# MIGRATORY BEHAVIOR OF CAPTIVE BLUE-WINGED TEALS (*ANAS DISCORS*)

By

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# ABSTRACT

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Migratory disposition (*i.e.*, migratory activity [*Zugunruhe*] and hyperphagia) can be experimentally induced in captive birds. Research focusing on captive migratory behavior is important because this research allows scientists to ask in-depth questions on bird condition related to behavior. Most research on migratory restlessness has been conducted on landbirds with a knowledge gap on captive waterfowl migratory behavior. We hypothesized that captive Blue-winged Teals would exhibit migratory restlessness during fall and spring migration. Employing video surveillance cameras and infrared motion sensors, we investigated whether teals would 1) enter migratory disposition, as shown by mass gain and 2) exhibit an increase of migratory activity, consistent with migratory activity (*Zugunruhe*). We found that teals, when photoadvanced, exhibit behavior consistent with migratory disposition, including hyperphagia and increased nighttime activity. In addition, the nighttime activity was consistent with *Zugunruhe* with increased restless behaviors like wing activity and looking up. According to our knowledge, this is the first study to successfully demonstrate that under controlled conditions waterfowl exhibit migratory disposition and restlessness.

# ACKNOWLEDGEMENTS

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# CHAPTER 1: Literature Review of the Study of Bird Migration

Many studies have been conducted focusing on bird migration. Although the literature covers a wide variety of such topics, this review will focus on introducing migration, describing migration cues and timing, highlighting migration behavior, and then focusing on captive migration studies. The primary focus of this literature review is to introduce readers to the concept of captive migration for birds and to acknowledge the knowledge gap present of controlled captive migratory studies focusing on waterfowl species making it necessary for research to be conducted in this area.

Migration is defined as the movement of populations between two differing geographical locations (Lincoln 1935). The migratory patterns of birds are likely the most studied, with studies dating back to Aristotle in the fourth century. Aristotle studied the systematics, physiology, morphology, ethology, and embryology of organisms in the field (Stresemann 1951). He attributed the disappearance of birds during the non-breeding season to hibernation and/or transmutation (change from one species to another); an idea that was widely accepted until the 18th century when it was disproven (Stresemann 1951; Mead 1983). The first ornithologist known to accurately describe bird migration was Hohenstaufen Emperor Frederick II in the 13th century; he described these annual movements of birds as a response to external factors such as lack of food and cold (Stresemann 1951). In the 19th century, Johann Andreas Naumann was the first to document migratory restlessness by observing an increase in captive nighttime activity during the migratory period. Furthermore, he suggested that the direction of migratory movement was “rooted in the nature of the bird” (Berthold 2001). Since then our understanding of migratory behavior of birds has been advanced by numerous controlled experiments (Berthold 2001).

## 1.1 Types of Migration

Birds vary in their migratory strategies. Some species do not migrate and are considered full-time permanent residents. However, more than half of the world's species of birds are migratory and employ differing migratory strategies referred to as obligate or facultative migration. Obligate migration, the most common strategy, is under genetic control, meaning the bird is programmed to migrate at a certain time of year and has predictable annual movements. The obligate migration strategy is observed in both long- and short-distance migrants (*e.g.*, warblers, cuckoos, and swallows) (Newton 2011). Facultative migration is when birds make movements in response to food availability and/or climatic variables, rather than predictable movements (Newton 2008). Birds do not necessarily follow either an exclusively obligate or facultative strategy, but rather can fall anywhere in between the two. There is also evidence of some birds changing from obligate to facultative modes during their journey. For example, according to Terrill (1990), geese nesting in the Arctic have a two-phase migration starting with obligatory and then ending with facultative; the geese leave each year at the same time, but the timing of their migratory flight varies with food availability. Likewise, White-throated Sparrows (*Zonotrichia albicollis*) in captivity show a two-phase system of both obligate and facultative modes of migration with nocturnal activity heightening in intensity during the first phase and then this activity decreasing and becoming more variable in the second phase (Helms 1963; Stuber & Bartell 2013). The behavior in captivity aligns with the behavior of free-living birds during spring migration; birds switch from a directional phase searching for food and habitat to a less active phase if appropriate habitat and food were found (Helms 1963).

Another migratory strategy is partial migration; some individuals of a population migrate from the breeding area and other individuals remain in the breeding area year-round. There are two types of partial migrants, obligate and facultative. Obligate partial migrants exhibit predictable movements however, some individuals in a population migrate while others remain resident (Terrill & Able 1988). Facultative partial migrants depart breeding area depending on food availability and habitat quality (Terrill & Able 1988).

## 1.2 Migration Timing

The daily pattern of migratory movements varies across species and can be divided into the following categories: 1) diurnal (*e.g*, raptors, cranes, pigeons, herons, and many passerines); 2) nocturnal (*e.g.*, the majority of passerines, grebes, quail, owls, hummingbirds, and nightjars); or 3) a combination of both (*e.g.*, marine and aquatic birds (Newton 2008). Some species of waterfowl *(e.g.*, Barnacle Geese, Brent Geese, Long-tailed Ducks, and Common Scoters) have been observed to be nocturnal migrants in the spring and diurnal migrants in the fall (Bergmann 1977).

The majority of long-distance migrants fly at night, with the exception of soaring birds which are the only diurnal migrants that travel long distances and shorebirds, that are considered both diurnal and nocturnal migrants (Newton 2008). The advantages of migrating at night are a lowered risk of predation, a more stable atmosphere, and cooler temperatures; it also allows the bird to feed during the day (Berthold 2001; Kerlinger & Moore 1989). When crossing an ecological barrier, a bird that takes off immediately after sunset may still be flying in the following day even if it might be a nocturnal migrant (*e.g.*, Eleonora's Falcon (*Falco eleonorae*)) (Newton 2008; Lopez-Lopez 2010).

### 1.3 Migration Cues

Birds use a variety of cues, acting as a Zeitgeber or synchronizer of circannual rhythms, to synchronize the timing of migration. Photoperiod is considered the primary cue that controls bird migration (Farner & Gwinner 1980; Berthold 1996). Over the annual cycle, birds experience physiological states based on photoperiod, including periods of being sensitive or refractory to photoperiod (Dawson & Sharp 2007). Birds exhibit photorefraction with no response to photoperiod at the end of the breeding season and become photosensitive in the spring. Furthermore, birds must go through a period of being photorefractory (Dawson & Sharp 2007). Given this sensitivity to daylength, scientists are able to induce this natural physiological state by manipulating photoperiod of captive birds. For instance, Agatsuma & Ramenofsky (2006) studied migratory behavior of Gambel's White-crowned Sparrows (*Zonotrichia leucophrys gambelii*) during fall and spring migration by altering photoperiod; migratory restlessness was displayed more frequently in the spring. Photoperiod can also alter the annual cycle of experimental birds and has led to the photoperiodic model of avian annual cycles (Helm 2006; Berthold 1996).

Other factors which birds may use as cues for timing migratory movements are climatic factors such as temperature, rain, and winds; all factors that can affect migration (Berthold 1996). During fall migratory periods, many bird species have been reported as flying on the tail winds of low pressure systems to avoid bad weather (Berthold 1996; Elkins 1988); on the other hand, during spring migratory periods, birds have been studied to migrate with the warm tail winds of high pressure areas (Berthold 1996; Elkins 1988).

In free-living birds, weather patterns and environmental conditions are being considered to initiate fall migration as well as social stimuli (Berthold 2001; Miskimen 1955). During fall migration, even though daylight decreases, food availability and climate conditions improve the closer to the breeding grounds the migrant is (Agatsuma & Ramenofsky 2006). Seasonality differs in the pace of migration as well; during spring, birds want to ensure early arrival on breeding grounds for increased reproductive success (Elmberg et al. 2005). In the fall, the pace is slower as there is less benefit in arriving early on the wintering grounds (Marra et al. 1998; Lack 1968). This seasonal variation in the pace has been observed in captive studies; for instance, Helm & Gwinner (2005) found that migratory restlessness was affected by day length cues during spring migration.

## 1.4 Genetic Program of Migratory Disposition and Behavior

Before migration begins, a bird will enter migratory disposition: a state of readiness to migrate. Scientists can see when a bird has entered migratory disposition by looking at fat intake and directional preferences.

In order to meet the energetic demands of the migratory period, birds increased food intake and fat deposition, which is referred to as hyperphagia. Waterfowl, particularly in the family Anatidae (geese, swans, dabbling and diving ducks), generally forage more in the fall and early spring whereas their foraging decreases in winter (Tamisier et al. 1995; King 1974). For instance, by using neck-band identification and recording both feeding and social behaviors, adult Giant Canada Geese (*Branta canadensis maxima*) wintering in Minnesota from February to April increased their body mass (males: 26% and females: 36%) (McLandress & Raveling 1981). This study was the first to observe both hyperphagia and social behavior in wild waterfowl prior to migration to their breeding grounds (McLandress & Rraveling 1981).  Similarly, by comparing both foraging and diving times for female and male Common Eiders (*Somateria* *mollissima*), it was found that hyperphagia was the primary cause of body mass gain in females (Guellemette 2001).

In additional to fattening, directional preferences are related to migratory disposition and under endogenous control (Newton 2008). Birds in the wild will show the same directional preferences if studied in captivity. One of the foundational studies on orientation was conducted on captive, wild-caught, hatch-year starlings (*Sturnus vulgaris*). Kramer (1952) showed that birds exhibited activity in the seasonally appropriate direction (southward) despite it being their first migration. In another study, Emlen (1969) tested directional preferences in captive Indigo Buntings (*Passerina cyanea*) and found that birds in autumn condition oriented southward, and birds in spring condition oriented northward, showing similar directional preferences if in the wild.

### 1.5 Field Techniques in Studying Migration

Migration is studied both in the field and in a captive setting using a variety of methods. Field study methods include: observation of visible, diurnal migration through aircraft and aerial surveys (Briggs et al. 1985), bird monitoring and recording programs (*e.g.*, point-counts, broadcasting calls, citizen science programs, and breeding bird surveys) (Bart 2005), shooting and collecting (Remsen 1995), acoustic registration (Farnsworth 2005), radar tracking (Alerstam & Gudmundsson 1998), light tracking using ceilometers (Gauthreaux 1969), telemetry and satellite tracking (Martell et al. 2001), and mistnetting and bird-banding (Burnham & White 2002; Dunn et al. 1997).

## 1.6 Captive Migratory Experiments

Migration has also been studied with wild-caught birds in captivity through orientation and migratory restlessness experiments. Registration cages are used to study migratory restlessness, or *Zugunruhe*, which refers to a bird in migratory disposition demonstrating restless behaviors, such as perch hopping, whirring wings, foraging, body turning and grounding, and flying in normal periods of rest (Berthold 2001). The first to hypothesize the amount of *Zugunruhe* based on migratory period and distance was Johann Andreas Naumann who studied Pied Flycatchers (*Ficedula hypoleuca*) and Golden Orioles (*Oriolus oriolus*) (Berthold 1996).

Captive avian studies allow scientists to document the onset, intensity, and direction of migratory restlessness by looking at directional preferences, body reserves, and responses to seasonal environmental changes (Newton 2008). Circular registration and orientation cages are used to study directional preferences and choices by using light cues or ink tracking to study activity in the cage (Berthold 1996). Albeit rare, orientation studies have also been used to identify direction of migratory movements in waterfowl. Wild Mallards were captured in the fall and then released in the spring; regardless of the release direction from their home lake, they correctly navigated and flew northward on clear nights (Bellrose 1958). Scientists (Kramer 1952; Sauer 1958) used circular orientation cages to find that birds used celestial cues to orient themselves. When the birds were displaced, they took longer to orient but used these cues to find their way (Kramer 1952; Sauer 1958). In general, orientation behavior is preceded by the disposition to migrate (Bellrose 1958). Blue-winged Teals (*Anas discors*) are also known to use celestial cues when flying northwestward during spring migration, but they alter this direction southward for fall migration (Bellrose 1963).

For nocturnal migrants, *Zugunruhe* can be measured using quantitative methods such as ink and paper, infrared sensors, and microswitch perches; microswitch perches are active when the bird hops on the perch and the switch operates through an electric circuit and records the impulse on a computer, microprocessor, or event recorder (Berthold 2001). The use of technology has made it easier to document migration. Recently, infrared video cameras have been employed to record nocturnal activity in captive birds. By using current technology, we can study bird migration more effectively to build on past research. This technology will hopefully help us discover and understand the complexity of bird migration.

# CHAPTER 2: Manuscript

## 2.1 Introduction

Since the 19th century it has been known that birds display migratory disposition and restlessness (*Zugunruhe*) in captivity. Migratory disposition, including migratory activity and hyperphagia, can be experimentally induced in captive birds by manipulating photoperiod (Newton 2008). This induced activity corresponds to the daily and annual pattern of migration of free-ranging conspecifics (Berthold 2001, Gwinner & Czeschlik 1978). Captive migratory research allows scientists to ask questions that we may not be able to answer in the field; for instance, we know that birds in poor condition do not display migratory restless or seasonably appropriate direction (Sandberg & Moore 1996). The predominant part of the captive migratory literature has been on landbirds. However, only a handful of studies have investigated the migratory behavior of captive waterbird species (*e.g.* Southern 1969, Gudmundsson & Sandberg 2000, Owen 1968, Owen 1970). In addition, most recent captive waterbird studies focus on orientation behavior. Moreover, only one study has focused on migratory restlessness of captive waterfowl, which was conducted by Owen (1968, 1970) on captive Blue-winged Teal (*Anas discors*).

Owen (1968) looked at the behavior of Blue-winged Teals during predeparture with field observations of wild teals, wild teals in orientation cages, and a group of hand-reared teals in flight pens. Results show that at the onset of migratory departure, hand-reared birds decreased feeding, increased resting, and increased calling behaviors (Owen 1968). Owen also reported that on one day (September 10th), the hand-reared birds were displaying restless behaviors explained by delayed migration (Owen 1968). Owen (1968) was the first to demonstrate that waterfowl will innate seasonably appropriate migratory behaviors. However, the study did not investigate migratory disposition with birds housed individually indoors, like most landbird studies (Newton 2008). The question remains, do wild-caught waterfowl exhibit migratory restlessness in captivity? A more controlled environment allows for testing migratory disposition and behavior given specific Zeigebers for migration and migration timing include daylength, temperature, and rainfall, with photoperiod as a proximate cue for migration especially in captive migrant studies (Berthold 2001). Photoperiod provides migratory birds that are confined a basis for seasonal timing. Increasing day length has been recorded as initiating migratory behavior before the normal migratory season; the effect of photoperiod can also alter the annual cycle of experimental birds and led to the photoperiodic model of avian annual cycling (Berthold 1996). Migratory disposition and restlessness can be triggered by altering photoperiod and daylight. Birds will also enter hyperphagia, a period of increased food intake and fat deposition to prepare for the energetic demands of migration (Newton 2008).

In this study, we designed an experiment to address the knowledge gap of captive waterfowl migratory research focusing on migratory disposition and restlessness using photoperiod as the experimental cue. We chose Blue-winged Teals (hereafter referred to as ‘teals’) as a focal species. Teals are an ideal study species because they are obligate migrants, meaning they have a genetic predisposition to migrate. The majority of waterfowl species are facultative or partial migrants, that is they chose to migrate or not dependent on resources available (Nichols et al. 1983). Furthermore, the migratory behavior of free-living teals has been well-defined (Bellrose 1963, Rohwer et al. 2002); they are one of the first ducks to migrate south for the winter and the last to migrate north for the summer (Rohwer et al. 2002, Owen 1970, and Gammonley & Fredrickson 1995). Based on the information presented above, we predict that Blue-winged Teals will enter migratory disposition in captivity when given the photoperiod cue (natural photoperiod during fall migration and manipulated photoperiod during spring migration) by increasing body mass (hyperphagia) and exhibiting an increase in activity, consistent with wild migratory activity (*Zugunruhe*).

## 2.2 Materials & Methods

### Source of Birds

Teal eggs were collected during nest dragging surveys from seven different nests in Egeland, ND during June and July 2011 (Federal permit #MB194270). The eggs were collected within a few days of laying and prior to any embryonic development. Eggs (n=61) were shipped and delivered in two shipments on 22 June 2011 and on 1 July 2011.  Only thirty-four eggs were unharmed during shipping and were viable upon arrival.

The viable eggs (n=34) were incubated (G.Q.F. Manufacturing Co. cabinet model) at 37.5 °C and an average humidity at 70%. The incubator electronically turned the eggs around 10 times every day and we lightly sprayed the eggs with water daily. Each week we candled the eggs to monitor embryonic development. After eggs pipped (*i.e.*, egg cracked as duckling was beginning to hatch), they were transferred to a hatcher set at 37.2 °C and 65% humidity until all duckling feathers were completely dry, which was typically for 1 day. Then the ducklings were moved into a brooder with a heat lamp to maintain birds at 30-35 °C for two weeks. At two weeks, the ducklings were moved into cages (see below, Housing & Food).

Twenty-four eggs successfully hatched, occurring in three distinct periods, 1 July (oldest; n=8; 5 males and 3 females), 13-16 July (middle; n=6; 3 males and 3 females), and 20-25 July (youngest; n=10; 6 males and 4 females).

Birds were captured, handled, and cared for according to the American Association of Accreditation of Laboratory Animal Care Guidelines and approved by the Institutional Animal Care and Use Committee at Michigan State University (Permit # 07/11-143-00).

### Housing & Food

The teals were housed at the MSU University Research Containment Facility (URCF) for the remainder of this study. The four week-old teals were placed in the custom built cages (1.82m long by 0.91m wide by 0.61m high; 2-3 teals per cage; Figure 1) for 7 days to get acclimated. Each cage contained a pool (0.84m long by 0.46m wide), food and water area, and a nestbox. The cages were lined with composite rib 0.91m wide corrugated rubberized mat and surrounded with 0.02m heavy knotted soft mesh netting. After acclimation, the teals (n=21) were individually housed and randomly assigned to two different rooms. The first room, identified as room 1 for fall and the migratory treatment group for spring had 11 cages. The second room, identified as room 2 for fall and the control group for spring had 11 cages, but only 10 cages were used for this study as 1 cage housed 3 of the youngest aged teals that were not apart of the study; these 3 were housed in captivity for the duration of the study in case of unforeseen mortality in the experimental groups. In each room, the cages were stacked in rows of two or three cages high (Figure 1).

**Figure 1. Custom built cage for Blue-winged Teals.**

Dimensions: 6’L x 3’W x 2’H. Pictured here is of the cages stacked in rows of two.

Rooms were equipped with full spectrum fluorescent lights to create artificial light for the teals. The light intensity varied among cages because the cages were stacked on each other. For the bottom cages, a light (GE 22” Fluorescent Plug-In with full spectrum light) was added to the video camera stands to provide adequate light intensity for these cages (see Figure 2). A nightlight was placed in each room measuring at a light intensity of 1 Lux to imitate moonlight.

**Figure 2. Experimental set up showing lights added to camera stands.**

Teals were fed *ad libitum* a diet primarily of Purina Flock Raiser® SunFresh® Recipe Crumbles (Purina Mills® Brand, LLC St. Louis, Missouri; 20% nutrient-rich). Two forms of enrichment were given in the pools: cracked corn and dandelion or collard greens. Cracked corn was used to promote dabbling behavior; dandelion or collard greens were used to simulate vegetation on the water. Birds were also provided fresh water daily with gravel (Stonemo Gran-I-Grit, Mt. Airy, North Carolina) sprinkled into water bowls to help with digestion of feed. Every other day, rubber mats and pools were scrubbed and pools refilled.

## 2.3 Experimental Design

### Fall Migration

Teals were separated into two rooms. For the fall migration study, these two groups were identified as Room 1 (n=11) and Room 2 (n=10). Both rooms were identical in dimensions and orientation. Room 1 had teals consisting of the oldest and middle age groups. Room 2 consisted of individuals from the middle and youngest age groups. After brooding (1 August onward), the birds were maintained on the natural photoperiod following the sunrise/sunset schedule in North Dakota. On 21 November 2011, to simulate fall migration photoperiod, we slowly transitioned the teals to the photoperiod of southern Louisiana sunrises/sunset by decreasing the sunrise time and increasing the sunset time by 10 minutes every 3 days until reaching a 10:14 Light: Dark (L:D) photoperiod, 27 November 2011. Teals were maintained on this photoperiod until the spring migration part of the study.

### Spring Migration

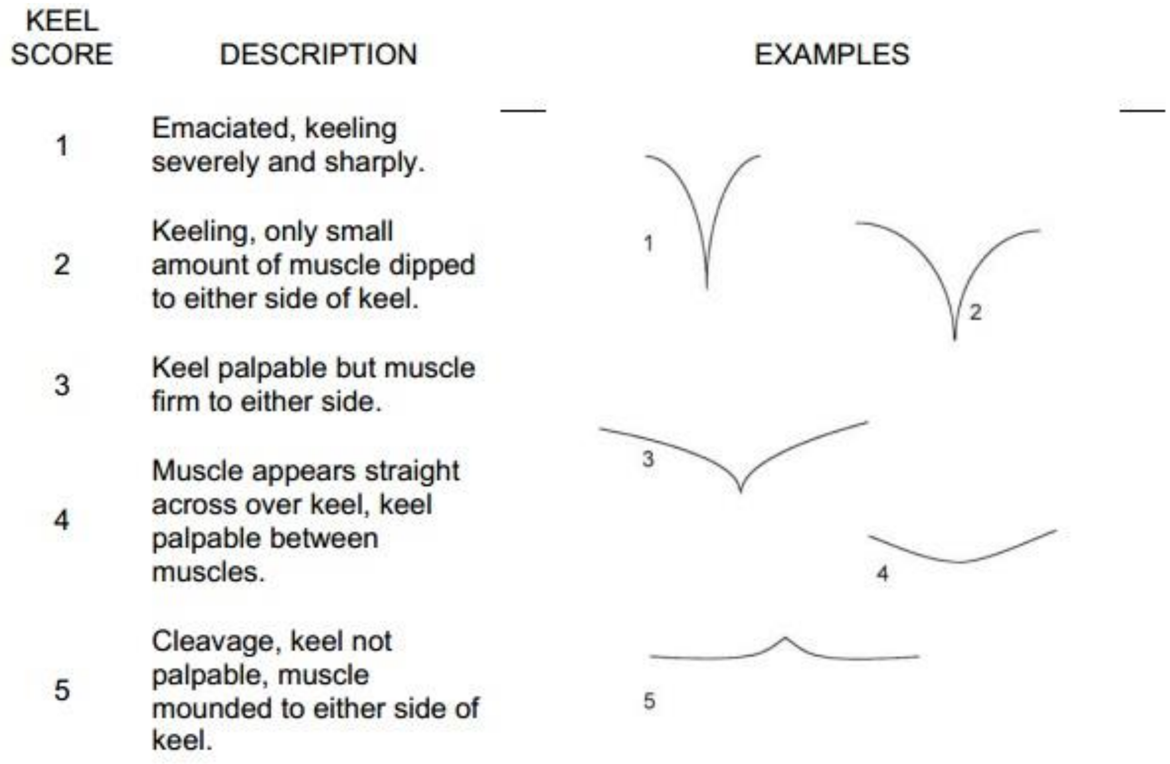
On 9 January 2012, teals were randomly reassigned and stratified by sex and age into two groups in the same two rooms. For the spring migration study, these two groups were identified as the migratory treatment group (n=11) and the control group (n=10). Both groups were maintained on the 10:14 L:D photoperiod until 5 February 2012. The migratory treatment group was photoadvanced 30 minutes every other day until the room was at a 14:10 L:D photoperiod on 20 February 2012. The control group was maintained on the 10:14 L:D until 22 March 2012, at which time they were photoadvanced 30 minutes every other day until at the 14:10 L:D photoperiod on April 5, 2012. The selection of the 14:10 photoperiod was based on the natural photoperiod in the wild for a bird migrating north in the US. In addition, this similar 14:10 L:D photoperiod was also used in a similar study on migratory restlessness focusing on captive White-throated Sparrows (*Zonotrichia albicollis*) (McMillan et al. 1970).

At the conclusion of the experiment for both groups, teals were adopted by Akron Zoo in Akron, OH. The migratory treatment group ended on 20 April 2012 and the experiment for the control group ended on 4 May 2012.

## 2.4 Experimental Parameters

### Body Condition – Spring Migration

Biweekly, teals were caught in their cages using a small net. Teals were weighed to the nearest 0.1 g using an electronic balance; body mass was recorded to measure if hyperphagia occurred. To place the bird on the scale, their head was tucked under their wing (a comfort behavior) and nylon stocking was wrapped around the duck's head and upper body to hold the wings to the body and then placed on the balance. Muscle condition was estimated by feeling the protuberance of the keel and assigning it a keel score, ranging from 1-5 (Figure 3). Muscle condition was taken into account with body mass recordings for understanding body condition of the teals. Breast muscle was recorded as an average of the left and right breast muscle (Gregory and Robins 1998). Nearing the end of the fall season, the tarsus, head length, and wing chord were measured to the nearest 1.0 mm for each teal.



| KEEL SCORE | DESCRIPTION |
|---|---|
| 1 | Emaciated, keeling severely and sharply. |
| 2 | Keeling, only small amount of muscle dipped to either side of keel. |
| 3 | Keel palpable but muscle firm to either side. |
| 4 | Muscle appears straight across over keel, keel palpable between muscles. |
| 5 | Cleavage, keel not palpable, muscle mounded to either side of keel. |

**Figure 3. Keel Scoring Guide used to determine breast muscle development using a 1-5 scale.**

0.5 increments used if between two scores. Adapted from Linda Henry at Sea World San Diego.

### Activity via Infrared Motion Sensors – Fall and Spring Migration

In each room, eight cages were equipped with custom-made infrared motion sensors to record if an increase in nocturnal activity occurred. The 0.08 by 0.08 meter sensors were attached to a bracket attached to the outside of the each cage (see Figure 4). The sensors were connected to a datalogger and the data was downloaded into LabVIEW (National Instruments, Austin, TX; http://www.ni.com/labview/) BirdMotion, which was developed by the MSU Engineering Department. Infrared motion sensors were on 24 hours a day, 7 days a week.

F**igure 4. Experimental set up.**

Sensor bracket was attached to the custom built cage. Video camera was attached to a camera stand and positioned at the pool end of the cage.

**Behavior via Infrared Cameras – Fall and Spring Migration**

Video cameras (Mace IR Night Vision CCTV Bullet Cameras) were placed approximately 0.30 meters from each cage and plugged into a DVR (EverFocus Digital Video Recorders) outside the room (see Figure 4). Video surveillance cameras recorded duck behavior closest to the pool; the observer could view the duck in all places in the cage (see Figure 5). Cameras started to record 30-min prior to sunset until midnight to capture nocturnal behavior.

**Figure 5. Screenshot of video camera footage that was used for behavioral coding.**

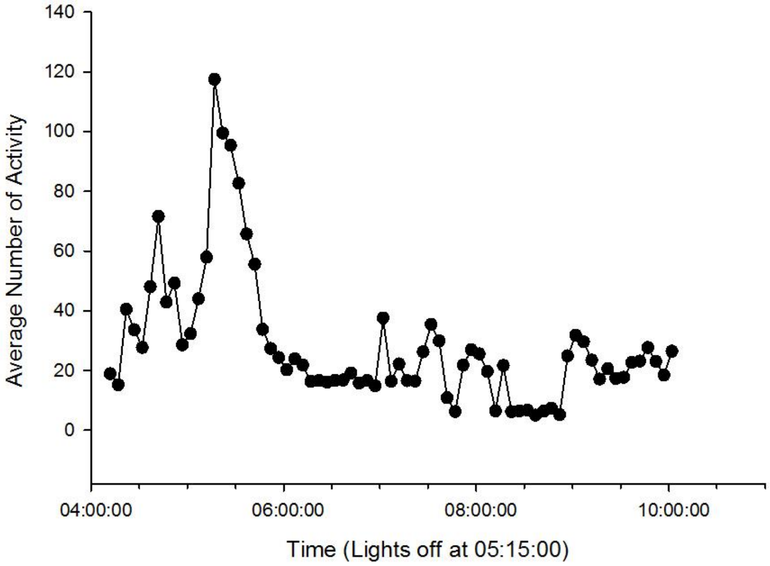
## 2.5 Quantifying/Measuring Behavior

### Activity and Motion via Infrared Sensors – Fall and Spring Migration

The BirdMotion software was programed to count the number of movements that an individual teal made for each 5 minute interval, with the max poll interval at 0.1 seconds and the minimum hop duration as 1 second. Files for each 24 hour period were downloaded daily at 12-noon and exported into Microsoft Excel. Nighttime activity was measured from 30 minutes after sunset (lights out) to 30 minutes before sunrise (lights on). We quantified the activity by calculating the proportion of 5 minute periods in the night that the birds were active.

According to Palmgren (1949), captive spring landbird migrants undergo a period of rest or sleep termed the period of quiescence. Through observations of night activity with motion sensors, we found presence of this quiescent period (Figure 6). To account for this period, when measuring sensor activity through the BirdMotion program, we selected the period 30 minutes after sunset (lights out) and the 30 minutes before sunrise (lights on).

a)



b)

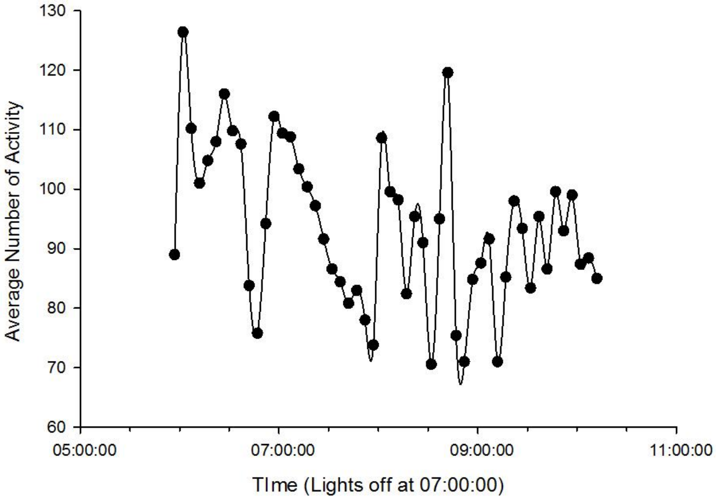


**Figure 6. Average number of night activity during each 5 minute time period representing one night**.

a) Pre-photoadvancement sensor activity in the migratory treatment group on 2 January. b) Post-photoadvancement sensor activity in the migratory treatment group on 30 March.

## Motion Sensor Validation – Spring Migration

We validated the activity recorded via motion sensors, by using the video camera footage collected for the corresponding periods. We randomly selected ten days for both migratory treatment group and control group throughout the experimental time period (01/16/12 – 04/04/12) within a five minute time frame for two 30-minute periods. From the dates selected, the video footage for a total of 16 teals, 8 teals in each room, was observed and any movements within the five minute time frame were counted. The number of movements recorded from these validation observations were then compared to the actual number of movements reported via motion sensors. Due to the fact that the data was not normally distributed, a Spearman's Rank-Order Correlation was conducted to see validity of motion sensors (see Table 1 for the migratory treatment group and Table 2 for the control group).

**Table 1. Spearman's Rank Correlation for the migratory treatment group comparing motion sensor data with video validation.**

| | S0 – V0 | S1 – V1 | S2 – V2 | S3 – V3 | S4 –V4 | S5 – V5 | S6 – V6 | S7 – V7 | S8 – V8 |
|---|---|---|---|---|---|---|---|---|---|
| R | 0.00459 | 0.21672 | 0.53892 | 0.33319 | 0.22055 | 0.57590 | 0.41238 | 0.36722 | 0.29822 |
| p | 0.9571 | 0.0101 | <0.0001 | <0.0001 | 0.0088 | <0.0001 | <0.0001 | <0.0001 | 0.0003 |

**Table 2. Spearman's Rank Correlation for the control group comparing motion sensor data with video validation.**

| | S0 – V0 | S1 – V1 | S2 – V2 | S3 – V3 | S4 –V4 | S5 – V5 | S6 – V6 | S7 – V7 | S8 – V8 |
|---|---|---|---|---|---|---|---|---|---|
| R | 0.47513 | 0.32307 | 0.28605 | 0.46573 | 0.38760 | 0.42381 | 0.48862 | 0.17189 | 0.74717 |
| p | <0.0001 | <0.0001 | 0.0006 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.0423 | <0.0001 |

Sensors with low validity correlation ($r < 0.30$) were eliminated from the analysis; these sensors were observed to be either hyposensitive or hypersensitive. For the migratory treatment group, the sensors eliminated were sensor 0, 1, 4, and 8. For the control group, the sensors eliminated were sensor 2 and 7.

## Behavior via Infrared Cameras – Spring Migration

Teal behavior was coded using a developed ethogram (see Table 3) that assigned position, behavior, and resource to video footage of each teal. Behaviors and postures were selected based on natural bird behaviors. Certain behaviors (*i.e*., looking-up and wing activity) were considered restless behaviors if observed. According to Agatsuma & Ramenofsky (2006), White-crowned Sparrows (*Zonotrichia leucophrys gambelii)* displayed stereotypical "beak-up" flight during migratory periods in captivity. Because this behavior was synonymous with migratory restlessness in White-crowned Sparrows, we were interested to see if a similar behavior was observed in waterfowl species; the "looking-up" behavior was included in our behavioral ethogram to see if this restless, stereotypical behavior was also observed.

**Table 3. Behavioral Ethogram used to code Blue-winged Teal video recordings.** The ethogram is broken up into posture, behavior, and resource.

| **Posture** | **Code** | **Description** |
|---|---|---|
| Sit | A | Assigned when teal is in sitting position (legs under body). Starts the second the teal first sits down. And ends when the teal stands up. |
| Walk | B | Assigned when teal is walking around cage. Starts the second the teal first starts to walk and ends when the teal stops. |
| Stand | C | Assigned when teal is standing and not moving around cage. Starts the second the teal first starts to stand and ends when the teal moves. |
| Swim | D | Assigned when teal is swimming in pool. Starts the second the teal enters the pool and/or starts to swim around and ends when the teal leaves the pool and/or stops swimming/remains motionless. |
| Float | E | Assigned when teal is staying motionless or very little motion while in pool. Different from swimming. Starts the second the teal seems motionless and not swimming and ends when the teal starts to swim around and/or leaves the pool. |
| Flying | F | Assigned when teal flaps wings or starts to fly in cage while **in air** (even if hovering). Ends when the teal stops flying. |
| Looking up | G | Assigned when teal looks up at the ceiling (usually while standing on the edge). |

**Table 3** (cont'd)

| **Behavior** | **Code** | **Description** |
|---|---|---|
| Forage - Feed or Drink | 1 | Assigned when teal starts feeding or drinking. Ends when the teal stops feeding or drinking. Teal might be observed feeding and drinking both on rubber mat and while in pool. |
| Maintenance - Preen/bathing/scratching/ body shaking | 2 | Assigned when teal starts to run bill through feathers. Ends when the teal stops. Preening/bathing can be observed on the rubber, on the edge, and in the pool. Also assigned when teal scratches face or feathers with webbed feet. |
| Sleep/rest | 3 | Assigned when teal is sleeping/resting (standing on one leg and/or head tucked back in feathers). Ends when the teal starts to move again. |
| Wing activity - stretching/flapping | 4 | Assigned when teal flaps wings repeatedly while staying stationary on ground or stretches wing, shakes body, or flaps wings usually assigned when on the edge of pool and rubber after exiting the pool. Ends when the teal stops wing flapping/shaking/stretching. |

| **Resource** | **Code** | **Description** |
|---|---|---|
| Pool | P | Assigned when teal is in the pool. |
| Edge | E | Assigned when teal is standing on edge of pool and mat |
| Rubber mat | R | Assigned when teal is on the rubber mat. |
| Nest box | N | Assigned when teal is in nestbox filled with shavings. |

We coded behavior using sampling methods first defined by Altmann (1974) and described in Martin & Bateson (2007). According to Altman (1974), there are three sampling techniques to study behavior which include continuous sampling, scan sampling, and time sampling. In continuous sampling, one observes and codes behaviors as they happen. In scan sampling, one observes behaviors at a fixed time interval. In time sampling, one observes portion of total behavior. We analyzed which sampling method to select by using techniques discussed in Mitlohner et al. (2001). At first, the continuous sampling (every 15s) was used to measure the behavior during one night period that was randomly selected (April 4th, 2012) for the migratory treatment group. From this continuous sampling, we extracted the behavior recorded at 1, 2, 5, 10, and 15 minutes to look at scan sampling and then multiplied each scan sampling method to average for the entire hour. In addition, to represent time sampling, we took continuous coding from the first 5, 10, and 15 minutes of each hour and created an average for the hour. Each sampling technique was analyzed to determine a level of detail needed for analysis of the remaining video footage. Using iPython Notebook (Perez & Granger 2007), the number of behaviors coded for each teal was quantified. Scan and time sampling techniques were used to assess which sampling technique was strongly correlated to the continuous sampling.

Using SigmaPlot (Systat Software, San Jose, CA), we used Pearson’s product correlation comparing continuous sampling with scan sampling (1, 2, 5, 10, 15 mins) and time sampling (5, 10, 15 mins). We found that the sampling technique with best correlation ($r > 0.90$) to the continuous sampling technique for all behaviors was the 2-minute scan sampling technique with an average of 0.975 (Table 4).

**Table 4. Pearson's product correlation results for each sampling method compared to continuous sampling.**

SS = scan sampling. TS = time sampling. 2-minute scan sampling was the technique selected to use for further sampling based on R coefficient.

| Sampling Technique | Forage | Maintenance | Rest | Wing Activity | Walk | Stand | Swim | Float | Flying | Average |
|---|---|---|---|---|---|---|---|---|---|---|
| SS - 1 min | 0.986 | 0.954 | 0.999 | 0.972 | 0.987 | 0.998 | 0.999 | 0.999 | 0.99 | 0.987 |
| **SS - 2 min** | **0.962** | **0.93** | **0.998** | **0.944** | **0.959** | **0.993** | **0.998** | **0.999** | **0.989** | **0.975** |
| SS - 3 min | 0.915 | 0.88 | 0.995 | 0.947 | 0.912 | 0.993 | 0.993 | 0.989 | 0.89 | 0.946 |
| SS - 5 min | 0.775 | 0.433 | 0.978 | 0.376 | 0.848 | 0.982 | 0.987 | 0.987 | NA | 0.796 |
| SS - 10 min | 0.685 | 0.221 | 0.957 | 0.722 | 0.368 | 0.938 | 0.985 | 0.975 | NA | 0.731 |
| SS - 15 min | 0.653 | 0.285 | 0.935 | 0.672 | 0.823 | 0.964 | 0.942 | 0.903 | NA | 0.772 |
| TS - 5 min | 0.826 | 0.469 | 0.665 | 0.92 | 0.653 | 0.874 | 0.917 | 0.983 | 0.994 | 0.811 |
| TS - 10 min | 0.897 | 0.545 | 0.528 | 0.904 | 0.673 | 0.916 | 0.96 | 0.976 | 0.994 | 0.821 |
| TS - 15 min | 0.905 | 0.663 | 0.616 | 0.917 | 0.65 | 0.944 | 0.975 | 0.949 | 0.994 | 0.846 |

Within a three hour period each night for the rest of the video data, we used a 2-minute scan sampling technique to behaviorally code the video footage. We then multiplied the data by eight to provide an estimate of behavior over one hour. We divided up the experimental period to correspond with photoperiod changes in the migratory treatment room; pre-photoadvanced (01/16/12 – 02/04/12), post-photoadvanced 1 (2/22/12 – 3/14/12), and post-photoadvanced 2 (3/20/12 – 4/10/12). The post-photoadvanced 1 period was 2 days past the period the teals were photoadvanced. Likewise, the video recordings were then correspondingly coded within three periods for the migratory treatment group: one pre-photoadvanced and two post-photoadvanced periods, and two periods for the control group: two control, pre-photoadvanced periods. When behavior was analyzed between groups, these two periods from the control group were compared to the first two periods from the migratory treatment group. Within each period, eight days of 20 days were selected to code, such that every three days a day was selected to code. The reason the control group had only two periods analyzed was due to the fact that the third period, the control group was being photoadvanced to see if it was an effective control group and if photoadvanced, it would show similar results to the migratory treatment group.

### Interobserver Agreement of Video Behavioral Coding – Spring Migration

Interobserver agreements (IOA) were assessed for our four observers coding behavioral data. For current behavioral research, IOA should be obtained among 25-30% of the study's session (Cooper et al. 2007). Each observer coded different amounts of video footage, so the IOA represented 25-30% of the data they had coded. In order for the observer's coding to be considered valid for our data analysis, an agreement of 80% needed to be met for each observer's IOA.

## 2.6 Data Analysis

### Fall Migration - Motion Sensors

The effects of age on sensor data during the fall were assessed using a linear mixed model in SAS 9.3 (SAS Institute Inc., Cary, NC, USA). The fixed terms were age and date and their interaction. For both analyses, the differences between means were assessed using Fisher's LSD.

Using SigmaPlot, we conducted a one-way repeated measures ANOVA comparing proportion of nighttime activity versus time blocks. Normality and equal variance assumptions were assessed and both tests passed. The alpha value was set at 0.05.

## Spring Migration

### *Body Condition*

Teal mass recordings were collected; this data was analyzed using SigmaPlot.  A paired t-test was conducted to examine if the change in mass before and after photostimulation for the migratory treatment group was statistically significant. A paired t-test was also conducted for the control group when the control group was photostimulated.

### *Motion Sensors*

A one-way repeated measures ANOVA was conducted along with a post-hoc paired t-test to compare the proportion of nighttime activity versus time blocks for the spring migration experiment. Normality and equal variance assumptions were assessed. The alpha value was set at 0.05.

### *Infrared Cameras*

The analysis on the normal variables, for behaviors like resting, swimming, and feeding, was done using a linear mixed model within MIXED procedure of SAS. The fixed terms in the model were group, period, and their interaction. Period was the repeated measure and the subject for it was dock nested within the room. To check the normality and equal variance assumptions, normal probability plots and box plots of residuals were assessed.

A large percentage of the data, for behaviors like looking-up and wing activity, were never observed so there are a lot of zeros in the data set. Hence, to run statistical analysis the observations were binerized. Then, generalized linear mixed model with a binary distribution was applied on them using the GLIMMIX procedure of SAS. This procedure was used to compare the likelihood of restless behaviors being exhibited during photoadvanced periods for our experimental group.

## 2.7 Results

### Fall Migration

For room 1, the mid-aged and oldest aged groups were compared. For room 2, the young-aged and mid-aged groups were compared. The age effect differences for both room 1 and 2 were considered significant at $P < 0.05$.

Teals in room 1 exhibited a significant decrease (Figure 7; $F_{13, 83} = 12.20$, $P<0.001$) in activity from the North Dakota photoperiod to Louisiana photoperiod according to post-hoc paired t-test. Even though the one-way repeated measure ANOVA was significant ($F_{13, 83} = 4.615$, $P<0.001$) for room 2, the post-hoc paired t-test showed no significant difference between the North Dakota photoperiod to Louisiana photoperiod.

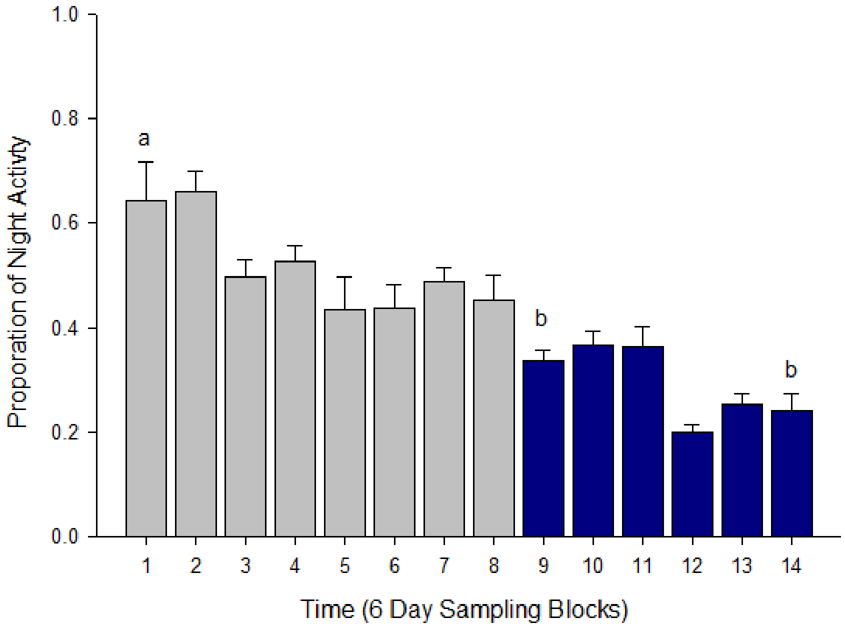


**Figure 7. Average proportion of night time spent active (± SE) for room 1 in Blue-winged Teals during the fall photoperiod.**

Blocks 1 – 8 = North Dakota sunrise/sunset photoperiod. Blocks 9 – 14 = Louisiana 10:14 L:D sunrise/sunset photoperiod. Different lower case letters denote significant differences according to post-hoc paired t-test.

## Spring Migration

### *Body Condition*

The body mass of the migratory treatment group significantly increased after photostimulation relative to the non-photoadvanced birds in the control group (Figure 8). When the control group was photostimulated months following the migratory treatment group, their body mass also significantly increased (Figure 8).

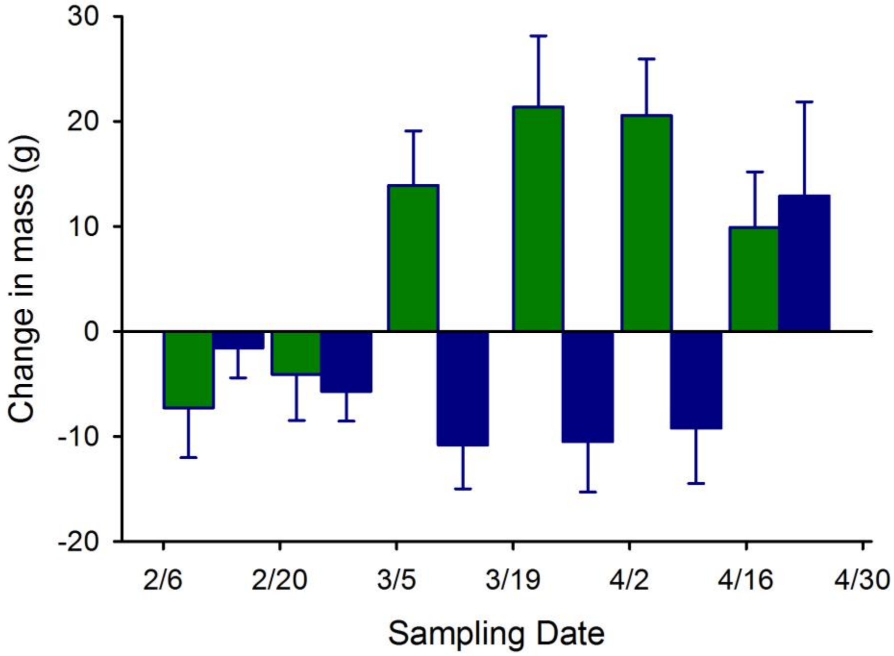


**Figure 8. Pre-spring migratory disposition and average change in body mass during the study period for each Blue-winged Teal group**.

Green bars = migratory treatment group (photoadvanced in February). Blue bars = control group (photoadvanced in April). Stars indicate significant difference: for the migratory treatment group, P<0.002; for the control group, P<0.009.

*Infrared Motion Sensor*

Teals in the migratory treatment group exhibited a significant increase (Figure 9; $F_{9, 100}$ = 16.12, P <0.001) in migratory activity according to the one way repeated measures ANOVA and showed elevated activity until April 20, 2012, the end date of the experiment for the migratory treatment group. A significant increase between sampling blocks pre-photoadvanced and post-photoadvanced was observed 40 days following photostimulation according to post-hoc paired t-test. The control group did not show increased activity during the same period of time, as expected. Due to the delay of onset of *Zugunruhe* (as evidenced by the migratory treatment group in Figure 9), we were unable to detect significance for the control group because the end date of the experiment, May 4, 2012, came prior to any possible photostimulation effects.

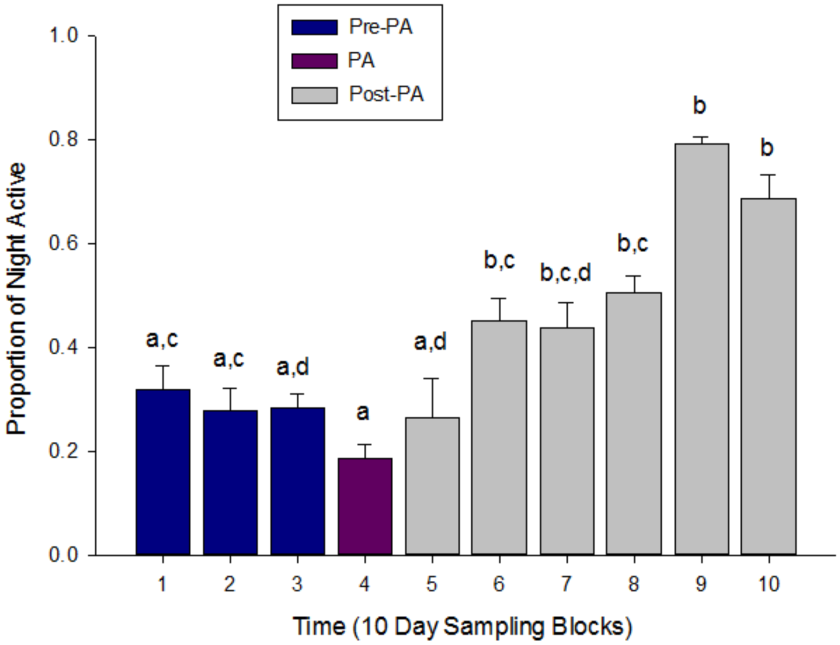


**Figure 9. Average proportion of night time spent active (± SE) for the migratory treatment group in Blue-winged Teals during the spring photoperiod.**

PA = Photoadvanced. Blocks 1, 2, 3 = pre-photoadvanced. Block 4 = photoadvanced. Blocks 5 through 10 = post-photoadvanced. Different lower case letters denote significant differences according to post-hoc paired t-test.

### *Video Data*

The results reported for the resting, maintenance, and feeding behaviors were averages because this data did not need to be binerized. For both the feeding behavior and the maintenance behavior, there was a significant difference for each behavior between migratory treatment group and control group (Table 5 and 6); within the migratory treatment group, there were also significant differences between the pre-photoadvanced period (1) and the post-photoadvanced periods (2 and 3), but not between each post-photoadvanced period (Table 7 and 8).

**Table 5. Differences between groups according to Least Squares Mean for behavior 1, feeding.**
Treatment = Migratory Treatment Group. Control = Control Group.

| Group | Group | Standard Error | t Value | Pr > \|t\| |
|---|---|---|---|---|
| Control | Treatment | 0.2649 | 4.72 | 0.0001 |

**Table 6. Differences between groups according to Least Squares Mean for behavior 2, maintenance.**
Treatment = Migratory Treatment Group. Control = Control Group.

| Group | Group | Standard Error | t Value | Pr > \|t\| |
|---|---|---|---|---|
| Control | Treatment | 0.1387 | 2.87 | 0.0097 |

**Table 7. Differences between periods within the migratory treatment group, according to Least Squares Mean for behavior 1, feeding.**

| Period | Period | Standard Error | t Value | Pr > \|t\| |
|---|---|---|---|---|
| 1 | 2 | 0.3709 | -1.92 | 0.0651 |
| 1 | 3 | 0.3697 | -2.47 | 0.0196 |
| 2 | 3 | 0.3628 | -0.56 | 0.5824 |

**Table 8. Differences between periods within the migratory treatment group, according to Least Squares Mean for behavior 2, maintenance.**

| Period | Period | Standard Error | t Value | Pr > \|t\| |
|---|---|---|---|---|
| 1 | 2 | 0.1670 | -8.12 | <0.0001 |
| 1 | 3 | 0.1665 | 9.52 | <0.0001 |
| 2 | 3 | 0.1592 | -1.44 | 0.1613 |

The resting behavior showed a significant difference between migratory treatment group and control group (Table 9). However, when looking at resting behavior within the three periods analyzed in the migratory treatment group, there was no significant difference among the pre-photoadvanced period (1) and the two post-photoadvanced periods (2 and 3) (Table 10).

**Table 9. Differences between groups according to Least Squares Mean for behavior 3, resting behavior.**
Treatment = Migratory Treatment Group. Control = Control Group.

| Group | Group | Standard Error | t Value | Pr > \|t\| |
|---|---|---|---|---|
| Control | Treatment | 0.1269 | 5.21 | <0.0001 |

**Table 10. Differences between periods within the migratory treatment group, for behavior 3, resting behavior.**

| Period | Period | Standard Error | t Value | Pr > \|t\| |
|---|---|---|---|---|
| 1 | 2 | 0.6890 | 0.09 | 0.9288 |
| 1 | 3 | 0.6913 | 1.19 | 0.2453 |
| 2 | 3 | 0.6914 | 1.10 | 0.2822 |

The results for the looking-up posture and wing activity behavior were reported as the probability of observing a certain behavior for each group because the data was binerized. For the looking-up posture, significant differences were reported not only between the migratory treatment group and control group (Table 11), but also between periods within the migratory treatment group (Table 12). We found similar results for the wing activity behavior as significant differences were reported within each group (Table 13) and also between periods within the migratory treatment group (Table 14).

**Table 11. Differences between groups and periods within each group according to Least Squares Mean for posture G, looking up.**
Treatment = Migratory Treatment Group. Control = Control Group.

| Group | Period | Group | Period | Standard Error | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| Control | 1 | Control | 2 | 0.7462 | -0.08 | 0.97376 |
| Control | 1 | Treatment | 1 | 0.9146 | -0.16 | 0.8719 |
| Control | 1 | Treatment | 2 | 0.8471 | -2.84 | 0.0105 |
| Control | 2 | Treatment | 1 | 0.9022 | -0.10 | 0.9214 |
| Control | 2 | Treatment | 2 | 0.8337 | -2.81 | 0.0111 |
| Treatment | 1 | Treatment | 2 | 0.6046 | -3.73 | 0.0014 |

**Table 12. Differences between periods within the migratory treatment group, according to Least Squares Mean for posture G, looking up.**

| Period within Treatment | Period within Treatment | Standard Error | t Value | Pr > \|t\| |
|---|---|---|---|---|
| 1 | 2 | 0.9230 | -2.41 | 0.0222 |
| 1 | 3 | 0.9339 | -3/07 | 0.0045 |
| 2 | 3 | 0.8534 | -0.75 | 0.4567 |

**Table 13. Differences between groups and periods within each group according to Least Squares Mean for behavior 4, wing activity.**
Treatment = Migratory Treatment Group. Control = Control Group.

| Group | Period | Group | Period | Standard Error | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| Control | 1 | Control | 2 | 0.4971 | 0.37 | 0.7112 |
| Control | 1 | Treatment | 1 | 0.4700 | -0.82 | 0.4123 |
| Control | 1 | Treatment | 2 | 0.4472 | -4.30 | <0.0001 |
| Control | 2 | Treatment | 1 | 0.4860 | -1.17 | 0.2417 |
| Control | 2 | Treatment | 2 | 0.4640 | -4.54 | <0.0001 |
| Treatment | 1 | Treatment | 2 | 0.3840 | -4.00 | <0.0001 |

**Table 14. Differences between periods within the migratory treatment group, according to Least Squares Mean for behavior 4, wing activity.**

| Period | Period | Standard Error | t Value | Pr > \|t\| |
|---|---|---|---|---|
| 1 | 2 | 0.4941 | -3.27 | 0.0027 |
| 1 | 3 | 0.4937 | -2.27 | 0.0305 |
| 2 | 3 | 0.4775 | 1.03 | 0.3100 |

## 2.8 Discussion

We are the first study to demonstrate waterfowl exhibit quantifiable migratory restlessness in captivity. Numerous studies in the past have measured migratory restlessness of landbirds in captivity; however, few studies on waterbird migratory behavior in captivity have been conducted in over a half century, when these types of experiments were first initiated. Most research on migratory behavior of waterbirds has been conducted in field settings (*e.g.*, Bellrose 1963, Elmberg et al. 2005, and Arzel et al. 2007) or in orientation experiments (*e.g.*, Southern 1969, Gudmundsson & Sandberg 2000). In addition to this, few waterfowl studies have focused on nocturnal behavior specifically, creating an additional challenge and need for more research in this area (Henson and Cooper 1994).

The most significant finding in this study was the initiation of spring migratory disposition for teals in response to experimentally extending daylength. Consistent with studies on landbirds (King & Farner 1959, 1963; Gifford & Odum 1965; Ramenofsky et al. 2003) and waterfowl (McLandress & Raveling 1981; Guellemette 2001), the teals exhibited significant mass gain in spring. We also anecdotally observed that the birds were eating at a faster rate due to visually messier cages and rate of food consumption. As birds enter migratory disposition they increase food consumption and fat deposition (King & Farner 1959, 1963; Ramenofsky et al.

2003). In our study, the mass gain in teals occurred before activity significantly increased. Similarly, Guellemette (2001) reported hyperphagia in Common Eiders (*Somateria mollissima*) prior to spring migration in the wild; Owen (1968) also observed feeding times increasing prior to migration for Blue-winged Teals.

We found consistent with migratory disposition was the significant increase in nighttime activity of teals of the migratory treatment group. There was an observed 40-day delay in *Zugunruhe* before activity significantly increased. As supposed by Owen (1968), this delay might be due to the captive teals needing more time to become physiologically ready for migration versus wild birds. A delay was also observed in hand-reared Redheads (*Aythya americana*) before they migrated; unfortunately the quantity of this delay was not reported in the study (Weller & Ward 1959). In our study, the nighttime activity significantly increased during the last 30 days of the experiment, in the month of April. Similarly, Coverdill et al. (2011) noted a significant increase in activity of photoadvanced White-crowned Sparrows by using photodetector/reflector, a similar technology to our motion sensors.

The increase in activity corresponded with an increase in behaviors consistent with migration for photoadvanced teals. In general, for migratory behaviors, we hoped to find significant difference among pre-photoadvanced period and two post-photoadvanced periods within the migratory treatment group and a significant increase of the behavior for the post-photoadvanced period. We also hoped to find significant difference between the migratory treatment group and control group with a significant increase of the behavior for the migratory treatment group. We would not expect to see a significant difference or increase between the two post-photoadvanced periods within the migratory treatment group.

We observed the migratory treatment group exhibited stereotypical looking-up/“beak-up” and wing activity that is consistent with other studies on restless behaviors (Agatsuma & Ramenofsky 2006). According to Agatsuma & Ramenofsky (2006) this “beak-up” behavior was considered a migratory restless behavior because it was a behavior the Gambel’s White-crowned Sparrows only exhibited at night. When teals in our study exhibited the looking-up behavior, the behavior itself was not a usual behavior seen in wild waterfowl; the behavior was stereotypical and very repetitive. Teals would look-up at the ceiling of the cage several times and then the behavior would conclude with them flying right at the ceiling; the teal would repeat the behavior soon after. It is important to note, this looking-up behavior was only observed on the edge of the pool or when the teal was in the pool. This potentially could make this behavior even more consistent of migratory restlessness as teals have been reported at showing more migratory behavior on water (Owen 1968).

As predicted, wing activity, which includes flying, flapping wings, and wing stretching, was also another behavior that showed a significant increase for the migratory treatment group. As previously noted, wing activity was consistent with looking-up and usually preceded after the looking-up behavior ended. On days of migratory departure for wild birds, we would expect wing activity to increase. Wing activity increase was recorded in Owen (1968) for Blue-winged Teals, including an increase of wing-flapping on the day Owen reported hand-reared teals looking restless.

In addition, we hoped our behavioral observations would highlight other examples of migratory activity consistent with teals in the wild. For our other two behaviors, feeding and maintenance, we found a significant increase for the migratory treatment group. Because mass gain was also noted in the teals, it was important to see if feeding changed based on the group or period. Our study confirms that teals experienced hyperphagia by increased feeding and mass gain. After wild bird migrants have exhibited hyperphagia, they decrease feeding before migratory departure; one instance of this was reported in Owen (1968) noting that teals increased feeding, prior to migration, and decreased feeding, on the day of departure. We might have observed this in our study as the change in mass decreased near the end of the post-photoadvanced period 2 and there was no significant difference of feeding between the two post-photoadvanced periods. In addition, it is important to note that our captive teals had food and water all the time, meaning teals used less energy to search for food. We were interested to find significance for maintenance behaviors. This was a natural bird behavior we decided to include, but this behavior has not been reported as having migratory relevance. However, more time spent maintaining and cleaning feathers would ideally help make the feathers fully functional for increased wing activity. There has been no evidence in the literature that we could find looking at maintenance behaviors for studies on migratory restlessness in captivity.

The resting behavior we showed unusual results. We predicted that resting behavior would be consistent regardless of group or period. In general, we would expect resting behavior to decrease slightly for the migratory treatment group to account for the night spent performing restless behavior. However, if teals exerted a lot of energy with restless behaviors, we might expect them to rest more. We did observe a significant decrease in resting behavior for the migratory treatment group overall, but when comparing significance within periods of the treatment group, no significant difference was reported. We observed the opposite of teal resting behavior as Owen (1968) reported hand-reared Blue-winged Teals increased resting on departure days. Agatsuma & Ramenofsky (2006) also noted an increase of resting behavior; however, this was most likely due to fatigue from over-exerted behaviors.

Behavioral studies are challenging given the time investment to analyze the videos; for this reason, we only conducted a behavioral assessment on spring migration video footage. We chose a 2-minute scan sampling technique to most-accurately quantify behavior. This is a similar and well-supported sampling technique by other studies on behavior (Altmann 1974; Mitlohner et al. 2001); however, scan sampling does not give a full, accurate representation of all of the behavior recorded. While coding, we observed behaviors before and after the 2-minute scan sampling, including wing activity and looking up. If we were able to record behaviors continuously yet effectively, certain behaviors might not have needed to be binerized to account for a large percentage of zeroes in the dataset. In addition to this, we also selected every 3 dates within a period to get an average representation of each month of data. Migratory birds, in the wild, stopover at different times. There might have been a chance the days coded were periods of rest for the group.

We cross-referenced motion sensor data with video footage to double check if dates that were selected showed high or low levels of activity. In addition, another limitation was the lack of congruency between motion sensors and videos, which has implications for studies that only use motion sensors. We did attempt to validate the motion sensor data by comparing this data to observations of movement from video camera footage. However, a few sensors were not validated properly and we believe this had to do with several complications with the lack of electricity at the containment facility the teals were housed in. We believe this complication was what made our motion sensors have periods of hyper- and hyposensitive activity.

There were days with observation, video data, and motion sensor data, where the control group showed a small increase in activity during the spring migration study. This could be because teals are obligate migrants they have an innate sense to migrate based on the time of the year. We made sure to photoadvance teals in the migratory treatment group much earlier than they would naturally experience this photoperiod in the wild to avoid the birds becoming naturally photostimulated and affecting the validity of the experiment. To determine if the control group was an accurate, effective control and to see if the control group could experience similar photoadvanced responses, we decided to photoadvance the control group nearing the end of our spring migratory study. However, due to the delay of onset of *Zugunruhe*, if the control group was housed longer, there is a possibility we might have observed activity increase when we photostimulated them.

Unlike our spring migration study, we did not observe distinct migratory restlessness in the teals during fall migration. We hoped to observe significant differences for the fall study in both room 1 and 2 seeing as both rooms had similar conditions. An inconsistency between fall and spring migration has also been observed in past literature. Agatsuma & Ramenofsky (2006) reported seeing less frequent migratory restlessness for fall in captive Gambel’s White-Crown Sparrows. Birds that were artificially photostimulated in the spring exhibited migratory restlessness (Agatsuma & Ramenofsky 2006). Past studies focusing on free-living landbird migrants have also noted inconsistent, asynchronous behavior for fall migration (King & Farner 1963). This inconsistency perhaps is due to the selective pressure for wild birds in the spring to arrive on breeding grounds whereas in the fall, this pressure is not as great (King & Farner 1963; Ramenofsky et al. 2003).

One reason we might not have observed migratory restless behavior during the fall migratory period was most likely due to teals not initiating and experiencing migratory disposition. Due to the early nature of migration of Blue-winged Teals in the wild and technology issues, we most likely missed the pre-migratory periods for fall migration. Mass was also not recorded for the fall migratory period; if we had recorded it, perhaps we might have noticed the absence of entering migratory disposition. Even though we were not able to see the onset of migratory activity, the motion sensor data alludes to the post-migratory activity during the fall season with a significant decrease in behavior between first (North Dakota) and second (Louisiana) photoperiods. Activity should naturally decrease and level-off once birds reach the wintering grounds and this is potentially what was shown here. However, due to technological issues with motion sensors, it made it impossible to fully analyze the entire fall period.

According to Owen (1968), hand-reared teals did not exhibit migratory restlessness. However, with our study, using a controlled indoor design with wild-caught and raised Blue-winged Teals, we found teals do exhibit migratory restlessness. For our spring migration study focusing on altered photoperiod, teals not only entered migratory disposition as shown through an increase in body mass data, but they also showed an increase of migratory activity and this activity was consistent with migratory restlessness. Using these techniques with behavioral observations recorded by advanced technology, we hope to describe and to define migratory behaviors of captive waterfowl in a way that has never been done before. Not only does this research embrace a novel form of technology, it helps to create detailed data for researchers to witness behaviors hard to capture in the field. This foundational research is considered a baseline study, which can possibly be used for future studies to advance migratory research, to see any potential effect the behaviors might have on zoonotic disease, and to recognize captive behaviors potentially useful for rehabilitation/reintroduction programs.

# LITERATURE CITED

# LITERATURE CITED

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