The Heat is On: Air Temperature, Burrow Temperature, Burrow Quality and Reproductive Success in a Long-Lived Seabird

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During early January 2013, thanks to the funds I received from a Grua/O’Connell Fellowship, I had the opportunity to travel to San Francisco to attend the annual meeting of the Society of Integrative and Comparative Biology (SICB). Not only was I exposed to the breadth and depth of biological research currently being conducted by enthusiastic scientists across the globe, but I also had the good fortune to meet and chat with many generous and encouraging members of a field I am considering entering. I attended many plenary talks and symposiums over the course of the four-day conference and also presented my own poster describing the joint research I did this summer with Claire O’Connell, a senior at Kenyon College.

Claire and I worked with a subset of a Leach’s Storm-Petrel colony at the Bowdoin Scientific Station on Kent Island, a small island in the Bay of Fundy, New Brunswick, Canada. Leach’s Storm-Petrels are small pelagic seabirds that return to offshore islands every summer to raise a single chick in an underground burrow. Though parents generally return to the same burrow every year, they choose a new burrow 4-8% of the time. Bowdoin alumni Evan Fricke found that petrels that switch burrows switch to drier, longer, and larger burrows in close proximity to other burrows, characteristics that may offer thermoregulatory benefits. This study aimed to support the hypothesis that these characteristics are also appealing because they increase reproductive success. Additionally, as Kent Island air temperatures have been on the rise over the past six decades, burrow temperatures and hatching success have also risen; we aimed to understand the relationship between burrow temperature and reproductive success.

To the greatest extent possible, nearly 400 burrows were monitored daily for egg and chick presence, and chicks with known hatch dates were measured around ages 30 and 60 days. We also monitored air and burrow temperatures using iButton™ temperature loggers. Using Fricke’s results, we created a burrow quality ranking system and compared burrow temperature and burrow quality to the hatching success and wing growth rate of chicks in each burrow.

We found that air temperature affects burrow temperature, and that a burrow temperature vary consistently both seasonally and annually (i.e. a warm burrow is always a warm burrow). We found a slight correlation between burrow temperature and burrow quality, and though burrow temperature does not appear to affect reproductive success, burrow quality does. Unexpectedly, offspring in high quality burrows took longer to hatch and grew more slowly than those in lower quality burrows. However, offspring in higher quality burrows were laid earlier in the season, suggesting that chicks in lower quality burrows are forced to grow faster in order to fledge before winter. Alternatively, harsh weather conditions earlier in the season may slow development of eggs laid in better quality (and earlier occupied) burrows. It is also possible that a better burrow allows parents more leniencies: parents with a better burrow may be able to afford to leave their egg unattended for a longer period of time, thereby slowing development; increased incubation for eggs laid earlier in the season may therefore be caused by the increased egg neglect behavior correlated with a better burrow.

Our prediction that a parents who occupied a better quality burrow would raise an offspring that would hatch faster, grow faster, and fledge earlier was not supported by our data; in fact, our study suggested the exact opposite was true, raising puzzling questions for future research. Discussing possible explanations for our results with esteemed biologists at the SICB conference was an incredible opportunity to practice scientific thinking and experience first hand how research progresses.

Faculty Mentors: Damon and Janet Gannon
Funded by the Peter J. Grua/Mary G. O’Connell Student Faculty Research Fellowship
The heat is on: air temperature, burrow temperature, burrow quality and reproductive success in a long-lived seabird.


Variation in Burrow Temperature

- Inter-burrow temperatures vary consistently.
- A warm burrow is always a warm burrow.

![Figure 7: Distribution of average burrow temperature from July 11-25, 2012 (N=40 burrows).](image)

![Figure 8: The consistency of normalized burrow temperatures across time periods (2011-2012) and burrow temperatures have increased at the Bowdoin Scientific Station at Kent Island in the Bay of Fundy.](image)

Global Temperature and Kent Island

- Summer air (Fig. 1) and sea surface temperatures have increased at the Bowdoin Scientific Station at Kent Island in the Bay of Fundy.
- Increased temperatures have been linked to the reproductive success of Leach’s storm-petrels (Oceanodroma leucorhoa) (Fig. 2).

![Figure 5: Mean annual air temperature at Kent Island from 1960 to 2010.](image)

![Figure 2: Mean annual hatching success (1965-2007) increases with air temperature.](image)

Storm-petrel breeding biology

- Long-lived pelagic seabird that raises a single offspring annually in an underground burrow.
- Highly site-philatric: ~8% of parents switch burrows between years.

![Figure 15: Burrow quality and temperature are not significantly related (ANOVA, P=0.307). Error bars=SEM, N=32 burrows.](image)

Measuring Burrow Temperature

- Tunnel temperature is a reliable index of nest chamber temperature in empty burrow (Fig. 4).
- Placed iButton™ temperature loggers in 53 burrows during 2008 and 2012 breeding seasons.

![Figure 13: Relation between normalized burrow temperatures and feather growth rate (Linear Regression, P=0.001, N=97 storm-petrels).](image)

![Figure 14: The relationship between ranked burrow status and feather growth rate (Linear Regression, P=0.096, N=98 storm-petrels).](image)

Ptilochronology

- Ptilochronology uses feather growth as an index of nutritional condition: growing a feather reflects available energy.
- The original outer right retrix (OR6) feathers from incubating storm-petrels were collected 10 days after eggs were laid.
- Induced (IR6) feathers were collected from recaptured birds 16-48 days later. We defined Feather Growth Rate as (R6/IR6 days grown).

![Figure 3: Implied burrow diagram, and placement of temperature loggers.](image)

![Figure 11: Relationship between monthly day (days after Jun 1, 2009) and burrow temperatures (Linear Regression, P=0.000, N=33 burrows).](image)

![Figure 12: Relationship between normalized burrow temperatures and ambient temperatures (Linear Regression, P=0.000, N=33 burrows).](image)

![Figure 10: Correlation of daily mean ambient temperature (Fig. 3) with breeding biology variables (indices).](image)

![Figure 9: The consistency of normalized burrow temperatures across years (2011, 2012) (Linear Regression, P=0.90, N=53 burrows).](image)

![Figure 8: The consistency of normalized burrow temperatures across time periods (2011-2012) (Linear Regression, P=0.000, N=33 burrows).](image)

Measuring Burrow Quality

- Prefer drier, longer, and larger burrows in close proximity to other burrows (Fig. 5).
- Rank burrows linearly (1=Best) and categorically (Top 25%=Good, Central 40%=Med, Bottom 25%=Bad).

![Figure 6: Skyline burrow diagram and important burrow characteristics.](image)

![Figure 16: Percent of burrows qualitatively marked as “Wet” and “Dry” in 2006 compared to the percentile ranking based on quantitative moisture data collected in 2009 (N=203 burrows).](image)

![Figure 19: Eggs laid in better burrows are laid earlier in the season (t-test, P=0.018, N=40 burrows).](image)

Conclusions

- Air temperature strongly affects burrow temperature.
- Burrow quality may not be correlated with temperature.
- Eggs laid in “better quality” burrows are laid sooner, incubated longer, and develop more slowly as chicks.
- The relationship between burrow temperature, burrow quality and reproductive success is complex and may influence trade-offs with regard to parent-offspring conflict and conditions at sea (i.e., food availability).

![Figure 17: Chick wing growth is linear between ages 30 and 80 days.](image)

![Figure 18: Normalized wing growth rate of chicks measured in 2009, 2007, 2008, and 2012 is slower in better ranked burrows (Linear Regression, P=0.38, N=72 burrows). The best burrow has a ranking of 1.](image)

![Figure 20: Eggs laid earlier in the season are incubated longer (Linear Regression, P=0.022, N=31 burrows).](image)

Reference (Cite)

