Footprints of Climate Change in the Antarctic Marine Ecosystem.
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I. Introduction
   a. Discuss Research in the Antarctic

Almost 100 years have passed since man was first able to reach the South Pole a journey attempted many times before by Shakelton but eventually completed by Admunson (also involved in Arctic expedition). More than 50 years have passed since man was able to make the first cross continental journey of the Antarctic continent accomplished by British geologist Vivien Fuchs, during the International Geophysical Year (IGY) of 1957-58. The IGY of 1958-59 also prompted the creation the Antarctic Treaty signed in 1959 where 12 nation designated all the area south of 60ºS as a protected area. The primary purpose of the Antarctic treaty was to ensure "in the interests of all mankind that Antarctica shall continue forever to be used exclusively for peaceful purposes and shall not become the scene or object of international discord." It is a treaty was eventually signed by 46 countries that set the stage for the creation of agreements and regulation that make up the Antarctic Treaty System (ATS). The ATS among other things guarantees the environmental protection of natural resources and of all biota terrestrial and marine in the Antarctic region as well as prohibiting the establishment of military bases while promoting cooperative scientific ventures. Since the signing of the Antarctic treaty in 1959, much scientific research as well as long term research projects have been enacted. The most recent International Polar Year (IPY) 2007-8, the fourth polar year since 1882, brought in over 200 projects from scientists from over 60 countries around the world to researched focus soley on polar regions. IPY 2007-8 called for a major focus on research surrounding the vulnerability of climate change and human impacts on the poles.

Due to its inaccessibility,uninhabitability by humans, and political cooperation estabilished by the Antarctic Treaty, the Antartic region has allowed for and encouraged vast amounts of scientific research compared to the Arctic pole. Wassman et al. 2010 report that Arctic publications account for 51% of Antarctic publications over the year 1991-2008.

In both the Arctic and Antarctic however there is significant evidence of impacts of climate change on the polar ecosystems. Here we seek to summarize all the impacts or footprints of climate change reported in the Antarctic marine ecosystem as well as to provide a clear definition of a footprint including a review of published literature before late 2010.

i. How research efforts compare to Arctic research efforts
ii. Antarctic Treaty, political situation
iii. Major historical projects
iv. Geographical comparison of Arctic and Antarctic

The Arctic Ocean and the Antarctic Ocean are geographical opposites. The Antarctic regions is characterized as a continent surrounded by ocean, while the Arctic Ocean is a actually Mediterranean sea.

b. Climate change in Antarctica
   i. Changes in Temperature

The Antarctic continent has warmed on average 0.9-1.2ºC (1959-1996) with the Antarctic Peninsula warming at more than twice this rate (Jacka and Budd 1998 –IPCC 2001). The Antarctic Peninsula region is considered an area of recent rapid regional (RRR) warming, one of three in high-latitude areas (Vaughan et al. 2003, IPCC 2001). Before the recent work of Steig et al. 2009, it was though that there was a contrast between strong warming in the AP region and slight cooling of the interior of the continent in recent decades (Thompson and Solomon 2002) which was attributed to the recent decadal increase in circumpolar westerlies in response to decrease in stratospheric ozone (Thompson and Solomon 2002, Gillett and Thompson 2003). Steig et al. 2009 show a positive temperature trend all throughout the Antarctic continent by contributing data from the most recent decade into the analysis (1957-2006). While the West Antarctic is still experiencing the most severe temperature increase (0.17 ± 0.06 per decade, 99% confidence), which can be attributed this to regional changes in sea surface temperature and sea ice due to regional changes in atmospheric circulation (Steig et al. 2009, Vaughan et al. 2003), the East Antarctic is experiencing a slightly lower increase of 0.10 ± 0.07 per decade. When combined the continent wide trend is about 0.08ºC per decade although statistical significance at 95% confidence has not been demonstrated (Steig et al 2009, Chapman and Walsh 2007). The drastic temperature increase in the West Antarctic and especially in the Antarctic Pennisula region are strongly associated with changes in sea ice content, sea ice extent, and length of sea-ice season (Vaughan 2003) possibly creating strong feedback effects in this region…

   ii. Changes in Ice extent
   iii. Glacier output
   iv. How does this climate change compare to Arctic climate change, why?
   v. Distinct changes in different areas

c. Climactic variation in Antarctica
   i. Seasonal/interannual variation
   ii. Multiannual/decadal oscillatory processes
   iii. Importance of ENSO, SOI, SAM

d. Historical climate fluctuations
   i. Evidence of past climate fluctuations affecting biota

II. Methods

a. Definition of Footprint

We used the same criteria as Wassmann et al. 2010 to qualify footprints. They use the term footprint in the sense of "a marked affect of impact" (Merriam-Webster Dictionary). Marine biological footprints of climate change refer to documented changes in range, community structure, abundance, phrenology, behavior, growth, or condition of any marine organism in the Antarctic that are consistent with or appear to be the response to a physical variable that is being forced by climate change in that region (Wassmann et al.

2010). Responses inferred from logic arguments, experimental evidence, models, or individual anomalous events are not include as footprints (Wassmann et al. 2010).

b. Latitudinal cutoff

We accepted a footprint when it was reported with the region of the Antarctic continent as designed by the Antarctic Treaty as 60ºS latitude.

c. Search Methodology

General searches for peer-reviewed literature were performed using Google Scholar™ and Web of Science™. Additional journals were selected for further searching based on their relevance to climate change or the polar regions. Examples include Polar Biology, Antarctic Science, and Global Change Biology.

d. Ranking system

We built on the methodology of Wassmann et al. 2010 by adding a ranking algorithm, to rate the strength of each footprint as some articles show stronger evidence than others for demonstrating a biological footprint of climate change. This algorithm was developed based on the work of (O'Conner et al. submitted) where they define the three pillars that will aid to strengthen the research of climate impacts on ecosystems: developed *a priori* expectations, adequate data, and strong statistical tests. We used these pillars to define our three ranking criteria. Because it is important that the findings and correlations presented in each footprint are associated with sufficient reason for causation of climate change as well. For our first criteria we weigh the rating based on the presence of supporting theoretical, paleologic, and/or experimental evidence. Sufficient knowledge and research about the environment and ecology of the organism in question for development of *a priori* expectations before carrying out experimentation or statistical analysis are important to be able to create hypotheses that are falsifiable (O'Conner et al. submitted). The second criteria ranks if each footprint encompassed sufficient data, time-series (temporal), and/or spatial coverage. For example, it is important to use a broad enough temporal scale to account for natural cyclic changes (O'Conner et al. submitted). The third criteria for ranking each footprint places emphasis on the importance of the strength of statistics reported as well as strength of statistical tests presented. Strong statistical test are important to accept or reject hypotheses and evaluate other lines of expectation to narrow down the specific driver of an observed change (O'Conner et al. submitted). With this algorithm with these three criteria outlined we hoped to allow for the assignment of a numerical value to how much confidence should be placed in the findings of each study (O'Conner et al. submitted).

The algorithm is outlined below. Ranks were added up for a total confidence ranking from 0- 10.

Confidence Ranking		
***a priori* expectations?**	**Sufficient Data ?**	**Statistical Analysis ?**
0= no a priori evidence	**0=** < 5 years	**0=** consistency of a trend (i.e. not backed by statistics) with observed physical driver
+1 for theorhetical justification	**1=** 5-10 years	**+1** if biological variable and physical driver are significantly correlated
+1 for paleological justification	**2=** 11-20 years	**+1** if biological variable shows a trend (consistent with trend in observed physical driver) with statistical significance
+1 for experiment justification	**3=** >20 years	**+1** if physical driver shows a trend with statistical significance
	+1 for large spatial coverage (i.e. more than one breeding colony, large ocean basin coverage in the case of plankton)	
	-1 if physical variable ≤ half the time series of the biological variable.	
	-1 for large gaps ≥ 5 years in data reporting, (i.e. non-continuous monitoring)	

e. Discussion of the approach to this work:

It is important also to mention that this review was carried out by an unbiased observer as opposed to an expert working and invested in the research in the Antarctic region, as there is much scientific debate in the Antarctic, especially whether the Antarctic is experiencing a top-down food or bottom up forcing from causes other than climate change.

III. Results
   a. Number of accounts (divide up by ranking)
   b. Highest and lowest ranking
   c. Distribution of types organisms
   d. Geological distribution of organisms
   e. Study effort graph

IV. Discussion
   a. Discuss results
      i. Many encountered footprints are outside of latitudinal cutoff, especially mammals

There were many more footprints encountered north of the 60ºS latitudinal cut off that where not included in this paper. Many of these observations were observed in birds and mammals (e.g. Forcada et al. 2005, Le Bohec et a. 2008). There are no records of mammals in our database, and effort was made to search specifically for footprints in relation to mammals, but all recorded evidence fall outside of the latitudinal cutoff.

      ii. Difference in Arctic and Antarctic of how effects are realized, direct vs. indirect
         1. Ice loss in Arctic is directly affecting habitat loss

Wassmann et al. 2010 have reported 12 footprints involving mammals in the Arctic, which leads us to question the difference of how affects are realized from one ecosystem to the next. It is easy to think of both ecosystems as being the same. Both polar, both cold, both effected more drastically by climate change than other regions in the world. We have already mentioned the importance of the geographical distinction between the poles, however these results indicate that also there may be a critical foodweb distinction between the ecosystems as well, a distinction that allows mammals to be buffered by the effects felt lower on the trophic web. We also suggest that one significant difference between mammals in the Arctic and the Antarctic is that climate change affects mammals in the Arctic directly while Antarctic mammals are affected indirectly by climate change. For example, seals and polar bears use the ice as their habit for breeding and nursing or for migration and roaming territory. These are ice obligate species. The loss of sea ice is directly affecting these life history processes. However in Antarctica mammals as well as penguins are not affected by habitat loss nor loss of roaming territory as these species solely require ice because their prey requires ice. The top predators in this way are not ice obligate and are only indirectly affected by ice loss. In this situation reduced ice hinders food availability and which is then relayed to the predator species.

2. In Antarctic ice loss has an indirect effect on animals food availability
3. Autochthonous vs. allochthonus, spending most of there lifecycles vs. temporal association

iii. Geographical distribution
1. Opposite trends in AP vs. Ross Sea

There are many reports of opposite climactic trends as well as opposite ecological trends in the different regions. It is well realized that the Antarctic Penninsula region is warming at the fastest rate of the whole continent, however climate studies suggest that the Ross Sea may actually be getting cooler. Ice loss has show a similar pattern, where ice loss is significant and decreasing steadily in the AP region, in the Ross Sea ice coverage seems to be increasing. These opposite trends also appear ecologically in the recent population trends of Adélie penguins. In the Ross Sea, Adélie penguins population numbers have been increasing (Wilson et al. 2001) where as Adélie penguin population numbers in the AP have suffered a decline in the past century (____).

2. Terre Adelie, Indian Ocean

iv. Why no mammals?
1. Changes affect organisms indirectly, unlike in Arctic were most changes directly affect the organisms (i.e. habitat)
2. Changes are buffered down the food web

v. Life history traits. Why are some animals affected and not others?

Also there is a noticeable difference in the number of accounts encountered for different species occupying a similar trophic level. Penguins (especially Adélie and Emperor penguins) seem to be more sensitive to climate variable than by other sea birds co-inhabiting the same geographical area and trophic niche. This is seen not only in the number of accounts reported, but also in the strength of reports (confidence rating). For example, a 50% decline was seen in Emperor penguin populations in Terre Adélie from the 1960s to 2001 (Barbraud and Weimerskirch 2001, Jenouvrier et al. 2005b) which was suggested and then later confirmed to be due to decreased adult survival (Jenouvrier et al. 2005b). There is a significant negative impact on of decreased sea-ice extent on several species of birds living in Terre Adélie (Barbraud and Weimerskirch 2001, Jenouvrier et al. 2005b, y más) but only the Emperor penguin shows significant decreases in population size. Jenouvrier et al. 2005b suggest that longer-lived species can opt out of breeding in years with poor environmental conditions, which enables enhancement of adult survival probability. This appears to be the case for the Snow Petrel (*scientific name here)* a species whose breeding population size, like the Emperor penguin (Barbraud and Weimerskirch 2001, Jenouvrier et al. 2005b) is negatively affected by sea-ice conditions (Jenouvrier et al. 2005b). In a sense, by abstaining from breeding, non-breeders are playing a critical role in population survival, by giving more individuals a greater probability of survival to the next breeding season.

b. Ask question of reliable baseline
    i. Do we have long enough time series?
    ii. Do we have well distributed studies?
        1. Limitations in some areas vs. others
        2. AP as a well studied region, also happens to be were most changes are occurring
        3. Eastern Antarctica?
    iii. The ice extent time series are very recent, many studies go back farther than do the ice extent data
    iv. For large animals (i.e. Penguins, seals) do we have more than just population number studies?
c. Synergistic effects of climate change with other human impact pressures, or faulty assignment of blame
    i. Tourism
    ii. UV radiation
    iii. Pollutants
    iv. Depletion of whales and fish stocks
    v. Are we attributing changes to climate change when we could attribute changes to other things
    vi. Bias of reporting only positive results?
d. Discuss Importance or rating weighting system
    i. *a priori* expectations
        1. Antarctic Climate Impact Assessment
    ii. Strong statistical testing
        1. To test the possibility of other forcing agents, such as UV… or bottom up top down control
    iii. Length of time-series
e. Prospects of climate change in Antarctic
    i. Acidification, already showing Carbon saturation
    ii. AP and Sourthern Ocean Islands heating up faster
    iii. Threshold changes, loss of entire ice shelves

Footprints Data Base:

Subject	Region	Latitude	Longitude	Time period	Climatic Driver	Footprint	Reference	Ranking
Emperor Penguin (*Aptenodytes forsteri)*	Terre Adélie	66.7 S	140.0 E	1952-2000	SST anomilies > decrease in winter ice extent	Population decline by 50% because of a decrease in adult survival during the 1970's warm period, with much higher SST. SST accounted for 89.9% of the yearly variation in survival. Sea ice extent explained 86.9% of the survival variation with greater ice extent leading to greater survival.	Barbraud and Weimerskirch 2001	5
Southern fulmar (*Fulmarus glacialoides)*	Terre Adélie	66.70 S	140.00 E	1950-2004	Sea ice extent	Phenological changes. Dates of species arrival to breeding colony occur significantly later with decreasing sea ice extent	Barbraud and Weimerskirch 2006	7
Cape petrel (*Daption capense)*	Terre Adélie	66.70 S	140.00 E	1950-2004	Sea ice extent	Phenological changes. Dates of species arrival to breeding colony occur significantly later with decreasing sea ice extent	Barbraud and Weimerskirch 2006	7
Wilson's storm petrel (*Oceanites oceanicus)*	Terre Adélie	66.70 S	140.00 E	1950-2004	Sea ice extent	Phenological changes. Dates of species arrival to breeding colony occur significantly later with decreasing sea ice extent	Barbraud and Weimerskirch 2006	7
South polar skua (*Catharacta maccormicki)*	Terre Adélie	66.70 S	140.00 E	1950-2004	Sea ice extent	Phenological changes. Dates of species arrival to breeding colony occur significantly later with decreasing sea ice extent	Barbraud and Weimerskirch 2006	5
Emperor Penguin (Aptenodytes forsteri)	Terre Adélie	66.70 S	140.00 E	1950-2004	Sea ice extent	Phenological changes. Dates of first egg laying occur significanty later with decreasing sea ice extent	Barbraud and Weimerskirch 2006	5
Adélie penguin (Pygoscelis adeliae)	Terre Adélie	66.70 S	140.00 E	1950-2004	Sea ice extent	Phenological changes. Dates of first egg laying occur significanty later with decreasing sea ice extent	Barbraud and Weimerskirch 2006	7
Cape petrel (Daption capense)	Terre Adélie	66.70 S	140.00 E	1950-2004	Sea ice extent	Phenological changes. Dates of first egg laying occur significanty later with decreasing sea ice extent	Barbraud and Weimerskirch 2006	7
Antarctic petrel (Thalassoica antarctica)	Terre Adélie	66.70 S	140.00 E	1950-2004	Sea ice extent	Phenological changes. Dates of species arrival to breeding colony occursignificantly later and trend is consistent with decreasing sea ice extent	Barbraud and Weimerskirch 2006	6
South polar skua (Catharacta maccormicki)	Terre Adélie	66.70 S	140.00 E	1950-2004	Sea ice extent	Phenological changes. Dates of first egg laying occur significanty earlier and trensis consistent with decreasing sea ice extent	Barbraud and Weimerskirch 2006	6
Phytoplankton biomass	West Antarctic Peninsula	62-69 S	59-78 W	1979-2006	Sea ice loss	Increased ice loss has increased the depth of the surface mixed layer by greater wind stress north of 64ºS while creating favorable UML conditions south of 64ºS. This has caused a decrease in phytoplankton biomass <64ºS, while at >64ºS the UML has become shallower causing and increase in phytoplankton biomass.	Montes-Hugo et al. 2009	7
Krill density	SW Atlantic SO			1976-2003	Sea ice extent	Krill density has declined significantly since the 1970's, density correlates to both the duration and the extent of sea ice the previous winter. Authors note the possiblity of both top-down and bottom-up control as well.	Atkinson et al. 2004	7
Antarctic bryozon *(Cellarinella nutti)*	Weddell Sea	54.30 -70.57 S	3.14-10.33 W	1985-2003	Warming	Warming effect of primary production leading to an increased growth rate of this bryazoan species. Increased growth not directly corelated to warming (specifically SST), but relationship with phytoplankton abundance was not tested.	Barnes et al. 2006	6
Chinstrap penguin (Pygoscelis antarctica)	Admiralty Bay, King George Island	62.10 S	58.20 W	1977-1987	Sea ice loss	Chinstrap penguin population is closely coupled to sea ice extent, population increases as sea ice decreases. Due to warming from 1973-1987 the number of cold years (defined as less tha -4.3ºC, a temperature therodynamically stable for sea-ice formation) has declined, thus increaseing the number of years with minimal sea-ice during this time period.	Fraser et al. 1992	3
Adélie penguin (Pygoscelis adeliae)	Admiralty Bay, King George Island	62.10 S	58.20 W	1977-1987	Sea ice loss	Adélie penguin population is closely coupled to sea ice extent, population decreases as sea ice decreases. Due to warming from 1973-1987 the number of cold years (defined as less tha -4.3ºC, a temperature therodynamically stable for sea-ice formation) has declined, thus increaseing the number of years with minimal sea-ice during this time period.	Fraser et al. 1992	3
Adélie penguin (Pygoscelis adeliae)	Signy Island, South Orkney Islands, AP	60.45 S	44.43 W	1978-2004	Warming, Sea Ice Loss	Decline of number of breeding pairs on Signey island at a mean annual rate of -2.8% between 1987 and 2004 explained by both with warming temperature and with loss of sea ice extent in that area.	Forcada et al. 2006	6
Gentoo penguin *(Pygoscelis papua)*	Signy Island, South Orkney Islands, AP	60.45 S	44.43 W	1978-2004	Warming, Sea Ice Loss	Increase of number of breeding pairs of gentoo penguins on Signey island at a mean annual rate of 5.5% between 1979-2004 which is explained by an increase in surface air temperature of 0.02ºC per year since 1903.	Forcada et al. 2006	6
Chinstrap penguin *(Pygoscelis antarctica)*	Signy Island, South Orkney Islands, AP	60.45 S	44.43 W	1978-2004	Waming, Sea Ice Loss	Decrease of number of breedng pairs of chinstrap penguins on Signey island at a mean annual rate of -1.2% between 1979-2004 explained by both with warming temperature and with loss of sea ice extent in that area.	Forcada et al. 2006	7
Antarctic petrel *(Thalassoica antarctica)*	Ardery island, Wilkes Land	66 S	110 E	1984-1997	Increased precipitation	Incread snow fall in 1996/1997 gave easy access to large predators, increasing adult mortality, egg predation, and total breeding failure. Due to lack of data on annual persitance of snowdrifts no statistical significance can be demostrated. However, local yearly snow accumulation rates had increased by 20% since 1960. Over the four sample seaons (84/84, 86/87, 90/91, 96/97) there was a significant decrease in breeder survial (from 95.9% in 84/85 to 15.4% the 96/97 the year of predation observation) as well as breeding success (from 45% in 84/85 to 1% in 96/97).	Van Franeker et al. 2001	3
Southern fulmar (Fulmarus glacialoides)	Terre Adélie	66.40 S	140.01 E	1963-2002	Warming and Sea Ice concentration decrease	The numer of breeding paris of the southern fulmar has increased significantly since 1963. Number of breeding pairs is positively correlated to winter SIC, also the proportion of birds attempting to breed was positivly correlated to SIC. The lowest number of breeding pairs were observed during 1975-1980, which intrerestingly is where several studies of other seabirds in Terre Adélie showed similar declines in the number of breeding pairs.	Jenouvrier et al. 2003	5
Krill density	Elephant Island	60-62.30 S	52- 57.30 W	1977-1995	Sea ice extent/concentration	Krill density in the AP has declined from 1977-1995, and because krill recruiment is independent of population density, we can say that krill recruiment is positivly relatied with ice extent, concentration, and duration. However this paper does not show a steady decline in ice cover from 1977-1995 to explain the drop in krill density.	Siegel and Loeb 1995	6
Salp density	Elephant Island	60-62.30 S	52- 57.30 W	1977-1995	Sea ice extent/concentration	duration with Salp density which was later not encountered by Atkinson et al. 2004 studying NW Atlatinc SO regionally. Authors do not show an increaseing trend of salp density.	Siegel and Loeb 1995	5
Snow petrel (Pagodroma nivea)	Terre Adélie	66.40 S	140.01 E	1964-1999	Sea ice extent	Percentage of breeding pairs is negativly related to winter sea ice extent (but with out significant long term trend) breeding success (number of chicks fledged from number of eggs) and fledgling body condition are positivly related to sea-ice extent in the winter which controls the food supply in the summer. However only body condition shows a significant long term (1990-1999) increasing trend. Reduced sea-ice extent favors a large breeding population, but it reduced breeding success and fledgling quality and therefore future recruitment.	Barbraud and Weimerskirch 2001	4
Phytoplankton community composition	Antarctic Peninsula	64.46.45 S	64.03.27 W	1991-1996	Warming, increased glacial melt water run-off	A recurrent shift in phytoplankton community composition from diatoms to crytophytes occurred conseculativly from 1991-1996 during the summer. Diatoms dominated the spring bloom, but there was a consitant transition to cryptophytes every year, often over 50%. The cryptophyte dominace is associated with relativly high air temperature/ low salinity water (glacial melt water input at temperature above freezing). As krill density has been deacreasing in the AP regions, authors suggest that this shift has negativly affected krill grazing, favoring salps instead. However there are no baseline data or long term trends reported.	Moline et al. 2004	3
Krill density	Elephant Island	60-62.30 S	52- 57.30 W	1976-1996	Warming, Sea Ice Loss	Krill density has decreased significantly from 1984- 1996, krill denisty relies on recruitment from year to year which is positivly correlated with sea-ice extent in the AP the preceeding winter	Loeb et al. 1997	5
Salp density	Elephant Island	60-62.30 S	52- 57.30 W	1976-1996	Warming, Sea Ice Loss	Salp density has increased during three summers within 1984- 1996 period. Salp abundance is negatively correlated with sea-ice extent during the preceeding winter	Loeb et al. 1997	4
Adélie penguin (Pygoscelis adeliae)	Ross Island, Ross Sea	77.34 S, 77.13 S	116,11 E, 166.28 E	1973-1997	Sea ice extent	Adélie penguin population on Ross isalnd increased substantial from the 1970's and raised to 3 times 1960's numbers in the 80's since then it has been fluctiatating or increasing. The number of breeding pairs is negativly realted to maximum winter/spring sea ice extent 5 years earlier. Sea- ice extent is realted with SOI annual changes, thus, number of breeding pairs is also negativly correlated to the SOI.	Wilson et al. 2001	6
Adélie penguin (Pygoscelis adeliae)	Ross Island, Ross Sea	66.30 - 77.30 S	116,10-166.14 E	1968- 1990	Sea ice extent	Increase of Adelíe penguin populations in the Ross sea since 1981 accompanied by a southerly range expansion of Adelíe penguins to Cape Barne (Ross Island) a previously abandoned rookery. But in the discussion authors admit to an unknown cause of range expansion and population increase...	Taylor and Wilson. 1990	2
Emperor Penguin (Aptenodytes forsteri)	Terre Adélie	66.40 S	140.00 E	1952-1998	Temperature increase	Authors correlate (negatively) average annual air tempeatures from 1960's to 1980's with population regime shift in Emperor penguins. Footprint is previously described by Barbraud and Weimerskirch 2001. The difference is that Weimerskirch et al. 2003 decribe it as a regime shift and correlate it to air tempreature.	Weimerskirch et al. 2003	5
Southern fulmar (Fulmarus glacialoides)	Terre Adélie	66.40 S	140.00 E	1964-1999	Temperature increase	Authors correlate (negatively) average annual air temperatures from 1960s- 1980s with population of Southern fulmars at the end of the 1960's. However Micol and Jouventin 2001 where data was estracted, show a significant increase in the population of fulmars from 1964-99 of 1.5% annually.	Weimerskirch et al. 2003	4
Adélie penguin (Pygoscelis adeliae)	Pointe Géologie Archipelago, Terre Adélie	66.40 S	140.01 E	1984-2003	Sea ice extent/concentration	Total number of breeding pairs for the Pointe Géologie Archipelago increased at a rate of 1.77% per year from 1984-2003. The number of breeding pairs was negatively related to sea ice conditions with an approximately 6 year delay. Population size increaed when SIE and SIC was reduced six years earlier. Adult survival was correlated with SOI (92%) but no general trend in survival was mentioned (suggests that adults survive better during warmer events).	Jenouvrier et al. 2006	6
Emperor Penguin (Aptenodytes forsteri)	Pointe Géologie Archipelago, Terre Adélie	66.40 S	140.01 E	1962-2001	Sea ice extent and SOI	There is a significant positive realtionship of both breeding population and breeding sucess with both SOI and SIE. both these perameters population and breeding sucess also show a significant decline.	Jenouvrier et al. 2005	6