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Early growth characteristics and relationships between early growth characteristics and behaviour of commercial male broiler breeders in small group settings

by

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in

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Abstract

The ability to determine the future reproductive value of broiler breeder males has been identified as one of the research gaps in the poultry industry. This study evaluated the presence of relationships between physiological growth parameters of broiler breeder males and both reproductive morphological and behavioural parameters.

The frequency and intensity of male dominance behaviours (including male to female) significantly decreased over a 4-week cycle. Broiler breeder males are capable of forming stable social hierarchies in small family group settings (33 birds). A principal component analysis identified the key characteristics relating to male performance and male quality. High body weight males at hatch and at the end of the study were more likely to be dominant than submissive.

Males with longer keel length at week 20 were likely to have heavier testes weights post-photostimulation. No strong relationship between growth and testis size were found for males pre-photostimulation.

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1. INTRODUCTION

Understanding the growth patterns of male broiler breeders (BB) would be economically beneficial for producers to allow them to cull poor quality or ineffective males earlier. The reduced costs of not raising inferior males, possible increases in male fertility and the possibility of not needing to spike flocks could result in an economic opportunity for producers. Striving to select the best male will improve traits of economic value to producers including improved fertility (Amann, 1999). There are many factors to consider when selecting the 'best' male for the breeding barn. An ideal candidate is motivated to mate, displays appropriate behaviours when approaching hens, does not display unnaturally aggressive behaviours towards hens or other males, and is physically capable of remaining reproductively sound over the life of the breeding flock. This literature review examines the concepts of overall male reproductive quality and the ability to select males for their future reproductive quality.

1.0 Copulatory Behaviour

The mating sequence for Japanese quail may be considered similar enough to be applicable to BB mating sequences. A description of mating of Japanese quail follows with: mating begins with the male grabbing the back of the head or neck, the male then mounts the females back with both feet, and only after a successful mount response does the male make the cloacal contact response. If the female is not receptive, the grab-mount-cloacal contact sequence may be interrupted several times before a successful

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cloacal contact is achieved (Domjan et al., 2003). Female Japanese quail regulate male copulatory behaviour by the length of immobility they express (Domjan et al., 2003). Domjan et al. (2003) found that the genetic line of female Japanese quail significantly affected the latency of the male's grab, mount and cloacal responses and also determined the efficiency of the males mating behaviour. In order to have successful sexual reproduction there must be an effective behavioural exchange between a male and female (Domjan et al., 2003). The ability to acquire copulations depends on a male's ability to outperform other males (intra-sexual competition) and to overcome the cryptic female choice/decision (inter-sexual competition) (Pizzari and Birkhead, 2002). It is difficult to determine the exact impact of hen behaviours on the reproductive success or failure of a flock. Normal roosters may become frustrated if hens fail to respond to their courtship advances or if hens purposely avoid them (Millman and Duncan, 2000b). Millman et al. (2000) found that BB males were motivated to mate but that they lacked the ability to communicate with the females. It is possible that male BB have low levels of sexual motivation, enough to facilitate copulation but not enough to facilitate the whole range of sexual behaviour (Millman et al., 2000).

The fact that BB males are larger and consistently socially dominant over females gives males the opportunity to coerce females into copulation and reduce the ability of the female to choose partners (Pizzari et al., 2002). It is also possible that the conformation of BB males may make courtship displays more physically difficult for them to perform (Millman and Duncan,

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2000b). These physical difficulties may make male BB less capable of inciting sexual motivation in female BB. There is no evidence suggesting that female BB have a lower sexual motivation than laying strain hens (Millman and Duncan, 2000b). This suggests that female choice or willingness may be more important than any other factor (Millman et al., 2000). According to Domjan et al. (2003) females of various species can control the reproductive process through behavioural or physiological selection. Domjan et al. *(2003)* reported that females could control fertility and paternity during any of the four stages of reproductive behaviour: (1) pre-copulation, (2) during copulation, (3) post-copulation and (4) after fertilization.

1.1 Copulatory Behaviour and Forced Matings

In terms of forced copulations, Domjan et al. (2003) reported that male Japanese quail will often pursue a female whether it is receptive or not. It should be noted that forced matings are infrequently reported in Red Jungle Fowl (RJF) (McGary et al. 2003). However, when considering the effectiveness of forced copulations, Adkins-Regan (1995) found that forced copulations were as effective in fertilising eggs as were regular mutual copulations. However, McGary et al. (2003) noted that forced matings were not associated with an improvement in fertility levels. Adkins-Regan's 1995 study suggests that forced copulations may be a viable reproductive strategy for male Japanese quail and for male BB. Pizzari and Birhead (2000) noted that regardless of male status female resistance has a limited effect on copulation success. Domjan et al. (2003) measured the efficiency of male

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copulatory behaviour and found that higher copulatory efficiency scores reflected fewer interruptions of the grab-mount-cloacal contact response sequence. This suggests that forced matings may be effective but fewer forced matings would be more efficient. The effect of male competition on forced matings is unclear. Bilcik and Estevez (2005) found similar amounts of forced matings regardless of the amount of male competition. This suggests that the problem of forced matings is unlikely to be caused by the presence of excess males or by high male competition levels. It is also interesting to note that Bilcik and Estevez (2005) found males who were originally in competition with each other, increased their mating frequency once they were placed in rooms without other males. This suggests that males may be unable to perform optimal mating behaviours due to the presence of other males or due to the presence of too many males. Furthermore, Bilcik and Estevez (2005) found males that used forced matings as a reproductive strategy were heavier and had larger wattles and combs. Therefore, larger males with well-developed secondary sexual characteristics are more likely to perform forced matings.

1.2 Copulatory Behaviour and Sperm

Sexual promiscuity extends the process of sexual selection beyond insemination and is key to understanding reproductive fitness in poultry (Pizzari et al., 2002). Multiple sexual partners or sexual promiscuity creates a potential of sexual selection to occur post insemination through competition between males ejaculates (sperm competition) (Pizzari et al., 2002). In the

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presence of sperm competition females evolve traits to preferentially utilise the sperm from preferred males (Pizzari et al., 2002). This is especially key in species where males can coerce females to copulate and thus limit the ability of the female to select reproductive partners. Female mate preference for socially dominant males may be driven by the pursuit of superior fitness and genes (Pizzari, 2003). There are three distinct sexually selective stages where male social dominance is favoured in the domestic fowl: (i) pre-insemination male-to-male competition, (ii) pre-insemination female choice and (iii) post-insemination female choice (Pizzari et al., 2002). More dominant males experienced a decreased probability of female sperm ejection (Pizzari et al., 2002). Pizzari (2003) found that inseminations from dominant males were not higher in volume than subdominant males indicating that females may not make partner choices on the basis of sperm provision. Males may also use ‘sperm provisioning’ to prevent sperm depletion, sperm may be a limiting factor in female reproduction (Pizzari, 2003). Dominant males enjoyed privileged access to females, were more likely to have lower motility and were less likely to have their semen ejected by hens after copulation (Pizzari et al., 2002). The number and the quality of sperm are the two factors that determine the fertilising efficiency of an ejaculate (Pizzari et al., 2002). In general, in nature males can increase their reproductive success simply by outperforming other rivals at fertilization opportunity (Pizzari et al., 2002). Sperm depletion may be a limiting factor in the reproductive success (Pizzari et al., 2002). Pizzari et al. (2002) found that the number of sperm

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inseminated had a positive effect on the number of sperm initially reaching the sperm storage tubules and more importantly the mobility of that sperm had a positive effect on the rate at which sperm is lost from the sperm storage tubules (High motility males had their sperm retained for longer). Among the galliformes RJF have the largest relative testes mass. This may indicate an evolutionary response to the problem of sperm depletion (Pizzari et al., 2002). When looking at the most common time of day when sperm depletion is most likely to occur Bilcik and Estevez (2005) found that the frequency of mating behaviours peaked between 19:00 and 21:00 and decreased until the lights went off at 22:00. When considering the presence or absence of a hard shell egg in the oviduct it makes sense for roosters to mate when there is not an egg present in the oviduct. A clear empty oviduct provides no impediment to the male's sperm from moving up the reproductive tract. However, it is likely that a hen would have a hard shelled egg in her oviduct in the evening if she lays her eggs in the morning. It is possible that evening matings may be related to the behaviours of RJF. More research is needed to determine the factors that cause mating to peak in the evening.

1.3 Male Dominance and Female Selection

There can be direct and indirect benefits for females when choosing to mate with a dominant male. In the *Gallus domesticus* males provide females with three commodities: food, vigilance and sperm (Pizzari, 2003). Pizzari and Birkehead (2000) described the direct benefits that females choosing a dominant male may receive; better courtship feeding, anti-predator vigilance

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and less harassment from subdominant males. A potential mechanism to explain the female selection of socially dominant males is the pursuit of direct benefits with females trading copulations for high quality resources (Pizzari, 2003). It is difficult to use this argument in the case of domestic poultry as 'resources' such as feed are provided without male involvement. Socially dominant males experience higher levels of copulation based on their differential ability to attract females and disrupt the initiated copulations of their rivals (Pizzari et al., 2002). Another explanation for the selection of dominant males by females is that socially dominant males are more likely to make honest and successful courtship attempts (Pizzari, 2003). The impact of social dominance is limited and regardless of the male's social position most subdominant males manage to secure some copulations (Pizzari et al., 2002). Pizzari and Birkhead (2000) found that dominance status had no effect on the copulation competency of males. Females can promote competition among males (which may increase the competitiveness of dominant males) by indicating when they are ready to be inseminated or by signalling to other males when copulations are occurring (Pizzari et al., 2002). Pizzari and Birkhead (2000) also report that female feral fowl consistently bias their sperm retention towards dominant males. Females signal to dominant males when they are approached to copulate by lower ranked males and in doing this they decrease the probability of the lower ranked male in completing the copulation (Pizzari et al., 2003). Unfortunately little is known

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about the reproductive mechanisms that ensure success after insemination (Pizzari et al., 2002).

1.4 Copulatory Behaviour and Micro-organisms

If carrying beneficial microorganisms is a signal to the health of the individual, then the ability to advertise health should have an impact on sexual attractiveness of males (and females). Evidence suggests that well developed secondary sexual characteristics (comb) may be reliable indicators of the health status of males as secondary sexual characteristics have been found to be positively correlated with superior immunocompetence (Folstad and Karter, 1992; Moller and Sanio, 1994 and Sanio *et al.*, 1995). Therefore, it could be assumed that highly developed secondary sexual characteristics may be a reliable indicator of individuals who carry high levels of beneficial microorganisms. Therefore, females should be attracted to the showiest males in a population as they are most likely to be the healthiest and fittest members of the population. Hamilton and Zuk (1982) found that animals select mates based on their genetic resistance to parasites and diseases and that males that displayed 'brightness' or striking plumage/fur were more likely to be attractive to the opposite sex. Female BB may use physiological traits such as comb colour and iris colour to determine the fitness and suitability of potential mates (Millman and Duncan, 2000b). It appears however that dominance is more important than comb size (Millman and Duncan, 2000b). The argument used by Lombardo et al. (1998) is that females receive not only 'good genes' from choosing showy males, but also the direct benefit of

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avoiding sexually transmitted diseases. When considering the risks of disease transmission Lombardo et al. (1998) pointed out that females are more at risk for disease transmission than males. Therefore, it could be expected that females would be better equipped to 'judge' the risk of acquiring diseases from males. Lombardo et al. (1998) hypothesized that multiple copulation partners benefit females if they receive a cloacal inoculation of beneficial sexually transmitted bacteria. Transmission of beneficial bacteria may protect against future infections or help with current infections.

1.5 Growth Characteristics

The selection for high growth rates and efficient feed conversion in BB may have come at the cost of sexual fitness (including primary and secondary sexual characteristics as well as frequency and efficiency of reproductive behaviours). Increased selection for growth in meat type birds may have come at the cost of reduced reproductive capacities (Emmerson, 1997; Singh, 1999). Breeder companies have selected specific traits for both male and female lines. Traits for male lines include growth rate, edible meat yield and feed conversion ratios and the traits for female lines are the same but also includes egg production (Pollock, 1999). If the current rate of genetic selection continues for growth rate and feed conversion ratio what will be the impact on reproduction and reproductive traits? Pollock (1999) hypothesized that the breeder industry will be forced to slow down the selection for growth on the basis of reproductive problems associated with increased growth traits. Singh (1999) suggested that the BB industry needed to seriously consider the

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option of artificial insemination as well as the formation of rooster stud farms. However, it is unlikely that the reproductive challenges associated with body weight (BW) selection of BB have advanced to the stage at which they require artificial insemination.

Barbato (1999) suggested that growth in meat type poultry should be considered as a non-linear phenomenon. If growth is to be considered as a non-linear phenomenon what points in the growth curve of male BB are good indicators of future reproductive quality? In terms of morphological indicators of future quality, Wolanski et al. (2006a; 2006b) found that shank length and chick length were better indicators of BW at d 14 than BW at d 0. This suggested that males cannot be selected by BW at d 0 and that a variety of measurements may be more useful at predicting growth BW.

Looking at fertility and growth, Barbato (1999) found that fertility was positively correlated with birds selected for growth from d 0 to d 14 of age but negatively correlated with birds selected for growth from d 0 to d 42 and fast growth in any time period negatively correlated with fertility. Furthermore, Barbato (1999) stated that the birds that have very rapid or very slow growth rates are less developmentally stable and more susceptible to environmental or genetic stresses.

There are many factors that influence successful reproduction including primary and secondary sexual characteristics. The impact of secondary sexual characteristics on fertility is unclear. However, McGary et al. (2002) found that comb size and testicular weight correlated positively with

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fertility. Amann (1999) reported that testis weight has up to a 35 -fold range in size in poultry lines and that males with small testis should be culled. It is however difficult to determine which BB males have small testes. It is possible to ultrasound males for testis size but this may not be practical for large flocks (10 000 birds). The selection of birds for high and low growth rates can also have an impact on testes weight. Barbato's (1999) study had birds selected for high and low growth rates at 14 d and 42 d (i.e. 14 H, 14 L, 42 L and 42 H). When testis size was examined, the 14 L birds had the smallest relative testis size but the 14 H, 42 L and 42 H birds were not significantly different from each other. Birds that were consistently selected for small frame size had smaller testis. In a commercial setting, small males are the most likely to be removed by the producer as they are seen to be inferior in quality or to be killed by larger males. In contrast Amann (1999) indicated that the genes regulating testis size and function are 'loosly' linked to the genes regulating body conformation. This suggests that relying on BW will not be sufficient to indicate testis size.

When considering the impacts of fertility it is more appropriate that we discuss the lack of fertility or the presence of sub-fertility in males. It should be noted that although commercial BB strains have been developed through genetic selection birds still operate on the principle of natural selection (McGary et al., 2003). When considering the heritability of fertility, Barbato (1999) and Pollock (1999) pointed out that fertility and fitness traits have a low heritability and that environmental factors influencing phenotype have more of

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an impact on fertility. There are other factors that play a role in the fertility and reproductive success of a flock. Singh (1999) suggested that the reduced reproductive efficiencies seen in today's BB are due to: 1) adverse effects of growth selection on semen traits; 2) physical incompatibility of males and females; and 3) behavioural problems. Pizzari and Birkhead (2002) reminded us that in order to draw clear conclusions about fertility and sex selection that researchers must remember to account for the evolutionary processes as well as behaviour of the subject in wild or semi-wild situations. Behaviour can further compound the problem of sub-fertility; a physically fertile male may not have an opportunity to reproduce if placed in an environment where he is unable to perform. This inability to perform could be caused by his aggressive behaviours or his flock mate's behaviour. Different male fertility may be in part, related to dominance status and to behavioural factors (McGary et al., 2003).

1.6 Dominance Behaviour

It has been shown that aggression in domestic fowl is a dynamic process with decisions being made regarding aggressive behaviours based on the costs and benefits at a particular time and place rather than being fixed at a constant level (Estevez et al., 2002). According to Duncan (1998) behaviour can be considered to consist of two phases; appetitive and consummatory. Examples of appetitive behaviour are the process of seeking food or the sequence of courtship behaviours prior to mating. Examples of consummatory behaviours include the consumption of food or the actual

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copulation/mating. Keeping this in mind the behaviour displayed by BB males seems to be misguided in the appetitive phase. Male BB perform the consumption phase (copulation) but fail to correctly perform the appetitive phase of courtship behaviour. There is usually a link between the motivation and triggering of the two phases of behaviour. McGary et al. (2003) noted that both reproductive and aggressive behaviours occurred infrequently in the 2 mixed BB strains in their study. This study may not be representative as their males were individually housed and were never in direct competition like males in BB barns.

Aggression is to be expected when mixing unfamiliar birds as they attempt to establish a peck order. However, aggression by mature males towards females is unusual and should be considered abnormal (Millman et al., 2000). It has been suggested than when domestic fowl are housed in larger flocks, birds will continually attempt to establish dominance relationships with other flock members. Unfortunately the flock will fail to establish a stable peck order, resulting in higher rates of aggression than in flocks with a stable peck order (Estevez et al., 2002). There is no evidence to suggest that aggression towards females diminishes with sexual experience or with familiarity with individual females (Millman and Duncan, 2000a). However McGary et al. (2003) found that as males increased in age the frequency of forced matings and aggression decreased and the display of courtship behaviours decreased.

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Pagel and Dawkins (1997) suggested that dominance relationships with other individuals are only advantageous when the probability of meeting the same individuals repeatedly occurs over time. In other words the cost of an aggressive act must be worth the benefit(s) of having a dominance relationship. Aggression exhibited by domestic fowl at a specific moment in time is governed by the potential cost of the aggressive behaviour; specifically the costs of aggression in terms of time, energy and risk of injury relative to the potential benefits in terms of the amount of resource gained (Estevez et al., 2002). It is likely that this cost/benefit ratio is only cost effective for a narrow range of (smaller) group sizes (Estevez et al., 2002). The 'tolerance' hypothesis of Estevez et al. (1997) suggested low levels of aggression in large groups of animals occur regardless of the presence of dominance relationships. This is based on the assumption that as the larger a group becomes, it is no longer possible for an individual to protect limited resource through aggressive acts. When limited resources are gathered in time and space (hens) there can be an attempt to monopolize them. In this case aggressive behaviours can be worth the costs to the individual given the benefits (more hens).

1.7 *Dominance and Strain*

Millman et al. (2000) found that BB males were significantly more aggressive towards both males and females than layer strain males and Millman and Duncan (2000a) found that BB males were significantly more aggressive towards females when compared to (Old English) game strain and

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laying strain males. It is difficult to determine if female avoidance causes male frustration and subsequent female directed aggression (Millman and Duncan, 2000b). Broiler breeder females had higher fertility levels and showed more interest in copulating when they were housed with laying strain males and when compared to BB males laying strain males exhibited more courtship behaviour. (Millman and Duncan, 2000b). In Millman and Duncan's (2000b) study, female BB were found to select males based on their behaviour rather than their morphology and that female BB did not inherently select against male BB. The willingness of BB females to mate with game and laying strain males suggests that same strain bias is not necessarily important to female BB. In Millman and Duncan's (2000b) study laying strain males not only performed more courtship behaviours than BB males they also received more allopreening by hens. Conversely BB males spent more time chasing females and females were more likely to struggle during mating with BB than with laying strain males. It is possible that the conditioning and learning pattern of laying strain males is faster than that of BB males and that laying strain males are able to adjust their courtship elements to better suit BB females (Millman and Duncan, 2000b). It is also possible that some of the male BB behaviour is due to an individual male's preference for particular females. Blohowiak et al. (1980) found that males show preferences for individual females; dwarf males showed a preference for dwarf females.

It is imperative to understand that behavioural elements of both the male and female BB play a key role in male aggression. Furthermore, it is

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important to note the social and environmental factors that can also contribute to male aggression. Millman and Duncan (2000b) suggested that BB females learn to avoid male BB rather than having an innate aversion to them. When looking at the behaviour of females, BB females appeared to be more motivated to mate and were more likely to crouch prior to courtship than game strain females (Millman and Duncan, 2000a). In terms of male behaviour, BB males significantly chased and forced more females to copulate more frequently than layer strain males. Millman and Duncan (2000a) also found that females were more likely to struggle against a BB male's mating attempt and more likely to interrupt a mating attempt by a BB male.

It has been reported that BB males have attacked their human handlers (Mench, 1993; Millman et al., 2000 and Millman and Duncan, 2000c). The welfare of the hens is also brought into question as females are seen with lacerations to their head, neck and back (Millman and Duncan, 2000c). Two explanations for the increased aggressive behaviours displayed by male BB are that they are failing to adequately dominate female BB and that the large size of BB males may incite fearfulness in females (Millman and Duncan, 2000a). The large physical size of males may allow for coercive matings as males can overpower females. One method that allows females to cope with coerced matings is the ability to eject semen following insemination (Pizzari and Birkhead, 2000). It seems unlikely that female BB are frightened of male BB by their size alone. The sexual behaviour of hens is mostly influenced by the presence of a rooster, with the exception of hens

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showing sexual crouching to human beings (Duncan, 1998). It has also been suggested that when a hen struggles during mating it may trigger aggressive behaviours by the male (Millman and Duncan, 2000a). Millman et al., (2000) suggested that the social hierarchies of males and females are not separate and that male dominance is rarely challenged due to the physical attributes (size) of males. It is possible that male BB are only adapting to current environmental and housing conditions. Estevez et al. (2002) found that individuals that retained flexibility in their expression of aggressive behaviour based on conditions have a selective advantage within populations. Retaining the ability to adapt to new circumstances allows male BB to have an advantage; unfortunately these adaptations may have led to increased aggression.

1.8 *Dominance Behaviour and Feed Restriction*

There is evidence that the male aggression seen in most commercial BB flocks may have a genetic origin (Millman et al., 2000). It is possible that by attempting to select males with high sexual vigour, breeder companies have inadvertently selected for high levels of sexual aggression. It has also been suggested that high levels of male aggression may have arisen from genetic drift from the inbreeding of foundation lines (Millman et al., 2000). Millman and Duncan (2000c) explain that Cornish-type males were used in BB lines to increase breast muscle yields. However, Cornish-type males have been associated with cock fighting and Wilson et al. (1979) associated problems of fertility with Cornish type males to defective mating behaviours.

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Furthermore, this selection for growth and feed efficiency has led to the need for special considerations in the management of feed and BW for BB.

BB are feed restricted in order to avoid physical and reproductive problems associated with obesity. Males that are too heavy during rearing tend to become over fleshed and generally have reduced persistency of semen production (Renema et al. 2007). Overfed males have reduced fertility compared to birds fed to meet target BW recommendations (Nir et al., 1975; McDaniel et al., 1981). Underfeeding males can also have a negative impact on the reproductive quality of male BB.

The experiences during rearing may impact the ontogeny of social behaviour. It has been suggested that feed restricted males would be more aggressive than ad libitum-fed males (Millman and Duncan, 2000a). Millman et al. (2000) found that ad libitum-fed roosters were more aggressive than feed restricted males. However Millman et al. (2000) reported that most of the aggressive encounters reported tended to occur at the feeder and are likely associated with frustrated feeding behaviour. It is possible that the aggressive behaviours directed towards females may be misplaced feeding aggression. When considering the impact of feed restriction on other male poultry strains Millman and Duncan (2000a) found that BB were more aggressive towards females when compared to game and laying strain females regardless of feed restriction.

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1.9 Dominance Behaviour and Hormones

Hormones influence many aspects of an animal's life: behaviour, physiology and morphology. Therefore, hormones may lie at the heart of many life history trade-offs including mate choice and fecundity (Ketterson et al., 1992). There appears to be correlations between androgen metabolism and aggressive behaviours. In birds, the testosterone hormone affects parental behaviour, vocal behaviour and aggressive behaviour (Ketterson et al., 1992). Millman et al. (2000) described that copulatory motivation and aggression are likely tied together in the hypothalamic region of the brain. However, there must be different motivations in BB males that caused them to react more aggressively than laying strain males (Millman et al., 2000). A manipulation of testosterone in free-living birds has shown a major influence on the components of fitness, specifically the ability to attract mates (Ketterson et al., 1992). Understanding the impact that an altered phenotype (high levels of testosterone) has will depend on the induced behavioural and physiological changes. It seems probable that there is a heritable component to testosterone variations seen in males. There are several bird species that exhibit a heritable variation in their aggressive behaviours (Boag, 1982; Moss et al., 1982) that depend on testosterone, and studies have demonstrated that testosterone related traits respond to selection (Sefton and Siegel 1975; Cunningham and Siegel, 1978).

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1.10 Fertility and Management

The impact of management on fertility can affect the reproductive success of a BB flock. The practice of 'spiking' older flocks with younger males is an attempt to increase the fertility of older flocks. The ratio of males to females and the decision whether to 'spike' a flock with younger BB males are two management strategies that producers can utilize to ensure reproductive success. These strategies however, come with drawbacks. The addition of extra males through increased stocking ratios or the addition of 'spiked' males may lead to increased male to male aggression. The addition of younger males to a flock may cause welfare concerns for the younger males and females, increased expense for producers and a possible bio-security threat for the entire farm.

Wolanski et al. (2004) reported that the reproductive efficiency of male BB declines towards the end of a production cycle. In studying the physiological and morphological characteristics of original and replacement males at the end of the production cycle Wolanski et al. (2004) reported that the primary difference between original and replacement males was BW. Original BW males were significantly larger than the replacement males, the BW and testes weight ranges were not affected by age and the original males had a trend towards a higher incidence of testicular regression.

1.11 Future

The lack of research into the presence or absence of relationships between the morphology and behaviours of male BB has left producers with inadequate information. Producers are left to make decisions about male

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quality based on aged and unproven theories. It is fundamentally important for producers to select quality males based on proven research. Ineffective breeding males can lead to economic losses for the producer and reduced welfare for the entire flock. This research will provide a clearer picture as to the use of growth morphology as an indicator for future reproductive quality (both physiological and behaviourally).

The first experiment examines the presence of relationships between the growth characteristics and morphological characteristics of two groups of male BB. The male BB had growth characteristics measured at day of hatch and every 5 wks up to and including wk 20. Measurements included BW, chick length, keel width, keel girth, shank length and shank width. Morphological measurements included the weight of the right and left testis, breast muscle, liver, fat pad and BW. The first group was killed at wk 23 and represented the morphology of male BB pre-photstimulation. The second group was killed at wk 30 and represented the physiology of male BB post-photostimulation.

The second experiment looked at the presence of relationships between growth/morphological characteristics and the behaviour that male BB expressed in 33 bird family group settings. The growth and morphological characteristics examined were the same as in the first experiment. The behaviours examined included the number and type of matings (complete, incomplete and interrupted) and the level of dominance expressed by males during mating. Male to male dominance behaviours were also examined

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including the frequency, intensity, instigator, recipient and winner of each male to male encounter.

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2.0 Relationships among growth characteristics and morphological characteristics of commercial male broiler breeders.

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Key words: Morphology, Growth, Reproduction, and Reproductive Quality.

2.1 Introduction

The meat bird industry has been selecting birds for increased growth rate. The market demands have caused a gradual shift towards high yielding strains (Renema et al., 2007). As of 1996, there were approximately 60 generations of intense selection for rapid broiler growth contributing to a reduced time for market for broilers (Nir, 2000). This selection for growth may have come at a cost of increased incidences of reduced reproductive capacities (Emmerson, 1997; Singh, 1999). Understanding the growth patterns of male broiler breeders (BB) and applying this understanding would allow producers to cull inferior quality males in the rearing stage. The reduced costs of raising excess males as well as the expected increase in male fertility would likely result in an increased economic return for producers. Striving to select a top quality-breeding male will improve traits of economic value to producers including improved fertility (Amann, 1999).

Growth should be considered as a non-linear phenomenon (Barbato, 1999). Very little research has been conducted to determine if there are any morphological indicators capable of predicting reproductive quality. Traditionally chick BW at hatch has been used as an indicator of chick quality. Joseph et al. (2006) suggested that the variation seen in chick BW at hatch

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was likely due to residual yolk mass. The different efficiencies of yolk utilization can be affected by the strain of broiler (Wolanski, 2006a). If growth is to be considered non-linearly are there any points in the growth of male BBs that are good indicators of future reproductive quality? Wolanski et al. (2006a; 2006b) found that shank length and chick length were better indicators of BW at d 14 than was BW at d 0. This research suggested that BW alone should not be used as basis to cull males and that a variety of measurements may be more useful at predicting growth.

When considering fertility in relation to growth Barbato (1999) found that fertility was positively correlated with birds selected for high and low growth rates to 14 d of age and that birds with very rapid or very slow growth rates were less developmentally stable and more susceptible to stresses. The genetic selection for growth in broilers was shown to affect fertility through changes to the musculo-skeletal structure (McGary et al., 2002).

The objectives of this study were to evaluate the morphological characteristics, reproductive characteristics and overall growth rates of BB. Some of the hatch and growth morphological characteristics of BB males may be indicative of future reproductive characteristics. The two age groups in this study were used to determine if relationships were present before and after photostimulation.

2.2 Materials and Methods

2.3 Animal Husbandry

This experiment was conducted in accordance with the Guidelines for the Care and Use of Animals in Agricultural Research and Teaching

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(Canadian Council on Animal Care, 1984). A total of 600 BB eggs were obtained from a primary breeding company (Aviagen North America, Huntsville, AL) and incubated at a commercial hatchery (Lilydale Hatchery, Calgary, AB).

On the d of hatch (d 0) male chicks were tagged and the length of chicks (cm) and the chick's weights (g) were recorded. Chicks were separated by sex and randomly placed in straw bedded pens (2.25 m x 5.5 m) with starter diet (Table 2-1) and unlimited access to water. The first 3 d chicks were exposed to continuous light at 30 lux. At d 4 chicks were exposed to 8 h of light and 16 h of dark at 10 lux and remained on this light schedule until photo stimulation.

At wk 5 male BW were recorded. At wk 10, 15 and 20 males had their keel length (mm), breast girth (mm), right shank length (mm) and BW (g) measured. Birds were group weighed once every wk during rearing to determine feed allocations.

Males were weighed at wk 20 and placed into weight groups based on their BW weights: small males (average 2.2 kg), medium males (average 3.2 kg) and heavy BW males (average 4.2 kg). At wk 23, 76 males were selected by BW (small, medium and heavy BW) and were killed via cervical dislocation. Another 40 males were selected by BW to be killed at wk 30. The morphological characteristics examined at wk 23 and wk 30 included breast muscle (*Pectoralis (P) major and P. minor*), fat pad, liver and testis (right and left). The % increase in BW growth or the % of growth was

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calculated for 4 time periods (d 0 to wk 5, wk 5 to wk 10, wk 10 to wk 15 and wk 15 to wk 20). The mean BW growth and other variable means can be found in table 2-2 (wk 23) and table 2-4 (wk 30).

At photo stimulation (wk 24) birds were exposed to 14 h of light (74 Lux) and 10 h of dark. At wk 27 birds were exposed to 16 h of light at (74 Lux) for every 24 h period. Males that were in obvious distress were humanly euthanized by cervical dislocation.

2.4 Statistical Analyses

Data were analysed as a one-way ANOVA using the GLM procedures of SAS and means were separated using the PDIFF *t*-test procedure (SAS System, 2002). Regressions were calculated between variables of interest. The bird was the experimental unit. Significance was assessed at a $P < 0.05$.

A principal component (PC) analysis was used to determine which of the measured variables are associated with each other. The proportion of the total variation that is explained by each PC will suggest the relative power of each PC in understanding male BB performance. The purpose of PC scores is to identify performance trends among BB males as they grow. The underlying concept that each PC represents may lead to a better understanding of the performance of BB males. The proportion of the total variation that is explained by each PC will indicate the relative power of each PC in understanding male BB growth.

2.5 Results and Discussion

2.6 Principal Components

A mean PC score was determined for PC 1, 2, and 3 for the wk 23 and wk 30 groups. Descriptive titles for the PC were chosen based on the 5

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highest scoring variables in each PC. In Figures 2-1, 2-2 and 2-3 these mean PC scores for wk 23 PC 1 (morphology), PC 2 (growth), and PC 3 (reproduction), respectively, have been charted for the following 5 category variables; breast muscle, BW wk 5, chick shank length, % growth period 2 and % growth period 1. In Figures 2-4, 2-5 and 2-6 these mean PC scores for wk 30 PC 1 (morphology), PC 2 (reproduction), and PC 3 (growth), respectively, have been charted for the following 5 category variables; testes weight, BW at hatch, keel length at wk 5, % testes and % growth period 2.

To provide an overview of the study parameters, a summary of the means and SD of the variables used in the PC analyses is reported in Table 2-2 (wk 23) and Table 2-4 (wk 30). The 3 PC for wk 23 explained approximately 59 % of the variation in performance (Table 2-3). The variables that explained a significant amount of variation in each PC are in bold in Table 2-3. The 3 PC for wk 30 explained approximately 64 % of the variation in performance (Table 2-5). The variables that explained a significant amount of variation in each PC are in bold in Table 2-5.

2.7 Principal component analyses for wk 23

The PC1 (morphology), which explained 41 % of the total variation, had the strongest positive association with the measured variables: BW wk 5, BW wk 20, BW wk 23 P. major at wk 23, P. minor, and total breast muscle. The BW wk 20 variable was the most strongly associated with PC 1. Morphology was the subjective descriptor chosen for this component as the BW and breast muscle variable scores were the strongest. Figure 2-1 shows that the males that had higher rates of growth in both time periods were likely

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to have a longer shank length at hatch, be heavier at hatch and to end up with greater total breast muscle than males who grew less in both time periods. All of the scores in Figure 2-1 were significantly different from each other as demonstrated by the standard error of the mean (SEM) bars.

The PC 2 (growth), which described 9 % of the variation, associated positively with BW at hatch, length of chick at hatch, shank length at hatch, BW at wk 5, % growth period 1 and negatively associated with % growth period 2. The BW wk 5 variable was the strongest associated variable with PC 2. Growth was the subjective descriptor chosen for PC 2. The > 1000 g and < 900 g males were not significantly different from each other but were different from the 900 – 1000 g males. The smaller and larger males were negatively associated with the growth component. Males with longer than 30 mm shanks at hatch were positively associated with growth component and significantly different from males with smaller than 30 mm shanks at hatch.

The PC 3 (reproduction), which accounted for 9 % of the variation, is positively associated with BW wk 5, % growth period 1, right testis weight, left testis weight, total testes weight and % testes. The % testes was the strongest associated variable for the reproduction component. Males with less than 177 % growth in the second period were positively and significantly associated with the reproduction component.

2.8 Principal component analyses for wk 30

The PC1 (morphology), which explained 44 % of the total variation, had the strongest positive association with the measured variables: BW wk 10, BW wk 20, BW wk 30, keel length wk 20, P. major at wk 30, and total

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breast muscle weight. The most strongly associated variable with PC 1 was the BW measurement from wk 20. Morphology was the subjective descriptor chosen for this component based on the strongest scoring variables. Figure 2-4 shows that the males that had heavier testes were likely to have a longer keel length, to have a higher % growth rate in period 2 and to have been between 40.5 and 42 g at hatch. These males had scores that were also positively associated with the morphology component. The testes weight, keel length and % growth period 2 variables in figure 2-4 were significantly different from each other as demonstrated by the standard error of the mean (SEM) bars.

The PC 2 (reproduction), which described 12 % of the variation, associated negatively with BW at wk 5, and positively with % fat pad, right testis weight, left testis weight, total testes weight and % testes. The % testes variable was the strongest associated variable with PC 2. Reproduction was the subjective descriptor chosen for PC 2. Figure 2-5 shows males that were smaller than 40.5 g at hatch were likely to have larger than 41.5 g of total testes weight at wk 30 and greater than 1 % testes. Testes weight, keel length and % testes variable categories were significantly different and the < 40.5 g males were significantly different from the other BW at hatch.

The PC 3 (growth), which accounted for 8 % of the variation, is positively associated with BW wk 5, % growth period 1, keel length at wk 10, fat pad weight, % fat pad and negatively associated with BW growth in period 2. The males that were less than 40.5 g at hatch were more likely to have

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longer keels and less than 175 % growth in the second period (Figure 2-6). These variables were positively associated with the growth component.

2.9 Regression Analyses

Regressions were calculated using the PC scores from PC 1, 2 and 3 and other variables of interest. The regressions of interest are shown in Tables 2-6 to 2-9. Model 1 in Tables 2-6 to 2-9 were run as a check to ensure that the PCs were relating to the data as expected. Not surprisingly the PCs in the model 1 were able to explain most of the variation seen in the data. This was as anticipated, as the dependent variable in Tables 2-6 to 2-9 were also independent variables in the PC analysis. Table 2-6 model (2) demonstrates that keel length at wk 10 ($p< 0.01$) and BW at wk 15 ($p<.0001$) were significant variables in explaining the total testes weight at wk 23. The R- square for table 2-6 (2) was 48.1%. This suggests that roughly half of the variation seen in total testes weight at wk 23 can be explained by the keel length at wk 10 and the BW at wk 15 alone. The significant variables in table 2-6 (2) that explain the total testis size are expected, as larger birds at wks 10 and 15 should have larger testes at wk 23. It is difficult to predict the total testes weight at this stage in male development as birds are maturing and about to be photo stimulated.

Table 2-7 model (2) shows the significant variables that related to final BW. The length of chick at hatch ($p<0.01$), BW wk 10 ($p<.0001$) and BW wk 15 ($p<.0001$) were all significant variables, with an R-square for this regression of 94.2%, indicating that these variables jointly explain most of the variation observed in final BW. It is not surprising that the BW of males at wk

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10 and 15 would strongly indicate the BW at wk 23. However, the length of chick at hatch as a variable that explains wk 23 BW requires further investigation. The use of chick length as an indicator of future growth may have on farm implications for male selection.

Table 2-8 and 2-9 show the regression models for wk 30 group with total testis weight and final BW as the dependant variables. Model (2) in table 2-8 shows that length at hatch ($p<0.01$) was significant. The R-square for model (2) was 18.5%. Model (2) in table 2-9 shows the significant variables in the model: Length at hatch ($p<0.05$), BW at wks 5 ($p<0.01$), BW wk10 ($p<.0001$) and keel length at wk 10 ($p<0.05$) were significant. The R-square value for model (2) was 65.1.

2.10 Discussion

Similar to Barbato (1999), this study found that the BW growth of male BBs were not linear and that the largest increase in % BW growth occurred during the first growth period (d 0 to wk 5). The usefulness of morphological measurements as a more appropriate indicator for future reproductive potential rather than BW alone was also confirmed. Figure 2-4 shows that the keel length at wk 20 variable is more associated with morphology than the BW at d 0 variable. This research supports Wolanski et al. (2006a; 2006b) who suggested that BW at hatch is not the best indicator of future BW. The length at hatch variable significantly associated with wk 23 final BW and with wk 30 final BW and total testes weight.

It is important however to consider the effect of strain on chick BW. Scheuermann (2003) compared chick growth and muscle development in 8

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strain crosses and suggested that different growth curves were present in each of the strain crosses. While the BB males in this study were raised according to industry standards, future research is needed to evaluate the strength of morphology/growth relationships in perspective to larger sample sizes and the application of morphology/growth relationships in other BB strains. Furthermore, the effect of photostimulation on the presence or absence of morphological/growth relationships in BB males needs examination.

Male BB chicks are expensive ($ 5 a chick) and if producers are over culling based on unproven principles they may be inadvertently reducing the potential fertility of their flocks and wasting economic resources. The potential to maintain more quality males may reduce the need for spiked males later in the flock's life and also decrease the costs to producers.

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Table 2-1. Composition and analysis of experimental diets

Ingredient and analysis	Starter (0 to 4 wk)	Grower (4 to 22 wk)	Breeder (22 to 30 wk)
	----------------------	(%)	----------------
Ground corn	14.14	16.44	41.51
Wheat	44.23	34.42	25.29
Soybean meal (44% CP)	17.34	7.37	18.78
Oats	5.00	12.50	--
Barley	5.00	10.00	--
Canola oil	2.00	0.70	1.63
Wheat shorts	7.50	15.00	--
Corn gluten meal	--	--	1.50
Ground limestone	1.65	1.72	7.93
Dicalcium phosphate	1.58	0.86	1.80
Choline chloride premix[2]	0.50	0.50	0.50
Broiler premix	0.50	0.50	--
Layer premix[3]	--	--	0.50
Salt	0.38	0.33	0.41
D, L-methionine	0.141	0.125	0.094
L-lysine	0.031	0.162	-
Avizyme	--	0.05	0.05
Amprol	0.05	--	--
Zinc bacitracin	--	0.05	--
Calculated nutrient composition			
CP (%)	18.2	15.1	16.0
ME (kcal/kg)	2,782	2,711	2,830
Calcium (%)	1.0	0.88	3.5
Available phosphorus (%)	0.47	0.32	0.45
Lysine (%)	0.83	0.72	0.75
Methionine (%)	0.41	0.34	0.36

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[1] Provided choline chloride in the diet at a level of 100 mg/kg.

[2] Broiler premix provided per kilogram of diet: vitamin A (retinyl acetate), 10,000 IU; cholecalciferol, 2,500 IU; vitamin E (DL-α-tocopheryl acetate), 35 IU; vitamin K, 2.0 mg; pantothenic acid, 14 mg; riboflavin, 5.0 mg; folacin, 0.8 mg; niacin, 65 mg; thiamine, 2.0 mg; pyridoxine, 4.0 mg; vitamin B12, 0.015 mg; biotin, 0.18 mg; iodine, 0.5 mg; Mn, 70 mg; Cu, 8.5 mg; Zn, 80 mg, Se, 0.1 mg; Fe, 100 mg.

[3] Layer premix provided per kilogram of diet: vitamin A (retinyl acetate), 12,000 IU; cholecalciferol, 3,000 IU; vitamin E (DL-α-tocopheryl acetate), 40 IU; vitamin K, 2.0 mg; pantothenic acid, 14 mg; riboflavin, 6.5 mg; folacin, 1.0 mg; niacin, 40 mg; thiamine, 3.3 mg; pyridoxine, 6.0 mg; vitamin B12, 0.02 mg; biotin, 0.2 mg; iodine, 0.5 mg; Mn, 75 mg; Cu, 15 mg; Zn, 80 mg, Se, 0.1 mg; Fe, 100 mg.

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Table 2-2. Measured variables that attributed to the performance of 76 commercial male BBs during 23 wk of growth (mean and SD of measured variables)

Variable	Age (wk)	Mean	SD
Length of chick (cm)[1]	0	19.5	0.42
BW (g)	0	41.6	3.1
	5	1018	743.6
	10	1665	212.8
	15	2529	429.6
	20	3089	527.5
	23[2]	3460	618.4
Shank length (mm)[3]	0	30.3	0.80
	10	103.9	4.90
	15	124.9	11.4
	20	130.2	4.88
Keel length (mm)[4]	10	132.3	6.53
	15	160.2	6.53
	20	174.8	8.32
Width of breast (mm)[5]	10	62.5	10.6
	15	65.9	4.38
	20	75.7	5.50
Girth of breast (mm)[6]	10	32.0	7.55
	15	32.8	22.8
	20	34.9	2.02
BW growth (%)[7]	0-5	2438	1633
	5-10	177.2	23.3
	10-15	151.7	16.4
	15-20	125.3	41.4
P. major muscle weight (g)	23	512.7	128.8
P. minor muscle weight (g)	23	162.6	37.5
Total breast muscle weight (g)[8]	23	675.3	164.9
Percentage breast muscle (%)[9]	23	19.3	2.09
Fat pad weight (g)	23	5.31	8.08
Percentage fat pad (%)[10]	23	0.140	0.185
Right testis weight (g)	23	3.78	3.56
Left testis weight (g)	23	4.04	3.80
Total testes weight (g)[11]	23	6.28	6.09
Percentage testes (%)[12]	23	0.167	0.156

[1] Measured from the tip of the bird's beak to the end of the middle toe (not including the nail).
[2] Measured post mortem.
[3] Measured from the top of the hock joint to the top of the footpad.
[4] Measured from the hypocleido-clavical joint to the caudal end of the sternum.
[5] Measured across the hypocleido-clavical joint.
[6] Measured around the hypocleido-clavical joint.
[7] Number of male dominance encounters over a cycle.
[8] Measurement includes the combined weights of *P. major and P. minor.*
[9] Measured the % of total BW that was attributed to total breast muscle weight.
[10] Measured the % of total BW that was attributed to fat pad weight.
[11] Measured the total weight of left and right testes.
[12] Measured the % of total BW that was attributed to the total testes weight.

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Table 2-3. Values between measured variables and principal components (PC) for wk 23. Values used to load each PC are shown in bold.

PC descriptor	PC1 Morphology	PC2 Early growth	PC3 Reproduction
Variation explained by PC	41%	9%	9%
BW at d 0 (g)	0.0398	**0.2956**	0.0613
Length of chick at d 0 (cm)[1]	0.1130	**0.3277**	0.0456
Shank length at d 0 (cm)[2]	0.0676	**0.3523**	-0.0496
BW at wk 5 (g)	-0.0292	**0.3604**	**0.3171**
BW growth 1 (%)[3]	-0.0371	**0.3368**	**0.3142**
BW at wk 10 (g)	**0.2314**	0.1097	-0.1125
BW growth 2 (%)[4]	0.1274	**-0.2900**	-0.2986
BW at wk 20 (g)	**0.2571**	-0.0113	0.0228
BW at wk 23 (g)	**0.2475**	-0.0256	0.0110
P. major at wk 23 (g)	**0.2501**	-0.0409	-0.0096
P. minor at wk 23 (g)	**0.2451**	-0.0301	-0.0276
Total breast muscle at wk 23 (g)[5]	**0.2510**	-0.0390	-0.0138
Right testis at wk 23 (g)	0.1817	-0.1462	**0.3155**
Left testis at wk 23 (g)	0.1888	-0.1345	**0.3042**
Total testes at wk 23 (g)[6]	0.1842	-0.1173	**0.2990**
Percentage total testis at wk 23 (%)[7]	0.1642	-0.1334	**0.3263**

[1] Measured from the tip of the bird's beak to the end of the middle toe (not including the nail).

[2] Measured from the top of the hock joint to the top of the footpad.

[3] Measured the % increase in BW from d 0 to wk 5.

[4] Measured the % increase in the BW from wk 5 to wk 10.

[5] Measurement includes the combined weights of *Pectoralis major and minor.*

[6] Measurement included the combined weight of the left and right testes.

[7] Measured the % of total BW attributed to the total testes weight.

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Table 2-4. Measured variables that attributed to the performance of 40 commercial male BBs during 30 wk of growth (mean and SD of measured variables)

Variable	Age (wk)	Mean	SD
Length of chick (cm)[1]	0	19.3	0.46
BW (g)	0	41.4	2.32
	5	943.9	103.4
	10	1686	209.7
	15	2529	433.5
	20	3116	618.6
	30[2]	3976	623.6
Shank length (mm)[3]	0	30.2	0.88
	10	103.2	4.49
	15	122.4	6.32
	20	129.5	5.98
Keel length (mm)[4]	10	131.4	5.24
	15	158.5	8.96
	20	172.4	9.84
Width of breast (mm)[5]	10	63.1	4.04
	15	65.9	6.71
	20	76.0	9.88
Girth of breast (mm)[6]	10	29.4	1.18
	15	33.5	5.97
	20	35.3	3.18
BW growth (%)[7]	0-5	2283	230.0
	5-10	178.9	15.1
	10-15	149.5	12.8
	15-20	123.1	13.0
P. major muscle weight (g)	30	534.4	130.3
P. minor muscle weight (g)	30	178.9	40.9
Total breast muscle weight (g)[8]	30	713.3	169.0
Percentage breast muscle (%)[9]	30	17.7	2.16
Fat pad weight (g)	30	2.13	1.57
Percentage fat pad (%)[10]	30	0.05	0.04
Right testis weight (g)	30	19.9	5.40
Left testis weight (g)	30	21.3	6.53
Total testes weight (g)[11]	30	41.3	11.5
Percentage testes (%)[12]	30	1.04	0.26

[1] Measured from the tip of the bird's beak to the end of the middle toe (not including the nail).
[2] Measured post mortem.
[3] Measured from the top of the hock joint to the top of the footpad.
[4] Measured from the hypocleido-clavical joint to the caudal end of the sternum.
[5] Measured across the hypocleido-clavical joint.
[6] Measured around the hypocleido-clavical joint.
[7] Number of male dominance encounters over a cycle.
[8] Measurement includes the combined weights of *P. major and P. minor.*
[9] Measured the % of total BW that was attributed to total breast muscle weight.
[10] Measured the % of total BW that was attributed to fat pad weight.
[11] Measured the total weight of left and right testes.
[12] Measured the % of total BW that was attributed to the total testes weight.

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Table 2-5. Values between measured variables and principal components (PC) for wk 30. Values used to load each PC are shown in bold.

PC descriptor	PC1 Morphology	PC2 Reproduction	PC3 Growth
Variation explained by PC	44%	12%	8%
BW at wk 5 (g)	0.1498	**-0.2358**	**0.3014**
BW growth 1 (%) [1]	0.1311	-0.0843	**0.4198**
BW at wk 10 (g)	**0.2236**	-0.1049	0.1130
BW growth 2 (%) [2]	0.1374	0.1372	**-0.2258**
BW at wk 20 (g)	**0.2372**	-0.0179	-0.1108
BW at wk 30 (g)	**0.2272**	0.0523	-0.1077
Keel length at wk 10 (cm) [3]	0.1898	-0.1176	**0.2897**
Keel length at wk 20 (cm)	**0.2332**	-0.0162	0.0353
Fat pad weight at wk 30 (g)	0.1064	0.1938	**0.2711**
Percentage fat pad at wk 30 (%) [4]	0.0726	**0.2098**	**0.3088**
P. major at wk 30 (g)	**0.2297**	0.0482	-0.1041
Total breast muscle at wk 30 (g) [5]	**0.2285**	0.0373	-0.1158
Right testis at wk 30 (g)	0.1228	**0.3877**	-0.0332
Left testis at wk 30 (g)	0.1455	**0.3546**	0.0469
Total testes at wk 30 (g) [6]	0.1400	**0.3827**	0.0110
Percentage total testis at wk 30 (%) [7]	0.0161	**0.4312**	0.0594

[1] Measured the % in BW growth from d 0 to wk 5.

[2] Measured the % in BW growth from wk5 to wk 10.

[3] Measured from the hypocleido-clavical joint to the caudal end of the sternum.

[4] Measured the % of BW that was attributed to the fat pad weight.

[5] Measurement includes the combined weights of *Pectoralis major and minor.*

[6] Measurement includes the left and right testes weight.

[7] *Maeasured the % of BW that was attributed to the total testis weight.*

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Table 2-6. Regression analysis of wk 23 group for dependant variable: Total testes weight with parameter estimates and standard errors (in parenthesis).

Independent variables	Model 1	Model 2
Principle component one	1.40 *** (0.068)	-
Principle component two	-2.32 *** (0.135)	-
Principle component three	0.763 *** (0.153)	-
Keel 10	-	-0.367 ** (0.128)
BW wk15	-	0.014 *** (0.002)
R squared	0.944	0.481
Number of observations	48	48

* Indicates significance at p <0.05.

** Indicates significance at p 0.01.

*** Indicates significance at p <.0001.

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Table 2-7. Regression analysis of wk 23 group for dependant variable: Final BW with parameter estimates and standard errors (in parenthesis).

Independent variables	Model 1	Model 2
Principle component one	174.1 *** (9.20)	-
Principle component two	-28.0 (18.4)	-
Principle component three	-37.7 (20.8)	-
Length 0[1]	-	-147.8 ** (56.1)
BW wk10	-	-1.65 *** (0.265)
BW wk 15	-	2.53 *** (0.157)
R squared	0.892	0.943
Number of observations	48	48

[1] Length of chick at hatch.

* Indicates significance at *p* <0.05.

** Indicates significance at *p* 0.01.

*** Indicates significance at *p* <.0001.

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Table 2-8. Regression analysis of wk 30 for dependant variable: Total testis weight with parameter estimates and standard errors (in parenthesis).

Independent variables	Model 1	Model 2
Principle component one	1.73 *** (0.070)	-
Principle component two	4.94 *** (0.127)	-
Principle component three	1.25 *** (0.174)	-
BW 0	-	-1.52 (0.77)
Length 0 [1]	-	9.95 ** (3.82)
R squared	0.984	0.185
Number of observations	39	40

[1] Length of chick at hatch.

* Indicates significance at p <0.05.

** Indicates significance at p 0.01.

*** Indicates significance at p <.0001.

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Table 2-9. Regression analysis of wk 30 group for dependant variable: Final BW with parameter estimates and standard errors (in parenthesis).

Independent variables	Model 1	Model 2
Principle component one	152.4 *** (15.3)	-
Principle component two	32.5 (27.7)	-
Principle component three	10.0 (37.9)	-
Length 0[1]	-	308.9 * (140.9)
BW wk 5	-	-3.44 ** (1.02)
BW wk 10	-	2.27 *** (0.496)
Keel length wk 10	-	48.4 * (20.0)
R squared	0.743	0.611
Number of observations	39	39

[1] Length of chick at hatch.

* Indicates significance at p <0.05.

** Indicates significance at p 0.01.

*** Indicates significance at p <.0001.

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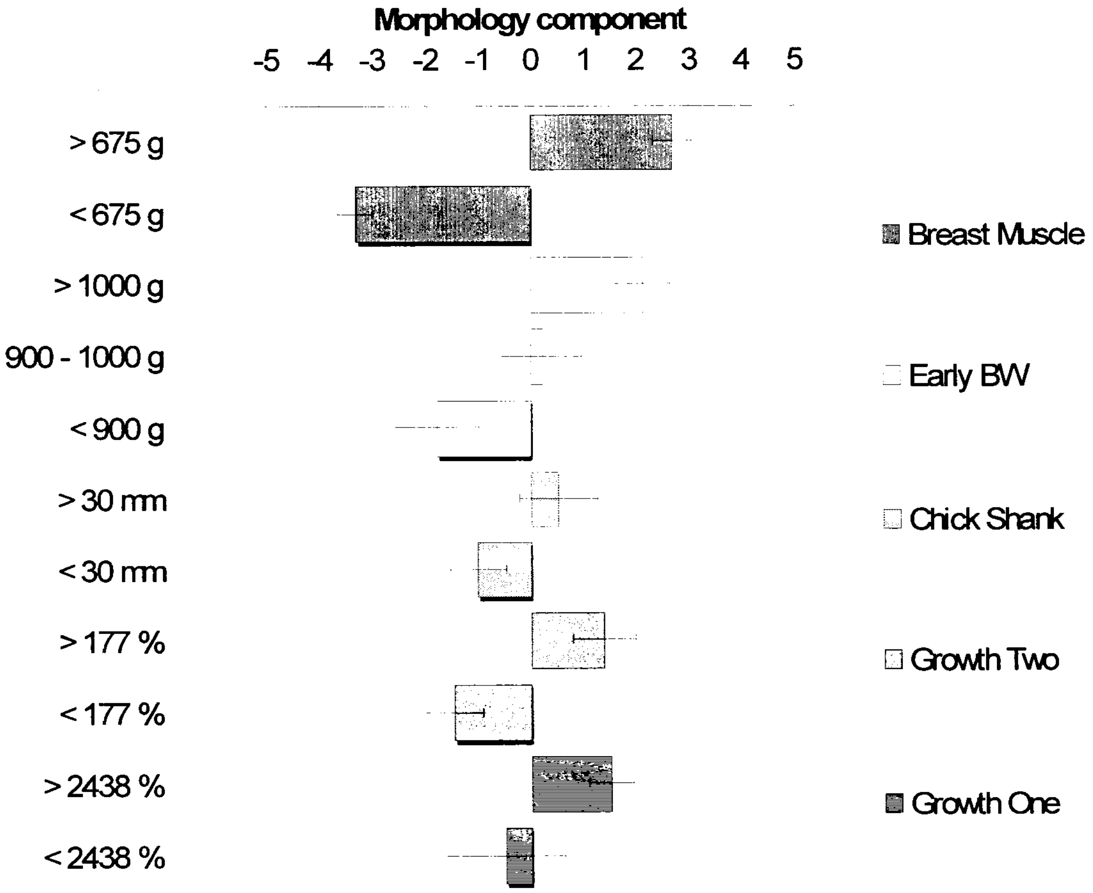

Figure 2-1. Mean 1 PC (morphology) scores for 5 independent category variables and standard error bars for 23 wks.

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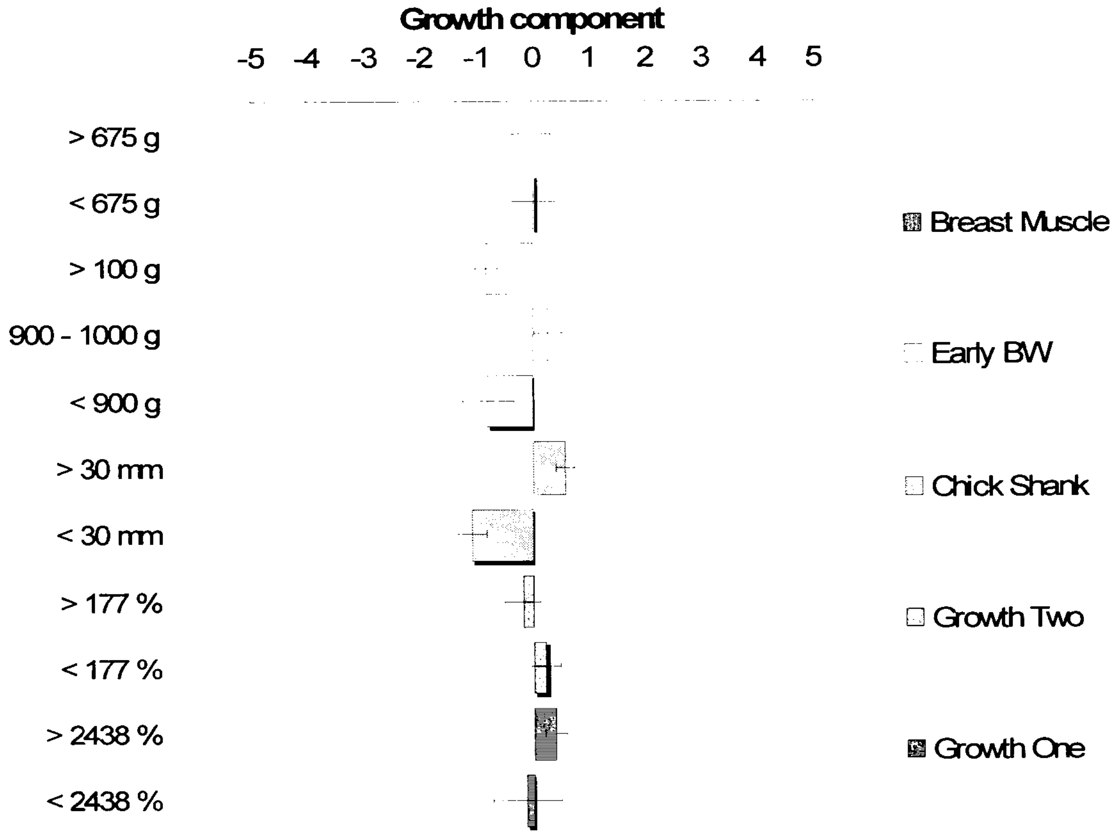

Figure 2-2. Mean PC 2 (growth) scores for 5 independent category variables and standard error bars for 23 wks.

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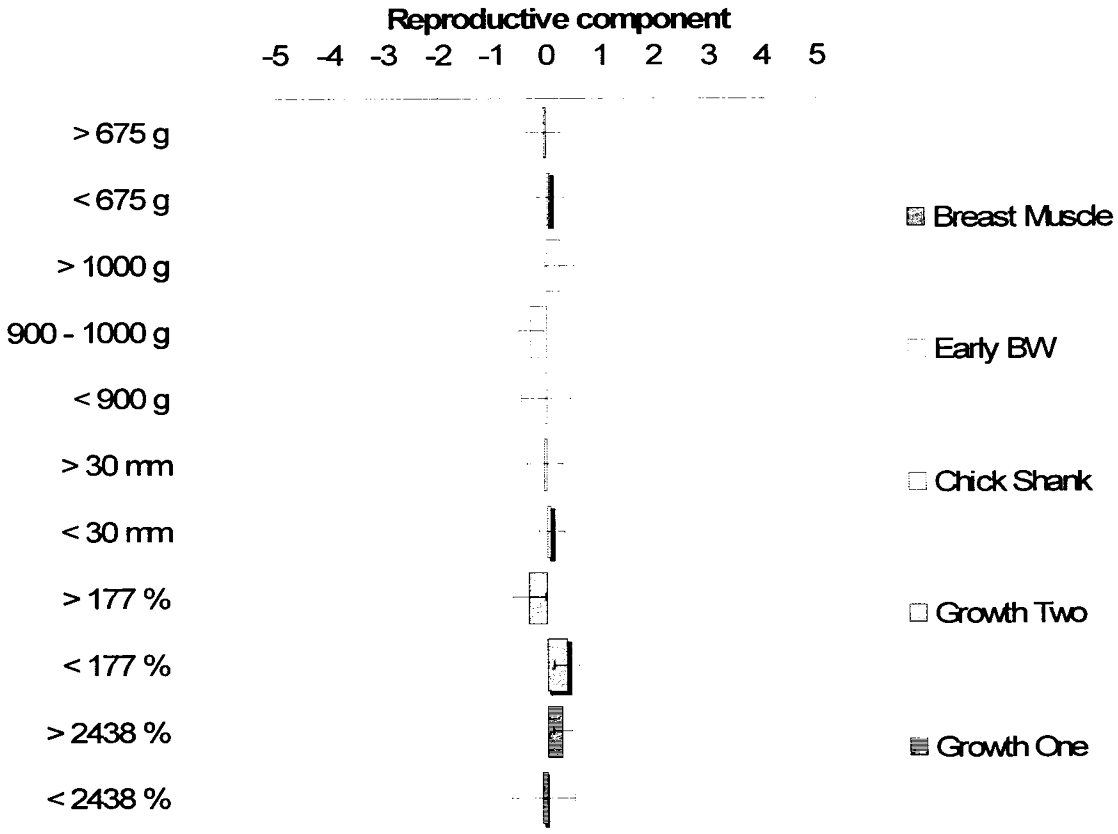

Figure 2-3. Mean PC 3 (reproductive) scores for 5 independent category variables and standard error bars for 23 wks.

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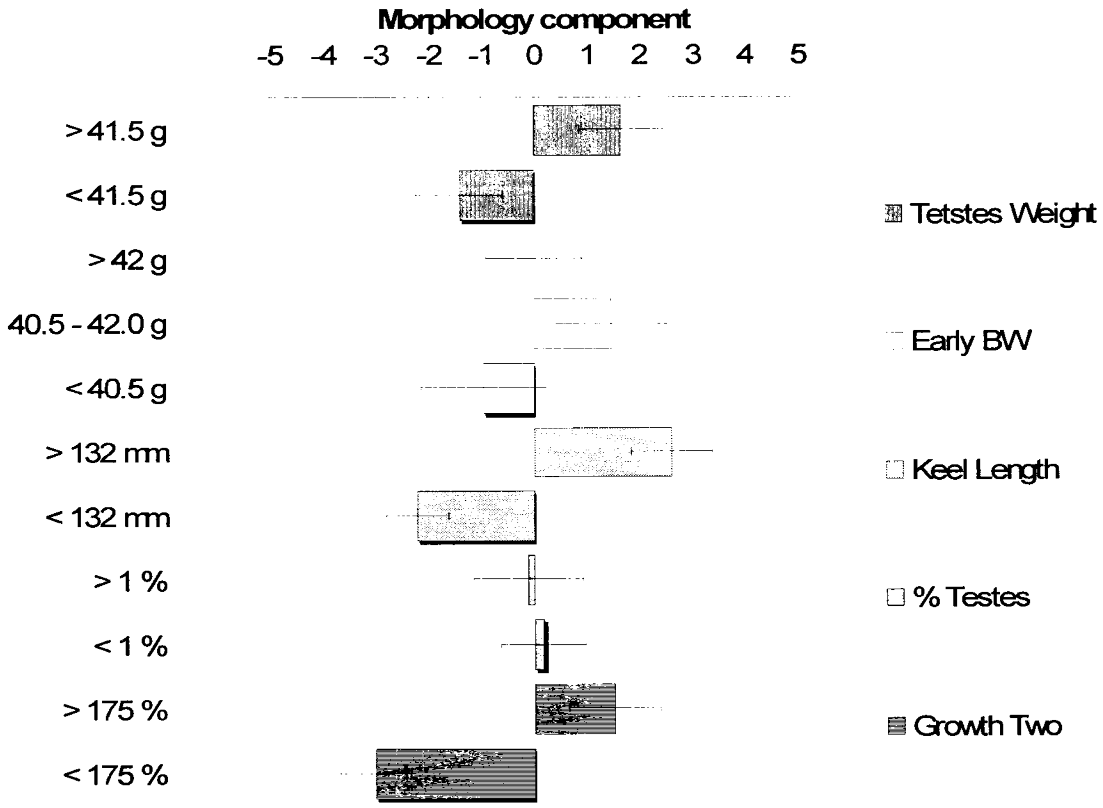

Figure 2-4. Mean PC 1 (morphology) scores for 5 independent category variables and standard error bars for 30 wks.

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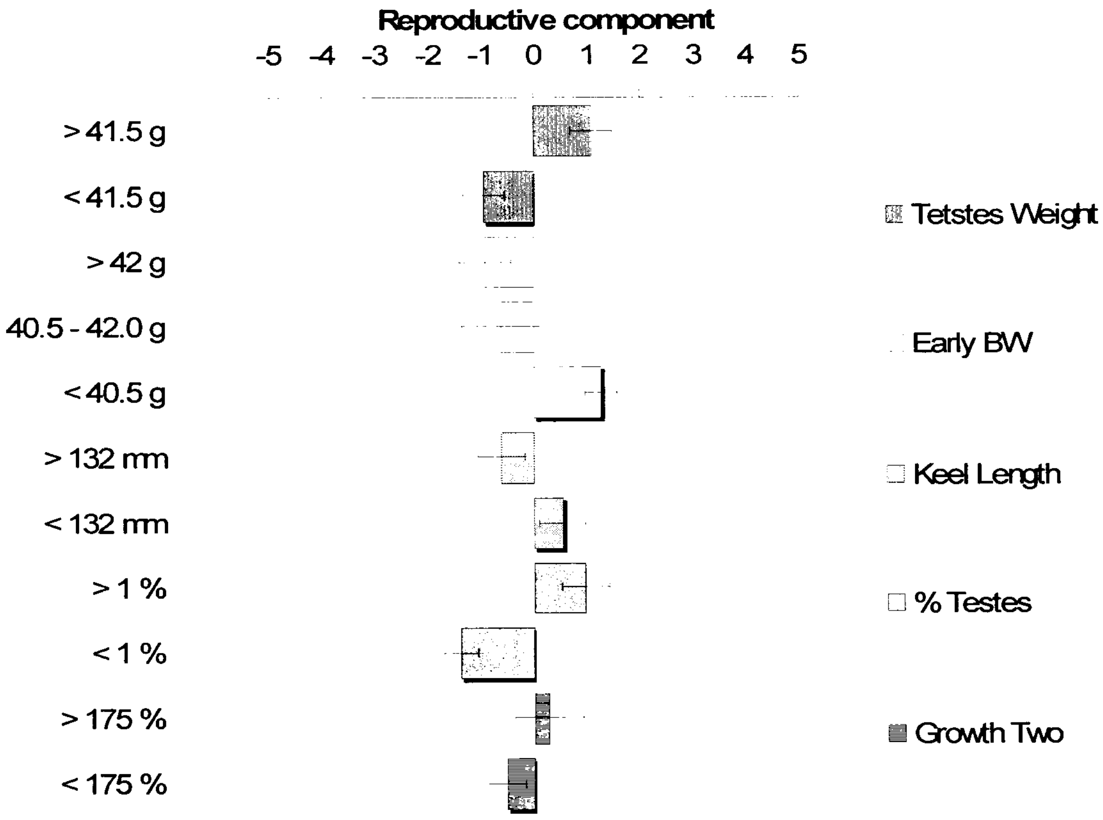

Figure 2-5. Mean PC 2 (reproduction) scores for 5 independent category variables and standard error bars for 30 wks.

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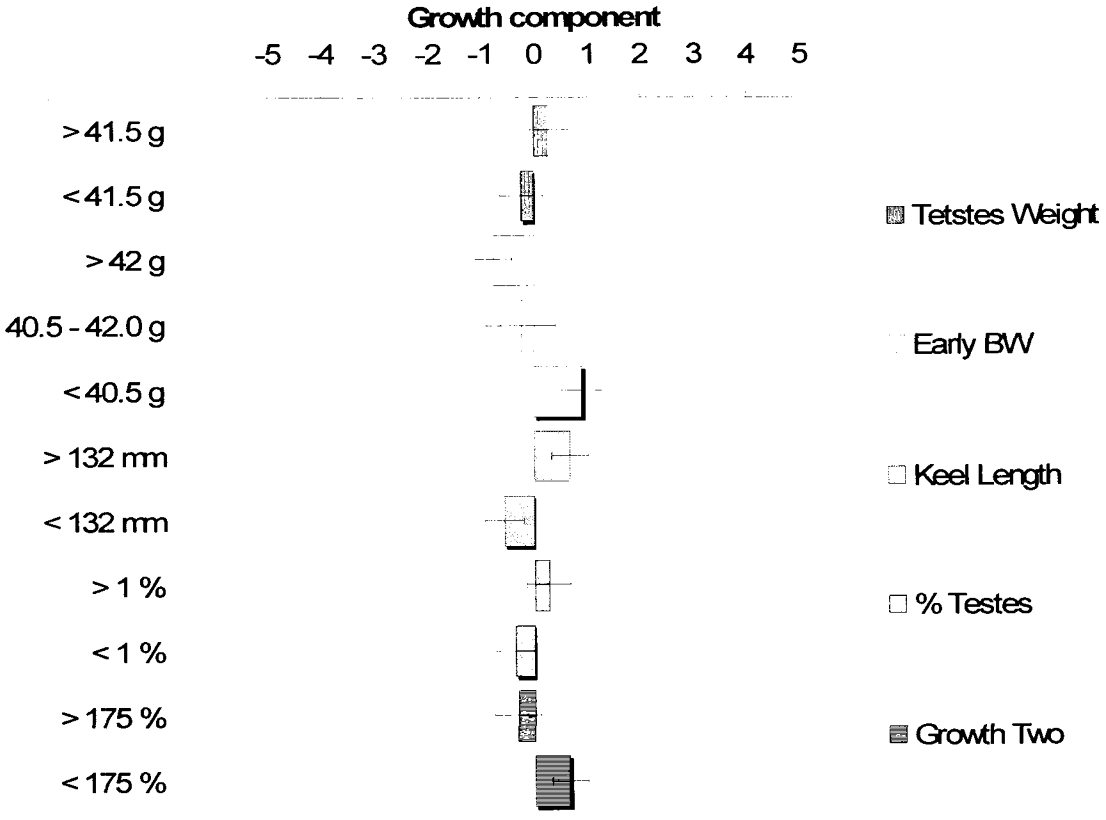

Figure 2-6. Mean PC 3 (growth) scores for 5 independent category variables and standard error bars for 30 wks.

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3.0 Relationships among growth characteristics, morphological characteristics and the behaviours expressed towards flock mates by commercial male broiler breeders.

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Key words: Male Behaviour, Aggression, Growth, and Reproductive Quality.

3.1 Introduction

Male broiler breeder behaviour, growth patterns and testicular weight influence the fertility of broiler breeder flocks (Adkins-Regan, 1995, Emmerson, 1997, Singh, 1999, Millman and Duncan 2000a, McGary et al., 2002 McGary et al., 2003).

In the investigation of the relationship between frame size with testes size, Barbato (1999) found that meat type birds that were consistently selected for small frame size over several generations had smaller testes. In a commercial setting, small roosters are the most likely to be culled as they are seen to be inferior in quality. Amann (1999) indicated that the genes regulating testes size and function are 'loosely' linked to the genes regulating body conformation.

In terms of behaviour; McGary et al. (2003) noted that although both reproductive and aggressive behaviours occur infrequently, they can have serious impacts on the reproductive success of a flock. Aggression exhibited by domestic fowl at a specific moment in time is balanced by the potential cost of the aggressive behaviour; specifically the costs of aggression in terms of time, energy and risk of injury relative to the potential benefits in terms of the amount of resource gained (Estevez et al., 2002). This research

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suggested that the benefits of aggressive behaviours outweigh the potential costs. It is unlikely that the behaviours exhibited by male BB can be summarized so simplistically. The welfare of the hens has been brought into question as females have been found to have lacerations to their head, neck and back (Millman and Duncan, 2000a). There is no potential benefit or resource gained from injuring a female. The male BB is actually damaging his potential reproductive success by compromising the health of the female. While the economic impact of having aggressive males has yet to be examined, it is likely that aggressive males are a cost to producers by reducing fertility and from female losses and injuries.

Courtship displays are key elements to the success of domestic flocks. Millman et al. (2000) described the deficiencies in BB courtship displays. Compared to laying strain males, BB are significantly less likely to perform behaviours such as tid bitting (ground pecking) and high step advance. In Japanese quail, Adkins-Regan (1995) suggested that forced copulations are as effective in fertilising eggs as regular mutual copulations. Therefore forced copulations may be a viable reproductive strategy for male broiler breeders. When Domjan et al. (2003) measured the efficiency of male copulatory behaviour; they found that higher copulatory efficiency scores reflected fewer interruptions of the grab-mount-cloacal contact response sequence. Also McGary et al. (2003) noted that forced matings did not seem to be associated with an improvement in fertility levels. This suggests that fewer forced matings

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would be more efficient in regards to fertility of the flock and would likely be less stressful than forced matings to hens.

3.2 Materials and Methods

3.3 Animal Husbandry

This experiment was conducted in accordance with the Guidelines for the Care and Use of Animals in Agricultural Research and Teaching (Canadian Council on Animal Care, 1984). A total of 600 BB Ross 308 eggs were obtained from a primary breeding company (Aviagen North America, Huntsville, AL) and incubated at a commercial hatchery (Lilydale Hatchery, Calgary, AB).

On the day of hatch (d 0) male chicks were tagged and the length of chick and chick weight was recorded. Chicks were separated by sex and randomly placed in straw bedded pens (2.25 m x 5.5 m) with starter diet (Table 3-1) and unlimited access to water. For the first 3 d chicks were exposed to continuous light at 30 lux. At d 4 chicks were exposed to 8 h of light and 16 h of dark at 10 lux and remained on this light schedule until photo stimulation occurred.

At wk 5, male BW were recorded. At wk 10, 15 and 20 males had their keel length (mm), breast girth (mm), right shank length (mm) and weights measured. Birds were group weighed once every wk during rearing to determine appropriate feed allocation.

Males were weighed at wk 20 and placed into weight groups based on their BW weights: small males (average 2.2 kg), medium males (average 3.2 kg) and heavy BW males (average 4.2 kg). At wk 24, 24 males were

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randomly placed by BW in 8 light controlled rooms with 3 males and 30 hens per room. The remainder of males were placed in individual cages (60 cages) and one group cage for spare males (12 males). At photo stimulation (wk 24) birds were exposed to 14 h of light (74 lux) and ten h of dark. At wk 27 birds were exposed to 16 h of light at (74 lux) for every 24 h period.

Males were placed in the rooms at 4 wk intervals based on BW to record behaviour. Average BW rooms (4) housed 3 males that were as close to the overall male BW average for that wk as possible. The other 4 rooms housed both 1 male below and above the overall male BW average for that wk as well as a close to average BW male. The first 4 rooms were to represent the social situation of males with similar BW and the last 4 rooms were to represent the social situation of males with different BW. Males that were in obvious distress (broken leg, broken wing, starve outs, etc.) were humanely euthanized by cervical dislocation. Males in the rooms (4.75m x 4m) were identified with one of 3 colours sprayed on their backs (green, blue or orange).

Males were killed via cervical dislocation at wk 58 and the breast muscle (*Pectoralis (P) major and P. minor*), fat pad, liver and testis (right and left) were dissected and weighed.

3.4 Digital Video Equipment and Behaviour

Male to male and male to female behaviours were recorded in each room by a Minton^{TM} (Taipei, Taiwan) 63V1H high resolution, colour, 'Starlight' camera with wide-angle lens. These cameras were chosen based on their frame integration and light sensitivity (minimum illumination required is 0.003

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Lux). Camera output was fed into 2 Sentry SMD-04 Digital Video Recorders (Kingston, Ontario) 4 cameras per recorder.

Video was recorded in an MPEG 2 format and saved on the Hard Drive of the Digital Video Recorder. Files were transferred to the hard drive of a central computer. Files were also viewed on 2 television screens. Behaviour was recorded using hard drives from wk 24 to 40. A technical failure with the hard drives made file retrieval impossible and the use of the hard drive was discontinued. From wk 42 to 58, behaviour was recorded using 8 video recorders (VCR).

Male behaviour was recorded on the first and last day of each 4 wk period. Males were placed in the rooms once every 4 wk during the evening before the lights went out. Videos from 3 separate 4 wk periods were analysed using Rooster Spy software developed at the University of Alberta. The system for recording behaviour used by McGary and Estevez (2003) was used as a base to develop Rooster Spy software. Rooster Spy software coded male to male and male to female interactions as presented in Figure 3-1 and 3-2.

The behaviours that were considered of interest for this study were the number of and severity of: male to male dominance encounters, male to female dominance encounters, male to male submissive encounters, and the number of and success of male to female mating encounters. A behavioural interaction was considered to be an ‘encounter’ when it lasted for more than 3

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s and was considered to have ended when no behaviour was expressed towards another individual for 30 s.

The act of one male causing another male to move away from the original male (physically or through presence alone) was recorded as male to male dominance interaction score. The act of one male moving away from another male was recorded as male to male submission interaction score (identifies the male that 'loses'). The level of dominance expressed by males during a mating encounter was called male to female dominance interaction score. The success or failed attempt at mating was called male to female mating score. The scores in each behaviour category were added together to get a cumulative behaviour score for all the categories at the start and end of each cycle.

3.5 Statistical Analyses

Data were analysed as a one-way ANOVA using the GLM procedures of SAS and means were separated using the PDIFF *t*-test procedure (SAS System, 2002). Regressions were calculated between variables of interest. The bird was the experimental unit. Significance was assessed at $P < 0.05$.

A principal component (PC) analysis was used to determine which of the measured variables are associated with each other. The underlying concept that each PC represents may lead to a better understanding of the performance of broiler breeder males. The proportion of the total variation that is explained by each PC will suggest the relative power of each PC in understanding male broiler breeder performance.

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3.6 Results and Discussion

3.7 Frequency Distribution

The frequency distributions of the behavioural parameters are presented in Figures 3-3 through 3-8. Looking at the effect of time on the frequency distributions, a general trend of a reduction in both the frequency and intensity of behaviours can be seen (Figures 3-3 through 3-8).

Figure 3-3a shows that during the start of the time periods, males had cumulative scores ranging from 12 to 102 and males were evenly distributed along the bottom axis. Looking at the end period for male to male dominance interactions (Figure 3-3b) all of the male scores have decreased in the cumulative dominance interaction score over time. Male BB had smaller dominance interaction scores over time indicating male BB formed a socially stable hierarchy.

The same trend is seen in the number of male to male encounters (Figure 3-4a and 3-4b). The number of male to male encounters decreased over time with the majority of males at the end of cycle having less than 2 encounters.

Figures 3-5a and b illustrate that the cumulative male to male interaction score also decreased over time. The majority of males have a score below 19 points and in the start of the time period scores ranged from 4 points to 115 points. Looking at figure 3-12 shows how the cumulative male to male aggression score decreased over time from the start of a cycle to the end of a cycle over three four wk cycles.

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The frequency distribution of male to female cumulative mating scores (Figure 3-6a and 3-6b) shows that males decreased their cumulative scores over time. The same trend is seen in the number of male to female mating encounters. The majority of males had fewer mating encounters by the end of the cycle (Figure 3-7b).

Looking at the intensity of dominance expressed by males towards females during mating (Figures 3-8a and 3-8b) it can be seen that the cumulative dominance interaction scores also decline over time. Taken together with the decrease in the number of male to female mating encounters (Figure 3-7a and 3-7b) this suggests that the level of dominance males express towards females doesn't decrease all that much over time although the number of male to female encounters does decrease over time.

3.8 Principal Components

The purpose of PC scores is to identify performance trends among broiler breeder males in small family group situations. The underlying concept that each PC represents may lead to a better understanding of male broiler breeder performance in small family group situations. The proportion of the total variation that is explained by each PC will indicate the relative power of each PC in understanding male broiler breeder performance in small family group situations. A mean PC score was determined for PC 1, 2, and 3. In Figures 3-9, 3-10 and 3-11 these mean PC scores for PC 1 (morphology), PC 2 (social dynamic), and PC 3 (pecking order), respectively, have been charted for the following 5 category variable: final BW, male submission, day, early BW, and male dominance.

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To provide an overview of the study parameters, a summary of the means and SD of the variables used in the PC analysis is reported in Table 3-2. The 3 PC explained approximately 39 % of the variation in performance (Table 3-3). The variables that explained a significant amount of variation in each PC are highlighted in Table 3-3.

The PC1, which explained 19.7 % of the total variation, had the strongest association with the measured variables: BW wk 10, shank wk 10, keel wk 10 and BW wk 15. Morphology was the subjective descriptor chosen for this component. Behavioural variables were not strongly associated with PC1 suggesting that behaviour later in life was not affected by growth patterns. The scores for the variables in Figure 3-9 show that the early BW variable categories were significantly different from each other as indicated by the standard error of the mean (SEM) bars. The early BW variable indicates that males in the < 2800 g category were likely to have been small in regards to their overall morphology and large if they were in the > 3400 g category. These results make sense in terms of morphology, as a large BW male is likely to have a larger girth, keel, etc. and a smaller male likely to have smaller measurements. The male dominance variable categories were also significantly different from each other although not as strong of scores as the early BW categories. The directional trends in Figure 3-9 indicate that larger males in early BW (> 3400 g) were more likely to be dominant males (> 25 points) and small males in early BW (< 2800 g) were more likely to be submissive males (< 20 points).

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The PC 2, which described 10.5 % of the variation, correlated positively with behavioural variables such as male to male dominance encounters, male to male dominance scores, male to female dominance encounters and male to female dominance scores. Social dynamic was the subjective descriptor chosen for PC 2. Day associated negatively with PC 2 indicating that as day increases behaviour variables decrease. Figure 3-10 shows the social dynamic component (PC 2) and included the behavioural variable categories (male dominance and male submission) as well as final BW and day variable categories were significantly different. In the case of the early BW variable categories the < 2800 g category was significantly different from the other two BW categories. Examination of the trends expressed in Figure 3-10 for the middle category indicates that early BW males scored higher on the social dynamic component than the other two categories. The initial day of cycle variable category also scored higher on the social dynamic component than the final day of cycle category. This is fitting considering that there was a decrease in the number of encounters in all behavioural variables in the frequency distributions. Interestingly, males that were > 4500 g at final BW scored higher on the social dynamic component than males that were < 4500 g. This suggests that males who end up heavy (> 4500 g) are more likely to be dominant than those who end up small (< 4500 g).

The PC 3, which accounted for 8.7 % of the variation, was positively correlated with BW wk 58, breast muscle weight at wk 58, length of chick at day of hatch and shank length of chick at hatch. Pecking order was the

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subjective descriptor chosen for the third PC. Figure 3-11 shows that the male dominance, male submission and day variable categories were all significantly different from each other. Looking at the directional trends in Figure 3-11 males that were in the smaller early BW category were more likely to be less dominant and more likely to be submissive than the males in the other early BW categories.

3.9 Regression Analyses

Regressions were calculated using the PC scores from PC 1, 2 and 3 and other variables of interest. The regressions of interest are shown in Tables 3-4 to 3-6. Model 1 in Tables 3-4 to 3-6 were run as a check to ensure that the PCs were relating to the data as expected. Not surprisingly the PCs in the model 1 were able to explain some if not all of the variation seen in the data. This was as anticipated, as the dependant variable in Tables 3-4 and 3-6 were also independent variables in the PC analysis. In the second regression model in Table 3-4 the variables of significant interest for male to male dominance scores were day ($p < .0001$) and entrance BW ($p < 0.01$). These variables jointly explain 54.3% of the variation seen in male to male dominance scores, as indicated by the R-square value. Model (2) shows that males at the start of a cycle were likely to have 34.02 (parameter estimate x # of days) more aggression points than at the end of the cycle,and that the heavier BW males at the start of a cycle were more likely to be aggressive than lighter weight males.

The second regression model for Table 3-5 shows that day ($p < .0001$) and BW wk5 ($p < 0.01$) were significant in explaining male-to-male submission

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scores.. These variables jointly explained 47.9% of the variation seen in the dependent variable. As in the model of aggression points shown in Table 3-4, day is a significant factor in the male to male submission score. Males were more likely to be submissive at the end of a cycle than at the start of a cycle. The interesting association between BW wk 5 and male to male submission score in table 3-5 suggests that a link between early physiology and behaviour may exist. This possible morphological indicator merits further study.

The significance of the models (2) in table 3-4 and 3-5 indicates that the behaviours seen in this experiment were strongly associated with the amount of time male BB spent with their male flock mates. The longer male BB were in their environment they less likely they were to be dominant or submissive with other males.

Model (2) in table 3-6 shows that male to male dominance and male to male submission scores were significant variables in explaining the variation seen in male to female dominance scores. Model (2) explained 15.7 % of the variation seen in male to female dominance interaction scores. This suggests that males with higher male to male interaction scores (both dominance and submission) are more likely to be aggressive with females. It is interesting that both dominant and submissive males are likely to be aggressive towards female flock mates. It appears that male position in social hierarchy does not affect the outcome of male attitude towards females. The effect of day was not found to be a significant variable in the model. This suggests that day or

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length of time spent with females does not reduce the level of aggression displayed towards them.

The models in Tables 3-7 and 3-8 were estimated to examine whether the age of the flock (as proxied by the cycle of the experiment) helped explain male to male aggression scores or number of encounters. In both cases, the day of the cycle continues to be significant (as in the models above), but cycle is not. It appears that the amount of time male birds spent together was more important than the age of the male in determining the level and number of aggressive encounters.

3.10 Discussion

There was no effect of treatment (room type) or of cycle (age) however the entrance BW was a significant variable for the male to male dominance scores suggesting that size or BW likely plays a role in determining social hierarchy.

This study evaluated if there were any links between early growth characteristics of BB males and the behaviours they expressed in the breeding barn as well as exploring connections between behaviours and final morphology. In this experiment the behaviours expressed by males in the breeding barn could not be satisfactorily predicted by the characteristics they exhibited during rearing. This study like Duncan et al. (1990) and Bilcik and Estevez (2005), found a lack of association between behaviour, morphological traits and broiler breeder success.

It is difficult to replicate the conditions male BB face in a breeder barn in an experimental setting, where typical commercial BB farms house

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between 5,000 and 20,000 birds. The smaller numbers of birds in the current study may not provide similar results to what may occur under commercial conditions. However unlike Millman et al. (2000) who found extreme levels of aggression in small groups of males this study shows that small groups of males can form stable social groups. It is to be noted as well that the stocking density in the current study (1 male for every 10 females) was the same as recommended on commercial farms.

The model (2) in Table 3-6 furthers the idea that aggression towards females does not diminish with sexual experience or with familiarity with individual females (Millman and Duncan, 2000b). However it should be noted that all of the males spent at least one month away from the hens in individual cages between cycles. It is possible that the time away from females may have led to an increase in the level of aggression expressed when they were returned to the mixed gender groups. According to Millman et al. (2000) male aggression peaks at 5 wk following mixing or 27 wk of age and males will continue to behave aggressively throughout the life of the flock. The behaviour displayed by the males in this study suggests that the aggression males display at the start of a four wk cycle is significantly less than they display at the end of that cycle. However more recently McGary *et al.* (2003) reported that as males increased in age the frequency of forced matings and aggression decreased. Unlike Millman and Duncan (2000b) and Millman et al. (2000), this study found that the frequency and intensity of male to male dominance interactions decreased significantly over time in all 3 cycles. The

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frequency and intensity of interactions were not significantly different between the cycles suggesting that the intensities of behaviours expressed were not related to the age of the males.

A birds' desire to express behavioural patterns can be strongly motivated, and if they are refused expression, the birds' welfare may be compromised (Duncan, 1998). It is likely that males in this experiment could quickly adjust and adhere to the social pecking order in their chambers. This experiment was unlike a breeding barn where males are constantly exposed to 'new' males and females. The birds in this study were able to form a stable group and a stable pecking order.

Two explanations for the increased aggressive behaviours displayed by male BB are that they are failing to adequately dominate female BB and that the large size of BB males may incite fearfulness (Millman and Duncan, 2000b). The female BB in this experiment were very curious and would readily approach human handlers and the males exhibited dominance behaviours towards females such as chasing females away from feeders.

The decrease in dominance towards other males and females by males over time suggests that the aggression problems reported by producers may be more of an environmental problem than a behavioural or genetic problem. This study proves that today's commercial BB male is capable of forming social relationships and relatively stable pecking orders when placed in groups of 33 birds. The problems producers have reported may be related to the male BB's reaction to a socially overwhelming situation

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of large flocks of several thousand birds and the inability to form stable social hierarchies. Further work is needed to determine how well the results of small-scale behavioural studies can be applied to potential results under large-scale, commercial conditions.

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Table 3-1. Composition and analysis of experimental diets

Ingredient and analysis	Starter (0 to 4 wk)	Grower (4 to 22 wk)	Breeder (22 to 58 wk)
	----------------------	(%)	----------------
Ground corn	14.14	16.44	41.51
Wheat	44.23	34.42	25.29
Soybean meal (44% CP)	17.34	7.37	18.78
Oats	5.00	12.50	--
Barley	5.00	10.00	--
Canola oil	2.00	0.70	1.63
Wheat shorts	7.50	15.00	--
Corn gluten meal	--	--	1.50
Ground limestone	1.65	1.72	7.93
Dicalcium phosphate	1.58	0.86	1.80
Choline chloride premix[2]	0.50	0.50	0.50
Broiler premix	0.50	0.50	--
Layer premix[3]	--	--	0.50
Salt	0.38	0.33	0.41
D, L-methionine	0.141	0.125	0.094
L-lysine	0.031	0.162	-
Avizyme	--	0.05	0.05
Amprol	0.05	--	--
Zinc bacitracin	--	0.05	--
Calculated nutrient composition			
CP (%)	18.2	15.1	16.0
ME (kcal/kg)	2,782	2,711	2,830
Calcium (%)	1.0	0.88	3.5
Available phosphorus (%)	0.47	0.32	0.45
Lysine (%)	0.83	0.72	0.75
Methionine (%)	0.41	0.34	0.36

[1] Provided choline chloride in the diet at a level of 100 mg/kg.

[2] Broiler premix provided per kilogram of diet: vitamin A (retinyl acetate), 10,000 IU; cholecalciferol, 2,500 IU; vitamin E (DL-α-tocopheryl acetate), 35 IU; vitamin K, 2.0 mg; pantothenic acid, 14 mg; riboflavin, 5.0 mg; folacin, 0.8 mg; niacin, 65 mg; thiamine, 2.0 mg; pyridoxine, 4.0 mg; vitamin B12, 0.015 mg; biotin, 0.18 mg; iodine, 0.5 mg; Mn, 70 mg; Cu, 8.5 mg; Zn, 80 mg, Se, 0.1 mg; Fe, 100 mg.

[3] Layer premix provided per kilogram of diet: vitamin A (retinyl acetate), 12,000 IU; cholecalciferol, 3,000 IU; vitamin E (DL-α-tocopheryl acetate), 40 IU; vitamin K, 2.0 mg; pantothenic acid, 14 mg; riboflavin, 6.5 mg; folacin, 1.0 mg; niacin, 40 mg; thiamine, 3.3 mg; pyridoxine, 6.0 mg; vitamin B12, 0.02 mg; biotin, 0.2 mg; iodine, 0.5 mg; Mn, 75 mg; Cu, 15 mg; Zn, 80 mg, Se, 0.1 mg; Fe, 100 mg.

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Table 3-2. Measured variables that attributed to the performance of 72 commercial male broiler breeders during three 4-wk cycles of two observation periods (mean and SD of measured variables).

Variable	Age (wk)	Mean	SD
Cycle entrance BW[1] (g)		4.36	0.42
Change in BW during cycle[2] (g)		0.04	0.52
Male to male dominance interaction score[3]		25.3	23.9
Number of male to male dominance encounters[4]		8.91	8.21
Male to male submission interaction score[5]		23.6	24.2
Male to female interaction score[6]		18.0	15.3
Number of male to female encounters[7]		5.66	4.58
Male to female dominance interaction score[8]		13.2	11.9
Length of chick (cm)[9]	0	19.5	0.48
BW (g)	0	41.6	3.02
	5	894.7	90.9
	10	1614	138.0
	15	2489	194.4
	20	3065	269.9
	58[10]	4587	424.8
Shank length (cm)[11]	0	30.4	0.93
	10	102.7	3.66
	15	122.7	4.91
	20	130.3	4.15
Keel length (cm)[12]	10	131.9	5.63
	15	159.5	6.31
	20	173.5	7.59
Width of breast (cm)[13]	10	61.6	3.72
	15	65.4	5.03
	20	75.7	6.86
Girth of breast (cm)[14]	10	29.4	1.65
	15	32.6	1.37
	20	35.0	2.04
Index toe length (cm)[15]	58	65.9	3.98
Second toe length (cm)[16]	58	43.5	3.28
Breast muscle weight (g)[17]	58	767.1	147.1
Fat pad weight (g)	58	1.73	2.63
Right and left testis weight (g)	58	24.3	9.14
Liver weight (g)	58	57.7	12.6

---

[1] BW of the male on first day of cycle.
[2] Change in BW of the male from the first day to the last day of the cycle.
[3] Male to male dominance score is the sum total of the dominance interactions between males over a cycle.
[4] Number of male dominance encounters over a cycle.
[5] Male to male submission score is the sum total of submission interactions between males over a cycle.

[6] Male to female interaction score is the sum total of successful and attempted mating interactions.
[7] Number of male to female encounters over a cycle.

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[8] Male to female dominance interaction is the dominance expressed by the male during successful and attempted mating interactions.
[9] Measured from the tip of the bird's beak to the end of the middle toe (not including the nail).
[10] Measured on last day of the experiment.
[11] Measured from the top of the hock joint to the top of the footpad.
[12] Measured from the hypocleido-clavical joint to the caudal end of the sternum.
[13] Measured across the hypocleido-clavical joint.
[14] Measured around the hypocleido-clavical joint.
[15] Measured from the bottom of the foot pad to the end of the of the middle toe (not including the nail).
[16] Measured from the bottom of the footpad to the end of the second toe (not including the nail).
[17] Measurement includes the combined weights of *P. major and P. minor.*

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Table 3-3. Values between measured variables and principal components (PC). Values used to load each PC are shown in bold.

PC descriptor	PC1 Morphology	PC2 Social dynamic	PC3 Pecking order
Variation explained by PC	19.7%	10.5%	8.7%
Day[1]	-0.0007	**-0.3397**	0.1640
Change in BW (g)[2]	-0.0550	0.0929	**0.2205**
Male to male dominance interaction score[3]	0.0407	**0.3815**	-0.0917
Number of male to male dominance encounters[4]	0.0591	**0.3607**	-0.1012
Male to female interaction score[5]	-0.0441	**0.3347**	-0.0971
Number of male to female encounters[6]	-0.0386	**0.3684**	-0.1093
Male to female dominance interaction score[7]	-0.0570	**0.3732**	-0.1009
Length of chick at day zero (cm)[8]	0.0897	0.0641	**0.2624**
Shank length at day zero (cm)[9]	0.1003	0.0664	**0.2621**
BW at wk 10 (g)	**0.307**	0.0026	-0.0744
Shank length at wk 10 (cm)	**0.2820**	0.0720	0.0119
Keel length at wk 10 (cm)[10]	**0.2871**	-0.0774	-0.1316
Girth of breast at wk 10 (cm)[11]	0.2018	-0.0384	**-0.2125**
BW at wk 15 (g)	**0.3241**	0.0019	0.0341
Keel length at wk 15 (cm)	**0.2693**	-0.0708	-0.0051
BW at wk 20 (g)	**0.2731**	0.0162	0.0957
BW at wk 58 (g)	0.0227	0.1721	**0.4535**
Breast muscle weight at wk 58 (g)[12]	0.0209	0.1721	**0.3633**

[1] Day indicates either the first or last day of the four wk observation period.
[2] Change in BW of the male from the first day to the last day of the cycle.
[3] Male to male dominance score is the sum total of the dominance interactions between males over a cycle.
[4] Number of male dominance encounters over a cycle.
[5] Male to female interaction score is the sum total of successful and attempted mating interactions.
[6] Number of male to female encounters over a cycle.
[7] Male to female dominance interaction is the dominance expressed by the male during successful and attempted mating interactions.
[8] Measured from the tip of the bird's beak to the end of the middle toe (not including the nail).
[9] Measured from the top of the hock joint to the top of the footpad.
[10] Measured from the hypocleido-clavical joint to the caudal end of the sternum.
[11] Measured around the hypocleido-clavical joint.
[12] Measurement includes the combined weights of *Pectoralis major and minor.*

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Table 3-4. Regression analysis for dependant variable: Cumulative male to male aggression points with parameter estimates and standard error (in parenthesis).

Independent variables	Model 1	Model 2
Principle component one	1.11* (0.534)	-
Principle component two	5.12 *** (0.688)	-
Principle component three	7.36 *** (0.745)	-
Day[1]	-	-1.26 *** (0.10)
Entrance BW[2]	-	7.94 ** (3.07)
R Square	0.57	0.54
Number of observations	123	143

[1] Day indicates the first and last day of a four week cycle.

[2] Entrance BW is the BW of a male just prior to starting a four week cycle.

* Indicates significance at p <0.05.

** Indicates significance at p 0.01.

*** Indicates significance at p <.0001.

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Table 3-5. Regression analysis for dependant variable: Cumulative male to male submission points with parameter estimates and standard error (in parenthesis).

Independent variables	Model 1	Model 2
Principle component one	-0.81 (0.691)	-
Principle component two	1.68 (0.892)	-
Principle component three	7.17 *** (0.965)	-
Day[1]	-	-1.21 *** (0.110)
BW wk 5	-	-0.04 ** (0.016)
R square	0.34	0.48
Number of observations	123	141

[1] Day indicates the first and last day of a four week cycle.

* Indicates significance at $p < 0.05$.

** Indicates significance at p 0.01.

*** Indicates significance at $p < .0001$.

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Table 3-6. Regression analysis for dependant variable: Cumulative male to female aggression points with parameter estimates and standard errors (in parenthesis).

Independent variables	Model 1	Model 2
Principle component one	-0.52 (0.26)	-
Principle component two	2.08 *** (0.34)	-
Principle component three	4.08 *** (0.36)	-
cumulative male to male submission	-	0.127 ** (0.042)
cumulative male to male aggression points	-	0.10 ** (0.043)
R square	0.58	0.16
Number of observations	123	143

* Indicates significance at $p < 0.05$.

** Indicates significance at p 0.01.

*** Indicates significance at $p < .0001$.

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Table 3-7. Regression analysis for dependant variable cumulative male to male aggression points with parameter estimates and standard errors (in parenthesis).

Independent Variables	Model
Day	-1.25 *** (0.101)
Cycle	-1.25 (1.67)
R square	0.52
Number of observations	143

* Indicates significance at p <0.05.

** Indicates significance at p 0.01.

*** Indicates significance at p <.0001.

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Table 3-8. Regression analysis for dependant variable number of male to male aggression encounters with parameter estimates and standard errors (in parenthesis).

Independent Variables	Model
Day	-0.41 *** (0.036)
Cycle	-0.16 (0.604)
R square	0.48
Number of observations	143

* Indicates significance at p <0.05.

** Indicates significance at p 0.01.

*** Indicates significance at p <.0001.

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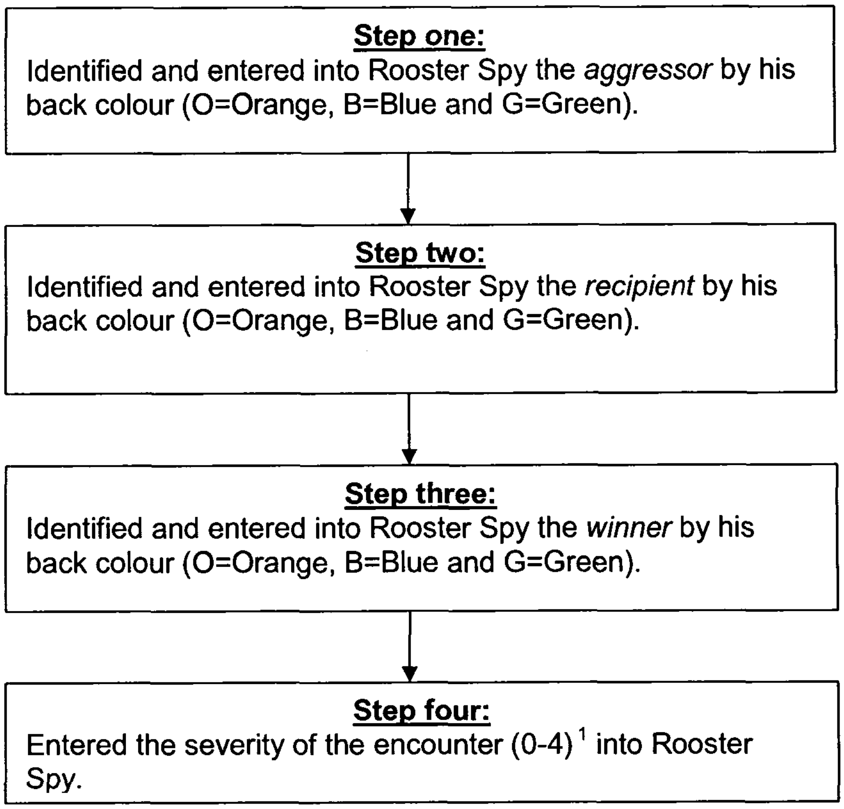

Step one:
Identified and entered into Rooster Spy the *aggressor* by his back colour (O=Orange, B=Blue and G=Green).

Step two:
Identified and entered into Rooster Spy the *recipient* by his back colour (O=Orange, B=Blue and G=Green).

Step three:
Identified and entered into Rooster Spy the *winner* by his back colour (O=Orange, B=Blue and G=Green).

Step four:
Entered the severity of the encounter (0-4)[1] into Rooster Spy.

Figure 3-1. Coding procedure for recording male to male dominance and male to male submission encounters. For every male to male encounter that lasted longer than 3 s the above scoring system was used. An encounter was considered to be over when no action was taken by either rooster for 30 s.

[1] 0=passive encounter, one rooster approached another rooster in passive manner and forced movement/submission by presence alone.
1= rooster one walked towards rooster two with raised body and head posture, second rooster either lowered his head or already had his head lower than the approaching rooster and runs/walked away (at least three steps).
2= rooster one ran at rooster two and rooster two ran away (at least three steps).
3=rooster one ran at rooster two and makes brief contact with the second roosters body.
4=rooster one had a prolonged attack with rooster two (may include multiple frontal jumps, multiple pecks and comb holding).

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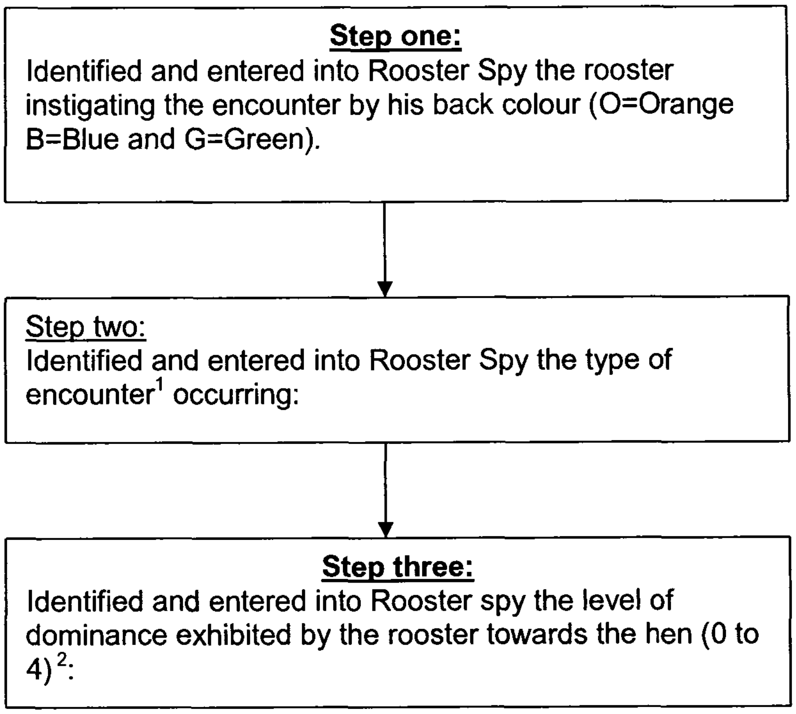

Step one:

Identified and entered into Rooster Spy the rooster instigating the encounter by his back colour (O=Orange B=Blue and G=Green).

Step two:

Identified and entered into Rooster Spy the type of encounter[1] occurring:

Step three:

Identified and entered into Rooster spy the level of dominance exhibited by the rooster towards the hen (0 to 4)[2]:

Figure 3-2. Coding for recording of male to female encounters and dominance expressed during these encounters. For every male to female encounter the above scoring system was used. An encounter was considered to be over when a male turned or walked away from a female.

[1] 1= Complete Mating (symmetry aligned and male deposited sperm
2= Incomplete Mating (symmetry was not aligned/male dismounted before completion)
3= Interrupted Mating: mating was interrupted by another male or by a hen

[2] 0= no aggressive behaviour was expressed
1=male attempted a force mount (non-crouched female)
2=male force mounted a female
3=male force mounted a female and hen was seen struggling against male
4= male chased female (more than two steps) and/or force mounted and/or female was seen struggling against male

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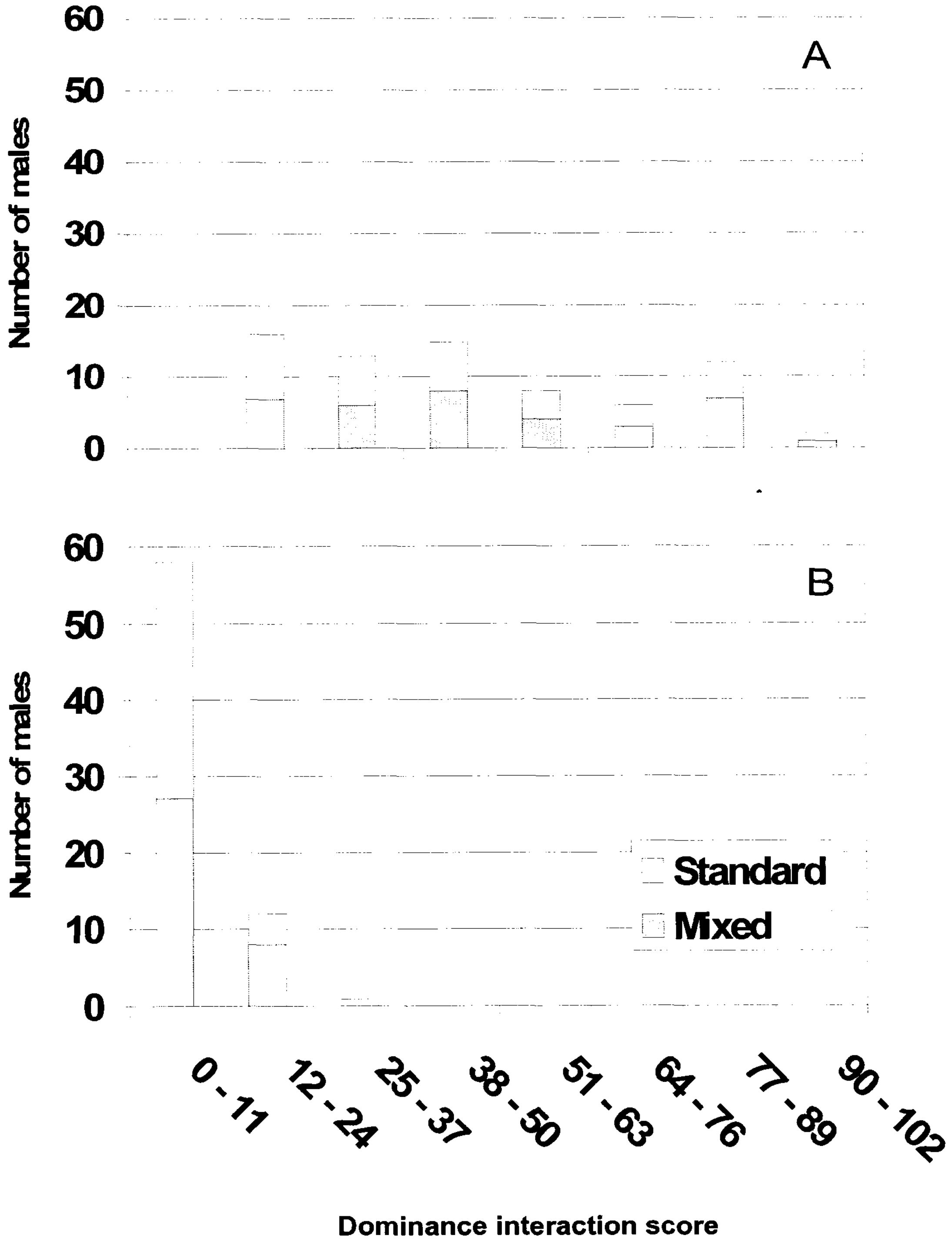

Figure 3-3. Frequency distribution of cumulative male to male dominance interaction score on first (A) and last day (B) of observation period. Male to male dominance interaction score is based on the level of aggression expressed by one male towards another during an encounter.

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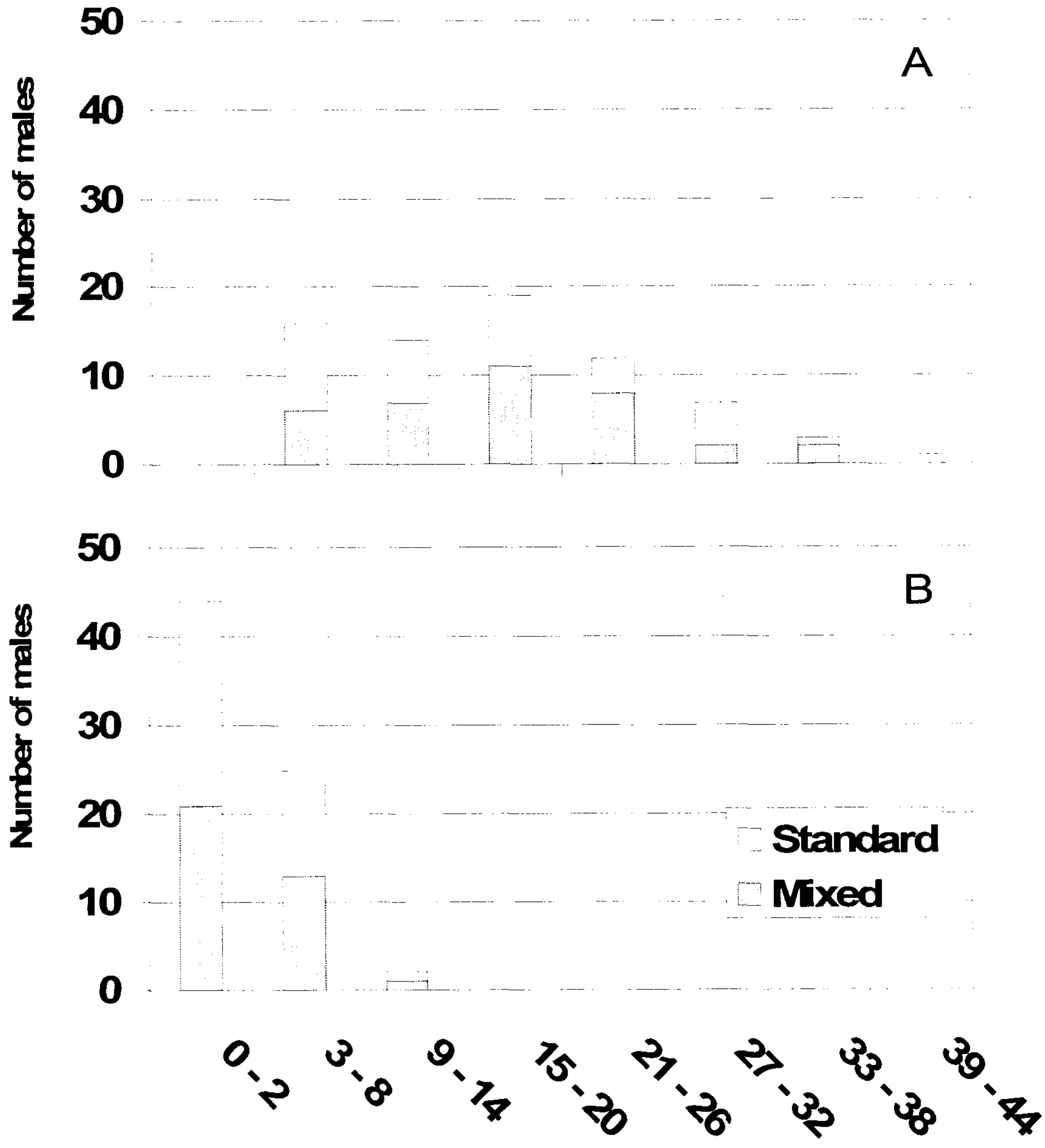

Figure 3-4. Frequency distribution of number of male to male encounters on the first (A) and last day (B) of observation period. Male to male encounters are defined as a dominance/submissive behavioral encounter that lasts longer than 3 s.

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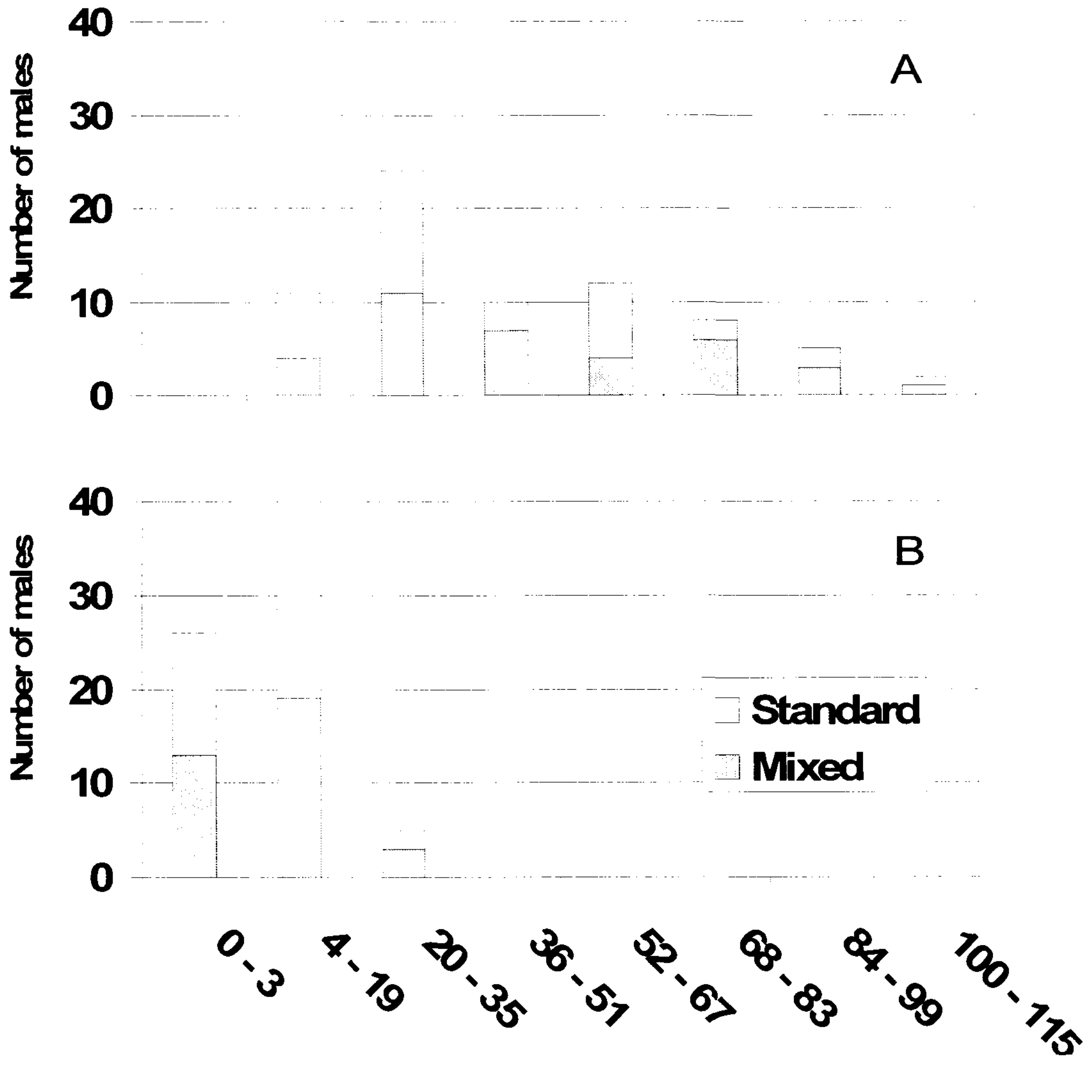

Subordinate encounter score

Figure 3-5. Frequency distribution of cumulative male to male subordinate encounter score on first (A) and last day (B) of observation period. The level of submission expressed by one male towards another during an encounter determined male to male submission score.

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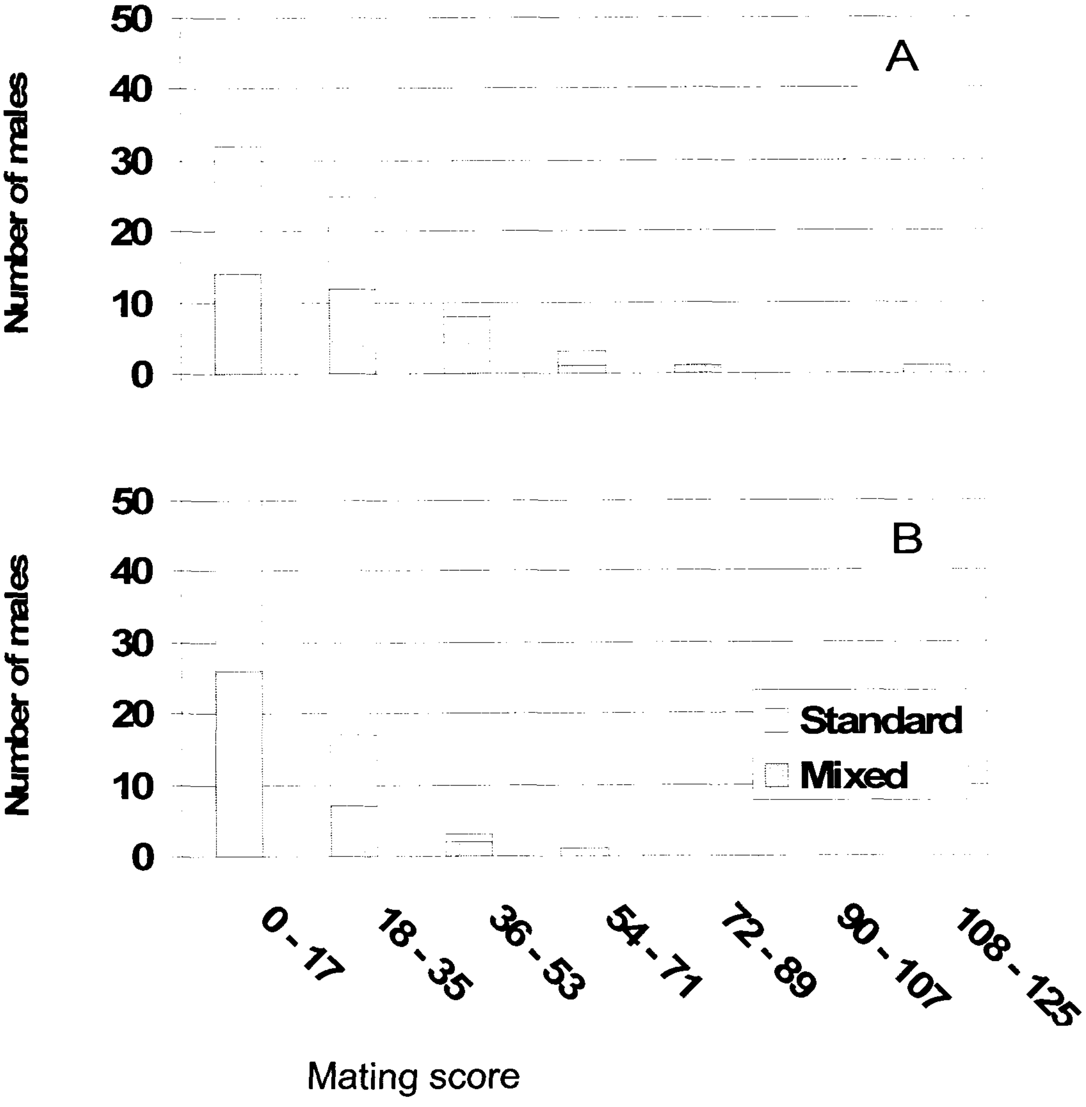

Figure 3-6. Frequency distribution of cumulative male to female mating score on first (A) and last day (B) of observation period. Mating scores are based on the completion or incompletion of a mating attempt.

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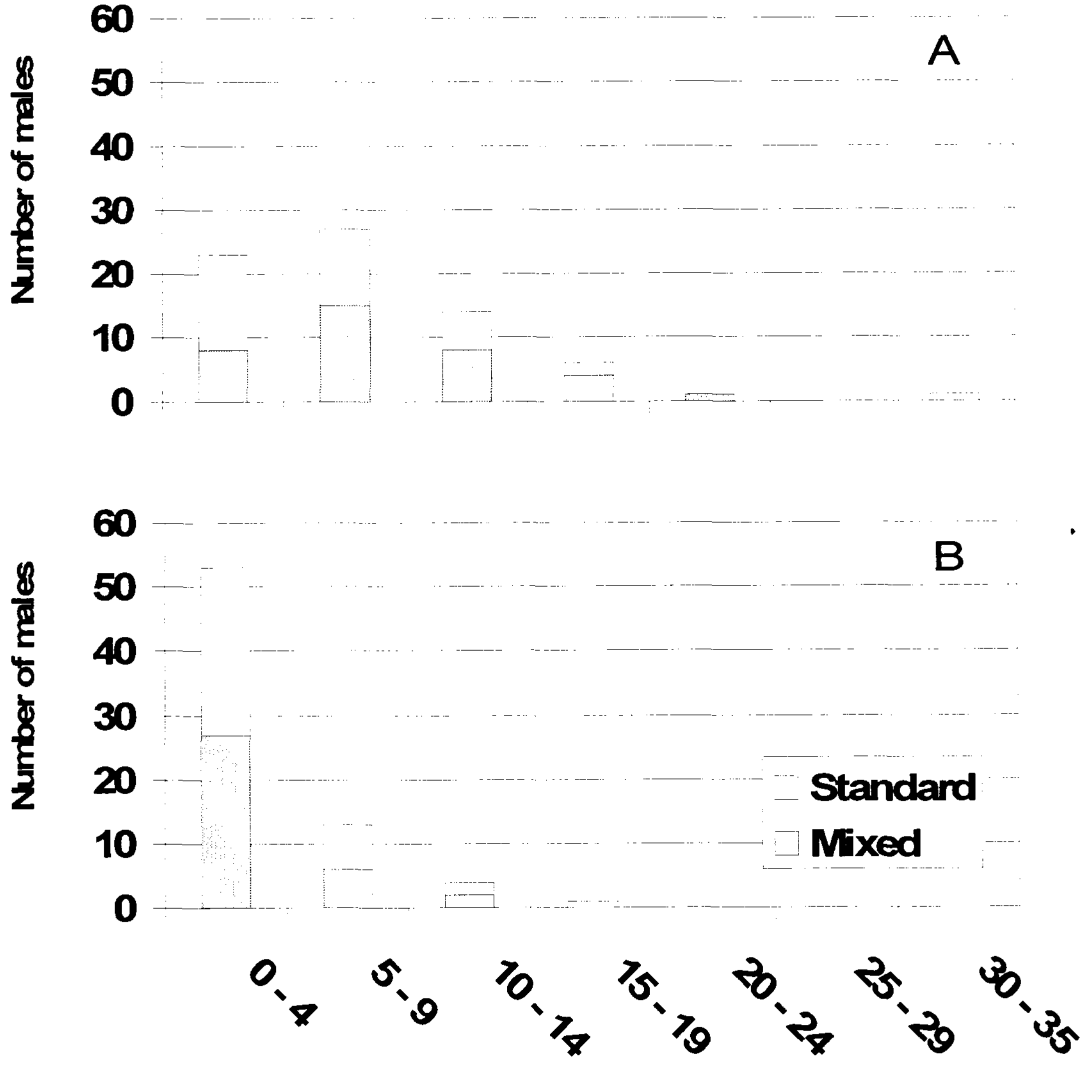

Figure 3-7. Frequency distribution of number of male to female mating encounters on the first (A) and last day (B) of observation period. A male to female mating encounter is any attempt by a male to mate a female.

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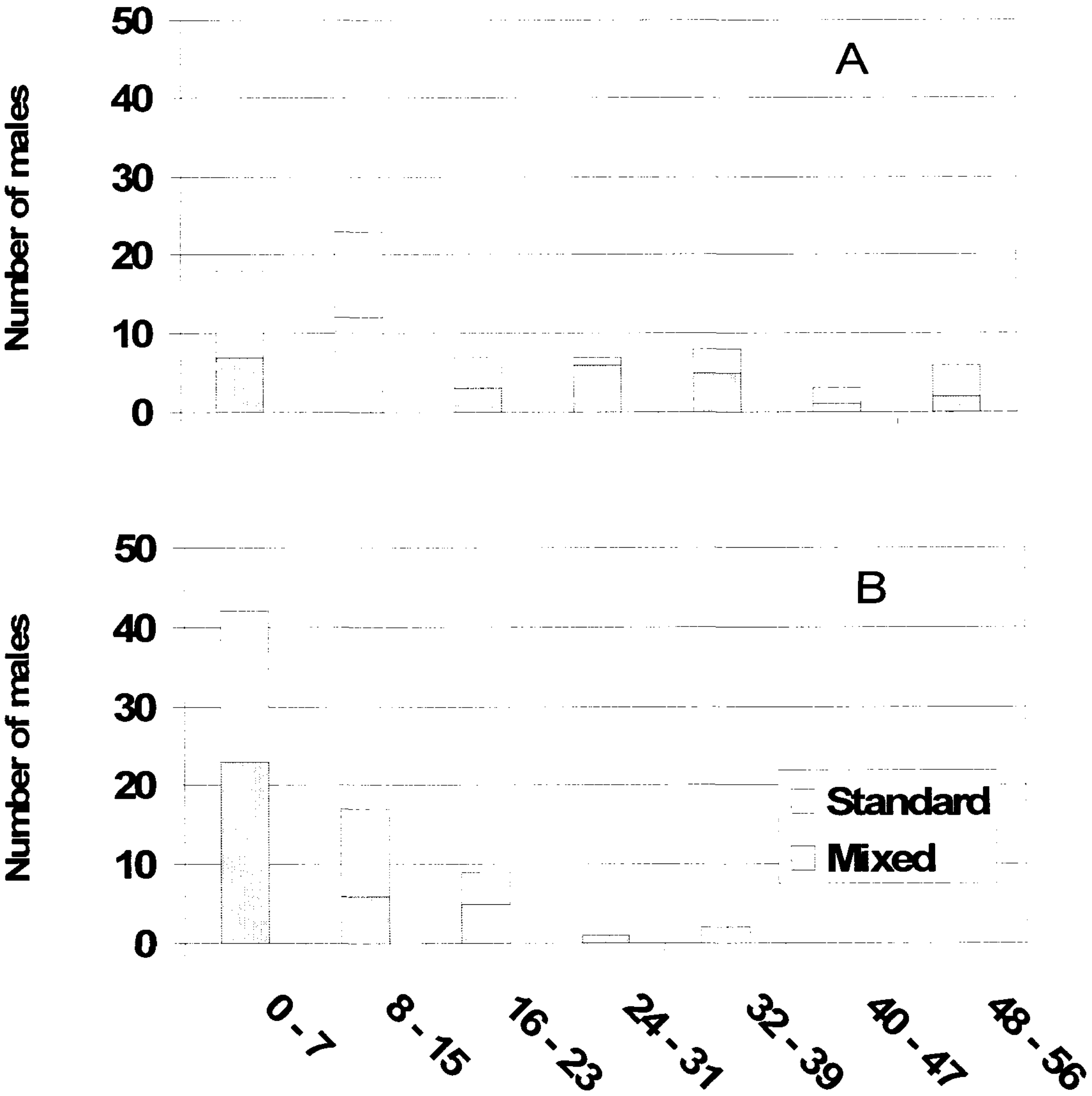

Dominance encounter score

Figure 3-8. Frequency distribution of cumulative male to female dominance interaction score on the first (A) and last day (B) of observation period. Male to female dominance interaction scores were determined to be any dominant action made by a male directed towards a female.

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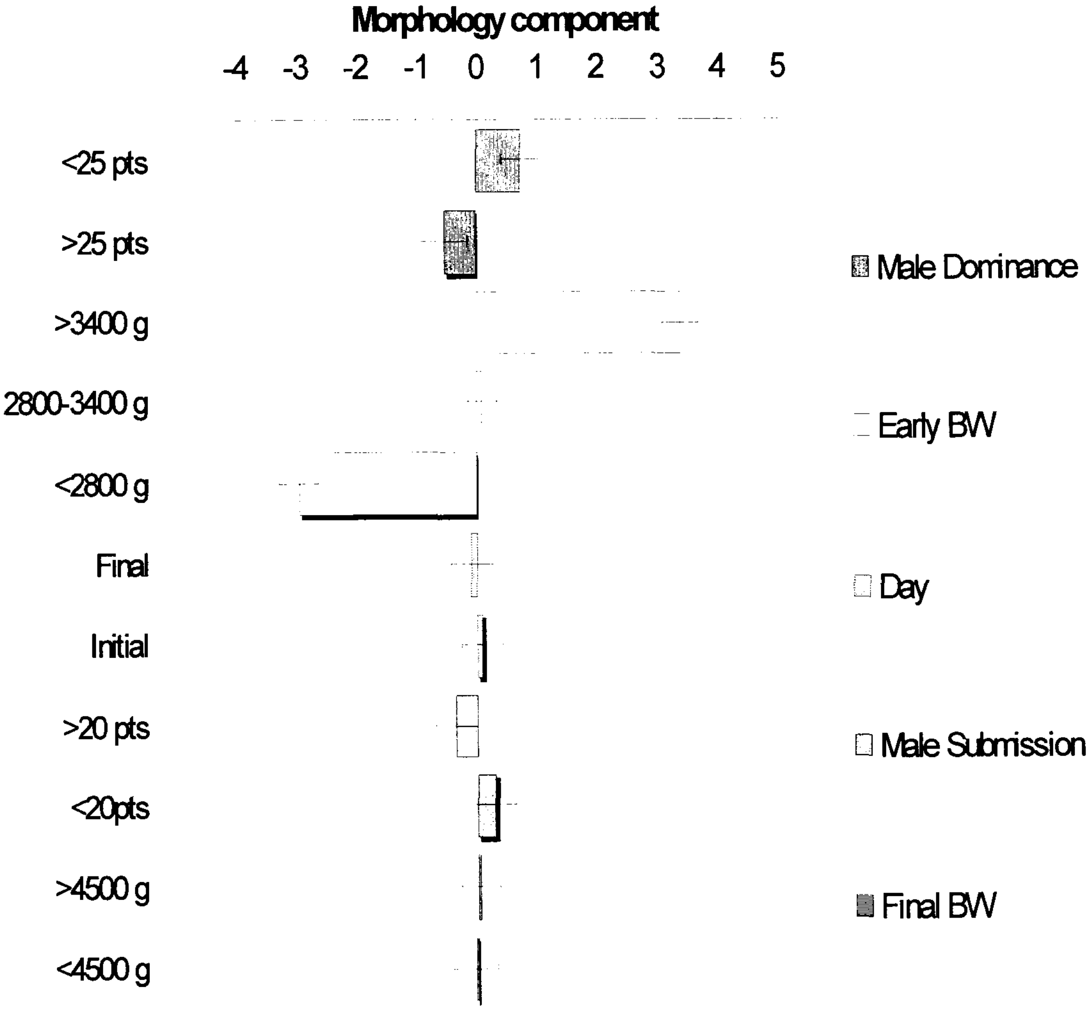

Figure 3-9. Mean first principal (morphology) component scores for 5 independent category variables and standard error bars.

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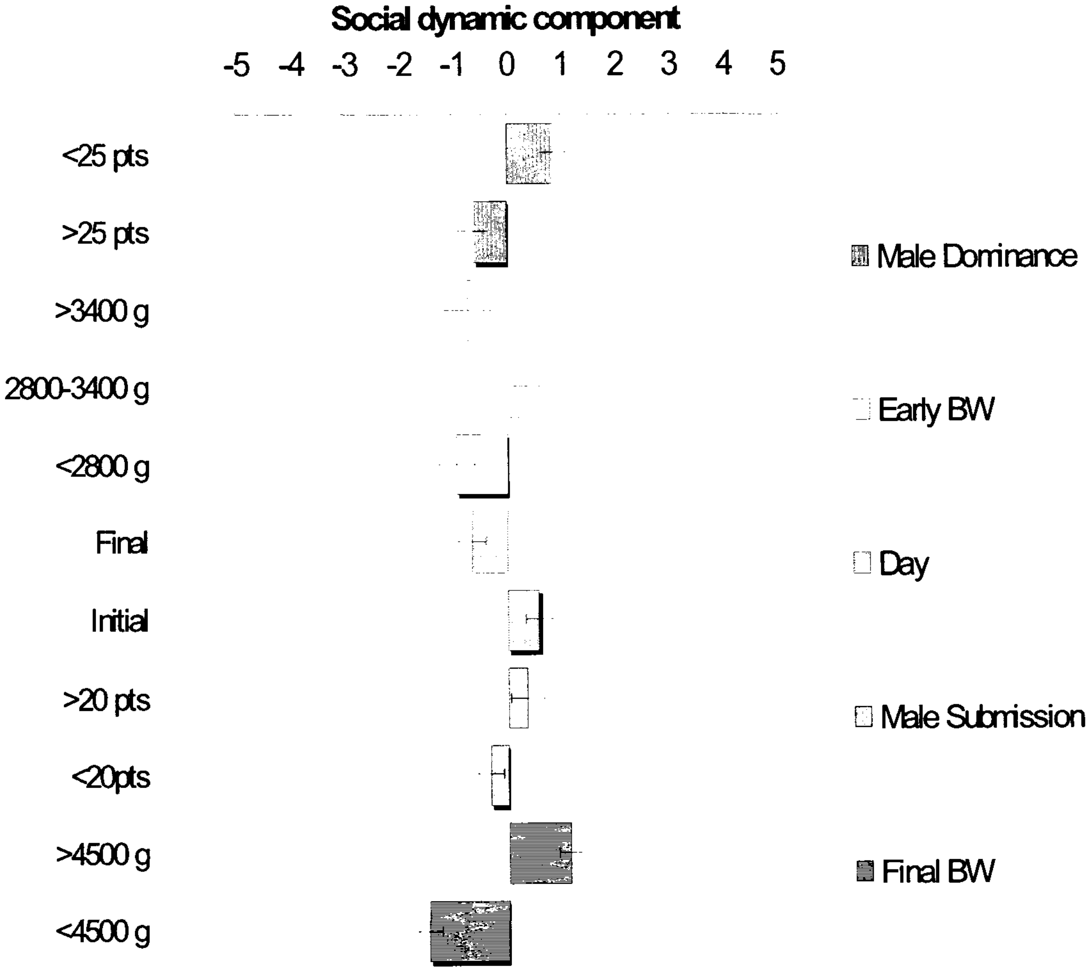

Figure 3-10. Mean second principal (social dynamic) component scores for 5 independent category variables and standard error bars.

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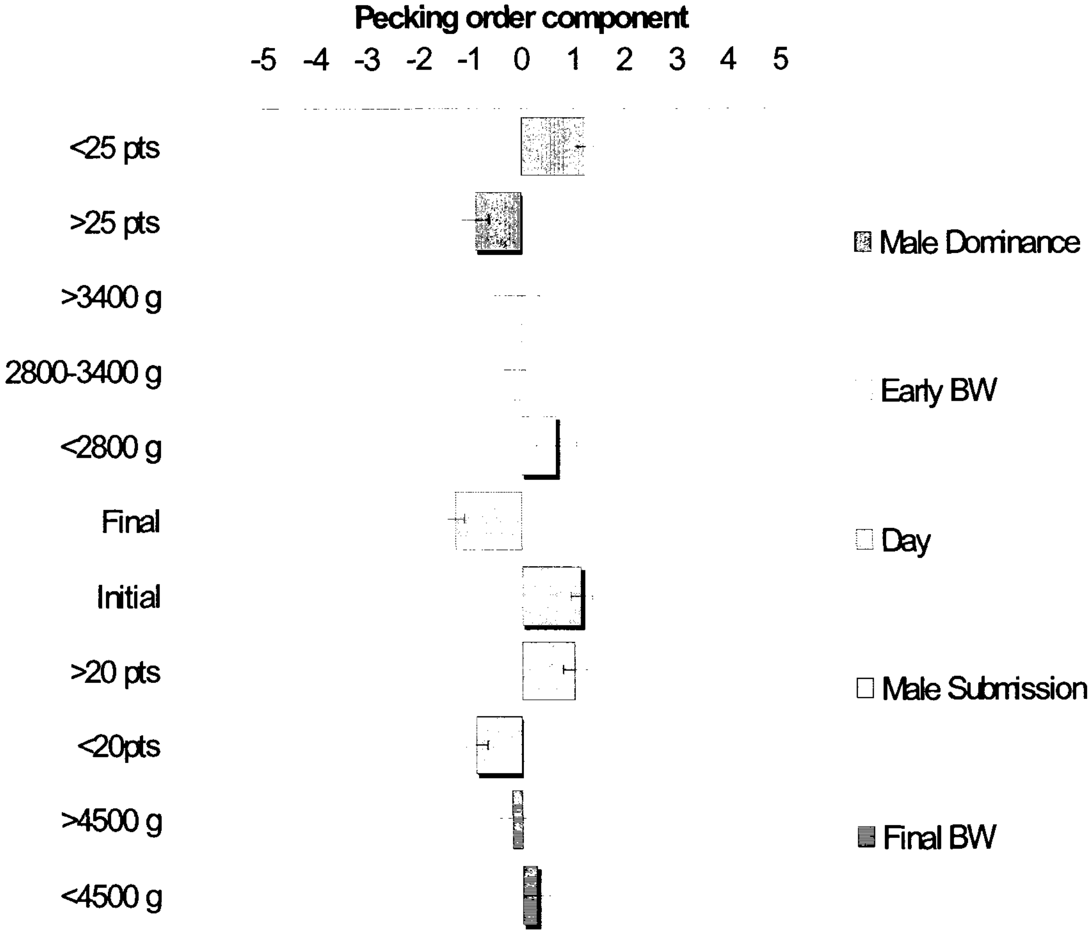

Figure 3-11. Mean third principal (pecking order) component scores for 5 independent category variables and standard error bars.

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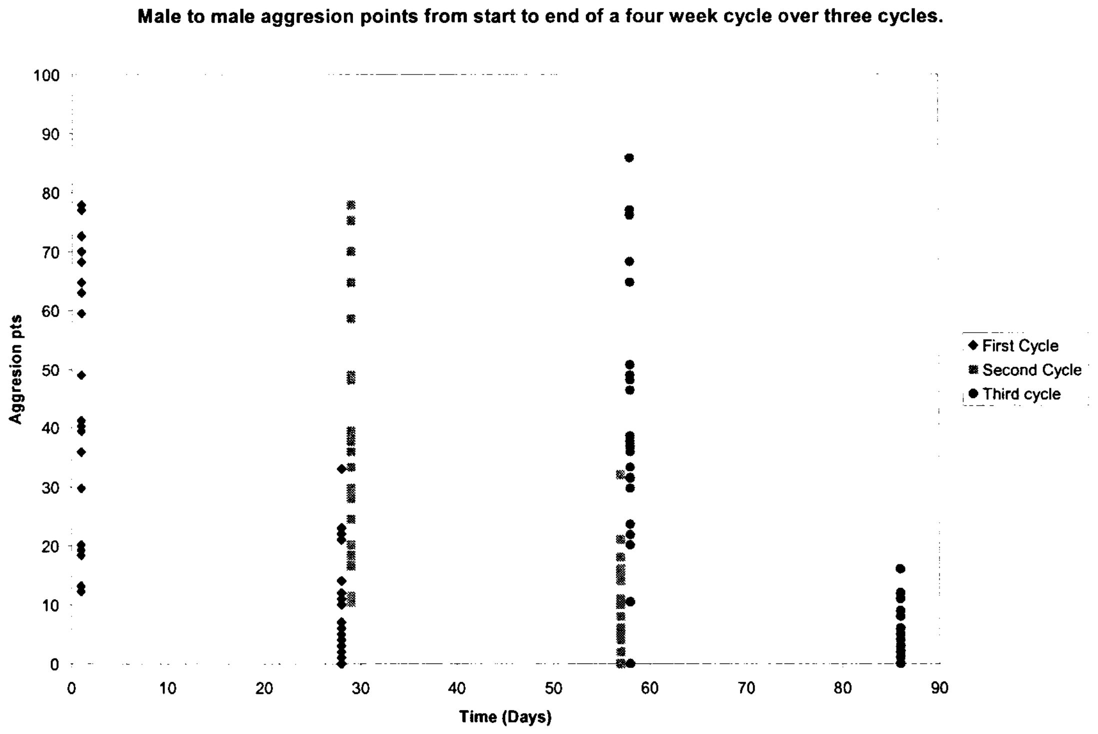

Figure 3-12. Male to male aggression points from start to end over four weeks cycles during three cycles.

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4.0 Summary and Conclusions

Behaviour is a good indicator of the states of suffering such as fear, frustration, and pain (Duncan and Mench 1993; Duncan, 1998). Duncan (1998) also concludes that an animal's behaviour is the best indicator of the animal's welfare. This study determined the frequency and distribution of the reproductive and dominance behaviours expressed by male BB. If an animal experiences more positive emotional states than negative ones, then it's welfare state is considered to be good (Duncan, 1998). The behavioural patterns expressed can be strongly motivated, and if they are suppressed, the bird's welfare may be compromised (Duncan, 1998).

According to Millman et al. (2000) male BB aggression peaks at 5wk following mixing and males will continue to behave aggressively throughout the life of the flock. This study found that when BB males are placed in groups of 33 birds the level of aggressive/dominance behaviours significantly declined from the start to the end of a 4 wk cycle. The aggression seen in this study appeared to peak in the first 24 hr of mixing. Further research is needed to determine the exact rate of decline for aggressive behaviour.

Since typical commercial BB farms confine anywhere from 5000 to 20,000 birds in one group, it could be inferred that the smaller numbers of birds in our experiment may not provide similar commercial conditions. However, Millman et al. (2000) found extreme levels of aggression were present even in small groups of males. The sex ratio in this study (1 male for every 10 females) is the same as recommended for commercial farms. This study suggests that BB males are capable of forming stable social pecking

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orders when housed in a group size of 33 birds. The aggression seen in commercial situations is likely caused by overwhelming social conditions where males are unable to form a stable pecking order. Domestic fowl's response to frustration has been documented to include increased aggression as well as stereotyped pacing (Duncan, 1998).

Duncan et al. (1990) and Bilcik and Estevez (2005) have established that there is a lack of association between behaviour and morphological traits in BB. This research determined that there are relationships between morphological traits and the reproductive behaviours in male BB. Male BB that were > 4500 g at the end of lay were more likely to be socially dominant than males that were less than < 4500 g. Unfortunately, this research was unable to establish any significant relationships between the early growth characteristics of male BB and the behaviours they express as mature breeding males other than model (2) in Table 3-5 that found BW wk 5 to be significant in the level of male to male submission. It is possible that these relationships exist but the small number of males used in this study was not enough to demonstrate them.

Part one of this research determined chicks that were longer at hatch, heavier at wk 5 and that had faster growth rates were more likely to be heavier at wk 23. The males with larger testis at wk 30 were more likely to have a longer keel length at wk 20 and to have a hatch BW between 40 g – 42.5 g. It is possible to infer from part one and two of this research that longer chicks at hatch with average BW could be more likely to have larger

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testis weights at wk 30. Further research is required with greater numbers of males to determine the strength and relevance of early growth characteristics in predicting the breeding quality of male BB.

A great deal of the research that has previously been conducted on the problems of male BB behaviour has been inflammatory and unconcerned with the true causes of the behavioural problems. This research although answering some of the questions surrounding male BB behaviour does not go far enough in determining solutions for improving the welfare of BB and increasing the economic return for BB producers.

This research has determined:

1) Male BB are capable of forming stable social pecking orders with other male BB (in groups of 33 birds).
2) The more time male BB spent with flock mates (in groups of 33 birds) the less aggression/dominance behaviour is observed.
3) Aggression/dominance behaviours seen in male BB are not related to the age of the male.
4) Larger male BB were more likely to be socially dominant.
5) Discrete relationships appear to exist between early growth characteristics and male BB quality.

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