Analysing Penguin Colonies:

Using satellite data to track colony size and movement

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Abstract

Over the past eight years the sentinel-2 satellite has allowed previously difficult to observe populations to be surveyed and monitored. In 2020, Peter Fretwell published a paper about discovering emperor penguin, *Aptenodytes forsteri,* colonies across Antarctica using satellite technology [1], however we wanted to investigate how the colonies had progressed since then. Using a couple of locations referenced in Peter Fretwell's paper and analysing the change in colony size from 2020 up to 2023. We decided to research this important area for our project as climate change is a pressing issue with far reaching consequences to nature. We focused on two penguin colonies, one large (Dawson Lampton) and one small (Pfrogner Point), this allowed us to investigate whether the size of the colonies affected their percentage change in the years since Peter Fretwell's paper [1]. In our analysis we have carried out research using online satellite images to look at penguin guano patch size to investigate how they change over time - whether they increase, decrease or stay the same. We have carried out this research as we believe there could be a link between the increase in global temperature and the penguins ability to survive. Using the change in size of guano patches we can investigate whether the colony size has noticeably changed, which then gives us an idea of whether or not there is a link between climate change and the penguin colony size. We predicted that there should be an overall steady decrease in penguin numbers due to the increasing temperature and reduction of habitat availability (loss of sea ice). Therefore we were expecting a small percentage decrease in the colony size from 2019-2023. We found that the guano patch size decreased over the course of 2019-2023 with some even being completely gone by 2023 - meaning the colonies either perished or relocated far away.

Context

The sentinel-2 satellite is mainly used to map changes in land cover and to monitor the world's rainforests. Satellite data has also been used to monitor populations of walruses as well as other animals such as whales [2]. These satellites have been used to track movement of these animals as well as looking at population size by counting them by searching through lots of images. Specifically, we are focusing on the Antarctic region to look at emperor penguins, *Aptenodytes forsteri,* to complete a similar task. The British Antarctic Survey published a paper in 2020 which outlined how they found new emperor penguin colonies by analysing the distance between already discovered colonies [1]. This allowed them to predict where new colonies could potentially be located. This enabled them to find eight new colonies across Antarctica, although this is a large increase in terms of the number of colonies of emperor penguins they calculated that it only increased the population of the penguins across Antarctica by 10-15% [1]. Since the smaller colonies were more difficult to spot they usually had only a small number of penguins leading to the relatively low percentage increase [1]. The advances made in penguin tracking technology is due to sentinel-2 satellite having a much larger resolution compared to previous pictures acquired by other satellites. The sentinel also has two satellites that go around the earth on the opposite sides to one another to increase the satellite data collection efficiency as you can cover both sides of the earth at one time. By using sentinel-2, which has greater resolution than the previously used Landsat data that was previously used to search for penguin colonies, people that are researching penguin colonies can locate them faster and analyse the colonies easier because you can see the land more clearly.

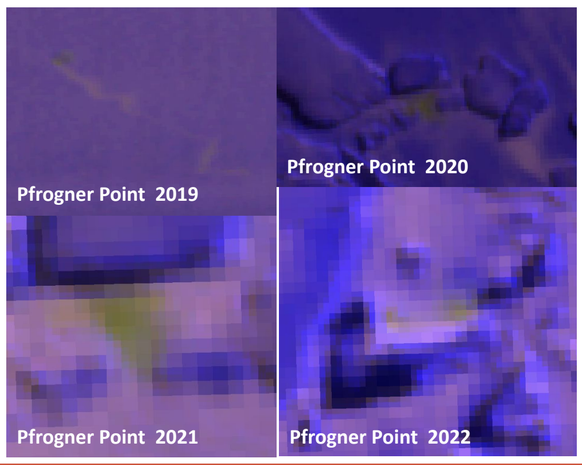
Methodology

In this investigation we used satellite images to observe penguin guano in different areas of Antarctica and used this to estimate population change over time. We decided to focus our efforts on two areas - Pfrogner Point and Dawson Lampton. Firstly, we use the coordinates provided by the British Antarctic Survey [1] as a starting point, as finding guano is extremely difficult due to the size of Antarctica in comparison to the amount of sizeable penguin colonies. We entered these coordinates into the EO Browser and looked at earlier and later years (compared to Peter Fretwell's 2020 study) and investigated whether the size of the guano has increased/decreased or stayed the same - allowing us to see how the colony size has changed over the span of multiple years. We used the custom colour filter B12 for red, B11 for green and B02 for blue. We then edited the custom script and changed the B12 to 4.5, B11 to 3.5 and B02 to 0.5 [3]. We tried other colour variations for looking at Antarctica however, the colour filter mentioned above seemed to be the most consistent as other colour variations could highlight rocks which would give inconsistent data collection which means penguin guano could blend in and look like a rock making it harder to find actual penguin guano. However, this method does not always work as you would quickly find that in a lot of scenarios that when you return to the location next year that you find nothing. This either means that the colony has migrated elsewhere during the year, or, the colony has perished. If this happened, we initially spent time looking around the area in both directions to try and locate where the colony has moved to (as suggested by Peter Fretwell), however, this is very difficult as it is hard to find such a small colour change in the ground as you have to cover such a large area. To combat this problem, the custom colour filters mentioned above made the guano stand out in a bright green colour whilst the rocks and ground are left as a purple/violet colour. This makes the guano a lot more vibrant which means we can zoom out when searching for where the guano patches have moved to cover more area quickly whilst also enabling us to see the guano patches at the same time. This increased the efficiency in which we could find guano patches years after the original guano patch however we still had problems finding the colony in some areas. Another issue we ran into was that sometimes - due to the colour of the rocks - we mistook some rocks for guano. This means that the colour filter brings up similarly coloured rock as well as guano so whenever we found guano we had to change the colour back to normal to ensure that we are looking at guano and not a rock. After repeating this numerous time at different coordinates, we then counted the amount of pixels that the guano takes up and compared this to other years. This allows us to compare colony sizes to other areas and how the size of a colony has changed over the years.

Results

As mentioned in the methodology, using the custom colours in the EO Browser the penguin guano stands out and is easy to spot (figures 1 and 2), the only problem with this is that the difference in area of highlighted area changes from the real image to the custom colours. This makes it difficult to predict the exact numbers of penguins in a specific area. However using the area tool, the change in area can be measured as a percentage increase or percentage decrease over time (figure 3).

Figure 1 - Satellite images taken from the EO Browser of Pfrogner Point from 2019-2022. The brown/green areas are penguin guano and give an indication of colony size. 2020-2022 pictures are in a slightly different location than 2019 - meaning the colony most likely moved.



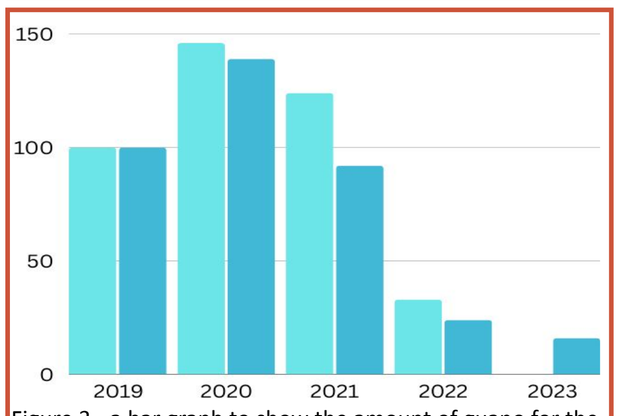
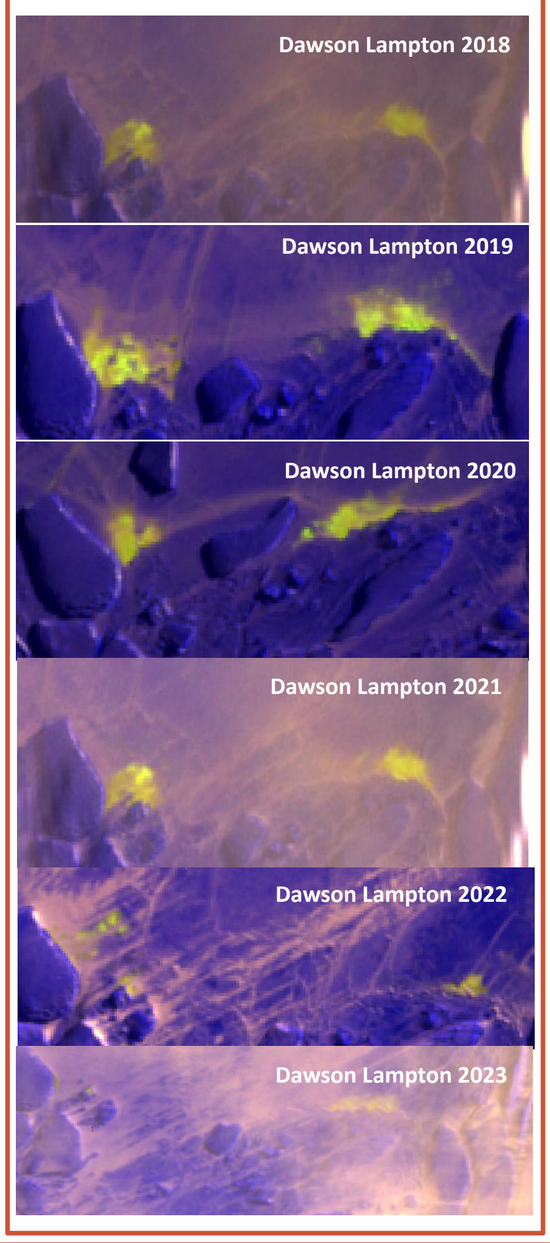


Figure 3 - a bar graph to show the amount of guano for the two colonies (light blue is Pfrogner Point and dark blue is Dawson Lampton) as relative percentages of their size in 2019.

Figure 2 - satellite images taken from the EO Browser of Dawson Lampton, Antarctica between 2018 and 2023. The fluorescent areas show the penguin guano.



Conclusions

Overall our investigation seems to portray a loss of total penguin numbers. In the Dawson Lampton colony the percentage of guano cover increased from 2019 to 2020, however it decreased from 2020 onwards up until and continuing into 2023. Pfrogner Point colony showed similar results in the fact that it increased considerably between 2019 to 2020 whereas between 2020-2022 it has shown a slight decrease in the percentage of guano cover. Overall this doesn't show a bright future for the emperor penguins of Antarctica as the results gathered paired with the increase of global warming [4] and deterioration of the penguins natural habitat [5] can only lead us to believe that they will decrease in number further across the coming years. Furthermore when looking for the Pfrogner Point colony in 2023 we were unable to find the colony at all. While this could indicate the eradication of the colony, it more likely means that the colony is too small to pick up easily on the satellite imagery or the remaining breeding pairs have moved to more populated colonies in the surrounding areas. Also due to the smaller and larger colonies having a similar decrease in population we can make the assumption that most other penguin colonies across antarctica are experiencing decreases in penguin numbers. Whilst we weren't able to quantify the specific number of penguins between the years, our research still provides a powerful insight into the risks these colonies face in the upcoming future. While we predicted that there would be a steady decrease in population, we didn't expect a rapid increase between 2019 and 2020. This could be due to breeding pairs from other colonies migrating however since it occurred on both colonies it can be predicted this was a successful year for penguin breeding. The decrease following 2020 was much larger than our initial expectation as roughly a 70% decrease between 2020 and 2023 is a devastating loss for the colonies and it is unlikely that they should be able to recover in the upcoming years.

Further Investigation

In this project we have investigated whether penguin colony size has increased or decreased based on the data that we have collected. However, we could quantify this further by giving how much we believe the population size has increased by using a scale of how many estimated penguins there are based on the area of guano. To do this we could take the values for area of guano cover and the area taken up by one penguin and multiply them to estimate population numbers. To look at links between climate change and guano patches, the new sentinel 3A and 3B satellites will monitor ocean colour, sea surface temperature and sea surface height and this data could be used to find a correlation between the decreasing guano sizes and the data that they collect about the sea and ice. There may also be new colonies not yet discovered. A way of potentially finding these undiscovered colonies is by looking for large gaps between known colonies (50-800 km apart). Peter Fretwell has suggested there may be some undiscovered colonies in these areas as there are usually no gaps greater than 500 km between colonies unless there is an ice shelf front. Further research in this area is exciting and vitally important for the future of penguins and other Antarctic species.

Acknowledgements

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References

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[5] P. Fretwell, A. Boutet and N. Ratcliff, Record low 2022 Antarctic sea ice led to catastrophic breeding failure of emperor penguins. Communications: Earth & Environment / 4, 2023.