NOTES

Using Kite-based Aerial Photography for Conducting Adélie Penguin Censuses in Antarctica

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Abstract.—Adélie Penguins (*Pygoscelis adeliae*) are sensitive indicators of change in Antarctic marine and terrestrial habitats, and have been intensively monitored as part of international efforts to understand the role of apex predators in the Southern Oceans. Among the key variables annually assessed by these monitoring programs are measures of population change which are typically obtained with ground and aerial censuses. Aerial censuses, however, are expensive and logistically complex, while the accuracy of ground censuses tends to decrease as colony size increases, especially in complex landscapes where high relief may block sections of the colony from the observer's view. Here we describe the use of kites equipped with remote-controlled cameras to census Adélie Penguin colonies at Palmer Station, a research site in the western Antarctic Peninsula region. We suggest that this method, which produced excellent results, may bridge an important gap between ground and aerial censuses, offering the opportunity to obtain better data for large or difficult to census colonies at a fraction of the cost of aerial surveys. *Received 29 March 1999, accepted 20 May 1999.*

Key words.—Adélie Penguin, aerial photography, Antarctica, census, kite photography, monitoring, population, seabirds.

Waterbirds 22(3): 435-440, 1999

Adélie Penguins (*Pygoscelis adeliae*) are sensitive indicators of change in Antarctic marine and terrestrial habitats, and factors such as climate warming, human disturbance and variability in prey abundance each have been shown to induce responses in the ecology and demography of this species over a range of space and time scales (Fraser *et al.* 1992; Woehler *et al.* 1994; Fraser and Trivelpiece 1995a, 1995b, 1996; Giese 1996; Fraser and Patterson 1997; Kaiser 1997; Loeb *et al.* 1997; Emslie *et al.* 1998; Smith *et al.* 1999). For these and other reasons, including the fact that they are abundant and widely accessible around the Antarctic continent (Woehler 1993), Adélie Penguins are intensively monitored as part of international efforts focused on understanding the role of apex predators in the Southern Oceans (Trivelpiece *et al.* 1990; Agnew 1997).

Among the key variables annually assessed by these monitoring programs are measures of population change such as breeding population size (CCAMLR 1992), which provide the essential data necessary to determine trends within and between regions. Although satellite imagery has recently been employed in the acquisition of these data (Bhikharidas *et al.* 1992; Guinet *et al.* 1995), ground censuses and censuses based on aerial photography have been the standard (Taylor *et al.* 1990; CCAMLR 1992; Guinet *et al.* 1995). Each method, however, presents some disadvantages. The accuracy of ground censuses, for example, tends to decrease as colony size increases, especially in complex landscapes where high relief may block sections of the colony from the observer's view. Aerial photography, which can resolve this problem, is on the other hand expensive and logistically complex, factors that in Antarctica have restricted its availability to regions with better developed support networks such as the Ross Sea (e.g., Taylor *et al.* 1990).

In this paper, we describe the use of kites equipped with remote-controlled cameras to census Adélie Penguin colonies. Unlike other research facilities in the United States Ant-

arctic Program, our study site in the western Antarctic Peninsula is not serviced or supported by aircraft, thus affording no opportunity to obtain aerial photography. Some of the area's largest penguin colonies are in addition difficult to census from the ground because high relief can limit the lines of sight. The method we discuss bridges an important gap between ground and aerial censuses, offering the opportunity to obtain better data for large or difficult to census colonies at a fraction of the cost of aerial surveys.

METHODS

Study Site

The kite photography was conducted during the 1996-1997 austral spring and summer and the 1999 summer and autumn in the vicinity of Palmer Station (64°46'S, 64°04'W), a U.S. research facility located on Anvers Island, western Antarctic Peninsula. Adélie Penguins occur along the entire southwest coast of Anvers Island on eight island rookeries that together encompass an estimated 30,000 breeding pairs (Woehler 1993). The terrain associated with these rookeries varies from relatively level terraces to steep ridges up to 100 m above sea level. Our immediate study area included five rookeries where seabird research has been continuous since the mid-1970s (cf. Parmelee *et al.* 1977; Fraser and Patterson 1997).

Materials

Our objectives were to test the feasibility of using aerial photos of Adélie Penguin colonies taken from a kite equipped with a remote-controlled camera as an alternate census method. Although this is a previously unexplored application of kite-based aerial photography, national and international interest in this type of small-format photography, primarily from hobbyists, has resulted in the availability of ready-to-purchase kits that vary in their complexity and capabilities. We obtained our materials from Mr. Brooks Leffler (P.O. Box 34, Pacific Grove, California, 93950, USA; internet, kyteman@aol.com), editor of the *Aerial Eye*, a quarterly publication devoted to kite aerial photography. The kit included the kite (FlowForm 16) and tail, camera (35 mm Nikon One Touch), a motorized camera cradle and radio receiver on a Picavet suspension system, and the transmitter control box required for remote operation of the camera and cradle. The kit and all accessories, including a hard carrying case and string-filled winder, cost approximately US $500.00.

Flight Methods and Conditions

The kite used was flown with two personnel, one of whom assisted the other by taking the kite downwind from the launch site so it could be properly positioned into the wind and inflated. The second person also proved useful in visually guiding the kite and its camera over the target colonies due to the distance and altitude that sometimes separated the camera from the individual flying the kite. Once airborne, the kite was held aloft at an elevation of approximately 20 m while the suspension system and camera were tested and attached to the kite line at ground level. This procedure permitted both initial assessment of wind conditions and kite stability prior to attaching the camera, and, if needed during the flight, allowed batteries or film to be exchanged by lowering the camera to the ground without interrupting the kite's flight and performance. It typically took less than 45 minutes to launch the kite and camera. During our trials, wind speeds varied between 10-60 km/h and air temperatures between –5.5 and 4.5°C.

RESULTS

Kite Performance and Effects on Penguins

The kite remained stable and the camera produced relatively sharp photographs in wind speeds up to 50 km/h, but the general process of repositioning the kite and camera over the colonies proved easier at lower wind speeds, which also produced consistently sharper images. Wind speeds of 20-30 km/h appeared closer to optimal for our particular kite but, in retrospect, a kite design capable of generating equal or better lift at lower wind speeds (10-20 km/h) would have increased both the number of days when we could fly the kite and the number of hours within a day that the kite could be keep aloft. There were no apparent problems associated with changes in temperature, but based on tests performed at ground level, the speed and performance of the motorized components associated with the cradle improved above 0°C.

These trials suggest that researchers contemplating the use of kites to census penguins would do well by developing a good understanding of wind patterns in the area of interest. This information is essential for kit manufacturers to match equipment more precisely with anticipated conditions. If this information is not available, we would suggest that at least two kites capable of flying in a range of wind speeds be taken into the field.

Reactions from penguins to the presence of a kite overhead varied with the height of the kite, but was generally ignored at altitudes in excess of 50 m. Below that height, birds occasionally stared at the kite, but we never observed any behaviors that indicated alarm, even at altitudes of 30 m, the mini-

mum height flown during our experiments. The likely reason, which is admittedly speculative, is that unlike the behavior of avian predators, the kite tends to remain motionless. Its color (pale blue) is also barely distinguishable against the background.

Photography, Problems and Solutions

The most difficult problems we encountered, at least initially, were knowing where the camera was pointed relative to the position of the colonies and how large an area was covered by the photos. Because Palmer Station has full darkroom facilities, however, we were able to develop and print film as it was exposed, thus obtaining rapid feedback in terms of both detecting difficulties with our photography and finding solutions. The guidelines we discuss below, which were developed through these experiments, eliminated most of the problems we encountered. Although not having access to such facilities, for example in remote field camps, could conceivably be an important factor limiting the wider application of kite aerial photography for seabird censuses, in practice there is probably no reason why a digital camera could not replace the camera we used and completely eliminate the need for a darkroom.

Knowing where the camera was pointed, which was a problem compounded by altitude, was essential because we were primarily interested in obtaining flat, vertical images of the colonies with minimal side distortion, such as the image shown in Fig. 1. Although with our equipment the position of the receiver's antenna provided some indication of where the camera was pointing, we found it more useful to use the alignment of two strips of bright yellow tape to determine the camera's position. One strip of tape was fixed to

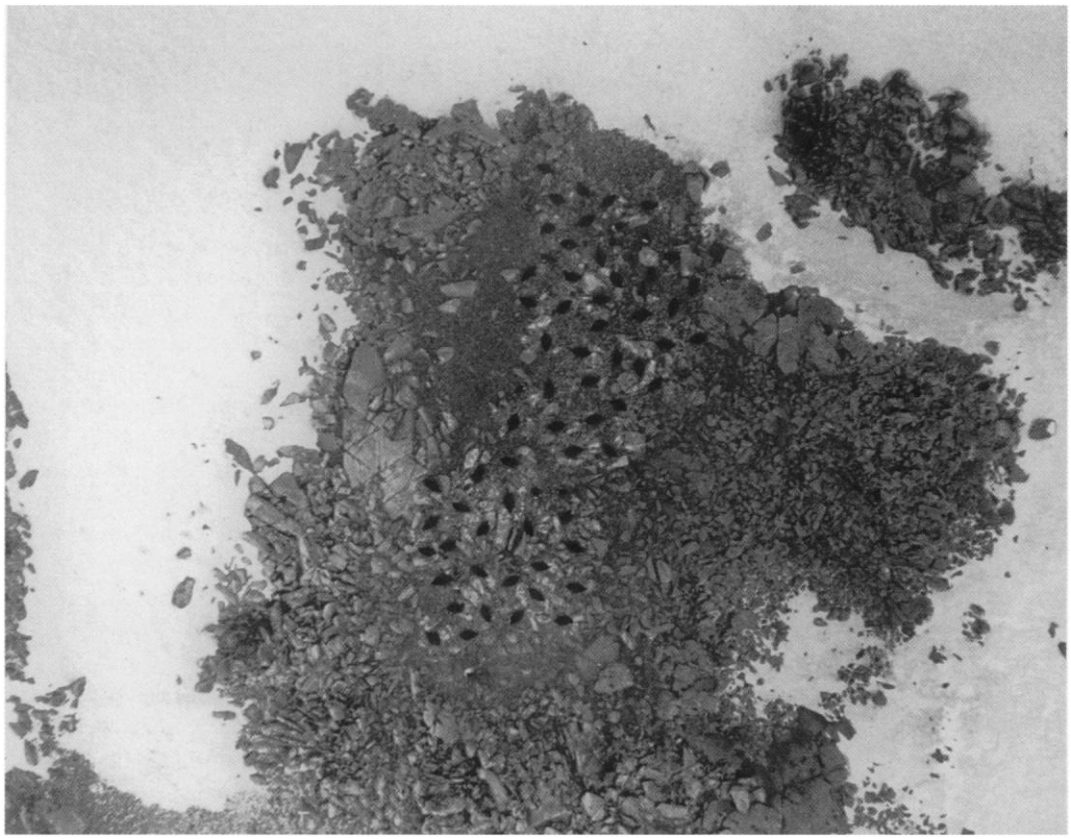

Figure 1. A vertical, low altitude image of a small Adélie Penguin colony during the first incubation shift in late November.

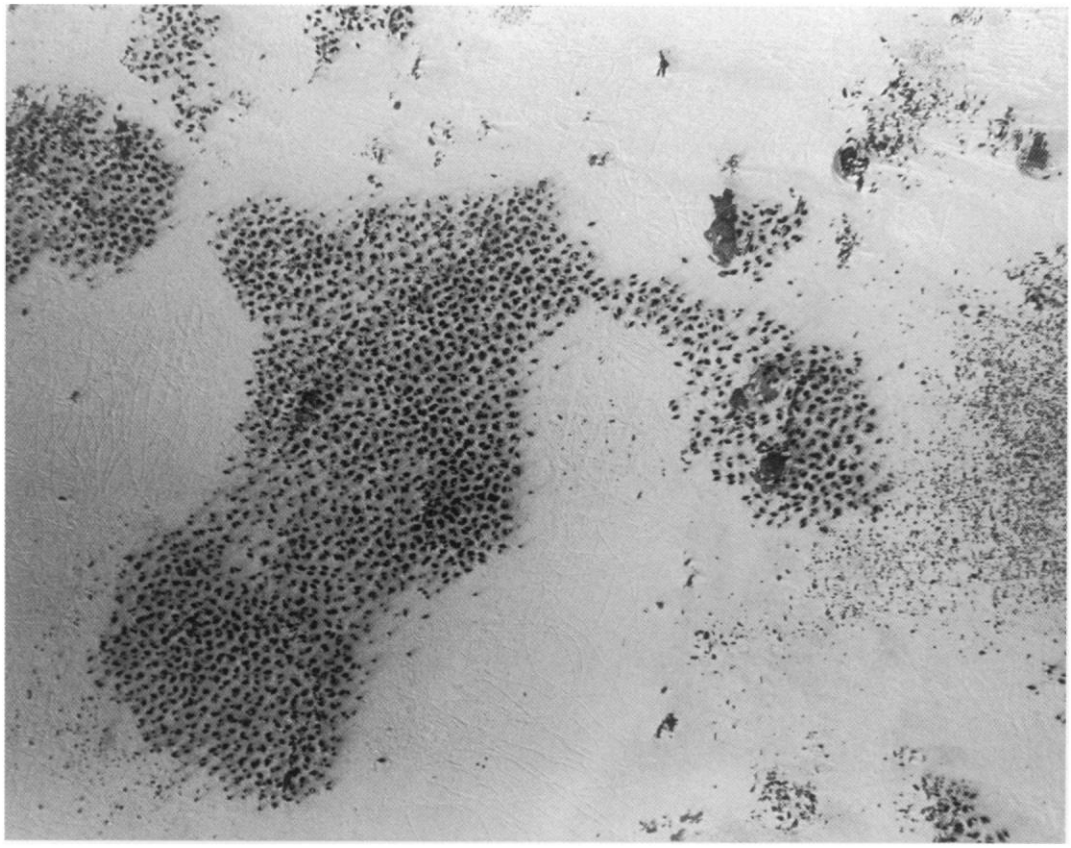

Figure 2. One of the largest Adélie Penguin colonies in the area during the peak occupation stage in early November.

the front and side of the camera body, which rotates down with the bottom portion of the cradle, and the other strip was fixed to an adjacent, non-moving surface of the cradle. When the two pieces of tape were perfectly aligned as the camera rotated towards the ground, we knew the camera was pointed straight down. An unexpected benefit of this process was that differences in the alignment of the two pieces of tape also provided information about how much side distortion was likely to be present in photographs of colonies adjacent to the target colony. This in turn helped us evaluate whether it was worth taking the image without repositioning the kite, which increased our efficiency in the field. In most cases, and particularly at camera elevations in excess of about 50 m, we used binoculars to determine tape alignment.

The camera we used had a fixed focus, 35 mm wide-angle lens, hence the only determinant of the surface area covered in an image was the altitude of the camera. To eliminate as much error as possible in estimating the camera's altitude, and thus increasing the probabilities of precisely capturing the right areas in the rookeries, we stained the kite line with a permanent red dye at 50 m intervals. By experimenting in the field and the darkroom, we were able to determine the amount of surface area that was added to an image with each 50 m rise in elevation. Although wind speed and the angle of the kite line altered these relationships to some extent, logging the number of 50 m intervals that spooled off the winder provided us with a fairly accurate estimate of the surface area likely to be covered by the image. The ability to produce these estimates proved especially useful when trying to photograph large colonies (Fig. 2) or several smaller colonies in a rookery (Fig. 3).

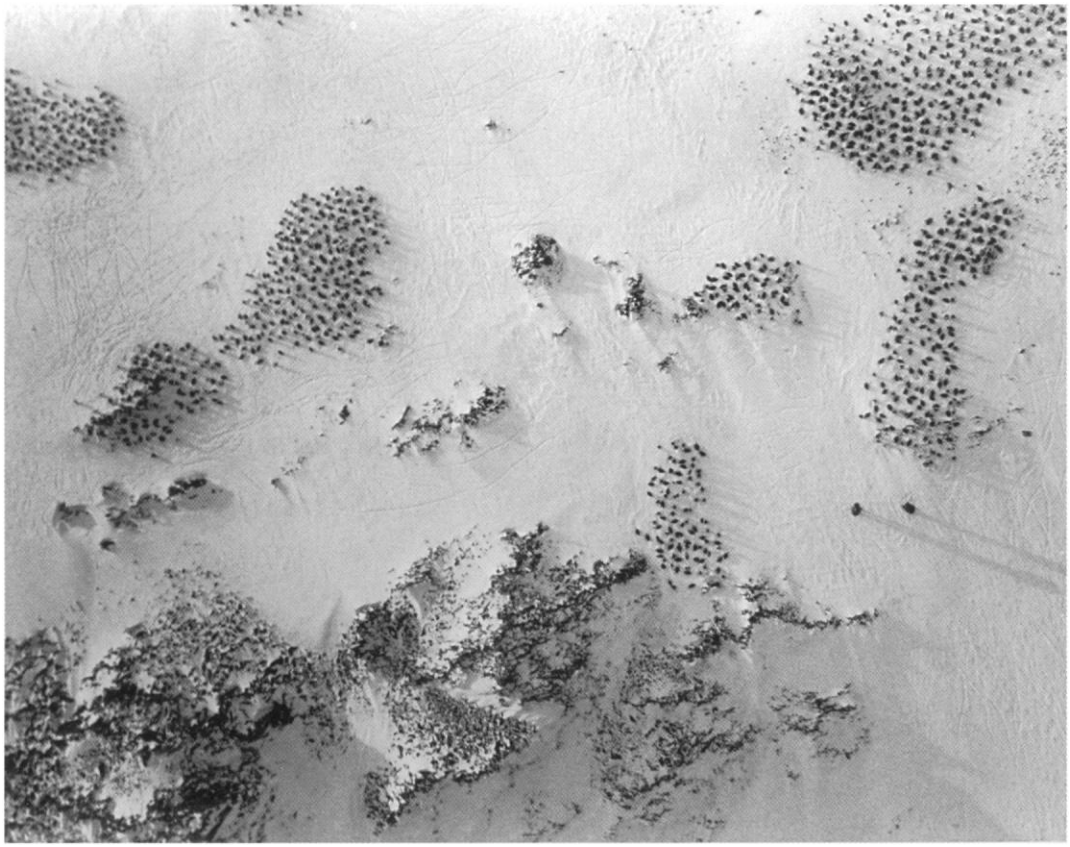

Figure 3. A high altitude image of several Adélie Penguin colonies on the Torgersen Island rookery.

DISCUSSION

As Figures 1-3 demonstrate, kite photography offers an opportunity to obtain high resolution aerial images of penguin colonies at a fraction of the cost of more conventional methods. From a practical standpoint, however, kite aerial photography is probably not a substitute for ground censuses if the colonies involved are small (< 500 breeding pairs) and do not occupy complex landscapes. Under these conditions, ground censuses are probably the more efficient method of determining breeding population size. Where the colonies are large, on the other hand, such as the one shown in Fig. 2 which numbers in excess of 1,100 breeding pairs, kite aerial photography probably offers the best alternative for obtaining accurate annual censuses.

An additional use of kite aerial photography which we are exploring, and which has applications to studies of seabird ecology beyond our own work, is the development of accurate maps that use Global Information System (GIS) technologies to integrate landscape features with the scales (e.g., individuals, colonies, rookeries) that need to be addressed to investigate links between demography and environmental variability. Our data suggest, for example, that differences in the terrestrial breeding habitat of Adélie Penguins may be a previously unrecognized source of demographic variability that in part explains observed changes in population trends between local rookeries (Fraser and Patterson 1997). Further progress on understanding the processes involved will require that we scale down (cf. Root and Schneider 1995) our investigations to examine how variability in the landscape affects the reproductive performance of individuals and the recruitment dynamics of

colonies. Kite aerial photography clearly provides a cost-effective and efficient alternative for acquiring and geo-referencing the images needed to meet these objectives.

ACKNOWLEDGMENTS

This work was funded through grants to WRF from the National Science Foundation (OPP-9505596 and OPP-9632763) and through a contract with the National Marine Fisheries Service. Sharon Delsack, Antarctic Support Associates, provided additional assistance in the field. We are also indebted to B. Leffler for his advice and assistance with all aspects of kite aerial photography, and to S. Emslie for his comments on an earlier draft of the manuscript.

LITERATURE CITED

Agnew, D. J. 1997. The CCAMLR ecosystem monitoring programme. Antarctic Science 9: 235-242.

Bhikharidas, A. K., M. D. Whitehead and J. A. Peterson. 1992. Mapping Adélie Penguin rookeries in the Vestfold Hills and Rauer Islands, East Antarctica, using SPOT HRV data. International Journal of Remote Sensing 13: 1577-1583.

CCAMLR. 1992. Standard methods for monitoring studies. Convention for the Conservation of Antarctic Marine Living Resources, Hobart, Tasmania, Australia.

Emslie, S. D., W. R. Fraser, R. C. Smith and W. Walker 1998. Abandoned penguin colonies and environmental change in the Palmer Station region, Anvers Island, Antarctic Peninsula. Antarctic Science 10: 257-268.

Fraser, W. R. and D. L. Patterson. 1997. Human disturbance and long-term changes in Adélie Penguin populations: A natural experiment at Palmer Station, Antarctic Peninsula. Pages 445-452 *in* Antarctic communities: species, structure and survival (B. Battaglia, J. Valencia and D. W. H. Walton, Eds.). Cambridge University Press, Cambridge.

Fraser, W. R. and W. Z. Trivelpiece. 1995a. Palmer LTER: relationships between variability in sea-ice coverage, krill recruitment and the foraging ecology of Adélie Penguins. Antarctic Journal of the United States 30: 271-272.

Fraser, W.R. and W. Z. Trivelpiece. 1995b. Variability in sea ice coverage and long-term change in the diets of Adélie penguins: implications for southern ocean ecosystem studies. SC-CAMLR, WG-EMM-95/64. Convention for the Conservation of Antarctic Marine Living Resources, Hobart, Tasmania, Australia.

Fraser, W. R. and W. Z. Trivelpiece. 1996. Factors controlling the distribution of seabirds: winter-summer heterogeneity in the distribution of Adélie penguin populations. Pages 257-252 *in* Foundations for ecological research west of the Antarctic Peninsula (R. Ross, E. E. Hofmann and L. Quetin, Eds.). Antarctic Research Series, Vol. 70, American Geophysical Union, Washington, D.C.

Fraser, W. R., W. Z. Trivelpiece, D. G. Ainley and S. G. Trivelpiece. 1992. Increases in Antarctic penguin populations: reduced competition with whales or a loss of sea ice due to global warming? Polar Biology 11: 525-531.

Giese, M. 1996. Effects of human activity on Adélie penguin *Pygoscelis adeliae* breeding success. Biological Conservation 75: 157-164.

Guinet, C., P. Jouventin and J. Malacamp. 1995. Satellite remote sensing in monitoring change of seabirds: use of Spot Image in King Penguin population increase at Ile aux Cochons, Crozet Archipelago. Polar Biology 15: 511-515.

Kaiser, J. 1997. Is warming trend harming penguins? Science 276: 1790.

Loeb, V, V. Siegel, O. Holm-Hansen, R. Hewitt, W. R. Fraser, W. Z. Trivelpiece and S. Trivelpiece. Effects of sea-ice extent and krill and salp dominance on the Antarctic food web. Nature 387: 897-900.

Parmelee, D. F., W. R. Fraser and D. R. Neilson. 1977. Birds of the Palmer Station area. Antarctic Journal of the United States 10: 14-21.

Root, T. L. and S. H. Schneider. 1995. Ecology and climate: research strategies and implications. Science 269: 334-339.

Smith, R. C., D. G. Ainley, K. Baker, E. Domak, S. D. Emslie, W. R. Fraser, J. Kennet, A. Leventer, E. Mosley-Thompson, S. Stammerjohn and M. Vernet. 1999. Marine ecosystem sensitivity to climate change. BioScience 49: 393-404.

Taylor, R. H., P. R. Wilson and B. W. Thomas. 1990. Status and trends of Adélie Penguin populations in the Ross Sea region. Polar Record 26: 293-304.

Trivelpiece, W. Z., S. G. Trivelpiece, G. R. Geupel, J. Kjelmyr and N. J. Volkman. 1990. Adélie and Chinstrap penguins: their potential as monitors of the Southern Ocean marine ecosystem. Pages 191-202 *in* Antarctic ecosystems, ecological change and conservation (K. R. Kerry and G. Hempel, Eds.). Springer-Verlag, Berlin.

Woehler, E. J. 1993. The distribution and abundance of Antarctic and Sub-Antarctic penguins. Scientific Committee on Antarctic Research, Hobart, Tasmania, Australia.

Woehler, E. J., R. L. Penney, S. M. Creet and R. H. Burton. 1994. Impacts of human visitors on breeding success and long-term population trends in Adélie penguins at Casey, Antarctica. Polar Biology 14: 269-274.