Biophysical Field Methods in the Namib Desert

Adaptation to a harsh environment: the Namib desert. An international field workshop

Gobabeb Namib Research Institute, 10-26 February 2020
Ben-Gurion University of the Negev
Before the course ...

Prior to leaving for Namibia, students from Israel, Namibia, and South Africa take Biophysical Field Methods, an eight-week online course together to reach a common background level.

*Biophysical Ecology in the Namib* is the second part of a hybrid online / field course in the biophysics of adaptation to harsh environments.
Off to Namibia ...

Once students complete Biophysical Field Methods, it’s off to Namibia.

For the Israeli students it’s a long international flight to Walvis Bay!

Thúc Nguyen and Ben Poodiack on the way.

Arrival in Walvis Bay!
Day 1. Settling in at Gobabeb

Students settle in to their accommodation.

The day ends with a meal in the Gobabeb dining hall.
Day 2. Orientation

In the morning, Dr Eugene Marais takes everyone on a walk through the desert habitats around Gobabeb.

On the dune crest

In the riparian corridor of the Kuiseb River

On a !nara hummock
Day 2. Orientation

We also took a bit of time to learn about the instrumentation we will be using.

Prof Scott Turner talks about operative temperature thermometers

Prof Berry Pinshow describes a psychrometer

Dr Dilia Kool demonstrates the micro-lysimeter ...

... and a meteorological shield for a thermocouple
Days 3-5: Field work

We divided up into three groups, for three days of hands-on field work

One problem studied was about desert beetles that are almost always black.

You would expect beetles inhabiting a hot sunny environment to be white!

But, they’re black!

Why?
Days 3-5: Field work

A second question addressed was about the indigenous !nara plant (*Acanthosicyos horridus*).

The !nara lives in the dunes in an extremely dry desert, but uses a lot of water. Where does it get water from? Does the water come from dew and fog?

We set out micro-lysimeters around a !nara thicket to measure air-borne water deposition in dune sands.
Days 3-5: Field work

The third group posed a question about thermal buffering.

We used operative temperature thermometers (made of painted ping-pong balls) to measure how their temperature responds when environmental temperature suddenly changes.

One ball was filled with water and had high thermal capacity, while the other was empty and had low thermal capacity.
Days 3-5: Field work

Each afternoon, we analyzed and discussed the data gathered in the morning.

There was also time to let our hair down.
Day 6: Data analysis workshop

After three days of field work, we got down to making sense of the data.

We had a charrette of posters at Gobabeb, to evaluate what makes a good (and what makes an ineffective) poster.

We discussed our own data and how to make sense of them.

We had a sundown discussion about what science is ... and what science isn’t.

We worked up draft slides to see what worked and what didn’t.
Day 7: Namib day trip

On the 7th day, we travelled to the Atlantic ocean, visiting lichen fields, geological formations and local cultural sites.

Arriving at the Walvis Bay lagoon... watched the flamingoes... and had lunch.
**Day 7: Namib day trip**

In the afternoon we
... looked over the “moonscape” of Goanikontes on the Swakop River ...

... checked out some *Welwitschia* ...

... enjoyed sundowners looking in vain for *Lithops plants* at the Hamiltonberg ...
Days 8-10: Field work

How fast does a beetle have to run across a hot stretch of sand?

Black Namib beetles are often seen running across hot sands. How do they avoid overheating?

One way is to run fast!

We measured how fast beetles run.

We measured temperatures along a transect between two !nara hummocks.
Days 8-10: Field work

Just how hot do beetles get?

We measured body temperatures of beetles walking across sand ...

This involved some pretty close work

... we also used an infrared thermometer to measure beetle surface temperature
Days 8-10: Field work

Do !nara hummocks actually capture fog?

Fog comes in overnight ...

It looks like they do (sort of)

!Nara hummocks capture fog water (and so does everywhere else) ...

... but !nara hummocks retain the water longer

... taking overnight measurements of water capture.

... so we spent the night at a !nara hummock ...
Day 12: Data analysis workshop (2)

After the second three days of field work, we learned new methods of data analysis.

... and broke into smaller groups to analyze and interpret our data.

Finally, we discussed the data as a group...
Days 13-14: Overnight trip into the dune sea

After an intense bout of intellectual work, it was time for an overnight outing into the dune sea.
Days 13-14: Overnight trip into the dune sea

We enjoyed each others’ company ...

... cooked a nice meal ...

... saw interesting nocturnal creatures ...

... and woke up to a rare cloudy morning.

[Images of people cooking, interesting nocturnal creatures, and a rare cloudy morning]
Day 15. Poster workup

First we had a poster design charette, learning from the work of others (left).

Then we set about making our own, preparing posters describing our findings.

We thought, and worked, together …

… and critiqued each other’s work

... and alone …
Day 16. Poster presentations
Then it was time to tell the Gobabeb staff what we had been doing

Dr Gillian Maggs-Kölling (Director of Gobabeb Namib Research Institute) welcomed us

The entire Gobabeb staff attended

Prof Nurit Agam added her welcome
Day 16. Poster presentations
The “Black Desert Beetle Paradox” solved!

The “Black Desert Beetle Paradox” solved!

Ella Agra, Ariel Drabkin, Nata Ndilenga, and Thúc Nguyen

Introduction

Why would a beetle in a hot sunny desert be black in color? This has been a paradoxical question for many years because being black would make the beetle very hot.

On the other hand, black coloration is apparently common in desert animals. Crows, for example, have black feathers, but they have a mechanism to deal with the heat.

 radiation

Beetle, you said you have an insulating layer. Then, we predict your body temperature will be lower than surface temperature of your surroundings.

You can see from the graph below that there is a time delay between my body temperature and my surface temperature. My insulating layer works!

Beetle, is it true that your body size and posture affect your operative temperature? (a)

Well, when I'm still, I'm more affected by convection. So, my body temperature should be lower than when I'm moving.

But, body size does not have any significant effect on my T_b

Beetle, you have an insulating layer and your heat budgets are mostly affected by convection. So it must take less time for you to heat up. What's your body constant?

The time constant (τ) indicates the time for a beetle’s body temperature to approach the T_b

τ = \frac{R}{C}

C = Thermal capacity of the beetle
R = Resistance to heat flux

The (1) insulating layer and (2) convection effect together combine to allow black beetles to (3) keep cool in hot sunny deserts.

Black coloration does not matter that much to a beetle’s body temperature, so let “the paradox” sleep!

Ella Agra, Ariel Drabkin, Nata Ndilenga, and Thúc Nguyen

Ariel Drabkin
Ella Agra
Nata Ndilenga
Thúc Nguyen
Day 16. Poster presentations

Nara hummocks help retain water for a longer period

Rorie Duncan
Yaniv Shmuel
Gal Lupovitch
Ailly Nabwandja

Water under arrest
Can the Nara (Acanthosicyos horridus) hummock take atmospheric water into custody? For how long can it imprison this water? Will the water be able to escape?

Rorie Duncan, Gal Lupovitch, Ailly Nabwandja, and Yaniv Shmuel
University of Cape Town; Alan Duine University of the Ngor, Namibia University of Science and Technology; the Namibian fixed Sandus.

In the hyper-arid Namib desert, the Nara (Acanthosicyos horridus) plant thrives. How is this possible? Can it be that fog plays a role?

How did we examine this?

1) I am a millimeter, I am filled with soil, representing the surrounding soil. My mass will increase when water accumulates in my soil and decrease when water evaporates. We were put in various locations around the Nara hummock.

2) After a fog event, water accumulates during the night, even two days later.

Water is accumulating in the hummock when there is fog, but also when there isn't fog. Can the Nara hummock capture other types of water? Dew? Water vapor?

Water accumulation across the Nara hummock

Wind direction - north

Acknowledgements:
This study was part of the 2020 class in Biophysical Ecology in the Namib. Our work was supported in part by a generous grant from the Silsars Foundation in Israel, and with additional support from Gobabeb Namib Research Foundation.
Beetles can use thermal inertia to cross hot sands without overheating, but only if they run really fast.

**Operative temperature**: The operative temperature of an object is its temperature once it reaches equilibrium with the environment. At equilibrium (the steady state), the energy budget is zero. For example, a hollow ping pong ball placed in the sun reaches its operative temperature when it’s in equilibrium with the environment.

**Thermal capacity**: Organisms are made largely of water which can store heat energy. This heat storage is quantified as the thermal capacity. A water-filled ping pong ball filled will reach its equilibrium temperature slowly as it stored within. This is the transient state.

**Time constant**: In the transient state, a body will approach its equilibrium temperature at a specific rate. This is quantified by the time constant, \( \tau \).

A body with large thermal capacity (like the water filled ping pong ball) has a longer time constant than a body with small thermal capacity (like the hollow ping pong ball). The time constant, \( \tau \), is the product of the thermal capacity, \( C \), and the resistance to heat flux, \( R \), across the body’s outer boundary.

\[
\tau = RC
\]

Now we can apply these concepts to our original question. We used the operative temperature, thermal capacity, and the time constant of desert beetles to model what would happen if a beetle ran across hot sand.

When the beetle runs faster, its body temperature is less coupled with the sand temperature it encounters (yellow trace above). If it runs fast enough, it will not overheat.

This is quantified by the gain ratio \( G \). \( G \) declines with running speed, so we see that body temperatures are closely coupled when \( G \) is higher and less coupled when \( G \) is lower.
Day 16. Poster presentations

The posters are now on display in the dining hall at Gobabeb, for all to see.
Day 16. We celebrate
Our last night at Gobabeb. We enjoy a good meal ...

... and good libations
Day 17. Departure

It was back in the bus from Gobabeb to Walvis Bay, where it all began.

We had a lot of fun, and learned a lot!
Biophysical Field Methods. Class of 2020

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BGU-BIDR – Ben-Gurion University of the Negev-Jacob Blaustein Institutes for Desert Research
UNISA – University of South Africa
NUST - Namibia University of Science and Technology
UCT – University of Cape Town

Acknowledgements: The BGU contingent, students and instructors, was funded generously by The Sillins Family Foundation, The Office of the President of BGU, The Jacob Blaustein Center for Scientific Cooperation and the three Blaustein Institutes.

Photo credits: Ella Agra, Ariel Drabkin, Scott Turner