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ESTROGEN AND PROGESTERONE ROLES IN AVIAN REPRODUCTION: A SYNTHESIS OF EXISTING DATA

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ABSTRACT

Thus, the current research concentration is on the functional effects of estrogen and progesterone on avian reproduction, which will include synthesizing secondary data from the literature as secondary data analysis. Estrogen promotes oocyte formation, vitellogenesis and the expression of most secondary sexual characters while progesterone controls ovulation, egg lay and ensures integrity of the reproductive tract. These hormones in consort operate harmoniously to regulate reproductive activities and other related behaviors that are critical for reproductive endeavor including nest building and incubation. The synthesis points to variations of hormonal roles between bird species as well as differences detected between domesticated and wild birds, and also variations attributed to various ecological factors. Despite these transitions, certain gaps can still be seen: Insufficient data on hormones' interactions in many species and the assessment of environmental stressors in avian reproductive endocrinology. Here, the results have significant implications for conservation and breeding programs in general and endangered species in particular, whose reproduction can be improved through knowing how they are regulated hormonally. Although the comprehensive and innovative studies conducted in this research clearly reveal gaps in both hormonal data and ecology/behavior, further research should focus on the cooperation of these two areas in order to correct these weaknesses and improve conservation practices. This synthesis points to the discreet role of estrogen and progesterone in the avian biology and reassesses them in the context of global bird conservation and ecosystem resilience.

Keywords: *Estrogen, Progesterone, Avian Reproduction, Hormonal Regulation, Secondary Data*

INTRODUCTION

There is great emphasis placed on hormonal control of avian reproduction because the physiological and behavioral sequences necessary for breeding are controlled by hormones (Greene, Deviche & Dridi, 2022). Hormones govern vital processes like gonadal growth, ovulation, and some characteristics of sexual conduct that are provide for species reproduction (Ubuka & Bentley, 2024). Two hormones, estrogen and progesterone, play a central role in this aspect to timely regulate these reproductive events to facilitate synchronization in egg production, fertilization process and, brooding (Vu & Trudeau, 2016). This regulation is vital not only for fitness of individual bird but also to population and species management and especially in view of local stresses and strains. Estradiol and progesterone dominate bird reproductive physiology, which are known to affect major physiological functions in birds (Johnson, 2015; Ottinger & Quinn Jr, 2024). Most of estrogen is synthesized in ovarian follicles, it promotes oocytes' growth, and stimulates the process of vitellogenesis, in which yolk proteins are synthesized (Sullivan & Yilmaz, 2018). It also plays a role in development of such secondary sexual organs and sexual display which are vital in reproductive enterprise. Ovulation on the

other hand is strongly associated with progestogen and the support of the reproductive tract during laying (Yoshimura & Barua, 2017). It has an opportunity to interact with other hormones to assure that the act of oviposition is well timed and controlled. These hormones as a group are involved not only in sexual reproduction but also control behaviors needed for nest construction, sitting on eggs and upbringing of young (Mota-Rojas et al., 2023; Healy et al., 2023). Much of the current knowledge on the participation of estrogen and progesterone receptors in avian reproduction also includes their physiological and behavioral effects with the view to construct a convincing premise for this research. The synthesis carried out in this research seeks to fill gaps in the existing body of knowledge by integrating findings from other similar researches in a systematic manner so as to develop a common framework. In order to synthesize knowledge, this paper aims at contributing a solid literature base for subsequent research and application like conservation ecology and avian reproduction. Population estrogen and progesterone, being the primary reproductive hormones, engage themselves in various physiological and behavioral processes in birds indispensable during reproductive cycles (Das, Mukherjee & Banerjee, 2023). The study covers avian domesticated and wild type, to compare and contrast the hormonal control in the species. Hence, the study will advance the knowledge of avian reproduction with an emphasis on the role of hormones in regulating reproduction and consequently species perpetuity.

Methodology

The present research is a theoretical study; as such, data has been collected only from secondary sources, viz., journal articles, books, and online databases, all of which bear academic hallmarks. These articles were sourced using electronic databases such as PubMed, Web of Science and Google Scholar using relevant key words. These were “estrogen in birds”, “progesterone in avian reproduction”, “and endocrine and cytokine regulation of avian reproduction”. To generalize hormonal functions among diverse avian taxa, data from various species were included in this study. Publication types investigating experimental data only and those also including observational data were included to provide a wide view. Appropriate inclusion criteria were established for this synthesis to sample the relevant and credible data for synthesis. Selected studies met the following criteria:

- Presented in popular academic databases, peer-reviewed journals, or reputable academic books.
- Specialized in the functions of estrogen and progesterone in birds only.
- Brought to the table either the empirical or theoretical analysis of reproductive physiology or behavior.
- Encompassing broader cross-sectional species distribution, both ranging from wild birds to domesticated birds.
- This paper is published in English so that the results could be easily understood and interpreted by others.

Moreover, such articles were excluded where there was no clear laid down methodology in the study or where the findings were inconclusive in order to avoid compromising the synthesis of this synthesis.

Role of Estrogen in Avian Reproduction

Estrogen is mainly produced in the female reproductive tissues of birds and modulated using hypothalamic-pituitary-gonadal feedback mechanism (Rudolph et al., 2016; Derese, Lu & Shi, 2024). The stimulation of the hypothalamus to release GnRH (gonadotropin-releasing hormone) in turn causes the release of FSH in the anterior pituitary tissues this hormone stimulates estrogen in the follicles (Marques et al., 2022). This hormone is of great importance in readiness for breeding by stimulating growth of reproductive organs and aids in follicular maturity (Marques et al., 2022). Through regulation estrogen ensures that physiological functions that are important for fertility occur at the right time.

Estrogen is important in the process of oocytes development in the ovarian follicles. Estrogen makes certain that the follicles are developed in a way that eggs ready for fertilization are produced (Li & Chian, 2017; Ma et al., 2023). Moreover, one cannot underemphasized the role of estrogen in the synthesis and transport of yolk from the liver to the developing ova in the form of vitellogenin (Sullivan & Yilmaz, 2018; Hiramatsu et al., 2015; Sun & Zhang, 2015). All these yolk proteins play a role of nutrients storage where the embryo will obtain energy and resources it requires. Furthermore,

estrogen controls the expression of characters including bright, distinct colorful patterns, changes in body form and signals that predict the organism's willingness to mate (Hiramatsu et al., 2015). These characteristics act a central function in mate selection, and therefore reproductive success.

But more importantly, estrogen plays a particularly crucial role in the regulation of the sexual behaviors in birds (Watts, 2020). High levels of estrogens are present during the breeding period, the phase when males show courtship activities and enhanced calling activities as well as territory establishment for nest. Such behaviors contribute to reproductive success that is, patterned matings which produce the ideal habitats for raising young ones (Kvarnemo, 2018). Estrogen also regulates nest making to prepare the female birds, which has instincts that relate with incubation and rearing of the young ones (Kvarnemo, 2018). These behavioral effects explain why the hormone has broad ontogenetic applicability in avian reproduction's physical and behavioral aspects.

Role of Progesterone in Avian Reproduction

Progesterone is produced nearly entirely in the ovarian follicles and in some birds in the corpus luteum after the ovulation (Hrabia, 2022). Its production is stimulated by the administration of luteinizing hormone (LH) from the anterior pituitary gland (Scanes, 2022). As for progesterone, it is vital for generating the necessary signal for reproductive cycle recipient to prepare the reproductive system for ovulation and timing the conditions necessary for egg-laying (Leboucher & Amy, 2024). This hormone helps coordinate with other hormonal controllers in timing functions that relate to reproductive systems.

Reproductive cycle functions of Progesterone include:

Ovulation: It becomes useful to determine its role in the menstrual cycle because its increase triggers the process of ovulation, that is, the release of oocytes from the ovary (Vigil et al., 2017). It operates in cooperation with LH so that ovulation takes place at the right time for fertilization to take place.

Regulation of Egg-Laying: Progesterone affects the coordination of contractions of oviduct and move the eggs through the reproductive system (Ritchison, 2023). This regulation has made sure that the laying of eggs is so efficient that it can really play a big role in reproduction.

Maintenance of Reproductive Tract Integrity: The antagonist of estrogen such as progesterone also has positive effects on structural and functional changes in the oviduct and other reproductive tissues (Jeon, Hwang & Choi, 2016). They allow maintenance of the reproductive conditions to support passage and fertilization of eggs and protection of the resultant fertilized eggs.

Progesterone is synergistic to estrogen and other reproductive hormones and is involved in the different phases of avian reproductive cycle (Das, Mukherjee & Banerjee, 2023). For example estrogen is responsible for preparing the contraceptive reproductive tract and also for oocyte maturation whilst progesterone is responsible for ovulation and transport of eggs (Das, Mukherjee & Banerjee, 2023). These hormones are best understood within the framework of reproductive success, and play a part not just in physiological regulation but in behaviors as well, including the tendency to nest or brood. Such hormonal balance makes a contribution to understanding of avian reproductive processes and the significance of progesterone within it.

Interaction between Estrogen and Progesterone

Estrogen and progesterone used in harmony are in a position to orchestrate the complicated features of avian reproduction (Gautron, Réhault-Godbert & Guyot, 2023). While estrogen plays the key role in organizing endometrium and initiating oocyte maturation, progesterone triggers ovulation and maintains structural competence of the female genital tract. Collectively these hormones ensure very delicate coordination of events that involve development of follicles, transport and laying of eggs and many other processes (Berg, Sieber & Sun, 2024). Together, their activities also affect behaviors regarded as vital for reproduction; they also are complementary and play crucial roles in the proper flow of the reproductive cycle.

Estrogen and progesterone are hormones that are secreted synchro-nously with the avian fertile period and exhibit complex temporal relations (Ubuka & Bentley, 2024). Estrogen level normally range at the beginning of follicular wave and its effect are to initiate oocyte growth and development. During the weeks before ovulation, progesterone levels rise to set the release of mature oocytes and control egg-laying (Ubuka & Bentley, 2024). This sequential pattern effectively means that each phase

of reproduction is started and finished as and when conditions for fertilization and subsequent embryonic development are best.

Even the hormone estrogen and progesterone play an important role in nesting and brooding in birds (Lynn, 2016). Estrogen is responsible for making female songbirds sing to males, which control the instincts to create nests to lay eggs in ideal conditions. In return, progesterone has a sort of an activity that promotes maternal behaviors including staying on the nest and incubating eggs and chicks (Lynn, 2016). This hormonal modulation of behaviors is essential for the sustenance of offspring and reproductive fitness hence the complexity of relations between these hormones for avian reproduction.

Comparative Insights from Avian Studies

Gonadal hormonal control in avian reproduction also display significant amount of variability across avian species in accordance with the species occupying distinct ecological opportunities, having divergent reproductive behaviors and life histories (Williams et al., 2017; Chen et al., 2023). For instance, certain species have circadian rhythm that permits hormonal changes that is characteristic of periods of the reproductive calendar while others species experience reproductive activities that are almost constant in a harmonious habitat (Williams et al., 2017). Also, hormonal receptors are sensitive and can differ at the estrogen and progesterone's level which will ultimately affect reproductive timing, clutch size, and parental investment. Such changes thus exemplify the species-typical modularity of hormonal systems in the context of global and proximate ecological and environmental challenges.

Literatures that have compared domesticated and wild birds show high differences on hormonal roles and reproductive physiology (Scanes, 2020; Assersohn, Brekke & Hemmings, 2021). Pets, especially birds that are usually put through selective breeding and a more stable environment will also experience changes such as altered seasonal changes in the hormones and /or lays eggs frequently than other uncaptive birds (Ottinger & Quinn Jr, 2024). Instead the wild birds depend on such factors as day length, food availability and the like to control their hormonal cycling. Such distinctions rage awareness at the effect of human interference and natural evolution on hormonal processes governing avian reproduction.

Sex steroid developmental changes related to social contexts offer profound knowledge on the constitutional variety of birds' reproductive systems (Fuxjager & Schuppe, 2018). For instance, organisms residing in unfavorable or presumably changeable ecosystems will in most cases have hormonal cycles that can enable them to produce young rapidly once the conditions are favorable. Likewise, long-evicted species might demonstrate lower hormonal activity for several offspring but significant investment on them, while short-evicted species have high hormonal activity to produce many offspring (Ottinger & Quinn Jr, 2024). These adaptations explain a useful relation between hormonal systems and ecological factors, and can provide more insight into avian species and how they have been molded to achieve the most reproductive success.

Implications for Avian Conservation and Breeding Programs

Noteworthy, knowledge of hormonal functions is crucial in enhancing avian breeding management, especially in aviary and artificial systems. An understanding of roller coaster changes in estrogen and progesterone levels can allow Specific interventions like artificial insemination, hormone supplementation or changes in environment to coax specific reproductive behaviors at the right time (Ubuka & Bentley, 2024). Programs that are developed to mimic natural hormonal cycles in breeding colonies will thus increase the chances of reproduction while increasing the general health of the offspring.

However, the following challenges are observed when undertaking hormonal research that could be used to apply conservation practices. Some ethical questions are arising over the amount of hormone invasion or any kind of hormonal interference that has to be thought through for the sake of people's health (Lynn, 2016). Due to scarcity of funds and resources, hormonal examination is often times constrained in terms of its sampling size, especially within the conservation sciences which tend to be resource demanding. Moreover, mimicking interaction of environmental and hormonal factors at experimental conditions is still challenging, which could restrict generalization of the results attained in captivity environment to those in the

wild (Lynn, 2016). To overcome these challenges a synthesis approach is appropriate that linking hormonal research with ecological, behavioral and conservation imperative.

Future Directions and Recommendations

While appreciable advancement has been realized in identifying the roles of estrogen and progesterone in avian reproduction, there are a number of blotting points. Despite the impressive increase in publications, most studies have been confined to a small number of taxa, particularly domesticated or model birds, while many wild bird species remain poorly investigated. Further, there is limited understanding of how these hormones can modulate other endocrine signals, stress hormones or metabolic regulators. Further, little is known regarding the influences of environmental stressors including climate change on hormonal regulation of bird reproduction.

For its part, the analysis of the populated data indicates that further research on estrogen and progesterone must necessarily be combined with ecological and behavioral studies to clarify the importance of these hormones for avian reproduction. The study of how hormonal changes affect reproductive behaviors, for example nest-building or choice of mate, in natural settings is possible. In the same way, estimating hormonal patterns in relation to certain ecological factors enables one to identify the impact of environmental conditions on reproductive outcomes. These areas of interdisciplinary will not only enhance scientific theory, but also help in understanding and implementing avian and conservation management. The work presented here shows that integration between these fields can help create more robust approaches to management and conservation that is applicable in both wild and agricultural settings.

Conclusion

Estrogen and progesterone are crucial hormones for avian reproduction, and the present data provide an overview of the various manners in which they are involved in the process. Estrogen and progesterone are both essential to avian reproduction; they can control both physiological aspects of reproduction as well as the behaviors of the birds. Estrogen is indispensable in oogenesis, vitellogenesis and the development of secondary sexual characteristics whereas progesterone is essential in ovulation, in control of egg-laying and preserving the reproductive tubular structure. All these hormones work hand in hand allowing reproduction and continued existence of bird species in the universe.

This synthesis concerns the development of avian reproduction hormones and elaboration on estrogen and progesterone hormones that play a mutually integrative and synergistic role. The reviewed studies emphasize that these hormones do not only play a role at an individual level, determining reproductive success, but also at the population and species levels. These conclusions also identify future directions of the research problem, specifically highlighting the deficiencies in understanding hormonal interactions in various avian taxa and under various environmental conditions.

Knowledge about endocrine mechanisms of avian reproduction is therefore fundamental for the growth of biological wisdom and the pursuit of applied benefits. From a biological standpoint, the study enhances the appreciation of evolutionary and ecological processes as well as traits that birds employ in procreation. Concerning the conservation, hormonal work makes available special aids for improvement of breeding and solving the problems of reproduction in the endangered species. With ever growing environmental pressures it is only going to emerge as more and more critical to incorporate hormonal perspectives into the framework of conservation to protect avian diversity and the overall health of ecosystems. This synthesis therefore highlights the importance of further studies and collaboration of other disciplines to add more knowledge and improve the experience towards providing an improved change for these avian species around the world.

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