Breeding under stress: hormones and fitness in a fluctuating environment

Jenny Ouyang

Netherlands Institute of Ecology (NIOO-KNAW)

28 October 2014
How commercial airplanes should be laid out

Screaming infant storage kennel

Show Disney movies on repeat to shut them up

Hakuna Matata

One of those hamster cage sippy water bottle things

Department of Psychology, SUNY New Paltz

Nicholas S. Thompson
Department of Psychology, Clark University
The dog was in the way while he was trying to push the chair.

I broke this cheese in half.
FAVORITISM

It sucks.
Physiological adaptation to changing environments

- Genotype
- Phenotype
- Fitness

- Past environment
- Current environment
Glucocorticoids (corticosterone)

- Steroid hormone
  - Regulation of metabolism
  - Released in response to stress
  - Increased blood sugar
  - Increasing metabolism
  - Suppressing immune system
  - Suppressing reproduction
Hormones as Mediators

- Corticosterone (CORT)
  - Baseline (Cort0)
  - Stress-induced (Cort30)

Bonier et al 2009 TREE
Stress series

Corticosterone (ng/mL)

Time (min)
n=20
Hormones as Mediators

- Corticosterone (CORT)
  - Baseline (Cort0)
  - Stress-induced (Cort30)

Bonier et al 2009 TREE
Breuner et al 2008 Gen Comp Endo
Talk outline

1) Characterization of the endocrine phenotype
2) Manipulation of this phenotype
3) Adaptation in novel environments
Characterization

• Is the endocrine phenotype stable over time?
• Is it related to fitness?
Study species: *Parus major*
Study Site

- Möggingen, Germany (47°N, 8°E)
- 300 nest boxes
- ~150 ha forests
Repeatability

• Are corticosterone concentrations repeatable across seasons and among years?

\[ R = \frac{\sigma_{\alpha}^2}{\sigma_{\alpha}^2 + \sigma_{\epsilon}^2} \]

\( R \) = proportion of the total variance accounted for by differences among individuals

= between-individual variance
Male great tit song is repeatable

Male song rate (strophes/minute)

Time (day)

R=0.75, n=41, p<0.0001

individual 1
individual 2
individual 3
individual 4
individual 5

Male song rate (strophes/minute)
Corticosterone is not repeatable over long term

<table>
<thead>
<tr>
<th>hormone</th>
<th>time-interval</th>
<th>R(SE)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>baseline corticosterone</td>
<td>March to breeding</td>
<td>0.26(0.12)</td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td>Among years</td>
<td>0.11(0.10)</td>
<td>0.191</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>0.16(0.07)</td>
<td>0.010</td>
</tr>
<tr>
<td>stress-induced corticosterone</td>
<td>March to breeding</td>
<td>0.00(0.08)</td>
<td>0.889</td>
</tr>
<tr>
<td></td>
<td>2009 breeding to 2010 breeding</td>
<td>0.08(0.10)</td>
<td>0.295</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>0.05(0.06)</td>
<td>0.245</td>
</tr>
</tbody>
</table>

Ouyang et al. 2011 Horm Beh.
High March cort0 = high fledgling #

<table>
<thead>
<tr>
<th>Total number of fledglings (n)</th>
<th>March baseline corticosterone concentrations (ng/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males z=2.49, p=0.013</td>
<td></td>
</tr>
<tr>
<td>Females z=3.08, p=0.002</td>
<td></td>
</tr>
</tbody>
</table>

Ouyang et al. 2013 *J. Evol Biol.*
High baseline cort = high parental feeding

Feeding rate (trips/hour)

breeding baseline corticosterone concentrations (ng/mL)

males  z=4.82, p<0.0001
females  z=3.94, p<0.0001

Residuals of fledgling number from mean at feeding rate

Low May cort0 = high fledgling #

May baseline corticosterone concentrations (ng/mL)

-6 -4 -2 0 2 4 6

0 5 10 15 20 25 30

males z=-2.05, p=0.04
females z=-3.54, p<0.0001

lower fledgling numbers higher fledgling numbers
Environmental data: 2010 = bad year

Average lay date

Precipitation (mm)

Mean temperature (°C)
Males abandoned nests faster than females

$z = 4.04, \, p < 0.0001$
Males with high stress-induced corticosterone have higher nest desertion rates

Ouyang et al. 2012 Anim Beh.
Males that abandoned in 2010 had higher stress-induced corticosterone levels

In 2010:
- did not abandon
- abandoned

Ouyang et al. 2012 Anim Beh.
Stress-induced corticosterone difference (ng/mL) vs. Frass weight difference (g)

Nest desertion decisions are adaptive

Average nestling mass (g)

- First brood: n = 12
- Second brood: n = 12

Total number of fledglings (n)

- Did not abandon: n = 45
- Abandoned: n = 12
Summary: characterization

• Baseline corticosterone
  – Metabolic hormone: related to reproductive effort
  – Life-history stage specific

• Stress-induced corticosterone
  – Responds to environmental variation
  – Nest desertion decisions
Manipulation

• Do experimental changes in corticosterone levels result in changes in behavior and fitness?
Experimental protocol

- 7 mm length
- 1.5 mm inner diameter
- 0.3 mm diameter punctured hole
- Filled with crystalline CORT or left empty
Timeline

Cort0 (ng/mL)

Days since implantation

1 6 11 16 21 26 31 36

0 5 10 15 20 25

11 ♀ 12 ♂ implanted with corticosterone implants
12 ♀ 12 ♂ implanted with control implants
incubation stage

**Female incubation bout (minutes/hour)**
- Control: n = 11
- Corticosterone: n = 9

**Male feeding female (trips/hour)**
- Control: n = 10
- Corticosterone: n = 9

*Ouyang et al. 2013 Horm Beh.*

---

*** indicates statistical significance.
Female feeding rate (trips/hour)

- Control: n = 11
- Corticosterone: n = 9

Male feeding rate (trips/hour)

- Control: n = 10
- Corticosterone: n = 9

Ouyang et al. 2013 *Horm Beh.*
Study Site

- Queen’s University biological station, Southern Ontario, Canada
- (45°N, 76°W)
Tree Swallows (Tachycineta bicolor)
Cort implant

Incubation (~13 days)

Day 4
Bleed/Implant

Day 3
Behavioral Observations

Chick rearing (~21 days)

0.5mg 60-day release pellet

16 females CORT
17 females control implanted
Massive nest failure

>92% nest failure

Days chicks alive in nest

Frequency
Cold + CORT = desertion

CORT | Control | Daily maximum temperature

<table>
<thead>
<tr>
<th>Date</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>May 25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>May 30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 19</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Relative risk of nest failure

Daily max. temperature °C
Weather * cort treatment affects brood failure
Summary: manipulation

• Great tits
  – Increase in cort = increase in reproductive behavior
  – When signal gone, behaviors returned to normal

• Tree swallows
  – In good weather, cort-treatment increased nest desertion, but in bad weather, no difference
  – Cort tracking environmental conditions
Further thoughts on the swallows

- IPCC⁴ (increasing incidents of extreme weather)
- How will populations adapt?
- Monitor internal state and physiological flexibility
Anthropogenic change

Physiological adaptation to novel environments
Main Question

• What are the individual nighttime activity patterns under different spectra of artificial light?
  – Does it matter?
8 replicates

[Graph showing power vs. wavelength with green light, red light, and white light curves]

Conclusions

• Hormone levels can give predictions on breeding success, dependent on life-history stage
• Hormone levels vary with environmental conditions and mediate reproductive decisions
• Functional significance of hormonal plasticity
  – (Lendvai et al. 2014)
• Next steps: how fast do endocrine systems respond?
Suzanne Austin
Evi Fricke
Tim Grieves
Michaela Hau
Marion Muturi
Michael Quetting
Frances Bonier
Roslyn Dakin
Alice Domalik
Vince Fasanello
Mark Haussmann
Ádám Lendvai
Ignacio Moore
Brian Vassallo
Maaike de Jong
Koosje Lamers
Sofia Scheltinga
Helen Schepp
Kamiel Spoelstra
Marcel Visser
Questions?