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**Critical Literature Review
(ANTA602)**

***Non-Invasive data capturing and identification methods
of Antarctic Mega Fauna***

Name: Ramcharan Vijayaraghavan

Student ID: 95161788

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Abstract (ca. 200 words):

Climate change combined with an ever-increasing human footprint is strongly impacting the polar ecosystem. It has become imperative to collect more frequent and accurate data and at the same time monitor various species. It is important to understand the role that non-invasive data-capturing and identification methods can play in assessing the vulnerability of species, apart from their reaction to climate change.

This literature review looks at various studies covering satellite imagery, infrared and thermal imagery, pattern matching, and respiratory and faecal analysis. The different studies highlight the use of various techniques on specific species (primarily penguins, pinnipeds and whales). The papers have been chosen from the last twenty years and offer diverse perspectives (such a range also allows for inclusion of long-term studies that might have started earlier but concluded in the recent past). The literature chosen is more a yardstick for comparison than a benchmark in methodology, as it will be technology that will drive scientific change in the near (Antarctic) future.

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1. Introduction

Numerous species have gone extinct over the last few decades as a result of climate change as well as an ever-increasing human footprint. Gathering data becomes even more essential for monitoring and identifying various species as well as providing vital information for scientific research. To keep this in context, it is also important to focus on two of the terms – “megafauna” and “non-invasive”. Antarctic megafauna (Eisert R. et al 2015) is unique especially with the absence of reptiles and amphibians. As compared to the Arctic, mammals like the arctic fox and polar bears (surface predators) are absent in the Antarctic. So there would be hardly any species that would be completely understood from land alone.

The study of mammals (whales and seals) and seabirds (primarily the species of penguins) in the harsh environment requires appropriate methodology. Another animal behaviour that influences data capturing and monitoring is philopatry (tendency to return to a particular area). This has been displayed in whales (Kellogg, 1929) as well as penguins. A certain amount of predictability or seasonality combined with a geographical range provides reference points to studying the same.

In medical terms, a ‘non-invasive’ procedure is defined as one when there is no break in the skin and there is no contact with the mucosa or internal body cavity beyond a body orifice. The evolution of the biomedical definition of ‘non-invasive’ as “insertion of an instrument or device through the skin or a body orifice” (Stedman’s Medical Dictionary 2008) contrasts the one involving field studies on animal species (Pauli et al 2010). The study compared and classified various definitions of the term ‘non-invasive’ and arrived upon one which states “where animals are unaware of sampling and, therefore, are unaffected by it (unperceived) or animals are unrestrained and do not exhibit a chronic or severe stress response or experience reduction in survival or reproduction (perceived).”

Keeping this definition in mind, we shall look at four scenarios – Satellite Imagery, Infrared and Thermal Imagery, Pattern Matching, and Respiratory and Faecal analysis. The mega fauna studied vary from whales and seals to penguins in the Antarctic and Southern Ocean. The need however is to also understand which scenario suits which species and how new methods can be incorporated to improve the same.

2. Non-Invasive Methods of Data Capture and Identification Methods

a. Satellite Imagery

A remote and harsh terrain such as Antarctica is one of the scenarios where satellite imagery comes as a boon. While it is logistically difficult to monitor populations, it is quite possible to track mega fauna using high-resolution imagery. From whales (Andrews-Goff V et al., 2014) to elephant seals (McMahon et al., 2014) to penguins (Lynch et al., 2013, LaRue et al. 2014, Dunn et al., 2016) it has become increasingly possible to accurately study and carry out conservation efforts in the Antarctic and Southern Ocean.

This is one area where scientists across disciplines need to closely collaborate to monitor the drastically changing ecosystem. With more than 70% glaciers retreating (Cook et al., 2005) and a substantial loss of sea ice, animal populations have become increasingly vulnerable.

There are various satellites such as the Geo-Eye-1, WorldView-1 and WorldView-2, QuickBird-2 and the recently launched ICESat-2 that provide high-resolution images of the Earth's surface. The images are also accessible to scientists across the world and have been particularly helpful in remote monitoring and studying of nesting habitats and colony sizes of various species especially penguins.

Penguins: Penguins are unique to the southern hemisphere and some of the species indicated are perceived act as sentinels to the Antarctic and Southern Ocean (Boersma et al., 2008).

With penguin colonies spread out so widely, and each having a high number in each colony, it might be easier to identify a colony or a rookery, but tougher to do a population count. Another trend has been that colonies can be easily identified much later in the breeding season when significant guano deposits pile up. Individual penguins might be more easily spotted earlier in the season against the snow or ice due to greater contrast.

In comparison, a long-term (38 year) study done with on-ground counts like the three species on Signy Island, South Orkney Islands (Dunn et al. 2016), it was possible to distinguish between chinstrap, gentoo and adelic colonies.

These are two extreme cases and the in the present scenario, use of satellite imagery would be to strike a balance between the frequency and accuracy of the counts. The use of high-resolution imagery over South Sandwich Island and Paulet Island were used for detection, differentiation and abundance estimation (Lynch et al., 2012). It was found that all four species - Gentoo, Chinstrap, Adélie, and Macaroni penguins could be detected using high-resolution imagery. Gentoos proved to be the toughest to identify due to their lower density (more scattered).

In the case of emperor penguins, a single synoptic survey was done using medium and very high resolution (VHR) imagery during the 2009 breeding season (Fretwell, LaRue et al. , 2012). Through the QuickBird satellite imagery, penguins could be uniquely identified when scattered but when clustered together, there was overlap and the shadows made them appear in bands. More importantly, the study provided a better understanding of the kinds of errors possible when compared to some of the aerial photos. It helped identify and differentiate shadows vs. ground vs. guano vs. penguins. Going forward, it paves way for long term monitoring techniques.

Pinnipeds: Historically, though it has been possible to monitor and identify large mammals such as whales, it has been a bit more difficult for pinnipeds (Laliberte et al., 2013). It was possible to carry out a study on Weddell seals (LaRue et al., 2011) as their dark body could be contrasted against the snow and sea ice. The counting was done using WorldView-1 and QuickBird-2 imagery, and was compared with on-ground counting in Erebus Bay around the same time. About 1,000 adult Weddell seals were counted from five images spanning across years. A comparison with on-ground counting was able to establish an increase in abundance in the period from 2004-2009.

In the case of the southern elephant seal – the largest of the pinnipeds, the study was done at Macquarie Island (McMahon et al., 2014) and a similar methodology was used. Satellite imagery from 2011 was compared with on-ground counts at the same time. Though it did not cover a range of years, it did give scope to understand breeding patterns, the number of female harems and the number of female seals per harem. Also, this was one of the studies which dealt with the scenario of a dark seal body against a dark background with a reasonable accuracy and error estimate.

One of the constraints with satellite imagery is that there could be unproductive days due to bad weather, cloud cover, shadow formations etc. Over the last few years though, the increase in the number of satellites and high resolution cameras, spotting from space has become a lot more feasible and reliable.

b. Infra-red and Thermal imagery

Thermal imaging helps identify the range of body temperatures in species and thereby helps in co-relation with warming and cooling in the environment. Two of the species from the Polar regions getting attention are the Polar Bear (Arctic) and the Emperor Penguin (Antarctic).

Technological advancements at the turn of the century in 'Forward Looking Infra-Red' (FLIR) systems have provided a wonderful opportunity to study differences in temperature. Previously, in the case of polar bears, these have helped identify dens (Amstrup et al., 2004) by measuring the temperature levels near the dens as well as warm air rising from the dens.

Another interesting observation made using FLIR cameras was that polar bears are wonderful at keeping their bodies well insulated so much so, that the surface temperature of their pelts was close to the snow surface temperature. So if it's tough to identify their body size against the snow with normal photography, it is not so easy with an infrared camera either!

When it comes to emperor penguins, thermal imaging from a breeding colony at Pointe Géologie in Terre Adélie (McCafferty et al., 2013) provided some interesting insights. The penguin plumage provided over 80% insulation cover. Like in the case of polar bears, the free ranging emperor penguins provided data on varying surface temperatures. Furthermore, the difference in some 'hotspots' indicated the heat fluxes from different body parts.

Both these studies are critical and the various parameters of on-going studies might indicate how body and surface temperatures vary in accordance with land and sea temperatures, thereby providing valuable clues to the impact of climate change on some of these species.

c. Pattern matching - Analysis of whisker spots/holes

One of the aspects when we monitor and understand animal behaviour is to also uniquely identify the animal. Quite a few of these have been achieved by mark-recapture or capture-recapture methods of population monitoring (Nichols 1992). The behaviour is studied over a period of time through microchips (tagging) or via branding (artificial marking). Some animal species though, have known to exhibit distinguishing features or natural markings, which can be used to identify the animal. These could be in the form of patterns or shapes of body parts or marks and scars (Walker et al. 2012).

Some of the identifiers seen are whisker spots in Lions (*Panthera leo*) and Polar bears (*Ursus maritimus* - Andersen et al 2007), identifiable flukes and fin marks in cetaceans (Hillman et al. 2003), and fur patterns such as stripes in tigers (*Panthera tigris*) and zebras (*Equus quagga* - Karanth and Nichols 1998, *Equus burchelli* - Foster et al. 2007) and spot patterns in the case of cheetahs (*Acinonyx jubatus* - Kelly 2001). Comparing images of their patterns using image-processing and pattern matching algorithms has been an on going process and a considerable repository of images are needed in order to achieve this.

Scars and other identifiers such as edge patterns/cuts have also been useful in identification of pinnipeds (Vincent et al. 2001), but these markers might change over time. This can typically happen when there is shedding of skin/moulting (McConkey 1999).

There have been on-going studies with Australian sea lions (*Neophoca cinerea*) on population estimates in certain colonies (Goldsworthy and Gales 2008). Typically, such species don't have a distinct coloration or body patterns and therefore a whisker spot analysis would be a logical method for photo-identification.

To successfully identify individual animals, it is important to know whether sufficient variation exists in the whisker spot patterns to uniquely identify the animal (at least within a given range). Once a representative sample has been collated and tested, then it would be safe to conclude that the results of the study are reliable enough (with the requisite accuracy or error rate mentioned).

Comparing and contrasting at least three of the studies – namely lions, polar bears and seals/sea lions, would offer some understanding about best practices when going forward.

Lions (*Panthera leo*): The concept of using a whisker spot method (Pennycuick and Rudnai, 1970) was first developed and highlighted to uniquely identify individual members of a population. Their sample size was about 25 of 50 lions in the Nairobi national park. A particular specimen was identified and sketched. Eventually, they took photos at 90 degrees angle to the lion's face. They observed a pattern of all lions having four to five rows of whisker spots or holes (with and without hair/whiskers) between the upper lip and the nose. The whisker spots / holes were roughly parallel to the upper lip. The top row had about 4-5

spots/holes, the next about 5-9 spots/holes and so on. The primary identification was made with spots in the first and second rows. To determine whether a spot/hole was directly above or away from another, a grid was used over the photographs. It was found that more or less, the pattern remained constant.

Polar Bears (*Ursus maritimus*): A similar method was later used for polar bears (*Ursus maritimus*), (Anderson et al. 2007) on an initial sample of 50 different polar bears whisker spot patterns. On analysis, it was found that close to 98% contained enough information to reliably identify individuals. The process is also mostly automated with only 1-2 aspects of manual intervention in marking/establishing reference points. One of the limitations with studying polar bears is the large range across seasons; as well as the terrestrial vs. marine time spans. Another factor being taken into account is the presence of scars (due to fights/hunting), which could be treated as a secondary parameter. The research is on going and collating photographs combines both profile shots as well body condition/composition.

Seals / Sea lions (Pinnipeds): In the case of pinnipeds – specifically seals and sea lions, there has been study of both captive and wild populations (Osterrieder et al. 2015). The study was done on 53 Australian sea lions (*Neophoca cinerea*) with a point-pattern matching algorithm.

The accuracy varied depending on the angles and times when the photographs were taken. Though there is enough variability in whisker spot patterns to help in identification within a small resident population, a lot of it depends on the accuracy (proximity to 90 degree) of the photographs. A few more such studies might be required before greater accuracy is reached and/or becomes more conclusive for larger populations/ranges.

d. Respiratory and Faecal samples

A recent cause for concern shown by the IUCN red list has been in the case of whales. Though a large number of whales disappeared due to commercial whaling (Clapham et al., 1999) in the previous two centuries, the international moratorium has given some scope for survival especially in the Antarctic and Southern Ocean. In quite a few cases there have been significant drop in numbers due to diverse reasons stated by various conservation efforts. (Baker et al. 2010, Ainley et al., 2009) There are also significant challenges in understanding the physiology of these species (Kathleen Hunt et al., 2013). Two of the popular methods in such scenarios for health and diet analysis of this species have been faecal samples and respiratory (blow) samples.

Faecal samples: Faecal samples have been studied for a long period of time to understand physiology, diet, as well as presence of parasites. Increasingly, there have been studies for hormones and other indicators of wellbeing (Palme et al. 2005). The challenge with whales has been their large migratory patterns as well as diving behaviour. On a positive note, most whales seem to defecate before they dive deep and it has been possible to collect samples from the surface.

Two effective ways have been following the whales on a boat, snorklers in tow and also having scent-detection dogs upfront on the boat (Rolland *et al.*, 2006, Ayres *et al.*, 2012). In the case of right whales, use of dogs increased sampling rates by over 4 times. The dogs were also able to detect from a range of about a nautical mile. But using these techniques will prove to be a problem in Antarctic waters. The water being too cold for snorkeling for most of the year and in the case of dogs - very little acclimitisation/favourable conditions.

Respiratory (Blow) samples: In the past, one of the toughest samples to gather has been whale blows. There have been pole-based samplers used from boats and radio controlled helicopters (Kathleen Hunt et al., 2013, Acevedo-Whitehouse et al., 2010).

Two blow collection devices for collecting respiratory samples for free-ranging whales (Acevedo-Whitehouse et al., 2010) were tested. A blow collection is deemed 'successful' usually when the collecting plate/modified petri-dish shows the presence of respiratory condensate. For larger whales, the extendable pole seems to be a better and cost-effective apparatus for blow collection. For smaller species it is important to ensure that the sample doesn't get contaminated due to splashing water as the subject might be closer to the boat.

Recent technological developments have enabled small drones to be fitted with sample collection apparatus. Though there is a limitation in terms of battery life (and how long it can be used)- it would enable researchers to collect samples more frequently via a boat/ship.

From hormones to micro-organisms, these enable researchers to study various parameters and micro-organisms related to whale physiology, endocrinology, and reproduction.

3. Conclusion and the road ahead

Having looked at various types of non-invasive data capturing and monitoring methods, it is fair to say that each of the studies have been fairly responsible in making sure that the species come first. It is 'horses for courses' when it comes to accuracy of data for each species. They vary depending on habitat (land-based, ice-based or marine), type of species, and population size.

Satellite imagery seems to be the least invasive but still needs to improve on the accuracy front. Slowly but surely, there needs to be a consistent collaboration across research and technology groups so that the best resources are shared for increased accuracy.

In the current era of rapidly growing technological tools, there have been instances where drones and seismic surveys have disturbed certain species. It is imperative that going forward, the best practices from past and current studies are used in order to set proper guidelines so that there is no impact on their regular behaviour - especially during feeding, nesting and breeding phases. We need to remember to prioritise this to ensure a combination of the least invasive methodology and greatest accuracy.

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Policy Brief – November 2018

by

Ramcharan Vijayaraghavan

The issue at hand

Numerous species have gone extinct over the last few decades as a result of climate change as well as an ever-increasing human footprint. While the debate is still on, the IPCC's special report of 2018 articulating the impact of global warming of 1.5°C above pre-industrial levels, emphasizes the impact that climate change can have on Antarctic mega fauna. Thereby arises an immediate need to gather more frequent and accurate data in order to identify/monitor various species.

Where do we stand?

1. The Species – The food web in the Antarctic is complex and strongly inter-connected. From phytoplankton and krill to penguins, seals and whales, it is important to study each species, as they are definite indicators of changes around the world.
2. Scientific Research – Moving away from invasive and 'traditional' methods that might affect Antarctic species is imperative. It is important to understand the role that non-invasive data-capturing and identification methods play in assessing the vulnerability of species, apart from their reaction to climate change. Some of the significant examples have been comparing the current and possible uses of technology in satellite imagery, photos via infrared cameras/thermal-imaging, camera-traps and UAVs.
3. Stakeholders - Some of the bodies that govern movement and manage the impact on specific species in the southern ocean such as the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) and the Convention for the Conservation of Antarctic Seals (CCAS) need to share and be up to date with their findings in order to take strong decisions backed by solid data.
4. The Next Generation - An emerging trend is the evolution of the 'citizen scientist'. Scientists have been collaborating with conservationists and photographers to populate their data samples. Projects like The Polar Citizen Science Collective and Zooniverse have proved to be interesting avenues to gather more data or resources to contribute to scientific research thereby involving the global citizen.

What happens next?

Everyone needs to be on the same page and we need to look at the following aspects:

- The Antarctic is not a closed system, and it is critical to take a closer look at best practices in the conservation of mega fauna (in the context of climate change) and share it across borders and between organizations.
- We also need to set proper guidelines so that there is no impact of various technologies on the regular behaviour of the species- especially during feeding, nesting and breeding phases. Scientists and researchers are increasingly collaborating to ensure that the sharing of ideas leads to a more comprehensive study of the Polar Regions.
- The various methodologies and studies outlined and used to monitor Antarctic species have ranged from on-ground research spanning decades to instant high-resolution imagery taken via satellites. There is a cost to methodology trade-off and therefore the need to share resources so that the environmental benchmark is not lowered.

These are significant challenges and there are hurdles that need to be crossed, but that is the only way for a stronger (Antarctic) future.