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USING RADIOTELEMETRY TO MONITOR CARDIAC RESPONSE OF FREE-LIVING TULE GREATER WHITE-FRONTED GEESE (*ANSER ALBIFRONS ELGASI*) TO HUMAN DISTURBANCE

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ABSTRACT.—We monitored the heart rates of free-living Tule Greater White-fronted Geese (*Anser albifrons elgasi*) during human disturbances on their wintering range in the Sacramento Valley of California during 1997. We used implanted radio transmitters to record the heart rates of geese as an observer experimentally approached them at a constant walking speed. On average, geese flushed when observers were 47 m (range: 25–100 m) away. Change point regression was used to identify the point in time when heart rate abruptly increased prior to flushing and when heart rate began to level off in flight after flushing. Heart rates of geese increased as the observer approached them during five of six disturbance trials, from 114.1 ± 6.6 beats/min during the observer's initial approach to 154.8 ± 7.4 beats/min just prior to flushing at the first change point. On average, goose heart rates began to increase most rapidly 5 sec prior to taking flight, and continued to increase rapidly for 4 sec after flushing until reaching flight speed. Heart rate was 456.2 ± 8.4 beats/min at the second change point, which occurred immediately after flushing, and 448.3 ± 9.5 beats/min 1 min later during flight. Although goose heart rates increased as an observer approached, the largest physiological change occurred during a 9-sec period (range: 1.0–15.7 sec) immediately before and after flushing, when heart rates nearly tripled. *Received 28 October 2003, accepted 12 April 2004.*

Wildlife may incur energetic costs when disturbed by humans; therefore, spatial buffer zones are commonly used by managers to separate wildlife from human activities (Knight and Temple 1995, Camp et al. 1997, Richardson and Miller 1997, Rodgers and Smith 1997). Buffer zones often are based on the distance at which a species flushes in response to human activities (Richardson and Miller 1997, Rodgers and Smith 1997, Ward et al. 1999, Swarthout and Steidl 2001, Blumstein et al. 2003). However, wildlife may have more subtle physiological responses to disturbances, such as increased heart rate, that also have energetic consequences (MacArthur et al. 1982, Gabrielsen and Smith 1995, Andersen et al. 1996, Weisenberger et al. 1996). Heart rate is a good indicator of an animal's energy expenditure (Wooley and Owen 1977, 1978; Woakes and Butler 1983; Nolet et al. 1992) and depends not only on an animal's physical activity, but also on the level of external stimulation caused by disturbances (Harms et al. 1997, Ely et al. 1999). Therefore, heart rate, rather than flushing distance, may be a better indicator of an animal's stress response to human disturbance (Fernández-Juricic et al. 2001).

In this paper, we provide the first radiotelemetry-based data on the cardiac response of free-living waterfowl to human disturbance. We used implanted radio transmitters to monitor the heart rates of Tule Greater White-fronted Geese (*Anser albifrons elgasi*, hereafter Tule Geese) as an observer experimentally disturbed each radio-marked bird by approaching it at a constant walking speed. We

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report the variation in heart rate throughout the disturbance event from roosting or feeding to flushing and flight, and use change point analysis to identify points in time when heart rate abruptly changed.

METHODS

Tule Geese are larger (>0.5 kg) than the other subspecies of Greater White-fronted Geese (*A. a. frontalis*) wintering in California (Ely and Dzubin 1994). We captured flightless Tule Geese by driving them into net corrals. We implanted radio transmitters in 28 adult female geese on 6 and 8 July 1997 at Kahiltna River Valley, Alaska (see Ely et al. 1999), as part of an aircraft disturbance study of Tule Geese in southcentral Alaska. Thirteen of the 28 transmitters were programmed to be active during 15 days the following winter. To minimize potential confounding effects of capturing and surgically implanting radio transmitters in Tule Geese, we collected heart rate data 5.5 months after the radio-marking procedure when geese were on their wintering grounds in the Sacramento Valley of California. We conducted disturbance trials during the last 2 weeks of December 1997—immediately after closure of the hunting season for dark geese (including Tule Geese)—within the Sacramento and Delevan National Wildlife Refuges and the surrounding agricultural (rice) fields. The main types of human disturbance in this area during our study included waterfowl hunting, farming, vehicular traffic, and birdwatching.

Transmitters (model HRT-150, Telonics Inc., Mesa, Arizona) were covered with a braided surgical mesh (Marlex Mesh, Davol, Charlotte, North Carolina) and implanted into the right abdomen using standard surgical procedures (except that the transmitters had coiled, internal antennas rather than extended, percutaneous antennas; Korschgen et al. 1996). The radio packages could transmit heart rates at a maximum rate of 600 beats/min. Leads of the 44 g transmitter were placed in a base-apex configuration and anchored using 2-vicryl (Ethicon, Somerville, New Jersey). The caudal lead was sutured to the dorsal side of the caudal end of the sternum and the anterior lead was brought through the incision and passed subcutaneously to the left clavicle, where it was sutured just lateral to the sternum. Each transmitter was secured with two simple, interrupted sutures of 0-vicryl placed through the mesh so that the antenna was situated on the dorsal side of the abdominal cavity, thus increasing transmission range. The incision was closed in two layers using 0-vicryl in a simple continuous pattern. We released the radio-marked geese 2 days after their capture.

We examined the variation in heart rate when Tule Geese were disturbed by approaching a radio-marked goose on foot and simultaneously recording both its heart rate and the time since we initiated the disturbance. During daylight hours, we located radio-marked individuals that were roosting or feeding in refuge ponds or in harvested rice fields that were protected from hunting. After locating a radio-marked goose in a flock, one observer approached on foot (about 0.53 m/sec) while simultaneously recording goose behavior (i.e., on ground, flush, or flying) into a data audio tape recorder (DAT) that added a digital time-stamp. At the same time, heart rate signals were being received by a truck-mounted Yagi antenna and ATS receiver (Advanced Telemetry Systems, Isanti, Minnesota), and recorded together with the time on a data logger (Advanced Telemetry Systems, Isanti, Minnesota) that was connected directly to the receiver. We synchronized the observations recorded on the DAT with the heart rate data by documenting precise start times on each recording device. In each trial, the observer continued to approach the radio-marked goose until it flushed, then immediately recorded the precise time of flushing and estimated flushing distance by pacing the distance between the observer and the site where the bird flushed. We continued monitoring heart rates of radio-marked birds in flight for 60 sec after they flushed from the disturbance. We then estimated the starting distance from the observer to the bird by re-pacing the distance between the site of flushing and the starting point of the observation.

Heart rates recorded on the data logger were transcribed using an ATS DCC II data logger (Advanced Telemetry Systems, Isanti, Minnesota) and a laptop computer with a ProComm macro program developed by ATS, which calculated the radio-marked bird's heart rate every 0.2 sec. We then calculated the average heart rate during each second. For each trial, we used change point analysis (PROC

NLIN, SAS Institute, Inc. 1999; also called segmented regression, Draper and Smith 1998) to fit a three-segment regression and identify the two points in time that flank the period when heart rate changed most rapidly. We examined whether heart rate increased as an observer approached radio-marked geese from the beginning of the trial until the first change point (just before flushing) by testing the slope (m) of this segment of the regression for significant difference from the null hypothesis of no slope (a slope of zero). We calculated the weighted average ± SE heart rate of radio-marked birds among trials in 5-sec time periods using PROC MEANS (SAS Institute, Inc. 1999). Each measurement was inversely weighted by the sample size for its corresponding time period, so that each trial would have equal total weights of one. We did this for (1) the first 5 sec during our initial approach, (2) the 5 sec immediately before the first change point in heart rate (before flushing), (3) the 5 sec immediately after the second change point in heart rate (after flushing), and (4) during the 55- to 60-sec time period following flushing when the radio-marked goose was in flight. Statistical significance was set at $\alpha = 0.10$.

RESULTS

We successfully documented the cardiac responses of Tule Geese to an approaching observer during six disturbance trials, representing four different birds. Four trials were conducted at Delevan National Wildlife Refuge and two trials were conducted nearby within harvested rice fields. Four additional trials on different birds were excluded due to equipment malfunction (two trials), outside interference by approaching hunters (one trial), or logistical limitations during approach of a radio-marked goose (one trial). The number of radio-marked birds available for study also was limited because we captured and radio-marked Tule Geese 5.5 months before we collected heart rate data in order to minimize any effects of handling and transmitter implantation. By the time radio-marked geese arrived on their wintering grounds, a few radio transmitters had failed and some radio-marked birds could not be located following fall migration.

During five of six trials, heart rates increased from the beginning of the disturbance trial to the first change point as an observer approached the radio-marked goose (Trial 1: $m = 2.54 \pm 0.56$, $t_{82} = 4.54$, $P < 0.001$; Trial 2: $m = 0.28 \pm 0.08$, $t_{175} = 3.51$, $P < 0.001$; Trial 3: $m = 0.10 \pm 0.06$, $t_{204} = 1.77$, $P = 0.08$; Trial 4: $m = -1.50 \pm 1.24$, $t_{76} = -1.21$, $P = 0.23$; Trial 5: $m = 0.40 \pm 0.13$, $t_{170} = 3.07$, $P = 0.003$; Trial 6: $m = 0.56 \pm 0.12$, $t_{160} = 4.65$, $P < 0.001$; Fig. 1). The average distance from observers to radio-marked geese at the start of disturbance trials was 102 m (range: 46–189 m). Heart rates increased from an average of 114.1 ± 6.6 beats/min (range means: 86.6–164.8 beats/min) during the first time period (0–5 sec) when observers began their approach to 154.8 ± 7.4 beats/min (range means: 116.3–199.7 beats/min) during the second time period just prior to flushing at the first change point. Average flushing distance was 47 m (range: 25–100 m). During the third time period, immediately after flushing at the second change point, heart rates averaged 456.2 ± 8.4 beats/min (range means: 417.1–478.0 beats/min); heart rates averaged 448.3 ± 9.5 beats/min (range means: 379.0–518.8 beats/min) during the 55- to 60-sec time period after flushing while in flight. In general, heart rates increased most rapidly at 5 sec (range: 1.2–9.8 sec) prior to flushing and continued increasing rapidly for an additional 4 sec (range: 0.2–8.7 sec) after flushing until reaching flight levels (Fig. 1).

DISCUSSION

The population of Tule Geese is one of the smallest goose populations in North America (about 8,000); the winter range, centered at Delevan National Wildlife Refuge in the Sacramento Valley of California (Callaghan and Green 1993, Ely and Dzubin 1994, Green 1996) is also small. This concentrated wintering distribution potentially subjects the entire population of Tule Geese to negative effects of human disturbance caused by farming, birdwatching, and hunting. In five of six disturbance trials, we found that the heart rates of radio-marked Tule Geese increased as an observer approached them. Heart rates increased by 36% from the time the trial began to the abrupt increase in heart rate that occurred 5 sec before a bird flushed. However, the largest increase in heart rate occurred dur-

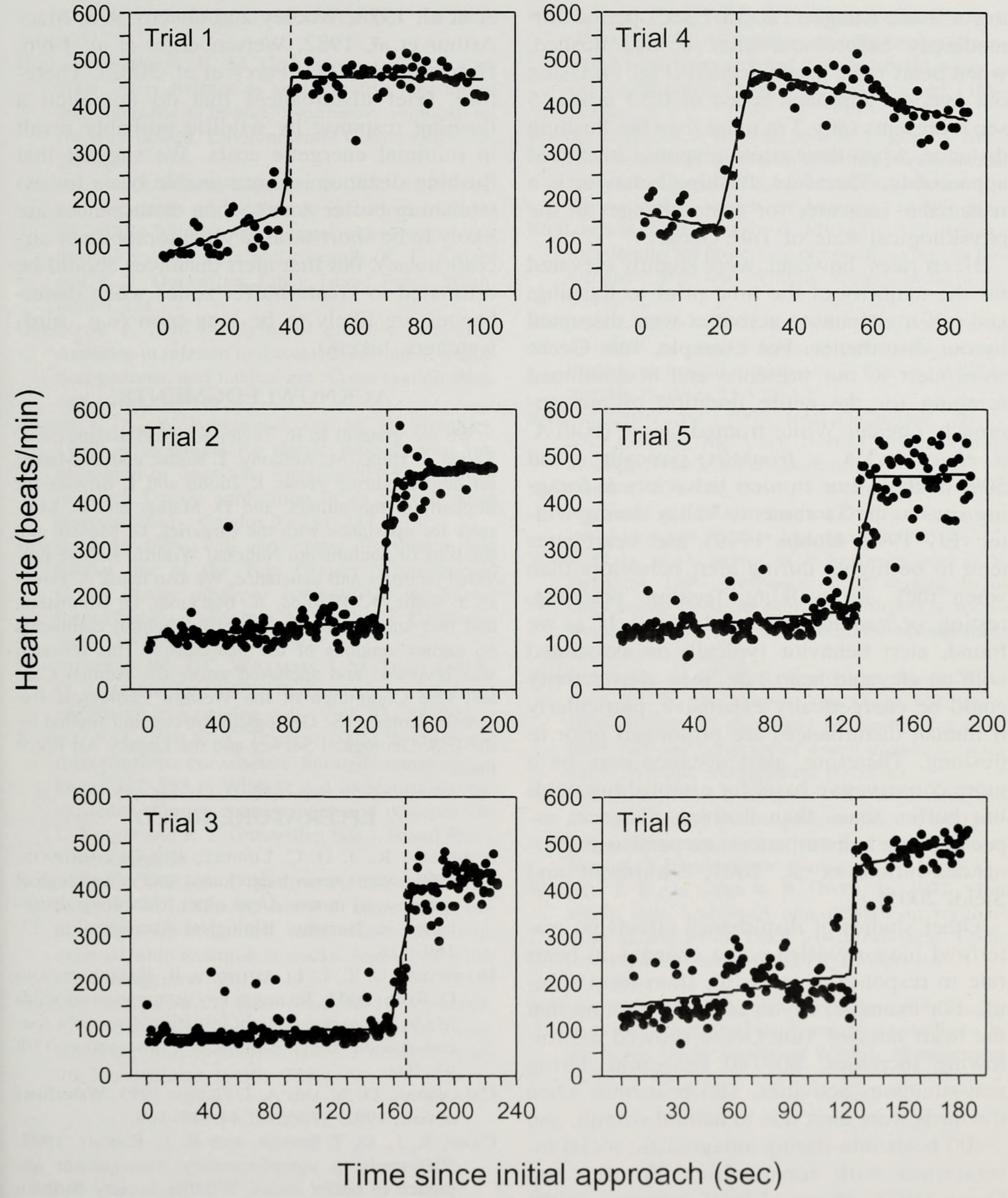

FIG. 1. Heart rates (beats/min) of Tule Greater White-fronted Geese (*Anser albifrons elgasi*) in relation to time elapsed since an observer began approaching radio-marked birds. Each panel represents a single trial conducted in the Sacramento Valley of California, December 1997. Trial numbers one and six, and three and four, were each conducted on the same two individuals, respectively, but on different days. Each data point is the average heart rate of an individual bird during a 1-sec period. The vertical broken lines indicate the time when the radio-marked bird flushed; data to the left of the broken line represent birds on the ground, whereas data to the right of the broken line represent birds in flight. Approximate human-to-bird distances when observers began their approaches for trials 1–6 were 46, 123, 189, 63, 99, and 91 m, respectively. Approximate flushing distances for trials 1–6 were 25, 50, 100, 50, 30, and 25 m, respectively. The solid (mean) lines were fitted using change point analysis.

ing a 9-sec (range: 1.0–15.7 sec) period immediately before and after a bird flushed, when heart rates nearly tripled (Fig. 1). Using our average approach speed of 0.53 m/sec, 5 sec represents only 3 m more than the flushing distance, when their stress response increased appreciably. Therefore, flushing behavior is a reasonable indicator for acute changes in the physiological state of Tule Geese.

Heart rates, however, were slightly elevated for the majority of the time prior to flushing, and self-maintenance activities were disrupted by our disturbance. For example, Tule Geese were alert to our presence and discontinued foraging for the entire duration of our approach. Greater White-fronted Geese (both *A. a. elgasi* and *A. a. frontalis*) typically spend 30% of their time in alert behaviors at foraging sites in the Sacramento Valley during winter (Ely 1992, Hobbs 1999), and heart rates tend to be higher during alert behaviors than when they are walking, feeding, preening, resting, or standing (Ely et al. 1999). If, as we found, alert behavior typically is associated with an elevated heart rate, then alert activity could be energetically expensive, particularly if human disturbances are prolonged prior to flushing. Therefore, alert distance may be a more conservative basis for establishing wildlife buffer zones than flushing distance, especially when disturbances are persistent (Fernández-Juricic et al. 2001, Swarthout and Steidl 2001).

Other studies of disturbance effects on waterfowl have revealed acute changes in heart rate in response to stressful, short-term stimuli. For example, Ely et al. (1999) found that the heart rates of Tule Geese showed the following increases: 80–140 beats/min during non-strenuous activities, 180 beats/min when the birds were alert due to natural stimuli, and >400 beats/min during antagonistic social interactions with conspecifics. Wooley and Owen (1978) observed brief increases in the heart rates of Black Ducks (*Anas rubripes*) in response to approaching herons, hawks, and low-flying planes. Harms et al. (1997) found that heart rates of captive Black Ducks briefly increased in response to simulated aircraft noise. However, in most studies examining the cardiac response of wildlife to stressful stimuli, heart rates quickly returned to normal levels after the stimulus was removed (Kanwisher et al. 1978, Wooley and Owen 1978, MacArthur et al. 1982, Weisenberger et al. 1996, Harms et al. 1997, Perry et al. 2002). Therefore, brief disturbances that do not elicit a flushing response by wildlife probably result in minimal energetic costs. We suggest that flushing distance is a reasonable basis for establishing buffer zones when disturbances are likely to be short-term (e.g., automobile or aircraft noise), but that alert distances should be estimated to create buffer zones when disturbances are likely to be long-term (e.g., birdwatchers, hikers).

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