Literature Review:

Population dynamics of Antarctic and sub-Antarctic Penguin species

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INTRODUCTION

Penguins are one of the most recognizable of all birds and are used extensively as symbols of Antarctica. There are 17 species of penguin, of which eight breed in the Antarctic region (the Antarctic continent and other areas within and around the Antarctic convergence) (Woehler 1993). These eight species comprise the Adelie (*Pygoscelis adelie*), the Emperor (*Aptenodytes forsteri*), the Chinstrap (*Pygoscelis antarctica*) the Gentoo (*Pygoscelis papua*), the King (*Aptenodytes patagonica*), the Macaroni (*Eudyptes chrysolophus*), the Rockhopper (*Eudyptes crestatus*) and the Royal Penguin (*Eudyptes schlegeli*), although some regard the Royal Penguin as a sub-species of the Macaroni (Woehler 1993). Of these eight species, only the Adelie and the Emperor breed on the Antarctic continent, with all others breeding either on the Antarctic Peninsula or on sub-Antarctic islands (see Figure 1 for distribution information).

Penguins are highly adapted for living in the cold environment of the Antarctic region. They have very dense plumage, made up of overlapping individual feathers, as well as a layer of down (Allen *et al.* 1985). Underneath the feathers and down is a thick layer of fat providing excellent insulation from the cold conditions they experience. Penguins are flightless, with their wings modified into flippers for swimming. They also possess a short stubby tail and a torpedo shaped body, all of which assist them in the water (Allen *et al.* 1985). Penguins feed on zooplankton, squid and fish, and feed their chicks by regurgitation (Young 1994).

Penguin species have been the focus of intensive study in the Antarctic region for many years. For example, scientific reports on Adelie Penguins date back to some of the earliest Antarctic scientific expeditions (Young 1994). A number of studies have focused on the population dynamics of particular Antarctic penguin species (e.g. Jenouvrier *et al.* 2006**,** Micol and Jouventin 2001). Such studies have revealed that penguin populations do not remain constant, with significant fluctuations in population size. Attempts have been made to determine the factors responsible for these changes, with a variety of factors identified. There is concern that Antarctic penguins may be particularly vulnerable to human disturbance and that at least some of the observed decreases in population size may be attributed to human activity (Nimon and Stonehouse 1995). In this report, I review the scientific literature in an effort to determine the current state of thinking regarding the key factors that influence population size in penguins, and in particular how much impact human disturbance is thought to have on Antarctic and sub-Antarctic penguin species.

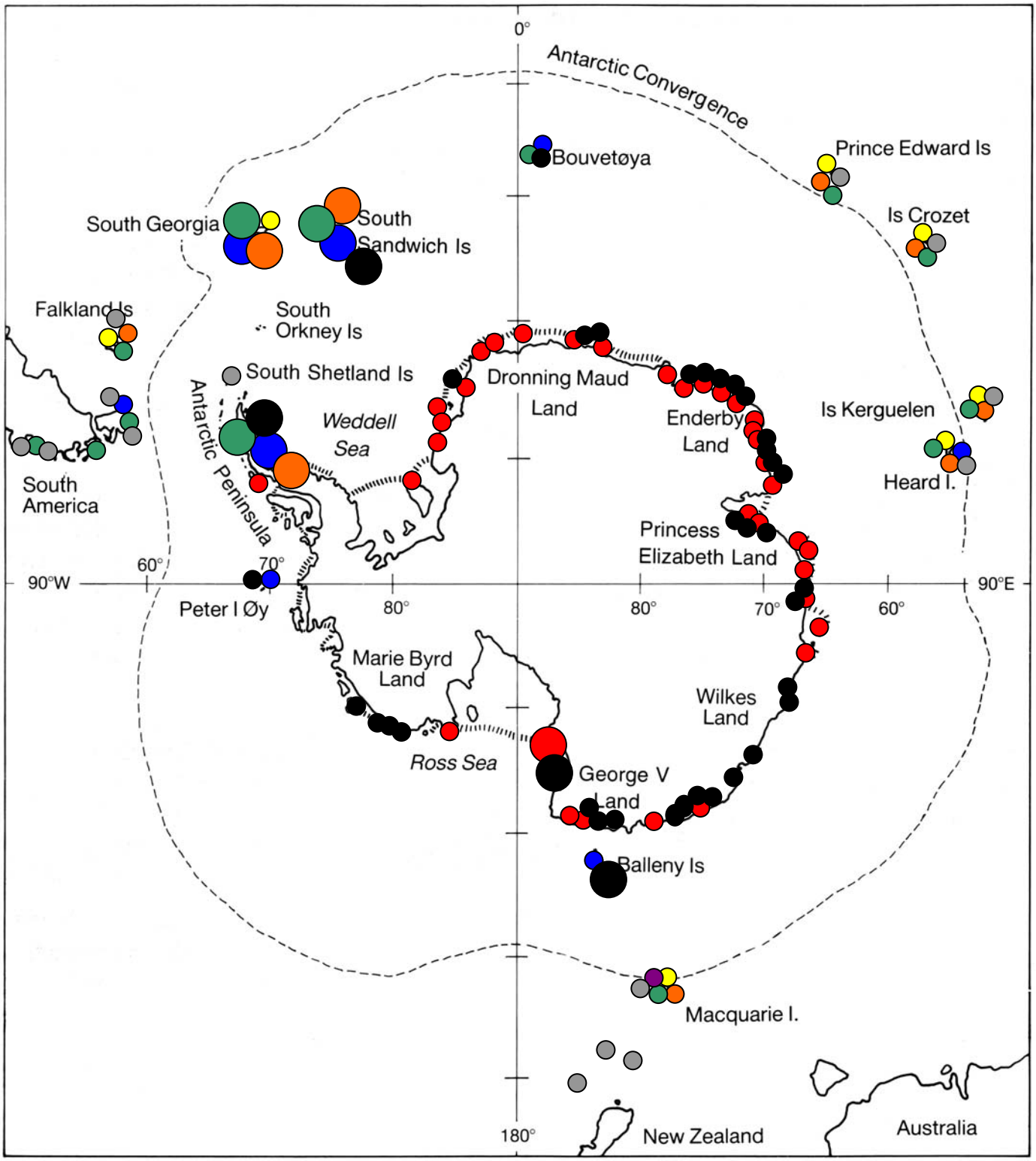

Figure 1: Map showing the distribution of breeding colonies for the eight Antarctic and sub-Antarctic penguin species.

A small circle represents a breeding colony while a larger circle represents several breeding colonies in the region of the map.

Modified from Woehler (1993)

Key

- = Emperor Penguin
- = King Penguin
- = Adelie Penguin
- = Chinstrap Penguin
- = Gentoo Penguin
- = Rockhopper Penguin
- = Royal Penguin
- = Macaroni Penguin

In the report, I will address the following questions:

1. How are estimates of Penguin population size made?
2. What are the key factors (other than human disturbance) that appear to impact on penguin population size?
3. What impact does human disturbance have on Penguin populations?

METHODS OF ESTIMATING PENGUIN NUMBERS

Studies investigating population dynamics in penguin populations require the accurate collection of data regarding population size over several seasons. For some populations, long term studies have allowed the collection of such data. For example, Chinstrap Penguins in Admiralty Bay on the Antarctic Peninsula have been monitored for over 25 years (Sander *et al.* 2007), Gentoo Penguin colonies have been studied on Goudier Island for 12 seasons (Tranthan *et al.* 2008), and Adelie Penguin populations in the Ross Sea for about 29 years (Wilson *et al.* 2001). These datasets allow scientists to determine how much fluctuation there is in population size. Most of these studies have relied on ground counts of adult penguins (e.g. Sander *et al.* 2007), a relatively costly and time consuming method of estimating population size. Recently, new methods have been developed for gathering data relating to population size in penguins. Use of aerial photography has made population estimates of penguin colonies much easier and more accurate. Taylor *et al.* (1990) used photographs of colonies to determine population size of Adelie Penguin colonies in the Ross Sea Region. Using this method, over one million breeding pairs were counted and 11 new breeding rockeries were identified, bringing the total number of breeding colonies in the region to 38 (Taylor *et al.* 1990). It is interesting to note that in 1981, accurate counts were available for only 4 of the 11 colonies then known for the Ross Sea region, with only one of these counts made in the 15 years prior to 1981 (Taylor 1981). Taylor (1981) stated that “an aerial photographic census to determine the size of all penguin colonies in the Ross Dependency is urgently needed”. In 2004, Tranthan used computer based analysis of aerial photographs of Macaroni Penguin colonies on South Georgia to estimate population size. In both cases (Taylor *et al.* (1990) and Tranthan 2004)), the estimates of population size were correlated with ground counts and confirmed that the aerial method was a reliable, non-invasive method of monitoring population size in the two species. More recently, Barber-Meyer *et al.* (2007) used remote sensing technology to estimate the size of Emperor Penguin colonies at inaccessible sites in the Ross Sea. This was seen as a much easier method than aerial and ground-based counts, and was perhaps the least invasive method of gathering data. This method of estimating population size in penguin populations and

monitoring change will likely become more common, particularly as improvements in satellite images (e.g. increased resolution) are made (Barber-Meyer *et al.* 2007).

In 1993, a comprehensive summary of the distribution and abundance of Antarctic and sub-Antarctic penguins was compiled on behalf of the Scientific Committee on Antarctic Research (SCAR) (Woehler 1993). This provided an excellent overview of the status of the eight penguin species breeding in the Antarctic region and provided good baseline data for future comparisons.

FACTORS IMPACTING ON PENGUIN POPULATION SIZE

A number of long-term studies have shown that penguin populations show considerable variation in numbers from year to year (e.g. Jenouvrier *et al.* 2006**,** Micol and Jouventin 2001**,** Figure 2). Overall, it appears that some species of penguin are in decline while others are increasing in population size (BAS 2008). For example, Macaroni Penguins on South Georgia have declined from 2.5 million breeding pairs 30 years ago to approximately 1 million pairs currently (BAS 2008). In the same location, King Penguins have increased from a few hundred birds to almost half a million. Considerable efforts have been made to understanding why these fluctuations occur and therefore identify the key factors that drive population size in penguin species. This has become even more important in recent years as scientists recognize penguins as good “bioindicators” (Barber-Meyer *et al.* 2007). Changes in population size in penguin species may provide vital information as to the health of Antarctic and sub-Antarctic ecosystems in general.

Many studies have identified sea ice conditions as the primary factor influencing population size in many penguin species (e.g. Wilson *et al.* 2001, Weimerskirch *et al.* 2003, Pezzo *et al.* 2007, Montague 1988, Kato *et al.*2002, Jenouvrier *et al.* 2006, Emmerson and Southwell 2008, Barber-Meyer *et al.* 2008). It appears that the sea ice conditions during the breeding season or during the first year at sea are important. For example, Pezzo *et al.* (2007) suggested that in seasons of increased sea ice, adult Adelie Penguins have less time to search for food which impacts negatively on breeding success and ultimately population size. Similarly, Wilson *et al.* (2001) proposed that growth in Adelie Penguin populations in the Ross Sea was inversely related to the extent of sea-ice in the region. In years when the winter sea ice extended further north than normal, Adelie Penguins were forced to feed in less productive waters, resulting in increased mortality of adults and ultimately decreased breeding success in subsequent years (Wilson *et al.* 2001). Taylor et al. (1990) proposed that warming in the Ross Sea region may have led to a reduction in sea-ice cover and thus led to an increased supply of food which resulted in growth of Adelie Penguin populations.

However, while the extent of sea-ice does appear to play some role in regulating penguin populations, there is evidence that the effect on population dynamics varies from species to species (Anderson 1991).

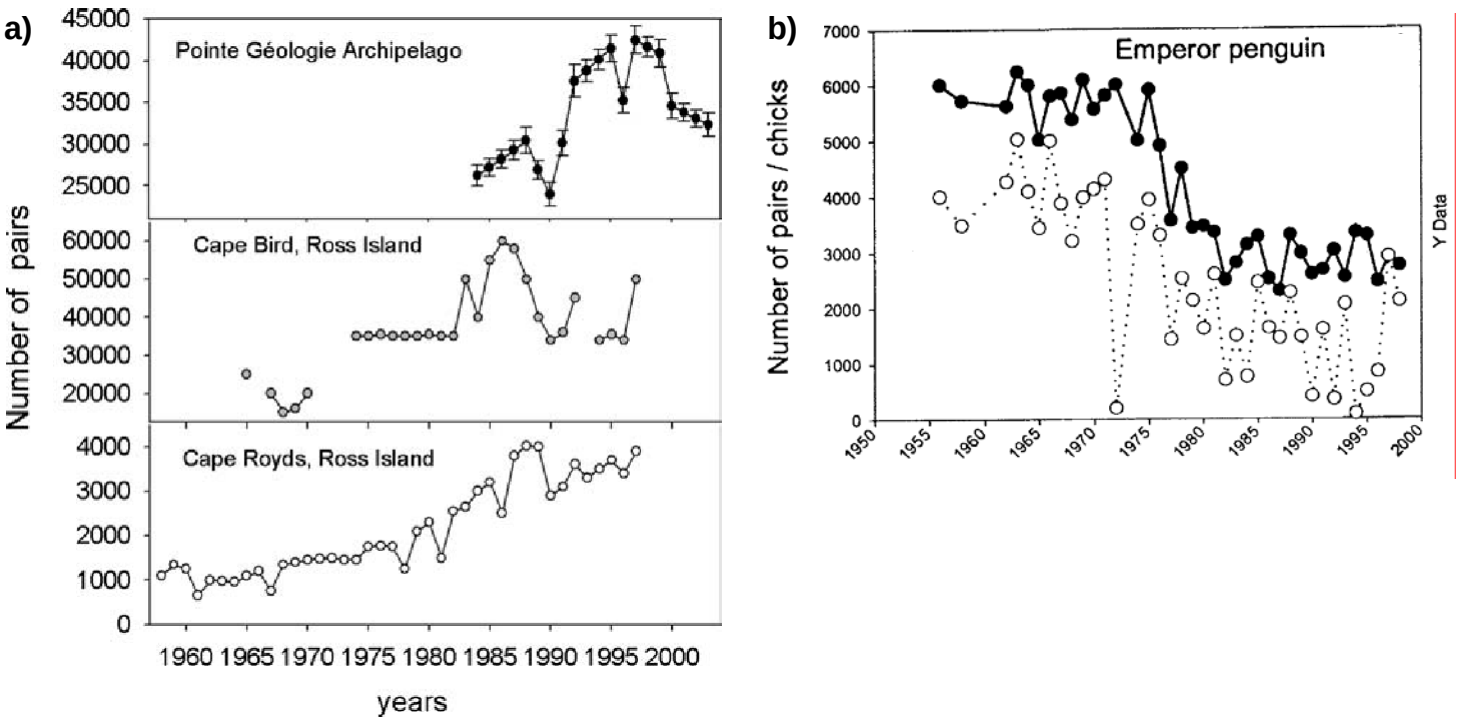

Figure 2: Examples of the fluctuations observed in breeding populations of penguins.

a) Number of breeding pairs of Adelie Penguin at Pointe Geologie (Terre Adelie) and the Ross Sea (Cape Bird and Cape Royds) (from Jenouvrier *et al.* 2006).

b) Number of Emperor Penguin breeding pairs (closed circles) and chicks produced between 1955 and 1999 at Point Genologie (Terre Adelie) (from Micol & Jouventin (2001)).

Another factor that appears to play a role in regulating population size in penguins is food availability. The breeding population of Gentoo Penguins at the sub-Antarctic Iles Kerguelen decreased by over 30% in the 15 years between 1987 and 2002 (Lescroel and Bost 2006) with the decrease attributed to reduced food availability due to overfishing. Anderson (2001) reported a decrease in Adelie and Chinstrap penguin populations on the Antarctic Peninsula of 20%. The fact that both species of penguin showed a decrease in population size suggested that the extent of the sea-ice was inadequate as a singular explanation for the decrease as this factor affected the two species quite differently. Instead Anderson (1991) proposed that overfishing of krill (*Euphausia superba*), the crustacean that make up the majority of the diet of penguins, was responsible for the decreases in population size for these two species.

In reviewing the literature it is evident that there is no consistent pattern across penguin species (or even across different populations of the same species) in terms of population growth or decline. For example Chinstrap penguins on the Antarctic Peninsula are generally increasing, while on the South Orkney Islands they are decreasing (Micol and Jouventin 2001). In contrast, Adelie Penguins have decreased at several locations on the Antarctic Peninsula but are generally increasing in the Ross Sea (Taylor and Wilson 1990, Micol and Jouventin 2001). Different factors appear to be affecting the various species of penguins differently and this also appears to depend on the locality of breeding. The specific different factors interact and influence population dynamics is not well understood (Tranthan *et al.* 2008). Further research is required to better understand how population size is regulated in the various Antarctic penguin species.

What is apparent in reading the literature is the increased influence human disturbance appears to be having on penguin populations. The increase in tourism traffic and research activities in Antarctica and the sub-Antarctic means that a good understanding of the impact of humans on these populations is vital.

THE IMPACT OF HUMAN DISTURBANCE ON PENGUINS

Several studies have attempted to directly measure the impact of human disturbance on penguin behaviour or physiology. In 1997, Regel and Putz monitored the stomach temperature of Emperor Penguin adults and chicks. Temperature changes were measured with varying degrees of human stimulus and this could then be converted to a measure of the energy cost involved in the response. The study showed that the energy cost associated with the response to a human could be up to about 10% of the daily energy requirement.

Nimon *et al.* (1995) studied the effects of human appearance on heart rate in Chinstrap Penguins. Heart rate was used as an indicator of stress with increased heart rate seen as strong evidence that the penguin is stressed. Instead of using a portable ECG device (as was used in a previous study), Nimon used artificial eggs with heart rate monitors to determine the heart rates of adult birds. Results showed that Chinstrap Penguins did show an increase in stress levels as humans approached (indicated by an increase in heart rate) despite there often being no other outward indications of stress.

Holmes *et al.* (2005) studied the impact of humans approaching Royal Penguins at Macquarie Island to the current recommended minimum distance (5 metres). The study showed that while individual penguin heart rates increased and the birds became six times

more vigilant, they did not leave their nests and thus compromise the safety of their offspring. While Holmes *et al.* (2005) concluded that this provided evidence that the impact of a single person on Royal Penguins was only minor or transitory, concern was raised as to the cumulative impact of this sort of disturbance.

A study of Gentoo Penguins at Macquarie Island (Holmes *et al.* 2006) looked at the different responses of penguins in areas of low and high human activity. Interestingly, penguins in the areas that experienced low human activity gave stronger responses, suggesting that penguins that are frequently exposed to human disturbance become somewhat habituated to humans (Holmes *et al.* 2006). However, despite any significant difference in breeding success between the penguins in the two types of area, Gentoo Penguins in high human activity areas still gave a response, suggesting that while some habituation may have occurred they still regard humans as some sort of threat. Holmes *et al.* (2006) concluded by suggesting that having tourists visit the same sites may be preferable as this would ensure disturbance is of birds that are habituated to humans to some degree.

Increased tourism and research activity have also resulted in an increase in fixed wing and helicopter activity. Hughes *et al.* (2008) investigated the response of King Penguins at South Georgia to overhead flights. Flights were conducted at various altitudes and the response of adult penguins monitored. Despite the fact that no eggs or chicks were taken by predators during the flights, penguin behaviour did change during all flights. However, normal behaviour generally resumed within 15 minutes of the flight activity and the King Penguins did show some evidence of being habituated to aircraft (Hughes *et al.* 2008).

The various studies discussed indicate that human disturbance does indeed have some impact on penguins at an individual level. An interesting and important question is whether or not all species of penguins are affected to the same degree. Holmes (2007) looked at the differences in response of three penguin species (King, Gentoo and Royal Penguins) to human visitation on MacQuarie Island in 2001-2003. The behaviour of the most affected species (Gentoo) remained altered for about 5 minutes after visitation (Holmes 2007). The study raises the interesting question of whether or not general rules can be established relating to tourist activity around penguins (e.g. recommended minimum distances) or whether differences in sensitivity of penguin species to human disturbance mean species-specific rules need to be established.

HUMAN DISTURBANCE AND POPULATION SIZE

As detailed previously, some studies have shown that human activities, and in particular human tourism activity, can have an impact on stress levels in individual birds (e.g. Hughes *et al.* 2008, *et al.* 1995, Regel and Putz 1997). However, it is also important to try to determine the effect that these activities have on populations as a whole. Does tourist traffic at penguin colonies have a negative impact on breeding and thus be leading to a reduction in population size over time?

Several studies have attempted to measure the effect of human activity in order to answer these questions. In a number of these studies, colonies that experienced human disturbance were compared to those colonies that were relatively free of human impact. Acero and Aguirre (1994) monitored Chinstrap Penguin colonies at Halfmoon Bay, South Shetland Islands (1991-1992) and showed that reproductive success was 5-10% less in areas that experienced tourist traffic. Carlini *et al.* (2007) compared 89 breeding groups of Adelie Penguin between 1995 and 2005, recording the number of breeding pairs, number of chicks in crèches and the number of chicks produced each season. Some of these groups experienced high levels of human disturbance and others experienced low levels of disturbance. Results indicated that while the number of chicks fledged decreased in the high disturbance area when compared to the area that experienced low disturbance, the physical environment appeared to have a bigger effect than human disturbance in impacting on population dynamics. Cobley and Shears (1999) looked at tourist effects on Gentoo Penguins at Port Lockroy on the Antarctic Peninsula. Comparisons were made of penguins at treatments areas which experienced between 35 and 55 tourists per day and control areas in which penguins did not experience human disturbance. Results suggested that tourist traffic had little impact on the Gentoo Penguin colonies with no difference in hatching success or chick mass or survival on the two types of areas. Overall, Cobley and Shears (1999) concluded that tourists were unlikely to be causing changes in penguin numbers.

Chinstrap Penguins at the Admiralty Bay ASMA (Antarctic Specially Managed Area) have showed a dramatic decrease in population over the last 25 years (Sander *et al.* 2007). While there is some ship traffic and airplane traffic in the vicinity, the population is not visited by humans. The population decreases mirror the declines seen in other parts of the Antarctic Peninsula and suggest that human impact does not play a role in the population changes in this species at this location.

Tranthan *et al.* (2008) looked at population trends and breeding productivity of Gentoo Penguin Colonies at Goudier Island in the Palmer Archipelago over 12 seasons. During this time two colonies showed significant reductions in population size. What is interesting to note is that one of these two colonies was a colony used to determine breeding chronology for the species in the region so was visited more frequently and visits were more invasive. The study revealed that while there were obviously many factors that could affect population dynamics, intensive and frequent human disturbance should be avoided as it appeared to have a negative impact on the Gentoo Penguin population at Goudier Island (Tranthan *et al.* 2008).

CONCLUSION

The monitoring of penguin populations on an ongoing basis appears to be a valid and important activity. Research has shown that penguin species play a vital role in the Antarctic and sub-Antarctic ecosystem as top consumers. Current research indicates a lack of consensus as to what regulates and controls population size in penguin species, although the extent of sea ice and food supply appear to be two key players in this. The impact of global warming will obviously play a role as it affects both sea-ice coverage and may impact on the abundance of key prey species (such as krill). What is evident in the literature is that the various factors impacting on penguins affect different species in quite different ways. Further research is required to better establish how the various Antarctic and sub-Antarctic penguin species respond to these factors.

Human disturbance does have an impact on individual penguins, with the studies detailed showing an increase in penguin stress levels with disturbance. "…Tourism does adversely affect breeding penguins, almost irrespective of how well behaved the tourists are" (Nimon *et al.*1995). However, the degree of response appears to differ between species and also depends on the previous levels of exposure to humans with some species showing evidence of habituation.

At a population level, there is little evidence to suggest that human disturbance is having a significant negative impact on penguin populations (Woehler and Croxall 1997). Current guidelines as to how tourists should behave when visiting penguin populations may be stringent enough and therefore effective at minimizing the potential impact. However, consistent monitoring of frequently visited penguin populations is required to ensure that populations are not being adversely affected by tourist traffic.

Some researchers raise the point that while the impact of individual tourists or small tourist groups may be “minor” or “transitory”, the cumulative effect is unknown. Tourist numbers in the Antarctic are increasing at a phenomenal rate (Figure 3), particularly in the Antarctic Peninsula region. One of the most frequently visited tourist spots in the Antarctic has seen tourist numbers increase from approximately 4000 in 1997 to almost 18,000 in 2008 (Figure 4). As tourism in the Antarctic continues to grow, more and more penguin colonies may be subjected to disturbance by humans. It is vital that the cumulative effect of tourists on these penguin populations is better understood. This will require a program of careful monitoring and focused research.

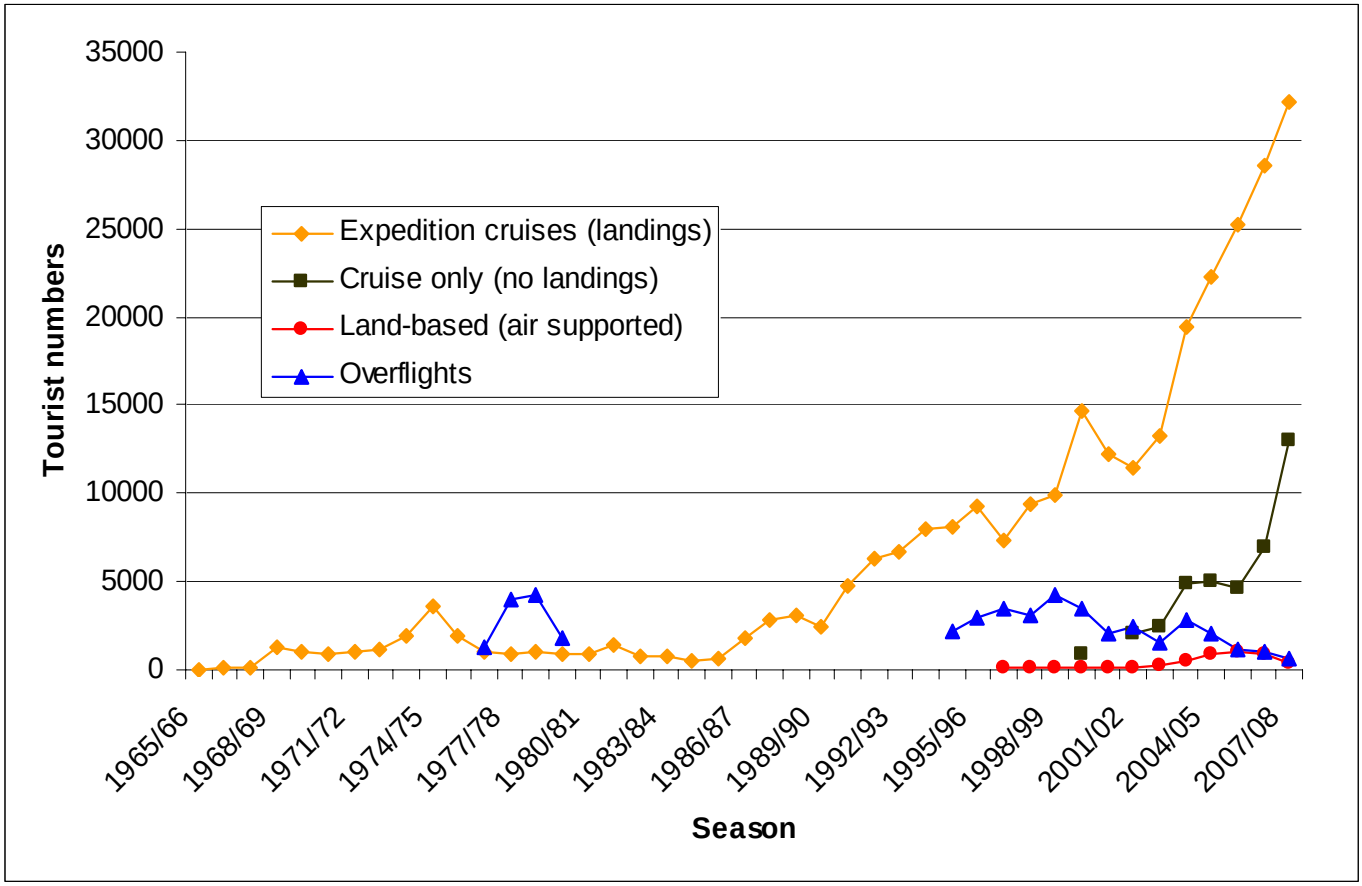

Figure 3: Graph showing the change in tourist numbers in the Antarctic region from 1965/66 to 2007/2008 (from Lamers *et al.* 2008)

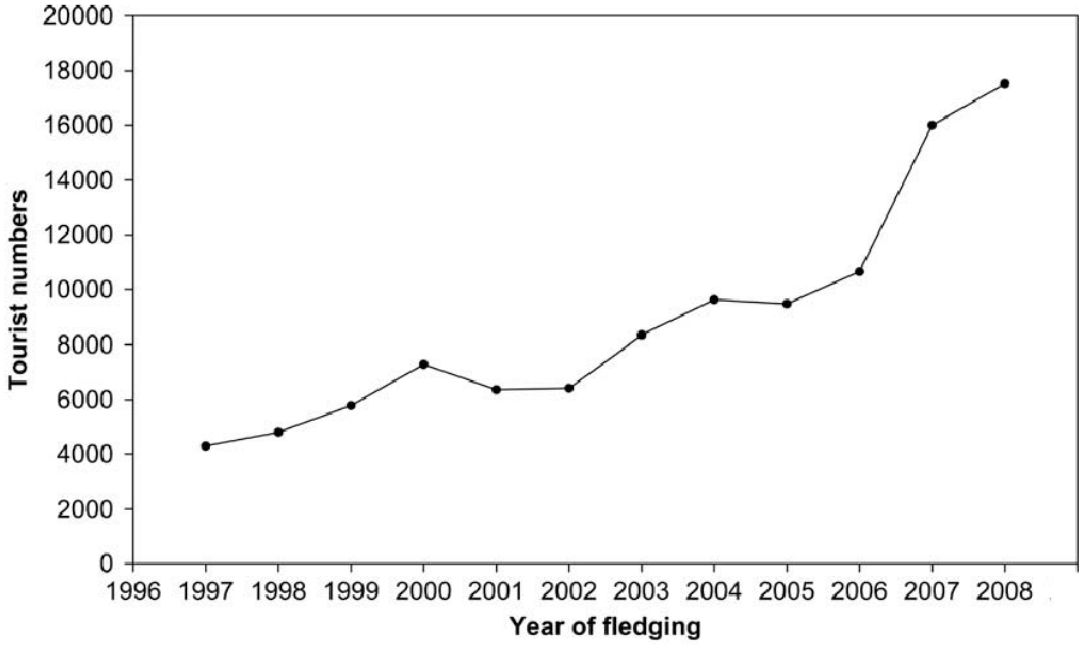

Figure 4: Graph showing the number of tourists visiting the Goudier Island (Antarctic Peninsula) Gentoo Penguin colony between 1997 and 2008 (from Tranthan *et al.* 2008).

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