

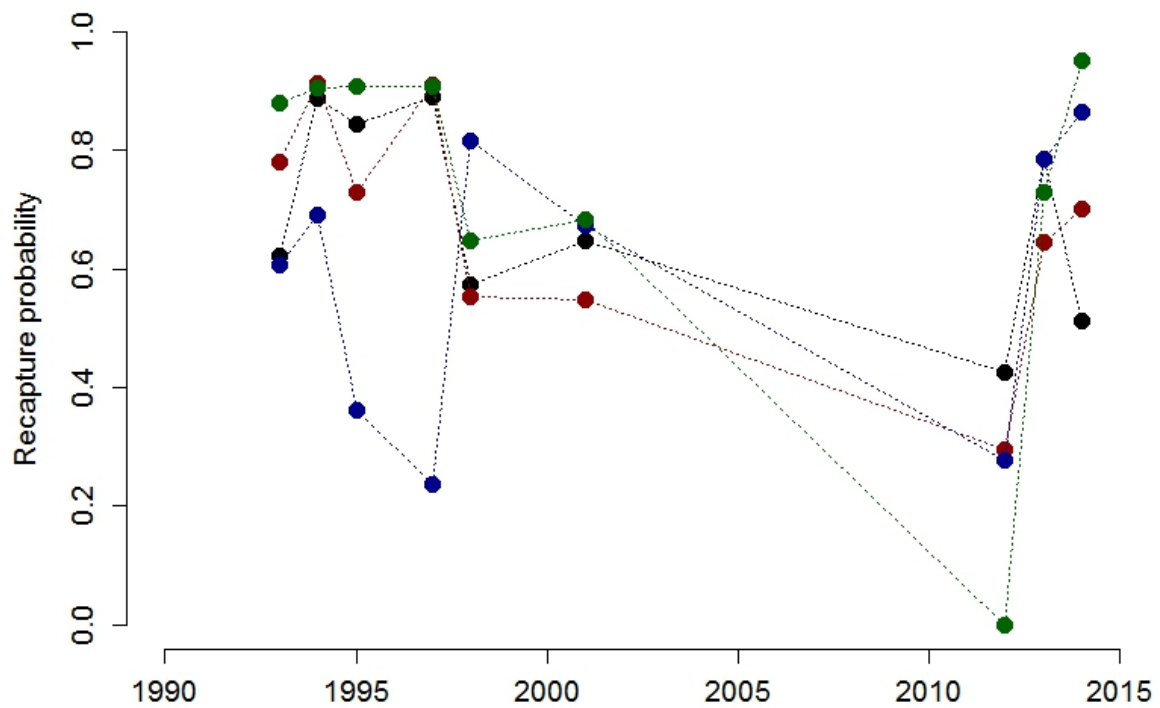
Ecography

ECOG-01659

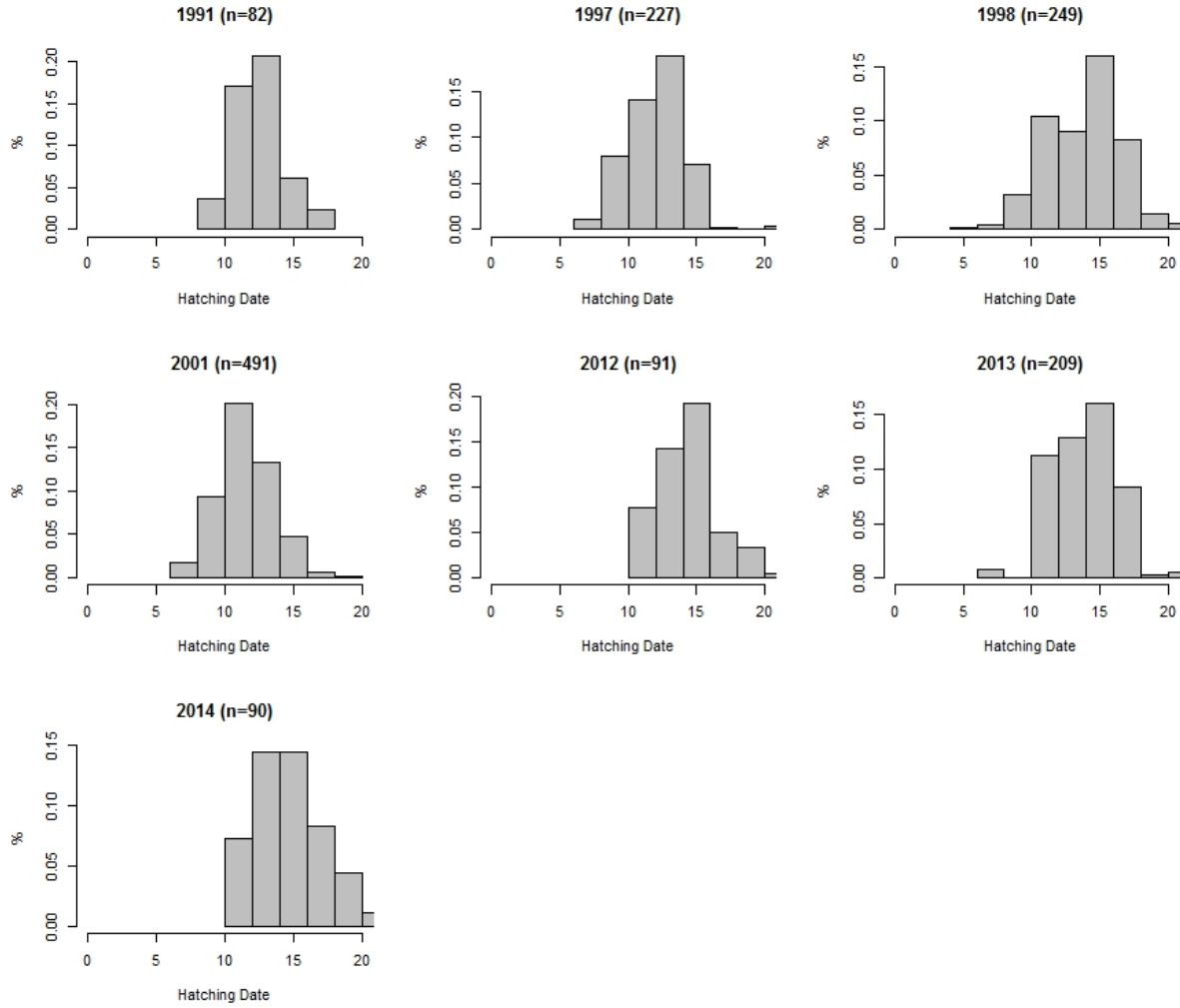
Descamps, S., Tarroux, A., Lorentsen, S.-H., Love, O. P., Varpe, Ø. and Yoccoz, N. G. 2015. Large-scale oceanographic fluctuations drive Antarctic petrel survival and reproduction. – *Ecography* doi: 10.1111/ecog.01659

Supplementary material

Appendix 1. Annual recapture probabilities (and their associated 95% confidence intervals) of Antarctic petrels breeding at Svarthamaren, Antarctica. Only years with field work (recapture probability >0) are shown. Estimates are from model $\Phi_t p_{t,g}$ (details in Table 1), where g indicates the plot and t the year. Each colour represents a specific plot where field work was conducted (in 2011, field work was only conducted in three of the plots, which explains the 0 value for the green point).



Appendix 2. Frequency distribution of Antarctic petrel hatching dates at Svarthamaren, Antarctica in period 1992-2014. Hatching dates are the dates in January.



Appendix 3. Summary of the literature review on the relationships between large scale Antarctic climatic and oceanographic processes and Antarctic seabirds. The table is sorted by environmental parameter, seabird species, latitude/region and seabird trait. References have been selected using the following key-words and ISI Web of Science: (Antarctic* or “Southern Ocean”) and (seabird* or albatross* or petrel* or penguin* or prion* or tern* sheathbill* or shearwater* or skua* or gull* or cormorant*) and (oscillation* or AAO or SAM or ENSO or SOI or nino or nina or mode). This gave 97 references in November 2014, among which 29 were selected. The selected references were the ones dealing with Antarctic or Sub-Antarctic seabirds and with the El Niño Southern or Antarctic Oscillation (ENSO and AAO). Moreover, six references were added: four that surprisingly did not appear in the Web of Science search (Barbraud, C. and Weimerskirch, H. 2006, Nel, D. C. et al. 2003, Nevoux, M. et al. 2007, Nevoux, M. et al. 2010) and two not yet indexed in ISI Web of Science in November 2014 but already published (Cimino, M. A. et al. 2014, Hinke, J. T. et al. 2014). The sign of the effect reported in the table corresponds to the relationships between fluctuation in ENSO and the trait considered. Therefore, the sign linking the SOI and this trait would be opposite as SOI is negatively related to ENSO; ns means *not significant*. Table (a) presents those 35 studies, with one line per parameter considered. Tables (b) and (c) are the ones used to draw figure 4. In these two tables, one line corresponds to one species at a given study site.

(a)

| Env. Param. | Season | Type/Sourc fe | Seabird trait | Sign | Species | Region | Lat/Long | Period | Comments | Ref. |
|-------------|---------------|---------------|--------------------|------|----------------|------------------------------------|------------------|-----------|--|---------------------------------------|
| AAO | Not specified | Not specified | Number of breeders | +/- | Adélie penguin | Signy Island, South Orkney Islands | 60°43'S, 45°36'W | 1979-2008 | Non linear effect (positive then negative) | (Forcada, J. and Trathan, P. N. 2009) |

| | | | | | | | | | | |
|-----|---------------|-------------------------------|--------------------|----|-------------------|--|-------------------|-----------|--|--|
| AAO | Annual | height anomalies | Number of breeders | ns | Adélie penguin | Signy Island, Drake passage | 61°00'S, 45°00'W | 1979-2000 | Effect of AAO either non significant or negligible | (Ainley, D. G. et al. 2005) |
| AAO | Winter | Zonal mean sea level pressure | Survival | ns | Adélie penguin | King George Island, South Shetland Islands | 62°10'S, 64°03'E | 1981-2010 | | (Hinke, J. T. et al. 2007) |
| AAO | Annual | height anomalies | Number of breeders | - | Adélie penguin | Arthur Harbour, Anvers Island | 64°00'S, 64°00'W | 1975-1998 | | (Ainley, D. G. et al. 2005) |
| AAO | Summer | height anomalies | Fledging mass | - | Adélie penguin | Humble Island, Antarctic Peninsula | 64°46'S, 64°03'W | 1987-2011 | | (Cimino, M. A. et al. 2014) |
| AAO | Annual | Zonal mean sea level pressure | Phenology | ns | Adélie penguin | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | | (Barbraud, C. and Weimerskirch, H. 2006) |
| AAO | Annual | height anomalies | Number of breeders | + | Adélie penguin | Lützow-Holm Bay, Dronning Maud Land | 69°00'S, 39°00'E | 1981-2000 | | (Ainley, D. G. et al. 2005) |
| AAO | Winter | height anomalies | Survival | ns | Adélie penguin | Cape Crozier, Ross Island | 77°27'S, 169°12'E | 1996-2006 | | (Lescroel, A. et al. 2009) |
| AAO | Annual | height anomalies | Number of breeders | + | Adélie penguin | Cape Royds, Ross Island | 77°34'S, 166°11'E | 1960-2000 | | (Ainley, D. G. et al. 2005) |
| AAO | Annual | Zonal mean sea level pressure | Phenology | ns | Antarctic petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | | (Barbraud, C. and Weimerskirch, H. 2006) |
| AAO | Annual | height anomalies | Survival | - | Antarctic petrel | Svarthamaren, Dronning Maud Land | 71°53'S, 5°10'E | 1992-2014 | | This study |
| AAO | Annual | Zonal mean sea level pressure | Phenology | ns | Cape petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | | (Barbraud, C. and Weimerskirch, H. 2006) |
| AAO | Not specified | Not specified | Number of breeders | - | Chinstrap penguin | Signy Island, South Orkney Islands | 60°43'S, 45°36'W | 1979-2008 | | (Forcada, J. and Trathan, P. N. 2009) |

| | | | | | | | | | |
|-----|---|-------------------------------|--------------------|----|-----------------|------------------------------------|-------------------|-----------|--|
| AAO | Winter/Spring/Summer (June to December) | Zonal mean sea level pressure | Breeding success | + | Emperor penguin | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1992-1999 | (Massom, R. A. et al. 2009) |
| AAO | Annual | height anomalies | Number of breeders | - | Emperor penguin | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1956-1999 | (Ainley, D. G. et al. 2005) |
| AAO | Annual | Zonal mean sea level pressure | Phenology | ns | Emperor penguin | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | (Barbraud, C. and Weimerskirch, H. 2006) |
| AAO | Annual | height anomalies | Number of chicks | ns | Emperor penguin | Cape Roget, Ross Sea | 71°59'S, 170°31'E | 1983-2005 | (Barber-Meyer, S. M. et al. 2008) |
| AAO | Annual | height anomalies | Number of chicks | ns | Emperor penguin | Coulman Island, Ross Sea | 73°20'S, 169°38'E | 1983-2005 | (Barber-Meyer, S. M. et al. 2008) |
| AAO | Annual | height anomalies | Number of chicks | ns | Emperor penguin | Cape Washington, Ross Sea | 74°39'S, 165°22'E | 1983-2005 | (Barber-Meyer, S. M. et al. 2008) |
| AAO | Annual | height anomalies | Number of chicks | ns | Emperor penguin | Franklin Island, Ross Sea | 76°07'S, 168°15'E | 1983-2005 | (Barber-Meyer, S. M. et al. 2008) |
| AAO | Annual | height anomalies | Number of chicks | ns | Emperor penguin | Beaufort Island, Ross Sea | 76°56'S, 167°03'E | 1983-2005 | (Barber-Meyer, S. M. et al. 2008) |
| AAO | Annual | height anomalies | Number of chicks | ns | Emperor penguin | Cape Crozier, Ross Sea | 77°30'S, 169°25'E | 1983-2005 | (Barber-Meyer, S. M. et al. 2008) |
| AAO | Not specified | Not specified | Number of breeders | - | Gentoo penguin | Bird Island, South Georgia | 54°10'S, 38°30'W | 1982-2009 | (Forcada, J. and Trathan, P. N. 2009) |
| AAO | Not specified | Not specified | Number of breeders | + | Gentoo penguin | Signy Island, South Orkney Islands | 60°43'S, 45°36'W | 1979-2008 | (Forcada, J. and Trathan, P. N. 2009) |

| | | | | | | | | | |
|-----|---------------|-------------------------------|--------------------|----|-----------------------|-------------------------------------|-------------------|-----------|--|
| AAO | Not specified | Not specified | Number of breeders | - | Macaroni penguin | Bird Island, South Georgia | 54°10'S, 38°30'W | 1980-2008 | (Forcada, J. and Trathan, P. N. 2009) |
| AAO | Summer | height anomalies | Survival | ns | Macaroni penguin | Bird Island, South Georgia | 54°10'S, 38°30'W | 2003-2012 | (Horswill, C. et al. 2014) |
| AAO | Not specified | sea level pressure anomalies | Phenology | - | Royal penguin | Macquarie Island | 54°30S, 158°57E | 1964-1997 | (Hindell, M. A. et al. 2012) |
| AAO | Annual | Zonal mean sea level pressure | Phenology | ns | Snow petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | (Barbraud, C. and Weimerskirch, H. 2006) |
| AAO | Annual | Zonal mean sea level pressure | Phenology | ns | South polar skua | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | (Barbraud, C. and Weimerskirch, H. 2006) |
| AAO | Annual | Zonal mean sea level pressure | Phenology | ns | Southern Fulmar | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | (Barbraud, C. and Weimerskirch, H. 2006) |
| AAO | Annual | Zonal mean sea level pressure | Phenology | ns | Southern Giant petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | (Barbraud, C. and Weimerskirch, H. 2006) |
| AAO | Seasonal | height anomalies | Breeding success | ns | Thin-billed prion | Mayes Island, Kerguelen Archipelago | 48°38'S, 68°38'E | 1986-2001 | (Nevoux, M. and Barbraud, C. 2006) |
| AAO | Seasonal | height anomalies | Survival | ns | Thin-billed prion | Mayes Island, Kerguelen Archipelago | 48°38'S, 68°38'E | 1986-2001 | (Nevoux, M. and Barbraud, C. 2006) |
| AAO | Annual | Zonal mean sea level pressure | Phenology | ns | Wilson's storm petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | (Barbraud, C. and Weimerskirch, H. 2006) |

| | | | | | | | | | | |
|------|---------------|----------------------------|------------------------|----|------------------|--|-----------------------|-----------|--|--|
| ENSO | Annual | SOI | Survival | ns | Adélie penguin | King George Island, South Shetland Islands | 62°10'S, 64°03'E | 1981-2010 | | (Hinke, J. T. et al. 2007) |
| ENSO | . | Events | Number of breeders | - | Adelie penguin | Ardley Island South Shetland Islands | 62°13'S, 58°56'W | 1980-2012 | No statistical test | (Zhang, H. S. et al. 2014) |
| ENSO | . | Events | Number of breeders | - | Adélie penguin | Ardley Island South Shetland Islands | 62°13'S, 58°56'W | 1970-2004 | No statistical test | (Zhang, H. et al. 2012) |
| ENSO | Summer | SOI | Fledging mass | ns | Adélie penguin | Humble Island, Antarctic Peninsula | 64°46'S, 64°03'W | 1987-2011 | | (Cimino, M. A. et al. 2014) |
| ENSO | Summer | El Niño3.4 (SST anomalies) | Fledging mass | ns | Adélie penguin | Humble Island, Antarctic Peninsula | 64°46'S, 64°03'W | 1987-2011 | | (Cimino, M. A. et al. 2014) |
| ENSO | Annual | SOI | Phenology | ns | Adélie penguin | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | | (Barbraud, C. and Weimerskirch, H. 2006) |
| ENSO | Not specified | SOI | Survival | + | Adelie penguin | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1990-1998 | | (Jenouvrier, S. et al. 2006) |
| ENSO | Winter | SOI | Survival | ns | Adélie penguin | Edmonson Point, Ross Sea | 74°20'S, 165°08'E | 1994-2005 | | (Ballerini, T. et al. 2009) |
| ENSO | Annual | SOI | Population growth rate | + | Adélie penguin | Cape Royds, Ross Island | 77° 34' S, 166° 11'E | 1968-1997 | | (Wilson, P. R. et al. 2001) |
| ENSO | Fall | SOI | Population growth rate | + | Adélie penguin | Cape Bird, Ross Island | 77° 13' S, 166° 28' E | 1968-1997 | | (Wilson, P. R. et al. 2001) |
| ENSO | Winter | SOI | Population growth rate | - | Adélie penguin | Cape Bird, Ross Island | 77° 13' S, 166° 28' E | 1968-1997 | | (Wilson, P. R. et al. 2001) |
| ENSO | Annual | SOI | Phenology | ns | Antarctic petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | | (Barbraud, C. and Weimerskirch, H. 2006) |
| ENSO | Spring | SOI | Breeding | - | Antarctic | Svarthamaren, | 71°53'S, | 1985-2014 | Trait considered was the number of chicks produced | This study |

| | | | | | | | | | | |
|------|------------------|--------|--------------------|----|------------------------|--------------------------------------|-------------------|-----------|---|--|
| | | | success | | petrel | Dronning Maud Land | 5°10'E | | after the peak of hatching | |
| ENSO | Spring | SOI | Phenology | + | Antarctic petrel | Svarthamaren, Dronning Maud Land | 71°53'S, 5°10'E | 1992-2014 | Later reproduction in high ENSO years (low SOI) | This study |
| ENSO | Winter | SOI | Breeding success | - | Black-browed albatross | Kerguelen Archipelago | 49°40'S, 70°15'E | 1986-2006 | | (Rolland, V. et al. 2010) |
| ENSO | Winter | SOI | Recruitment | - | Black-browed albatross | Kerguelen Archipelago | 49°40'S, 70°15'E | 1980-2005 | | (Nevoux, M. et al. 2010) |
| ENSO | Winter | SOI | Survival | ns | Black-browed albatross | Kerguelen Archipelago | 49°40'S, 70°15'E | 1986-2006 | | (Rolland, V. et al. 2010) |
| ENSO | Winter | SOI | Survival | - | Black-browed albatross | Kerguelen Archipelago | 49°40'S, 70°15'E | 1979- | Survival of inexperienced breeders | (Nevoux, M. et al. 2007) |
| ENSO | Winter | SOI | Survival | - | Blue petrel | Mayes, Island, Kerguelen Archipelago | 49°41'S, 70°14'E | 1986-2001 | | (Barbraud, C. and Weimerskirch, H. 2003) |
| ENSO | Annual | SOI | Phenology | + | Cape petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | Later reproduction in high ENSO years (low SOI) | (Barbraud, C. and Weimerskirch, H. 2006) |
| ENSO | | Events | Number of breeders | - | Chinstrap penguin | Ardley Island South Shetland Islands | 62°13'S, 58°56'W | 1980-2012 | No statistical test | (Zhang, H. S. et al. 2014) |
| ENSO | | Events | Number of breeders | - | Chinstrap penguin | Ardley Island South Shetland Islands | 62°13'S 58°56'W | 1970-2004 | No statistical test | (Zhang, H. et al. 2012) |
| ENSO | Not specified | SOI | Breeding success | - | Emperor penguin | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1962-2001 | Sign of the correlation change through time | (Jenouvrier, S. et al. 2005a, Jenouvrier, S. et al. 2005b) |
| ENSO | June to December | SOI | Breeding success | ns | Emperor penguin | Pointe Géologie, | 66°40'S, 140°01'E | 1992-1999 | | (Massom, R. A. et al. |

| | | | | | | | | | | |
|------|---------------|--|--------------------|----|-----------------|------------------------------|-------------------|-----------|--|--|
| | | | | | | Adélie Land | | | | 2009) |
| ENSO | Not specified | SOI | Number of breeders | - | Emperor penguin | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1962-2001 | | (Jenouvrier, S. et al. 2005a, Jenouvrier, S. et al. 2005b) |
| ENSO | Annual | SOI | Phenology | ns | Emperor penguin | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | | (Barbraud, C. and Weimerskirch, H. 2006) |
| ENSO | Annual | SOI (difference in sea level pressure) | Number of chicks | ns | Emperor penguin | Cape Roget, Ross Sea | 71°59'S, 170°31'E | 1983-2005 | | (Barber-Meyer, S. M. et al. 2008) |
| ENSO | Annual | SOI (difference in sea level pressure) | Number of chicks | ns | Emperor penguin | Coulman Island, Ross Sea | 73°20'S, 169°38'E | 1983-2005 | | (Barber-Meyer, S. M. et al. 2008) |
| ENSO | Annual | SOI (difference in sea level pressure) | Number of chicks | ns | Emperor penguin | Cape Washington, Ross Sea | 74°39'S, 165°22'E | 1983-2005 | | (Barber-Meyer, S. M. et al. 2008) |
| ENSO | Annual | SOI (difference in sea level pressure) | Number of chicks | ns | Emperor penguin | Franklin Island, Ross Sea | 76°07'S, 168°15'E | 1983-2005 | | (Barber-Meyer, S. M. et al. 2008) |
| ENSO | Annual | SOI (difference in sea level pressure) | Number of chicks | ns | Emperor penguin | Beaufort Island, Ross Sea | 76°56'S, 167°03'E | 1983-2005 | | (Barber-Meyer, S. M. et al. 2008) |
| ENSO | Annual | SOI (difference in sea level pressure) | Number of chicks | ns | Emperor penguin | Cape Crozier, Ross Sea | 77°30'S, 169°25'E | 1983-2005 | | (Barber-Meyer, S. M. et al. 2008) |
| ENSO | Annual | SOI | Number of breeders | - | Gentoo penguin | Falkland Islands | 51-53°S, 57-62°W | 1990-2010 | Several colonies considered and SOI effect not always linear | (Baylis, A. M. M. et al. 2012) |
| ENSO | Not specified | SOI (difference | Arrival date | + | King penguin | Possession Island, Crozet | 46°25'S, 51°45'E | 1999-2008 | Negative effect of the SOI (high SOI; later arrival) ; | (Saraux, C. et al. |

| | | | | | | | | | | |
|------|------------------|--|-----------------------|----|---------------------|---|----------------------|-----------|--|---|
| | | in sea level pressure) | | | | archipelago | | | effect mostly pronounced for flipper banded birds | 2011) |
| ENSO | Annual | SOI | Breeding success | - | King penguin | Possession Island, Crozet archipelago | 46°25'S, 51°45'E | 1999-2004 | Sign of the correlation change through time | (Le Bohec, C. et al. 2009) |
| ENSO | Annual | SOI | Survival | ns | King penguin | Possession Island, Crozet archipelago | 46°25'S, 51°45'E | 1999-2004 | Sign of the correlation change through time | (Le Bohec, C. et al. 2009) |
| ENSO | . | Event | Mass at arrival | - | Macaroni penguin | Marion Island | 46°54'S, 37°45'E | 1994-2002 | No statistical test: based on 1 El Niño event | (Crawford, R. J. M. et al. 2003) |
| ENSO | Summer | Bivariate ENSO time series index | Survival | ns | Macaroni penguin | Bird Island, South Georgia | 54°10'S, 38°30'W | 2003-2012 | | (Horswill, C. et al. 2014) |
| ENSO | . | events | Breeding success | - | Snow petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1963-1990 | No statistical test | (Chastel, O. et al. 1993) |
| ENSO | Not specified | SOI | Breeding success | ns | Snow petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1963-2002 | Sign of the correlation change through time | (Jenouvrie r, S. et al. 2005b) |
| ENSO | Not specified | SOI | Breeding success | ns | Snow petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1963-2002 | | (Jenouvrie r, S. et al. 2005a) |
| ENSO | . | events | Number of breeders | - | Snow petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1963-1990 | No statistical test | (Chastel, O. et al. 1993) |
| ENSO | Not specified | SOI | Number of breeders | ns | Snow petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1963-2002 | | (Jenouvrie r, S. et al. 2005a) |
| ENSO | Not specified | SOI | Number of breeders | ns | Snow petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1963-2002 | Sign of the correlation change through time | (Jenouvrie r, S. et al. 2005b) |
| ENSO | Annual | SOI | Phenology | ns | Snow petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | | (Barbraud, C. and Weimerski rch, H. 2006) |
| ENSO | . | Events | Survival | - | Snow petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1963-1990 | | (Chastel, O. et al. 1993) |

| | | | | | | | | | | |
|------|---------------|--|--------------------|----|------------------------|---------------------------------------|-------------------|-----------|---|--|
| ENSO | Summer | SOI | Breeding success | + | Sooty albatross | Possession Island, Crozet archipelago | 46°25'S, 51°45'E | 1986-2006 | | (Rolland, V. et al. 2010) |
| ENSO | Summer | SOI | Survival | ns | Sooty albatross | Possession Island, Crozet archipelago | 46°25'S, 51°45'E | 1986-2006 | | (Rolland, V. et al. 2010) |
| ENSO | Annual | SOI | Phenology | ns | South polar skua | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | | (Barbraud, C. and Weimerskirch, H. 2006) |
| ENSO | Not specified | SOI | Breeding success | + | Southern fulmar | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1963-2002 | Sign of the correlation change through time | (Jenouvrier, S. et al. 2005b) |
| ENSO | Not specified | SOI | Number of breeders | - | Southern fulmar | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1963-2002 | Sign of the correlation change through time | (Jenouvrier, S. et al. 2005b) |
| ENSO | Annual | SOI | Phenology | ns | Southern Fulmar | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | | (Barbraud, C. and Weimerskirch, H. 2006) |
| ENSO | Annual | SOI | Phenology | ns | Southern Giant petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | | (Barbraud, C. and Weimerskirch, H. 2006) |
| ENSO | Seasonal | SOI (difference in sea level pressure) | Breeding success | ns | Thin-billed prion | Mayes Island, Kerguelen Archipelago | 48°38'S, 68°38'E | 1986-2001 | | (Nevoux, M. and Barbraud, C. 2006) |
| ENSO | Seasonal | SOI (difference in sea level pressure) | Survival | ns | Thin-billed prion | Mayes Island, Kerguelen Archipelago | 48°38'S, 68°38'E | 1986-2001 | | (Nevoux, M. and Barbraud, C. 2006) |
| ENSO | Winter | SOI | Breeding success | - | Yellow-nosed albatross | Amsterdam Island | 37°51'S, 77°31'E | 1986-2006 | | (Rolland, V. et al. 2009), (Rolland, V. et al. 2010) |
| ENSO | Winter | SOI | Survival | ns | Yellow- | Amsterdam | 37°51'S, | 1986-2006 | | (Rolland, |

| | | | | | | | | | | |
|------|---------------|---------------------------|------------------|----|-----------------------|---------------------------------------|-------------------|-----------|----------------------------------|--|
| | | | | | nosed albatross | Island | 77°31'E | | | V. et al. 2009), (Rolland, V. et al. 2010) |
| ENSO | Annual | SOI | Breeding success | ns | White-chinned petrel | Possession Island, Crozet archipelago | 46°25'S, 51°45'E | 1983-2004 | | (Barbraud, C. et al. 2008) |
| ENSO | Annual | SOI | Recruitment | ns | White-chinned petrel | Possession Island, Crozet archipelago | 46°25'S, 51°45'E | 1983-2004 | | (Barbraud, C. et al. 2008) |
| ENSO | Annual | SOI | Survival | - | White-chinned petrel | Possession Island, Crozet archipelago | 46°25'S, 51°45'E | 1983-2004 | | (Barbraud, C. et al. 2008) |
| ENSO | Annual | SOI | Phenology | ns | Wilson's storm petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | | (Barbraud, C. and Weimerskirch, H. 2006) |
| ENSO | Not specified | El Niño 3 (SST anomalies) | Recruitment | + | Wandering albatross | Marion Island | 46°54'S, 37°45'E | 1994-2001 | Effect on % of 1st time breeders | (Nel, D. C. et al. 2003) |
| ENSO | Summer | SOI | Breeding success | ns | Wandering albatross | Possession Island, Crozet archipelago | 46°25'S, 51°45'E | 1986-2006 | | (Rolland, V. et al. 2010) |
| ENSO | Summer | SOI | Survival | ns | Wandering albatross | Possession Island, Crozet archipelago | 46°25'S, 51°45'E | 1986-2006 | | (Rolland, V. et al. 2010) |

(b)

| Env. Param. | Seabird trait | Potential effect on fitness or population dynamics | Species | Region | Lat/Long | Period | Source(s) |
|-------------|----------------------------|--|-------------------|--|-------------------|-----------|----------------------------------|
| AAO | Number of breeders | + | Adélie penguin | Cape Royds, Ross Island | 77°34'S, 166°11'E | 1960-2000 | (Ainley et al. 2005) |
| AAO | Number of breeders | + | Adélie penguin | Lützow-Holm Bay, Dronning Maud Land | 69°00'S, 39°00'E | 1981-2000 | (Ainley et al. 2005) |
| AAO | Number of breeders | + | Gentoo penguin | Signy Island, South Orkney Islands | 60°43'S, 45°36'W | 1979-2008 | (Forcada and Trathan 2009) |
| AAO | Phenology | + | Royal penguin | Macquarie Island | 54°30'S, 158°57'E | 1964-1997 | (Hindell et al. 2012) |
| AAO | Number of chicks | ns | Emperor penguin | Beaufort Island, Ross Sea | 76°56'S, 167°03'E | 1983-2005 | (Barber-Meyer et al. 2008) |
| AAO | Survival | ns | Adélie penguin | Cape Crozier, Ross Island | 77°27'S, 169°12'E | 1996-2006 | (Lescroel et al. 2009) |
| AAO | Number of chicks | ns | Emperor penguin | Cape Crozier, Ross Sea | 77°30'S, 169°25'E | 1983-2005 | (Barber-Meyer et al. 2008) |
| AAO | Number of chicks | ns | Emperor penguin | Cape Roget, Ross Sea | 71°59'S, 170°31'E | 1983-2005 | (Barber-Meyer et al. 2008) |
| AAO | Number of chicks | ns | Emperor penguin | Cape Washington, Ross Sea | 74°39'S, 165°22'E | 1983-2005 | (Barber-Meyer et al. 2008) |
| AAO | Number of chicks | ns | Emperor penguin | Coulman Island, Ross Sea | 73°20'S, 169°38'E | 1983-2005 | (Barber-Meyer et al. 2008) |
| AAO | Number of chicks | ns | Emperor penguin | Franklin Island, Ross Sea | 76°07'S, 168°15'E | 1983-2005 | (Barber-Meyer et al. 2008) |
| AAO | Survival | ns | Adélie penguin | King George Island, South Shetland Islands | 62°10'S, 64°03'E | 1981-2010 | (Hinke et al. 2007) |
| AAO | Breeding success, survival | ns | Thin-billed prion | Mayes Island, Kerguelen Archipelago | 48°38'S, 68°38'E | 1986-2001 | (Nevoux and Barbraud 2006) |
| AAO | Phenology | ns | Adélie penguin | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | (Barbraud and Weimerskirch 2006) |
| AAO | Phenology | ns | Antarctic petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | (Barbraud and Weimerskirch 2006) |
| AAO | Phenology | ns | Cape petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | (Barbraud and Weimerskirch 2006) |

| | | | | | | | |
|-----|---|----------|-----------------------|--|-------------------|-----------|--|
| AAO | Breeding success, Number of breeders, Phenology | +, -, ns | Emperor penguin | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1956-1999 | (Massom et al. 2009), (Ainley et al. 2005), (Barbraud and Weimerskirch 2006) |
| AAO | Phenology | ns | Snow petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | (Barbraud and Weimerskirch 2006) |
| AAO | Phenology | ns | South polar skua | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | (Barbraud and Weimerskirch 2006) |
| AAO | Phenology | ns | Southern Fulmar | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | (Barbraud and Weimerskirch 2006) |
| AAO | Phenology | ns | Southern Giant petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | (Barbraud and Weimerskirch 2006) |
| AAO | Phenology | ns | Wilson's storm petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | (Barbraud and Weimerskirch 2006) |
| AAO | Number of breeders | ns | Adélie penguin | Signy Island, Drake Passage | 61°00'S, 45°00'W | 1979-2000 | (Ainley et al. 2005) |
| AAO | Number of breeders | - | Adélie penguin | Arthur Harbour, Anvers Island | 64°00'S, 64°00'W | 1975-1998 | (Ainley et al. 2005) |
| AAO | Number of breeders | - | Gentoo penguin | Bird Island, South Georgia | 54°10'S, 38°30'W | 1982-2009 | (Forcada and Trathan 2009) |
| AAO | Number of breeders, Survival | -, ns | Macaroni penguin | Bird Island, South Georgia | 54°10'S, 38°30'W | 1980-2008 | (Forcada and Trathan 2009), (Horswill et al. 2014) |
| AAO | Fledging mass | - | Adélie penguin | Humble Island, Antarctic | 64°46'S, 64°03'W | 1987-2011 | (Cimino et al. 2014) |
| AAO | Number of breeders | - | Adélie penguin | Peninsula Signy Island, South Orkney | 60°43'S, 45°36'W | 1979-2008 | (Forcada and Trathan 2009) |
| AAO | Number of breeders | - | Chinstrap penguin | Islands Signy Island, South Orkney | 60°43'S, 45°36'W | 1979-2008 | (Forcada and Trathan 2009) |
| AAO | Survival | - | Antarctic petrel | Svarthamaren, Dronning Maud Land | 71°53'S, 5°10'E | 1992-2014 | this study |

(c)

| Env. Param. | Seabird trait | Potential effect on fitness or population dynamics | Species | Region | Lat/Long | Period | Ref. |
|-------------|---|--|-----------------------|--|-----------------------|-----------|---|
| ENSO | Population growth rate | + | Adélie penguin | Cape Royds, Ross Island | 77° 34' S, 166° 11' E | 1968-1997 | (Wilson et al. 2001) |
| ENSO | Recruitment | + | Wandering albatross | Marion Island | 46°54'S, 37°45'E | 1994-2001 | (Nel et al. 2003) |
| ENSO | Survival | + | Adelie penguin | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1990-1998 | (Jenouvrier et al. 2006) |
| ENSO | Phenology | + | Cape petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | (Barbraud and Weimerskirch 2006) |
| ENSO | Breeding success | + | Sooty albatross | Possession Island, Crozet archipelago | 46°25'S, 51°45'E | 1986-2006 | (Rolland et al. 2010) |
| ENSO | Number of chicks | ns | Emperor penguin | Beaufort Island, Ross Sea | 76°56'S, 167°03'E | 1983-2005 | (Barber-Meyer et al. 2008) |
| ENSO | Survival | ns | Macaroni penguin | Bird Island, South Georgia | 54°10'S, 38°30'W | 2003-2012 | (Horswill et al. 2014) |
| ENSO | Population growth rate | +, - | Adélie penguin | Cape Bird, Ross Island | 77° 13' S, 166° 28' E | 1968-1997 | (Wilson et al. 2001) |
| ENSO | Number of chicks | ns | Emperor penguin | Cape Crozier, Ross Sea | 77°30'S, 169°25'E | 1983-2005 | (Barber-Meyer et al. 2008) |
| ENSO | Number of chicks | ns | Emperor penguin | Cape Roget, Ross Sea | 71°59'S, 170°31'E | 1983-2005 | (Barber-Meyer et al. 2008) |
| ENSO | Number of chicks | ns | Emperor penguin | Cape Washington, Ross Sea | 74°39'S, 165°22'E | 1983-2005 | (Barber-Meyer et al. 2008) |
| ENSO | Number of chicks | ns | Emperor penguin | Coulman Island, Ross Sea | 73°20'S, 169°38'E | 1983-2005 | (Barber-Meyer et al. 2008) |
| ENSO | Survival | ns | Adélie penguin | Edmonson Point, Ross Sea | 74°20'S, 165°08'E | 1994-2005 | (Ballerini et al. 2009) |
| ENSO | Number of chicks | ns | Emperor penguin | Franklin Island, Ross Sea | 76°07'S, 168°15'E | 1983-2005 | (Barber-Meyer et al. 2008) |
| ENSO | Fledging mass | ns | Adélie penguin | Humble Island, Antarctic Peninsula | 64°46'S, 64°03'W | 1987-2011 | (Cimino et al. 2014) |
| ENSO | Survival | ns | Adélie penguin | King George Island, South Shetland Islands | 62°10'S, 64°03'E | 1981-2010 | (Hinke et al. 2007) |
| ENSO | Breeding success, survival | ns | Thin-billed prion | Mayes Island, Kerguelen Archipelago | 48°38'S, 68°38'E | 1986-2001 | (Nevoux and Barbraud 2006) |
| ENSO | Phenology | ns | Antarctic petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | (Barbraud and Weimerskirch 2006) |
| ENSO | Phenology | ns | South polar skua | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | (Barbraud and Weimerskirch 2006) |
| ENSO | Breeding success, number of breeders, phenology | +, -, ns | Southern fulmar | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1963-2002 | (Jenouvrier et al. 2005b), (Barbraud and Weimerskirch 2006) |
| ENSO | Phenology | ns | Southern Giant petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | (Barbraud and Weimerskirch 2006) |

| | | | | | | | |
|------|---|----|------------------------|---------------------------------------|-------------------|-----------|---|
| ENSO | Phenology | ns | Wilson's storm petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1950-2004 | (Barbraud and Weimerskirch 2006) |
| ENSO | Breeding success, survival | ns | Wandering albatross | Possession Island, Crozet archipelago | 46°25'S, 51°45'E | 1986-2006 | (Rolland et al. 2010) |
| ENSO | Breeding success | - | Yellow-nosed albatross | Amsterdam Island | 37°51'S, 77°31'E | 1986-2006 | (Rolland et al. 2009), (Rolland et al. 2010) |
| ENSO | Number of breeders | - | Adélie penguin | Ardley Island, South Shetland Islands | 62°13'S, 58°56'W | 1970-2004 | (Zhang et al. 2012), (Zhang et al. 2014a) |
| ENSO | Number of breeders | - | Chinstrap penguin | Ardley Island, South Shetland Islands | 62°13'S, 58°56'W | 1980-2012 | (Zhang et al. 2012), (Zhang et al. 2014a) |
| ENSO | Number of breeders | - | Gentoo penguin | Falkland Islands | 51-53°S, 57-62°W | 1990-2010 | (Baylis et al. 2012) |
| ENSO | Breeding success, Recruitment, survival of inexperienced breeders | - | Black-browed albatross | Kerguelen Archipelago | 49°40'S, 70°15'E | 1986-2006 | (Rolland et al. 2010), (Nevoux et al. 2010), (Nevoux et al. 2007) |
| ENSO | Mass at arrival | - | Macaroni penguin | Marion Island | 46°54'S, 37°45'E | 1994-2002 | (Crawford et al. 2003) |
| ENSO | Survival | - | Blue petrel | Mayes, Island, Kerguelen Archipelago | 49°41'S, 70°14'E | 1986-2001 | (Barbraud and Weimerskirch 2003) |
| ENSO | Breeding success, Number of breeders | - | Emperor penguin | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1962-2001 | (Jenouvrier et al. 2005a, Jenouvrier et al. 2005b) |
| ENSO | Survival, breeding success, number of breeders | - | Snow petrel | Pointe Géologie, Adélie Land | 66°40'S, 140°01'E | 1963-1990 | (Chastel et al. 1993), (Jenouvrier et al. 2005a), (Jenouvrier et al. 2005b), (Barbraud and Weimerskirch 2006) |
| ENSO | Breeding success | - | King penguin | Possession Island, Crozet archipelago | 46°25'S, 51°45'E | 1999-2004 | (Le Bohec et al. 2009), (Saraux et al. 2011) |
| ENSO | Survival | - | White-chinned petrel | Possession Island, Crozet archipelago | 46°25'S, 51°45'E | 1983-2004 | (Barbraud et al. 2008) |
| ENSO | Breeding Success, Phenology | - | Antarctic petrel | Svarthamaren, Dronning Maud Land | 71°53'S, 5°10'E | 1992-2014 | this study |

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Appendix 4. Length of time-series used in studies where a negative, positive or no effect of the AAO or ENSO on Antarctic seabirds has been found. Differences were not significant ($p > 0.3$ for both indices) indicating that finding a positive, negative or no effect of the AAO or ENSO on seabirds was not due to different statistical powers.

| | Negative effect | Positive effect | No effect |
|-------------|-------------------------|-------------------------|-------------------------|
| AAO | 27.9 years \pm 1.3 SE | 30.3 years \pm 6.1 SE | 36.9 years \pm 3.9 SE |
| ENSO | 21.9 years \pm 2.9 SE | 23.6 years \pm 8.6 SE | 29.1 years \pm 3.6 SE |

Appendix 5. Pearson's correlation coefficient between the maximum sea ice extent in the Weddell Sea (sea ice extent in September) and the spring Southern Oscillation Index (SOI averaged over the months September, October and November). The "Prev. spring" corresponds to the correlation between the spring SOI in a given year and the maximum SIE in the following September. Sea ice extent data available from the Cryosphere Science Research Portal of the NASA (<http://neptune.gsfc.nasa.gov/>). SOI data come from www.cpc.ncep.noaa.gov.

