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Seasonal Variation in Plasma Levels of Luteinizing Hormone and Steroid Hormones in the European Blackbird *Turdus merula*

By Hubert Schwabl, John C. Wingfield and Donald S. Farner

1. Introduction

Seasonal changes in avian endocrine systems have been investigated mainly in caged birds. The recent development of radioimmuno-assays has made it possible to analyze such small volumes of plasma that serial samples of blood can be drawn from free-living birds at frequent intervals (FOLLETT, SCANES & CUNNINGHAM 1972; WINGFIELD & FARNER 1975; 1976). This opened new possibilities for the investigation of hormones in relation to behavior under natural conditions.

In an attempt to understand behavioral differences between juveniles and adults and between sexes we report here some data on plasma hormone levels in free-living Blackbirds obtained with the methods of WINGFIELD & FARNER (1976). We have measured luteinizing hormone (LH), testosterone, 5α-dihydrotestosterone (5α-DHT), corticosterone and estradiol-17β in relation to the gonadal cycle, incubation, molt and related annual events.

2. Materials and Methods

The investigations were carried out from autumn 1976 to spring 1979 on the Blackbird population at Schloß Möggingen, Radolfzell (47.46 N, 09.00 E). A few samples of plasma were collected in winter 1976, but most were obtained in 1977. The birds were captured with mist nets or live traps and 500—600 μ l of blood were drawn from a wing vein with heparinized micropipettes, usually within 2—4 minutes after capture. Each bird was marked with colored bands and an aluminium ring and weighed. A laparotomy was performed on each bird: in males the small diameter of the left testis and in females the diameter of the largest oocyte was measured. During the breeding season, females were not laparotomized, because we developed the impression that this procedure might jeopardize breeding success. We attempted to recapture each bird at intervals of about 14 days for subsequent blood samples.

Blood samples were centrifuged within ½ hour after procurement and the plasma was frozen at —20° C after adding 1 μ l of NaN_3 per 100 μ l. Samples were shipped to the University of Washington for analysis.

Age was determined according to SVENSSON (1975) and RICHTER (1972); juveniles are defined as those birds in the first year of life up to the first complete molt in the summer following the year of birth. According to this scheme, firstyear birds changed to adult status in July.

Assay of plasma hormones

Plasma levels of LH were measured by the post-precipitation double antibody radioimmunoassay of FOLLETT, SCANES & CUNNINGHAM (1972) as modified by FOLLETT, MATTOCKS & FARNER (1974). The assay utilizes an anti-chicken LH serum raised in rabbits, and highly purified chicken LH for radioiodination and standard curves. Plasma samples were assayed in duplicate: the interassay variation is less than 15%.

The validity of using the chicken LH assay system to measure LH in Blackbirds was tested as follows: adenophypophyses from Blackbirds were homogenized in assay buffer and the LH content measured in

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triplicate at several dilutions. LH levels were also measured in triplicate at several dilutions of a plasma pool from Blackbirds. In both cases the dilution curves were parallel to the standard curve for chicken LH suggesting that LH from Blackbirds binds to the antiserum in a manner similar to chicken LH. It is not possible to prove specificity in an absolute sense because purified preparations of gonadotrophins are not available from Blackbirds. However, the validity of such an approach is supported by a large body of evidence (see FOLLETT et al. 1978).

Plasma levels of the steroid hormones 17β-hydroxy-5α-androstan-3-one (DHT), testosterone, estradiol-17β and corticosterone, were measured by radioimmunoassay, using the procedures described by WINGFIELD & FARNER (1975). Briefly plasma samples are equilibrated with approximately 2000 cpm of each ^{3}H-steroid for at least 2 hours at 4° C for determination of fraction recovered following chromatography. The samples are then extracted with 5 ml of dichloromethane, the extracts dried under a stream of nitrogen and transferred to the top of microcolumns packed with Celite: propylene glycol: ethylene glycol (6:1.5:1.5 w:v:v). Steroid fractions are eluted according to their polarity with increasing concentrations of ethyl acetate in iso-octane. After chromatography steroid hormones are assayed by radioimmunoassay with bound and unbound fractions being separated by addition of dextrancoated charcoal.

Aliquots of the plasma pool, for interassay variation, and two 1-ml solvent blanks of distilled water are taken through the entire procedure in each assay. Data on interassay variation and solvent blanks are presented in Table 1. The accuracy and plasma blanks in the steroid assay systems for Blackbird samples (Table 2) were determined as follows. Aliquots of the plasma pool were treated with dextran-coated charcoal to remove endogenous steroids. After centrifugation the supernatant contains an essentially steroid-free plasma that was then assayed following addition of 0, 250 and 500 pg of respective steroid hormone.

Statistics

Since the data are not normally distributed, medians plus or minus their standard errors have been calculated (SACHS 1978). Levels of significance were determined by the two-tailed median test of SACHS (1978).

Table 1: Solvent blanks and interassay variation of steroid hormone radioimmunoassays.

Hormone assay system	Solvent[1]) blank (pg)	Interassay[2]) variation (%)
DHT	2	16.7
Testosterone	2	14.6
Estradiol	4	16.8
Corticosterone	10	14.1

[1]) Amount of steroid hormone apparent from % bound in the solvent blank.
[2]) Expressed as the coefficient of variation on a pool of plasma from Blackbirds.

Table 2: Plasma blanks and accuracy of the steroid radioimmunoassay systems in Blackbird plasma.

Hormone assay system	Amount of steroid added[1])		
	0 pg	250 pg	500 pg
DHT measured	7.2	274	494
Testosterone measured	5.0	221	426
Estradiol measured	2.0	291	494
Corticosterone measured	3.9	264	422

[1]) Amount of steroid added to a plasma pool from Blackbirds that had been stripped of endogenous steroids.

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3. Results

3.1. Adult males (Figure 1)

Plasma LH in the adult males begins to increase early in February and reaches a first maximum in the last 10 days of February, which is significantly greater ($p < 0.01$) than the level in early February. In March the LH concentration decreases significantly from this peak ($p < 0.05$), falling to one half the peak value. A second maximum is reached in early April, when most of the females begin to lay the first clutch. Subsequently the levels decline to about

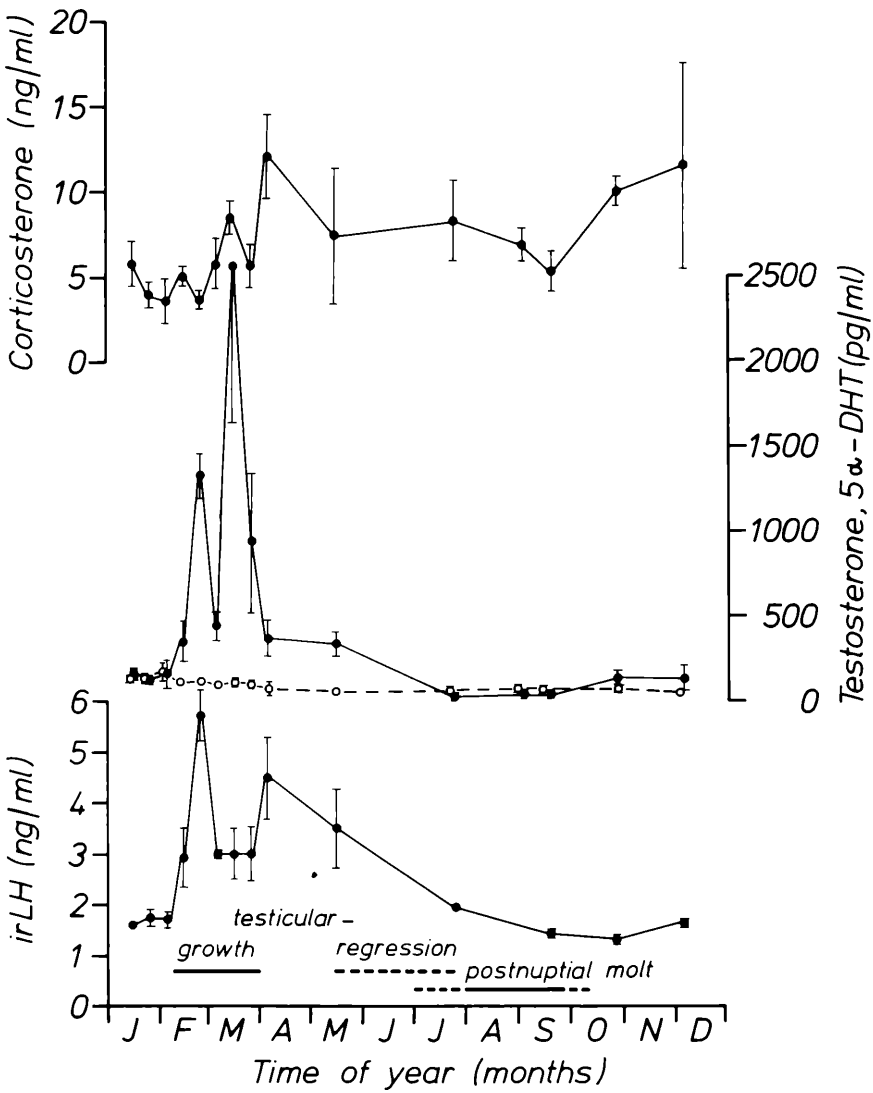

Fig. 1: Plasma concentrations of corticosterone, testosterone (right scale: black dots), 5α-dihydrotestosterone (right scale: open dots) and luteinizing hormone in adult males. Medians and standard errors. When the standard error is not shown, it is covered by the point. Bars „testicular growth" and „testicular regression" represent schematically the state of testes derived from measurements of the width of the left testis. The bar „postnuptial molt" represents schematically the time when birds molting primaries have been caught (SCHWABL unpublished data).

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1.6 ng/ml in autumn. Concomitantly with the increase of LH, testosterone begins to increase and reaches a first maximum simultaneously ($p < 0.01$ for the comparison of the peak value with the value in early February). A second increase in testosterone level occurs in mid March, while the level of LH is low ($p < 0.002$ for the comparison with the preceding value). Despite the second increase in concentration of LH, the plasma level of testosterone decreases as the first clutches are laid. During the breeding season of late March to July testosterone levels decline ($p < 0.002$ for the comparison of the values of May and July).

There is an increase of testosterone in autumn after molt ($p < 0.05$ for the comparison of the combined values of July and September with the combined values of October and

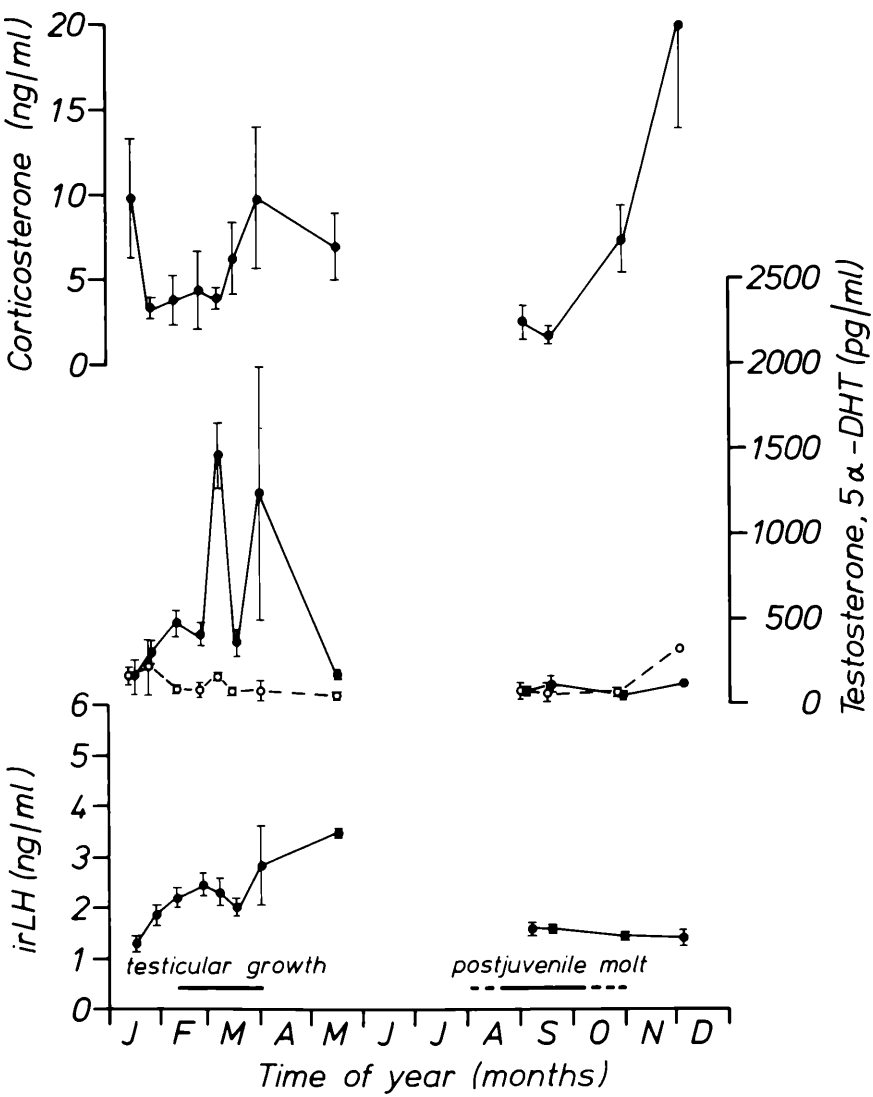

Fig. 2: Plasma concentrations of corticosterone, testosterone (right scale: black dots), 5α-dihydrotestosterone (right scale: open dots) and luteinizing hormone in juvenile males. Medians and standard errors. Bar „testicular growth" see legend Figure 1; bar „post-juvenile molt" represents schematically the time, when juvenile birds molting body feathers have been caught (SCHWABL unpublished data).

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December). 5α-DHT, a metabolite of testosterone, declines during the breeding season from higher levels in winter, but without marked seasonal pattern.

The plasma concentration of corticosterone apparently declines at the end of January and increases towards the breeding season ($p < 0.05$ for the comparison of the combined values of January and February with the combined values of March and April). In September, during postnuptial molt, levels are low followed by increasing concentrations towards the winter season.

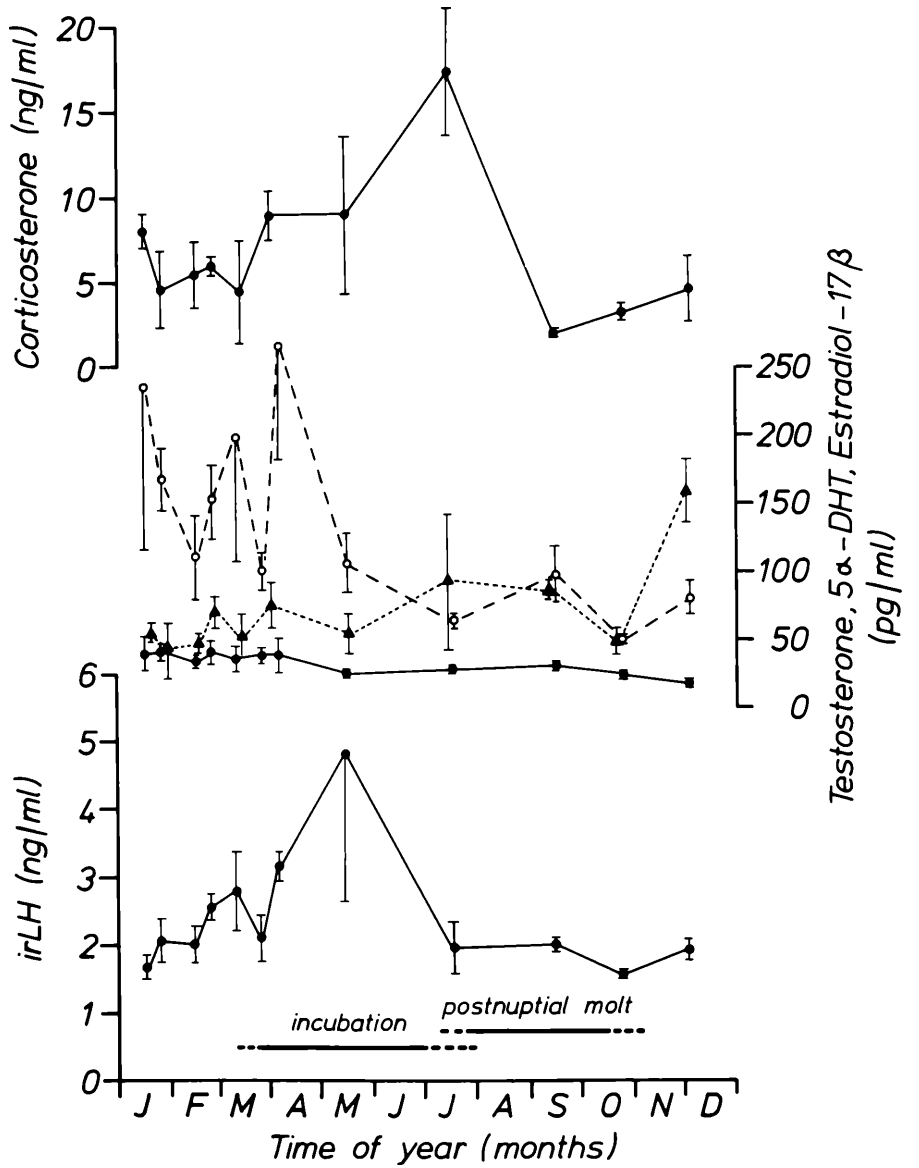

Fig. 3: Plasma concentrations of corticosterone, testosterone (right scale: black dots), 5α-dihydrotestosterone (right scale: open dots), estradiol-17β (right scale: triangles) and luteinizing hormone in adult females. Medians and standard errors. Bar „incubation" represents schematically the time, when incubating females have been observed in the population (SCHWABL unpubl. data); bar „postnuptial molt" see legend Figure 1.

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3.2. Juvenile males (Figure 2)

In juvenile males, in contrast to adults, there is no marked increase in plasma LH in February, and even the concentrations in March are significantly lower ($p < 0.01$) than in adult males. However, the levels do increase steadily from mid-March to May. In contrast to LH, the plasma concentrations of testosterone in juveniles and adults are not significantly different at any time. As in adults, 5α-DHT does not vary seasonally although levels seem to be slightly

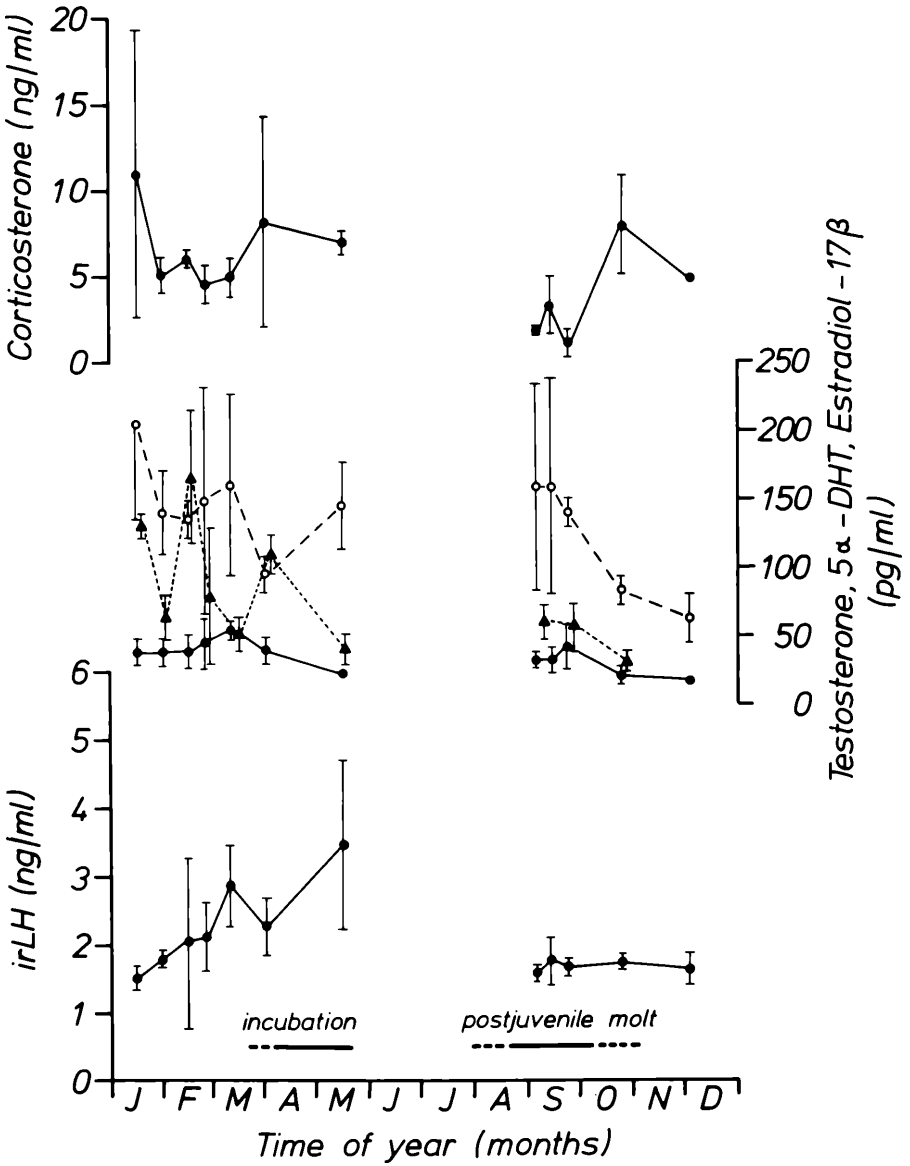

Fig. 4: Plasma concentrations of corticosterone, testosterone (right scale: black dots), 5α-dihydrotestosterone (right scale: open dots), estradiol-17β (right scale: triangles) and luteinizing hormone in juvenile females. Medians and standard errors. Bar „incubation" see legend Figure 3; bar „postjuvenile molt" see legend Figure 2.

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higher in winter than during the breeding season. In early March the level of 5α-DHT is significantly higher in the juveniles than in the adults ($p < 0.05$). In the juvenile males first autumn LH and androgen levels are low.

Plasma corticosterone levels decline significantly from January to February ($p < 0.05$), when feeding in flocks decreases. Although the apparent higher levels after the onset of the breeding season are not significantly different from the preceding levels, circulating levels were considerably elevated as the season progressed. From low levels in September, during postjuvenile molt, to the winter season plasma corticosterone increases ($p < 0.05$ for the comparison of September with October and December values).

3.3. Adult females (Figure 3)

From low winter concentrations LH in the plasma of adult females appears to increase rather steadily to a maximum in May when most females have completed the first clutch. Due to the scatter of the data this maximum is not significantly different from levels of the preceding and following measurements. However, compared with the combined levels in February and March, and July and September, respectively, the levels at this time are higher ($p < 0.10$ and $p < 0.02$, respectively). Autumn levels of LH are the same as in winter. The testosterone concentrations, on the average about one tenth those in males, shows no seasonal cycle. Concentrations of 5α-DHT are higher than those of testosterone. They show a slight tendency to decline from early spring to late autumn. Estradiol-17β was below the detectable limit in 29% of the samples. None of the apparent increases before the breeding season are statistically significant.

Corticosterone is following the same seasonal changes as in the males, except very high concentrations in July at the end of the breeding period. The increase from low levels during postnuptial molt is not significant.

3.4. Juvenile females (Figure 4)

LH concentrations in the plasma of the juvenile females are not different from those of the adult females at any time of the year. Testosterone levels tend to decline during the breeding period, the short increase in March being not significant. In September, during postjuvenile molt, testosterone levels are slightly elavated ($p < 0.20$ for the comparison of the concentration in September with the October and December concentrations). As in the adult females the levels of 5α-DHT are higher than those of testosterone. They decrease from March to April ($p < 0.05$). The levels in the first year females in September are higher than the combined levels of October and December ($p < 0.02$) and also higher than in the adult females ($p < 0.05$). Estradiol-17β was below the detectable limit in 33% of the samples. Levels before the breeding season (January to April) are significantly higher in juveniles than those in adults ($p < 0.05$).

Corticosterone levels in spring are not different from those of the adult females. In the juvenile females first fall there is a significant increase from September to October/December ($p < 0.01$), the level in October being higher than in the adult females ($p < 0.05$).

4. Discussion

The relationship between LH and testosterone

Preparation for the breeding season involves many physiological, endocrinological and behavioral changes. In males the most striking events are the growth and maturation of the testes, song and territorial behavior.

The primary hormonal event triggering this preparation for breeding is an increase in the rate of release of gonadotrophic hormones from the pituitary gland. LH stimulates the Leydig cells of the testes to produce and secrete testosterone, which together with FSH induces spermatogenesis (Brown, Bayle, Scanes & Follett 1975; Brown & Follett 1977; Follett & Maung 1978; Maung & Follett 1977).

Our data on LH and testosterone in male Blackbirds are consistent with the hypothesis that at the beginning of the testicular growth phase the elevation in LH-concentrations causes

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increased plasma levels of testosterone. However, during later development the relationship between LH and testosterone seems to change. Moreover, the second maximum in the LH concentration in the adult males does not coincide with the second maximum in concentrations of testosterone, since the latter occurs when LH levels are low. Such changes in the relationship between LH and testosterone have been reported in the Pekin duck (JALLAGEAS, ASSENMACHER & FOLLETT 1974) and two races of the White-crowned sparrow *Zonotrichia leucophrys* (WINGFIELD & FARNER 1978a, 1978b).

There are different possible explanations for this change in the relationship between LH and testosterone subsequent to the initial direct correlation between LH and testosterone:

(1) an increased metabolic clearance rate caused by an increased concentration of plasma thyroid hormones (ASSENMACHER, ASTIER, DANIEL & JALLAGEAS 1975);
(2) a decreased sensitivity of the Leydig cells to LH (PURVIS & HANSSON 1978; S. ISHII, K. TSUTSUI, J. C. WINGFIELD & D. S. FARNER, submitted ms) and
(3) that the radioimmunoassay mesures more TSH than LH, when TSH secretion is high (FOLLETT e. a. 1978).

Age-dependent hormonal differences

For the low levels of LH in the juvenile Blackbirds in spring we can propose several hypotheses.

1. The low levels of LH in juvenile male Blackbirds may be related to sexual immaturity. Deferred sexual maturity in male birds is known for many species (e. g. BERTHOLD 1964; KING et. al. 1966). In captive Herring Gulls the irLH levels of younger birds do not increase in spring as in the adults (SCANES, CHEESEMAN, PHILLIPS & FOLLETT 1974).
2. The difference in the LH levels between adult and juvenile males may also have been correlated with differences in social relationships. Although testosterone appears to induce aggressive behavior, a reduction in the levels of LH and androgens related to aggressive interactions has recently been reported in freeliving Redwinged Blackbirds *Agelaius phoeniceus* (HARDING & FOLLETT 1979). High numbers of aggressive encounters by trying to establish territories against the territorial adult males may thus cause a reduction in gonadotrophic function, which may even result in a degeneration of reproductive functions (e. g. BRONSON & DESJARDIN 1971). In our Blackbird population juvenile males have significantly smaller testes than adult males during the testicular growth phase (SCHWABL 1979). On the other hand, the outcome of the aggressive encounters might determine the subsequent LH level, in which case winners would have high levels and losers low ones.
3. The population studied is partially migratory which means that some individuals overwinter in the breeding grounds and others migrate. More juvenile than adult males of the population migrate (SCHWABL 1979). The lower LH levels of the juveniles may be due to the greater proportion of migrants among the former, which fail to establish territories against the already established residents. This is supported by the observation of an increase in aggressive encounters at the time of arrival of the migrants (SCHWABL 1979).

Despite the lower plasma levels of LH in the juvenile males, the levels of testosterone are not significantly different from those of adult males, although the pattern is more irregular. Since most adult males have well established territories and are mated, whereas the group of the juveniles is composed of residents, migrants, territorial and non-territorial birds, it is not surprising, that the androgen levels in the latter are more variable. Furthermore, in the Redwinged Blackbird, androgen levels are more variable in aggressive than in foraging males (HARDING & FOLLETT 1979).

The difference in hormonal patterns between adult and juvenile females are much smaller than those between juvenile and adult males. The increase of LH in mid March in both adult and juvenile females occurs later than that of the males. This is in accordance with the suggestion that the final ovarian maturation will not begin until the neuroendocrine control systems of the female receives essential supplementary information from the environment. Such information includes suitable nest sites, favorable food resources for production of eggs and rearing of young, a territorial mate and his courtship behavior (e. g. KERN 1972;

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WINGFIELD 1980; WINGFIELD & FARNER 1980). Among our Blackbirds the largest oocytes in juvenile females are smaller than those of adults before the breeding season, and oviposition in the juveniles occurs later (SCHWABL, unpupl.). It is well known for some species (e. g. SELANDER & HAUSER 1965) that juvenile females often lay the first clutches later than adults. Sin estradiol-17β is involved in the development of the oviduct and in egg-formation, pos y in synergy with testosterone (YU & MARQUARDT 1973a, 1973b, 1973c), one would exp higher estradiol-17β levels in the adult females before the breeding season. However, in our Blackbirds the levels are higher in the juvenile females.

Testosterone and territoriality

Testosterone is known to induce aggressive, territorial and courtship behavior in birds (e. g. HUTCHISON 1975, see also WINGFIELD & FARNER 1980) in addition to its effects upon secondary sex characteristics and spermatogenesis. In figures 1 and 2 it can be seen that circulating levels of testosterone in male blackbirds are highest in early spring, when competition for territories and females is most intense.

In contrast with female White-crowned Sparrows (WINGFIELD & FARNER 1977, 1978a, b) we found no increase in the plasma level of testosterone in female Blackbirds at the time of territorial defense, even though they participate therein.

The autumnal plasma levels of LH and androgens are low in the males, but there is a tendency toward higher testosterone levels in autumn. Furthermore, normal adult song can be induced in young male Blackbirds in their first autumn by injections of moderate doses of testosterone (THIELCKE-POLTZ & THIELCKE 1960). Whether this slight elevation in the testosterone levels is related to the reactivation of sexual behavior in fall, well known for many species including the Blackbird (e. g. MORLEY 1943; MARSHALL 1951), needs further investigations, particularly in years with mild stimulating climate in fall.

The cycle of corticosterone in comparison with other species

The corticosterone levels in juveniles and adults of both sexes show nearly the same pattern. Since the blood samples in winter were collected from flocks at feeding places, where there are many aggressive encounters between individuals, the relatively high levels of corticosterone at that time may be related to the social stress associated with winter flocking. On the other hand the winter levels could be caused or aggravated by unfavorable food conditions or low temperature. All these factors are known to elevate circulating levels of corticosterone in birds (HOLMES & PHILLIPS 1976). The results of histological studies of the avian adrenal cortex differ (LORENZEN & FARNER 1964; FROMME-BOUMAN 1962; BURGER 1938; MOENS & COESSENS 1970; SILVERIN 1978), apparently depending, in part, on whether the species is sedentary or migratory. The high corticosterone levels during the breeding season and low levels during early spring and fall found in this study are in agreement with histological results from sedentary species (BURGER 1938; MOENS & COESSENS 1970; SILVERIN 1978). PÉCZELY (1976) found that invitro production of corticosterone was greater in adrenal glands removed from migratory species during the time of migration than in those removed at the same time from sedentary species. These results would lead one to predict that the mean autumnal and vernal concentrations of corticosterone in the plasma of our juvenile Blackbirds should be higher than those of adults, since a higher fraction of the former is migratory. However, we found no such difference in spring at the time of arrival of migrants. In the migratory White-crowned Sparrow *(Z. l. gambelii)* plasma levels of corticosterone increase dramatically in male during the vernal migratory period. However, in females, that may migrate even further than males, no such increase in plasma levels of corticosterone was observed, although levels were elevated above those of the pre-migratory period (WINGFIELD & FARNER 1978b).

At the time before the departure of the migrants in autumn juvenile male Blackbirds seem to have lower levels of corticosterone than adults. In October the juvenile females have significantly higher corticosterone levels than the adults. The fact, that the corticosterone levels in the juvenile females are high in late October, when the probability of trapping of migratory females is high, supports the opinion that corticosterone is only elevated during actual migration. Investigations on populations of *Z. l. gambelii* have show that plasma

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corticosterone levels increase in adult and juvenile males and females during the autumnal migratory period with highest levels measured in birds that had recently arrived on the wintering grounds (WINGFIELD & FARNER 1978b, WINGFIELD, SMITH & FARNER 1980).

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6. Summary

1. Seasonal changes in the levels of luteinizing hormone (LH), testosterone, 5α-dihydrotestosterone (DHT), estradiol-17β and corticosterone have been investigated in a population of *Turdus merula* in southwest Germany, with respect to age dependent differences.
2. In the males the plasma levels of LH and testosterone increase before the breeding season and decrease during the incubation period.
3. Subsequent to the initial direct correlation between LH and testosterone during the beginning of the testicular growth phase the relationship changes during the incubation period.
4. LH of juvenile males during breeding season is significantly lower than that in the adults, but juvenile males do not differ in androgen levels. We propose the hypothesis that this age-dependent difference is caused by the failure of juvenile males to establish territories against the territorial adult males.
5. 5α-DHT shows no marked seasonal rhythm in the males.
6. In fall after molt, there is a slight elevation in the concentration of testosterone in the adult males.
7. The level of LH in females is elevated during the breeding season, without age-dependent differences.
8. Testosterone in the females shows no marked seasonal rhythm. There is no increase in the females testosterone level during their participation in territorial defence.
9. Although egglaying starts later in juvenile than in adult females, levels of estradiol-17β are higher in juvenile than in adult females before the incubation period.
10. The changes in corticosterone levels are similar in both sexes and in agreement with results from histological studies on adrenals in sedentary species. Age dependent differences in fall cannot exactly related to partial migration.

7. Zusammenfassung

Jahreszeitliche Änderung der Plasmakonzentration von Luteinisierendem Hormon und Steroidhormonen bei der Amsel *Turdus merula*

1. In einer südwestdeutschen Amselpopulation wurden die jahreszeitlichen Muster folgender Hormone untersucht; Luteinisierendes Hormon (LH), Testosteron, 5α-Dihydrotestosteron (DHT), Östradiol-17β und Corticosteron. Unterschiede zwischen adulten und juvenilen Individuen werden berücksichtigt.
2. Zu Beginn der Brutzeit erhöhen sich die Konzentrationen von LH und Testosteron bei den Männchen, während der Brutzeit nehmen sie ab.
3. In der Anfangsphase des Hodenwachstums besteht eine direkte Korrelation zwischen LH und Testosteron, die sich in der Brutzeit ändert.
4. Juvenile Männchen haben zu Beginn der Brutzeit signifikant niedrigere LH-Spiegel als adulte Männchen, während bei den Androgenen keine ausgeprägten Unterschiede bestehen. Es wird die Hypothese vorgeschlagen, daß dieser Altersunterschied dadurch entsteht, daß die juvenilen Männchen in der Besetzung von Territorien gegen die schon etablierten adulten Männchen unterlegen sind.
5. 5α-DHT zeigt keine ausgeprägte jahreszeitliche Änderung bei den Männchen.
6. Im Herbst, nach der Mauser, zeigt sich in der Testosteronkonzentration bei den adulten Männchen ein leichter Anstieg.
7. Der LH-Spiegel bei den Weibchen ist während der Brutzeit erhöht. Altersunterschiede sind nicht festzustellen.
8. Der Testosteronspiegel bei den Weibchen zeigt keinen ausgeprägten jahreszeitlichen Rhythmus. Zur Zeit ihrer Teilnahme an der Revierverteidigung ist die Testosteronkonzentration nicht erhöht.
9. Obwohl die Eiablage bei den juvenilen Weibchen später erfolgt als bei den adulten, ist die Konzentration von Östradiol-17β vor der Brutzeit bei den juvenilen höher als bei den adulten Weichen.
10. Der jahreszeitliche Verlauf der Corticosteronkonzentration ist bei den Geschlechtern ähnlich und entspricht Ergebnissen aus histologischen Studien an Nebennieren von Standvogelarten. Altersabhängige Unterschiede im Herbst lassen sich nicht mit dem Teilzieherverhalten in der Population erklären.

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Vergleich der Gehalte an chlorierten Kohlenwasserstoffen und PCB's in Silbermöwen (*Larus argentatus*)-Eiern von Mellum 1975 und 1979

Von Peter H. Becker, Bernd Conrad und Hans Sperveslage

1. Einleitung

Als möglichen Erfolg der Anwendungsbeschränkungen und -verbote von DDT (1971) und HCB (1974) stellten Baum & Conrad (1978) einen deutlichen Rückgang des Gehalts an diesen Schadstoffen in Habicht- und Wanderfalkeneiern (*Accipiter gentilis, Falco peregrinus*) über den Zeitraum von 1973—1978 fest. Die Kontamination mit PCB's aber hat in Eiern dieser Arten (Wanderfalke: Schilling & König 1980) und von Rohrweihe (*Circus aeruginosus*) und Uhu (*Bubo bubo*) zugenommen (Conrad in Vorb.). Vor diesem Hintergrund erscheint uns die Frage interessant, ob ähnliche Trends auch bei Küstenvögeln zu beobachten sind. Wir hatten die Möglichkeit, Biozidgehalte in Silbermöwen (*Larus argentatus*)-Eiern von 1975 (s. Conrad 1977) mit solchen aus dem Jahre 1979 zu vergleichen, die aus der ca. 9000 Paare umfassenden Kolonie von Mellum stammen.

2. Material und Methode

1975 wurden 30 Eier bei Bestandslenkungsmaßnahmen auf Mellum (53.43 N, 08.09 E) gesammelt und im Tierhygienischen Institut in Freiburg untersucht (s. Conrad 1977). Für Rückstandsuntersuchungen im Rahmen anderer Fragestellungen entnahmen wir 1979 aus 12 Nestern 38 Eier, die im Staatl. Veterinäruntersuchungsamt Oldenburg analysiert wurden.

Die Untersuchungsmethoden beider Institute, ausführlich dargelegt bei Conrad (1977), entsprechen sich mit Ausnahme geringfügiger Unterschiede. Mehrfachbestimmungen (im Veterinäruntersuchungsamt auch auf zwei verschieden gefüllten Gaschromatographie-Säulen) ergaben weitgehend übereinstimmende Werte und Wiederfindungsversuche gute Wiederfundraten. Unserer Ansicht nach ist daher die Vergleichbarkeit der Untersuchungsergebnisse gegeben. Alle Ergebnisse sind auf das Trockengewicht bezogen und in mg/kg (ppm) angegeben (Tab. 1). Unterschiede zwischen den Jahren wurden mit dem t-Test auf Signifikanz geprüft (Schranke $p \leq 0.05$).

3. Ergebnisse und Diskussion

Tab. 1 gibt die Analysenwerte der beiden Jahre im Vergleich wieder. Bei HCB, DDE und PCB sind deutliche Abnahmen festzustellen. Der Rückgang der HCB-Gehalte um den Faktor 10,5 fällt wesentlich stärker aus als derjenige von DDE (um das 1,7fache). Ein entsprechendes

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