also very costly and prone to error. A large part of this error comes from human error in the counting and spotting of individuals, as well as the avoidance of animals if they hear the aircraft before they can be seen. Drive surveys are a good alternative when an aerial survey cannot accurately sample an area. However, there is also a problem with the probability of detection in which the species may not be seen due to avoidance behaviour before they can be spotted. If the species, such as a Caribou, has a large range then it is also less likely to come across any individuals without bias being applied. Any counts provided by hunters are useful but can't be relied on to heavily as they are also prone to bias. Over the last few decades, evidence has accumulated for problems of bias and imprecision in censusing large herbivores by all the widely used methods (Morellet *et al*. 2007).

More recently the use of GPS systems has been widely used in the tracking of large ungulate species. As this method is costly, time-consuming, and produces a large amount of data it is not done for the entire population for logistical reasons. Although it focuses on individuals, it provides data such as movement ecology, migrations, and habitat selection that is useful for the entire population (Ensing *et al*. 2014).

TELEMETRY AND RADIO COLLARING

In monitoring species, an intimate knowledge of their ecology and movements are needed in order for management to be effective. Wildlife satellite collaring helps collect part of this data by taking timestamped locations of the animal it is on. There are a few steps to this process, the first being to put a collar on the study animal. The location of the animal will then be taken and stored by the onboard GPS unit until it can be sent to the Argos Satellite system. From there the data can be emailed to biologists so they can analyze it (Environment and Natural Resources 2019).

The satellite collars are more convenient than conventional radio collars. They can collect constant data day or night in many weather conditions without sending anyone into the field. The data itself is better as well with an accuracy of 3 to 8 meters with an unlimited range versus a 100m approximation with the conventional collars with limited tracking abilities (Johnson *et al.* 2019). Of course, these benefits do come at a cost, which can range anywhere from $2000 to $8000 USD whereas the conventional collars come in at a fraction of the cost. This cost is for the devices themselves and excludes any additional costs involved with putting them into service or any networks and data downloads (Thomas *et al.* 2011). Part of the reason these devices can be so expensive is due to them needing to be custom ordered. This is because they are not a product that has a large customer base and it is never known ahead of time what species the devices will be needed for. Since orders are usually small scale due to the expense, it runs up costs again since mass production is cheaper (Telemetry Solutions 2017). As well as the cost the satellite collars, they also have a shorter expected life span than the conventional collars. Both collars also have the chance of falling off or breaking and rendering them useless in a study.

Although there are downsides, the telemetry collars are still effective and are commonly used in the tracking of wildlife. The data that is collected from the collars can be compared with satellite imagery to determine whether there could be an alternate way of tracking species. If the results are promising it could mean that there is the future possibility of cutting out the expensive collars while providing equally useful data.

PENGUINS FROM SPACE

Within the past few decades, projects have been carried out with the intent of tracking animals using Landsat imagery. One of the most notable has been the NASA study focusing on Adelie penguin populations in Antarctica. The system of tracking did not involve searching for the penguins themselves, instead, scientists were looking for fecal stains on the ice sheets (NASA 2019). This was because the size of each Landsat pixel is equivalent to a 30 meter by 30 meter square. This quality meant penguins would be difficult to spot or may even be mistaken for rocky outcrops. However, the densely packed colonies excrete fecal stains that have a distinct pink colouration that can be easily identified (Fretwell & Trathan 2009). Once it is determined that an area has a high probability of containing a penguin colony finer imagery is required. This can come in a few forms such as finer resolution imagery from commercial satellites or ground crews with unmanned aerial vehicles, sometimes both are necessary (Borowicz *et al.* 2018).

This method of population monitoring for penguins has proven very successful, as it has found multiple supercolonies of up to a million penguins that were previously unknown (Borowicz *et al.* 2018). This system does, however, have a downside in that it sometimes has difficulty detecting smaller colonies, yet still has an estimated 97% success overall since most penguins live in larger colonies (NASA 2019). This work has also opened up opportunities for other species that leave behind disturbances that can be detected by satellite imagery. The species that could leave such disturbances would mostly be herding species since their disturbances would be more significant. However, that is not to say that non-herding species cannot be detected if a proper method and algorithm are developed.

MATERIALS AND METHODS

The woodland caribou (*Rangifer tarandus caribou*) is the wildlife species of focus in this study. Caribou locations from GPS data was obtained from OMNRF telemetry collars for the entire province from the mid-1990s to 2015. This collaring data was input into ArcMap/ArcGIS and examined to create a vector file of timestamped locations of the caribou. The vector file was then spliced into smaller files for easier processing; this splicing was based on years, with everything after the year 2010 being made into individual vector files. The Caribou locations from after 2010 were the main focus since that is when the collaring data overlapped with more complete Planet Labs satellite imagery. Planet Labs is an earth imaging company that uses a large constellation of satellites including 5 RapidEye, 13 SkySat, and hundreds of small dove satellites with 5 and 3 meter resolutions as well as 72 centimeter resolutions (Planet 2019). This system of satellites images the entire earth daily and can be easily accessed by logging in on their website (https://www.planet.com/).

Because of limiting OMNRF telemetry data, the timestamped locations did not take place during the time of Planet Labs full Earth Imaging. This meant that most of the imagery would be coming mostly from either 5 meter RapidEye or 3 meter SkySat satellites. This data lapse also made imagery that matched timestamped locations harder to find so a method was developed in an attempt to expedite the search. For each year after and including 2010, a shapefile was created that encompassed the extent of the caribou locations from the vector file for that year. The shapefile for a given year would be uploaded into planet labs to create an area of interest (AOI).

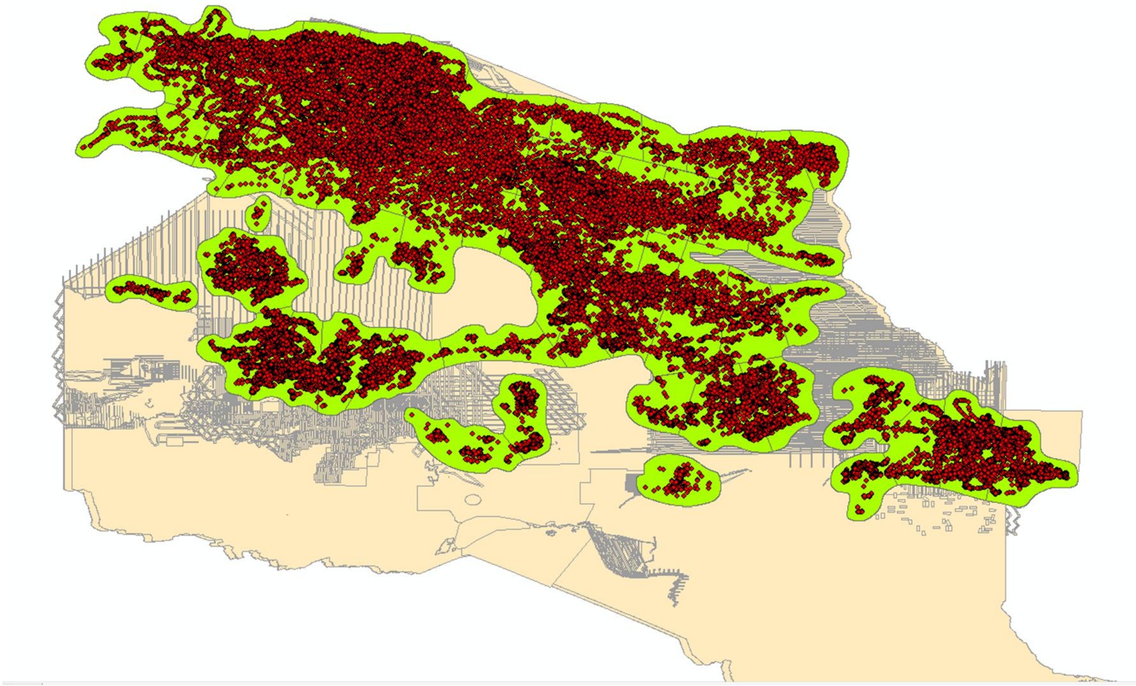

Figure 1. Example of Shapefile Created for AOI of Caribou Locations.

In ArcMap, the timestamped locations were sorted by date in the attributes table, while at the same time searching for available imagery in Planet in the AOI that matched these timestamped locations.

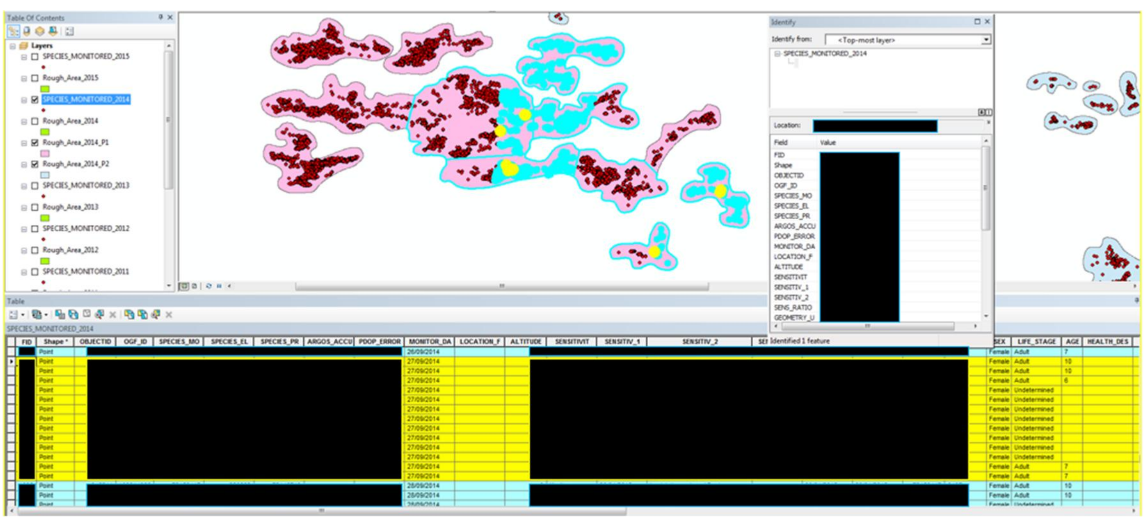

Figure 2. Attributes Table with Caribou Information (Redacted).

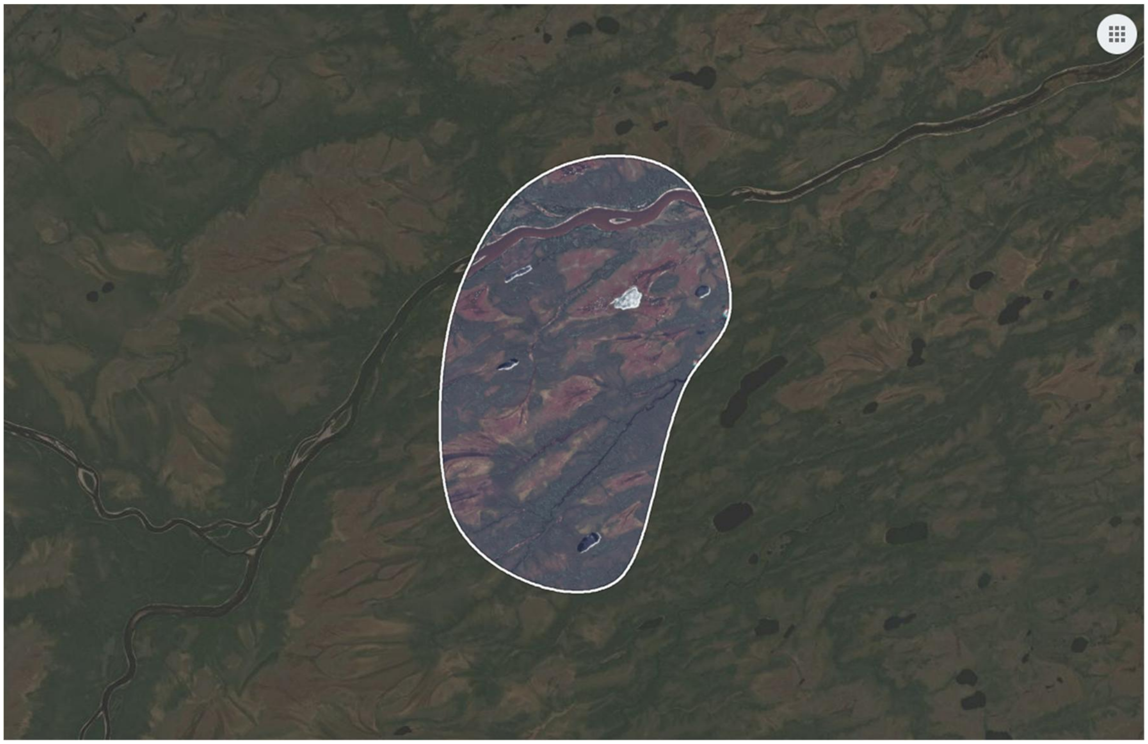

Figure 3. AOI for Caribou Locations in Planet Labs with Available Imagery.

In Planet Labs a date range for the search was set according to what shapefile and respective telemetry data was being inspected at the time. When satellite imagery that matched up with the timestamped locations was found, an order was created in the planet so that the imagery could be processed and become available for download. In addition to downloading the imagery that matched the timestamped caribou locations, imagery of the same areas was downloaded from before the caribou were there to be used in a change detection. The two images for each location were imported into ArcMap to be clipped to a more manageable size. These clipped images were then uploaded into ERDAS Imagine (Earth Resources Data Analysis System) with a Vector file of the caribou location.

Spectral Bands/Wavelengths

Band	Resolution	Wavelength µm	Description
1	5m	0.44-0.51	Blue
2	5m	0.52-0.59	Green
3	5m	0.63-0.685	Red
4	5m	0.69-0.73	Red-edge
5	5m	0.76-0.85	Near Infrared

Figure 4. Band order for RapidEye Satellites (Planet 2019).

The spectral bands for the satellite imagery was then ordered properly so that the image layers would appear properly. Once the images were uploaded with the proper bands a model was created for each set of imagery to be used in a change detection.

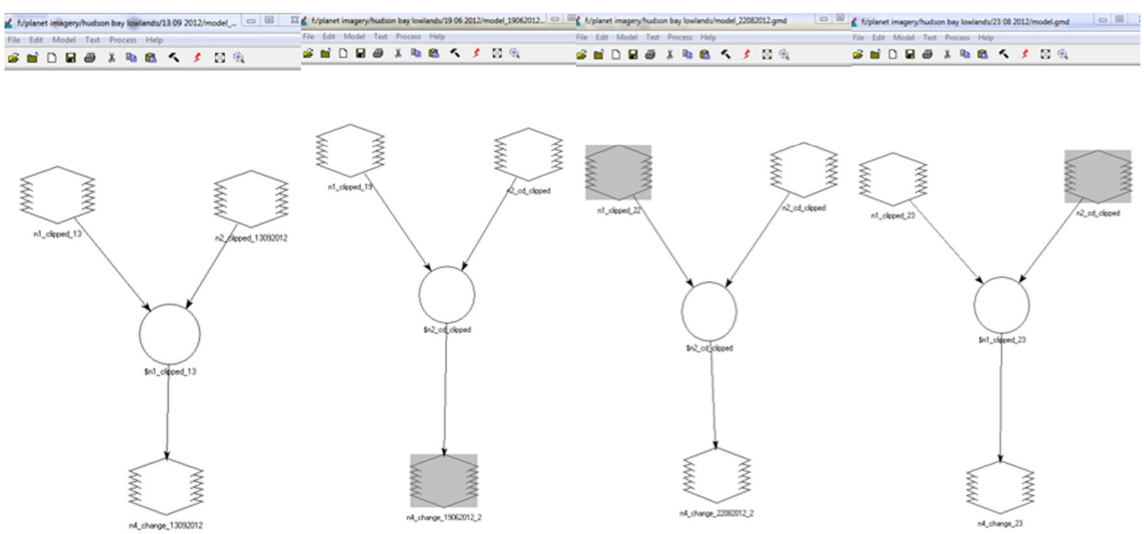

Figure 5. ERDAS Models to be used in the Change Detections.

Change Detections were then run in ERDAS using the models and the subsequent results were uploaded into ERDAS to be examined for caribou disturbances.

RESULTS

The result from the first change detection in ERDAS can be seen below in Figure 6. The imagery is displayed in False Colour in order to make any changes more clear to the human eye. The location of the collared caribou is symbolized by the yellow dot.

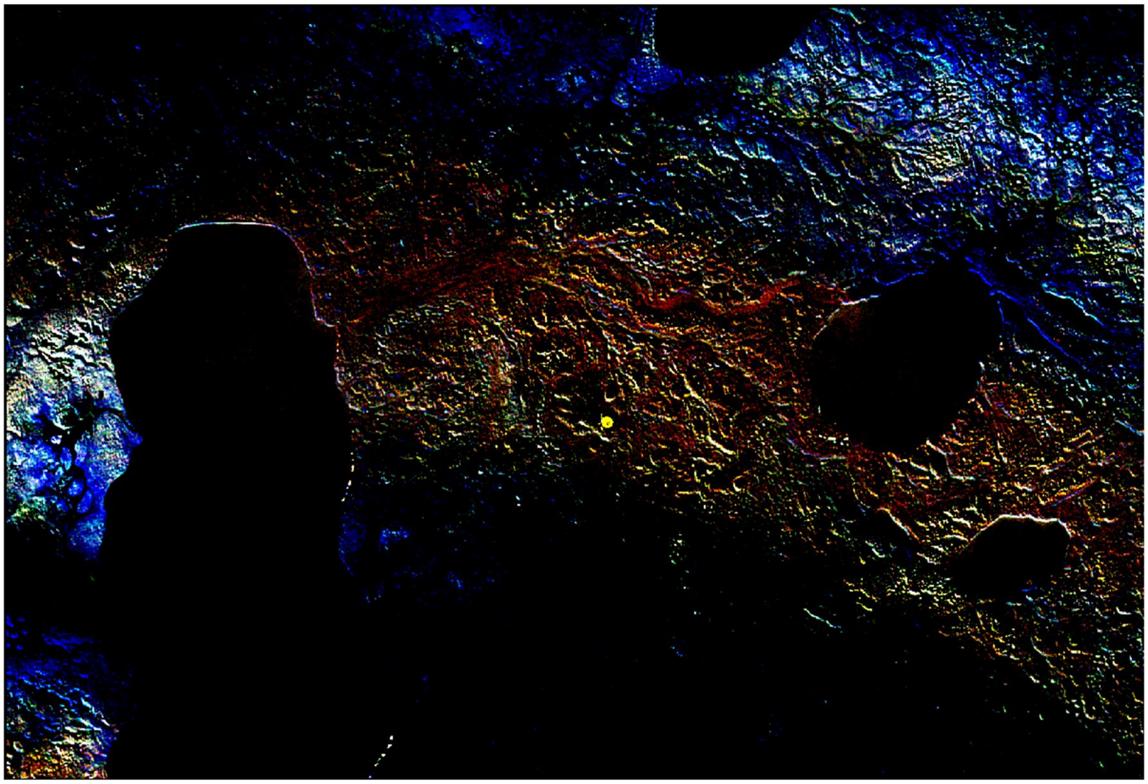

Figure 6. Change Detection with False Colour Imagery and Caribou Location.

After examination, it was decided that no clear disturbance caused by caribou migration could be seen. Even if there was some caribou disturbance present it was not enough to be conclusively separated from the seasonal changes in vegetation. A more zoomed in example of the location can be seen below in Figure 7. It is clear from the imagery that no clear path of caribou migration can be distinguished on the landscape.

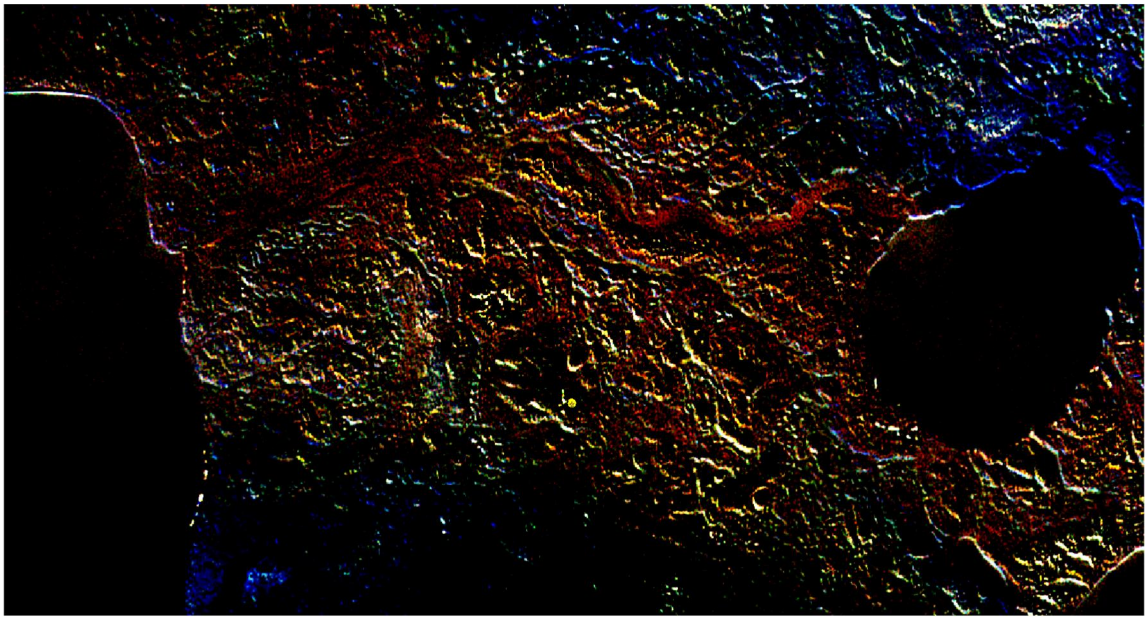

Figure 7. Zoomed-in View of Caribou Location in Change Detection in False Colour.

All of the changes that resulted in the change detection appear to be from seasonal changes in vegetation and water levels or cloud cover. This determination was based upon the spectral signatures from the NDVI band. This band is created through an arithmetic function using the NIR and Red bands and the formula: NDVI = (NIR-Red)/(NIR+Red). The NDVI works on a scale of -1 to +1 with items of low reflectance such as rocks, dirt, and snow yielding more positive values. Healthy vegetation would yield a more positive value and the vegetation disturbed by caribou herds would be expected to fall between both value ranges. An example of this can be seen in figure 8. The seasonal variation can also be seen in the two satellite images, Figures 9 & 10, that were used to produce the change detection.

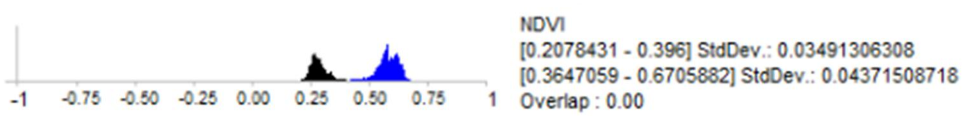

Figure 8. NDVI Band with Vegetation (Black) and Bare Ground (Blue) Spectral Values.

Figure 9. Image of Area Prior to Caribou Telemetry Location in False Colour.

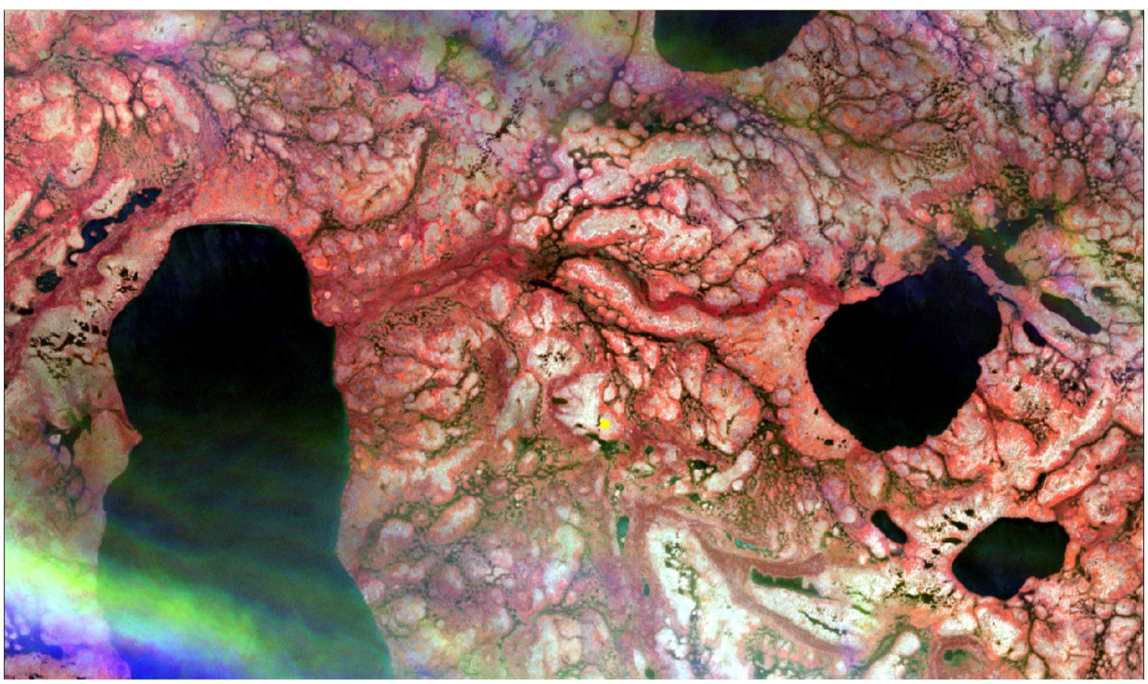

Figure 10. Image of Area at Time of Caribou Telemetry Location in False Colour.

As seen in the first, the second change detection shows no distinct path of caribou migration that can be seen on the landscape. The result of the second change detection can be seen in Figure 11 with the caribou location symbolized as a yellow dot.

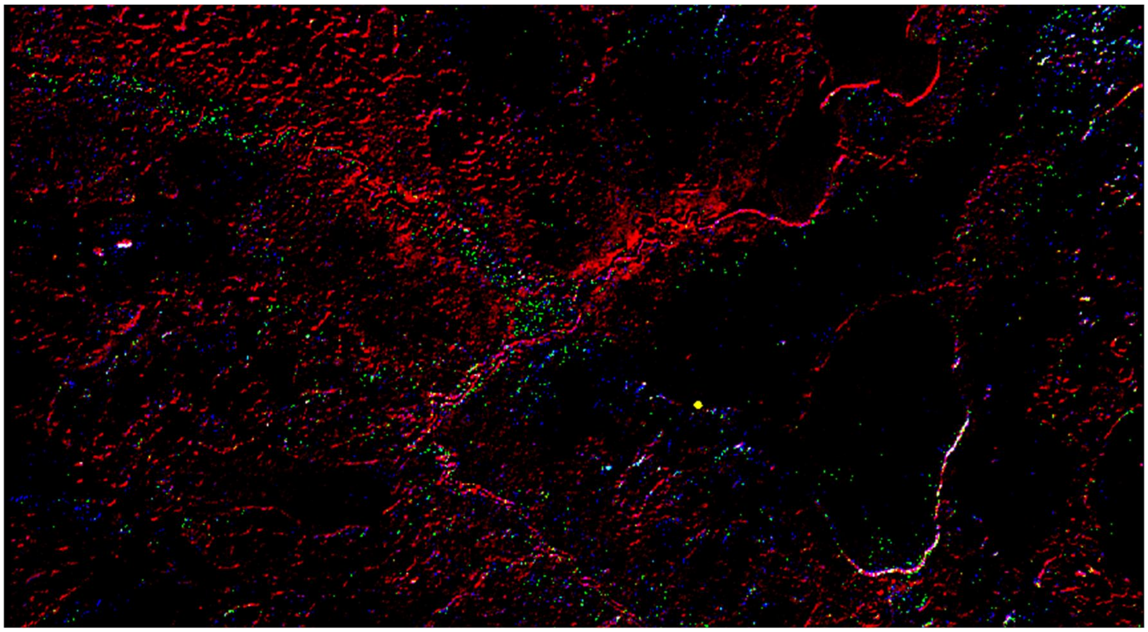

Figure 11. Change Detection with False Colour Imagery and Caribou Location.

The two images that were used for the second change detection also showed the same results. Although not seen as clearly as in the change detection the differences between the before and at time of caribou telemetry locations are easily spotted. In comparing these two images it can still be clearly seen that the majority of the change appears to be from seasonal changes in vegetation and water levels. These two images used in the second change detection can be seen in Figures 12 & 13.

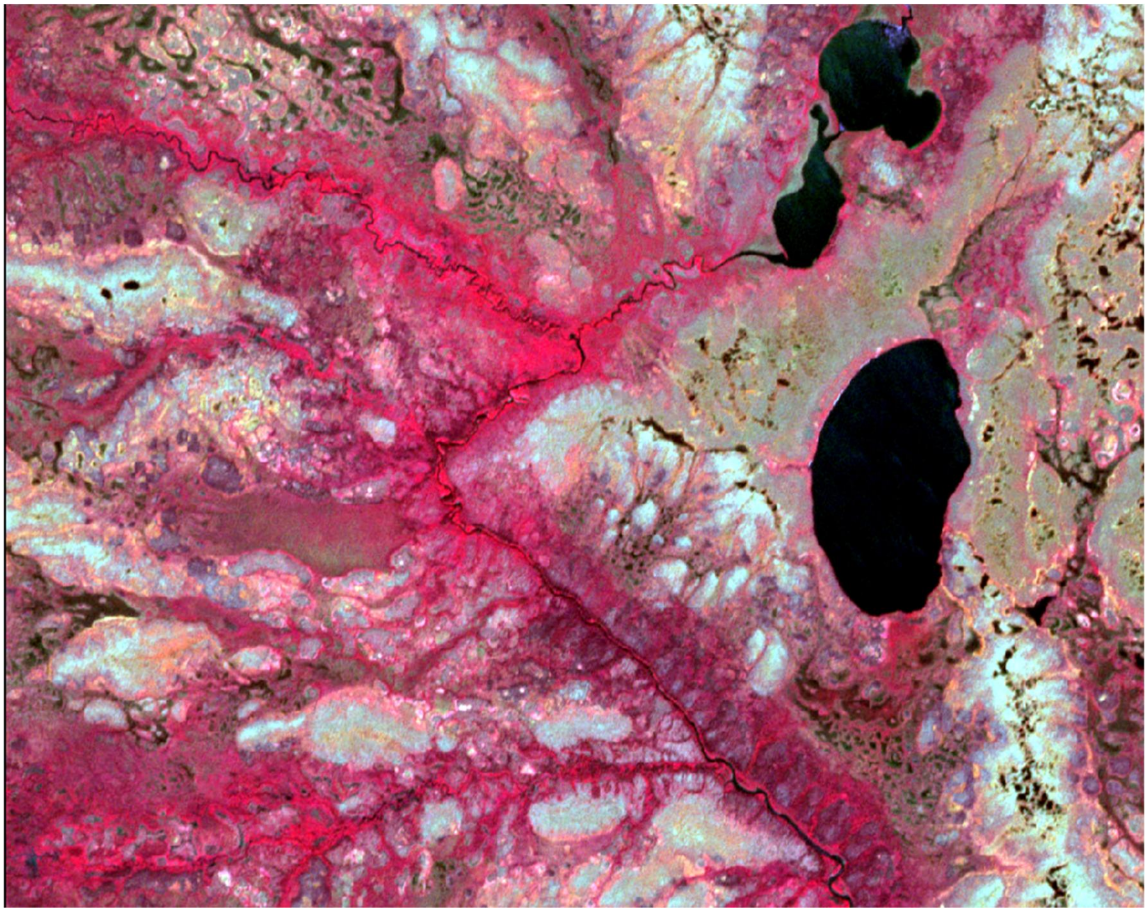

Figure 12. Image of Area Prior to Caribou Telemetry Location in False Colour.

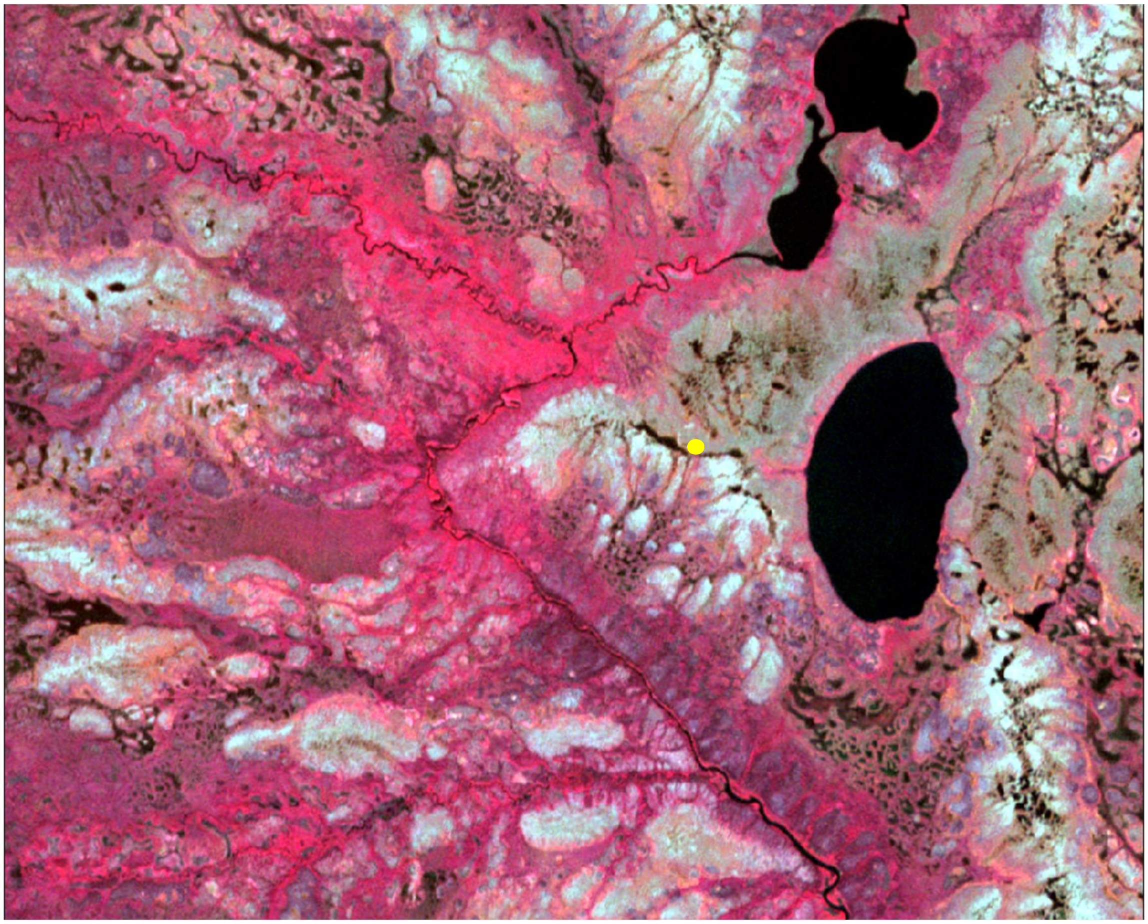

Figure 13. Image of Area at Time of Caribou Telemetry Location in False Colour.

The third change detection also showed the same results as the first two detections. Once again no clear path of caribou disturbance from migration could be distinguished from the landscape. Only seasonal variation in vegetation and water levels were seen as in the previous change detections. The resulting image of the change detection can be seen in Figure 14, displayed in standard Red, Green, Blue (RGB) band colouration. And in Figure 15, in False Colour for easier detection of changes.

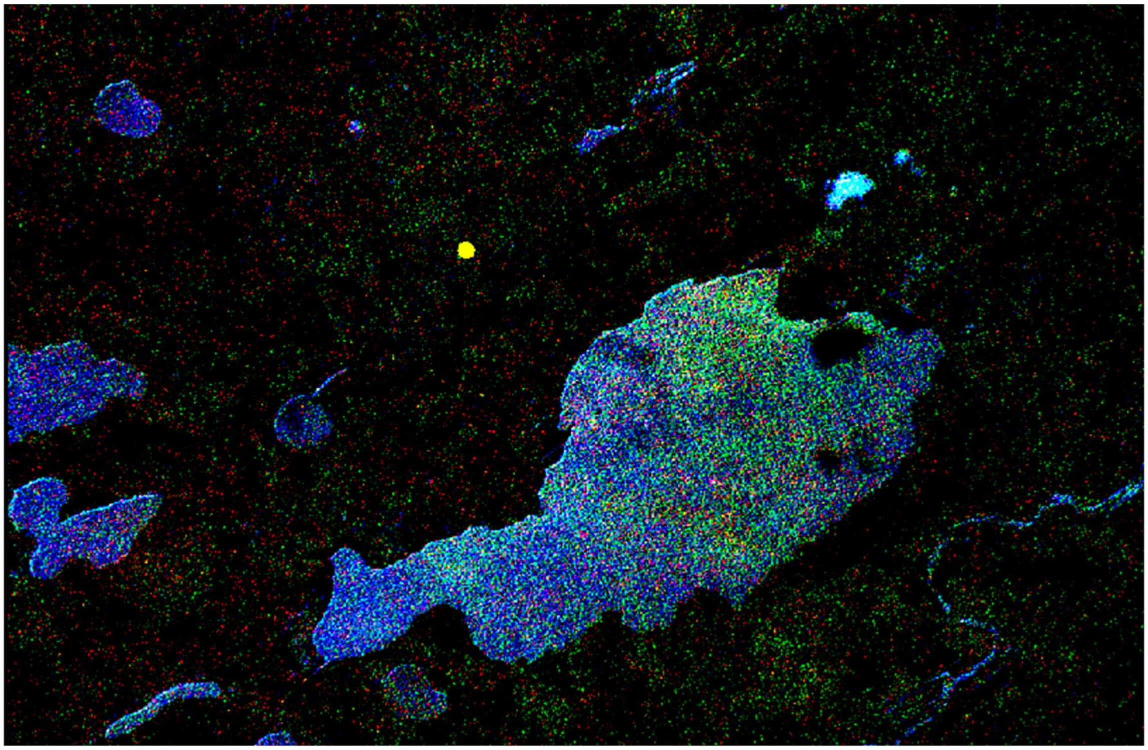

Figure 14. Change Detection with RGB Imagery and Caribou Location.

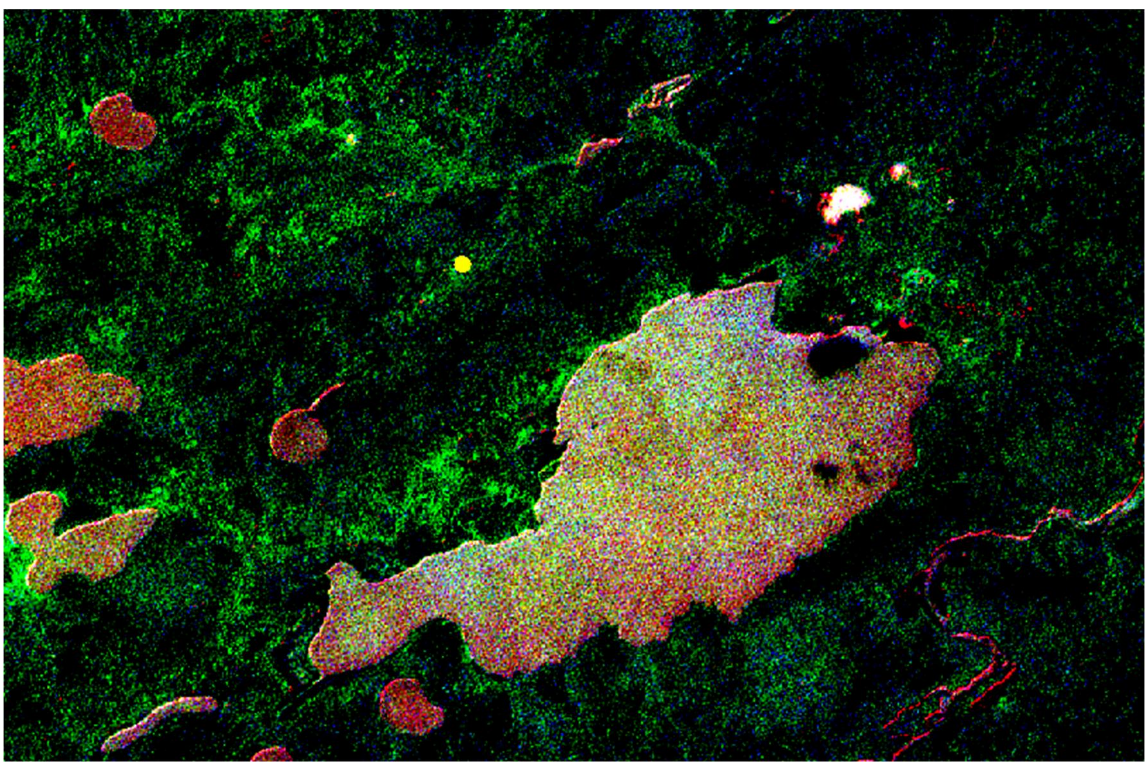

Figure 15. Change Detection with False Colour Imagery and Caribou Location.

The fourth and final change detection continued the trend and showed no distinct path of caribou migration. However, the resulting image did not turn out as clear as the others and part of the image did not undergo the change detection. This was due to a lack of prior imagery in the desired location at the ideal time.

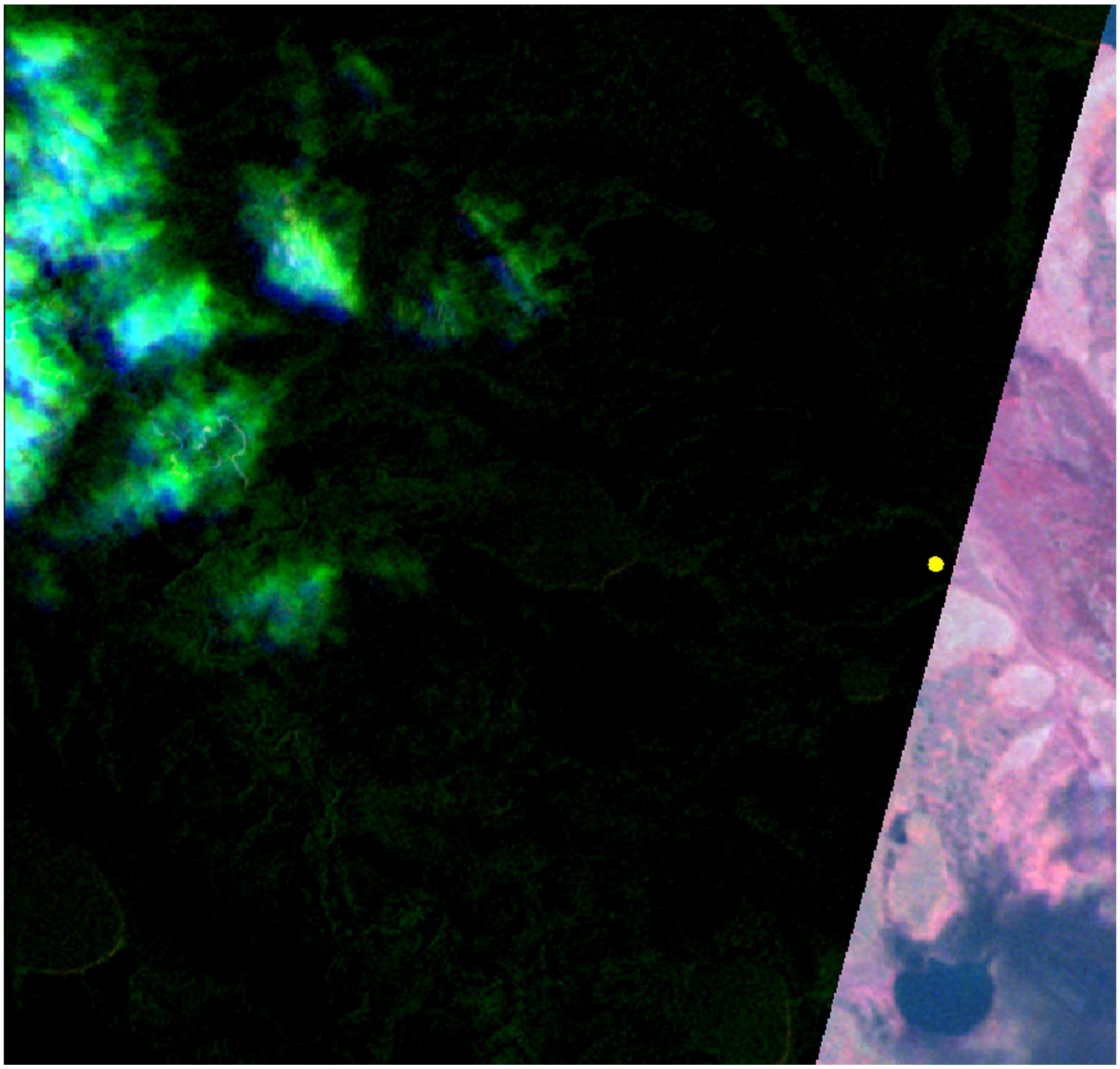

Figure 16. Change Detection with False Colour Imagery and Caribou Location.

DISCUSSION

The aim of this thesis was to obtain proof for the concept of whether the Planet Labs imagery could be used to track caribou through disturbance patterns. Four study sites with timestamped caribou locations from RapidEye (5m) were processed and examined to see if the caribou disturbance could be detected. However, as seen in all four examples of satellite imagery for caribou locations there was no distinct change that could be classified as caribou disturbance. Even if there were such caribou disturbances present on the landscape they were not distinguishable from any of the seasonal changes in vegetation and water levels with the NDVI band. Because these disturbances could not be separated, if both present, then a classification in eCognition could not be run. A supervised classification in eCognition would require samples of each class that is to be separated. Since a classification could not be run, an accuracy assessment was also not applicable.

There are a few factors that cumulatively led to not being able to effectively track the caribou through there disturbance patterns. One of these factors being that the best imagery available was from the Planet Labs RapidEye Satellites at 5 meter resolution. The reason this was the only imagery available was that there was limited caribou telemetry data from after 2015 and none in the most recent years with the best imagery. This was likely the result of limited funding and time constraints for the OMNRF to be able to continue on with many of their caribou telemetry projects. As the collars started to expire in 2015, they were not replaced leaving only the newest collars to collect data from in more recent years. Unfortunately for this study many of the more recent caribou telemetry locations came from more southern areas. In partnership with this, the telemetry data in locations of value to the study was far enough back that Planet labs had not started their daily full earth imagery. This made the process of finding imagery for the timestamped locations much more difficult, as the day and location of the caribou needed to line up precisely where there happened to be imagery from the Planet Labs satellites. This, however, would not have been a problem if there were more recent caribou telemetry data to compare with the Planet Labs imagery. This would also allow for higher resolution imagery to be used in such a study since there would be many more much newer satellites available to collect imagery from.

However, the resolution of the imagery may not have influenced the results that much as another similar study was done by NASA scientists worked at much worse resolution. Their study tracked penguins in Antarctica through disturbance with Landsat with a resolution equivalent to a 30 meter by 30 meter square. Although, in this case, the species of interest happened to be in a mostly flat very bleak white landscape. This made it so that the distinct pink colouration seen by certain colour bands could easily be seen on the ice sheets (Fretwell & Trathan 2009). The caribou telemetry locations in this study were from areas in the Hudson Bay Lowlands so that there were more open areas and larger herds to track. Despite this fact, there is still far more variance and features on the landscape in comparison to the NASA penguin study. This would mean that regardless of what resolution their study had success with, a far better resolution would be required to track caribou in the Hudson Bay Lowlands. In respect, this would also mean that to track caribou in more southern locations where they are more at risk, extremely fine resolution satellite imagery would be required.

This is well within the realm of possibilities for future studies with the goal of tracking caribou as Planet Labs opened a new state of the art facility in San Francisco in September 2018. This new facility is capable of producing up to 40 satellites images per week with some having resolution as good as 80 centimeters (Planet 2019). With resolution of this magnitude, future studies would most likely be able to spot any disturbance paths caused by caribou migrations. The 80 centimeter resolution may even be able to provide the opportunity to track caribou populations by individuals and not just herd disturbance patterns. If a study such as this were to take place and be successful it could eliminate the need for the collaring programs the OMNRF currently have in place. This could also potentially save money and help with the amount of data that needs to be processed. There are currently hundreds of thousands of telemetry data points in the OMNRF database and it is difficult to use such an amount with any ease and in some cases, there is just too much to handle.

According to sales representatives at Planet Labs (2019) there is a standard access fee for the system and a fee for downloading imagery. The standard fee for downloading imagery from Planet seems to come in around $1.50 USD per square kilometer. However, Planet has various offerings for governments and commercial industries that allow access and unlimited downloads for a flat rate. Each Organization may work out a different deal for access and imagery based on their needs so it is difficult to estimate at the approximate cost of such a deal. In the future, if a program was ever set in place, tracking caribou could become equally or more cost efficient and the Planet Imagery could be equally or more effective at locating caribou. At the very least if newer OMNRF caribou data becomes available to work with, another study could be done using Planets Free Education and Research license to examine the possibility of tracking caribou using the satellites with better resolution.

CONCLUSION

. Based on the findings of this study, it can be concluded that the woodland caribou populations cannot be tracked through disturbance using 5 meter RapidEye satellites from Planet Labs. However, in future research using better resolution imagery such as 3m or 80cm resolution, it may be possible. These future studies would also require more recent caribou telemetry data for comparison with the imagery. If such data does not become available in Ontario, a study could be done in another province or country that has recent telemetry data to match with the Planet daily full earth imagery. The cost of using such a system is difficult to price as various deals can be made with governments and industries in terms of access and imagery downloads.

Regardless of what deals and pricing may be worked out, it is very important that research continues into the monitoring of species such as the Woodland Caribou. In the future, this data may be even more important for the persistence of various species in an increasingly anthropogenically disturbed world.

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