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THE EFFECTS OF EXOGENOUS CORTICOSTERONE AND TESTOSTERONE ON
JUVENILE EASTERN FENCE LIZARDS, *SCELOPORUS UNDULATUS*

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ABSTRACT

Hormones, such as corticosterone (CORT) and testosterone (T), play a critical role in an animal's stress response, sexual maturation, and growth and development. These hormones interact through the hypothalamic-pituitary-adrenal (HPA) axis, and have reciprocal effects. Maternal levels of CORT and T can have important effects on juveniles through two pathways: 1) maternal hormones can enter the eggs and directly affect the developing offspring and/or 2) these hormones can affect maternal behavior or maternal allocation of nutrients to the eggs, thereby indirectly affecting the developing offspring. We used the Eastern Fence Lizard, *Sceloporus undulatus*, to test the effects of CORT and T on hatching success, size at hatching, sex, growth rate, and survival of offspring. We topically applied exogenous hormones to pregnant female Fence Lizards and to eggs from unmanipulated females post-laying, to distinguish between direct effects of these hormones and effects caused by hormonally-driven changes in maternal behavior or allocation. Hormone application to the mothers, but not direct application to the eggs, affected hatching success and size at hatching, suggesting that these changes were driven by maternal responses to CORT and T rather than being a direct effect of these hormones on the developing embryos. Offspring survival was affected both by application of hormones to the eggs and to the mothers, suggesting this might be a direct hormonal effect. CORT and T differentially affected these traits: offspring of CORT-dosed mothers had higher hatching success and were larger at hatching than control-dosed mothers, whereas dosing mothers with T had the opposite effect. Similarly, applying CORT to eggs or mothers increased survival over 4-months, whereas applying T decreased survival, relative to controls. Applying CORT or T to both the mothers or the eggs did not affect the sex ratio of the offspring. Our findings suggest that maternal levels of CORT and T can have significant effects on fitness-relevant traits in offspring, both directly and via hormonally-driven changes in maternal behavior or allocation.

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Introduction

Hormones, including corticosterone (CORT) and testosterone (T), are chemical messengers that control several important functions in animals. CORT is the primary glucocorticoid, or “stress hormone”, in birds, reptiles, amphibians, and some rodents (Romero 2004). It is released in response to an environmental stressor and is associated with an appropriate behavioral response (Romero 2004), such as the “fight or flight” response to predator threat (Sapolsky *et al.* 2000). While CORT is vital to these responses, increased levels of CORT can have seemingly negative effects like decreased growth rates and immune function (juvenile alligators and birds: Morici *et al.* 1997; Hayward & Wingfield 2003; Saino *et al.* 2002), and high levels of prenatal CORT have been connected to low birth weight and small body size (Sheriff & Love 2013). T is a steroid hormone that drives male and female sexual development, ornamentation, aggression, activity level, behavior, and growth (Balthazart *et al.* 1983; Cox *et al.* 2009). While it is often thought of as a growth stimulant, increased prenatal exposure to T can cause decreased immune function and growth, and high mortality (lizards: Uller & Olsson 2013; Cox *et al.* 2005 a).

Both CORT and T are part of the hypothalamus-pituitary-adrenal (HPA) axis, a central control system that connects the central nervous system to the endocrine system (Kudielka & Kirschbaum 2005). As a result, stress-induced increases in CORT levels often simultaneously decrease T hormone secretion (Moore *et al.* 1991).

CORT concentrations are often higher in females than in males after HPA axis stimulation (Kudielka & Kirschbaum 2005), and exposure to these hormones during development can affect offspring. This can happen as a result of direct exposure of the embryo to these hormones, because mothers with high levels of CORT or T deposit higher concentrations of these

hormones into their eggs (Hayward & Wingfield 2004; Andersson *et al.* 2004). Alternatively, exposure of a mother to high concentrations of CORT or T during pregnancy could indirectly affect the offspring by altering maternal behavior (such as thermoregulation) or physiology, which can affect offspring development (Shine & Harlow 1993; Wapstra *et al.* 2009), or by altering maternal allocation of nutrients or other materials to her eggs (Shine & Harlow 1996; Sheriff & Love 2013).

Prenatal exposure to CORT and T can have striking effects on offspring growth and development. Maternal effects of CORT include feminization of male offspring (Hayward & Wingfield 2004; Ward 1972), decreased fertility and fecundity of female offspring (Hayward & Wingfield 2004; Herrenkohl 1979), increased responsiveness of the offspring's HPA axis (Hayward & Wingfield 2004; Henry *et al.* 1994; Takahashi *et al.* 1992), and suppressed growth and immune function (alligators and birds, Morici *et al.* 1997; Hayward & Wingfield 2004). While these effects of CORT exposure are typically viewed as detrimental, juveniles pre-exposed to high levels of CORT through maternal allocation may in fact be better adapted to survive in a stressful environment (Sheriff & Love 2013). For example, experimentally increasing levels of CORT in pregnant female side-blotched lizards (*Uta stansburiana*) resulted in males that were smaller but had increased survival (Sinervo & DeNardo 1996), and larger females, which may increase competitive ability (Comendant *et al.* 2003).

Like CORT, increased levels of prenatal T can have profound effects on offspring development. Increased T during pregnancy can increase activity, suppress immune function, increase ectoparasite load and mortality in offspring, and alter offspring growth rates (lizards: Uller & Olsson 2013; Cox *et al.* 2005 a; Cox & John-Alder 2005). Higher levels of T can also skew sex ratios towards sons (Veiga *et al.* 2004). Male juveniles exposed to higher levels of T during development may have higher fitness since testosterone plays a role in the development of

sexually dimorphic ornaments, such as colored badges (Cox *et al.* 2005 b), which are important in social interactions and mate attraction (Cooper & Burns 1987; Swierk *et al.* 2012).

We tested for effects of CORT and T on offspring hatching success, size at hatching, sex ratio, growth, and survival. We used the oviparous Eastern Fence Lizard, *Sceloporus undulatus*, because it allowed us to separate the direct effects of the hormones (by applying hormones to eggs) from the possible maternal effects through hormone-related changes in behavior and allocation (by exposing gravid females to exogenous hormones).

Based on the literature, we predicted that exposure to CORT and T in both the dosed mothers and dosed eggs would decrease the hatching success, size at hatching, growth rates, and survival of offspring. We also hypothesized that females dosed with T would have male-biased clutches.

Methods and Materials

Animal Collection and Husbandry

We hand-captured gravid female *Sceloporus undulatus* from 7 populations (Holly Springs National Forest (HS), Marshall County, Mississippi; Fall Creek Falls State Park (FCF), Van Buren County, Tennessee; Blakely State Park (BSP), Baldwin County, Alabama; St. Francis National Forest (SF), Lee County, Arkansas; Edgar Evins State Park (EE), DeKalb County, Tennessee; Conecuh National Forest (SD), Covington County, Alabama; Huntington County (HCH), Pennsylvania). We toe-clipped each lizard for unique identification using a pair of curved-tip dissection scissors. We transported all captured lizards to Mueller Laboratory at the Pennsylvania State University, where we housed them in plastic terraria (56 x 40 x 30 cm L x W x H) filled with 10 mm of moist sand and kept in a room with a temperature of $29^{\circ}\text{C} \pm 1^{\circ}\text{C}$ and a

light cycle of 12 light:12 dark (on at 0700 hours, off at 1900 hours). We suspended a 60-W light bulb 50 mm above the terrarium to provide a temperature gradient for thermoregulation from 0900 hours to 1500 hours. We provided food (crickets dusted with vitamins and minerals) every other day and we provided water *ad libitum*.

Egg Collection and Incubation

Each terrarium housed three to four gravid females and we checked it at least twice daily (at 0900 hours and 1600 hours) for freshly laid eggs. We were able to assign maternity to clutches through regular egg checks and palpation of the females. We incubated the eggs in plastic tubs (11 x 11 x 7.5 cm L x W x H) filled with moist vermiculite (-200 kpa), covered with plastic wrap, and sealed with a rubber band. We placed the tubs in an incubator ($29^{\circ}\text{C} \pm 1^{\circ}\text{C}$) until hatching (approximately 45 days). We rotated the tubs within the incubator every other day to avoid any within-incubator effects of position.

Hormone Application

We created solutions of CORT and T for dosing the gravid females (4mg hormone/1 mL oil vehicle [12 μg dose]; Meylan & Clobert 2005) and the eggs (1 mg hormone/1 mL oil vehicle [5 μg dose]; Warner *et al.* 2009). To do this, we dissolved 500 mg of corticosterone (CORT; $\geq 92\%$, Sigma C2505) in 75 mL of 70% ethanol. We made a 4 mg CORT/1 mL oil stock solution (30 mL of this dissolved CORT solution added to 50 mL of sesame oil and left under a fume hood overnight to allow the ethanol to evaporate), which we used to dose the gravid females. We removed 25 mL of this solution and added it to 75 mL of sesame oil for a final concentration of 1 mg CORT/1 mL oil for dosing the eggs. Similarly, we dissolved 1 g of testosterone (T; $\geq 98\%$,

Sigma T1500) in 150 mL of 70% ethanol and followed the same steps to create 4mg/mL and 1mg/mL concentrations of T for applying to gravid females and eggs, respectively. We created a control oil solution by adding 30 mL of ethanol to 50 mL of sesame oil and allowing it to evaporate overnight.

Female Dosing

We used seven gravid female *Sceloporus undulatus* captured from 4 populations (Standing Stone State Park (SS), Overton County, Tennessee; HS; BSP; FCF). We determined the level of gravidity by abdominal palpation, and scored it on a 1 to 4 scale (1: nonyolked follicles; 2: developing yolked follicles; 3: large preovulatory follicles; 4: oviducal eggs; McKinney 1982). We divided the females into treatment groups (n= 2 control, 3 CORT, 2 T) so that each group had an equal number of females at each stage of pregnancy. We housed each female with two to three other females and one male, all from the same site but different treatments, in plastic terraria (56 x 40 x 30 cm L x W x H). In addition to their unique toe-clip, we placed a spot of nail polish (color coded for treatment) at the base of their tails for easy identification.

We applied 3 μ L of the appropriate solution (4 mg hormone/mL oil; 12 μ g of CORT or T) to the middle of each female's back five days per week using a micropipette. We captured the lizards and the oil was applied to their backs in under one minute at 1530 hours (after their supplemental lights had been turned off) to reduce the stress of capture and handling. We applied the treatment until each female laid her eggs (2 to 36 doses, depending on starting gravidity and time until laying). We collected and incubated the eggs (one clutch per incubation tub) from these lizards until hatching.

Egg Dosing

We removed 6 eggs from 10 different clutches immediately after they were laid by unmanipulated females from 6 populations (SF; SD; HS; EE; FCF; HCH). We randomly designated two eggs from each clutch to receive control oil, T, or CORT (n= 20 eggs per treatment). On the day the eggs were laid, we applied a 5 μ L drop of the treatment-appropriate hormone (or oil) solution (1 mg hormone/mL oil) to each egg, so that each embryo was exposed once, at laying, to 5 μ g of CORT, T, or control oil. We used this design to test for the effect of increased levels of CORT and T, as compared to controls, within the yolk at laying. We separated the eggs by clutch and by treatment, so that there were only two eggs per container (6 x 6 x 7.5 cm L x W x H) and we incubated them until hatching (see above).

Raising Hatchlings

After 40 days of incubation, we checked the incubator twice daily (0930 hours and 1700 hours) for hatchlings. We removed hatchlings from the incubator and toe-clipped them for unique identification using a pair of curved-tip dissection scissors. We measured their snout-vent length (SVL) using a ruler (\pm 1 mm) and their mass using a balance (\pm 0.01 g). Lastly, we determined the sex of each hatchling by the presence (male) or absence (female) of enlarged post-anal scales. We housed the hatchlings in plastic terraria (42 x 28 x 27 cm L x W x H) in groups of one to seven lizards, separated by the site of their mother's origin. We fed the hatchlings crickets (dusted in vitamins and minerals) daily, and we provided water *ad libitum*.

We measured the SVL and mass of each hatchling monthly for 4-months to determine growth rates, and recorded any mortality that occurred during this time.

Statistical Analysis

We used JMP (version 7, SAS Institute Inc., Cary, NC, USA) to analyze our resulting data. We compared hatching success between treatments using a Chi-Squared test. We assessed size at hatching using an Analysis of Variance (ANOVA), with sex, site of origin, and site nested within mother ID (mother ID [site]) included as covariates. We compared differences in sex ratios between treatments using a Chi-Squared test, with site of origin and mother ID [site] included as covariates. We compared changes in mass and SVL over 4-months between treatments using a Repeated Measures ANCOVA, with sex, site of origin, and maternal ID included as covariates. Lastly, we compared survival between treatments using a Parametric Survival Analysis, with sex and site of origin included as covariates.

Results

Hatching Success

Hatching success was significantly higher for offspring of CORT-dosed mothers (72.2%) than for T-dosed mothers (30%) and controls (13.3%) (chi-squared test $\chi^2_2=19.5$, $p<0.0001$). Hatching success was higher for CORT (75%) and T-dosed (80%) eggs than those of the control group (50%), achieving marginal statistical significance (chi-squared test $\chi^2_2=5.91$, $p=0.052$).

Size at Hatching

Treatment significantly affected size at hatching for offspring of dosed mothers (ANCOVA. Mass: treatment $F_{2,27}=25.33$, $p<0.0001$; SVL: treatment $F_{2,27}=19.05$, $p<0.0001$; Figure 1). Hatchlings from CORT-dosed mothers were larger and hatchlings from T-dosed

mothers were smaller, than hatchlings from control mothers. Female hatchlings were longer ($F_{1,27}=5.87$, $p=0.02$), but not heavier ($F_{1,27}=2.03$, $p=0.17$) than male hatchlings. Hatchlings born to mothers from northern sites (HCH) were larger than those born to mothers from southern sites (SS, HS, BSP, FCF; mass $F_{5,27}=61.33$, $p<0.0001$; SVL $F_{2,27}=26.09$, $p<0.001$).

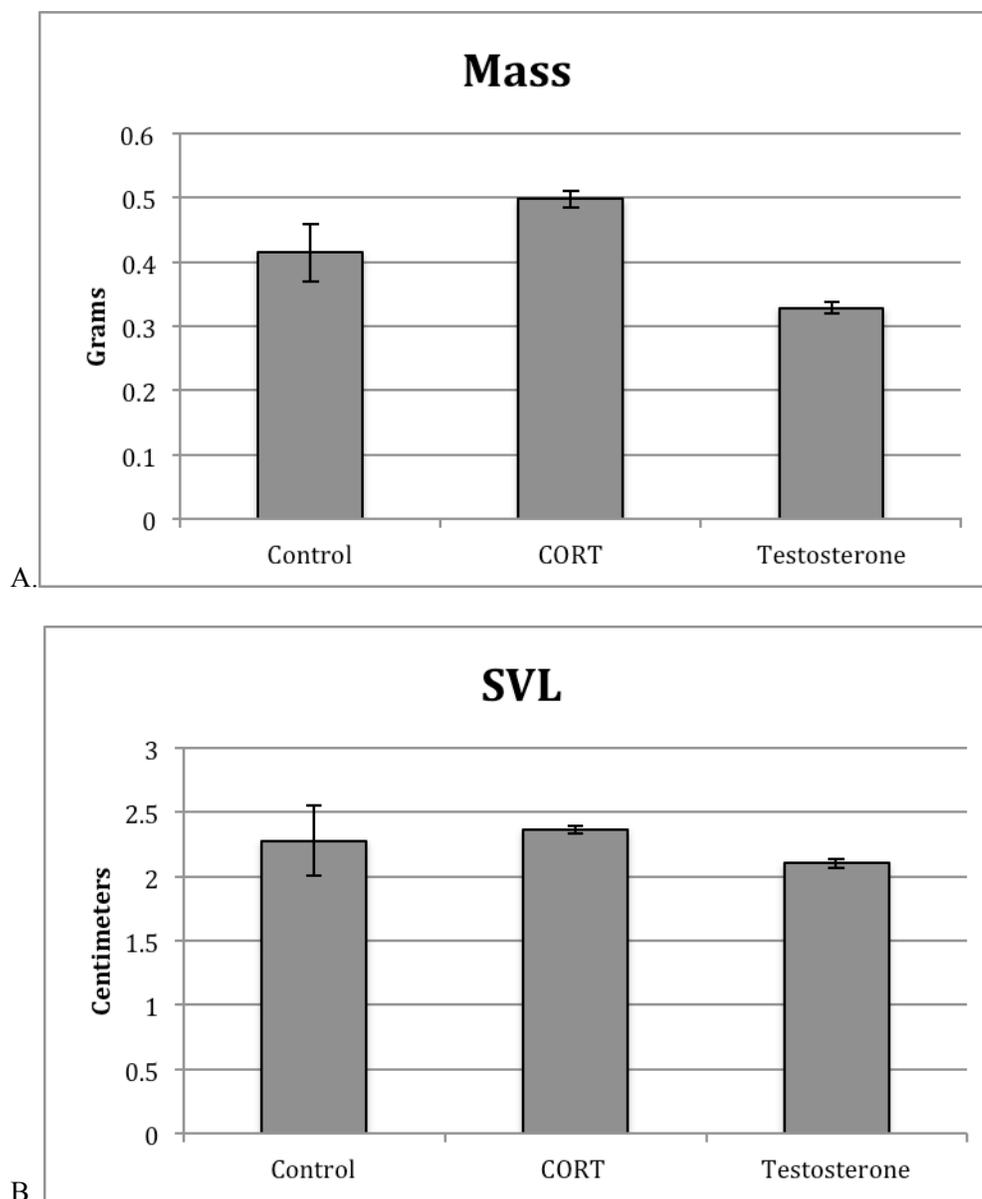
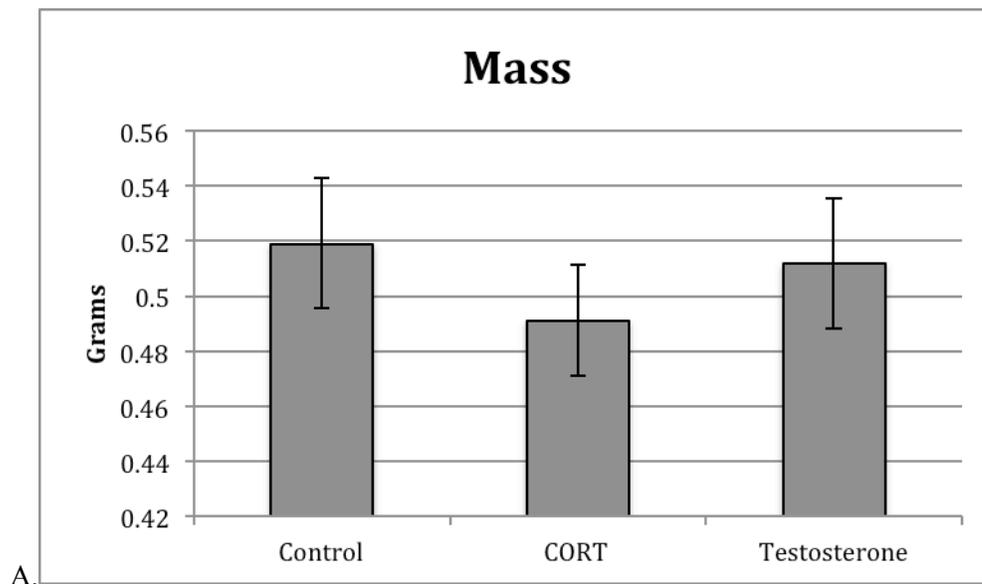


Figure 1. Size at hatching (A: mass (g) and B: SVL (cm)) of offspring from mothers dosed with 12 ug of corticosterone (CORT) or testosterone (T), or an oil vehicle control during pregnancy.

Treatment did not affect size at hatching for hatchlings from dosed eggs (ANOVA. Mass: treatment $F_{2,32}=0.60$, $p=0.55$; sex $F_{1,1}<0.001$, $p=0.99$; mother ID [site] $F_{4,32}=4.83$, $p<0.01$; SVL: treatment $F_{2,32}=0.01$, $p=0.99$; sex $F_{1,32}=1.39$, $p=0.25$; mother ID [site] $F_{4,32}=3.55$, $p=0.02$; Figure 2). However, hatchlings born to mothers from northern sites (HCH) were larger (SVL: $F_{5,32}=24.42$, $p<0.001$), but not heavier (Mass: $F_{5,32}=5.92$, $p<0.001$) than those born to mothers from southern sites (SF, SD, HS, EE, FCF, HCH).



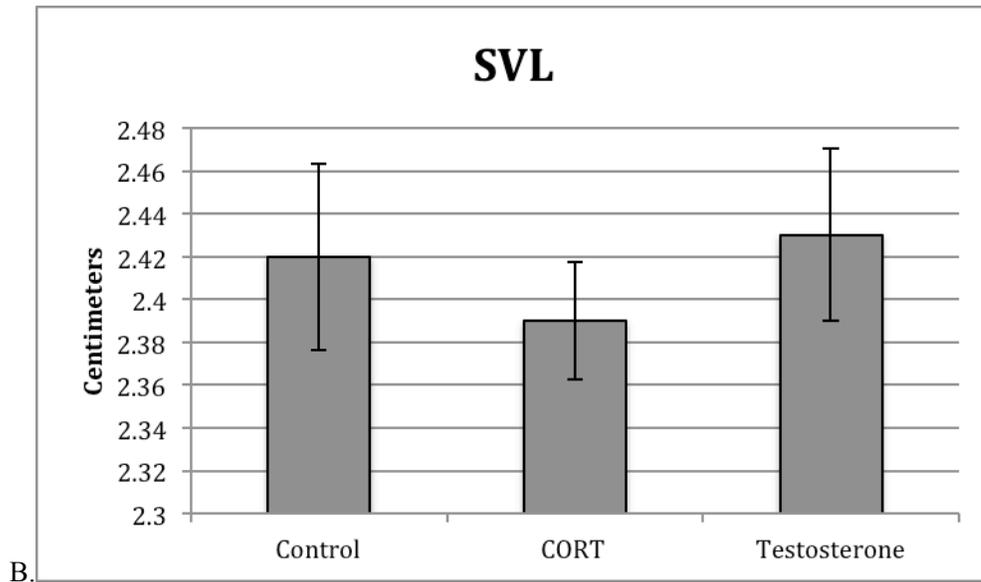


Figure 2. Size at hatching (A: mass (g) and B: SVL (cm)) of offspring from eggs dosed with 5 ug of corticosterone (CORT) or testosterone (T), or an oil vehicle control at laying.

Sex Ratios

The sex ratio of clutches appeared to be more male-skewed in the T-dosed mother treatment (control 1:1, CORT 2:1, T 4:1 male:female), but this was not statistically significant, possibly due to small sample sizes ($n=7$ clutches total; chi-squared test, treatment $\chi^2_4=2.26$, $p=0.69$; site $\chi^2_4=3.28$, $p=0.51$; mother ID [site] $\chi^2_4=2.48$, $p=0.65$). The sex ratio was not affected by treatment in the CORT-dosed eggs (control 1:1, CORT 1:2, T 1:1 male:female; $n=10$ clutches per treatment; chi-squared test, treatment $\chi^2_2=1.68$, $p=0.43$; site $\chi^2_{10}=3.85$, $p=0.95$; mother ID [site] $\chi^2_8=7.61$, $p=0.47$).

Growth

We did not measure growth of the hatchlings from dosed mothers due to high mortality in control and T offspring, leading to small sample sizes over time. There was no significant

difference in growth rates over 4-months of hatchlings from eggs dosed with control oil, CORT, and testosterone (repeated-measures ANOVA. Mass: treatment $F_{8,22} = 0.67$, $p = 0.71$; sex $F_{4,11} = 0.81$, $p=0.54$; mother ID $F_{16,34.2}=1.04$, $p=0.45$; site $F_{20,37.4}=1.30$, $p=0.24$; SVL: treatment $F_{8,22}=0.46$, $p=0.87$; sex $F_{4,11}=0.82$, $p=0.54$; mother ID $F_{16,34.2}=0.76$, $p=0.71$; site $F_{20,37.4}=1.41$, $p=0.18$; Figure 3).

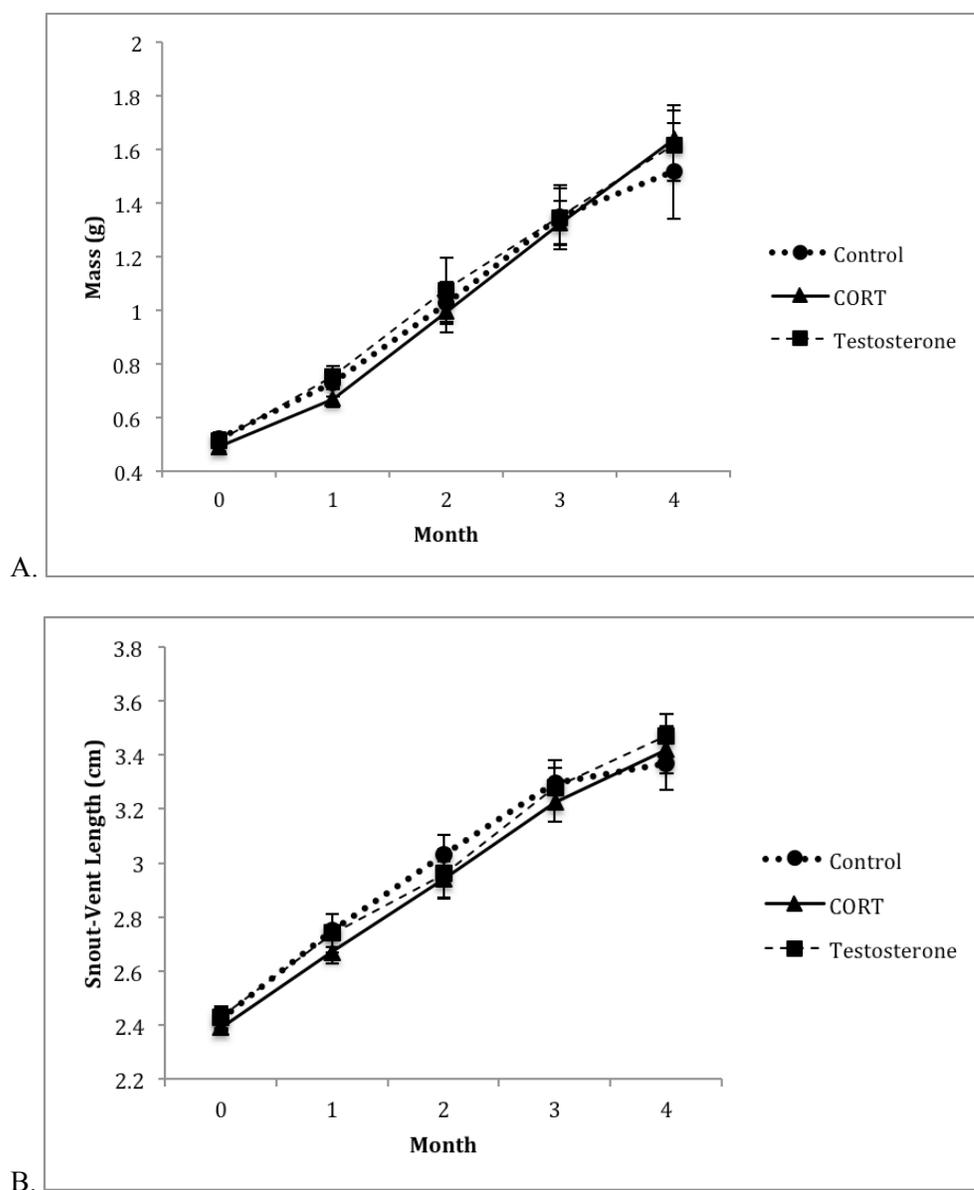


Figure 3. Growth (A: mass (g) and B: SVL (cm)) over 4 months of juveniles from eggs dosed with 5 ug of CORT (triangle symbols, solid line) or T (square symbols, dashed line), or an oil vehicle control (circle symbols, dotted line) at laying.

Survival of Hatchlings

Treatment group significantly affected hatchling survival over 4-months for hatchlings of dosed-mothers (Figure 4). Hatchlings from CORT-dosed mothers had higher survival, and those from T-dosed mothers had lower survival, than hatchlings from control mothers (Parametric Survival Analysis, treatment $\chi^2_2=7.92$, $p=0.02$; sex $\chi^2_1=5.02$, $p=0.03$; site $\chi^2_2=12.67$, $p<0.01$; mass at hatching $\chi^2_1=0.45$, $p=0.50$).

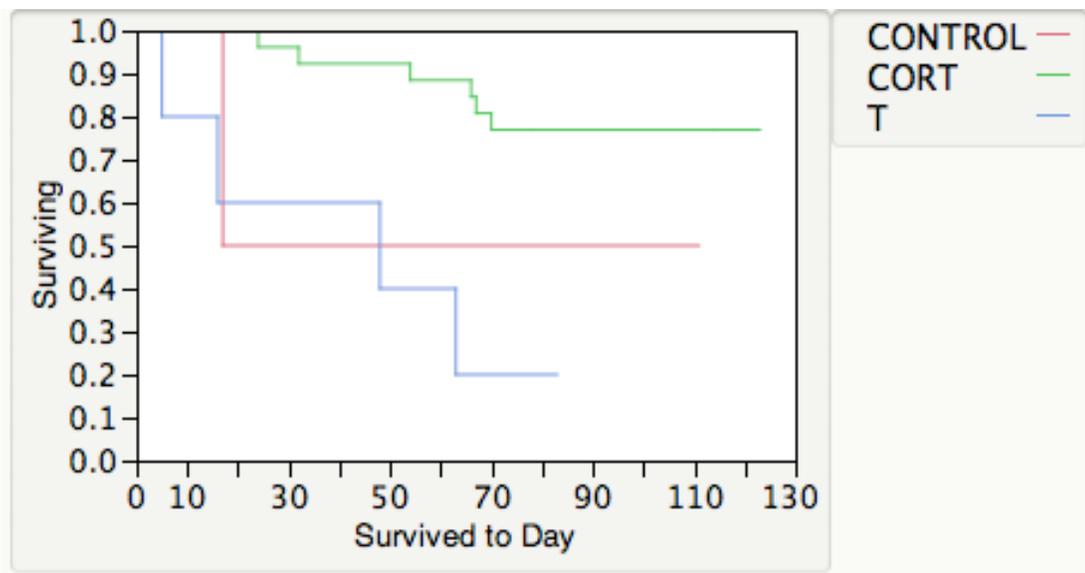


Figure 4. Changes in survival over 4-months post hatching of offspring from mothers dosed with 12 ug corticosterone (CORT) or testosterone (T), or an oil vehicle control during pregnancy.

Treatment significantly affected survival of hatchlings of dosed-eggs (Figure 5). Hatchlings from CORT-dosed eggs had higher survival, and those from T-dosed eggs had lower survival, than did hatchlings from eggs exposed to control oil (Parametric Survival Analysis $\chi^2_2=7.42$, $p=0.02$; sex $\chi^2_1=0.03$, $p=0.87$; site $\chi^2_5=3.04$, $p=0.69$). Heavier hatchlings had higher survival (mass $\chi^2_1=4.32$, $p=0.04$), and there were significant clutch-effects on survival (mother ID $\chi^2_4=10.04$, $p=0.04$).

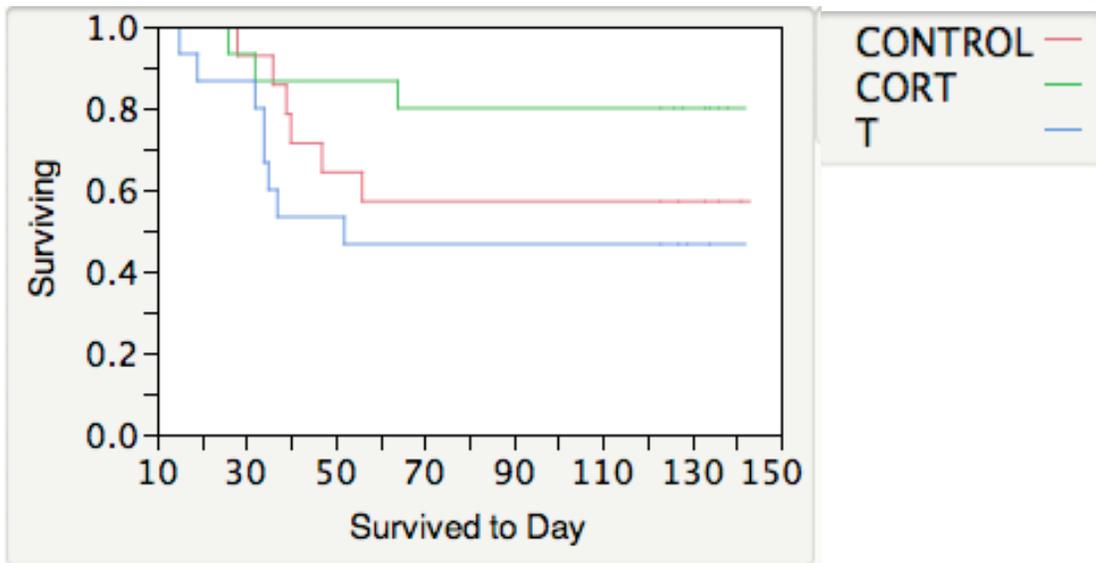


Figure 5. Changes in survival over 4-months post hatching of offspring from eggs dosed with 5 ug of corticosterone (CORT) or testosterone (T), or an oil vehicle control at laying.

Discussion

We found effects of CORT and T on fitness-relevant traits of offspring. Some of these effects can be attributed directly to the hormones (dosed eggs) and others are likely driven by hormone-induced changes in maternal behavior or physiology (dosed mothers). Offspring from the CORT group generally had higher hatching success and post-hatching survival, and were larger at hatching than did offspring from the control and T treatment groups. Overall, the offspring in the T treatment groups experienced lower hatching success and post-hatching survival, and were smaller at hatching than did the control and CORT treatment groups.

Corticosterone

Mothers dosed with CORT during pregnancy produced offspring with greater hatching success and that were larger at hatching. This effect was not observed in offspring from CORT-dosed eggs, suggesting that these changes were mediated by effects of CORT on the gravid females, rather than being a direct affect of CORT on the developing embryos. Mothers with increased levels of CORT may allocate extra nutrients to their offspring (Sheriff & Love 2013) to compensate for a stressful environment, causing offspring to hatch at a larger size (Sinervo & DeNardo 1996). Larger hatching size may be a mechanism to increase offspring survival in a competitive environment (Sheriff & Love 2013; Comendant *et al.* 2003). Alternatively, these differences in body size could be due to hormone-induced changes in maternal behavior such as feeding or thermoregulation, both of which are affected by CORT (CORT suppresses appetite in fish, Barton *et al.* 1987, and increases heat-seeking behavior in lizards, Preest & Cree 2008). Changes in thermoregulatory behavior would be more likely to explain our results, as higher incubation temperatures increase offspring size at hatching (Andrews *et al.* 2000), but suppressed appetite should reduce offspring size (Shine & Downes 1999). It is possible that the differences between CORT-treatments could also be due to the different developmental stages of the embryos (the embryos of the dosed mothers were at an earlier stage than those of the eggs dosed post-laying), or the different doses of CORT: mothers received 12 μg per day, while the dosed eggs received 5 μg one time immediately after they were laid. We gave mothers higher doses as not all of the hormones will be deposited into the eggs (Hayward & Wingfield 2004). Also, exogenous CORT treatments in birds only elevate yolk CORT levels for a few days (Hayward & Wingfield 2004), so we continually applied the treatment to the mothers to ensure that the effects were maintained until the eggs were laid. Future studies testing how much of the applied hormone

crosses the egg membranes and enters the egg for both the dosed eggs and dosed mothers would be informative.

Both the offspring of the dosed mothers and dosed eggs showed increased hatching success and subsequent survival over 4-months compared to the control group, and this was likely due to a direct effect of CORT. Elevated CORT levels in juveniles can significantly increase mortality (Morici *et al.* 1997); however, it is possible that CORT during development prepares offspring to cope with a high stress environment (Sheriff & Love 2013). One could argue that the conditions under which we raised these offspring were high stress – being held in captivity in high densities with competition for food, shelter, and thermoregulatory opportunities – and so the increased survival of the offspring that were exposed to high levels of CORT during development could suggest that they were better adapted to these stressful conditions. In a study conducted using the common lizard (*Lacerta vivipara*), males given excess CORT had significantly increased survival rates compared to controls and to dosed females (Cote *et al.* 2005). They reasoned that this could be caused by overall better body condition due to increased appetite (Cote *et al.* 2005).

There was no significant difference in the sex ratios of the offspring from either the CORT-dosed eggs or mothers. The Trivers-Willard hypothesis suggests that “poor quality” mothers should invest more reproductive energy in producing females rather than males (Trivers & Willard 1973), and studies show that mothers with high levels of glucocorticoids have female-biased clutches (European Starlings, Love & Williams 2008; Japanese Quail, Pike & Petrie 2006). However, contrary to these results, we found no evidence that CORT directly or indirectly affects sex ratios.

Testosterone

Mothers dosed with T produced offspring that had lower hatching success and hatched at a smaller size than those from the control treatment. Preliminary data also suggest that growth rates of offspring from T-dosed mothers are lower (Norjen, unpubl data). These results are not surprising since eggs of many oviparous vertebrates can contain significant amounts of maternally derived steroids, including T (Andersson *et al.* 2004), and T inhibits growth in juvenile *Sceloporus undulatus* (Cox *et al.* 2005a). However, our results contradict a study on another lizard *Ctenophorus fordi*, which found that increased yolk T in offspring of dosed mothers had no significant effect on hatching success or size (mass, SVL, or body condition) at hatching (Uller *et al.* 2007).

Offspring from T-dosed eggs did not show these same effects in our study. Therefore, the effects of T on hatching success and hatching size (and growth rate) were likely the result of effects of T on maternal behavior or allocation of nutrients rather than a direct effect of T on the developing offspring. It is possible that mothers that received exogenous T allocated excess T to their offspring in levels higher than those that we provided to the T-dosed eggs, leading to reduced hatching success, hatching size, and growth rates. Alternatively, the mothers themselves could have had increased activity levels without increased intake, decreasing the amount of energy and nutrients available for them to allocate to reproduction (Cox *et al.* 2005a).

Testosterone decreased the survival rate of offspring from both the dosed mothers and dosed eggs, suggesting a direct affect of T on survival. A study on American Kestrels similarly found that increased yolk androgens decreased survival rate (Sockman & Schwabl 2000).

Similar to the CORT group, there was no effect of T on the sex ratios for offspring of either the dosed mothers or the dosed eggs. Although high maternal levels of T can result in male-biased clutches (Spotless Starlings, Viega *et al.* 2004), our results contradict the “sexy son

hypothesis” that masculinized females with elevated T should have more male offspring (Fisher 1930). However, a study on an ecologically-similar oviparous lizard, *Amphibolurus muricatus*, also found no direct effect of maternal T on the sex ratios of the resulting clutches (Warner *et al.* 2007).

Conclusion

Our findings suggest that maternal levels of CORT and T can affect fitness-relevant traits of resulting offspring. These effects can be due to direct exposure of the embryos to the hormones, or may be manifested via maternal effects likely due to hormonally-driven changes in maternal behavior or allocation to the eggs. Despite CORT being largely thought to have “negative” effects on offspring, we found that CORT increased hatching success, size at hatching, and subsequent survival. This supports the emerging theory that high levels of maternal stress hormones can produce offspring that are better adapted for stressful environments. High levels of T had the opposite effect of CORT, reducing hatching size, growth, and survival of offspring. This has interesting implications for understanding the costs of high T levels in females. Future studies addressing the consequences of these effects of CORT and T on offspring in different natural contexts would shed important light on the potential adaptive significance of these striking maternal effects.

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ACADEMIC VITA

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Education

Bachelor of Science in Veterinary and Biomedical Sciences

Schreyer Honors College and College of Agricultural Sciences
The Pennsylvania State University, University Park, PA
Expected Graduation: May 2014

Institute for Sustainable International Studies

Belize Field School, San Ignacio, Belize; Summer 2012

- Participated in the field with a large animal veterinarian for 75 hours performing castrations, palpations, and physical examinations
- Assisted a wildlife veterinarian for 75 hours at the wildlife clinic, the Belize Zoo, the Belize Bird Rescue, and the Iguana Breeding Program

Awards

Eberly College of Science Undergraduate Research Grant: \$333; Fall 2012

Activities

Pre-Vet Club

THON Co-Chair; Fall 2011 – Present

- Lead a committee of 25 members and a club of 130 members in fundraising for the Penn State IFC/Panhellenic Dance Marathon (THON), grossing in \$26,000 over the past two years

President; Fall 2013-Spring 2014

Member: Schreyer Honors College Student Council; Fall 2010 – Present

Member: Habitat for Humanity; Fall 2011 – Present

Penn State's Dance Marathon Morale Committee; Fall 2013-Spring 2014

Experience

Veterinary Assistant

Paradise Animal Hospital, Catonsville, MD; Summer 2011 – Present

- Assisted 7 doctors and 20 technicians in daily activities at a small animal hospital, including caring for the animals and educating the owners

Research Assistant: Langkilde Lab

The Pennsylvania State University; Fall 2012 – Present

- Care for 80 wood frogs, 500 tadpoles, and 150 eastern fence lizards
- Video analysis wood frog behavior and morphology to determine if male-male competition affects quality of resulting offspring
- Quantify the effects of testosterone on coloration and sex ratio of offspring in eastern fence lizards

Research Assistant: Animal Diagnostics Lab

The Pennsylvania State University; Fall 2011 – Spring 2012

- Performed PCR and gel electrophoresis to examine antibiotic resistance in *E. coli* as it pertains to poultry and livestock

Student Exhibit Guide

National Aquarium in Baltimore, Baltimore, MD; Summer 2009

- Interacted with visitors in the various exhibits to answer questions about marine ecosystems and the animals in the aquarium