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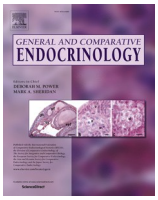

Editorial

Resiliency of the comparative endocrinology community in the face of COVID-19

1. The problem

The COVID-19 pandemic upended all aspects of academia — labs were shuttered, research was halted, a switch to online pedagogy was in full swing, and academic researchers scrambled to create online content delivery in class and to adjust to lockdowns and work-from-home protocols. We all were impacted by this (ongoing) global crisis and chronic stressor. However, certain groups in academia were disproportionately impacted. Particularly, women, those individuals with minoritized racial or ethnic identities, disabled individuals, those with minoritized sexual or gender identity and/or intersecting identities, and caregivers have faced a tremendous and disproportionate burden (Malisch et al., 2020; Myers et al., 2020; Pineault and Rouzer, 2020; United Nations, 2020; Davis et al., 2022; National Academies of Sciences, Engineering, and Medicine, 2021; Staniscuaski et al., 2021; Wagner et al., 2022). Additionally, this amplified burden is particularly notable for academic mothers, especially those who have intersecting identities, are in non-tenure-track or contingent positions, or are early career investigators (Arnold and Woolston, 2020; Cardel et al., 2020a; CohenMiller, 2020; Inouye et al., 2020; Krukowski et al., 2021; Fulweiler et al., 2021; López-Vergès et al., 2021; Schneider et al., 2021; Lokhtina et al., 2022; Staniscuaski et al., 2023). Minoritized groups in academia experienced bias and discrimination before COVID-19 (Asplund and Welle, 2018; Cech and Blair-Loy, 2019; Asai, 2020; Cardel et al., 2020b; Malisch et al., 2020; Cech and Waidzunas, 2021; Maas et al., 2021; Stevens et al., 2021; Valenzuela-Toro and Viglino, 2021; Yerbury and Yerbury, 2021; Berhe et al., 2022; Fox Tree and Vaid, 2021; Kozlowski et al., 2022; Mays et al., 2023) and the disparities have only been further widened by the pandemic.

How we remedy these growing disparities is not yet clear, but multiple authors have suggested solutions. A particularly helpful paper with concrete options suggested the idea of increasing publishing opportunities for those who were disproportionately impacted, particularly women and parents of young children (Fulweiler et al., 2021; also see Cardel et al., 2020a). We took this suggestion, and this Special Issue of *General and Comparative Endocrinology* was born. For this Special Issue we invited manuscripts that highlight the resiliency of our endocrinology research community. Specifically, we sought submissions from individuals who have minoritized identities, and particularly those who hold intersecting identities (e.g., Black, indigenous, people of color, disabled, contingent appointment, early career, located in the global south, countries especially impacted by the pandemic, caregivers, parent of a (young) child/children, sole parent, etc.). We see this Special Issue as an opportunity to 1) contribute to equity and 2) to document how the pandemic impacts our *GCE* community.

We are accustomed to elucidating hormonal and behavioral responses to acute and chronic challenges and to investigating the regulation and control of reproduction across a wide array of study organisms in the field of comparative endocrinology. Here, we aim to flip that lens and instead focus on the response not of the organism of study, but of the individuals who are designing studies, collecting and analyzing data, and authoring papers. Manuscripts on any topic relevant to *General and Comparative Endocrinology (GCE)* were welcome, but we particularly encouraged submissions addressing organismal response to acute or chronic challenges; perseverance and resilience; and/or care giving. For submissions, we asked that the first or last author hold a minoritized or disproportionately impacted identity (see above) and/or be a caregiver, and that manuscripts were in some stage of preparation (e.g., data collection, analysis, writing) during the (ongoing) pandemic.

2. The special issue

The papers included in this Special Issue, *Resiliency of the comparative endocrinology community in the face of COVID-19,* highlight important factors that influence the relationships among stressors, hormonal responses, reproduction, and behavior. They contain data on when and under what conditions hormones, particularly glucocorticoids, influence various fitness-related outcomes. The breadth of science covered is vast and many exciting new findings are reported. Our issue contains 17 contributed manuscripts with a total of 59 different authors, ranging from undergraduate students to full professors. Sixteen manuscripts detail results of empirical studies in endocrinology; one manuscript focuses on the scientists conducting those studies and pandemic productivity. A total of 25 of our 59 special issue authors completed a voluntary demographic survey. Of those 25, 88% did not identify as men; 24% identified as LGBTQ+; 64% identified as LGBTQ+ allies; 12% were pregnant during the pandemic; 64% were caregivers to children and 18.75% of those individuals also cared for elderly adults; 44% of respondents identified as non-white; 72% of authors had COVID-19 infections during the pandemic, 11% of those with COVID-19 infections developed Long COVID; and 20% lost someone close to them due to COVID-19. The science was assessed by a total of 33 reviewers, out of which 21 (63%) were women. We asked a total of 122 people to review, 48 men and 73 women, and our reviewer invitation acceptance response rate was 29% for women and 23% for men. We extend our gratitude to all our reviewers for their critical role in making this special issue possible, especially given the pandemic and the challenges it has posed. Their time and expertise were invaluable in this process.

Physiological responses to stressors, particularly glucocorticoids, were a major theme of the papers in this issue. We live in a world with a

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rapidly changing climate and therefore four author groups incorporated aspects of temperature and urbanization in their studies. Guzman et al. (2023) investigated how elevated water temperature affects the fitness, physiology, cognition, and behavior in an urban adapted species of live-bearing Western mosquitofish, *Gambusia affinis*. Rearing mosquitofish at warmer temperatures did not affect cortisol secretion or fecundity. However, females reared at warmer temperatures were more likely to drop underdeveloped offspring, suggesting a metabolic tradeoff of some type. Females were also less likely to exit the start chamber on day 7 of exposure to elevated water temperatures. Yet, female fecundity, cognition, and behavior recovered after 34 d indicating that this tolerant species can acclimate and ultimately physiologically cope with warmer temperatures. Heppner et al. (2023) examined the effects of urbanization on maternal hormone transfer in house wrens (*Troglodytes aedon*). They measured egg concentrations of corticosterone and testosterone across the laying sequence in birds from one urban and one rural site. They report that egg testosterone concentrations were not different between birds from urban and rural sites. However, across all life stages (e.g., egg, nestling, and adult female), corticosterone concentrations were higher at the urban site. Corticosterone levels in nestlings from the urban site, but not the rural site, correlated with fine-scale urban density scores. Their study is one of the first to show that egg hormone concentrations differ in an urban environment with differences persisting in chick development and adult life stages. Virgin et al. (2023) examined endocrine traits underlying immune tradeoffs and differences between urban and rural lizard egg yolk physiology in side-blotched lizards (*Uta stansburiana*). Urban females had higher mite loads than rural females, however mite burden was related to immune status in rural eggs, but not urban eggs. While yolk immune status differed between urban and rural sites, egg mass and egg viability were strong predictors of yolk physiology and may imply that tradeoffs exist between maintenance and reproduction. Urban lizards laid a higher proportion of unfertilized eggs, which differed in egg yolk immune status, corticosterone, and triglycerides in comparison to fertilized eggs. Because rural lizards laid only viable eggs during this study, these results suggest that reduced egg viability is a potential cost of living in an urban environment. Guindre-Parker et al. (2022) explored the behavioral and endocrine coping styles that arise in nestlings from urban and rural sites in European starlings (*Sturnus vulgaris*), an urban-adapted species. They found no differences in various behavioral and physiological measures between nestlings raised in urban versus rural sites. Urban nestlings, however, developed a stronger corticosterone stress response than rural birds before fledging the nest. Their findings support prior work suggesting that behavioral and endocrine coping mechanisms act independently of one another. Importantly, their findings indicate that endocrine changes associated with urbanization develop earlier in life, and in fact may precede behavioral adaptations.

The role that hormones, particularly corticosteroids, play in life-history and seasonal tradeoffs was the topic for a few papers in this special issue. Terry et al. (2023) investigated the relationships between glucocorticoids, sex steroids, immunity, and reproduction during normal seasonality in male and female red-eared sliders (*Trachemys scripta elegans*) in the wild. Thus, the authors were able to capture natural seasonal tradeoffs between investment in innate immunity and reproduction and the role that hormones may play in this process. They report a tradeoff involving increased reproductive readiness and reduced immunocompetence in adult female turtles early in the nesting season. Interestingly, this tradeoff was associated with high circulating corticosterone and progesterone levels in female turtles. A similar tradeoff was not observed in males, as immunocompetence and baseline blood levels of corticosterone and testosterone were higher prior to fall spermatogenesis and mating. Palacios et al. (2023) studied the transgenerational effects of maternal corticosterone levels during gestation (i.e., preparturition) across early life in two life-history ecotypes (fast and slow living) of a viviparous snake, Western terrestrial garter snakes (*Thamnophis elegans)*. They report that pregnant snakes with higher natural corticosterone levels gave birth to smaller, lighter offspring under common-garden conditions. Neonate baseline corticosterone varied with preparturition maternal corticosterone levels in a sex-specific manner (positive trend for females, negative for males). Furthermore, neonates from mothers with higher corticosterone grew faster during early postnatal life, perhaps in compensation for their bad start. Maternal corticosterone effects on offspring phenotype were no longer detectable in juvenile snakes after one year. Rather, juvenile phenotypes, irrespective of their ecotype, were most influenced by rearing environment, with offspring raised under a cool regime (mimicking the habitat of the slow-living, montane meadow ecotype) having higher baseline corticosterone and slower growth than those raised under a warmer regime (mimicking the habitat of the fast-living low elevation lakeshore ecotype). Their findings support the notion that offspring phenotype might be continuously adjusted in response to environmental cues, both pre- and postnatal. Ledón-Rettig et al. (2023) explore how environmental differences early in an amphibian's life cycle can have major impacts on physiology and fitness later in life. Studying plains spadefoot toads (*Spea bombifrons*), Ledón-Rettig et al. fed one larval cohort live brine shrimp and a second cohort a diet of detritus and investigated physiological and endocrine correlates one year later, after the larvae had metamorphosed and started their terrestrial life. Fascinatingly, frogs fed live brine shrimp during the larval stage were not only larger than frogs in the cohort detritus but had elevated baseline corticosterone levels. Their study provided important information and methodological considerations for determining the lasting effects of early-life environments on later-life hormonal regulation in natural populations. (Madelaire and Gomes, 2023) examined the relationships between endocrine function, immune competence, parasite load and metabolism across seasonal cycles in Cururu toads (*Rhinella jimi*) from a semi-arid region of Brazil. Toads with the lowest resting metabolic rate had lower levels of testosterone and corticosterone. Interestingly, there was an inverse relationship between blood corticosterone and testosterone levels and the metabolic response to an adverse stimulus (phytohemagglutinin injection), suggesting that both hormones may be promoting energy conservation at high levels. Lastly, during breeding, male toads that had a higher swelling response to phytohemagglutinin and had higher plasma corticosterone, opposing the idea of a tradeoff between reproduction and other physiological traits.

Four of the papers in this issue examined endocrine associations with social behavior in birds and mammals. Gormally and Lopes (2023) examined transcriptomic changes in endocrine function in normal female quail paired with immune-challenged male quail. Female quail paired with challenged males ate more and exhibited activation of genes involved in immune response and downregulation of the dexamethasone response pathway. Guoynes and Marler, (2023) examined the effects of intranasal oxytocin on breaking of the parent-offspring bonds in *peri*-adolescent California mice (*Peromyscus californicus*). They report that intranasal oxytocin, but not arginine vasopressin, increased bonding to parents in *peri*-adolescent male but not female mice. Neither hormone affected anxiety.

Maternal separation has well-established adverse impacts on behavior and endocrine function later in life (Nylander and Roman, 2013), but less is known about the long-term impacts of fostering offspring during early life. Guan et al. (2023) examined the endocrine effects of fostering offspring in a rodent species that uses plural breeding and communal strategies, degus (*Octodon degus*). They report that fostering had long-term, age-dependent effects on the hypothalamus–pituitary–adrenal (HPA) axis response to stressors, as fostered offspring had higher stressor-induced glucocorticoid levels and weaker glucocorticoid-mediated negative feedback than non-fostered offspring of the same age. They are the first to report that cross-fostering has important endocrine consequences later in life. Ridenour et al. (2023) examined the role that a key growth-related hormone, insulin-like growth factor 1 (IGF-1), plays in the development of sibling rivalry in

an altricial bird species, eastern bluebirds (*Sialia sialis*). Experimental manipulation of brood size did not influence endogenous IGF-1 levels, but male nestlings with higher IGF-1 levels tended to be fed more frequently by parents. They conclude that bluebird nestlings do not adaptively elevate IGF-1 in response to the presence or number of siblings, although IGF-1 may influence growth during the nestling period. In birds, parental behavior can indirectly affect nest microclimate and impact nest temperature; previous studies have linked early life cooling to subsequent changes in activity of the HPA axis (Lynn et al., 2022). In this issue, Lynn et al. (2023) examined whether early life cooling affects telomere length in eastern bluebird chicks. They report that experimental early life cooling, which has been shown to reliably increase glucocorticoid levels in young nestlings, did not affect telomere shortening, although this process was affected by brood size and the rate of nestling growth. Their results suggest that under some conditions, physiological mediators of stress (such as glucocorticoids) may act as protective regulators. Thus, selection for parental brooding behaviors in a changing climate may favor behaviors that optimize physiological stress responses such that offspring survival is enhanced. In many bird species, social interactions play a role in yolk deposition into eggs. Dean et al. (2022) investigated the direct role of testosterone in influencing egg yolk deposition by applying testosterone to the combs of domestic chicken hens. They report testosterone-treated hens grew their egg yolks slower and oviposited fewer eggs than vehicle-treated hens. The egg yolk produced by testosterone-treated hens had a larger mass, but yolk diameter was unaffected.

Two papers in this special issue address the stress response and behavior in mammals. Li et al. (2023) independently examined the effects of an anticipatory and a reactive stressor on a) salivary cortisol and alpha amylase and b) visual attention to food images in humans. They hypothesized that exposure to either stressor would activate the HPA axis and sympathetic nervous system and would reduce the attention to food images as determined by eye-tracking software. Both stressors elevated salivary cortisol although only the anticipatory stressor elevated salivary alpha-amylase levels. Only the reactive stressor reduced gaze duration on food images relative to controls, and this effect was not linked to palatability or salivary cortisol levels and there were no stressor effects on saccade latency or saccade bouts. Harris et al. (2023a) tested the glucocorticoid cascade hypothesis (Sapolsky et al., 1986) in a large study centered on wild type and transgenic (APPswe/PS1dE9) mice that express human beta-amyloid protein in the brain and are a common model for Alzheimer's disease. They also assessed several behaviors during aging and measured ghrelin levels, as this hormone is related to cognitive function, stress, and anxiety. They found that baseline blood levels of corticosterone increased up to middle age, partially supporting the glucocorticoid cascade hypothesis, but post-stressor corticosterone did not change with age. Overall, sex and genotype, but not age, had the most influence on HPA activity. Transgenic mice had higher post-stressor, but not baseline, corticosterone than non-transgenic mice, and across both genotypes, females consistently had higher (baseline and post-stressor) corticosterone than males. Interestingly, despite high levels of amyloid beta accumulation, no cognitive deficits were noted and there were no statistically significant correlations among corticosterone, ghrelin, recognition memory, anxiety-like behaviors, or amyloid beta, suggesting outcomes are not strongly related on the individual level.

Lastly, in a collaborative paper, Harris and colleagues (Harris et al., 2023b) show that identity matters for how we, as academics, respond to and recovery from stressors (here the pandemic) and provide data which suggests that for the *General and Comparative Endocrinology* community, the COVID-19 pandemic was a chronic stressor. As endocrinologists, we are accustomed to assessing how stressors impacts multiple ecological and life history tradeoffs (Harris, 2020), but we rarely apply these same concepts to ourselves as authors. Harris et al. describe how the pandemic altered academic impact factors, specifically manuscript submission rates broadly and at *General and Comparative Endocrinology*, and how factors of impact on individual academics (e.g., gender, caregiver status, career stage, etc.) influenced how identity altered the pandemic-inflicted push/pause productivity tradeoff. They compiled manuscript submission and publication data for *GCE* from 2019 to 2023, inferred first- and corresponding-author gender for all 1688 submitted manuscripts, and recorded country of manuscript origin (based on corresponding author affiliation). Overall, the COVID-19 pandemic had the greatest impact on article submission, and numbers have still not reached pre-pandemic levels. In terms of location and gender, women corresponding authors from Asia and the Middle East were the most heavily impacted by COVID-19. Harris and colleagues also include examples of authors' lived experiences and how axes of their individual identities impacted their ability to navigate the pandemic. Lastly, they conclude with suggestions and recommendations for rebuilding a more equitable and inclusive endocrine community.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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