PCAS 17 (2014/2015)

Critical Literature Review (ANTA602)

The Effect of Climate Change on Antarctic Seals

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Word count: 2529

Abstract (ca. 200 words):

Climate change will have a significant impact on the seals of Antarctica, the Weddell (*Leptonychotes weddellii*), crabeater (*Lobodon carcinophagus*), leopard (*Hydrurga leptoynx*), Ross (*Ommatophoca rossii*), southern elephant (*Mirpunga leonina*) and Antarctic fur seal (*Arctocephalus gazella*). It is likely to affect food supply, habitat availability and reproductive rates, altering population size. Survival will depend on seals' ability to change behaviour and adapt to changing conditions but the severity of the impact will vary with different species. It is important to determine how seals wil react to climate change as they can be used as indicators of sea ice condition and prey availability. Crabeater populations are likely to decline due to the loss of sea ice affecting krill abundance, habitat availability and protection from predators. Leopard seals have a very diverse diet so may not experience the same decline due to loss of food sources, however juvenile mortality may still cause a population decline. Populations of Weddell seals may decrease due to a lower breeding rate. Populations of Ross seal may also decrease due to loss of sea ice and increased forgaing costs from changing distribution of squid. Whilst southern elephant seals and Antarctic fur seals will not be negatively affected by loss of sea ice (indeed, this may lead to population expansion), loss of food sources may still cause a population decline. The declining population numbers is a very serious issue as it reduces the species ability to adapt to the changing conditions. Seals are an important part of the Antarctic biota therefore changes in their lifestyle characteristics will affect the whole marine ecosystem.

The Effect of Climate Change on Antarctic Seals

How will climate change affect Antarctic seals in terms of habitat availability, food supply and population size?

A Critical Literature Review

Antarctic Fur, Weddell and Crabeater Seal (Prokosch, 2010a, 2010b, 2011)

Contents

Introduction

It is an established fact that climate change is occurring due to increased greenhouse gas emissions from human activity (Houghton & Intergovernmental Panel on Climate Change. Working Group, 2001). As a result there will be many changes to the marine ecosystem such as higher temperature, altered circulation and ocean acidification (Doney et al., 2012). Changes to the Antarctic system include higher atmospheric temperatures from ocean warming, increased frequency of westerlies, glacier retreat, lower salinities and loss of sea ice (Constable et al., 2014; Doney et al., 2012; Mayewski et al., 2009). These changes will also vary spatially. As the effects from climate change become more severe, the fauna of Antarctica will be affected, testing the tolerance limits of species that are already living in extreme conditions (Doney et al., 2012). Reactions will differ, but may include changes in timing of events, dispersal patterns, reductions in population size, adaption or even extinction depending on their ability to adapt (Constable et al., 2014; Doney et al., 2012; Le Roux, 2012).

This critical review will look at the effect of altered habitat and food source availability, and the changes in population size and reproductive rates of Antarctic seals as a result of climate change. Seals are heavily reliant on both the terrestrial environment as habitat and the marine environment as a food source therefore they will be vulnerable to the effects of climate change (Sun et al., 2004). They can also be used as indicators of sea ice condition and prey availability therefore it is important to evaluate the current literature on the subject and identify areas of future research.

There are six species of seals found in Antarctica, five species of true seals (Family Phocidae): the Weddell (*Leptonychotes weddellii*), crabeater (*Lobodon carcinophagus*), leopard (*Hydrurga leptoynx*), Ross (*Ommatophoca rossii*) and southern elephant seal (*Mirpunga leonina*); and one species of eared seal (Family Otariidae): the Antarctic fur seal (*Arctocephalus gazella*) (Stewardson, Child, & Australian National Antarctic Research, 1997). This critical review will focus on these six species.

Habitat

The habitat preferences of Antarctic seals vary between species. All of the true seals have a circumpolar distribution, with crabeater, leopard and Ross seals found on pack ice and southern elephant and Weddell seals distributed on ice-free areas (Shirihai, Jarrett, & Kirwan, 2002; Stewardson et al., 1997). Antarctic fur seals have a patchier distribution but are also only found in ice-free areas (Stewardson et al., 1997).

Seals that rely on ice as habitat will be more severely affected by climate change than those that live in ice-free areas. Due to atmospheric and oceanic warming, sea ice is declining dramatically in some areas (Moline, Claustre, Frazer, Schofield, & Vernet, 2004). Sea ice provides a medium for reproduction and defense against predators for species such as crabeater and leopard seals (Siniff, Garrott, Rotella, Fraser, & Ainley, 2008). The size and structure of the ice floe is also important (Siniff et al., 2008) so any change is likely to be detriemental to the reliant populations, as shown below in Figure 1.

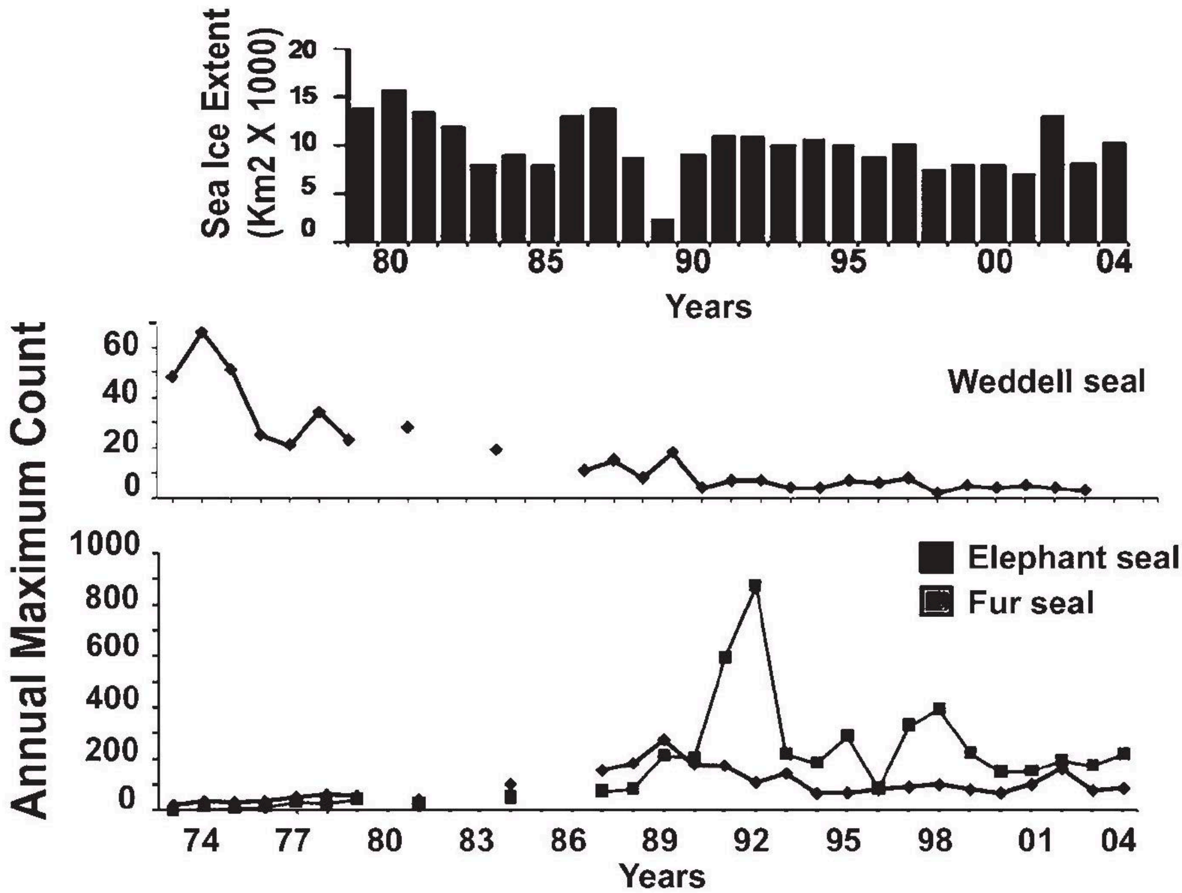

Figure 1. Relationship between sea ice extent and seal population size. Area of sea ice on the west coast of Antarctic Peninsula from satellite imagery and the yearly census of Weddell, elephant and fur seal populations in Arthur Harbour and Anvers Island, 1974–2005 (Siniff et al., 2008).

With the exception of southern elephant seals, all Antarctic seals that rely on pack ice are usually found solo or in small groups of two to five individuals (Shirihai et al., 2002; Stewardson et al., 1997) as seals can be territorial, aggressive animals (Coffey, Caldwell, & Caldwell, 1977). Population dynamics are likely to be affected as habitat availability decreases and these solitary animals are forced together. Interspecies conflict may also increase, for example crabeater seals, especially pups, are predated on by leopard seals which may lead to a population decline if these species are forced to be in close proximity.

In a study on the adaptability of harp seals in the North Atlantic it was predicted that the observed higher mortality rate was due to loss of sea ice and therefore lack of suitable breeding habitat resulting in high pup mortality (Stenson & Hammill, 2014). It was suggested that they might adapt by moving further north where there is more ice (Johnston, Bowers, Friedlaender, & Lavigne, 2012; Stenson & Hammill, 2014). Seals in Antarctica may react similarly with those that rely on sea ice moving further south in the future. Other responses to the reduction of sea ice could be a change in timing of breeding season or changes in behaviour such as beginning to breed on ice free areas (Stenson & Hammill, 2014). It has also been found that there is a lack of flexibility in the breeding habits of harp seals (Johnston et al., 2012) which may also be true for Antarctic seals, preventing them from adapting to the changing conditions. In this case, population declines can be expected.

Seals that do not rely on pack ice, such as southern elephant, Antarctic fur and Weddell seals may expand their range as more ice-free areas become available. This has already been seen in some penguin species with reduced ranges for ice dependant species such as Emperor and Adelie penguins and non ice dependent species such as gentoo and chinstrap penguins enlarging their range (Jaume Forcada & Trathan, 2009). But these seals may also encounter competition for territory if those that previously used pack ice are able to adapt and move into ice free areas.

Food Sources

All seals are completely dependent on the ocean as a food source (Shirihai et al., 2002) therefore any changes in the ocean system will have an impact on the seal's ability to obtain food.

As well as variations in habitat preferences, Antarctic seals also differ in their food preferences. Krill is a major food source for crabeater, Antarctic fur and leopard seals, however is also occasionally taken by the other seal species (Stewardson et al., 1997). There have been many studies on changes in Antarctic krill (*Euphausia superba*) abundance and how it will affect the foodweb (J. Forcada et al., 2012; Hill, Phillips, & Atkinson, 2013; Moline et al., 2004; Thomson, Butterworth, Boyd, & Croxall, 2000; Trivelpiece et al., 2011). Studies have found that krill populations are declining due to the loss of sea ice (Atkinson, Siegel, Pakhomov, & Rothery, 2004; J. Forcada et al., 2012; Moline et al., 2004; Trivelpiece et al., 2011). Changes in krill abundance is likely to affect crabeater seals the most as it makes up ninety percent of their diet (J. Forcada et al., 2012), whereas both Antarctic fur and leopard seals have other food sources such as squid, krill, fish, penguins, and in the case of leopard seals, the occasional baby seal (Shirihai et al., 2002; Stewardson et al., 1997).

Krill populations are also one of the most heavily fished species in the Antarctic and the loss of sea ice has subsequently allowed an expansion of the krill fishery (Atkinson et al., 2004) putting even more strain on this species (Figure 2a). The demand for krill by seals and other predatory species needs to be taken into account in fisheries models or climate change will not be the only pressure on seal food supply (Thomson et al., 2000). However, populations of crystal krill may increase with the loss of sea ice (Pakhomov & Perissinotto, 1996) providing an alternative food source.

While seals are on land or sea ice they are fasting (Coffey et al., 1977) and if they are unable to get enough food whilst at sea, survival will be seriously impacted when they return to land. Krill already have a variable distribution (Ross, Quetin, & Lascara, 1996) (Figure 2b) and a declining population means that the cost of foraging trips for seals will be greater in terms of energy expenditure, unable to be countered by greater food demand. This decline in krill population will have negative impacts on reliant seal populations, leading to reduced breeding output and eventually population declines. Seals will not be the only organisms that suffer, the decline in krill will also affect peguins, baleen whales, birds and fish (Thomson et al., 2000).

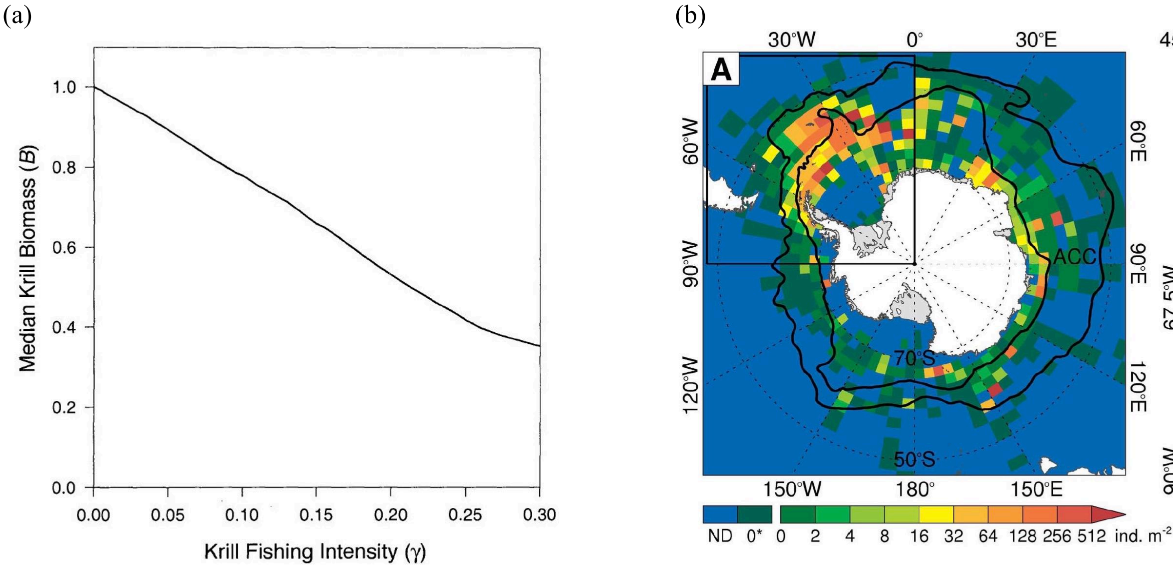

Figure 2. (a) Median krill abundance, which is defined here as krill spawning biomass (B'P) after 20 years of krill fishing, as a proportion of pre-exploitation krill spawning biomass (KSP), for a range of krill fishing intensities (-y) (Thomson et al., 2000). (b) The distribution of krill in Antarctica (Hill et al., 2013).

Ross, southern elephant and Wedell seals are not reliant on krill but climate change will still affect their food supply. Ross seals feed mostly on squid, Weddell seals predominately on fish, and southern elephant seals on both squid and fish. Populations of fish are also likely to decline due to warmer and more acidic oceanic conditions, depending on their adaptability (Constable et al., 2014; Mintenbeck et al., 2012; O'Brien & Crockett, 2013) and negatively impact seal populations. Squid distribution, not population size, will change in response to warmer ocean temperature (Rodhouse, 2013) therefore Ross and southern elephant seals may suffer through increased foraging costs. As a result, populations of Ross, southern elephant and Wedell seals are likely to decline as well, due to reduced food availability (Ainley & Blight, 2009).

With the possible exception of crabeater seals, most seal species in the Antarctic are not solely reliant on one food source. It can then be expected that competition for food sources will also increase between seal species as shifts in preference occur, as a result of availability. Those less able to compete will have reduced survival rates.

Population size & reproduction

Historical records make it easier to predict how seal popualtions will react to changing climate conditions. Looking at patterns in seal populations over the past 1,500 years in Antarctic shows that population size is influenced by changes in the climate, such as sea ice and food availability (Sun et al., 2004). As there is a reduction in sea ice, seal populations will decline due to lack of suitable habitat (de Bruyn et al., 2009; J. Forcada et al., 2012) but this is species-specific to those that rely on sea ice as a habitat. Non reliant populations may increase in size, provided their food supply is not affected. The loss of sea ice, and increasing temperature may cause a food shortage and subsequently lead to population decline (McClintock, Ducklow, & Fraser, 2008). It has been proven that krill popualtions are decreasing (T. Huang, Sun, Wang, & Emslie, 2014) and that squid and fish populations will be affected by climate change (Mintenbeck et al., 2012), therefore seal populations can be expected to decline further (Weimerskirch, Inchausti, Guinet, & Barbraud, 2003). An unrelated cause of population decline may be human impact, for example, tourism causing behavioural changes, fishing bycatch, poisoning or disturbance (Chwedorzewska & Korczak, 2010). It is most likely that a combination of factors will lead to population decline.

Reproduction is very energetically expensive and there is a tradeoff with survival. Rates can be expected to decrease due to climate change as a result of stressors such as poor food and habitat availability (Hadley, Rotella, & Garrott, 2007). Weddell seals selectively breed when conditions are good (Lake, Burton, Barker, & Hindell, 2008) so with the adverse conditions of climate change their breeding rate can be expected to decrease in favour of future reproduction opportunities and longevity (Hadley et al., 2007). Southern elephant seals breeding is negatively correlated with low sea ice availability (Hadley et al., 2007). Female crabeaters need constant sea ice cover until lactation is finished and if not achieved, juvenile mortality will be high (Proffitt, Garrott, & Rotella, 2008; Siniff et al., 2008). Timing of breeding seasons could change as a result of climate change for example, Weddell seals breeding later due to poor foraging (Lake et al., 2008). The energetic expense of competing for mates and maternal investment is not viable in times of food shortage (de Bruyn et al., 2009; McMahon & Burton, 2005) leading to a decrease in reproductive rates. Even if breeding is successful, juveniles may not survive due to insufficient maternal investment, underdeveloped immune systems or not enough experience (Gaillard, Festa-Bianchet, & Yoccoz, 1998; Gaillard & Yoccoz, 2003; Proffitt et al., 2008), again leading to population decline.

Conclusion

Seals will be very susceptible to the effects of climate change. Survival will depend on their ability to change behaviour and adapt to changing habitat availability and food supply. Food supply is possibly the most important factor as during the last glacial maximum populations also declined as a result of food shortages (J. Huang, Sun, Wang, Wang, & Huang, 2011; Thatje, Hillenbrand, Mackensen, & Larter, 2008) however habitat availability and reproductive rates will also influence population size. The severity of the impact will vary with different species.

Crabeater populations are likely to decline due to the loss of sea ice affecting krill abundance, habitat availability and protection from predators (J. Forcada et al., 2012; Siniff et al., 2008; Stewardson et al., 1997). Leopard seals have a very diverse diet so may not experience the same decline due to loss of food sources, however juvenile mortality may still cause a population decline (Shirihai et al., 2002; Siniff et al., 2008; Stewardson et al., 1997). Populations of Weddell seals may decrease due to a lower breeding rate (Lake et al., 2008; Siniff et al., 2008). There is a significant lack of information about the Ross seal making the impact of climate change difficult to determine. It can be assumed that this species will also decline for many of the same reasons, such as loss of sea ice and increased foraging costs due to changing distribution of squid (Rodhouse, 2013; Siniff et al., 2008). Whilst southern elephant seals and Antarctic fur seals will not be negatively affected by loss of sea ice (indeed, this may lead to population expansion), loss of food sources may still cause a population decline (Ainley & Blight, 2009; Siniff et al., 2008).

It is important to determine how seals wil react to climate change as they can be used as indicators, however there is still a lack of information that makes predicting the overall impact very difficult. The fishing industry is adding pressure to food sources such as krill and marine reserves could offer a temporary solution but further research is needed into more accurate models (O'Brien & Crockett, 2013). The declining population numbers is a very serious issue as it reduces the species ability to adapt to the changing conditions. Understanding the effect that climate change will have on the habitats of seals is vital to predicting the flow on effects to food supply, breeding systems and population dynamics. Seals are an important part of the Antarctic biota therefore changes in their lifestyle characteristics will affect the whole marine ecosystem.

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