# Physiological ecology of Adélie penguins during the reproductive season

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Adélie penguins (*Pygoscelis adeliae*) experience a wide range of thermal conditions during the reproductive season. Both adults and chicks may be exposed to severe cold during storms or to substantial heat loads on clear, calm days (Ainley, LeResche, and Sladen 1983; Murrish 1982). We examined thermal microclimates during the breeding season in the Adélie colony on Torgersen Island, near Palmer Station. In addition, we made laboratory measurements of the thermoregulatory physiology of young and adult Adélies. When these studies are completed, the combined data should improve our understanding of climatic influences on reproductive success.

Field and laboratory measurements were performed from November 1986 to February 1987. We captured six adult penguins and 12 chicks (4 each of 1-, 2-, and 3-kilogram body mass) for physiological measurements. Using open-flow respirometry, we measured oxygen consumption ($\dot{V}O_2$), carbon dioxide production ($\dot{V}CO_2$), and evaporative water loss ($\dot{m}H_2O$) at ambient temperatures ($T_a$) from $-20°C$ to $30°C$. A sensitive pressure transducer allowed simultaneous determination of breathing rate ($f$) and tidal volume ($V_T$), and therefore minute volume ($V_{min}$) and oxygen extraction efficiency ($O_2EE$). Birds were unrestrained within the metabolism chamber during measurements (Bucher 1981).

For microclimate studies we recorded air and ground temperatures, wind speeds, solar radiation, and the temperatures of taxidermic mounts of Adélie adults and chicks. The mounts respond to wind, sun, and ambient temperature in a manner similar to live birds, except that the mounts lack physiological reponses (Chappell and Bartholomew 1981). Accordingly, mount temperatures provide a useful integrated index of the thermal environment (Bakken 1980). When mount temperatures are combined with wind speed data, the "standard operative temperature" ($T_{es}$) can be calculated. $T_{es}$ is an index of heat flow that can be directly compared to physiological responses in a metabolic chamber. Microclimate data were sampled every 30 minutes by a weatherproofed microcomputer.

Adult Adélies are extremely tolerant of cold; they show no significant increases in metabolic thermogenesis (measured as $\dot{V}O_2$) until ambient temperature drops below $-10°C$ (figure 1). At high temperatures (20 and 30°C), they pant vigorously and $\dot{m}H_2O$ increases to 0.3 percent of body mass per hour. Nevertheless, body temperatures increase only slightly (to 40.1°C, compared to 39.4°C at low $T_a$). Ventilation parameters ($V_T$, $f$, $V_I$, and $O_2EE$) are fairly constant at $T_a$ below 20°C (figure 2). At higher $T_a$, $f$ increases rapidly (from 8 breaths per minute at 10°C to 55 breaths per minute at 30°C), with a parallel increase in $V_I$ ($V_T$ is constant at all $T_a$). $O_2EE$ declines sharply during panting (from 35 percent to 10°C to 6 percent at 30°C). We saw no indication that $O_2EE$ rises at low $T_a$ in order to reduce respiratory heat loss, as has been suggested for other species (e.g., Brent et al. 1984).

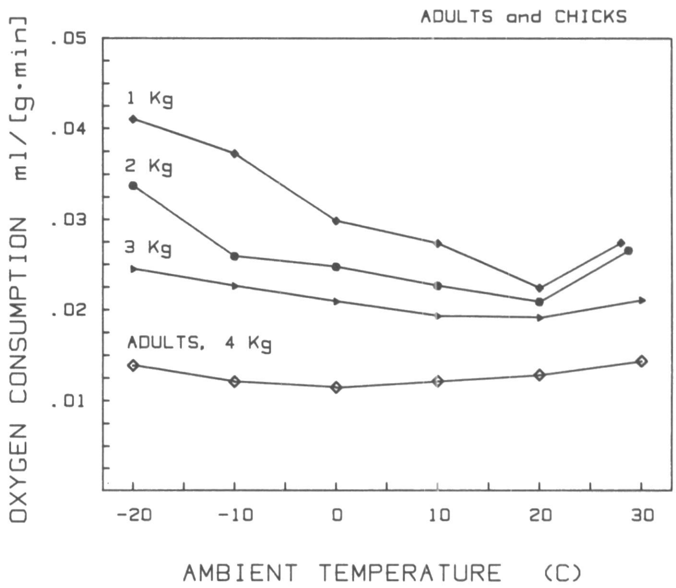


**Figure 1. Oxygen consumption at different ambient temperatures in Adélie penguin adults and chicks.**

In contrast to adults, small chicks showed substantial increases in $\dot{V}O_2$ at low $T_a$ (figure 1). This thermogenic response was reduced as chicks grew larger. Nevertheless, molting chicks (about 3 kilograms) still had mass-specific metabolic rates 60–80 percent larger than for adults (about 4 kilograms). The overall pattern of ventilation in chicks strongly resembled that of the adults, except that $f$, $V_T$, and $V_I$ were proportionally smaller in small chicks.

During most of the 1986–1987 breeding season, microclimate conditions on Torgersen Island were within the thermal tolerances of adults (figure 3). The season was unusually cool, so we observed few indications of heat stress (we did see long-term panting on several occasions). Despite the relatively cool season, we estimate from calculated $T_{es}$ values that thermal conditions requiring additional metabolic heat production (above resting levels) comprised less than 1 percent of the season.

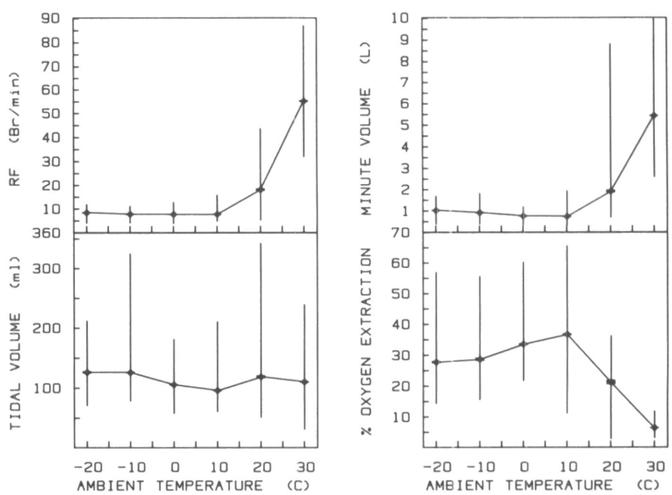


**Figure 2. Ventilation parameters of adult Adélie penguins at different ambient temperatures. (Symbols: vertical lines show range; boxes around means are 95 percent confidence intervals.)**

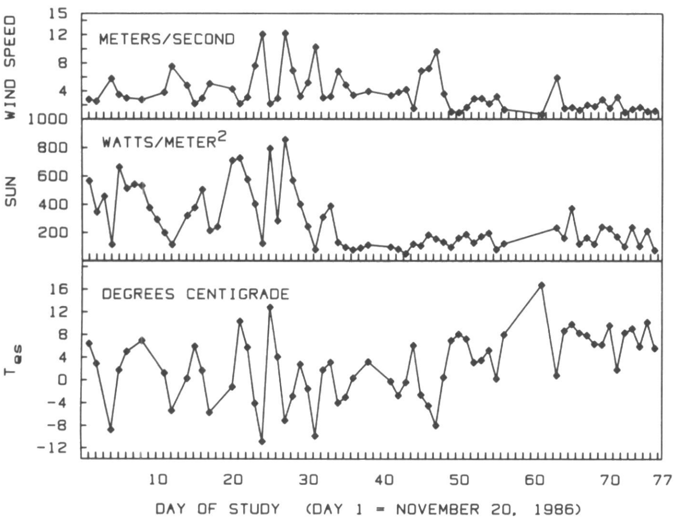


**Figure 3. Microclimate conditions in the Torgersen Island Adélie rookery during the 1986–1987 breeding season. The points represent daily mean values; data were sampled every 30 minutes. The $T_{es}$, or "standard operative temperature," is an index of heat flow integrating the effects of ambient temperature, wind, and solar radiation.**

However, substantial heat production by unbrooded chicks would have been necessary, particularly for small individuals.

This research was supported by National Science Foundation grant DPP 85-15357. We are grateful to D. Wiggin, S. Akely, M. Snyder, and the rest of the Palmer Station staff for their help.

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# Continuing penguin research at Sea World Research Institute, San Diego, California

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Since the successful establishment of the original research colony of high antarctic penguins in San Diego in 1976–1977, much has transpired. The initial founder colony of Adélie (*Pygoscelis adeliae*) and emperor (*Aptenodytes forsteri*) penguins was acquired from the Ross Island/McMurdo Sound region (Todd 1977, 1978). Over a decade later, many of these penguins are still thriving and reproducing. In 1980, the first successful captive breeding of the emperor penguin occurred. The long-term, year-round research that the Division of Polar Programs at the National Science Foundation originally envisioned has been facilitated.

Over the years, techniques have been developed which enabled us to acquire additional species from regions not noted for extensive logistic support. Live penguins are no longer required and all current acquisitions are made via eggs. The advantages of penguin transport by eggs are numerous; logistics are far less complicated (it is much easier to move 100 penguins in a 1-meter-square, self-contained field incubator than employing an entire frozen USAF C-141 Starlifter); quarantine is much less traumatic; accurate daily growth rate data is easily obtainable; and a population of known-age birds results. In addition, in the case of those species which produce two eggs, only one egg of the clutch is collected. Typically, despite the production of two eggs and even hatching two chicks, seldom is more than one young fledged per pair. Thus, the removal of a single egg should facilitate the establishment of controlled environment penguin populations without compromising the wild reproductive potential.

In 1983, a joint cooperative pilot program was initiated with the Chilean Antarctic Institute (INACH) and the Chilean Air Force (FACH) and eggs were collected at Nelson Island, South Shetland Islands. During 1984, eggs were acquired from the Cape Horn sector (Chile), and in 1985, penguin eggs were obtained in the Falkland Islands in conjunction with the British Forces/Falkland Islands (BFFI).

During November and December 1986, we returned to Nelson Island, once again working with FACH and INACH. The field season was long and difficult and numerous unanticipated problems arose. As a result of unseasonably bad weather and C-130 mechanical problems, the field team was stranded in Punta Arenas, Chile for more than 2 weeks. Ultimately, the mission was successfully accomplished, but it required the assistance of many people, agencies, and countries. If ever a single project clearly illustrated the international cooperative spirit of the Antarctic, this was it.

The field team was transported to the Antarctic aboard the M/V *World Discoverer*, a West German tourist ship chartered by an American travel company. Upon arrival at Marsh Base, the cargo was off-loaded by Filipinos and Indonesians into a Russian landing craft from Bellingshausen Station driven by East Germans. At Marsh Base, all support was provided by the