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Physiological Response and Habituation of Endangered Species to Military Training Activities: SERDP 2006 Annual Report

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COVER: Heart-rate transmitter on white-eyed vireo at Fort Hood, Texas.

Physiological Response and Habituation of Endangered Species to Military Training Activities: SERDP 2006 Annual Report

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Final report

Abstract: Effects of transient human disturbance on avian species is a concern on Department of Defense installations that support populations of federally listed endangered birds. Military training often is conducted within habitats that support endangered bird species, thus exposing individuals of these species to harassment as defined under the Endangered Species Act (ESA) of 1973. During the 2006 breeding season on Fort Hood, Texas, evaluations of two major physiological response systems determined response in passerine species to disturbances characteristic of military training activities: a hormonal (adrenocortical) response to stress in white-eyed vireos and endangered black-capped vireos, and energy expenditure as measured by remotely monitored heart rate in white-eyed vireos. Heart-rate radio telemetry was used to measure avian metabolic demands in response to potential stressors related to military training. This study is the first to demonstrate that 1) heart-rate transmitters can successfully be mounted on small (10-g) migratory passerines, 2) heart rate can be continuously monitored and recorded in these birds for at least 60 hours, and 3) heart rate is a robust measure of energy expenditure in small passerines and therefore is a powerful method to test the effects of military activity on survival in species of concern.

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Executive Summary

Organisms must respond to unpredictable, novel, and/or dangerous conditions in their environment to maintain homeostasis and optimize fitness (survival and reproduction). Effects of transient human disturbance on avian species is of particular concern on Department of Defense installations that support populations of federally listed endangered birds. Military training activities are often conducted within habitats that support endangered bird species, thus exposing individuals of these species to "harassment" as defined under the Endangered Species Act (ESA) of 1973, as amended. If military training activities elicit a stress response in individuals of endangered species, this would constitute harassment and is considered "take" as defined under the ESA. The regulatory consequences of take are significant and can result in widespread restrictions on training activity in habitats of endangered species.

The objectives of this project are to (1) determine chronic and acute stress response in passerines in response to non-lethal human disturbance as measured by endocrine response and energy expenditure in free-flying individuals, (2) determine whether individuals modulate their stress response to multiple exposure to human disturbance, and (3) determine whether species differ in stress response as a function of life history traits.

During the 2006 breeding season on Fort Hood, Texas, we evaluated two major physiological response systems to determine response in passerine species to disturbances characteristic of military training activities. We evaluated a hormonal response to stress, the adrenocortical response, in white-eyed vireos and endangered black-capped vireos (Section 2 of this report), and energy expenditure as measured by remotely monitored heart rate in white-eyed vireos (Section 3 of this report). These response measures are qualitatively different; however, both have potential costs relative to fitness of an individual. Concurrently measuring both these response systems in wild populations is important because, unlike captive experimental populations, free-flying individuals may have the option of responding to a perceived threat through activation of the adrenocortical response or behaviorally by avoiding the disturbance, thus potentially increasing energy demands. Data from captive populations may not reflect this plasticity of response in wild populations.

One of our study species, the black-capped vireo (*Vireo atricapillus*), is endangered and has a limited breeding distribution. Our other study species, the white-eyed vireo (*V. griseus*), is common and widely distributed in eastern North America. We used changes in plasma concentrations of corticosterone, the avian glucocorticoid, to measure the response to the following stressors: (1) capture and restraint for at least 30 minutes, (2) 60 minutes of continuous human presence on the breeding grounds, and (3) at least one week of rotating, nest-directed stressors (chronic stress). Both species exhibited the typical vertebrate response to capture and handling: a marked increase in corticosterone in the plasma. Black-caps, but not white-eyes, showed increased corticosterone after 60 minutes of human presence, suggesting that black-caps are more sensitive than white-eyes to some forms of anthropogenic disturbance. Contrary to prediction, following our chronic stress treatment, neither species exhibited the suppressed corticosterone levels typical of chronically stressed vertebrates. However, we found unexpected differences in corticosterone between our study sites, with both species from one site exhibiting an apparently suppressed response to capture and handling, suggesting birds at that site are chronically stressed. These findings suggest that birds breeding on Fort Hood, including two endangered species—the black-capped vireo and the golden-cheeked warbler—might be susceptible to negative physiological effects of ongoing military training disturbance, but several further tests are required to validate this hypothesis.

We use heart-rate radio telemetry to directly and continuously measure avian metabolic demands in response to potential stressors related to military training. Heart rate has been correlated to daily energy expenditure in birds and has proven to be a good physiological indicator of stress responses to external stimuli in an organism's environment. In this report, we present data obtained during the 2006 field season in which we use the non-endangered white-eyed vireo as a surrogate for the black-capped vireo.

Heart rate was highly correlated to O^2 consumption in white-eyed vireos (see Fig. 4) and was therefore a good indicator of energy expenditure in these birds. Two of five telemetered birds showed significant differences in heart rate between disturbance and non-disturbance experiments. In fact, one bird showed significantly lower mean heart rate and lower energy expenditure during the disturbance experiment. However, all birds showed an initial increase in heart rate at the start of the disturbance experiment

followed by a decrease in heart rate (within the following 10 minutes), indicating an initial alarm phase followed by a rapid habituation. Our data indicate there may be some level of individual variation and the 7h00–11h00AM period may not have been a period of elevated heart rate for these birds, regardless of our presence. Further data are necessary to make sound conclusions on the physiological effects of human activity in this species.

Our study conducted at Fort Hood in 2006 is the first to demonstrate that 1) we can successfully mount heart-rate transmitters on small (10-g) migratory passerines, 2) we can continuously monitor and record heart rate in these birds for at least 60 hours, and 3) heart rate is a robust measure of energy expenditure in small passerines and is therefore a powerful method to test the effects of military activity on survival in species of concern.

Preface

At the time this report was published, Timothy J. Hayden was the TES Program Manager; Alan Anderson was Chief, CEERD-CN-N; and Dr. John T. Bandy was Chief, CEERD-CN. The associated Technical Director was Dr. William D. Severinghaus, CEERD-CV-T. The Director of CERL was Dr. Ilker Adguzel. Colonel Richard B. Jenkins was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

1 Introduction

1.1 Objective

The objectives of this project are to (1) determine chronic and acute stress response in passerines in response to non-lethal human disturbance as measured by endocrine response and energy expenditure in free-flying individuals, (2) determine whether individuals modulate their stress response to multiple exposure to human disturbance, and (3) determine whether species differ in stress response as a function of life history traits.

1.2 Background

Organisms must respond to unpredictable, novel, and/or dangerous conditions in their environment to maintain homeostasis and optimize fitness (survival and reproduction). Individuals can respond proximately to environmental challenges through a variety of mechanisms, including neophobic (avoidance) and neophilic (exploratory) behaviors (Greenberg 1984, 1990; Greenberg and Mettke-Hofmann 2001), endocrine responses such as the adrenocortical response in vertebrate taxa (Wingfield et al. 1997, Romero et al. 2000), or production of catecholamines in vertebrate taxa (epinephrine and norepinephrine) through the sympathetic-adrenal medullary response (Selye 1946, Henry and Stephens 1977). Activation of these behavioral and physiological response systems represents cost/benefit tradeoffs to the individual. For example, the well-documented adrenocortical response to an environmental challenge has the benefit of mobilizing energy resources to meet the perceived threat (Wingfield et al. 1997); however, this response may have the cost of redirected behavior and deleterious physiological effects if this response persists over extended time periods (Sapolsky 1987). Proximate behaviors such as flushing from nests by parental birds in response to a perceived threat may enhance parental survival at the cost of reduced nestling survival (Steidl and Anthony 2000, Lord et. al 2001). From an ecological perspective, these tradeoffs represent a "stress" when the result is reduced fitness of the individual (Hofer and East 1998).

Effects of transient human disturbance on avian species is of particular concern on Department of Defense installations that support populations of federally listed endangered birds. Training activities on these installa-

tions are typically distributed across the landscape and not confined to roads or trails. These activities are often conducted within habitats that support endangered bird species, thus exposing individuals of these species to "harassment" as defined under the Endangered Species Act (ESA) of 1973, as amended. If military training activities elicit a stress response in individuals of endangered species, this would constitute harassment and is considered "take" as defined under the ESA. The regulatory consequences of take are significant and can result in widespread restrictions on training activity in habitats of endangered species. Understanding avian response to transient human activity and whether individuals are capable of modulating their response to repeated disturbance is important in mitigating potential effects of military training activities and reducing potential restrictions on training activities.

Human activity can present novel and potentially threatening conditions to wildlife populations. Extensive research has been conducted to determine effects of human activities on wildlife, particularly species of conservation concern (e.g., Boyle and Samson 1985, Gutzwiller et al. 1994, Knight and Cole 1995, Miller et al. 1998). Much of this work has focused on birds because of their relative abundance and observability (see review by Gutzwiller and Hayden 1997). Examples of human activities that may be perceived as threats but do not directly impact individual organisms include recreational activities such as hiking and boating, noise events, and transient human presence under a variety of circumstances, including military training activities.

Several deleterious effects of human presence in proximity to wildlife populations have been observed. Avoidance flights and abnormal vigilance induced by human activities may alter daily activity budgets and lessen the time and energy used for fitness-enhancing activities such as feeding, nest attentiveness, mate attraction, and territory defense (Burger and Gochfeld 1991, Gutzwiller et al. 1998, Lord et al. 2001). Steidl and Anthony (2000) examined the effects of camping on breeding bald eagles (*Haliaeetus leucocephalus*) and found that activity budgets were altered considerably when camping activities were closer to nesting eagles. These significant behavior modifications suggested that frequent human activities near nests could adversely affect nestling survival and, therefore, reproductive success.

Environmental factors such as severe storms, pollution, or human disturbance can act as stressors (Hofer and East 1998), triggering a cascade of hormone secretions typical of stress in all vertebrates studied so far (Boersma 1987, Silverin et al. 1997, Wingfield et al. 1997, Wasser et al. 1997). The measurement of circulating levels of corticosterone, the major stress-related hormone in birds, allows monitoring of stress at the organismal level. Increases in circulating corticosterone to acute stress can be viewed as an adaptive response in that it prepares the individual for "flight or fight" (Wingfield et al. 1997). However, chronic elevation and initiation of this response has been shown to detrimentally affect an individual's fitness by such mechanisms as reducing immune response and increased mortality (Sapolsky 1987).

Although negative effects of human activity have been recognized, some data indicate that wild populations may habituate in some respects to activity that initially may be perceived as threatening, but that ultimately presents no direct threat. Birds that habituate to human disturbance may devote more time to incubation, foraging, and other fitness-enhancing activities than those birds that avoid disturbance (Burger and Gochfeld 1991). Burger and Gochfeld (1991) found that the flushing distance of some resident and migrant bird species in India decreased as the number of people increased. Cooke (1980) found that birds were significantly more approachable in suburban areas than in rural areas. These studies indicate that some species are capable of modulating their response to human activity with repeated exposure, particularly if it is perceived as not being a direct threat.

Researchers evaluating the effects of human disturbance in wild populations are challenged by the great variability of potential response variables, the multiple levels of biological organization where a response may be expressed, and the difficulty in controlling levels of predictor variables in studies of free-living populations.

During the 2006 breeding season at Fort Hood, Texas, we evaluated two major physiological response systems to determine response in passerine species to disturbances characteristic of military training activities. We evaluated a hormonal response to stress, the adrenocortical response in white-eyed vireos and endangered black-capped vireos (Section 2 of this report), and energy expenditure as measured by remotely monitored heart rate in white-eyed vireos (Section 3 of this report). These response meas-

ures are qualitatively different; however, both have potential costs relative to fitness of an individual. Concurrently measuring both these response systems in wild populations is important because, unlike captive experimental populations, free-flying individuals may have the option of responding to a perceived threat through activation of the adrenocortical response or behaviorally by avoiding the disturbance, thus potentially increasing energy demands. Data from captive populations may not reflect this plasticity of response in wild populations.

Our use of multiple measures of stress and adaptation of newly available technologies provides a unique opportunity to address key knowledge gaps in how wild animals respond and adapt to potential disturbance from human activities. By framing the research design in the context of military training activities, our study will provide the Department of Defense with data that will assist in meeting the challenges of balancing the training mission with requirements to promote conservation of endangered species populations on military lands. Detailed descriptions of methods and results for our 2006 field experiments are presented in Sections 2 and 3 of this report.

2 Corticosterone Response to Experimentally Induced Acute and Chronic Disturbance in Black-Capped and White-Eyed Vireos at Fort Hood, Texas

2.1 Introduction

Free-living animals occasionally must cope with unpredictable disturbances to normal activities, such as a predator attack or a severe weather event. Vertebrates exhibit an adaptive hormonal response to such acute stressors, starting when the hypothalamus stimulates the anterior pituitary to release adrenocorticotropic releasing hormone (ACTH), and ending with the release of glucocorticoid from adrenal tissue into the bloodstream, causing much higher than normal (baseline) concentrations of glucocorticoid in the plasma (Sapolsky et al. 2000). Activation of that "hypothalamic-pituitary-adrenal (HPA) axis" has several beneficial physiological effects that help an animal survive an acute stress, such as increasing available energy in the bloodstream, and decreasing short-term investment in processes unrelated to immediate survival, such as reproduction (Sapolsky et al. 2000, Wingfield and Romero 2001).

However, when the HPA axis is activated chronically—repeatedly and for a long time—fitness is compromised in two important ways. First, processes, tissues, and behaviors that promote survival and reproduction may be altered in ways that harm long-term fitness, such as reduced response to immune challenges, neuronal cell death, and abandonment of the reproductive life-history stage (Wingfield et al. 1997, Sapolsky et al. 2000). Second, baseline and acute response levels of glucocorticoid are lower in the plasma of chronically stressed animals (Rich and Romero 2005), suggesting that chronic stress may alter the HPA axis in a costly way: by causing an animal to mount an inadequate response to a true acute threat to survival. Therefore, the costs of chronic stress are important when considering threats to populations of threatened and endangered species, especially when those species could be exposed to ongoing disturbance from human activity.

Suppression of glucocorticoid levels is a potentially costly consequence of prior chronic stress, but it also provides a way to detect chronic stress in free-living populations. For many species, the acute glucocorticoid response can be readily measured by capturing an animal and quickly taking a baseline blood sample, then inducing an acute stress response by restraining the animal for a short period of time (30 minutes is used in many vertebrate studies) and taking another blood sample for comparison with the baseline level. In this experimental "challenge" to the HPA axis, chronically stressed individuals are predicted to mount a smaller increase in glucocorticoid after restraint compared to individuals that have not been subjected to prior chronic stress (Rich and Romero 2005). That effect was shown clearly in a controlled laboratory experiment in European starlings (Class Aves, *Sturnus vulgaris*): a group exposed to acute stressors four times per day, for several days, had lower baseline and acute-response levels of the major avian glucocorticoid, corticosterone, compared to a control group (Rich and Romero 2005). The same suppression of baseline corticosterone levels was recently demonstrated in free-living adult starlings exposed to experimentally induced, nest-directed chronic stress (Cyr and Romero 2007).

Several observational studies of free-living vertebrates have demonstrated a parallel difference in corticosterone levels between populations exposed to different degrees and types of human disturbance: Magellanic penguins exposed to tourists walking through a breeding colony (Walker et al. 2006), Galápagos marine iguanas exposed to tourists on foot, but restricted to trails (Romero and Wikelski 2002), and spotted salamanders in disturbed habitat (Homan et al. 2003). Together, these observations suggest that exposure to various forms of human activity can be chronically stressful to free-living vertebrates. As contact between humans and wild animals increases, understanding effects of human activity on threatened and endangered species becomes increasingly important to conservation efforts.

We studied the effect of experimentally induced acute and chronic stress in the endangered black-capped vireo (*Vireo atricapillus*) and the related but common white-eyed vireo (*V. griseus*), migratory songbirds that breed in south-central and southeastern North America. Our specific aim was to increase our understanding of the effect of human disturbance on black-caps inhabiting Fort Hood, Texas, which supports about 2000 males during the breeding season (Cimprich and Kostecke 2006), and which is also

the site of extensive and ongoing military training activity. Within each species, we tested the hypothesis that human presence on the breeding grounds is acutely stressful to adults. We predicted that one hour of human presence on the breeding grounds would cause an increase in corticosterone concentration. We also tested the hypothesis that chronic stress would alter the HPA axis, so that baseline and acute-response concentrations of corticosterone would decrease after several days of nest-directed disturbance (i.e., chronic stress). Finally, we looked for evidence that black-caps were more sensitive to our short- and long-term disturbances than white-eyes, because black-caps are uncommon and have a limited distribution, but white-eyes are common and widely distributed in eastern North America, perhaps suggesting a greater susceptibility of black-caps to human development and disturbance.

2.2 Methods

2.2.1 Study Sites

Field work was conducted on Fort Hood, an approximately 87,000-ha military base in central Texas (USA). The base is shaped approximately as a north-pointing triangle, with the central third comprising a live-fire area surrounding a munitions impact zone. The west and east sides of the base are used to practice land- and air-based maneuvers involving vehicles and troops on foot. Black-capped and white-eyed vireos are common breeders on Fort Hood, and often have overlapping territories. This was true in both of our study sites, and territory density appeared to be similar in both areas, although we were unable to quantify population density for either area.

Because we wanted to control and minimize exposure to human activity other than our experimental manipulations as much as possible, we worked in low-use maneuver areas east and west of the live-fire area. The human presence experiment (described below) was conducted in western Fort Hood (training areas 13, 21, 22, and 64; hereafter referred to as the "western site"), where the relatively open habitat and flat terrain permitted an observer to locate and follow adults on their territories. The western site was about 1 km from the nearest paved road. The chronic stress experiment (described below) was conducted atop the secluded Owl Creek plateau in far eastern Fort Hood (training area 20; hereafter referred to as the "eastern site"), about 8 km from the closest paved road and 25 km east of the western site.

It was impossible to control for all potential site effects in our two experiments, because we could not perform both experiments at the same site. We wanted birds in the human disturbance experiment to be as naïve as possible to humans on foot, thereby maximizing the likelihood of detecting a true acute effect of human presence on the territory, and we wanted birds in the chronic stress experiment to be from the most secluded suitable habitat possible on the base, thereby maximizing the likelihood of detecting a true effect of our chronic stress treatment. Our chronic stress protocol required up to six people per day walking through breeding habitat, which could have caused habituation to that potential disturbance, and therefore confounded our test to determine whether human presence caused an acute increase in corticosterone. Also, compared to the western site, the more wooded habitat and hilly terrain in the eastern site made detecting and following adults much more difficult, so the human presence experiment would have been impossible in the east. Thus, we found the potential confound of working at sites in different parts of Fort Hood less important than the problem of testing for an effect of human presence in birds exposed to almost daily human disturbance, and the considerable logistical difficulty of performing the human presence experiment in the eastern, more secluded site. Furthermore, to reduce the number of animals used in the study, we used one control group for each species, taken from the eastern site, for comparison with birds exposed to an hour of human presence and birds exposed to chronic stress.

2.2.2 Human Presence Experiment

From 23 April to 30 May 2006, adult black-capped and white-eyed vireos were followed on their breeding grounds by one of the authors (TJH) for 60 minutes. The 60-minute period began when an adult was detected and approached on foot. For about the next 50–55 minutes, the focal bird was continuously approached on foot along the most direct line possible, at a moderate walking pace. When the bird hopped or flew away, it was followed on foot to the next perch. No other disturbance was attempted (e.g., no hand-clapping, waving, or vocalizing). Territory boundaries were not mapped for any bird in order to prevent habituation to human presence, so it is possible that focal birds left their breeding territory during the following disturbance, but no followed adult that was eventually sampled for corticosterone escaped human detection and approach for more than 1–2 minutes during the hour. Visual contact was attempted at all times. Also, although samples were taken over the same time of year as the chronically stressed and control samples (see below), we could not confirm that all

adults in this group had nestlings on the day they were sampled, as we did for the other groups.

After about 50–55 minutes of following, a 6- × 2-m mist net was stretched open between two poles in a part of the territory frequented by the focal bird during the preceding disturbance. Mist net setup was occasionally stopped to approach and make close visual contact with the bird. Once the mist net was raised, adults were captured and corticosterone was sampled as described below. Any difference in corticosterone levels between followed and control adults suggested an effect of 60 minutes of human presence on the territory.

2.2.3 Chronic Stress Experiment

From 26 April to 5 June 2006, we attempted to create chronically stressed adult black-capped and white-eyed vireos inhabiting a secluded area of Fort Hood. The aim of this experiment was to create a known group of chronically stressed birds for future comparison with birds exposed to military training activities.

Our chronic stress treatment comprised four stressors per day at active nests for 7–10 d, while adults were incubating eggs and brooding or feeding nestlings, following the laboratory chronic stress protocol of Rich and Romero (2005) and the field adaptation of that protocol by Cyr and Romero (2007). Stressors were presented in random order but never repeated at a nest within one day. Our six stressors were

1. *Naturalistic decoys* of predators on adults and nestlings: 2-m rubber snake, plastic crow with call playback, and plastic screech owl with call playback, and

2. *Anthropogenic disturbances* known to cause chronic stress in captive European starlings (and indirectly known for free-living, nesting European starlings based on Cyr and Romero [2007]): human presence, radio playback, and novel objects, such as a helium balloon tied to nearby vegetation (Rich and Romero 2005).

Stressors were positioned 1–2 m from each nest, for 30–60 min, with varying amounts of time between presentations (0.5–3.0 h). Predator call and radio playback were made using battery-powered, handheld digital audio players (Muvo mp3 players, Creative Labs) connected to small (9- ×

8- × 5-cm) amplified speakers (Mini Audio Amplifier, RadioShack). Predator calls were played randomly among two 20-second bouts of silence, and radio playback was 35 minutes of a talk show with multiple human voices and other anthropogenic noises. Audio players and speakers were placed on the ground below, or in vegetation < 1 m from the decoys, which were always placed in an upright, perched position in vegetation near the nest, and oriented toward the nest. During the human presence stressor, one person sat or stood and occasionally moved (waved, clapped, etc.) and vocalized.

Rich and Romero (2005) showed that corticosterone concentration dropped significantly in captive starlings exposed to chronic stress for approximately 8–10 d. We sampled most adults after 7–9 d of stress treatment in order to reduce the risk of losing samples because of nest loss to predation or weather, and to keep the timing of corticosterone samples as similar as possible within the nestling stage. After 7–12 days of rotating stressors, and always when adults were feeding nestlings, we captured adults and measured plasma corticosterone levels as described below.

2.2.4 Control Group

From 29 April to 8 June 2006 we captured and sampled blood from adult black-capped and white-eyed vireos (as described below) for comparison with our samples of adults exposed to 60 min of human presence or our chronic stress treatment. All control samples came from the eastern site, as discussed above (see 2.2.1 Study Sites, page 7), and were taken from adults known to have nestlings on the day they were sampled.

2.2.5 Capture, Blood Sampling, and Corticosterone Analysis

When adults were feeding nestlings, we captured them with mist nets, occasionally and only where necessary, using playback of conspecific song or screech owl calls to attract birds to the net. In most cases adults were netted passively. For nearly all control and chronic stress samples we cut mist net lanes and suspended the net (closed) the day before we intended to sample, then approached the territory and opened the net when adults were away gathering food for the nestlings.

Blood samples (20–50 μL) were taken within 3 min of capture (T = 0) as a measure of baseline circulating corticosterone concentration. Another blood sample was taken after 30 min of handling and restraint in an

opaque cloth bag (T = 30). Blood was held on ice until it could be centrifuged (within 24 h), then the plasma was frozen and returned to Tufts University for analysis using a standard radioimmunoassay (Wingfield et al. 1992).

In order to minimize any effects of our capture and bleeding protocol, 60-minute samples were not taken from the smaller and endangered black-capped vireos in the control and chronically stressed groups. Little was lost by forgoing the 60-minute sample for these groups because the difference in corticosterone between control and chronically stressed groups was relatively small after 60 minutes of capture compared to 30 minutes after capture in captive European starlings (Rich and Romero 2005).

2.2.6 Comparisons and Statistical Analyses

Our major purpose in this study was to describe any effect of our acute and chronic stressors on plasma corticosterone within each study species. Direct species comparisons were less important, so we analyzed and report each species separately.

Contrary to prediction, mean baseline corticosterone was slightly higher in the chronic stress sample than the control sample within each species (Table 1). Therefore, in order to increase statistical power, we pooled baseline corticosterone data for the chronic and control samples for each species, and compared that pooled sample to the 60-min human presence group in a two-way analysis of variance. All samples for that analysis met the assumptions of normal distribution (in Shapiro-Wilks test all $P > 0.05$) and all contrasts met the assumption of homogeneity of variance (in F-ratio variance test, all $P > 0.10$). We used Wilcoxon signed ranks test to compare corticosterone levels at capture and 30 and 60 min after capture within control, chronically stressed, and human presence samples, because within each species at least some samples or contrasts violated the assumptions of normality and homogenous variance. Repeated-measures analysis of variance was used to test for differences among samples in the change in corticosterone over time, because baseline and 30-min corticosterone levels were correlated strongly among control white-eyed vireos ($r = 0.83$, $P = 0.02$, $n = 7$) and weakly among black-capped vireos ($r = 0.75$, $P = 0.09$, $n = 6$). Not all samples met the assumption of normality, but analysis of variance is somewhat robust to that problem (Zar 1996), and that minor violation was preferable to using non-parametric methods that cannot control for correlated corticosterone levels within individuals.

Table 1. Plasma corticosterone concentration (ng × mL⁻¹) in adult black-capped and white-eyed vireos breeding at Fort Hood, Texas, after exposure to 60 minutes of human presence, chronic stress treatment, or no prior experimental treatment (mean ± SE). Sample sizes in parentheses. The human presence experiment was conducted in western Fort Hood, and the other samples were taken from a secluded area of eastern Fort Hood.

	Minutes after capture		
	0	30	60
Black-capped vireos			
Human presence	16.8 ± 4.5 (11)	35.7 ± 5.8 (9)	50.0 ± 9.4 (8)
Chronic stress	8.1 ± 4.7 (7)	56.0 ± 10.8 (10)	—
Control	7.3 ± 3.0 (8)	54.3 ± 10.7 (8)	—
White-eyed vireos			
Human presence	4.7 ± 1.2 (12)	26.5 ± 3.1 (12)	32.6 ± 8.4 (9)
Chronic stress	5.7 ± 1.6 (7)	41.9 ± 7.3 (8)	41.7 ± 8.1 (6)
Control	5.3 ± 1.7 (7)	41.5 ± 5.3 (8)	49.4 ± 10.6 (5)

2.3 Results

2.3.1 Black-Capped Vireos

Human presence appeared to increase plasma corticosterone in black-capped vireos. Corticosterone at the time of capture averaged 6.4 ± 2.4 ng mL⁻¹ (n = 14) among control and chronic samples, and 16.8 ± 4.5 ng mL⁻¹ (n = 11) in birds followed on their territories for one hour ($F_{1,23}$ = 4.73, P = 0.040; Fig. 2.1a). Followed birds also differed in their response to capture stress compared to the other samples. Thirty minutes of capture and handling caused corticosterone to increase to only 35.7 ± 5.8 ng mL⁻¹ in followed birds (comparison to corticosterone at time of capture, Z = -1.84, P = 0.066, n = 9), but it increased to 56.0 ± 10.8 ng mL⁻¹ in the chronic stress sample (Z = −2.37, P = 0.018, n = 7) and to 54.3 ± 10.7 ng mL⁻¹ in the control sample (Z = −2.20, P = 0.028, n = 6). Furthermore, followed birds had a significantly smaller increase in corticosterone from capture to 30 minutes after capture compared to control birds (repeated measures, $F_{1,13}$ = 5.26, P = 0.039). It is unlikely that the relatively small increase in corticosterone after 30 minutes in the followed group was caused by inability of the adrenal tissue to produce more corticosterone, because corticosterone increased to 50.0 ± 9.44 ng mL⁻¹ by 60 minutes after capture (Z = 2.38, P = 0.017, n = 8).

Our chronic stress treatment had no effect on baseline (Fisher's protected least squares P =0.51) or response levels of corticosterone compared to

controls ($P = 0.92$), suggesting that we did not cause chronic stimulation of the hypothalamic-pituitary axis in black-caps.

2.3.2 White-Eyed Vireos

In contrast to black-caps, white-eyed vireos exhibited no increase in corticosterone after one hour of human presence. At the time of capture, corticosterone averaged 4.7 ± 1.2 ng mL^{-1} among birds exposed to human presence and 5.5 ± 1.6 ng mL^{-1} among control and chronic samples ($F_{2,23} = 0.14$, $P = 0.87$). Thirty minutes after capture, followed white-eyes showed a significant increase in corticosterone ($Z = -2.98$, $P = 0.003$, n = 12), as did chronic ($Z = -2.20$, $P = .028$, n = 6) and control ($Z = -2.37$, $P = .018$, n = 7) samples. However, as with black-caps, the change in corticosterone in white-eyes was significantly smaller in the followed sample (to 26.5 ± 3.1 ng mL^{-1} after 30 minutes) than the control sample (to 42.8 ± 6.0 ng mL^{-1}; repeated measures, $F_{1,17} = 7.14$, $P = 0.016$). Corticosterone did not continue to increase 60 minutes after capture in the followed sample ($Z = -0.30$, $P = 0.77$, n = 9) or in the chronic ($Z = -0.11$, $P = 0.92$, n = 6) or control ($Z = -0.41$, $P = 0.69$, n = 5) samples.

There was no effect of our chronic stress treatment on either baseline (Fisher's protected least squares $P = 0.84$) or response levels of corticosterone compared to our control sample of white-eyes ($P = 0.97$). As in black-caps, our chronic stress treatment appeared to have no effect on the HPA axis.

2.4 Discussion

2.4.1 Patterns of Corticosterone Change in Control Groups

Black-capped and white-eyed vireos exhibited a typical vertebrate response to capture and handling. Thirty minutes after capture and restraint, plasma corticosterone concentration increases from (mean $\pm$ SE) 4.7 ± 1.7 ng/mL to 54.3 ± 10.7 ng/mL in black-caps, and from 4.1 ± 1.4 ng/mL to 40.4 ± 6.5 ng/mL in white-eyes. These data, which were taken from vireos inhabiting one of the most secluded areas on Fort Hood, probably reflect typical, undisturbed baseline and acute response concentrations of corticosterone during the nesting stage. They provided the basis for comparisons with vireos exposed to the experimental disturbances we created in this study, and they provide the basis for future comparisons

with vireos nesting in areas of Fort Hood that experience high levels of military training activity.

2.4.2 Human Presence Experiment

The disturbance of being followed by a human for 60 minutes caused plasma corticosterone to increase in black-capped but not in white-eyed vireos. Therefore the black-capped vireo, an endangered songbird that nests in many areas of Fort Hood, may be susceptible to acute physiological stress due to military training activities. Further tests are needed to determine whether other military training activities on Fort Hood, such as bivouacking and operating a generator, cause the same stress response as being unable to escape the presence of a human on foot for 60 minutes.

It remains to be tested whether black-capped vireos habituate to human disturbance, thereby reducing the long-term physiological impact of military training activities. For example, after several days of training activity in an area, black-caps may not perceive humans on foot as a threat and thus they may not respond with an acute corticosterone increase. The ability to habituate to disturbance during the nesting stage could explain why our attempt at causing chronic stress failed. Alternatively, black-caps may not habituate to military training activities, suggesting the need for a further evaluation of the physiological impact of particular areas, times, durations, or types of training activity.

White-eyed vireos did not increase corticosterone in response to 60 minutes of human presence. White-eyes have wider habitat preferences than black-caps (Grzybowski 1995, Hopp et al. 1995), so white-eyes may have had, or perceived that they had, many escape routes and vegetation patches available to them while being followed, which might have reduced the perceived threat of, and therefore the corticosterone response to, a human on foot. Also, radio-transmitter tracking (I. Bisson, unpublished data) and our anecdotal observations during mist-netting suggest that white-eyes commonly move long distances (> 1 km) and into neighboring territories during the breeding season, so it may not be stressful for white-eyes to be pursued into habitat surrounding their breeding territories. White-eyes might exhibit a corticosterone response after a longer period of human presence, and to other types of anthropogenic disturbance, but this remains to be tested.

Notably, the much smaller geographical distribution and smaller total population of black-caps than white-eyes is correlated with our finding that black-caps were more sensitive than white-eyes to our mild human disturbance. Therefore, black-capped vireos might be predisposed to limited range as a result of expansion of the human population.

2.4.3 Chronic Stress Experiment

To our surprise we found no effect of our chronic stress treatment on plasma corticosterone concentrations in either black-capped or white-eyed vireos. This finding contradicted expectation, because various forms of chronic disturbance are correlated with decreased corticosterone levels in birds and reptiles in the lab (Rich and Romero 2005) and field (e.g., Homan et al. 2003, Romero and Wikelski 2002, Walker et al. 2006, Cyr and Romero 2007). Interestingly, in both vireos we found lower corticosterone after 30 minutes of restraint in our west site than in our east site. We made no prediction about site differences in this study, but this result is consistent with the hypothesis that vireos in the west site are chronically stressed, and vireos in the east are not. Unfortunately, we cannot exclude the possibility that eastern vireos would show low 30-minute corticosterone levels if they were exposed to 60 minutes of human presence before capture, as were the western vireos.

We conclude, tentatively, that our "chronically stressed" group was not truly chronically stressed, either because focal adults escaped our stressors by flying away, or because they habituated to our stressors and thus stopped responding to them with an acute corticosterone response. We find it unlikely that our stressors were not perceived as threats by either species, based on our human presence experiment for black-caps, and based on anecdotal behavioral observations of black-caps and white-eyes responding to crow and owl presentation and playback. Whatever the reason, we probably did not cause the repeated acute corticosterone increase necessary to cause the suppressed response characteristic of chronically stressed animals (Rich and Romero 2005, Cyr and Romero 2007).

Failure to cause chronic stress with our protocol does not imply that black-capped vireos, white-eyed vireos, or the endangered golden-cheeked warbler (*Dendroica chrysoparia*), another common breeder on Fort Hood, are not susceptible to long-term human disturbance in general, or military training activities in particular. The east-west site differences we found in vireos in this study suggest that chronically stressed bird populations may

exist on Fort Hood. The west site in this study was only about 1 km from a paved road and the vireos there appeared to have suppressed corticosterone response to capture, but the east site, chosen for its seclusion, was about 8 km from the nearest paved road, and vireos there appeared to have a typical corticosterone response to capture.

2.5   Results and Conclusions

Our initial tests, presented here, suggest that black-capped vireos are susceptible to novel stressors they cannot escape, as when they were followed by a human, but that they might not be susceptible to novel stressors they can escape, such as our nest stressors. A third possibility is that they simply habituate to escapable and non-escapable stressors during nesting. White-eyed vireos did not respond to being followed by a human or to our nest-directed stressors. This research provides a substantial basis for future comparisons of corticosterone levels in black-capped and white-eyed vireos exposed to different kinds of military training activity, and in areas of Fort Hood that experience more training activity (e.g., live-fire areas) than the secluded area we sampled (far eastern Fort Hood).

Several tests are necessary to test the hypotheses developed here. First is the need to take control samples at the west site, which would allow us to exclude the possibility that the low corticosterone response in the west site to 30 minutes of capture was somehow caused by the 60 minutes of disturbance prior to capture. Second is the need to test for a corticosterone response to our nest-directed stressors in eastern birds, which would confirm that they are perceived as threats by vireos there. Finally is the need for a reference sample of vireos away from Fort Hood, with very little exposure to any form of human disturbance. Even our relatively secluded east site was exposed to low-flying helicopters, blast noise from a nearby demolition site, occasional recreational vehicle traffic, and our nest-searching activities. Samples from an even more secluded site would make us sure that the east site at Fort Hood serves as a legitimate control site for comparison with vireos from other parts of the base.

Figure 1. Plasma corticosterone concentration at time of capture (T = 0) and after 30 and 60 minutes of handling and restraint, in (a) black-capped and (b) white-eyed vireos exposed to 1 hr of human presence, 7–10 days of rotating, nest-directed stressors (chronic stress), or with no prior exposure to direct human disturbance (control).

3 Physiological Stress Responses to Human Activity Using Heart-Rate Telemetry

3.1 Introduction

Determining the effects of human activity on wildlife is a crucial step toward developing sound management programs for species of concern. Previous studies seeking to quantify these effects have primarily focused on habitat assessments (e.g., Johns 1991), consequences on nesting success (e.g., Safina and Burger 1983), or have attempted to evaluate these effects through observations of behavioral responses (e.g., Gill and Sealy 1996), all of which can be time-consuming and costly. Measurements of physiological responses such as energy expenditure and the adrenocortical response to human-caused disturbance may, however, offer a more direct, continuous, and robust approach.

Organisms physiologically respond to negative or positive conditions in their environment in order to maintain homeostasis and optimize fitness. In turn, allostasis maintains stability of the homeostatic system through change (e.g., maintaining blood oxygen, body temperature). Faced with a perceived threat, organisms respond by turning on an allostatic response initiating a variety of physiological and behavioral coping mechanisms. The body then shuts off these responses once the threat has gone. However, if physiological and behavioral responses do not result in maintaining allostasis, as is the case when activation of the response systems persists over an extended period of time (no habituation), the costs outweigh the benefits of such responses, resulting in decreased fitness of the individual. We can also refer to this condition as allostatic overload. In this study we use measures of energy expenditure to assess avian responses to human activity associated with military operations and determine whether allostasis is achieved in the presence of such activity. Because military activities are unpredictable, periodic, and differ in intensity, they offer a powerful tool to assess a full range of disturbance types on avian physiological responses. Such responses may include an increase in energy expenditure that may result in decreased fitness, including overall decreased survival (Daan et al. 1996).

We use heart-rate radio telemetry to directly and continuously measure avian metabolic demands in response to potential stressors related to military training. Heart rate has been correlated to daily energy expenditure in birds (Bevan et al. 1995, Cochran and Wikelski 2005) and has proven to be a good physiological indicator of stress responses to external stimuli in an organism's environment (Nephew et al. 2003). Our overall goal was to formulate management practices that will benefit endangered species, the black-capped vireo (*Vireo atricapillus*) and golden-cheeked warbler (*Dendroica chrysoparia*), inhabiting military training areas and that will ensure long-term sustainable and successful military installations. Our specific objectives were 1) to develop dose/response models for physiological response of selected priority endangered species to military stressors; 2) to determine capacity of species of concern to habituate to non-threat disturbances; and 3) to test predictive models for physiological stress response based on life history characteristics and taxonomic affiliation of endangered species. This report presents data obtained for the 2006 field season in which we use a surrogate non-endangered relative of the black-capped vireo, the white-eyed vireo (*Vireo griseus*).

3.2 Methods

3.2.1 Study System

The white-eyed vireo is a small (11-g) migratory passerine that breeds in the eastern region of North America from southern Canada to Florida. Its winter range expands from Virginia to Honduras and parts of the Caribbean (Hopp et al. 1995). The study was conducted on one of the vireos' breeding sites on the Fort Hood military post in Killeen, Texas (31°7'48" N, 97°46'49" W) during the white-eyed vireo's breeding season from March to June 2006 (Fig. 2). Fort Hood, a 340-mile^2 installation, is one of the most intensely used ground-training sites for US military troops (Hayden et al. 2001) and therefore provides excellent grounds to test the effects of human and military activity at varying degrees of intensity. Fort Hood comprises three main training areas with varying military training intensity (Fig. 2). To measure stress response in birds that were typically not habituated to human or military activity, we conducted the study in the eastern region of the Fort Hood post (Fig. 2), where activity was limited. During the three-month study period, we observed very little human and/or military presence, other than our own. The study site was typical of white-eyed vireo habitat: open patchy secondary scrubland dominated

by ashe juniper (*Juniperus ashei*), shin oak (*Quercus incana*), and Texas oak (*Quercus texana*).
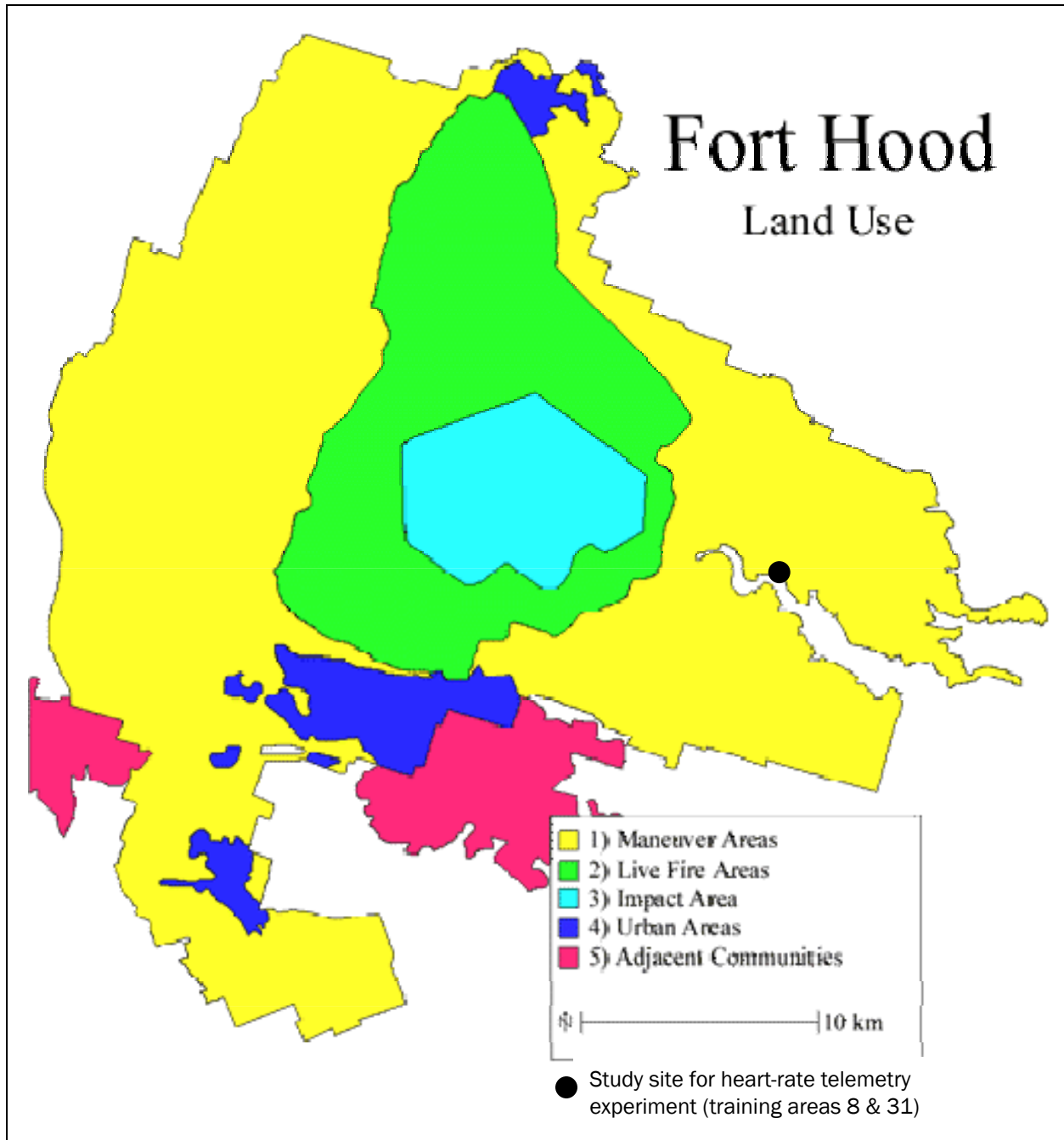
Figure 2. Study area on Fort Hood post (Killeen, Texas).

3.2.2 Heart-Rate Telemetry

Before the start of the heart-rate monitoring experiments, we mapped territories and monitored territorial male vireos. We captured paired males

one hour before roosting (approximately 5:00PM) by luring them into mist-nets using song playbacks. Each vireo was marked with a unique combination of US Fish and Wildlife Service band and color bands. We used heart-rate transmitters (Sparrow Systems, Dewey, Illinois) to capture and transmit heart rate for seven white-eyed vireo males. Each transmitter was first fitted with a small piece of cloth to enable its attachment to the bird's dorsum. The transmitters and cloth together weighed less than 5% (250 mg) of the species' average body weight. Transmitters emitted a continuous signal amplitude modulated (AM) by a 1,800-Hz subcarrier oscillator that was frequency modulated (FM) by heart muscle potentials. In turn, the heart muscle potential was captured via two wire electrodes placed subcutaneously on the dorsum. We mounted heart-rate transmitters following protocols by Cochran and Wikelski (2005), but without the use of isoflurane to anesthetize the birds. Our first attempts at placing heart-rate transmitters with the use of isoflurane resulted in two deaths. Isoflurane alone was not the cause of death, but rather a combination of isoflurane and isopropyl alcohol used to wet the feathers for cutting. We therefore do not discourage the use of isoflurane for these experiments, but found that we successfully mounted transmitters without having to anesthetize the birds. The procedure lasted an average of 15 minutes from the time of capture to the time of release.

3.2.3 Heart-Rate Tracking and Disturbance Experiments

Each bird mounted with a transmitter ($n = 7$) was continuously monitored for two days and three nights (60 hours). Average duration of battery life for heart-rate transmitters was five days. All male vireos were mated and most (n = 4) were actively feeding fledged young during the entire monitoring period, with the exception of one male that was nest building and one male that was incubating. Heart rate was radio transmitted and remotely recorded using Yagi antennae and AR800 receivers (AOR Ltd., Tokyo, Japan) that were connected to a PC laptop computer. We used the CoolEdit 2000 sound recording analysis software (Syntrillium Software Corp., Phoenix) to record and analyze heart rate. CoolEdit provides a band-pass filtering option that enables the removal of noise for heart-rate analysis. Heart rate (beats/min) was subsequently calculated manually every 10 minutes during the disturbance and non-disturbance period and every 30 minutes for the remaining tracking period.

Each bird mounted with a heart-rate transmitter was disturbed continuously for four hours (7–11AM) on Day 2 of the study. Disturbance experi-

ments involved one observer following and threatening the bird at 5–12 feet with loud noises and aggressive chases. Observers (n = 3) were changed after 60–90 minutes of disturbance. We used the same four-hour time period (7–11AM) on Day 1 as the control non-disturbed experiment. Behavioral observations were monitored during both disturbed and non-disturbed periods to correlate behavior with heart-rate recording.

3.2.4 Measuring Metabolic Activity

Energy expenditure was determined for five additional white-eyed vireos by measuring oxygen consumption and carbon dioxide production using an open flow, push-through respirometry system in the laboratory (Withers 1977). Heart rate was simultaneously recorded to calculate energy expenditure from that obtained in the field for seven vireos. We used Fick's equation that, for the cardiovascular system,

*Oxygen consumption = heart rate x cardiac stroke volume x
(oxygen content of arterial blood – oxygen content of venous blood).*

Heart rate was decreased from high to resting levels by placing the bird in a dark chamber for 5–10 minutes.

3.3   Results and Conclusions

We obtained heart rate for non-disturbed vs. disturbed experiments for seven vireos, but in this report we present heart-rate data for five vireos only (Fig. 3). Heart rate was highly correlated to O^2 consumption in white-eyed vireos (Fig. 4) and was therefore a good indicator of energy expenditure in these birds.

Only two birds showed significant differences in heart rate between disturbance and non-disturbance experiments (Fig. 3). In fact, one bird showed significantly lower mean heart rate and lower energy expenditure during the disturbance experiment (individual 2, Table 2 and Fig. 3). However, all birds showed an initial increase in heart rate at the start of the disturbance experiment (Fig. 3), followed by a decrease in heart rate (within the following 10 minutes), indicating an initial alarm phase followed by a rapid habituation. Changing the observer (twice every 60–90 minutes) did not alter heart rate during the experiments. Our results therefore indicate that birds quickly habituate to human disturbance regardless of the person conducting the disturbance. However, the rapid

habituation may be a result of prior exposure to our presence. Although we limited our activities during territory searches early in the field season, we may have nonetheless habituated the birds to our presence prior to the start of the experiments. Furthermore, there appears to be some level of individual variation and the 7h00–11h00AM period may not have been a period of elevated heart rate for these birds regardless of our presence (Fig. 3). Further data are necessary to make sound conclusions on the physiological effects of human activity in this species.

Our study conducted at Fort Hood in 2006 is the first to demonstrate that 1) we can successfully mount heart-rate transmitters on small (10-g) migratory passerines, 2) continuously monitor and record heart rate in these birds for at least 60 hours, and 3) heart rate is a robust measure of energy expenditure in small passerines and is therefore a powerful method to test the effects of military activity on survival in species of concern. We are therefore confident that our methodology can be used on the endangered black-capped vireo and potentially on the golden-cheeked warbler in 2007. Our 2007 goals therefore include studying physiological effects of military operations on species of concern at Fort Hood using heart-rate telemetry.

Table 2. Mean heart rate and corresponding energy expenditure of five white-eyed vireos monitored during four-hour (7h00–11h00AM) disturbance and non-disturbance experiments at Fort Hood, Texas, 2006. Individual numbers correspond to those in Figure 3.

Individual	Mean heart rate (beats/min)		Mean energy expenditure (kJ/day)	
	Disturbance	No disturbance	Disturbance	No disturbance
1	1005	680	88	49
2	532	748	34	59
3	760	812	63	63
4	1006	963	88	83
5	771	772	61	61
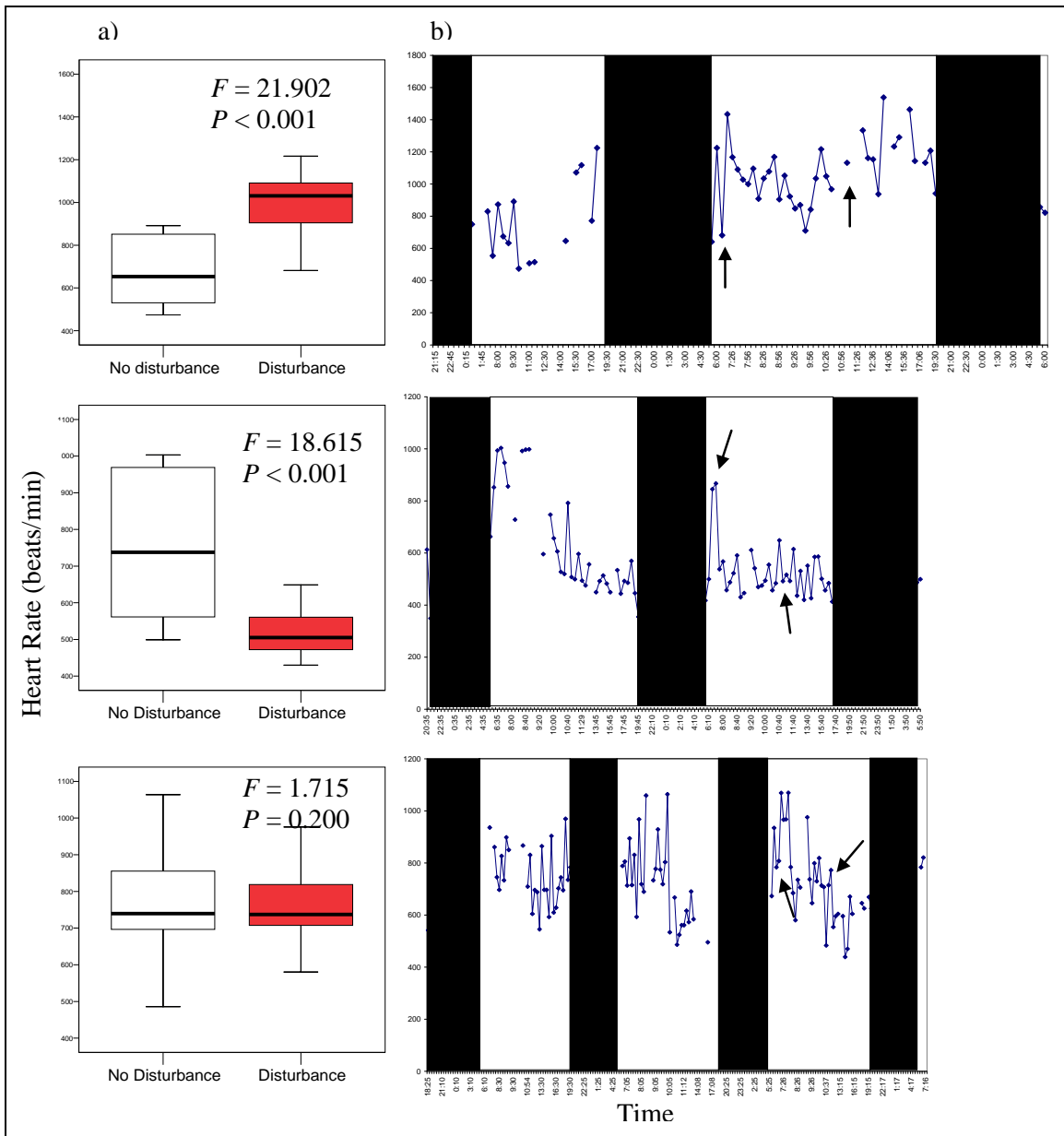
Figure 3. Heart rate (beats/min) for five white-eyed vireos at Fort Hood, 2006. a) ANOVA comparisons between disturbed vs. non-disturbed experiments during the 7h00–11h00AM period and b) corresponding heart rate during the entire (ca. 60 hrs) monitoring period. Shaded areas indicate night/roosting and arrows indicate start and end of disturbance experiment on Day 2 of monitoring period.
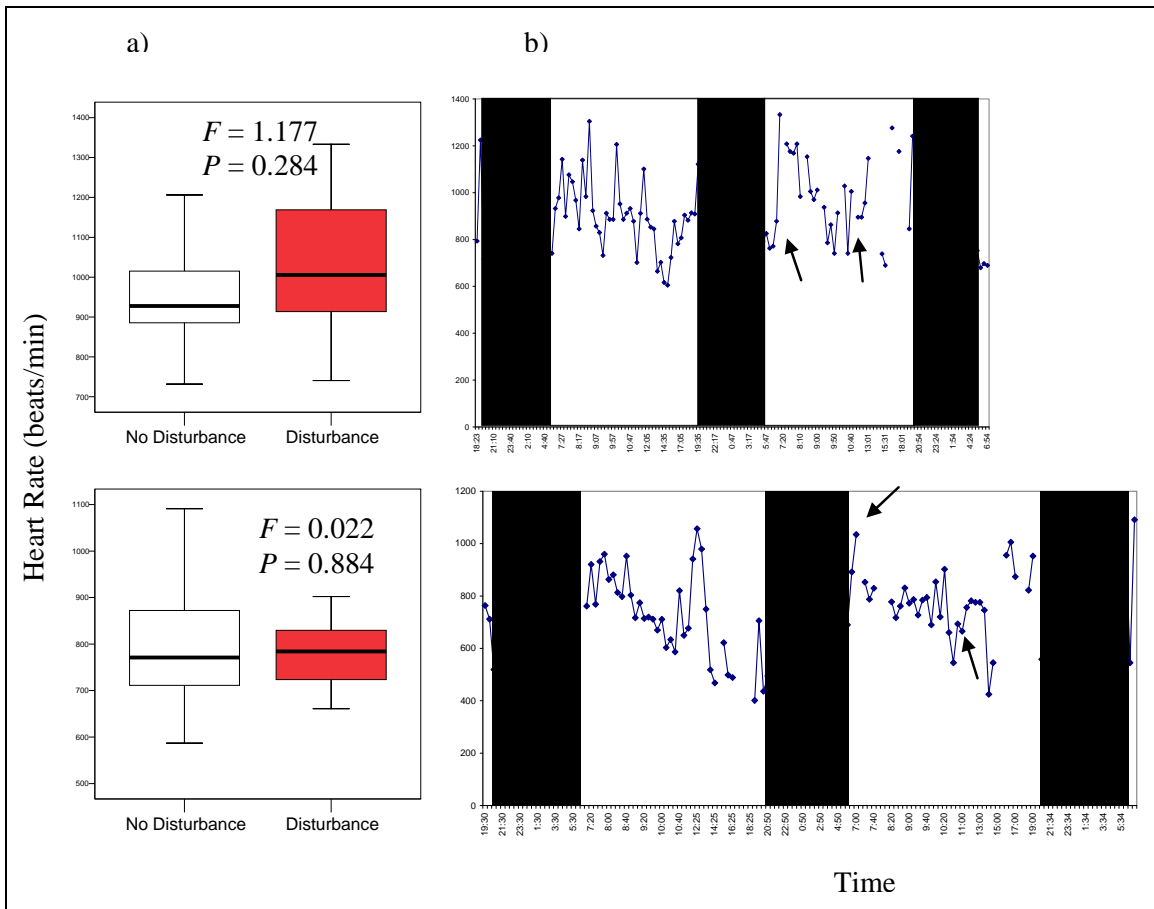
Figure 3. (cont'd).
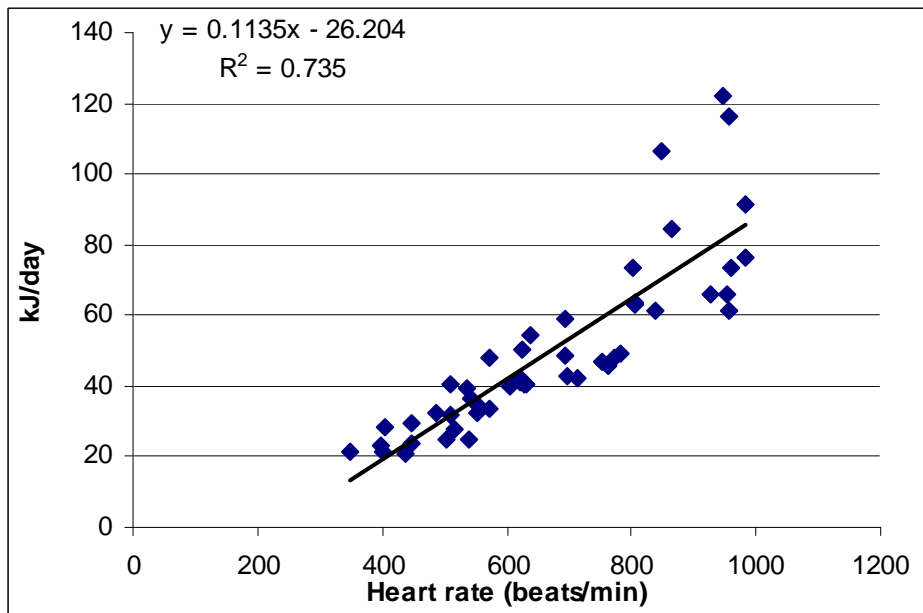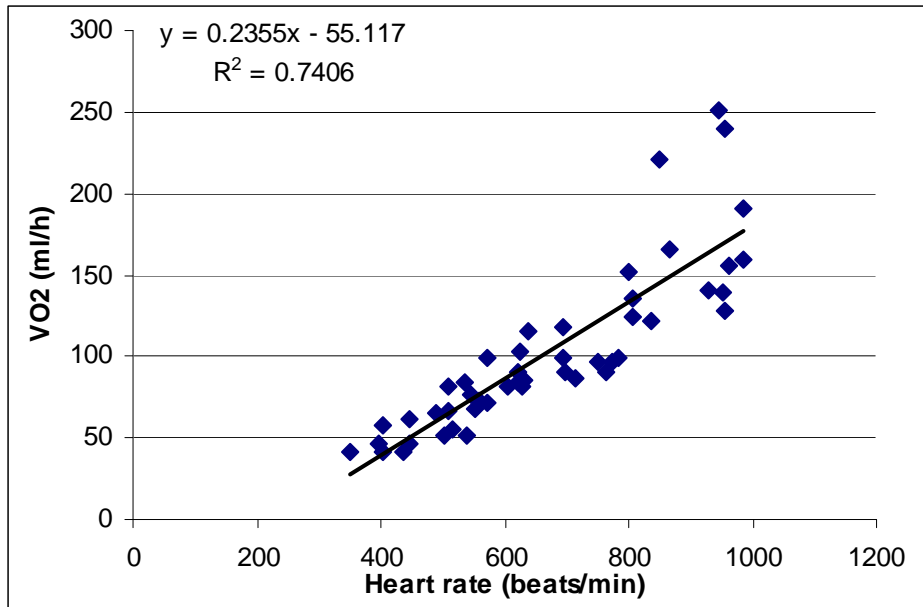
Figure 4. a) O_2 consumption and b) energy expenditure (kJ/day) of five white-eyed vireos in relation to their heart rate.

4 Concluding Summary

During the 2006 breeding season at Fort Hood, Texas, we evaluated two major physiological response systems to determine response in passerine species to disturbances characteristic of military training activities. We evaluated a hormonal response to stress, the adrenocortical response in white-eyed vireos and endangered black-capped vireos (Section 2 of this report), and energy expenditure as measured by remotely monitored heart rate in white-eyed vireos (Section 3 of this report).

Our initial tests of corticosterone response suggest that black-capped vireos are susceptible to novel stressors they cannot escape, as when they were followed by a human, but that they might not be susceptible to novel stressors they can escape, such as our nest stressors. White-eyed vireos did not respond to being followed by a human or to our nest-directed stressors. This research provides a substantial basis for future comparisons of corticosterone levels in black-capped and white-eyed vireos exposed to different kinds of military training activity, and in areas of Fort Hood that experience more training activity (e.g., live-fire areas) than the secluded area we sampled (far eastern Fort Hood).

Future endocrine response work will test the hypotheses developed from our 2006 studies. First is the need to take control samples at the west site, which would allow us to exclude the possibility that the low corticosterone response in the west site to 30 minutes of capture was somehow caused by the 60 minutes of disturbance prior to capture. Second is the need to test for a corticosterone response to our nest-directed stressors in eastern birds, which would confirm that they are perceived as threats by vireos there. Finally is the need for a reference sample of vireos away from Fort Hood, with very little exposure to any form of human disturbance. Even our relatively secluded east site was exposed to low-flying helicopters, blast noise from a nearby demolition site, occasional recreational vehicle traffic, and our nest-searching activities. Samples from an even more secluded site would make us sure that the east site at Fort Hood serves as a legitimate control site for comparison with vireos from other parts of the base.

Our heart-rate telemetry study conducted on Fort Hood in 2006 is the first to demonstrate that 1) we can successfully mount heart-rate transmitters on small (10-g) migratory passerines, 2) continuously monitor and record heart rate in these birds for at least 60 hours, and 3) heart rate is a robust measure of energy expenditure in small passerines and is therefore a powerful method to test the effects of military activity on survival in species of concern. We are therefore confident that our methodology can be used on the endangered black-capped vireo and potentially on the golden-cheeked warbler in 2007. Our 2007 goals therefore include studying physiological effects of military operations on species of concern at Fort Hood using heart-rate telemetry.

Pending review by the SERDP staff, this report will be published as a US Army Corp of Engineers Engineer Research and Development Center special report. Sections 2 and 3 of this report will be revised and formatted for independent submission for publication in peer-reviewed journals.

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Appendix A: Banding and Sampling Records for 2006 Field Season

Band Number	TA	Species	Age	Sex	Date	Blood	Transmitter
14546	20	BCVI	AHY	F	4/20/2002	Y	N
1921-45901	20	BCVI	ASY	M	6/26/2002	Y	N
1921-45907	20	BCVI	ASY	M	6/28/2002	Y	N
1921-45918	20	BCVI	ASY	M	7/3/2002	Y	N
1921-45919	20	BCVI	SY	M	7/4/2002	Y	N
1921-45933	64	BCVI	ASY	M	7/7/2002	Y	N
1921-45940	64	BCVI	ASY	M	7/8/2002	Y	N
1921-45942	64	BCVI	SY	F	7/8/2002	Y	N
1921-45957	64	BCVI	ASY	M	7/14/2002	Y	N
1921-45958	64	BCVI	ASY	M	7/14/2002	Y	N
1921-45962	43	BCVI	AHY	U	7/15/2002	Y	N
1921-45963	43	BCVI	ASY	M	7/15/2002	Y	N
1921-45966	20	BCVI	SY	F	7/16/2002	Y	N
1921-45970	46	BCVI	ASY	M	7/17/2002	Y	N
1921-45984	64	BCVI	HY	U	8/1/2002	Y	N
1921-45992	64	BCVI	AHY	M	8/5/2002	Y	N
1921-45994	20	BCVI	AHY	M	8/6/2002	Y	N
2340-14465	20	BCVI	AHY	F	5/16/2002	Y	N
2360-63010	20	BCVI	ASY	M	6/4/2002	Y	N
2400-45872	20	BCVI	ASY	M	6/6/2002	Y	N
2410-77003	13	BCVI	ASY	M	4/23/2006	Y	N
2430-90756	20	BCVI	AHY	M	4/20/2002	Y	N
2430-90767	20	BCVI	ASY	M	5/2/2002	Y	N
2430-90769	20	BCVI	ASY	F	5/3/2002	Y	N
2430-90771	20	BCVI	AHY	F	5/4/2002	Y	N
2430-90772	20	BCVI	AHY	M	5/4/2002	Y	N
2430-90775	20	BCVI	ASY	F	5/6/2002	Y	N
2430-90778	20	BCVI	AHY	F	5/7/2002	Y	N
2430-90779	20	BCVI	ASY	M	5/7/2002	Y	N
2430-90780	20	BCVI	ASY	F	5/7/2002	Y	N
2430-90782	20	BCVI	ASY	M	5/8/2002	Y	N
2430-90784	20	BCVI	ASY	F	5/9/2002	Y	N
2430-90785	20	BCVI	SY	M	5/9/2002	Y	N
2430-90787	20	BCVI	SY	M	5/10/2002	Y	N

Band Number	TA	Species	Age	Sex	Date	Blood	Transmitter
2430-90788	20	BCVI	SY	F	5/11/2002	Y	N
2430-90789	20	BCVI	ASY	M	5/11/2002	Y	N
2430-90791	20	BCVI	SY	M	5/12/2002	Y	N
2430-90792	20	BCVI	SY	M	5/15/2002	Y	N
2430-90797	20	BCVI	SY	F	5/18/2002	Y	N
2450-91301	64	BCVI	AHY	M	5/9/2006	Y	N
2450-91303	64	BCVI	ASY	M	5/29/2006	Y	N
2450-91305	64	BCVI	AHY	M	5/29/2006	Y	N
2450-91306	64	BCVI	ASY	M	5/30/2006	Y	N
2450-91451	21	BCVI	AHY	M	5/12/2006	Y	N
2450-91452	21	BCVI	AHY	F	5/12/2006	Y	N
2450-91453	64	BCVI	AHY	M	5/13/2006	Y	N
2450-91453	64	BCVI	SY	M	6/2/2002	Y	N
2450-91454	21	BCVI	ASY	M	5/23/2006	Y	N
2450-91456	64	BCVI	ASY	M	5/24/2006	Y	N
2450-91463	20	BCVI	ASY	F	5/25/2002	Y	N
2450-91464	20	BCVI	ASY	M	5/25/2002	Y	N
2450-91467	20	BCVI	ASY	M	5/31/2002	Y	N
2450-91468	20	BCVI	SY	F	5/31/2002	Y	N
2450-91471	64	BCVI	AHY	F	6/3/2002	Y	N
2450-91477	20	BCVI	SY	F	6/5/2002	Y	N
2450-91478	20	BCVI	ASY	M	6/5/2002	Y	N
2450-91481	20	BCVI	AHY	F	6/6/2002	Y	N
2450-91489	20	BCVI	ASY	F	6/9/2002	Y	N
2450-91490	20	BCVI	SY	M	6/19/2002	Y	N
2450-91491	20	BCVI	SY	F	6/19/2002	Y	N
2450-91496	20	BCVI	SY	M	6/24/2002	Y	N
2450-91497	20	BCVI	SY	M	6/24/2002	Y	N
2450-91498	20	BCVI	SY	M	6/24/2002	Y	N
2450-91499	20	BCVI	SY	F	6/24/2002	Y	N
2450-91500	20	BCVI	ASY	F	6/25/2002	Y	N
2460-94704	64	BCVI	HY	U	8/14/2002	Y	N
2460-94707	64	BCVI	AHY	M	8/14/2002	Y	N
2460-94710	20	BCVI	AHY	M	8/17/2002	Y	N
2460-94711	20	BCVI	HY	U	8/17/2002	Y	N
2460-94714	64	BCVI	AHY	F	8/18/2002	Y	N
2460-94715	64	BCVI	AHY	M	8/21/2002	Y	N
2460-94716	64	BCVI	AHY	M	8/21/2002	Y	N
2460-94717	64	BCVI	AHY	M	8/21/2002	Y	N
2460-94722	20	BCVI	HY	U	8/23/2002	Y	N

Band Number	TA	Species	Age	Sex	Date	Blood	Transmitter
1921-45961		lost					N
1921-45990		lost					N
1991-17214		lost					N
1991-17215		lost					N
1991-17216		lost					N
2430-90763		lost					N
2430-90765		lost					N
2430-90768		lost					N
1991-17201	20	NOCA	AHY	M	3/26/2002	Y	N
1991-17202	20	NOCA	AHY	M	4/22/2002	Y	N
1991-17203	20	NOCA	AHY	F	5/2/2002	Y	N
1991-17204	20	NOCA	AHY	M	5/5/2002	Y	N
1991-17205	20	NOCA	HY	M	6/6/2002	Y	N
1991-17206	20	NOCA	HY	U	6/8/2002	Y	N
1991-17207	20	NOCA	AHY	M	7/2/2002	Y	N
1991-17208	20	NOCA	HY	U	7/2/2002	Y	N
1991-17209	20	NOCA	AHY	F	7/3/2002	Y	N
1991-17210	64	NOCA	HY	U	7/13/2002	Y	N
1991-17211	64	NOCA	AHY	F	7/14/2002	Y	N
1991-17212	64	NOCA	HY	U	7/14/2002	Y	N
1991-17213	64	NOCA	HY	U	7/14/2002	Y	N
1991-17217	46	NOCA	AHY	F	7/17/2002	Y	N
1991-17218	46	NOCA	AHY	F	7/17/2002	Y	N
1991-17219	20	NOCA	AHY	M	7/23/2002	Y	N
1991-17220	20	NOCA	AHY	M	7/24/2002	Y	N
1991-17222	64	NOCA	HY	M	8/1/2002	Y	N
1991-17223	64	NOCA	HY	U	8/1/2002	Y	N
1991-17224	64	NOCA	HY	M	8/5/2002	Y	N
1991-17225	64	NOCA	AHY	M	8/5/2002	Y	N
1991-17226	64	NOCA	HY	F	8/5/2002	Y	N
1991-17227	64	NOCA	HY	F	8/5/2002	Y	N
1991-17228	20	NOCA	AHY	F	8/6/2002	Y	N
1991-17229	20	NOCA	HY	M	8/6/2002	Y	N
1991-17230	20	NOCA	HY	M	8/7/2002	Y	N
1991-17231	20	NOCA	AHY	F	8/7/2002	Y	N
1991-17232	20	NOCA	HY	F	8/9/2002	Y	N
1991-17233	20	NOCA	HY	M	8/9/2002	Y	N
1991-17234	20	NOCA	HY	M	8/9/2002	Y	N
1991-17235	64	NOCA	HY	F	8/10/2002	Y	N
1991-17236	64	NOCA	HY	F	8/10/2002	Y	N

Band Number	TA	Species	Age	Sex	Date	Blood	Transmitter
1991-17237	64	NOCA	HY	M	8/11/2002	Y	N
1991-17238	64	NOCA	HY	M	8/11/2002	Y	N
1991-17239	46	NOCA	HY	M	8/13/2002	Y	N
1991-17240	46	NOCA	AHY	F	8/13/2002	Y	N
1991-17241	64	NOCA	HY	F	8/14/2002	Y	N
1991-17242	64	NOCA	HY	M	8/11/2002	Y	N
1991-17243	64	NOCA	HY	M	8/15/2002	Y	N
1991-17244	20	NOCA	HY	M	8/17/2002	Y	N
1991-17245	20	NOCA	HY	M	8/22/2002	Y	N
not banded	64	NOCA	HY	F	8/11/2002	Y	N
not banded	20	NOCA	AHY	F	3/22/2002	Y	N
1991-17221	64	NOCA	HY	U	7/26/2002	N	N
1921-45927	64	PABU	AHY	F	7/6/2002	Y	N
1921-45928	64	PABU	ASY	M	7/6/2002	Y	N
1921-45934	64	PABU	ASY	M	7/7/2002	Y	N
1921-45935	64	PABU	AHY	F	7/7/2002	Y	N
1921-45956	64	PABU	AHY	U	7/13/2002	Y	N
1921-45960	64	PABU	ASY	M	7/14/2002	Y	N
not banded	20	PABU	AHY	F	5/11/2002	Y	N
not banded	20	PABU	AHY	U	5/17/2002	Y	N
not banded	20	PABU	AHY	F	5/31/2002	Y	N
not banded	20	PABU	ASY	M	5/9/2002	Y	N
not banded	20	PABU	SY	F	5/11/2002	Y	N
not banded	20	PABU	AHY	F	4/27/2002	Y	N
not banded	20	PABU	AHY	M	4/27/2002	Y	N
not banded	20	REVI	AHY	U	6/27/2002		N
1921-45902	20	WEVI	AHY	M	6/26/2002	Y	N
1921-45904	20	WEVI	AHY	M	6/27/2002	Y	N
1921-45905	20	WEVI	SY	M	6/27/2002	Y	N
1921-45908	20	WEVI	ASY	M	6/30/2002	Y	N
1921-45909	20	WEVI	SY	M	6/30/2002	Y	N
1921-45910	20	WEVI	HY	U	6/30/2002	Y	N
1921-45911	20	WEVI	ASY	M	6/30/2002	Y	N
1921-45912	20	WEVI	AHY	F	7/1/2002	Y	N
1921-45913	20	WEVI	SY	M	7/1/2002	Y	N
1921-45915	20	WEVI	SY	M	7/3/2002	Y	N
1921-45916	20	WEVI	ASY	U	7/3/2002	Y	N
1921-45917	20	WEVI	ASY	M	7/3/2002	Y	N
1921-45920	20	WEVI	SY	F	7/4/2002	Y	N
1921-45921	20	WEVI	AHY	F	7/4/2002	Y	N

Band Number	TA	Species	Age	Sex	Date	Blood	Transmitter
1921-45922	20	WEVI	HY	U	7/4/2002	Y	N
1921-45923	20	WEVI	ASY	M	7/5/2002	Y	N
1921-45924	20	WEVI	HY	U	7/5/2002	Y	N
1921-45925	20	WEVI	ASY	M	7/5/2002	Y	N
1921-45926	20	WEVI	ASY	M	7/5/2002	Y	N
1921-45929	64	WEVI	ASY	F	7/6/2002	Y	N
1921-45930	64	WEVI	ASY	M	7/6/2002	Y	N
1921-45931	64	WEVI	ASY	U	7/6/2002	Y	N
1921-45932	64	WEVI	HY	U	7/6/2002	Y	N
1921-45936	64	WEVI	SY	F	7/7/2002	Y	N
1921-45937	64	WEVI	HY	U	7/7/2002	Y	N
1921-45938	64	WEVI	ASY	M	7/7/2002	Y	N
1921-45939	64	WEVI	SY	F	7/7/2002	Y	N
1921-45941	64	WEVI	ASY	F	7/8/2002	Y	N
1921-45943	64	WEVI	ASY	M	7/8/2002	Y	N
1921-45944	64	WEVI	ASY	M	7/8/2002	Y	N
1921-45945	20	WEVI	ASY	F	7/9/2002	Y	N
1921-45946	20	WEVI	ASY	M	7/9/2002	Y	N
1921-45947	20	WEVI	ASY	M	7/9/2002	Y	N
1921-45948	20	WEVI	HY	U	7/9/2002	Y	N
1921-45949	20	WEVI	AHY	M	7/9/2002	Y	N
1921-45950	20	WEVI	SY	M	7/9/2002	Y	N
1921-45951	20	WEVI	HY	U	7/11/2002	Y	N
1921-45952	20	WEVI	SY	M	7/11/2002	Y	N
1921-45953	64	WEVI	SY	M	7/12/2002	Y	N
1921-45954	64	WEVI	ASY	F	7/13/2002	Y	N
1921-45955	64	WEVI	HY	U	7/13/2002	Y	N
1921-45959	64	WEVI	SY	M	7/14/2002	Y	N
1921-45964	43	WEVI	HY	U	7/15/2002	Y	N
1921-45967	20	WEVI	SY	F	7/16/2002	Y	N
1921-45968	20	WEVI	ASY	M	7/16/2002	Y	N
1921-45969	46	WEVI	SY	M	7/17/2002	Y	N
1921-45971	46	WEVI	ASY	M	7/17/2002	Y	N
1921-45972	46	WEVI	SY	U	7/17/2002	Y	N
1921-45973	46	WEVI	SY	M	7/17/2002	Y	N
1921-45974	46	WEVI	ASY	M	7/22/2002	Y	N
1921-45975	20	WEVI	ASY	M	7/23/2002	Y	N
1921-45976	20	WEVI	SY	M	7/23/2002	Y	N
1921-45977	20	WEVI	ASY	U	7/24/2002	Y	N
1921-45978	20	WEVI	SY	M	7/24/2002	Y	N

Band Number	TA	Species	Age	Sex	Date	Blood	Transmitter
1921-45979	20	WEVI	ASY	M	7/24/2002	Y	N
1921-45981	64	WEVI	ASY	M	7/25/2002	Y	N
1921-45982	20	WEVI	SY	F	7/31/2002	Y	N
1921-45983	20	WEVI	AHY	U	7/31/2002	Y	N
1921-45985	64	WEVI	HY	U	8/1/2002	Y	N
1921-45986	64	WEVI	AHY	M	8/2/2002	Y	N
1921-45987	64	WEVI	ASY	M	8/2/2002	Y	N
1921-45988	64	WEVI	AHY	M	8/3/2002	Y	N
1921-45989	64	WEVI	AHY	M	8/3/2002	Y	N
1921-45991	64	WEVI	HY	U	8/5/2002	Y	N
1921-45993	20	WEVI	SY	M	8/6/2002	Y	N
1921-45995	20	WEVI	AHY	M	8/6/2002	Y	N
1921-45996	20	WEVI	AHY	M	8/7/2002	Y	N
1921-45997	20	WEVI	AHY	F	8/8/2002	Y	N
1921-45998	20	WEVI	AHY	M	8/8/2002	Y	N
1921-45999	20	WEVI	AHY	F	8/9/2002	Y	N
1921-46000	64	WEVI	HY	U	8/10/2002	Y	N
2410-77004	64	WEVI	AHY	M	4/24/2006	Y	N
2410-77005	64	WEVI	AHY	M	4/24/2006	Y	N
2430-90742	20	WEVI	ASY	M	3/21/2002	Y	N
2430-90743	20	WEVI	ASY	M	3/23/2002	Y	N
2430-90744	20	WEVI	ASY	M	3/26/2002	Y	N
2430-90745	20	WEVI	AHY	M	3/28/2002	Y	N
2430-90746	20	WEVI	AHY	M	3/30/2002	Y	N
2430-90747	20	WEVI	SY	F	5/21/2002	Y	N
2430-90748	20	WEVI	AHY	M	3/31/2002	Y	N
2430-90749	20	WEVI	ASY	M	5/21/2002	Y	N
2430-90750	20	WEVI	ASY	M	3/26/2002	Y	N
2430-90751	20	WEVI	AHY	M	3/29/2002	Y	N
2430-90752	20	WEVI	ASY	M	3/29/2002	Y	N
2430-90753	20	WEVI	AHY	M	3/29/2002	Y	N
2430-90754	20	WEVI	ASY	M	3/30/2002	Y	N
2430-90755	20	WEVI	AHY	M	3/31/2002	Y	N
2430-90757	20	WEVI	AHY	M	4/20/2002	Y	N
2430-90758	20	WEVI	AHY	M	4/20/2002	Y	N
2430-90759	20	WEVI	AHY	M	4/21/2002	Y	N
2430-90760	20	WEVI	AHY	M	4/22/2002	Y	N
2430-90761	20	WEVI	AHY	F	4/27/2002	Y	N
2430-90762	20	WEVI	ASY	F	4/28/2002	Y	N
2430-90764	20	WEVI	AHY	M	4/28/2002	Y	N

Band Number	TA	Species	Age	Sex	Date	Blood	Transmitter
2430-90766	20	WEVI	SY	M	4/30/2002	Y	N
2430-90770	20	WEVI	AHY	M	5/3/2002	Y	N
2430-90773	20	WEVI	SY	M	5/4/2002	Y	N
2430-90774	20	WEVI	ASY	M	5/5/2002	Y	N
2430-90776	20	WEVI	AHY	M	5/6/2002	Y	N
2430-90781	20	WEVI	SY	M	5/7/2002	Y	N
2430-90783	20	WEVI	SY	M	5/8/2002	Y	N
2430-90786	20	WEVI	AHY	M	5/10/2002	Y	N
2430-90790	20	WEVI	ASY	M	5/11/2002	Y	N
2430-90793	20	WEVI	SY	F	5/17/2002	Y	N
2430-90794	20	WEVI	SY	M	5/17/2002	Y	N
2430-90795	20	WEVI	AHY	M	5/17/2002	Y	N
2430-90796	20	WEVI	SY	F	5/18/2002	Y	N
2430-90798	20	WEVI	SY	M	5/18/2002	Y	N
2430-90799	20	WEVI	SY	F	5/18/2002	Y	N
2430-90800	20	WEVI	ASY	M	5/21/2002	Y	N
2450-91302	64	WEVI	AHY	M	5/10/2006	Y	N
2450-91302	64	WEVI	SY	M	6/3/2002	Y	N
2450-91304	64	WEVI	SY	M	5/29/2006	Y	N
2450-91307	64	WEVI	AHY	M	5/30/2006	Y	N
2450-91455	64	WEVI	ASY	M	5/23/2006	Y	N
2450-91455	64	WEVI	ASY	M	7/6/2002	Y	N
2450-91457	22	WEVI	ASY	F	5/24/2006	Y	N
2450-91458	64	WEVI	ASY	M	5/25/2006	Y	N
2450-91459	64	WEVI	ASY	M	5/26/2006	Y	N
2450-91460	64	WEVI	AHY	M	5/27/2006	Y	N
2450-91461	20	WEVI	AHY	F	5/23/2002	Y	N
2450-91462	20	WEVI	ASY	M	5/23/2002	Y	N
2450-91466	20	WEVI	ASY	M	5/25/2002	Y	N
2450-91469	20	WEVI	SY	M	5/31/2002	Y	N
2450-91470	20	WEVI	SY	F	5/31/2002	Y	N
2450-91472	64	WEVI	SY	M	6/3/2002	Y	N
2450-91473	64	WEVI	SY	F	6/3/2002	Y	N
2450-91474	20	WEVI	ASY	M	6/4/2002	Y	N
2450-91475	20	WEVI	AHY	F	6/4/2002	Y	N
2450-91476	20	WEVI	HY	U	6/4/2002	Y	N
2450-91479	20	WEVI	SY	M	6/6/2002	Y	N
2450-91480	20	WEVI	SY	F	6/6/2002	Y	N
2450-91482	20	WEVI	SY	F	6/6/2002	Y	N
2450-91483	20	WEVI	AHY	F	6/8/2002	Y	N

Band Number	TA	Species	Age	Sex	Date	Blood	Transmitter
2450-91484	20	WEVI	SY	F	6/8/2002	Y	N
2450-91485	20	WEVI	ASY	M	6/8/2002	Y	N
2450-91486	20	WEVI	ASY	F	6/8/2002	Y	N
2450-91487	20	WEVI	ASY	M	6/8/2002	Y	N
2450-91488	20	WEVI	SY	U	6/9/2002	Y	N
2450-91492	20	WEVI	AHY	F	6/19/2002	Y	N
2450-91493	20	WEVI	AHY	M	6/19/2002	Y	N
2450-91494	20	WEVI	AHY	F	6/19/2002	Y	N
2450-91495	20	WEVI	AHY	M	6/20/2002	Y	N
2460-94701	64	WEVI	HY	U	8/11/2002	Y	N
2460-94702	64	WEVI	SY	M	8/11/2002	Y	N
2460-94703	46	WEVI	ASY	M	8/13/2002	Y	N
2460-94705	64	WEVI	HY	U	8/14/2002	Y	N
2460-94706	64	WEVI	HY	U	8/14/2002	Y	N
2460-94708	64	WEVI	ASY	M	8/15/2002	Y	N
2460-94709	64	WEVI	SY	M	8/15/2002	Y	N
2460-94713	64	WEVI	HY	U	8/18/2002	Y	N
2460-94718	64	WEVI	HY	U	8/21/2002	Y	N
2460-94719	20	WEVI	AHY	M	8/22/2002	Y	N
2460-94720	20	WEVI	AHY	M	8/22/2002	Y	N
2460-94721	20	WEVI	AHY	M	8/22/2002	Y	N
2460-94723	20	WEVI	HY	U	8/23/2002	Y	N
2460-94724	20	WEVI	HY	U	8/25/2002	Y	N
2460-94726	46	WEVI	AHY	M	8/27/2002	Y	N
2460-94727	64	WEVI	HY	U	8/27/2002	Y	N
2460-94731	64	WEVI	AHY	M	8/27/2002	Y	N
2460-94732	64	WEVI	AHY	M	8/27/2002	Y	N
2460-94736	20	WEVI	AHY	U	8/28/2002	Y	N
2460-94737	20	WEVI	AHY	U	8/28/2002	Y	N
No Band	20	WEVI	ASY	M	6/24/2002	Y	N
No Band	20	WEVI	SY	M	6/22/2002	Y	N
No Band	20	WEVI	SY	M	6/25/2002	Y	N
not banded	20	WEVI	HY	U	6/22/2002	Y	N
not banded	20	WEVI	ASY	M	6/22/2002	Y	N
not banded	20	WEVI	AHY	M	6/24/2002	Y	N
not banded	20	WEVI	AHY	M	6/25/2002	Y	N
not banded	20	WEVI	AHY	M	5/17/2002	Y	N
not banded	20	WEVI	AHY	F	3/31/2002	Y	N
not banded	20	WEVI	SY	M	6/26/2002	Y	N
not banded	20	WEVI	ASY	M	6/25/2002	Y	N

Band Number	TA	Species	Age	Sex	Date	Blood	Transmitter
not banded	20	WEVI	AHY	M	3/26/2002	Y	N
not banded	20	WEVI	ASY	M	6/22/2002	Y	N
1921-45906	20	WEVI	HY	U	6/28/2002	N	N
1921-45965	43	WEVI	SY	M	7/15/2002	N	N
2280-50684	31	WEVI	U	U	recpatured	N	N
2321-09587	31	WEVI	U	U	recpatured	N	N
2430-90731	31	WEVI	ASY	M	3/16/2006	N	N
2430-90732	31	WEVI	ASY	M	3/20/2006	N	N
2430-90733	31	WEVI	ASY	U	4/7/2006	N	Y
2430-90734	31	WEVI	ASY	U	4/10/2006	N	N
2430-90735	31	WEVI	ASY	U (F?)	3/11/2006	N	Y
2430-90736	31	WEVI	SY	M	4/18/2006	N	Y
2430-90737	31	WEVI	ASY	M	4/28/2006	N	Y
2430-90738	31	WEVI	ASY	M	4/30/2006	N	Y
2430-90739	31	WEVI	U	M	5/9/2006	N	Y
2430-90740	31	WEVI	ASY	M	5/15/2006	N	Y
2430-90741	31	WEVI	ASY	M	5/18/2006	N	Y
2450-91441	31	WEVI	ASY	M	5/23/2006	N	Y
2450-91442	31	WEVI	SY	M	5/26/2006	N	Y
2450-91443	31	WEVI	ASY	M	5/30/2006	N	Y
2450-91444	31	WEVI	ASY	M	6/3/2006	N	Y
2450-91445	31	WEVI	ASY	M	6/9/2006	N	Y
2450-91446	31	WEVI	SY	M	6/12/2006	N	Y
2460-94733	20	WEVI	HY	U	8/28/2002	N	N
2460-94735	20	WEVI	AHY	M	8/28/2002	N	N
not banded	20	WEVI	HY	U	6/26/2002	N	N
not banded	20	WEVI	AHY	M	3/22/2002	N	N

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

   Effects of transient human disturbance on avian species is a concern on Department of Defense installations that support populations of federally listed endangered birds. Military training often is conducted within habitats that support endangered bird species, thus exposing individuals of these species to harassment as defined under the Endangered Species Act (ESA) of 1973. During the 2006 breeding season on Fort Hood, Texas, evaluations of two major physiological response systems determined response in passerine species to disturbances characteristic of military training activities: a hormonal (adrenocortical) response to stress in white-eyed vireos and endangered black-capped vireos, and energy expenditure as measured by remotely monitored heart rate in white-eyed vireos. Heart rate radio telemetry was used to measure avian metabolic demands in response to potential stressors related to military training. This study is the first to demonstrate that 1) heart rate transmitters can successfully be mounted on small (10-g) migratory passerines, 2) heart rate can be continuously monitored and recorded in these birds for at least 60 hours, and 3) heart rate is a robust measure of energy expenditure in small passerines and therefore is a powerful method to test the effects of military activity on survival in species of concern.

15. SUBJECT TERMS

Black-capped vireo	Fort Hood	Radio telemetry
Endangered species	Heart-rate transmitter	White-eyed vireo

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