

Final Report

**Construction Engineering
Research Laboratory**



**US Army Corps
of Engineers®**
Engineer Research and
Development Center

Assessment of Training Noise Impacts on the Red-cockaded Woodpecker: Final Report

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Executive Summary

We submit this report as partial fulfillment of the terms of the Strategic Environmental Research and Development Program (SERDP) funded project CS-1083. The purpose of this research is to assess the effects of military training noise on the endangered Red-cockaded Woodpecker (RCW) and to develop assessment methodology. The results of this research will provide a scientific basis for RCW management protocols, and will partially satisfy requirements of a 1996 U.S. Fish and Wildlife Service (USFWS) biological opinion that requires the Army to assess effects of implementing the 1996 "Management Guidelines for the RCW on Army Installations." These new guidelines will significantly reduce restrictions on training for Army installations on which RCWs are present. These Army installations include: Camp Blanding, FL; Fort Benning, GA; Fort Bragg, NC; Fort Gordon, GA; Fort Stewart, GA; Fort Polk, LA; Peason Ridge, LA; Camp Mackall, NC; MOT (Military Ocean Terminal) Sunny Point, NC; Fort Jackson, SC; Leesburg Training Center, SC (Schreiber et al. 1997a, b; Shaw et al. 1997). This research was conducted on Fort Stewart jointly by the U.S. Army Construction Engineering Research Laboratory (CERL), an element of the U.S. Army Engineer Research and Development Center (ERDC), Fort Stewart, and the U.S. Army Forces Command (FORSCOM). This project was developed by CERL in coordination with FORSCOM, the USFWS RCW Recovery Coordinator and the Region 4 office, the Fort Stewart Directorate of Training, the Fort Stewart Directorate of Public Works (DPW) Fish and Wildlife Branch, and the Army Threatened and Endangered Species (TES) User Group.

We experimentally tested RCW response in 1999 and 2000 (during the breeding season) to controlled military training noise events under realistic conditions, namely .50-caliber blank fire and artillery simulators. From 1998-2000, we passively (i.e., no control over the noise source) monitored RCW response to various military training noise events. We measured both proximate response behavior and nesting success, while continuing to measure baseline behavioral data from undisturbed RCW groups. Measured levels of experimental noise did not affect RCW nesting success or productivity. RCW flush response increased as stimulus distance decreased, regardless of stimulus type. Woodpeckers returned relatively quickly after flushing from the nest, with return times being comparable between 1999 and 2000 rates. Unweighted noise levels within RCW nest cavities were substantially louder than levels recorded at the base of the tree. When noise data were examined using Woodpecker weighting (dBW), noise levels inside nest cavities were not significantly different compared with levels recorded outside the nest cavity.

Foreword

We conducted this study for the Strategic Environmental Research and Development Program (SERDP) under an FY98 Conservation Project, No. CS-1083, "Assessment of Training Noise Impacts on the Red-cockaded Woodpecker." The technical monitor was Dr. Robert Holst. The work was performed by the Ecological Processes Branch (CN-N) of the Installations Division (CN), Construction Engineering Research Laboratory (CERL) in cooperation with Jones Technologies, Inc. The CERL Principal Investigator was Dr. Larry L. Pater; David K. Delaney was Co-Principal Investigator. The technical editor was Vicki A. Reinhart. Steve Hodapp is Chief, CEERD-CN-N, and Dr. John T. Bandy is Chief, CEERD-CN. The Director of CERL is Dr. Alan W. Moore. CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Director of ERDC is Dr. James R. Houston and the Deputy to the Commander is A.J. Roberto, Jr.

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Contents

EXECUTIVE SUMMARY	3
FOREWORD	4
LIST OF FIGURES	7
LIST OF TABLES	9
1 INTRODUCTION.....	10
BACKGROUND.....	10
OBJECTIVES	13
APPROACH	13
SCOPE	13
MODE OF TECHNOLOGY TRANSFER.....	14
2 LITERATURE REVIEW.....	15
ECOLOGY	15
ANTHROPOGENIC IMPACTS.....	16
3 TECHNICAL APPROACH	20
NULL HYPOTHESES	20
STUDY AREA	20
SAMPLE CLUSTER SELECTION.....	21
IMPACT MEASURES	23
BEHAVIOR AND PROXIMATE RESPONSE MEASUREMENT PROTOCOLS.....	25
DEMOGRAPHIC AND NESTING SUCCESS DATA.....	26
VIDEO SURVEILLANCE	27
SOUND INSTRUMENTATION AND RECORDING	28
SOUND METRICS	28
STATISTICAL DATA ANALYSIS	30
4 RESULTS.....	31
INITIATION DATES FOR EACH NESTING PHASE	31
OVERALL POPULATION DYNAMICS	31
SAMPLE GROUP POPULATION DYNAMICS.....	32
NOISE AND RESPONSE MONITORING SUMMARY.....	34
DISTANCE AND NOISE LEVEL THRESHOLDS FOR RESPONSE	35
OBSERVATION OF NEST PREDATION EVENTS	48

5	DISCUSSION	49
	NESTING SUCCESS.....	49
	FLUSH RESPONSE AND RELATED BEHAVIORS	50
	DISTANCE AND SOUND THRESHOLDS	51
	MANAGEMENT IMPLICATIONS	53
6	PLANS AND CONCLUSIONS.....	55
	PLANS	55
	CONCLUSIONS.....	55
	REFERENCES	56
	APPENDIX A: SIGNIFICANT LEGAL REQUIREMENTS	65
	APPENDIX B: WOODPECKER AUDIOGRAM.....	66
	INTRODUCTION	66
	METHODS.....	66
	RESULTS.....	68
	CONCLUSIONS.....	72
	APPENDIX C: SUMMARY DATA TABLES.....	73
	APPENDIX D: SOURCE SPECTRA EXAMPLES.....	82
	APPENDIX E: VIDEO IMAGES FROM RCW NESTS	91

List of Figures

Figures

FIGURE 1. ADULT RED-COCKADED WOODPECKER DELIVERING PREY TO THE NEST.....	12
FIGURE 2. LOCATION OF FORT STEWART WITHIN THE STATE OF GEORGIA.....	21
FIGURE 3. LOCATIONS OF TRAINING AREAS AND RCW GROUPS ON FORT STEWART.....	22
FIGURE 4. ARTILLERY SIMULATOR BLAST.....	23
FIGURE 5. SOLIDER FIRING A .50-CALIBER MACHINE GUN WITH BLANKS.....	23
FIGURE 6. ASSESSMENT HIERARCHY FOR TRAINING IMPACT ON THREATENED AND ENDANGERED SPECIES	24
FIGURE 7. EXAMPLES OF AUDIOGRAMS AND FREQUENCY WEIGHTING.....	29
FIGURE 8. 1998 POWER ANALYSIS COMPARING DISTURBED VERSUS CONTROL FITNESS PARAMETERS.....	34
FIGURE 9. RCW FLUSH FREQUENCY BY STIMULUS TYPE AND DISTANCE.....	37
FIGURE 10. MEAN RETURN TIME FOR RCWs IN RESPONSE TO EXPERIMENTAL TESTING IN 1999-2000.....	37
FIGURE 11. DOSE-RESPONSE THRESHOLD RELATION BETWEEN .50-CALIBER BLANK FIRE EVENTS AND DISTANCE FOR RCWs ON FORT STEWART IN 1999-2000.....	38
FIGURE 12. DOSE-RESPONSE THRESHOLD RELATION BETWEEN ARTILLERY SIMULATOR BLAST EVENTS AND DISTANCE FOR RCWs ON FORT STEWART IN 1999-2000.....	39
FIGURE 13. NOISE LEVELS FROM M-16 LIVE FIRE EVENTS AT CLUSTER 103 ON 12 MAY 1999.....	40
FIGURE 14. NOISE LEVELS FROM M-16 LIVE FIRE EVENTS AT CLUSTER 103 ON 17 MAY 1999.....	41
FIGURE 15. NOISE LEVELS FROM M-16 LIVE FIRE EVENTS AT CLUSTER 103 ON 13 MAY 1999.....	41
FIGURE 16. SEL WEIGHTING COMPARISON FOR M-16 LIVE FIRE EVENTS ON 17 MAY 1999.....	42
FIGURE 17. DESCRIPTION OF RCW FLUSH RESPONSE TO ARTILLERY BLAST EVENTS AT CLUSTER ON 20 MAY 1998.....	83 43
FIGURE 18. DESCRIPTION OF RCW FLUSH RESPONSE TO ARTILLERY BLAST EVENTS AT CLUSTER ON 21 MAY 1998.....	83 44

Figures (cont).

FIGURE B 1. EXAMPLE OF AN AUDITORY BRAINSTEM RESPONSE (ABR).....	67
FIGURE B 2. AUDIOGRAMS FOR THREE INDIVIDUAL DOWNY WOODPECKERS OBTAINED USING ABR. ...	68
FIGURE B 3. AVERAGE ABR AUDIOGRAM FOR THREE DOWNY WOODPECKERS	69
FIGURE B 4. AVERAGE POWER SPECTRA FOR THREE COMMON DOWNY WOODPECKER CALLS AND THE “DRUM: OF THIS SPECIES.	70
FIGURE B 5. AVERAGE POWER SPECTRUM OF TWO COMMON VOCALIZATIONS OF THE RED- COCKADED WOODPECKER.	71
FIGURE B 6. AVERAGE AUDIOGRAM FOR THREE DOWNY WOODPECKERS	71
FIGURE B 7. AVERAGE AUDIOGRAM FOR THREE DOWNY WOODPECKERS	72
FIGURE D 1. WEIGHTING COMPARISON FOR EXPERIMENTAL ARTILLERY SIMULATOR BLAST.....	83
FIGURE D 2. WEIGHTING COMPARISON FOR EXPERIMENTAL .50-CALIBER BLANK FIRE	83
FIGURE D 3. WEIGHTING COMPARISON FOR PASSIVE M-16 LIVE FIRE	84
FIGURE D 4. WEIGHTING COMPARISON FOR PASSIVE M-16 LIVE MUZZLE BLAST	84
FIGURE D 5. WEIGHTING COMPARISON FOR A PASSIVE HELICOPTER FLIGHT	85
FIGURE D 6. WEIGHTING COMPARISON FOR PASSIVE ARTILLERY MUZZLE BLAST NOISE	85
FIGURE D 7. WEIGHTING COMPARISON FOR A PASSIVE MILITARY VEHICLE NOISE EVENT	86
FIGURE D 8. WEIGHTING COMPARISON FOR PASSIVE VEHICLE NOISE	87
FIGURE D 9. WEIGHTING COMPARISON FOR PASSIVE MLRS FIRE	87
FIGURE D 10. WEIGHTING COMPARISON FOR PASSIVE STINGER/DRONE MISSILE IMPACT	88
FIGURE D 11. WEIGHTING COMPARISON OF PASSIVE STINGER MISSILE FIRE.....	88
FIGURE D 12. WEIGHTING COMPARISON OF A PASSIVE GRENADE SIMULATOR BLAST	89
FIGURE D 13. WEIGHTING COMPARISON FOR PASSIVE C-130 AIRPLANE FLIGHT.....	89
FIGURE E 1. RED-BELLIED WOODPECKER USURPING A NEST	92
FIGURE E 2. RAT SNAKE LEAVING A RED-COCKADED WOODPECKER	92
FIGURE E 3. NEST PREDATION ATTEMPT BY A RED-SHOULDERED HAWK.....	93
FIGURE E 4. NEST PREDATION ATTEMPT BY AN AMERICAN CROW	93

List of Tables

TABLE C 1. FLUSH RESPONSE OF NESTING RED-COCKADED WOODPECKERS VERSUS THE NUMBER, DISTANCE, AND NOISE LEVELS OF EXPERIMENTAL ARTILLERY SIMULATOR TESTING ON FORT STEWART, GA, 1999-2000.	74
TABLE C 2. FLUSH RESPONSE OF NESTING RED-COCKADED WOODPECKERS VERSUS THE NUMBER, DISTANCE, AND NOISE LEVELS OF EXPERIMENTAL .50-CALIBER BLANK FIRE TESTING ON FORT STEWART, GA, 1999-2000.	75
TABLE C 3. FLUSH RESPONSE OF NESTING RED-COCKADED WOODPECKERS VERSUS THE NUMBER, DISTANCE, AND NOISE LEVELS OF PASSIVE M-16 LIVE FIRE ON FORT STEWART, GA, 1999-2000.	76
TABLE C 4. FLUSH RESPONSE OF NESTING RED-COCKADED WOODPECKERS VERSUS THE NUMBER, DISTANCE, AND NOISE LEVELS OF PASSIVE HELICOPTER FLIGHTS ON FORT STEWART, GA, 1998-2000. STIMULUS DISTANCES REPRESENT THE CLOSEST ESTIMATED APPROACH DISTANCE BY A HELICOPTER.	76
TABLE C 5. FLUSH RESPONSE OF NESTING RED-COCKADED WOODPECKERS VERSUS THE NUMBER, DISTANCE, AND NOISE LEVEL OF PASSIVE LARGE-CALIBER (> 20MM) LIVE FIRE ON FORT STEWART, GA, 1998-2000.	76
TABLE C 6. FLUSH RESPONSE OF NESTING RED-COCKADED WOODPECKERS VERSUS THE NUMBER, DISTANCE, AND NOISE LEVELS OF PASSIVE VEHICLES ON FORT STEWART, GA, 1998-2000.	77
TABLE C 7. FLUSH RESPONSE OF NESTING RED-COCKADED WOODPECKERS VERSUS THE NUMBER, DISTANCE, AND NOISE LEVELS OF PASSIVE MISSILE FIRE ON FORT STEWART, GA, 2000.	77
TABLE C 8. FLUSH RESPONSE OF NESTING RED-COCKADED WOODPECKERS VERSUS THE NUMBER, DISTANCE, AND NOISE LEVELS OF PASSIVE SIMULATORS BLASTS ON FORT STEWART, GA, 1998-1999.	77
TABLE C 9. FLUSH RESPONSE OF NESTING RED-COCKADED WOODPECKERS VERSUS THE NUMBER, DISTANCE, AND NOISE LEVELS OF EXPERIMENTAL M-16 BLANK FIRE ON FORT STEWART, GA, 1998.	77
TABLE C 10. FLUSH RESPONSE OF NESTING RED-COCKADED WOODPECKERS VERSUS THE NUMBER, DISTANCE, AND NOISE LEVELS OF PASSIVE FIXED-WING AIRCRAFT (I.E., C-130) ON FORT STEWART, GA, 1998.	77
TABLE C 11. VARIATION IN ARTILLERY SIMULATOR BLAST NOISE LEVELS BASED ON YEAR, STIMULUS DISTANCE, MICROPHONE POSITION AND WEIGHTING FUNCTION ON FORT STEWART, GA, 1999-2000.	78
TABLE C 12. VARIATION IN .50-CALIBER BLANK FIRE NOISE LEVELS BASED ON YEAR, STIMULUS DISTANCE, MICROPHONE POSITION, AND WEIGHTING FUNCTION ON FORT STEWART, GA, 1999-2000.	80

1 Introduction

Background

The Endangered Species Act (ESA) requires that all Federal agencies carry out programs to conserve Threatened and Endangered Species (TES) and to evaluate the impacts of federal activities on listed species (Scott et al. 1994). TES management on military installations, particularly that involving the Red-cockaded Woodpecker (RCW; *Picoides borealis*), has raised questions about the interaction between Army training and the conservation of RCWs on military lands. The goal of RCW management on Fort Stewart is to recover the population while eliminating conflicts with the training mission by eliminating the need for training restrictions (Fort Stewart Endangered Species Management Planning Team {ESMPT} 2001). A brief summary of legal requirements is presented in Appendix A. Because noise management has traditionally focused on minimizing human annoyance, loud activities have often been relocated to sparsely populated areas where wildlife resides. This has led to increased interactions between military activity and wildlife (Holland 1991). Increasing importance has been placed on determining the extent of human-based impacts on wildlife (Bowles 1995), especially TES (Pater et al. 1999; Delaney et al. 1999, 2000, 2001; Hayden et al. in press).

Red-cockaded Woodpeckers inhabit mature, open pine forests of the southeastern United States (Jackson 1994; Figure 1). This species was listed as endangered throughout its range on 13 October 1970 (35 Federal Register 16047) and received federal protection with the passage of the ESA in 1973. Habitat loss has been cited as the single most important factor that has led to the decline of RCWs throughout its range (USFWS 2000). Intensive logging for lumber and clearing of forests for agriculture are leading causes of habitat loss (Frost 1993; Martin and Boyce 1993). Grazing by free-ranging hogs (*Sus scrofa*) and pine resin exploitation were two additional factors contributing to pine tree habitat loss in the 1800's (Frost 1993). Landers et al. (1995) and others have reported that human-based activities, such as fire suppression and clear cutting, further impacted longleaf pine ecosystems and associated RCW populations. Consequently, RCWs are experiencing severe limitations in the number of available cavity trees (Costa and Escano 1989; Rudolph et al. 1990; Conner et al 1991; Walters et al. 1992) and are suffering from a fragmented distribution (USFWS 2000).

Historically, RCW populations were widely distributed throughout the southern United States from eastern Texas to the Atlantic coast, and north to New Jersey (Jackson 1987). The distribution has been reduced with the extirpation of RCWs from New Jersey (Lawrence 1867),

Missouri (Cunningham 1946, as cited in Jackson 1987), and most recently Maryland (Devlin et al. 1980). The majority of RCWs are currently restricted to public lands, namely National Forests and military installations (Jackson 1978a; Lennartz et al. 1983). Military installations, in particular, represent a valuable resource in the recovery of TES (Jordan et al. 1995; USFWS 2000). It has been estimated that nearly a quarter of the remaining RCWs are located on 16 military installations in the southeastern United States (Costa 1992; USFWS 2000), which includes the Fort Stewart population. Such a close association has led to increased conflicts between TES conservation requirements and the military's mission of maintaining a high degree of combat readiness (Jordan et al. 1995).

In 1984, the Army established a 200 ft (61 m) buffer zone around all RCW clusters to protect nesting habitat and identify RCW management units. In 1996, the Department of the Army (DA) issued revised guidelines for the management of RCWs on military lands, to reduce training restrictions, and increase adaptive management of the RCW and its habitat. Under the revised guidelines, certain transient military activities are permitted within 50 ft (15 m) of RCW cavity trees. These include: (1) military vehicle and personnel travel, including armor; (2) .50-caliber machine gun blank fire and 7.62-mm blank fire and below; (3) artillery/hand grenade simulators and Hoffman type devices; (4) hand digging of hasty individual fighting positions; (5) use of smoke grenades and star cluster/parachute flares; and (6) smoke and haze operation (see Hayden 1997 for a more detailed description of past and current Army guidelines for RCWs). A 1996 USFWS biological opinion requires the Army to assess effects due to implementing the 1996 guidelines (Jordan et al. 1997). This noise project provides an important aspect of this required assessment.



Figure 1. Adult Red-cockaded Woodpecker delivering prey to the nest.

The Fort Stewart ESMPT (2001) has prepared a Multi-Species Endangered Species Management Plan (ESMP) for the installation that details changes under these revised guidelines: (1) consideration will be given jointly to training mission requirements and RCW biological requirements when implementing the Multi-Species ESMP; (2) reduction in off-limit area for thru-cluster maneuver traffic around cluster trees from 200 ft (61 m) to 50 ft (15 m); (3) the types of training activities allowed within RCW clusters will be expanded; (4) proactive management is required to achieve population RCW goals (i.e., recruitment cluster establishment and single RCW group augmentation); (5) increased monitoring and reporting requirements; (6) reductions in potential training restrictions give Base Commanders incentive to expand RCW populations; and (7) establishment of provisions for critical mission areas that have no training restrictions on new RCW clusters (Fort Stewart ESMPT 2001).

Fort Stewart has a Mission Compatible Goal (MCG) of 411 active RCW clusters, which is the number of protected clusters that Fort Stewart can manage under their current military mission (Fort Stewart ESMPT 2001). In addition to Fort Stewart's MCG, the U.S. Fish and Wildlife Service (USFWS) has established a minimum number of active RCW clusters required to maintain a viable, recovered population of RCWs on Fort Stewart (500 active RCW clusters), which the USFWS refers to as the Installation Regional Recovery Goal (IRRG). To meet the USFWS goal of 500 active clusters, the Fort Stewart ESMPT (2001) has proposed the establishment of additional Supplemental Recruitment Clusters (SRCs). Supplemental Recruitment Clusters are RCW clusters on the installation that are not subject to standard USFWS requirements for RCW foraging habitat or training restrictions. This will ensure that installation use of SRCs

will not constrain future facilities development on Fort Stewart (Fort Stewart ESMPT 2001).

Objectives

The primary research objective for this multiyear study was to determine the impact of military training noise on the endangered Red-cockaded Woodpecker. Our second objective was to develop a dose-response threshold relation for quantifying RCW responses to noise levels and stimulus distances, and relate these to nesting success. Our third objective was to develop and disseminate cost-effective techniques for documenting the effects of training noise on TES populations. These techniques include the capability to characterize noise stimuli, to document behavioral responses, and to determine resulting population effects due to military noise. Achieving these objectives will provide a means to manage impact on both military training capability and TES, and will provide a factual basis for mitigation and management protocols and guidelines. This research directly addresses the #1 Army Conservation Pillar User Requirement, which is concerned with impacts of military operations on TES. The results of this research will partially satisfy requirements of the 1996 USFWS biological opinion (Jordan et al. 1997) that requires the Army to assess effects due to implementing the 1996 “Management Guidelines for the RCW on Army Installations.”

Approach

Chapter 3 presents details of the technical approach used in this research. The chapter includes discussions of the study area, RCW group selection, impact measures, response protocols, nesting success, video surveillance, sound instrumentation and recording, sound metrics, and statistical analyses.

Scope

All aspects of the research plan were reviewed and approved by the USFWS and Fort Stewart before field work began. Results from this research apply directly to Fort Stewart, but are applicable to other installations in the southeastern United States where RCWs are exposed to similar noise levels and stimulus types. This study used population data collected at Fort Stewart under a Forces Command (FORSCOM) program. Specific evaluation of maneuver training

impacts on RCWs was conducted under a separate, but closely coordinated research effort (Hayden et al. in press). Training noise sources examined during this study include: artillery simulators, .50-caliber blank fire, large-caliber live fire, small-arms live fire, grenade simulators, and helicopters. RCW response to other military activity, such as vehicle noise associated with maneuver training, aircraft flights, Multiple Launch Rocket System (MLRS) fire,

and Stinger/Drone Missile fire, was documented opportunistically, but was not a priority in this study.

Mode of Technology Transfer

We have provided products of this research directly to the Military Services for use during consultation with the USFWS and for development of management protocols. This aspect of the transition plan will directly help to alleviate impacts on military training capability and will provide information to the military that will guide effective management of impacts on endangered species populations. Other technology transfer methods will include technical papers and journal articles, and TES and noise workshops. We are in the process of developing manuscripts from this study for submission to peer-reviewed professional journals (Journal of Wildlife Management, Condor, Wilson Bulletin). We will disseminate project information through the Environmental Noise Program of the U.S. Army Center for Health Promotion and Preventive Medicine, the Army TES User Group, and the U.S. Air Force (USAF) International Bibliography on Noise (IBON). Other forums for dissemination include the U.S. Air Force/U.S. Army International Committee on Challenges of Modern Society (CCMS) subcommittees on noise effects, the International Committee on the Biological Effects of Noise (ICBEN), the Acoustical Society of America Animal Bioacoustics technical committee, and the Department of Defense (DoD) Environmental Noise Working Group.

2 Literature Review

Ecology

Red-cockaded Woodpeckers are gregarious, territorial, non-migratory, cooperative breeders (USFWS 2000). Red-cockaded Woodpeckers are unusual woodpeckers in that they excavate nest and roost cavities in living pine trees (Jackson 1994). This behavior is thought to have evolved due to limited cavity availability in fire-adapted forests in the southeastern United States (Ligon 1970). Red-cockaded Woodpeckers appear to select old trees for cavity excavation due to their large heartwood diameter (Conner et al. 1994) and because older trees have a higher frequency of red heart fungus infection which greatly reduces cavity excavation time (Conner and Rudolph 1995). Red-cockaded Woodpeckers use a variety of pine tree species for cavities (Jackson 1971; Fort Stewart ESMPT 2001), though they appear to prefer longleaf pine trees (Jackson 1971). On Fort Stewart, upwards of 79% of natural RCW cavities are in longleaf pine (*Pinus palustris*), while slash (*P. elliottii*; 16%), loblolly (*P. taeda*; 4%), and pond pine (*P. serotina*; 1%) are utilized to a smaller degree (Fort Stewart ESMPT 2001).

Red-cockaded Woodpeckers feed on all life stages of arthropods from adult insects to larvae and eggs (Jackson 1994). The diet of adult and nestling RCWs may vary geographically (USFWS 2000). Researchers in South Carolina and Georgia found that nestlings primarily were fed wood roaches (Hanula and Franzreb 1995; Hanula et al. 2000), while RCW nestlings in Florida were fed equal proportions of various arthropods (Hess and James 1998). Red-cockaded Woodpeckers foraging patterns vary by gender (Hooper and Lennartz 1981). Females forage mainly on the boles of trees, while males tend to forage in upper tree trunks and branches of pine trees (Ligon 1968; Ramsey 1980). RCWs appear to prefer foraging on large pine trees versus small diameter pine trees, though seasonal and habitat-based variations have been observed (Ramsey 1980). Larger trees appear to provide a greater surface area for foraging and easier access to prey due to looser and larger bark on older trees than smaller trees (Ramey 1980). Arthropod abundance and biomass also appears to increase with tree age and size (Hanula et al. 2000).

Anthropogenic Impacts

Noise disturbance studies have often been anecdotal and fail to quantitatively measure either the stimulus or the behavioral response related to the animal's fitness. Predictive models for the relationship between disturbance dosage and quantifiable effects are even more scarce (Awbrey and Bowles 1990; Grubb and King 1991; Grubb and Bowerman 1997). Although many types of human disturbance have been reported as affecting birds (Fyfe and Olendorff 1976), little research had addressed the effects of human activity on woodpeckers. Charbonneau et al. (1983) and Beaty (1986) investigated the effects of habitat alteration on RCW fitness parameters. Until recently, researchers did not consider the possible effects of military training activities and noise on RCWs, though a large proportion of the population resides on military installations (Costa 1992). Jackson (1983) was first to comment on the potential impacts of noise on RCWs. Subsequent research (Jackson and Parris 1995; Mobley et al. 1996; Wagner 1999; Doresky et al. 2001; Fort Stewart ESMPT 2001; Hayden et al. in press) has compared RCW population parameters to different land management practices and passive military training intensities on various Army installations. None of these projects found any significant reduction in RCW fitness parameters. Only this study has experimentally tested the potential effects of military training activities and noise on RCW fitness parameters (Pater et al. 1999; Delaney et al. 2000, 2001).

Few researchers have directly compared differences in bird responsiveness between aerial and ground-based disturbances (Bowles et al. 1990). Studies that have examined the effects of aircraft activity on nesting birds (e.g., Platt 1977; Windsor 1977; Ellis 1981; Anderson et al. 1989; Delaney et al. 1999) have often noted a slight but insignificant decrease in nesting success and productivity for disturbed versus undisturbed nests. In contrast, ground-based disturbances appear to have a greater effect than aerial disturbances on the nesting success of some bird species. In their classification tree model of Bald Eagle (*Haliaeetus leucocephalus*) responses to various anthropogenic disturbances, Grubb and King (1991) determined that Bald Eagles in Arizona showed the highest response frequency and severity of response toward ground-based disturbances, followed by aquatic, and lastly by aerial disturbances. Delaney et al. (1999) reported similar findings for Mexican Spotted Owl (*Strix occidentalis lucida*) response to military helicopter activity and chain saws, observing that chain saws elicited a greater flush response rate than helicopters at comparable distances and noise levels.

A bird's behavior during the nesting season is an important determinant of its ultimate nesting success or failure (Hohman 1986). Various bird species have

been reported to abandon their nests after being exposed to ground-based and aerial disturbances. White and Thurow (1985) reported that approximately 30 percent of Ferruginous Hawks (*Buteo regalis*) abandoned their nests after being exposed to various ground-based disturbances, but there were no controls for comparison. Anderson et al. (1989) reported that

two of 29 Red-tailed Hawk nests were abandoned after being flushed by helicopter flights, compared with zero of 12 control nests. Ellis et al. (1991) found only one of 19 Prairie Falcon (*Falco mexicanus*) nests were abandoned when exposed to frequent low-altitude jet flights during the nesting season (no control sites used). Platt (1977) reported similar rates with only one of 11 Gyrfalcon (*F. rusticolus*) nests failing (reportedly due to snow damage), compared with zero of 12 control nests. Of the six Peregrine Falcon (*F. peregrinus*) nests exposed to helicopter flights, only one was abandoned (also apparently due to inclement weather) compared with zero of three control sites (Windsor 1977).

Birds may be more susceptible to disturbance-caused nest abandonment early in the nesting season, possibly because parents have less energy invested in the nesting process (Knight and Temple 1986). Some animals appear reluctant to leave the nest later in the nesting season (Anderson et al. 1989; Ellis et al. 1991; Delaney et al. 1999). Steenhof and Kochert (1982) reported that Golden Eagles (*Aquila chrysaetos*) and Red-tailed Hawks exposed to human intrusions during early incubation had significantly lower nesting success than individuals exposed later in the season. Although reactions of adult birds at the nest can influence hatching rates and fledging success (Windsor 1977), flush behavior of adult birds from the nest is poorly quantified (Fraser et al. 1985; Holthuijzen et al. 1990; Delaney et al. 1999). In the few studies that have examined bird responses to specific disturbance types (e.g., aircraft approach distance), flush rates were higher if birds were naive (i.e., not previously exposed; Platt 1977). Some birds are more reluctant to flush off the nest during incubation and early nestling phases than later in the season (Grubb and Bowerman 1997; Delaney et al. 1999). Animal responsiveness has been shown to increase as the nesting season progresses (Grubb and Bowerman 1997). Delaney et al. (1999) found that Mexican Spotted Owls were more responsive to helicopters later in the reproductive cycle, which suggests that adult defensive behavior may decrease as the young mature. In contrast, Holthuijzen et al. (1990) found Prairie Falcon responsiveness to nearby blasting activity decreased as the nesting season progressed.

Few studies have documented the threshold distance that causes birds to flush in response to noise disturbance events. In those studies that reported stimulus distance, it was rare for birds to flush when the stimulus distance was greater than 60 m (Carrier and Melquist 1976; Edwards et al. 1979; Craig and Craig

1984; Pater et al. 1999; Delaney et al. 1999, 2000, 2001). Similar findings were reported by Carrier and Melquist (1976) for Osprey (*Pandion haliaetus*), and by Ellis (1981) for Peregrine Falcons. Many disturbance studies report that animal response increases with decreasing stimulus distance (Platt 1977; Grubb and King 1991; McGarigal et al. 1991; Stalmaster and Kaiser 1997), though only a few studies have experimentally tested this relationship (Delaney et al. 1999, 2000, 2001; Pater et al. 1999). Delaney et al. (1999) found that the proportion of owls flushing in response to a disturbance was strongly and negatively related to stimulus distance and positively related to noise level. Spotted owls were not observed flush-

ing when noise stimuli were > 105 m from owl locations. Pater et al. (1999) and Delaney et al. (2000, 2001) found similar results when RCW were exposed to passive and experimental military training noise. Red-cockaded Woodpeckers did not flush from the nest when: artillery simulator blasts were > 152 m from nests; .50-caliber blank fire events were > 152 m; military helicopters were > 60 m; small-caliber live fire was > 400 m; large-caliber live fire was > 700 m; and when grenade simulators were > 200 m.

Even fewer examples exist for dose-response relations. Snyder et al. (1978) reported that Snail Kites (*Rostrhamus sociabilis*) did not flush even when noise levels were up to 105 decibels, A-weighted (dBA) from commercial jet traffic. This result was qualified by the fact that test birds were living near airports and may have habituated to the noise. Edwards et al. (1979) found a dose-response relationship for flush responses of several species of gallinaceous birds when approach distances were between 30 and 60 m and noise levels approximated 95 dBA. Brown et al. (1999) reported no difference in the frequency of Bald Eagle activity and non activity behaviors when noise levels were < 110 dBP (unweighted Peak) and \geq 110 dBP for either roosting or nesting eagles. Delaney et al. (1999) reported that Mexican Spotted Owls did not flush during the nesting season when the Sound Exposure Level (SEL) for helicopters was \leq 102 owl-weighted, dBO (\leq 92 dBA) and the Equivalent Average Sound Level (LEQ) for chain saws was \leq 59 dBO (\leq 46 dBA). Delaney et al. (2000, 2001) and Pater et al. (1999) developed noise response thresholds for RCWs based on a number of military noise sources. Their preliminary results show that woodpeckers do not flush during the nesting season when the SEL for artillery simulators are < 89 dB, unweighted (< 84 dBA); .50-caliber blank fire was < 82 dB, unweighted (< 72 dBA); military helicopter overflights were < 102 dB, unweighted (< 85 dBA); small-caliber live fire events were < 79 dB, unweighted (< 77 dBA); large-caliber live fire events were < 103 dB, unweighted (< 85 dBA); and grenade simulators were < 91 dB, unweighted (< 84 dBA).

Distance has been described as the most commonly used surrogate for noise disturbance in the literature on animal response to noise, and has been proposed to

be the best representative for quantifying the relationship between stimulus and response measures (Awbrey and Bowles 1990). The reason appears to be that distance is more conveniently implemented into management practices (i.e., establishing buffer zones) than other variables. However, use of a properly measured noise level as the stimulus measure facilitates broader application of response results, in particular to sources of similar aural character but different acoustic power emission.

No studies have specifically addressed the hearing sensitivity of Red-cockaded Woodpeckers. One project has studied the hearing sensitivity of the Downy Woodpecker (*Picoides pubescens*) as a surrogate to the Red-cockaded Woodpeckers (Pater et al. 1999). The authors determined that RCWs were most sensitive in the 1000-3000 Hz range. Sensitivity appears to

drop off quickly at frequencies below 1000 Hz and above 4000 Hz (Pater et al. 1999). More research is needed to further test RCW hearing sensitivity at frequencies below 500 Hz.

3 Technical Approach

Null Hypotheses

Data collection, summary, and statistical analyses to assess and characterize military training noise in RCW groups, and to evaluate the relationship between noise levels and RCW demographic data, are based on the following formal null hypotheses:

- Ho: There is no difference in the nesting success, productivity, or nesting behavior between disturbed and undisturbed RCW groups.
- Ho: There is no relationship between stimulus distance or noise level and RCW response behavior.
- Ho: There is no difference in RCW response between types of training activities.

Study Area

Fort Stewart is located in southern Georgia (Figure 2), within Liberty, Long, Bryon, Tattnall, and Evans counties, and has the largest land area of any Army Installation east of the Mississippi River. Fort Stewart lies within the Atlantic Coastal Flatwoods Province, within a humid, semi-tropical latitude, that averages 50 in. (127 cm) of rain per year. The average temperature in January is 62 °F (17 °C) with a relative humidity of 70 percent, while July averages 91 °F (33 °C) with a relative humidity of 76 percent (National Oceanic and Atmospheric Administration). Approximately 82.6 percent of the 279,081 acres on Fort Stewart is forested and cover four main forest types: upland pine stands composed primarily of longleaf (*Pinus palustris*), loblolly (*P. taeda*), and slash pine (*P. elliottii*); mixed pine-hardwood sites; upland hardwood management areas; and forested wetland areas. Only 49.1 percent of the installation is considered suitable or potential RCW habitat (Fort Stewart ESMPT 2001)

The primary mission of Fort Stewart is training and operational readiness of the 3rd Infantry Division (Mech.) and other non-division units. The 3rd Infantry Division (previously the 24th) was activated in 1975 and re-designated as a mechanized division in 1979 (Hayden 1997). Training activities are conducted year-round at Fort Stewart to maintain a combat ready fighting force. The installation also supports training of regional National Guard and Reserve units, as well



Figure 2. Location of Fort Stewart within the state of Georgia.

as joint training exercises with troops from other installations and DoD Branches (Fort Stewart ESMPT 2001). Fort Stewart contains a variety of impact and firing areas (Figure 3). The central feature of the installation is the Artillery Impact Area (AIA; about 5,200 ha), which is surrounded by dozens of artillery firing points varying in distance from a few hundred meters to thousands of meters from the impact area. On the western border of the AIA is the Red Cloud Complex which contains eight separate ranges. Just south of the AIA is the Explosive Ordnance Disposal Area (EOD), the Demolition Area (DEMO), and the Small Arms Impact Area (13 live fire ranges, about 2,300 ha). To the east and northeast of the AIA are the CALFAX and Luzon Ranges, and three smaller Aerial Gunnery Ranges (AGRs). There are also seven drop zones located throughout the installation (Hayden 1997).

Sample Cluster Selection

There are currently 304 known RCW clusters (the aggregate of cavity trees used by a group of RCWs) distributed across Fort Stewart (Figure 3; Fort Stewart ESMPT 2001). No RCW groups are known to be in the AIA, though this area has not been ground surveyed due to safety concerns. We classified RCW groups according to type and level of training noise based on: (1) number; (2) distance; and (3) noise level of stimulus events that each group typically receives. Three types of sample groups were chosen: passive disturbed; undisturbed; and experimental. “Passive disturbed” groups were those groups that received potentially significant noise disturbance as part of normal training operations; we had no direct control over time, number, or level of noise events at these clusters.

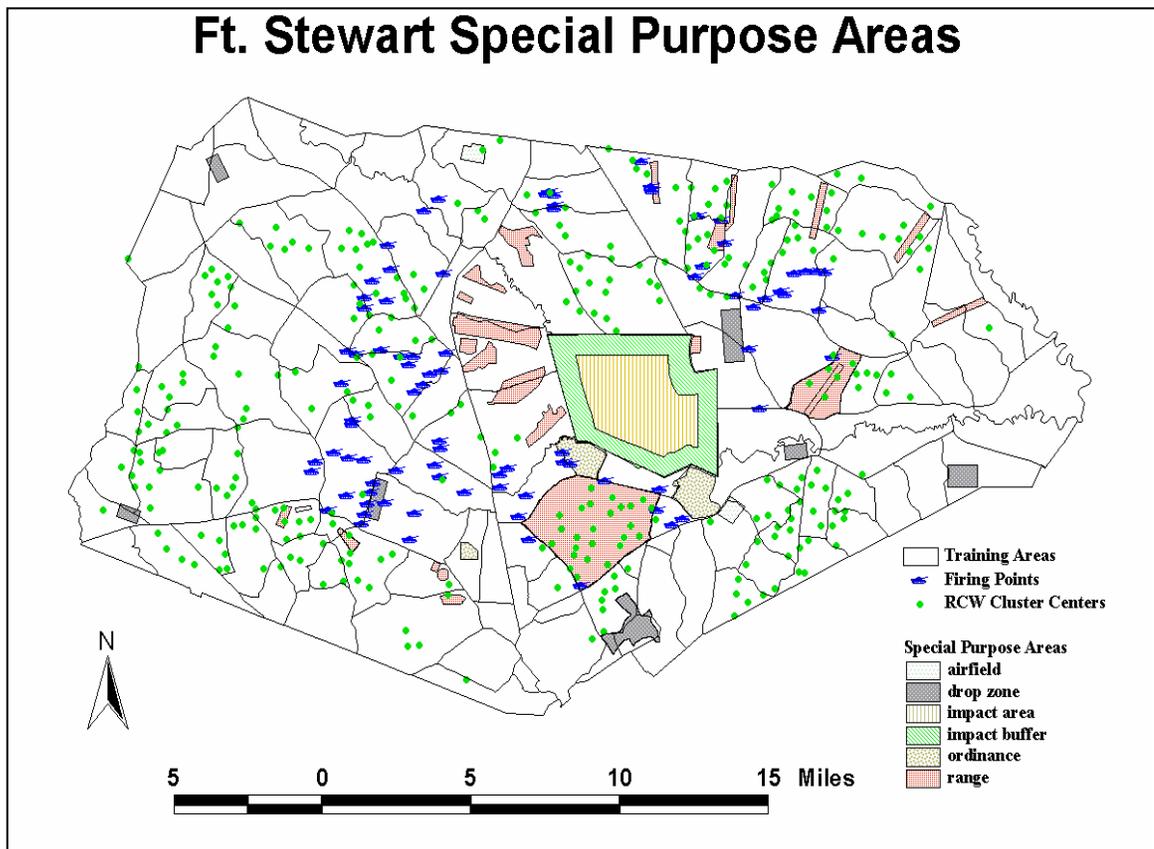


Figure 3. Locations of training areas and RCW groups on Fort Stewart. Green dots represent RCW locations (Map developed by Ron Owens at the Fish and Wildlife Branch Office, Fort Stewart).

During our first field season in 1998, we selected 25 passive disturbed RCW groups and 16 undisturbed groups (i.e., control) out of 141 RCW groups that nested. In 1999, we selected 48 groups for experimental testing and 25 groups as controls out of 165 nesting RCW groups. An additional 14 RCW groups also were monitored for response to passive disturbance events (9 of 14 passive sample groups also were used in experimental testing). During our third and final field season in 2000, we selected 50 groups for experimental testing and 27 groups as controls out of 170 nesting RCW groups. Thirty-one RCW groups also were monitored for response to passive disturbance events (21 of 31 passive sample groups were also used in experimental testing).

The loudest and most prominent passive noise types on Fort Stewart were large-caliber live fire, small arms live fire, and helicopter flights (Delaney, pers. observation). We attempted to choose RCW groups that received predominantly one type of noise, but this was sometimes impossible if we also used the highest noise level groups. “Undisturbed” or “low disturbance” RCW groups (the two terms are equivalent and are used interchangeably in this report) are groups where noise levels were judged likely to be consistently low or absent for all of the noise types. We documented sound levels, observed behavior, and measured nesting

success at undisturbed groups as a baseline for judging impact at disturbed groups.

It is likely that at least some level of military noise can be perceived at all RCW groups on Fort Stewart. Our criterion for low disturbance is noise levels at or near ambient noise levels. At “experimental” RCW groups we exposed birds to either artillery simulators (Figure 4) or .50-caliber blank fire (Figure 5) under controlled conditions at distances of 15.2, 30.5, 45.7, 61.0, 76.2, 91.5, 121.9, 152.4 and 243.9 m from the nest tree (Tables C1 and C2, Appendix C).

Figure 4. Artillery simulator blast. Figure 5. Soldier firing a .50-caliber machine gun with blanks.



Not all distances were tested for each noise source or RCW group because bird response dictated which distances would be used for developing a distance-response threshold. If RCWs flushed during the initial experimentation, the test was ended for that day and the next scheduled test was initiated 15-30 m farther away to establish a distance-response threshold. If the initial test did not cause a flush, the next test about 2-3 days later was presented 15-30 m closer. Experimental groups were chosen from among RCW groups that had low to moderately low disturbance levels. This implies that woodpeckers in these groups were not habituated to the noise stimulus. Sample size was limited by the number of groups that fit protocol criteria and by available field observations.

Impact Measures

Selection of noise impact criteria is a critical issue. For humans the response criterion is typically annoyance. For domesticated species the issue may be damage to individual animals or impacts on profits. For TES, the ultimate concern is long-term survival of the species. The challenge is to develop a relatively short-

term procedure for inferring impact on long-term survival. The conceptual approach used in this study was developed by Tim Hayden at the Engineer Research and Development Center, Construction Engineering Research Laboratory (Figure 6; ERDC/CERL). First, proximate responses to noise stimuli are measured. A proximate response is the direct and immediate response of the animal to a stimuli; for example a behavioral (flight) or a physiological (change in heart rate) response. Next, we examine whether the stimulus that elicited the proximate response affects “individual fitness” which is typically evaluated in terms of adult and juvenile mortality or reduced reproductive fitness. Mortality and reproductive fitness rates are established by field monitoring of many individuals throughout the nesting season. Population effects can be inferred from measures of individual fitness by application of Population Viability Analysis (PVA) models. Current applications of PVA do not capture the temporal and spatial variability of training events, and thus cannot model the resulting effects on endangered species’ demographic parameters. Researchers at ERDC/CERL are currently developing PVA modeling approaches capable of capturing training effects in predictive population models. This is a shared effort under this project and a related ERDC/CERL research effort to evaluate effects of maneuver training (vehicles and troops) on RCWs (Hayden et al. in press).

In summary, the research paradigm is that proximate effects can be linked to individual fitness, which in turn can be linked to population effects. As a specific example, consider that a bird might flush from a nest (a proximate response) in response to a noise event. It is possible that this could lead to nest failure, especially if the noise and flush response occurred repeatedly. Monitoring is required to determine nesting success of disturbed and undisturbed nests. A population

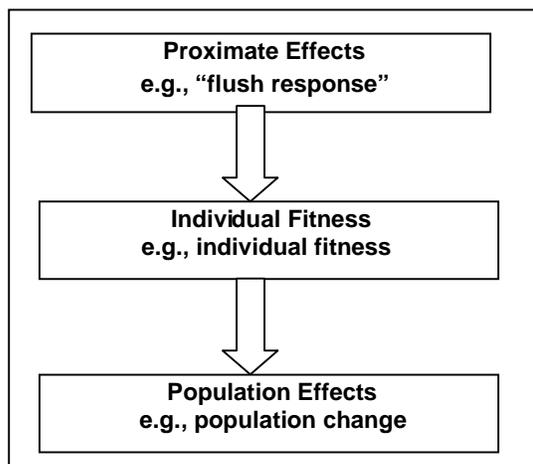


Figure 6. Assessment hierarchy for training impact on Threatened and Endangered Species (Hayden, unpublished).

model is required to determine if such failure of some percentage of nests has an effect on survival of the population.

Behavior and Proximate Response Measurement Protocols

We documented RCW behavior at low and high noise disturbance nest sites by direct observation and through video surveillance. We divided the nesting cycle into three stages: incubation (eggs present from nest day zero to 11); brooding (adult RCWs attend young chicks between zero to four days old to assist with thermoregulation: nest days 12 through 15); and nestling (larger chicks typically unattended for long periods of time in nest: nest day 16 until fledging around nest day 37-40). A “data session” consisted of behavioral observations of at least one adult RCW, typically for 1 hour or longer. At disturbed RCW groups we attempted to observe behavior for at least 30 minutes before and after each noise event. This was sometimes not possible for passive disturbed groups because noise events were so frequent that we could not document undisturbed behavior for extended periods of time.

To evaluate RCW baseline behavior and responses to military training activities, we measured several parameters:

1. Alert - RCW moves to the cavity entrance, head movements, orient to noise source;
2. Flush from nest - RCW departs from the nest cavity in response to the stimulus, and remains away from the nest for a measured period of time;
3. Return time - length of time an adult is away from the nest cavity after being flushed;
4. Nest attentiveness - proportion of time that adult RCWs spend attending the nest cavity through the nesting season (calculated for diurnal, 24-hour periods, and for the incubation and nestling phases);
5. Prey deliveries - number and rate of prey deliveries to the nest cavity;
6. Trips - number and duration of times the attending adult left the nest cavity.

Due to the amount of video data that we collected over the three years of this study (> 10,000 hours on 35 RCW groups), behavior categories four through six are not fully analyzed and therefore will not be presented in this report. These data will appear in a separate CERL report and will also be developed into manuscripts for submission to professional peer-reviewed journals in 2002.

Demographic and Nesting Success Data

Red-cockaded Woodpecker demographic data (population size, growth, density, and distribution) were collected in accordance with established protocols used by the Fort Stewart Fish and Wildlife Branch. Demographic data included the following parameters for each RCW group:

1. Cluster occupancy - cluster occupied by one or more RCWs. Most individuals are identified by unique leg band combinations (provides a measure of population size, growth, and stability);
2. Mated status - presence of both an adult male and an adult female RCW;
3. Active nest — at least one egg was laid;
4. Nesting success - at least one fledgling was produced (provides a measure of the proportion of RCW groups that are reproductively successful);
5. Nesting productivity - number of young fledged per nest (provides a measure of fecundity);
6. Number of eggs produced;
7. Number of nestlings hatched;
8. RCW group size - (provides a possible measure of territory quality and availability).

These data enable several trends to be detected:

1. Reproductive loss - mortality rate of eggs, nestlings, and fledglings during nesting;
2. Annual nest re-occupancy rates - provides a potential measure of RCW response to disturbance. Sites with heavy disturbance levels may be abandoned in subsequent years in favor of other sites further from specific disturbances;
3. Site tenacity - turnover rate of adult and helper RCWs within a cluster across years;
4. Nesting success rates for disturbed and undisturbed RCW groups;
5. Mean number of young fledged for disturbed and undisturbed RCW groups;
6. Mean clutch and brood size for disturbed and undisturbed RCW groups;
7. Reproductive potential - total number of young that could be produced if all eggs and nestlings survived to fledge successfully.

The majority of demographic data for Red-cockaded Woodpecker groups was collected by DPW Fish and Wildlife personnel from Fort Stewart. Each active (at least one RCW present) RCW group was initially visited to determine occupancy. Adult RCWs were banded to determine group size and affiliation using methods similar to Walters et al. (1988). A 25 percent random sample of all RCW groups

were then monitored approximately every seven to nine days to record clutch and brood size (Fort Stewart ESMPT 2001). Nestlings were uniquely color banded approximately five to ten days after hatching. Groups were visited 20 to 25 days after nestlings were banded to determine the number and sex of fledglings (Walters et al. 1988). The 25 percent sample in-

cluded many of our sample groups. We augmented the DPW Fish and Wildlife sample by monitoring demographic data (particularly the number of young fledged) for additional RCW groups to provide more complete coverage of our sample groups.

Video Surveillance

Video cameras were used as a means to record RCW behavior over prolonged periods, to reduce costs, and to avoid potentially disruptive effects of human presence. The camera systems also documented response in areas that could not be safely monitored (e.g., downrange from firing positions). Cameras were attached to tree trunks with adjustable, jointed angle-brackets and screws. Cameras were mounted at the same level or slightly above nest height in the nearest practical tree and at least 5 m from the nest tree so as not to disturb incubating woodpeckers. The solid state, 12-volt, flexible circuit-board black and white cameras were equipped with 12.0-mm lenses, while the color cameras had 75-mm lenses. The cameras provide a minimum of 380 lines of resolution and have a minimum sensitivity of 0.45 Lux. Black and white cameras were mounted in waterproof heavy-gauge plastic switch boxes with transparent covers (12.9 x 6.7 x 4.1 cm) which were painted black, except for the lens and LED (light-emitting diode) area. Color cameras were housed in metal weatherproof containers (30 x 9.7 x 9.0 cm). Two ports are threaded into the protective housing: one for the power supply and the second for the video signal (Delaney et al. 1998). Power and coaxial cables were attached to a DC (direct current) monitor and battery so camera placement could be directed from the base of the camera tree. At least two people were required for camera placement: a climber to position the camera and a person on the ground to check the video signal and placement. Then a trunk line was attached at the base of the tree (covered by a camouflaged 1.2 cm diameter hose for protection against rodents), allowing the power/recording station to be placed between 30-60 m from the tree to minimize potential disturbance to the woodpeckers. Panasonic Model AG-1070DC Professional/Industrial VHS video recorders, were connected to cameras via coaxial cable (RG-59), provided approximately 24-32 hours of coverage per tape. These 12-volt, DC-powered recorders were designed for surveillance applications. Cameras and video recorders were powered by two 12-volt, 33.0-amp-hour, Power-Sonic Model PS-12330 sealed rechargeable batteries connected in parallel (a 24-hour taping would draw a single battery below operational limits). These "gel-cell" type batteries

(weighing 11.3 kg each) reduce the risk of battery damage, and eliminate the potential for spillage during backpack transport. We put the recorder, twin batteries, and all connectors inside a weatherproof bin concealed under a camouflaged tarpaulin. Freshly recharged batteries are used for each set of recordings. We did not observe any nest abandonment due to camera placement.

Sound Instrumentation and Recording

Sony TCD-D8, Digital Audio Tape (DAT) recorders were used to continuously record all noise events, along with the exact time and date. We attached Bruel & Kjaer (B&K) Type 4149 1.3 cm Condenser Microphones with 7.5 cm wind screens to B&K Model 2639 Preamplifiers, mounting the microphone on a 1-m stick, and placing the unit directly under a woodpecker's nest about 1 m from the tree trunk. The power supply and DAT recorder were also placed at the base of the nest tree in a small camouflaged container. A 1.0-kHz, 94-dB calibration signal (20 micropascals reference) from a B&K Type 4250 Sound Level Calibrating System was recorded before and after each noise event recording. This signal provides a reference for sound levels and spectra when data are later analyzed using a B&K Type 2144 Frequency Analyzer. All noise data were analyzed at ERDC/CERL. In addition to recording noise levels at the base of the nest tree, we also recorded noise levels within cavities after the nesting season.

Sound Metrics

Noise is defined as sound that is undesirable or constitutes an unwarranted disturbance, and can alter behavior or normal functioning (ANSI S1.1-1994). The types of military noise that are within the scope of this study vary widely in instantaneous transient amplitude, duration, spectral energy content, and suddenness of onset. Appropriate noise metrics and frequency weighting are essential to adequately quantify noise impact for each type of noise. Noise metrics are chosen to measure the noise dose in a way that meaningfully correlates with subject response. Frequency weighting is an algorithm of frequency-dependent attenuation that simulates the hearing sensitivity and range of the study subjects. Frequency weighting discriminates against sound that, while easily measured, is not heard by the study subjects. The current project requires specialized metrics and techniques to meaningfully measure noise impacts on animals. Our paradigm is to measure noise events in terms of unweighted one-third-octave band levels, apply frequency weighting to the resultant spectra, and calculate appropriate overall metrics.

Only noise that is audible to the study species should be accounted for in the metric used to quantify noise level. Frequency weighting designed for humans may not be appropriate for animal species. The commonly used "A" frequency weighting (ANSI S1.4-1983) attenuates noise energy according to human hearing range and sensitivity. For human response to blast noise, "C" frequency weighting is often applied to received blast noise signals, rather than "A" weighting which is more representative of human hearing response (ANSI S1.4-1983). This is done to retain low frequency energy that, while not heard by humans, causes a secondary rattle in buildings which does evoke response (ANSI S12.4-1986). This is not appropriate for most wildlife. An audiogram, which describes hearing range and sensitivity, provides guidance regarding appropriate frequency weighting for the species of interest and aids in

interpretation of noise response data. We searched the literature and consulted several leading experts on bird hearing without finding an audiogram for the RCW or for any species in RCW's order, *Piciformes*. Thus, as part of this project we obtained a preliminary woodpecker audiogram that we used to develop a frequency weighting function. Figure 7 shows the woodpecker audiogram (Pater et al. 1999), a composite average audiogram of seven orders of birds (Dooling et al. 2000), with an approximate representation of a human audiogram. The differences are substantial. The owl audiogram further illustrates how audiograms can vary among species (Delaney et al. 1999). Additional information on the current RCW audiogram work can be found in Pater et al. (1999).

It is well-established (ANSI S12.40-1990; S12.9-1996; S12.17-1996; Homans 1974; NAS 1977, 1981; Rice 1983; Rice et al. 1986; Schomer et al. 1994) that the appropriate metric for blast noise is SEL, which is essentially the time integral of the square of the acoustic pressure. We measured blast noise as unweighted one-third-octave band SEL, to which we applied appropriate frequency weighting for the RCW, to obtain Woodpecker weighted noise levels (dBW). The same metric and procedure was also used with small arms noise (Buchta 1990; Hede and Bullen 1982; Hoffman et al. 1985; Luz 1982; Sorenson and Magnusson 1979; Vos 1995). Two metrics, the SEL and the maximum 1-second equivalent average (LEQ) level, were used for helicopter noise, airplane noise, and vehicle pass-by noise, since both are meaningful in terms of correlation with response (Environmental Protection Agency [EPA] 1974, 1982; Federal Interagency Committee on Urban Noise [FICUN] 1980; Fidell et al. 1991; Schomer 1994; Schultz 1978; U.S. Code of Federal Regulations 1980). Ambient noise was measured as LEQ for various appropriate time periods (EPA 1982). In all cases, the noise signals were recorded on digital audio tapes and preserved for possible further analysis.

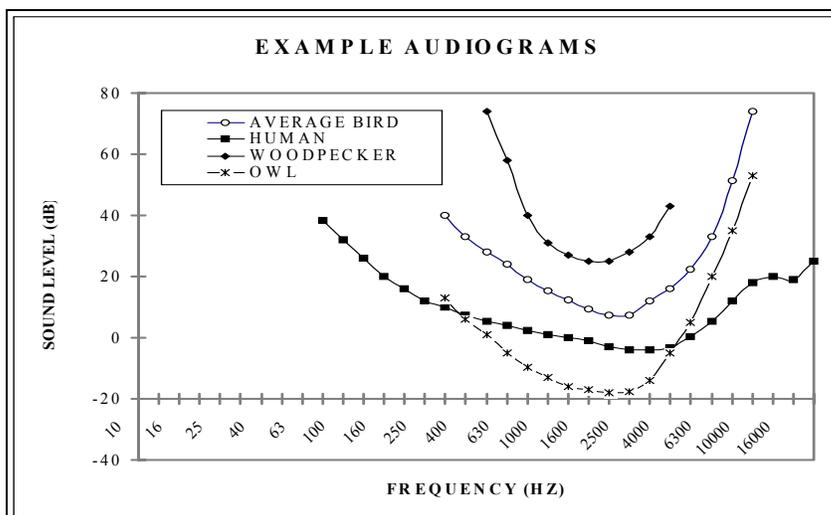


Figure 7. Examples of audiograms and frequency weighting. Average bird audiograms are from Dooling et al. (2000); owl audiogram were developed by Delaney et al. (1999) based on data

from Trainer (1946) and Konishi (1973); woodpecker audiogram was by Lohr et al. reported in Pater et al. (1999); and Human audiograms are based on the ANSI standard (1969).

Statistical Data Analysis

We used SPSS 8.0 for Windows (SPSS Inc. 1998) to perform all descriptive statistics; for example, one-way ANOVA for comparing the mean number of eggs, nestlings, and young fledged between the first and second nesting attempts and for comparing noise levels between stimulus type, year and distance. Independent sample *t*-tests were used to compare nest productivity data between experimental and control sites. Whenever appropriate, multiple observations at single nests were averaged before inferential tests were performed so that the sample sizes are the number of nests examined. We used a 1-tailed Fisher Exact Test to assess 2x2 contingency tables for variability in nesting success between disturbed and undisturbed nest sites (Zar 1984). We used Sample Power 1.0 to conduct power analyses (Borenstein et al. 1997). Alpha levels of 0.05 will be required to reject a null hypothesis for all tests. Means \pm standard error (SE) are presented throughout this document.

4 Results

Initiation Dates for Each Nesting Phase

The first woodpecker clutches were initiated in 1998-2000 on approximately 10 April through 3 June, while secondary clutches (RCW groups that re-nested after initial nest failure) were initiated on 2 May through 15 June. Third clutches were initiated on 16 May through 23 May. Eggs from initial nesting attempts hatched on approximately 23 April through 16 June, while nests from second nesting attempts hatched on 13 May through 27 June. Third nesting attempts hatched on approximately 5 June through 3 July. We observed young fledging from initial nesting attempts on 20 May through 12 July, and from 8 June through 22 July for fledglings from secondary nesting attempts. Third nesting attempts fledged on approximately 21 June through 9 July. There were no third nesting attempts observed during 1998 or 2000, only during the 1999 nesting season.

Overall Population Dynamics

The total number of potential breeding RCW groups on Fort Stewart increased from 165 in 1998 to 174 in 1999 to 181 in 2000, for an overall increase of 9.7%. The number of nesting RCW groups increased from 141 in 1998 to 165 in 1999 to 170 in 2000, for an overall increase of 20.6%. Overall fledging success rates remained consistent over the three years of this study (84.4%; range of 79.4 to 87.7%). Approximately a quarter of all RCW groups from 1998-2000 (25.3%; range 20.6-28.5%) failed in initial nesting attempts; 62.8% (range of 54.3-70.2%) of these RCW groups re-nested within the following two weeks. Groups that re-nested were as successful and productive as groups that nested only once during each year of this study (Pater et al. 1999, Delaney et al. 2000, 2001). Fitness data from initial nesting attempts and re-nesting attempts were pooled to determine mean fitness rates for the overall RCW population each year.

Clutch sizes for RCW groups from 1998-2000 ranged from 2.75-3.01 eggs/nest; brood size ranged from 2.01-2.22 nestlings/nest; and the average number of young fledged ranged from 1.57-1.76 young/occupied nest (range of 1.83-2.04 young/successful nest). Occupied nests include successful and unsuccessful groups, while successful nests only include groups that successfully fledge at

least one young. The number and proportion of male and female fledglings varied each year. The approximate number of young fledged each year on Fort Stewart ranged from 200 in 1998 to 290 in 1999, to 279 in 2000. These numbers were comparable to fledge rates in 2001 (272 young fledged) when no experimental noise testing occurred. RCW groups fledged a slightly higher proportion of males than females in 1998 (53.5%) and 1999 (53.1%), while we observed a reverse pattern in 2000 (46.2%) and 2001 (47.4%), when slightly more females fledged than males.

There was a significant reduction in the reproductive potential (i.e., total number of young produced if all eggs and nestlings survive to fledge) of RCW nests from the incubation phase to the nestling phase across all three years of this study (range 35.9-38.7%; Pater et al. 1999; Delaney et al. 2000, 2001). The decline between nestling and fledgling phases was not as dramatic each year, but was still significant in 1998 and 1999 (range 10.3-16.9%). Overall, we observed a significant decline in the reproductive potential from incubation through the fledgling phase from 1998-2000 (ranged from 45.7-53.2%; Pater et al. 1999, Delaney et al. 2000, 2001).

Sample Group Population Dynamics

Of the 58 experimental RCW groups that received disturbance testing in 1999-2000, 83.3% of the 96 nesting attempts were successful in fledging young. Twenty-eight of these 96 nesting attempts initially failed. Sixteen of the 28 RCW groups that initially failed during their first nesting attempt were found re-nesting within the following two weeks, with 68.8% successfully fledging young. Experimental RCW groups that re-nested were as successful (Fisher Exact Test, $P = 0.08$; 68.8 percent for groups that re-nested versus 85.0 percent for initial nesting attempts) and productive as groups that nested only once. Experimental groups that nested only once, nested successfully in 68 of 80 nesting attempts and produced an average of 3.06 ± 0.09 eggs/nest, 2.16 ± 0.12 nestlings/nest, and 1.81 ± 0.12 young/occupied nest (2.12 ± 0.10 young/successful nest). In comparison, groups that re-nested were successful in 11 of 16 nesting attempts and produced an average of 2.75 ± 0.19 eggs/nest, 1.75 ± 0.19 nestlings/nest, and 1.25 ± 0.23 young/occupied nest (1.82 ± 0.12 young/successful nest). We observed no significant difference in the number of eggs ($F_{1,94} = 0.42$, $P = 0.15$), number of nestlings ($F_{1,94} = 2.92$, $P = 0.14$), or the number of fledglings ($F_{1,94} = 0.07$, $P = 0.053$) between groups that re-nested and groups that nested only once. Therefore, data were pooled before determining overall sample group fitness rates.

Of the 34 RCW control groups monitored in 1999-2000, 88.9% of the 54 nesting attempts made by these groups were successful in fledging young. Fourteen of these 54 initial nesting attempts failed. This was not significantly different from initial failure rates for experimental RCW groups (Fisher Exact Test, $P = 0.14$). Ten of the 14 RCW groups that initially failed to nest re-nested within the following two weeks, with 80.0% successfully fledging young.

Control groups that re-nested were as successful (Fisher Exact Test, $P = 0.24$; 80.0 percent for groups that re-nested versus 88.9 percent for initial nesting attempts) and productive as groups that nested only once. RCW groups that nested only once were successful in 44 of 54 nesting attempts and produced an average of 2.93 ± 0.10 eggs/nest, 2.18 ± 0.11 nestlings/nest, and 1.82 ± 0.12 young/occupied nest (2.12 ± 0.10 young/successful nest). In comparison, RCW groups that re-nested were successful in 8 of 10 nesting attempts and produced an average of 2.80 ± 0.36 eggs/nest, 1.90 ± 0.38 nestlings/nest, and 1.80 ± 0.39 young/occupied nest (2.25 ± 0.31 young/successful nest). We observed no significant difference in the number of eggs ($F_{1,52} = 4.78$, $P = 0.64$), number of nestlings ($F_{1,52} = 4.79$, $P = 0.33$), or the number of fledglings ($F_{1,52} = 6.33$, $P = 0.95$) between groups that re-nested and groups that nested only once. Therefore, data were pooled before determining overall sample group fitness rates.

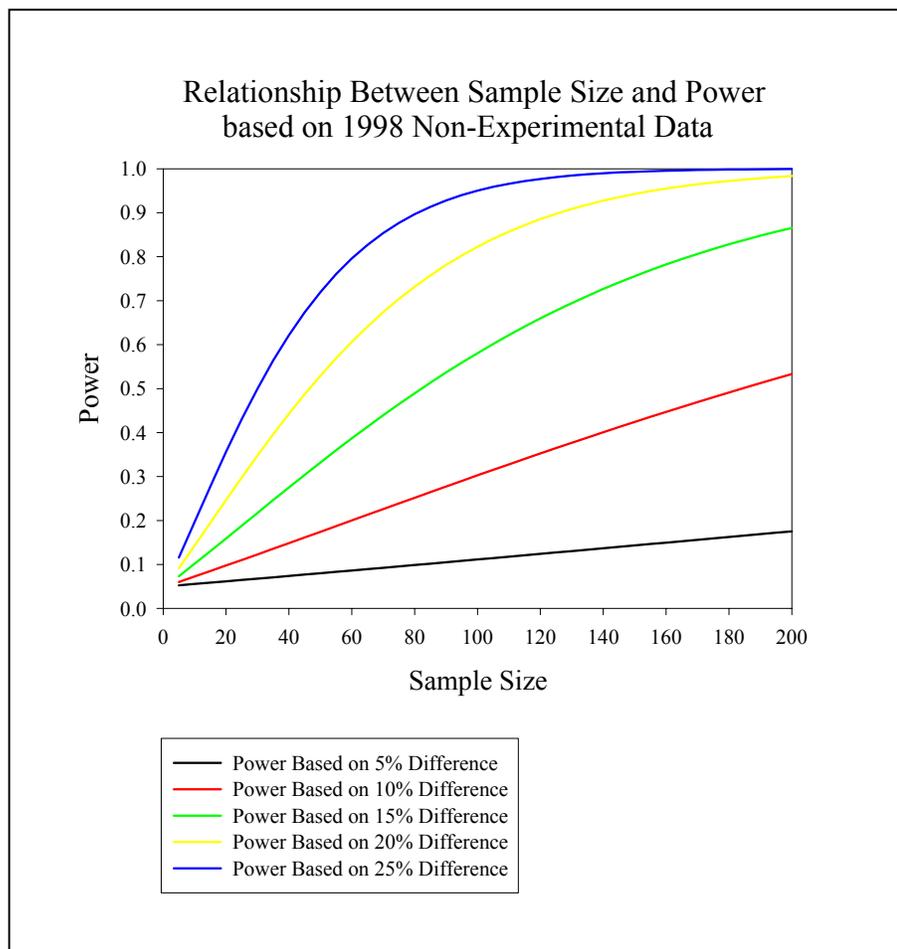
Overall, experimental RCW groups produced an average of 2.98 ± 0.07 eggs/nest, 1.89 ± 0.11 nestlings/nest, and 1.54 ± 0.12 young/occupied nest, while control groups produced an average of 2.73 ± 0.11 eggs/nest, 1.91 ± 0.13 nestling/nest, and 1.57 ± 0.13 young/occupied nest. The proportion of experimental nesting attempts that were successful (81.3 percent) was not significantly different from the proportion of control nests (85.2 percent) that successfully nested (Fisher Exact Test, $P = 0.12$). Experimental and control RCW groups did not differ significantly in number of eggs ($F_{1,90} = 4.16$, $P = 0.058$), number of nestlings ($F_{1,90} = 1.06$, $P = 0.88$), or number of fledglings ($F_{1,90} = 1.00$, $P = 0.88$) from 1999-2000.

We also compared 1999-2000 fitness data from experimental groups with 2001 fitness data for these same RCW groups, when no experimental testing occurred. We found no significant differences between the proportion of RCW groups that initially failed in their nesting attempts (Fisher Exact Test, $P = 0.20$) or the proportion of re-nesting groups that nested successfully (Fisher Exact Test, $P = 0.25$) between experimental test years (1999-2000) and 2001 that did not received any experimental testing. We found no significant difference in the number of eggs ($F_{1,109} = 5.43$, $P = 0.86$), number of nestlings ($F_{1,109} = 5.69$, $P = 0.41$), or the number of fledglings ($F_{1,109} = 2.61$, $P = 0.72$) between experimental test years and post year fitness data.

Power Analysis

Based on a preliminary power analysis in 1998, we estimated a group size of 95 experimental and 95 control RCW groups would be necessary to reach an adequate power level of 0.80 (Figure 8). Our power analyses in 1999 and 2000 showed only a 0.33-0.41 probability of detecting a 25 percent decrease in reproductive productivity in control nest sites (Alpha level of 0.05; 2-tailed test).

Figure 8. 1998 Power analysis comparing disturbed versus control fitness parameters.



Power decreased to 0.23-0.29 for detecting a 20 percent decrease in reproductive productivity, to 0.15-0.18 for a 15 percent decrease, and down to 0.09-0.11 for detecting a 10 percent decrease in reproductive productivity between disturbed and control RCW groups.

Noise and Response Monitoring Summary

During the 1999-2000 field seasons, we documented RCW response to experimental noise from controlled .50-caliber blank fire and artillery simulators. Passive noise from large-caliber live fire (20-mm M2A2 Bradley Fighting Vehicles, 120-mm M1A1-Tanks, and 155-

mm M109 Howitzers), small-arms live fire (5.56-mm M-16 and Saw, 7.62-mm, and .50-caliber machine guns), grenade simulators, military helicopters, military vehicles, MLRS, Stinger/Drone Missiles, and fixed-wing aircraft was recorded as it occurred from 1998-2000. Passive noise was monitored during all nesting phases, while experimental tests were performed only during the incubation and early portions of the brooding phase when adults were present at the nest for extended periods of time.

We made noise measurements and behavioral response observations at a total of 58 experimental and 50 passive sample groups. Detailed results are described below and are presented in data tables and figures in Appendices C and D, respectively. The tables of Appendix C present summaries of the noise level measurements and RCW responses for each of the noise sources recorded. Typical spectrum for the most prevalent noise sources are presented in Appendix D. Noise level summaries for each noise stimulus type and detailed noise measurements in terms of one-third-octave band SEL levels are reported in previous RCW reports (Pater et al. 1999; Delaney et al. 2000, 2001). We also monitored 40 undisturbed sample clusters for the purpose of obtaining baseline behavioral information against which to judge proximate response at the disturbed groups.

Passive Monitoring

We recorded 2,846 passive noise events in 157 data sessions at 50 RCW groups during 1998-2000. Small-caliber live fire events (M-16 rifles and .50-caliber machine guns) were recorded most frequently, followed by large-caliber live fire events (greater than 20-mm), missiles (MLRS and Stinger/Drone), helicopters, vehicles, simulators, and fixed-wing aircraft. Multiple noise events and stimulus types were usually recorded during each passive data session. Stimulus type, noise of disturbance events, and noise level varied for each RCW group (Tables C1-C10, Appendix C).

Distance and Noise Level Thresholds for Response

Experimental Tests

In 1998, we exposed four RCW groups to small arms blank fire (5.56 mm M-16) fired at a distance of 15.2 m from the nest tree during a 5-minute period. Due to logistical constraints, only one test was conducted at each RCW nest sites during 1998 (Table C9, Appendix C).

From 1999-2000, we conducted 206 experimental tests at 58 RCW groups (37 groups received artillery simulator testing, while 38 received .50-caliber blank fire testing; Tables C1 and C2, Appendix C; noise spectral examples Figures D1 and D2, Appendix D). Some RCW groups received testing from both experimental noise types, though only one noise type was tested per nesting season, except Cluster 81 in 2000. Cluster 81 received both .50-caliber blank fire and artillery simulators in 2000, with only one noise type per test during each of two nesting attempts. The first nesting attempt at cluster 81 failed, while the second was success in fledgling two young.

Artillery Simulators

As stimulus distance decreased, RCW flush frequency increased (Figure 9), regardless of stimulus type or year (Tables C1 and C2, Appendix C). Woodpeckers did not flush from nests when artillery simulator blasts were > 152.4 m away and SEL noise levels < 65 dBW (72 dB, unweighted). Only one flush response was documented at a distance of 121.9 m (Table C1, Appendix C). Woodpeckers returned to their nests on average within 4.4 minutes after being flushed, while returning no later than 16.2 minutes overall (Figure 10).

.50-caliber Blank Fire

We recorded two flush responses due to .50-caliber blank fire at 121.9 m (Table C2, Appendix C). We tested RCW response to .50-caliber blank fire at distances > 121.9 m and did not observe any flush responses at distances of 152.4 or 243.8 m. At distances \leq 122 m, .50-caliber blank fire elicited a higher proportion of flushes (51.5 percent) than comparably distant artillery simulators (43.3 percent; Appendix C: Tables C1 and C2), though this difference was not significant (Fisher Exact Test; $P = 0.057$). Woodpeckers did not flush from the nest when .50-caliber blank fire events were > 152.4 m away and SEL noise levels < 68 dBW (80 dB, unweighted). Woodpeckers returned to nests on average within 6.3 minutes after being flushed, while returning no later than 26.8 minutes overall. We found no relationship between return time and stimulus distance (Figure 10).

Figure 9. RCW flush frequency by stimulus type and distance. Numbers in parentheses represent the number of RCW groups tested at each distance.

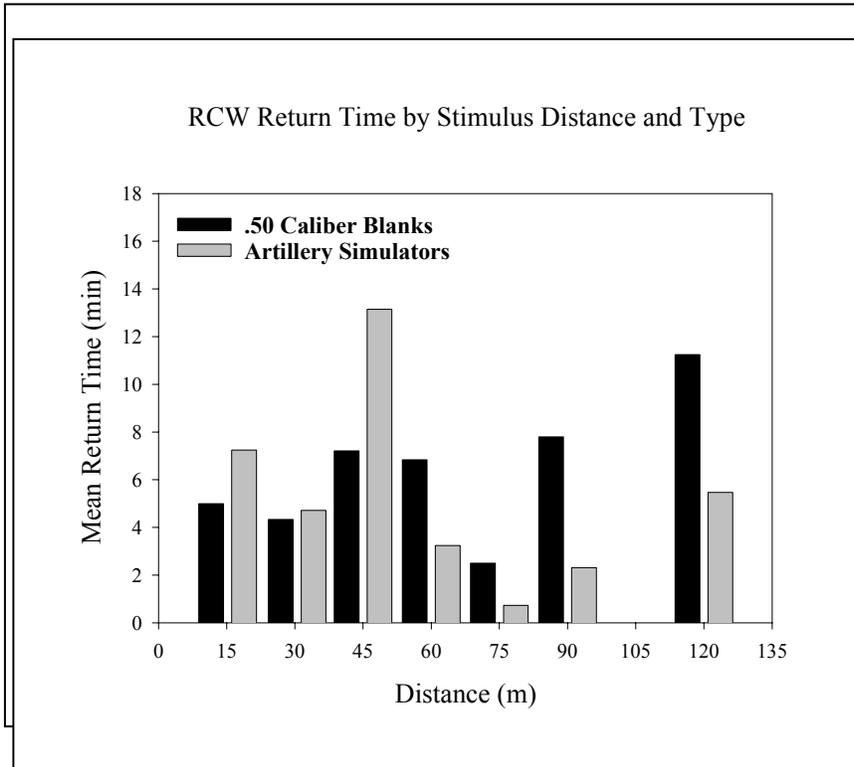


Figure 10. Mean return time for RCWs in response to experimental testing in 1999-2000.

Dose-Response Relation

We averaged noise levels across categorical stimulus distances for .50-caliber blank fire events and artillery simulators to illustrate the proportion of woodpecker flush responses as a function of noise level and stimulus distance (Figures 11 and 12). Both figures show that RCW flush frequency increases rapidly with increasing noise level and when stimulus distances were ≤ 121.9 m, with the .50-caliber blank fire curve rising more abruptly than artillery simulators overall. Mean noise levels were more variable during artillery simulator tests than .50-caliber blank fire events across years (Figures 11 and 12). On average, .50-caliber blank fire events ranged from 42 dBW at 243.9 m up to 92 dBW at 15.2 m from RCW nest trees, while artillery simulators, on average, ranged from 67 dBW at 152.4 m to 86 dBW at 30.5 m from RCW tree trees (Figures 11 and 12).

Passive Events

Small-Caliber Live Fire

There was only one RCW group monitored (cluster 103) between 1998-2000 that received small-caliber live fire noise at distances less than 400 m. Noise levels in cluster 103 were louder than in other clusters due to supersonic bullet noise and ricocheting bullets hitting

trees in close proximity to the nest tree (M-16 range – Golf; example of noise spectral data: Figure D3, Appendix D). The other 11 clusters monitored for passive small-caliber noise were much further downrange or were positioned behind the firing lines compared with cluster 103 and therefore

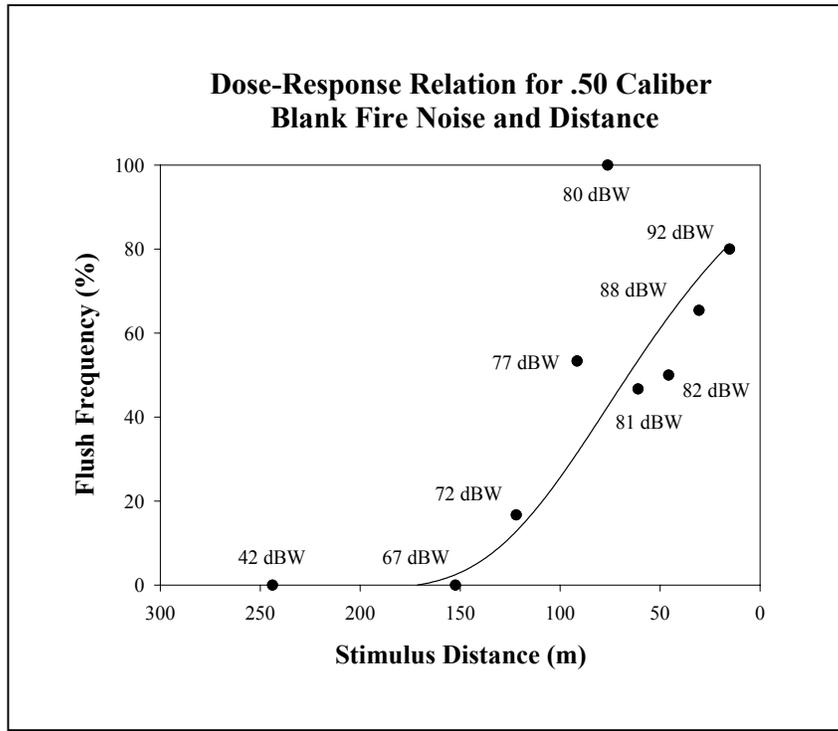


Figure 11. Dose-response relation between .50-caliber blank fire events and distance for RCWs on Fort Stewart in 1999-2000. Noise levels are based on Woodpecker weighting.

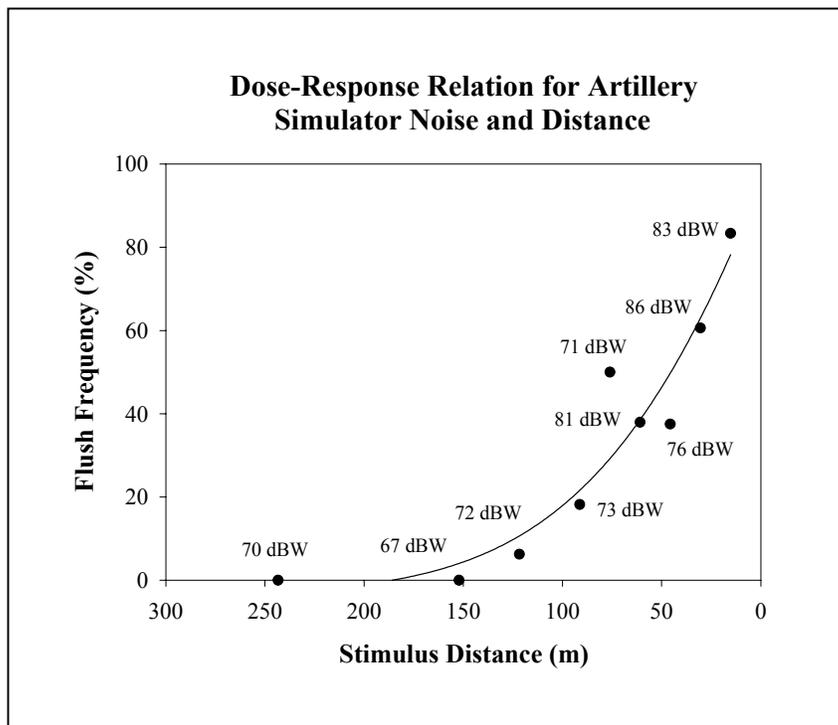


Figure 12. Dose-response relation between artillery simulator blast events and distance for RCWs on Fort Stewart in 1999-2000. Noise levels are based on Woodpecker weighting curves.

received substantially lower noise levels (Table C3, Appendix C). RCW groups in live fire ranges were monitored remotely via video cameras that were synchronized with audio recording equipment.

Woodpeckers did not appear to flush in response to small-caliber noise at cluster 103, though their flight activities may have been influenced. On 3 separate days, over a 6-day period in 1999, Woodpeckers were only observed arriving and departing from the nest during inactive firing periods on the range (Figures 13-15). Data points for Figures 13-15 represent individual bullet noise events or groups of muzzle blast events that are separated in time from other shots. Noise events were separated into bullet noise (located between the range and RCW location) or muzzle blast (located at firing range) categories in Figures 13-15. Red lines represent RCW arrivals and blue lines represent departs from the nest. Noise levels from supersonic bullets and ricocheting bullets were substantially louder than rifle muzzle noise coming from the range (Figure 16). Each noise event in Figures 13-15 are quantified in terms of unweighted and Woodpecker weighted (dBW) metrics. Events with equal “W” weighted and unweighted levels, or where “W” weighted levels are higher than unweighted values, represent supersonic bullet noise (approximately 78 dB, unweighted or higher; Figures 13-15). Events with “W” weighted levels below unweighted levels (< 78 dB, unweighted) represent muzzle blast noise from ranges. Supersonic bullet noise was 20-25 dBW louder than muzzle blast noise within the 1-4kHz frequency range when

peak levels for both noise types were compared (Figure 16). Supersonic bullet noise represented 19 percent (284 noise events, Table C3, Appendix C) of the noise events that were recorded at cluster 103. Cluster 103 successfully fledged two young in each year that we monitored nesting success (1999 and 2000).

We recorded 1930 small arms live-fire noise events during 29 data sessions at 14 RCW groups during 1998-2000 (Table C3). We did not observe any flush responses to passive small arms live-fire at documented noise levels and stimulus distances. RCWs did not flush from the nest when small-arms live fire events were > 400 m from active RCW nests and SEL noise levels were < 51 dBW (76 dB, unweighted; Table C3). Small arms live-fire events < 200 m did not represent muzzle noise from rifles themselves, but were from supersonic bullet noise. We were not able to determine the exact distances that bullets were hitting

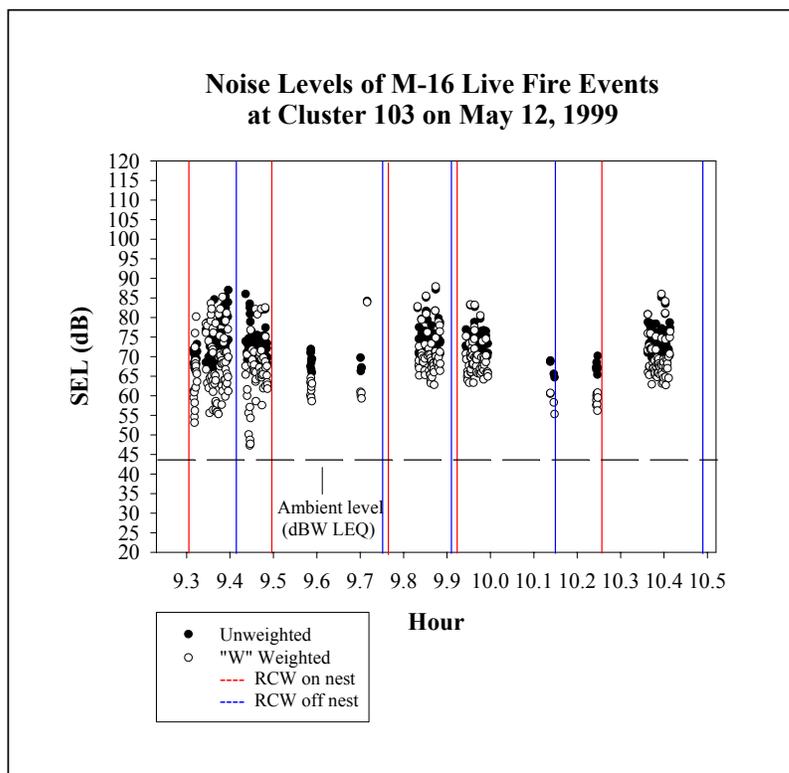


Figure 13. Noise levels from M-16 live fire events at cluster 103 on 12 May 1999.

surrounding trees, but due to the received noise levels and characteristics and the fact that we have seen bullets lodged in nearby trees, distances appear to be relatively close. Rifle noise from Small Arms - Golf M-16 range was approximately 430 m from the nest (example of noise spectral data: Figure D4, Appendix D). We did not locate any other active RCW nests < 400 m from any small arms ranges to which we had access for testing purposes.

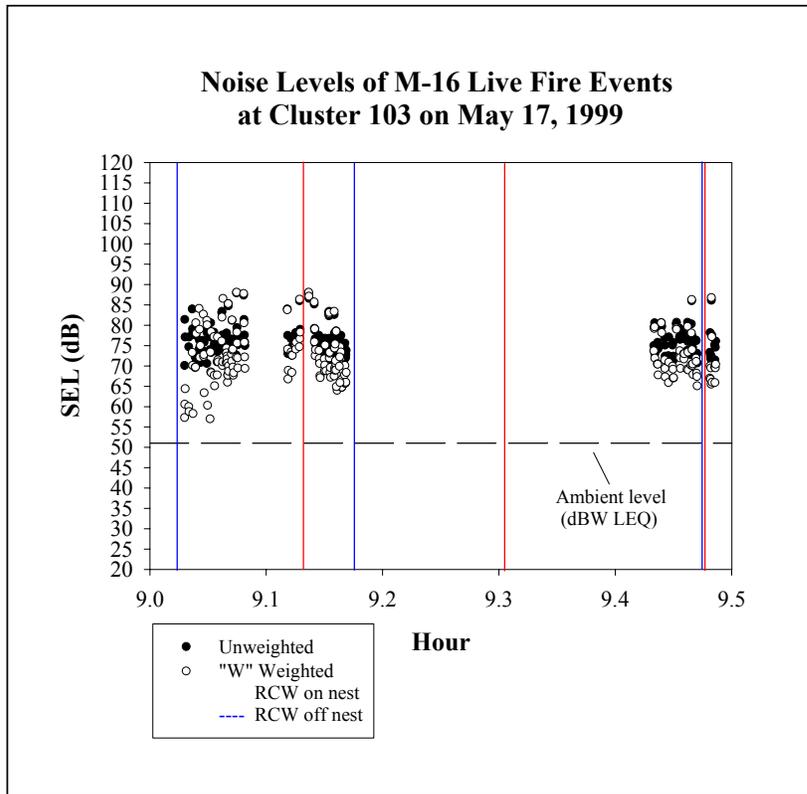


Figure 14. Noise levels from M-16 live fire events at cluster 103 on 17 May 1999.

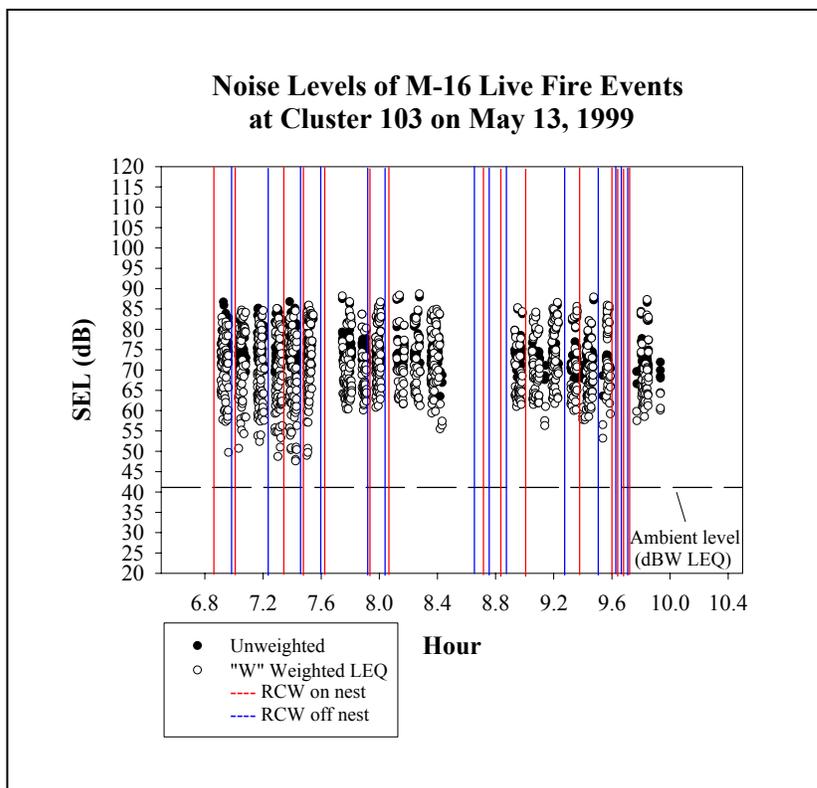


Figure 15. Noise levels from M-16 live fire events at cluster 103 on 13 May 1999.

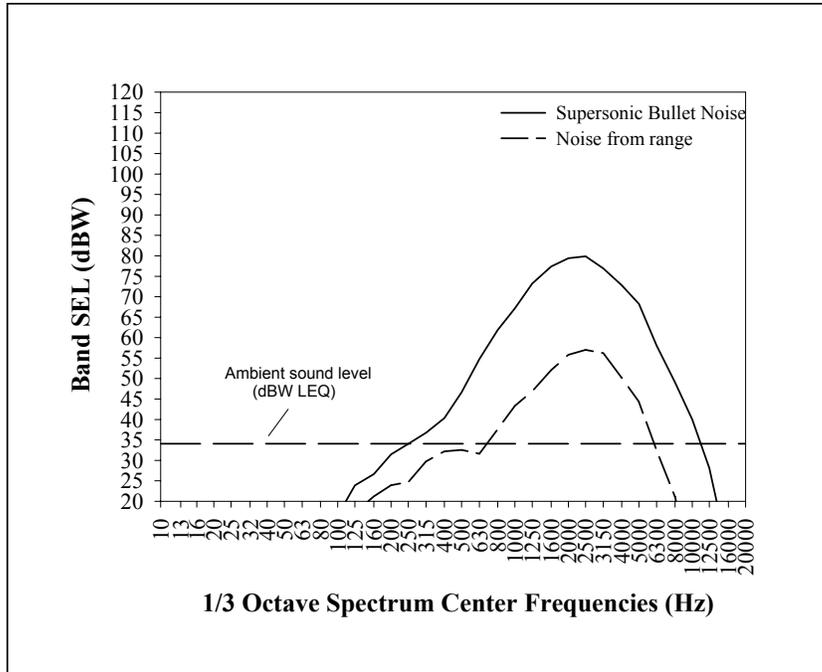


Figure 16. SEL weighting comparison for M-16 live fire events on 17 May 1999, from supersonic bullet noise and muzzle blast noise near cluster 103.

Helicopters

We recorded 83 helicopter passes during 45 data sessions at 19 RCW groups from 1998-2000 (Table C4, Appendix C). More than twice the number of helicopter events and data sessions were recorded during the 2000 field season than 1998-1999 combined. We did not observe any flush responses by RCWs relative to documented noise levels and stimulus distances. RCWs did not flush from the nest during the incubation or early brooding phase when military helicopters were > 30 m from nests and SEL noise levels were < 84 dBW (102 dB, unweighted; Table C4, Appendix C; example of noise spectral data: Figure D5, Appendix D).

Large-Caliber Live Fire

Woodpeckers flushed twice in response to large-caliber (≥ 20 -mm) blast noise during 1998-2000. Both flush responses occurred at cluster 83 during close artillery blast noise events. This site received the highest passive noise levels of any RCW group monitored. On 20 May 1998, we recorded 13 artillery blasts (155-mm rounds) during one data session at cluster 83. In Figure 17, blasts one through eight are shown in both W-weighted and unweighted SEL. The attending adult flushed from the nest in response to the loudest blast event recorded during that data session (seventh of 13 blast events recorded; SEL = 77 dBW, [108 dB, unweighted]). The RCW returned to the nest after 6.25 minutes and did not flush in response to a subsequent blast of approximately equal noise

level. On 21 May 1998, we recorded 60 artillery blast events during another data session at cluster 83. This time the attending adult flushed in response to the fifty-second blast event during that data session, returning to the nest after 4.42 minutes, shortly before the last noise event recorded occurred during that data session (Figure 18). This blast event was one of the louder blasts of the day with an SEL noise level of 79 dBW (105 dB, unweighted).

We recorded 630 large-caliber blasts/impacts during 45 data sessions at 24 RCW groups from 1998-2000 (Table C5, Appendix C; example of noise spectral data: Figure D6, Appendix D). Woodpeckers did not flush when large-caliber guns were fired at distances > 700 m from nests and SEL noise levels were < 59 dBW (102 dB, unweighted; Table C5). Woodpeckers flushed from nests in response to large-caliber blasts between 500-600 m from nests (1998). We did not record any large-caliber gun fire < 500 m from any active RCW nest site, therefore, we could not test for response within that range.

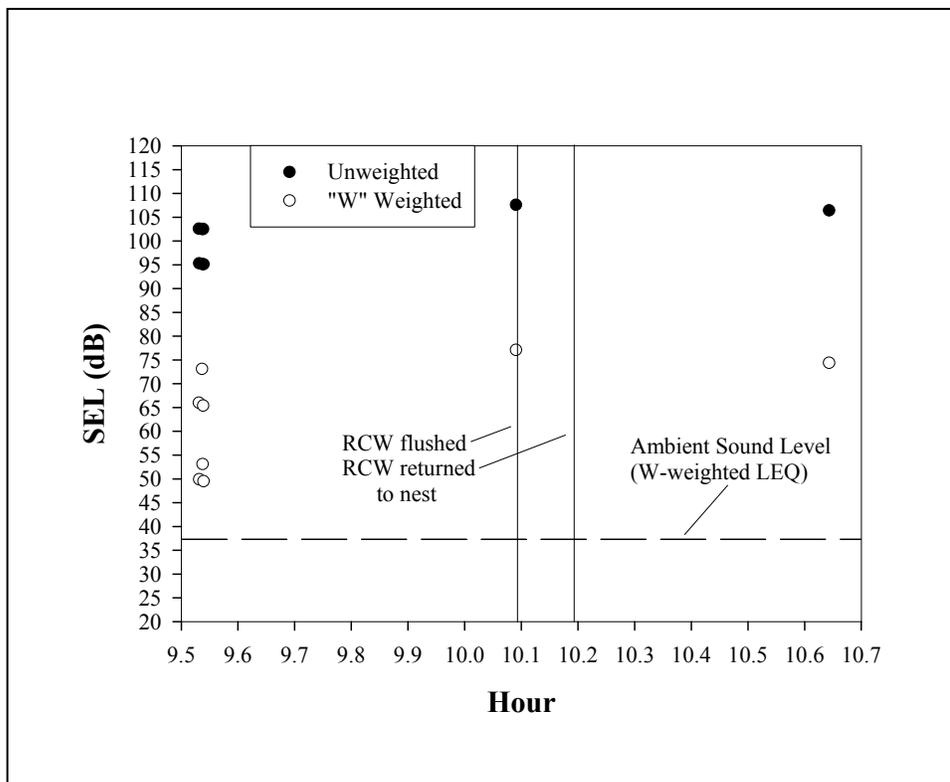


Figure 17. Description of RCW flush response to artillery blast events at cluster 83 on 20 May 1998.

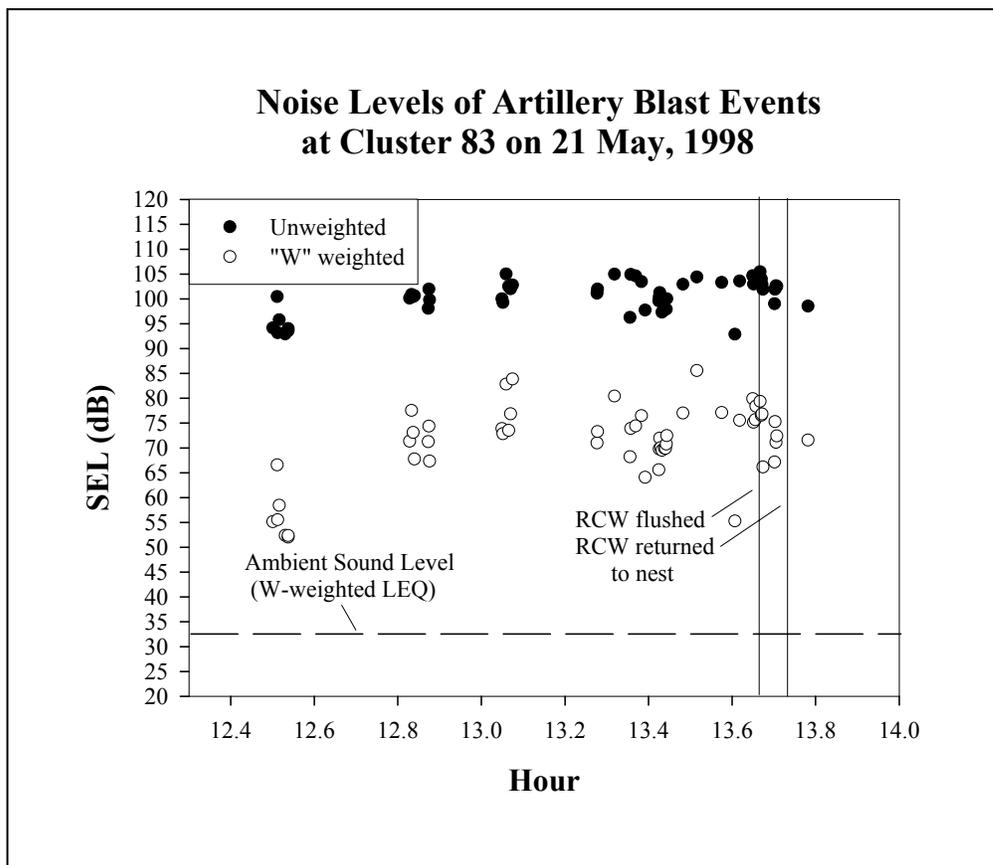


Figure 18. Description of RCW flush response to artillery blast events at cluster 83 on 21 May 1998.

Military/Civilian Vehicles

We recorded 81 military/civilian vehicle passes during 22 data sessions at 15 RCW groups from 1998-2000 (Table C6). Woodpeckers flushed twice in response to vehicle noise from 1998-2000. These flush events occurred at clusters 216 and 23 in response to a Bradley Fighting Vehicle convoy and a civilian vehicle, respectively. At cluster 216, a convoy of 17 Bradley Fighting Vehicles passed within 30 m of the nest tree which elicited a flush response by the attending adult. A RCW returned to the nest in 10 minutes after the convoy had passed. This site successfully fledged one young. The noise spectral data for a small portion of this event is in Figure D7 (Appendix D). The second flush occurred at cluster 23 as a civilian vehicle passed 15 m from the nest tree. A bird returned to the nest within 3 minutes after the flush had occurred. This site failed during this first nesting attempt, but did successfully fledge one young during a second nesting attempt. The noise spectral data for this event is shown in Figure D8 (Appendix D). Overall, RCWs did not flush when vehicles were > 50 m from nests and SEL noise levels were < 55 dBW (75 dB, unweighted; Table C6).

Missiles

We were only able to record RCW response at the nest for one MLRS event at cluster 88 during the early brooding phase. This noise event did not elicit a flush response. All other missile recordings occurred prior to nesting or during the nestling phase (Table C7, Appendix C). An example of noise spectral data for missiles are shown in Figure D9 (Appendix D). Missile events shown in Table C7 at distances < 1000 m represent MLRS noise events, while distances > 2000 m represent Stinger/Drone Missile noise events (examples of noise spectral data: Figures D10 and D11, Appendix D). We were unable to test for RCW flush response at clusters 83 and 99 because it was late in the nestling phase and adults were not spending long periods of time at the nest (Table C7). RCWs did not flush when MLRS were fired > 750 m from nests and SEL noise levels were < 25 dBW (69 dB, unweighted; Table C7). Due to the low probability of encountering missile fire, we were unable to test for RCW response at distances < 750 m.

Artillery/Grenade Simulators

We recorded eight passive simulator blasts during eight data sessions at two RCW groups from 1998-1999 (Table C8, Appendix C). Woodpeckers flushed once in response to passive grenade simulator blast ~100 m from nesting RCWs in 1999 during a realistic training maneuver (example of noise spectral data: Figure C8, Appendix C). A bird returned to the nest within eight minutes after the flush had occurred (this site successfully fledged one young). Overall, RCWs did not flush when grenade simulators were detonated > 200 m from nest sites and SEL noise levels were < 47 dBW (82 dB, unweighted; Table C8; example of noise spectral data: Figure D12, Appendix D). We did not record any passive grenade simulator blasts < 100 m from any active RCW nests, therefore we could not test for response within this range.

Fixed-Wing Aircraft

We were only able to record RCW response at the nest (cluster 51; 1998) for one fixed-wing aircraft (i.e., C-130) event during the incubation phase. This noise event did not elicit a flush response. All other fixed-wing recordings occurred prior to nesting or during the nestling phase and therefore we not used in our analysis. An example of noise spectral data for fixed-wing aircraft are shown in Figure D13 (Appendix D). RCWs did not flush when fixed-wing aircraft were > 600 m from nests and SEL noise levels were < 62 dBW (90 dB, unweighted; Table C10). Due to the low probability of encountering fixed-wing aircraft during the incubation and early brooding phases, we were unable to test for RCW response at distances < 600 m.

Cavity versus Base Noise Comparison

In addition to recording experimental noise events at the base of active RCW nest trees during the breeding season, we also measured and compared base and nest cavity noise measurements for these same cavity trees during the post-breeding season. We found that unweighted noise levels inside RCW cavities were significantly louder than levels recorded at the base of nest trees, regardless of stimulus type, year, or stimulus distance from the nest tree (One-way ANOVA, Dunnett's T3: $P < 0.05$; Tables C11 and C12, Appendix C). As an example, an artillery simulator blast recorded in 2000 registered 102.8 dB (unweighted) inside a RCW nest cavity at 61.0 m, while the same blast registered only 87.9 dB (unweighted) at the base of the same cavity tree. The same pattern held for .50-caliber blank fire tests, where a blank fire event recorded in 2000 registered 106.0 dB (unweighted) inside the nest cavity compared with 91.0 dB (unweighted) at the base of the same tree (One-way ANOVA, Dunnett's T3: $P < 0.05$; Tables C11 and C12).

We also observed differences in how noise energy was distributed along the frequency spectrum for cavity versus base measurements. Nest cavities acted as sound resonators, emphasizing the 125 to 250-Hz frequencies, and varied by individual tree (Delaney et al. 2001). Maximum spectral noise levels (dB, unweighted) from .50-caliber blank fire events and artillery simulators were 17.5 and 24.4 dB (unweighted) greater, respectively, inside cavities compared with recordings for the same events measured at the base of the tree (Delaney et al. 2001, Figures C1 and C2, Appendix C). Mean differences in unweighted noise levels between RCW nest cavities and base measurements increased with increasing distance from nest trees regardless of stimulus type or year (Tables C11 and C12). Mean differences for artillery simulator blasts between cavity and base measurements in 2000 varied by 9.0 dB (unweighted) at 15.2 m from RCW cavities, to 14.9 dB (unweighted) at 61.0 m, and to 20.7 dB (unweighted) at 121.9 m distance (Tables C11 and C12). Mean differences in .50-caliber blank fire blasts registered similar differences between cavity and base measurements according to distance regardless of year. Mean differences in .50-caliber blank fire blasts between cavity and base measurements in 2000 varied by 9.6 dB (unweighted) at 15.2 m from RCW cavities, to 15.0 dB (unweighted) at 61.0 m, and to 18.0 dB (unweighted) at 121.9 m distance (Tables C11 and C12). This pattern was not evident using Woodpecker weighting. We found no significant difference between cavity and base noise measurements, regardless of stimulus type or distance, nor did we find that differences between cavity and base measurements varied with distance (Tables C11 and C12).

Frequency Weighting Comparison

Unweighted noise levels were significantly louder than Woodpecker weighted noise levels, regardless of stimulus type, year, or microphone position (One-way ANOVA, Dunnett's T3: P

< 0.05; Tables C11 and C12, Appendix C). Woodpecker weighted noise levels in cavities were not significantly louder than Woodpecker weighted noise at the base of nest trees, regardless of stimulus type, year or distance (Tables C-11 and C12).

Stimulus Type Comparison

Artillery simulator and .50-caliber blank fire events generated comparable noise levels during the 1999 field season, regardless of microphone position (i.e., cavity or base of tree; Tables C11-C12, Appendix C). In 1999, RCWs flushed from their nests at significantly higher rates during .50-caliber blank fire tests than artillery simulator tests at comparable distances (Fisher Exact Test, $P = 0.03$; Tables C11-C12). In 2000, we observed that .50-caliber blank fire events were significantly louder than artillery simulators at comparable distances and microphone locations (One-way ANOVA, Dunnett's T3: $P < 0.05$; Tables C11-C12). Higher noise levels during .50-caliber blank firing testing did not translate into greater flush response levels for RCWs in 2000. In 2000, RCWs flushed at similar rates during .50-caliber blank fire tests compared with artillery simulator tests over comparable distances (Fisher Exact Test, $P = 0.15$; Tables C11-C12).

Yearly Noise Comparison

Noise levels from artillery simulator blasts varied by year. On average, artillery simulator blasts in 1999 were significantly louder than blasts in 2000, regardless of stimulus distance (One-way ANOVA, Dunnett's T3: $P < 0.05$; Tables C11 and C12, Appendix C). We also observed a significant difference in RCW response to artillery simulators between years, with a greater proportion of RCWs flushing in 2000 than 1999 at comparable distances (Fisher Exact Test; $P = 0.01$). We did not observe a yearly variation in noise level (One-way ANOVA, Dunnett's T3: $P > 0.05$) or RCW flush response during .50-caliber blank fire tests between 1999 and 2000 (Fisher Exact Test; $P = 0.13$).

Natural versus Artificial Cavity Comparison

We experimentally tested the difference in noise level between cavity and base measurements for natural and artificial cavities in 1999-2000 using .50-caliber blank fire and artillery simulators. We found that on average there was a 4.43 ± 0.41 dBW difference between artillery simulator blasts recording in natural nest

cavities and levels recorded at the base of natural nest trees. This compared with a 3.41 ± 0.36 dBW difference between artificial nest cavities and base comparisons. Natural and artificial base/cavity comparisons did not differ significantly using a paired t -test ($F_{1,59} = 1.89$, $P = 0.06$). We found similar results when we compared natural and artificial cavities with base measurements during .50-caliber blank fire testing. On average, natural cavities were $4.29 \pm$

0.21 dBW higher than base measurements, while artificial cavities were 4.32 ± 0.48 dBW greater. These differences did not vary significantly ($F_{1, 162} = 0.064$, $P = 0.95$).

Observation of Nest Predation Events

We documented one cavity kleptoparasitism (termed by Kappes 1997) event by a Red-bellied Woodpecker (*Melanerpes carolinus*) and one nest predation event by a Rat Snake (*Elaphe obsoleta*) during three years of intensive video work on RCWs on Fort Stewart (Figures E1 and E2, Appendix E). A rat snake was video-taped entering an active RCW nest with two eggs and two nestlings present. The rat snake left the nest the following day after spending > 32 hours in the cavity. We also video-taped a Red-bellied Woodpecker eject an adult and a juvenile RCW in the process of usurping the nest. The adult and juvenile RCW appeared to be unharmed by this event. The juvenile was approximately 25 days old when it was ejected from the nest and was found two days later during a fledge check for the cluster. This RCW group did not use the same nest tree the following year, though they did use another cavity tree and was reproductively successful in fledging young.

Four other RCW groups may have failed due to nest predation (two rat snake events and two southern flying squirrel events [*Glaucomys volans*]), but we could not confirm that these sites were still active just prior to occupation by predators. In 1999, Fish and Wildlife personnel on Fort Stewart removed a rat snake from an RCW nest that had produced a second clutch. The snake later passed identification bands for the young of that RCW group confirming that it had consumed the nestlings (Larry Carlile, pers. comm.). We also documented two nest predation attempts using video; one by a Red-shouldered Hawk (*Buteo lineatus*; Figure E3) and the other by an American Crow (*Corvus brachyrhynchos*; Figure E4).

5 Discussion

Nesting Success

Based on the level (i.e., noise levels, stimulus distances, and frequency of noise events tested) and type of noise sources tested, experimental and passive military training noise events did not significantly affect Red-cockaded Woodpecker nesting success or productivity. We believe the small but non-significant decrease in reproductive success and productivity between disturbed and undisturbed RCW groups was attributable to natural attrition inherent in the larger disturbed sample. Overall, reproductive success rates for disturbed and control sample groups were comparable with population level success rates on Fort Stewart. Other researchers have reported similar findings when comparing RCW fitness parameters between passive disturbed RCW groups and undisturbed groups (Fort Stewart ESMPT 2001; Doresky et al. 2001).

Based on the observed six to 13 percent variation of reproductive success rates (disturbed, undisturbed, and overall population levels) from 1998 to 2000, we believe that fitness rate differences of 20 percent between disturbed and undisturbed groups are biologically meaningful for RCWs and should be used when conducting power analyses. Such a rate level has been suggested by other researchers as biologically meaningful (Steidl et al. 1997). Our ability to detect differences in Red-cockaded Woodpecker fitness parameters on Fort Stewart was limited by population size (i.e., control group availability). Samples sizes of 95 experimental and 95 controls RCW groups were required to reach an adequate power level of 0.80. Therefore, we attempted to study as many experimental and control RCW groups as possible in 1999 and 2000. Since only 165 and 170 RCW groups nested in 1999 and 2000, adequate sample power could not be reached during any year of this study. Control sites were selected from the Fort Stewart RCW population due to limited numbers of active RCW groups on private and state lands in the Coastal Plain and Piedmont province in Georgia (Baker 1995). Active RCW groups have steadily declined on much of the private land in Georgia due to limitations in cavity tree availability, habitat fragmentation, poor foraging habitat, and ineffective burning regimes (Baker 1995). No RCW groups are currently known to reside within three miles of Fort Stewart (Fort Stewart ESMPT 2001).

Flush Response and Related Behaviors

Flush Response

The proportion of Red-cockaded Woodpeckers that flushed in response to experimental training noise was negatively related to stimulus distance and positively related to noise level. Similar patterns have been reported for other bird genera (Grubb and King 1991; McGarigal et al 1991; Delaney et al. 1999), but not previously for any woodpecker species. The only exception to this trend occurred during .50-caliber blank fire testing in 2000 at the 76.2 m distance. We observed that RCWs flushed in all three presentations at this distance. It is possible that the flush rate at the 76.2 m distance was inflated due to small sample size, and that an increase in the number of trials would have decreased overall flush rates at this distance.

Trend data indicate that RCWs may flush more frequently in response to .50-caliber blank fire events than artillery simulators at comparable distances. The visibility of the noise source, frequency of occurrence, and the duration of the noise stimuli may explain this trend. There were inherent differences in how .50-caliber and artillery simulators were presented to RCWs. Artillery simulator blasts lasted only 10-15 seconds and required just one person to detonate the simulator, while blank fire events required two people to set up and lasted between 1-5 minutes. This may explain why the dose-response threshold curve for .50-caliber blank fire events increased more rapidly than artillery simulators over similar distances. It is possible that a disturbance in close proximity to a RCW's location may be more visible to RCWs from the mouth of the nest cavity and therefore elicit a greater response than a disturbance further away, regardless of noise level. It is important to consider all aspects, including visual impacts of a stimuli, when examining an animal's response to a disturbance. Although season and nesting phase influence avian response to disturbance (Thiessen 1957; Knight and Temple 1986; Delaney et al. 1999), habituation, prior experience, and animal temperament are important factors that should be taken into account (Hart 1985; Mancini et al. 1988).

Red-cockaded Woodpeckers flushed infrequently in response to passive military training noise during the 1998-2000 nesting seasons. Most of the passive noise events recorded were relatively distant compared with experimental testing and had moderate to low noise levels. Woodpeckers returned to their nests relatively quickly after being flushed. We did not find a relationship between return time and stimulus distance. Return times by RCWs were comparable with times re-

ported for bird species in other noise disturbance studies (Awbrey and Bowles 1990; Holthuijzen et al. 1990), and were comparable between years during this study (Delaney et al. 2000, 2001).

Natural Disturbance Effects

The amount of time that an attending adult is away from the nest has important consequences when we consider the role that nest predation and nest kleptoparasitism has on this species. Rat snakes frequently prey on cavity nesting birds (Jackson 1970), and have been documented to prey on RCW eggs and nestlings (Jackson 1978b; Neal et al. 1993; Pater et al. 1999). There are a number of species that are capable of usurping nesting cavities from RCWs. Both Red-bellied Woodpeckers (Kappes 1997), and Red-headed Woodpeckers (Jackson 1994) have been shown to remove and eat eggs, usually in the process of usurping the cavity from the RCW. Southern flying squirrels (*Glaucomys volans*) have also been documented to eat RCWs eggs while usurping RCWs nest cavities (Harlow and Doyle 1990), though there is disagreement over whether cavity kleptoparasitism by flying squirrels significantly reduces reproduction of RCWs (U.S. Fish and Wildlife Service 2000). Some researchers suggest that cavity kleptoparasitism by flying squirrels reduce nesting attempts by RCWs (Loeb and Hooper 1997), while others researchers have reported no impact by flying squirrels on RCW nesting attempts (Mitchell et al. 1999). It does not appear that nest predation or cavity kleptoparasitism has a significant impact on RCW nesting success on Fort Stewart based on the low number of documented cases on Fort Stewart from 1998-2000.

Nesting Behaviors

We are currently analyzing RCW nesting behavior (collected by video data and direct observation) to determine if nest attentiveness, trip frequency, timing, duration, or the number of prey deliveries are influenced by experimental or passive training activities on Fort Stewart compared with undisturbed groups. This information will be presented in a separate CERL report that will be submitted by the end of this calendar year. We recorded over 10,000 hours of video on RCW nest behavior at 35 RCW groups from 1998-2000. Eleven of these video sites received experimental testing during this study, while 13 received passive disturbance events. An additional 11 were considered control groups and will be used to develop baseline behavioral trends from which passive and experimental groups will be compared. We did not observe any nest abandonment relative to camera use. Birds were observed using camera trees for foraging and perch sites when coming and going from the nest tree.

Distance and Sound Thresholds

Due to the variation in noise level and frequency spectra for other noise sources on Fort Stewart, passive noise event distances and sound thresholds were addressed on a case-by-case basis. Due to the varied nature and location of maneuver training activities on Fort Stewart, it is highly unlikely that woodpeckers would receive as much disturbance activity during the nesting season as the experimentally disturbed RCW groups received during any one year for this study. Hayden et al. (in press) findings support this assertion, in which the authors re-

ported that few RCW groups receive high levels of military maneuver training activities on Fort Stewart. Despite the aggressive nature of our testing regime (i.e., close proximity and repeated exposure), RCW responses were minimal when experimental stimuli were greater than 121.9 m away and did not flush from the nest when noise sources were greater than 152.4 m away. Even when more aggressive noise tests were performed (≤ 91.4 m from RCW position), RCWs returned to their nests relatively quickly after being flushed, they did not abandon their nests, and they did not suffer a reduction in fitness rates compared with undisturbed RCW groups.

An examination of the data (Appendix C) reveal a wide range of received noise levels at a given distance. One reason is that different types of noise sources have different acoustic source energy. Another reason is that certain noise sources can vary in the number of noise events that occur within a specific period of time (i.e., one round from a .50-caliber machine gun versus a 10 round burst). Variation in the frequency and timing of a noise source can greatly change its total emissive power. Noise sources can also vary depending on how they were manufactured (e.g., amount of explosive power in an artillery simulator). We observed a difference in the emissive power of artillery simulators (at similar distances) during experimental testing between 1999 and 2000, though this did not translate into any detectable variation in RCW flush response between years.

For a given noise source, received noise level also depends on differences in propagation conditions, a result of differences in atmospheric wind and temperature structure. It is well known that at distances of several kilometers, received noise level can vary by as much as 50 dB above and below the mean due to changes in meteorological conditions (Embleton 1982; Li et al. 1994; Larsson and Israelsson 1991; Pater 1981; Piercy et al. 1977; White and Gilbert 1989; White et al. 1993). Differences in received noise level can also be due to orientation of the weapon relative to the receiver. Many weapons exhibit substantial directivity; some as much as 15 dB louder downrange (Pater 1981; Pater et al. (Draft); Schomer et al. 1976a and 1976b [Vol I and II]; Schomer et al. 1979; Schomer et

al. 1981; Schomer 1982; Schomer 1984; Schomer and Goebel 1985; Schomer 1986a, 1986b; Walther 1972). Some other important factors that should be taken into account are the orientation of the nest cavity relative to the noise source and any barriers between the noise source and the bird's position.

Noise Measurement Test

Unweighted noise levels in RCW nest cavities were substantially louder than noise levels recorded at the base of the nest tree due to a possible Helmholtz resonating effect. Due to differences in cavity and weapon orientation, presence or absence of barriers, and weapon directivity, we were not always able to extrapolate noise levels recorded at the base of the tree

to received levels within RCW nest cavities. Noise measurements were therefore taken inside nest cavities after the nesting season for each noise source to determine the noise levels that birds may actually be experiencing. Based on Woodpecker weighted algorithms, it does not appear that RCWs perceive noise levels inside cavities any louder than noise levels outside the cavity. Our data indicate that cavity resonance does not influence RCW perception of its surrounding noise environment. We also did not find a significant difference in noise levels between natural and artificial nest cavities. This is an important finding when we consider how valuable artificial cavities are to the management and recovery of RCWs (USFWS 2000).

Management Implications

This research differs from previous noise disturbance studies in a number of important ways. First, we interpreted noise levels based on woodpecker weighting algorithms, which is more specific to the subject animal's hearing sensitivity than the generalized and less applicable A- or Unweighted algorithms. This provided us with a much more accurate picture of how RCWs perceive their environment. Secondly, controlled experimentation, with actual military noise sources, allowed us to develop realistic dose-response thresholds for this species. Such thresholds should provide resource managers with the tools necessary to determine the potential impacts of future disturbance activities and provide information on what proportion of the population may be impacted.

Our data indicate that infrequent, short duration (less than two hours) military training exercises, that are in close proximity to active RCW nest sites, will not significantly impact RCW fitness rates on military installations. It is important to note that this assertion is based on a few caveats, namely that we did not test

military training activities within RCW groups that lasted longer than two hours in duration, habitat quality was not a limiting factor in the RCW groups that we tested, and our results are only applicable to the level of noise testing (i.e., noise level, number and frequency of noise events, and disturbance distance) conducted during this study. We do not believe that military maneuver training noise is a limiting factor in the recovery of Red-cockaded Woodpeckers on military installations. This is evident in the fact that the numbers of active, nesting, and successful RCW nests on Fort Stewart increased each year during this study (Fort Stewart ESMPT 2001), and that we did not see a difference in RCW fitness rates in the year following the conclusion of our experimental testing.

We suggest that land management practices play a more important role in the overall success and continued existence of RCWs on military lands than military maneuver training activities or noise. Fort Stewart, as other DoD installations, has made significant strides in improving RCW habitat quality on their lands (e.g., Fort Stewart ESMPT 2001). Land management

practices (i.e., frequent prescribed burning rotations, hardwood control, commercial thinning, reestablishment of native ground cover, and conservation, and regeneration of longleaf pine) and population management techniques (i.e., provisioning of RCW clusters with artificial cavities and drilled starts) have been vital in improving habitat quality for Red-cockaded Woodpeckers on military lands (Fort Stewart ESMPT 2001). This does not preclude the possibility that a small portion of RCW groups may be impacted by maneuver training activities and noise on military installations. We suggest that RCW adaptation to natural disturbance (i.e., fire and various predation pressures), through cooperative breeding and re-nesting (USFWS 2000), provide RCWs with the necessary tools to deal with other disturbance factors. We also suggest that habitat quality (i.e., foraging habitat and adequate number of nest cavities) plays an important role in an RCWs ability to cope with extraneous disturbance factors during the breeding season.

6 Plans and Conclusions

Plans

Red-cockaded Woodpecker nesting data from 1998 to 2000 (i.e., nest attentiveness, prey delivery rates, trip frequency and duration) are currently being analyzed and will be presented in a final report that will be submitted to SERDP by December 2002. In this report we will detail baseline RCW nesting behaviors and compare various nesting behaviors between disturbed and undisturbed RCW nest sites.

Conclusions

During this study we observed and documented experimental training noise events and the resulting RCW responses under realistic conditions. Both proximate response behavior and nesting success were measured. We also observed RCW behavior and nesting success for groups where noise stimuli were absent or minimal (near or below ambient sound levels), to provide an undisturbed behavior baseline to judge response and impact against. No significant differences in nesting success or productivity were found between experimentally disturbed and relatively undisturbed RCW groups.

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Appendix A: Significant Legal Requirements

The Endangered Species Act (ESA) requires Federal agencies to carry out programs for the conservation of threatened and endangered species. Agencies are further required to ensure that their actions do not jeopardize the continued existence of listed species or result in the destruction or adverse modification of the critical habitat of these species. These requirements fall under provisions of Section 7 of the Act, which also requires agencies to conduct biological assessments to evaluate the impacts of their activities on listed species. This assessment serves as the primary basis for coordination with the U.S. Fish and Wildlife Service which, in turn, issues a biological opinion and specific endangered species management recommendations. Implementation of these recommendations can place constraints on execution of the military mission. To avoid possible penalties resulting from findings of “take” due to harassment or harm resulting from exposure to military-related noise, a capability is needed to evaluate and monitor the impact of noise on both behavior and breeding success of affected species. Under the ESA it is the responsibility of the land owner, not of the U.S. Fish and Wildlife Service, to evaluate effects of land use activities on threatened and endangered species.

The ESA prohibits take of endangered species, where “take” means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct. Within the definition of take, the term “harm” has been subject to significant judicial scrutiny. “Harm” is clearly an act that actually kills or injures wildlife, but it may also include actions that significantly impair essential behavioral patterns, including breeding, feeding, or sheltering.

The National Environmental Policy Act (NEPA) requires Federal agencies to assess the impact of planned activities on the environment and to make the assessment available to the general public. The decision making procedures are documented by either an Environmental Assessment (EA) or an Environmental Impact Statement (EIS). Noise and threatened and endangered species are often important issues in these documents, particularly as reviewers place a stronger emphasis on cumulative effects of activities.

Appendix B: Woodpecker Audiogram

Introduction

As a means of estimating the hearing ability of an endangered species, the Red-cockaded Woodpecker, we are examining the hearing of a surrogate species, the Downy Woodpecker (*P. pubescens*). Downy Woodpeckers are one of the RCW's closest relative and serve as an excellent model to test the effects of noise on hearing in Red-cockaded Woodpeckers. Together with data for Budgerigars (*Melopsittacus undulatus*), for which we have both behavioral and physiological auditory data, we are able to provide a preliminary audiogram for small woodpeckers. In addition, we have been comparing the structure of vocalizations in these species because the spectral characteristics of a species' communication signals are often related to hearing ability.

Methods

Measuring Auditory Brainstem Response in small birds

To obtain Auditory Brainstem Response (ABR) recordings in small birds (see Figure B1 for an example of an ABR), birds are first anesthetized lightly using a mixture of ketamine and diazepam. Once sedated, a bird is secured to a foam pad and Grass pin electrodes are placed under the surface of the skin on the scalp. The active electrode is placed at the vertex of the skull and the reference electrode is placed in the skin just dorsal and posterior to the ear that will receive the auditory stimuli. A ground electrode is placed under the skin on the opposite side of the head from the reference electrode.

We use 5 ms alternating phase tone bursts with 2 ms cosine-ramped rise/fall times delivered at a rate of 20 per second. Responses are collected for 20 ms following each tone burst. Birds are tested at the following frequencies: 300 Hz, 500 Hz, 1000 Hz, 1500 Hz, 2000 Hz, 2860 Hz, 4000 Hz, 5700 Hz, and 8000 Hz. Click stimuli are 0.1 ms onset/offset pulses (also alternating in phase) delivered in the same way at a rate of 5 per second. Sound generation and waveform averaging are controlled with Tucker-Davis Technologies hardware modules and software running on a Pentium 133 microcomputer. Tones and clicks are cali-

brated before and after each recording session using a Larson-Davis 824, Type 1, sound level

meter. Stimuli are recorded and examined using the sound level meter and the SIGNAL sound analysis software package.

Estimating thresholds

Thresholds are estimated using peak-to-peak waveform amplitude of the ABR, as it varies with stimulus intensity. We follow a 1 mV criterion; we estimate the intercept at a level of +1 mV, which accounts for noise inherent in the ABR trace. Our thresholds are therefore the intensity values for tones at each frequency of the peak-to-peak amplitude as it falls to a level of +1 mV. Such thresholds for tone bursts differ by an absolute value from auditory thresholds determined behaviorally. For this reason, we adjusted the thresholds obtained using auditory evoked techniques to get an estimate of behavioral thresholds (true thresholds) in woodpeckers. To make this adjustment, we used values from budgerigars, the only species for which we currently have both physiological and behavioral data.

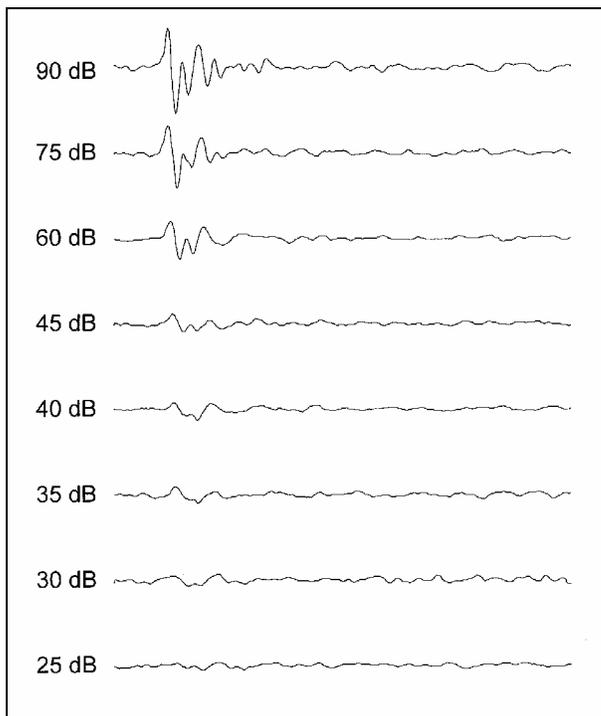


Figure B 1. Example of an Auditory Brainstem Response (ABR).

Results

Audiograms

Results reported below indicate our best estimate of woodpecker hearing abilities based on data obtained from three individuals. Physiological audiograms for each of these three individuals are shown in Figure B2. An average Downy Woodpecker audiogram is shown in Figure B3, along with an average behavioral audiogram for 20 species of small passerine birds, and the average Downy Woodpecker audiogram adjusted for the absolute difference between physiological and behavioral curves in budgerigars (a 35 dB difference). Figure B2 illustrates the variability in data across individuals, suggesting that further tests with a larger sample are warranted. It appears that the shape of the woodpecker audiogram (Figure B3) is broadly comparable to that of small passerine birds but shows a greater sensitivity at relatively higher frequencies compared to the average passerine (frequency of best sensitivity is higher). Also, woodpeckers may be some-what less sensitive in absolute terms than the typical passerine. Data for tones

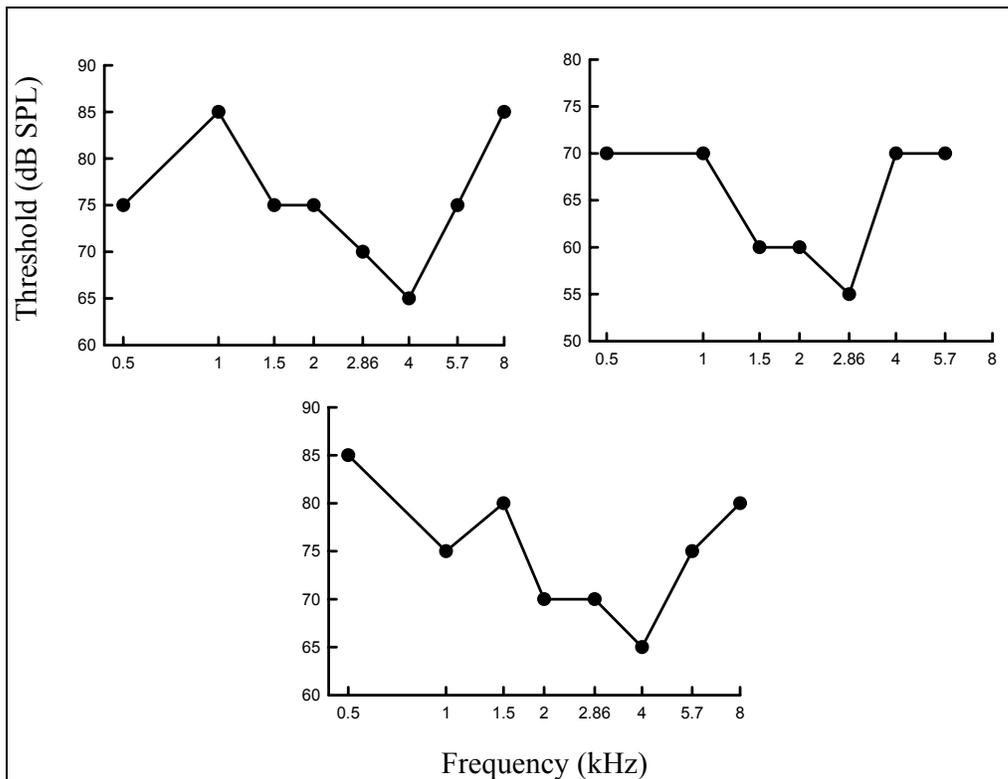


Figure B 2. Audiograms for three individual Downy Woodpeckers obtained using ABR.

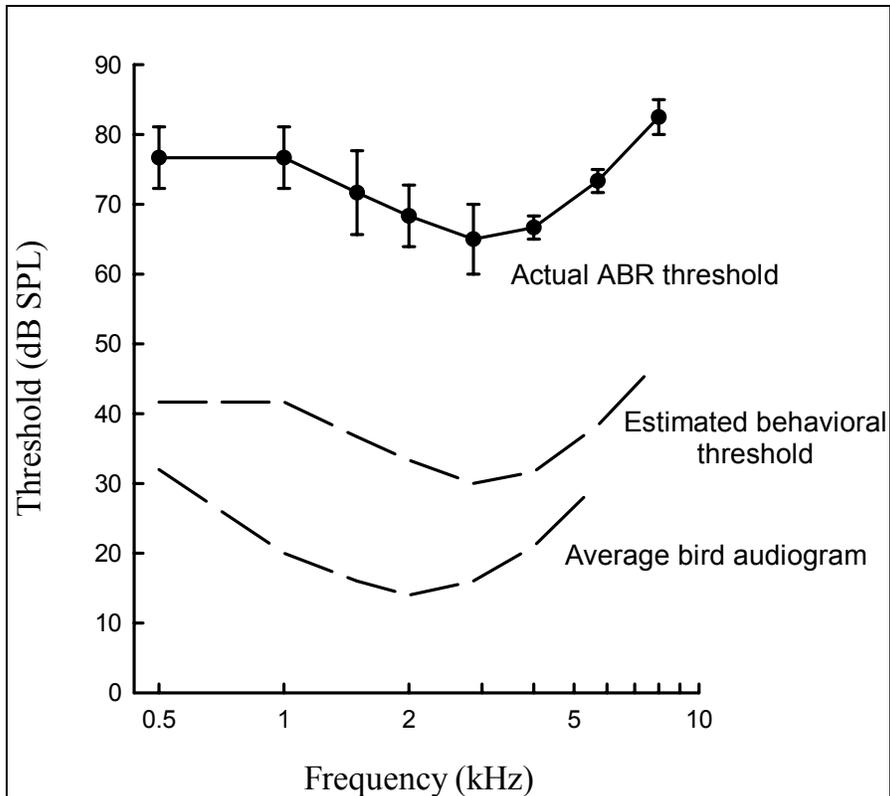


Figure B 3. Average ABR audiogram for three Downy Woodpeckers (top), audiogram adjusted for absolute difference between physiological and behavioral thresholds (middle), and average passerine audiogram (estimated using behavioral techniques).

at 300 Hz are not displayed on these audiograms as woodpeckers exhibited no sensitivity at this lowest tested frequency (all peak-to-peak waveform amplitudes were less than 1 mV). Woodpeckers also showed little sensitivity to 8000 Hz tones using the ABR technique. Behavioral thresholds for budgerigars are typically at least 50 - 60 dB higher at this frequency than at their best frequency (approximately 2860 Hz), possibly accounting for our lack of response with the generally less sensitive ABR method of estimating hearing thresholds.

What might account for the higher threshold at best frequency for Downy Woodpeckers when compared with small passerines? One potential explanation derives from our technique of measuring evoked potentials at the surface of the skull. The skull is generally much thicker in woodpeckers than in budgerigars or small passerines. An increased skull thickness is likely to be a protective adaptation for drumming and other percussive behaviors in woodpeckers. It remains to be determined whether such adaptations also include a reduction in auditory sensitivity compared with other small birds, or whether skull thickness (or other active hearing protective mechanisms in the woodpecker ear) prevents us from measuring true tone thresholds using the ABR technique. As we obtain more birds and continue testing, we can provide more confident assessments of the

actual thresholds involved for small woodpeckers and their relationship to thresholds already determined for other species of small birds.

Vocalizations

We obtained archived recordings of vocalizations of Downy Woodpeckers and RCWs from the Cornell University Library of Natural Sounds and the Ohio State University Borror Laboratory of Bioacoustics. These recordings represent several different vocalization types of each species. Figure B4 shows average power spectra for three common vocal signals of the downy woodpecker, and for the percussive drumming of this species. Note the much lower frequencies present in the drum. Figure B5 shows the average power spectra for two vocalizations of the Red-cockaded Woodpecker. As these figures illustrate, most energy in the calls of these two woodpeckers spreads across a broad range of relatively high frequencies (2 – 6 kHz) compared with the songs and calls of most passerines (2 – 4 kHz).

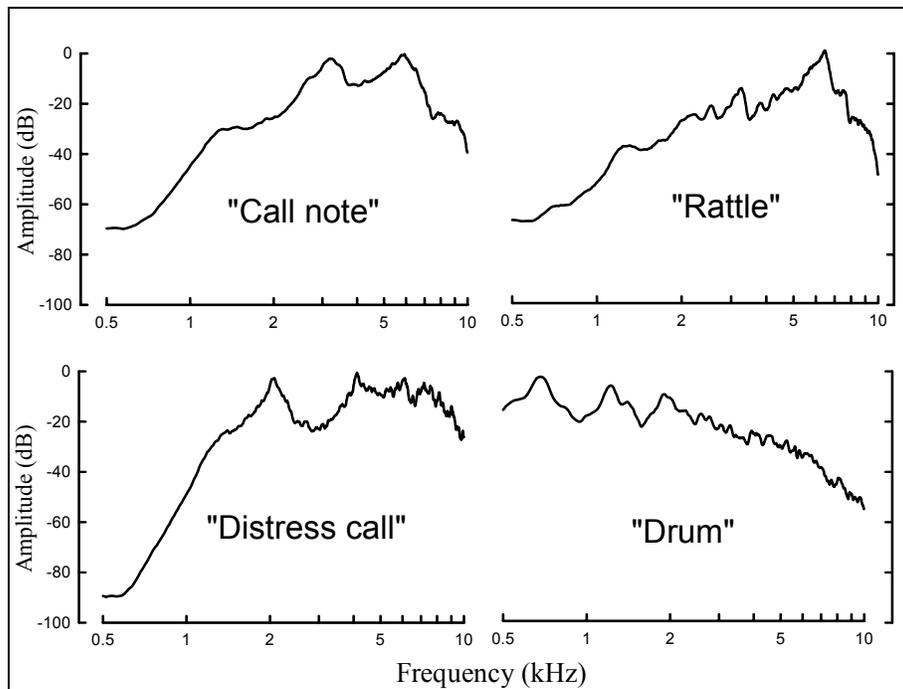


Figure B 4. Average power spectra for three common Downy Woodpecker calls and the “drum: of this species.

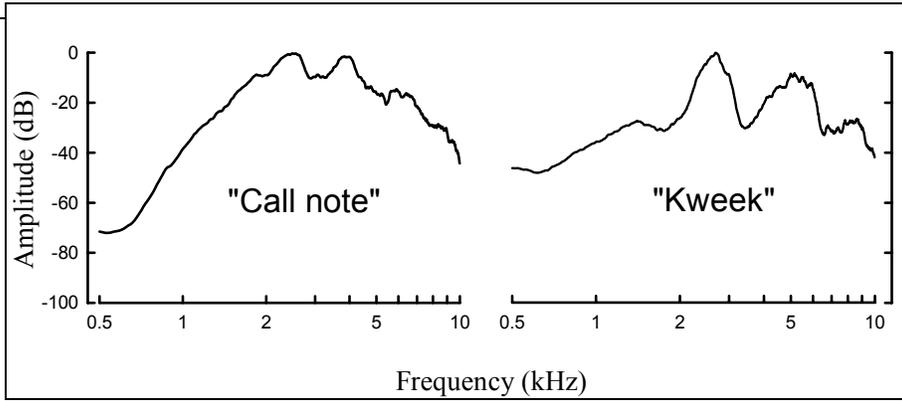


Figure B 5. Average power spectrum of two common vocalizations of the Red-cockaded Woodpecker.

Best sensitivity in the audiogram of most species, particularly passerines and other small birds such as budgerigars typically coincides well with the peak of the average power spectrum of their vocal communication signals (Dooling et al. 2000). In Figure B5, the average spectra for the “drum” and “call note” of the downy woodpecker are superimposed over the average ABR audiogram from our three individuals. While the “drum” has frequencies generally lower than the best sensitivity of the audiogram, the “call note” peak frequency corresponds reasonably well to the audiogram best sensitivity. Figure B6 shows the same audiogram with the “call note” of the Red-cockaded Woodpecker superimposed. Once again, there is a good correspondence between peak power in the average

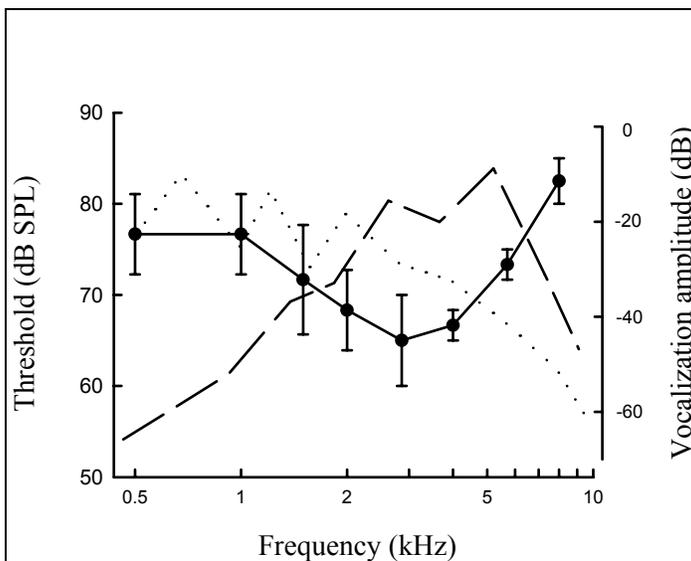


Figure B 6. Average audiogram for three Downy Woodpeckers (solid line) with superimposed average power spectra for the percussive “drum” (dotted line), and the “call note” vocalization (dashed line) of Downy Woodpeckers.

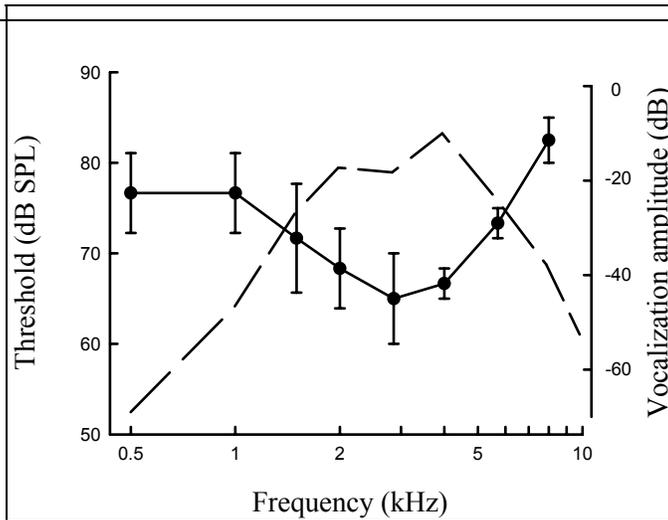


Figure B 7. Average audiogram for three Downy Woodpeckers (solid line) with superimposed average power spectra for the “call note” of Red-cockaded Woodpeckers (dashed line).

spectrum of this vocalization and best sensitivity of the audiogram. The general similarity in characteristics of the vocal spectra of Downy Woodpecker and RCWs, in addition to their close relationship, further suggests that hearing abilities of the two species should be similar and that the Downy Woodpecker serves as a good model for hearing in the RCW.

CONCLUSIONS

1. Best sensitivity of the Downy Woodpecker ABR thresholds corresponds to the peak in the power spectrum of both downy and Red-cockaded Woodpecker vocalizations, and best sensitivity is at a somewhat higher frequency than that for a typical passerine.
2. Woodpeckers may have a reduced auditory sensitivity relative to other species of small birds.
3. Given the similarity in spectral structure of the vocalizations of small woodpeckers, auditory sensitivity is probably similar between the Downy Woodpecker and other *Picoides* spp. such as the Red-cockaded Woodpecker.

Appendix C: Summary Data Tables

Table C 1. Flush response of nesting Red-cockaded Woodpeckers versus the number, distance, and noise levels of experimental artillery simulator testing on Fort Stewart, GA, 1999-2000.

Stimulus Distance (m)	Cluster Tested	Number of Noise Events	Number of Data Sessions	Number of Flushes	Cavity level unweighted	Noise Levels, SEL (dB) Base unweighted	"W" weighted	Typical Ambient LEQ (dB) "W" weighted
15.2	79,81,126,136,137,183	6	6	5	98-115	93-107	79-91	27-35
30.5	1,41,47,51,53,79,80,81,86,87,107,126,136,137,159,172,177,179,183,184,197,198,205,206,221,227,295	33	33	20	99-112	89-105	71-91	23-37
45.7	23,41,137,159,197,198,206,221	8	8	3	97-107	80-100	70-82	24-31
61.0	1,2,6,23,41,47,48,62,75,80,86,87,107,126,159,172,177,179,183,197,198,205,218,221,232	29	29	11	97-109	81-104	66-89	23-32
76.2	57,80	2	2	1	102-106	74-97	66-75	29-34
91.4	1,2,6,23,57,62,75,80,86,183,184,218,295	13	13	4	100-105	74-101	64-83	27-30
≤ 91.4	36	91	91	44				
121.9	1,2,6,47,48,62,71,75,87,172,179,184,198,206,218,295	16	16	1	93-104	73-99	61-82	30-39
152.4	206	1	1	0	92	74	67	30
243.8	184	1	1	0	---	98*	66	31
Totals	37	109	109	45	* two artillery simulators were detonated together			

Table C 2. Flush response of nesting Red-cockaded Woodpeckers versus the number, distance, and noise levels of experimental .50-caliber blank fire testing on Fort Stewart, GA, 1999-2000.

Stimulus Distance (m)	Cluster Tested	Number of Noise Events	Number of Data Sessions	Number of Flushes	Cavity level unweighted	Noise Levels, SEL (dB) Base unweighted	"W" weighted	Typical Ambient LEQ (dB) "W" weighted
15.2	23,53,61,151,194	69	5	4	108-119	96-108	85-98	26-28
30.5	10,23,32,36,47,48,51,60,61,81,87,88, 120,129,148,151,163,172,194,206	328	26	17	105-115	91-106	81-97	30-34
45.7	10,32,107,148,	108	4	2	103-114	88-101	74-90	31-42
61.0	6,10,12,23,36,48,51,57,60,61,75,81,88,107, 120,129,133,139,148,163,172,176,194,205, 206,207,227,289	384	30	14	100-109	84-100	69-87	25-39
76.2	2,36,87	51	3	3	97-105	89-93	78-82	27-32
91.4	6,36,42,57,107,129,133,139,176,205,218,228,289	120	15	8	94-103	80-95	68-82	28-36
≤ 91.4	37	1060	83	48				
121.9	12,23,42,51,57,133,148,176,205,216,228	94	12	2	93-100	84-89	65-79	28-35
152.4	228	24	1	0	94-100	81-87	64-69	32
243.8	228	21	1	0	74	61	42	35
Totals	38	1199	97	50				

Table C 3. Flush response of nesting Red-cockaded Woodpeckers versus the number, distance, and noise levels of passive M-16 live fire on Fort Stewart, GA, 1999-2000.

Stimulus Distance (m)	Cluster Tested	Number of Noise Events	Number of Data Sessions	Number of Flushes	Noise Levels, SEL (dB)		Typical Ambient LEQ (dB) "W" weighted
					Unweighted	"W" weighted	
200-300	103	284	6	0	76-96	75-89	34-43
400-600	3,51,103	1128	8	0	58-77	43-75	34-41
800-900	51	29	1	0	67	47-51	34
1200-2500	23,25,26,83	313	7	0	64-72	34-62	32-35
4000-5000	36,39,48,71,159,267	171	6	0	62-76	33-47	30-34
5001-7000	2	5	1	0	75-76	27-30	23-25
Totals	14	1930	29	0			

Table C 4. Flush response of nesting Red-cockaded Woodpeckers versus the number, distance, and noise levels of passive helicopter flights on Fort Stewart, GA, 1998-2000. Stimulus distances represent the closest estimated approach distance by a helicopter.

Stimulus Distance (m)	Cluster Tested	Number of Noise Events	Number of Data Sessions	Number of Flushes	Noise Levels, SEL (dB)		Typical Ambient LEQ (dB) "W" weighted
					Unweighted	"W" weighted	
30-50	8,53,57,83,206	11	5	0	103-110	84-92	33-35
51-100	23,53,57,60,206	11	5	0	96-101	79-84	33-37
101-200	2,6,23,48,53,57,60,83,206,207,216	21	12	0	90-104	68-81	23-37
201-300	2,6,10,23,44,48,53,60,83,143,151,206,218	25	16	0	87-99	61-74	31-36
301-500	2,25,26,53,142,206,216,218	15	7	0	73-85	40-64	25-34
Totals	19	83	45	0			

Table C 5. Flush response of nesting Red-cockaded Woodpeckers versus the number, distance, and noise level of passive large-caliber (> 20mm) live fire on Fort Stewart, GA, 1998-2000.

Stimulus Distance (m)	Cluster Tested	Number of Noise Events	Number of Data Sessions	Number of Flushes	Noise Levels, SEL (dB)		Typical Ambient LEQ (dB) "W" weighted
					unweighted	"W" weighted	
500-600	83	73	2	2	98-108	64-86	33-41
700-800	172	2	1	0	102-103	70-75	30
1000-3000	23,62,84,159,183,206,267	284	14	0	69-103	39-61	28-35
3001-5000	41,48,55,81,83,159,162,177,184	168	14	0	60-96	36-61	20-33
5001-7000	10,23,57,143,159,184	11	5	0	59-86	30-42	28-31
7001-9000	62,67,76,218	72	3	0	72-84	26-31	22-25
9001-11000	36,37,67,142,172,184	20	6	0	66	27-30	20-25
Totals	24	630	45	2			

Table C 6. Flush response of nesting Red-cockaded Woodpeckers versus the number, distance, and noise levels of passive vehicles on Fort Stewart, GA, 1998-2000.

Stimulus Distance (m)	Cluster Tested	Number of Noise Events	Number of Data Sessions	Number of Flushes	Noise Levels, SEL (dB)		Typical Ambient LEQ (dB) "W" weighted
					Unweighted	"W" weighted	
15-50	12,23,47,57,83,197,216	58	13	2	58-110	56-91	28-39
50-100	82,206	12	2	0	82-99	58-73	23-42
101-200	62,139	5	2	0	72-93	64-75	30-34
201-300	6	2	2	0	84-87	49-52	33-36
301-500	51,172,207	4	3	0	76-79	43-54	30
Totals	15	81	22	2			

Table C 7. Flush response of nesting Red-cockaded Woodpeckers versus the number, distance, and noise levels of passive missile fire on Fort Stewart, GA, 2000.

Stimulus Distance (m)	Cluster Tested	Number of Noise Events	Number of Data Sessions	Number of Flushes	Noise Levels, SEL (dB)		Typical Ambient LEQ (dB) "W" weighted
					Unweighted	"W" weighted	
750-1000	88	33	2	0	67-105	25-85	22-24
2000-4000	83,203	62	3	0	65-93	39-64	30-32
4001-6000	75,99	18	2	0	58-85	32-53	27-31
Totals	5	113	7	0			

Table C 8. Flush response of nesting Red-cockaded Woodpeckers versus the number, distance, and noise levels of passive simulators blasts on Fort Stewart, GA, 1998-1999.

Stimulus Distance (m)	Cluster Tested	Number of Noise Events	Number of Data Sessions	Number of Flushes	Noise Levels, SEL (dB)		Typical Ambient LEQ (dB) "W" weighted
					Unweighted	"W" weighted	
100-200	41,103	2	2	1	92-95	78-84	35-38
300-400	103	6	6	0	80-83	47-61	44-45
Totals	2	8	8	1			

Table C 9. Flush response of nesting Red-cockaded Woodpeckers versus the number, distance, and noise levels of experimental M-16 blank fire on Fort Stewart, GA, 1998.

Stimulus Distance (m)	Cluster Tested	Number of Noise Events	Number of Data Sessions	Number of Flushes	Noise Levels, SEL (dB)		Typical Ambient LEQ (dB) "W" weighted
					unweighted	"W" weighted	
15.2	36, 37, 76, 142	243	4	1	79 - 93	68-80	33-40
Totals	4	243	4	1			

Table C 10. Flush response of nesting Red-cockaded Woodpeckers versus the number, distance, and noise levels of passive fixed-wing aircraft (i.e., C-130) on Fort Stewart, GA, 1998.

Stimulus Distance (m)	Cluster Tested	Number of Noise Events	Number of Data Sessions	Number of Flushes	Noise Levels, SEL (dB)		Typical Ambient LEQ (dB) "W" weighted
					unweighted	"W" weighted	

500-1000	51	1	1	0	90	62	26
Totals	1	1	1	0			

Table C 11. Variation in artillery simulator blast noise levels based on year, stimulus distance, microphone position and weighting function on Fort Stewart, GA, 1999-2000.

Noise Type	Year	Sample Size	Stimulus Distance (m)	Microphone Position	Weighting Function	Mean (dB)	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Artillery Simulators	2000	16	15.2	Cavity	Unweighted	107.6 ^{a,c}	0.39	106.8	108.4
Artillery Simulators	2000	16	15.2	Base	Unweighted	98.6 ^{b,c}	0.89	96.7	100.4
Artillery Simulators	2000	34	30.5	Cavity	Unweighted	106.1 ^{a,b,c}	0.57	104.9	107.2
Artillery Simulators	2000	34	30.5	Base	Unweighted	94.8 ^{b,c}	0.85	93.0	96.5
Artillery Simulators	2000	9	45.7	Cavity	Unweighted	104.8 ^{a,c}	1.03	102.4	107.1
Artillery Simulators	2000	9	45.7	Base	Unweighted	94.8	1.78	90.6	98.9
Artillery Simulators	2000	37	61.0	Cavity	Unweighted	102.8 ^{a,c}	0.56	101.6	103.9
Artillery Simulators	2000	37	61.0	Base	Unweighted	87.9 ^b	1.13	85.6	90.2
Artillery Simulators	2000	5	76.2	Cavity	Unweighted	102.2 ^a	2.36	95.7	108.8
Artillery Simulators	2000	5	76.2	Base	Unweighted	82.8	3.29	73.7	91.9
Artillery Simulators	2000	27	91.4	Cavity	Unweighted	98.7 ^a	1.02	96.6	100.7
Artillery Simulators	2000	27	91.4	Base	Unweighted	81.3	1.4	78.4	84.2
Artillery Simulators	2000	13	121.9	Cavity	Unweighted	95.1 ^{a,b}	0.71	93.5	96.6
Artillery Simulators	2000	13	121.9	Base	Unweighted	74.4 ^{b,c}	0.60	73.1	75.7
Artillery Simulators	2000	2	152.4	Cavity	Unweighted	90.0	3.15	49.9	130.0
Artillery Simulators	2000	2	152.4	Base	Unweighted	70.1	1.95	45.3	94.8
Artillery Simulators	1999	16	15.2	Cavity	Unweighted	110.0 ^a	0.89	108.1	111.9
Artillery Simulators	1999	16	15.2	Base	Unweighted	105.8	0.76	104.2	107.4
Artillery Simulators	1999	33	30.5	Cavity	Unweighted	109.6 ^a	0.72	108.1	111.1
Artillery Simulators	1999	33	30.5	Base	Unweighted	103.8 ^c	0.49	102.8	104.8
Artillery Simulators	1999	3	121.9	Cavity	Unweighted	105.5	1.68	98.2	112.7
Artillery Simulators	1999	3	121.9	Base	Unweighted	97.5 ^c	1.62	90.5	104.5
Artillery Simulators	2000	16	15.2	Cavity	W-weighted	87.7 ^{b,c}	0.98	85.7	89.8
Artillery Simulators	2000	16	15.2	Base	W-weighted	84.8 ^{b,c}	1.08	82.5	87.1
Artillery	2000	34	30.5	Cavity	W-weighted	82.5 ^{b,c}	0.76	80.9	84.0

Simulators									
Artillery Simulators	2000	34	30.5	Base	W-weighted	79.6 ^{b,c}	0.39	79.0	80.6

Table C 11 (cont.)

Noise Type	Year	Sample Size	Stimulus Distance (m)	Microphone Position	Weighting Function	Mean (dB)	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
Artillery Simulators	2000	9	45.7	Cavity	W-weighted	77.7 ^c	1.77	73.6	81.8
Artillery Simulators	2000	9	45.7	Base	W-weighted	77.3 ^c	1.49	73.8	80.7
Artillery Simulators	2000	37	61.0	Cavity	W-weighted	74.7 ^c	0.79	73.1	76.3
Artillery Simulators	2000	37	61.0	Base	W-weighted	73.0 ^{b,c}	0.59	71.8	74.2
Artillery Simulators	2000	5	76.2	Cavity	W-weighted	72.7	2.76	65.0	80.4
Artillery Simulators	2000	5	76.2	Base	W-weighted	72.0 ^c	1.75	67.1	76.8
Artillery Simulators	2000	27	91.4	Cavity	W-weighted	69.9 ^c	1.14	67.6	72.3
Artillery Simulators	2000	27	91.4	Base	W-weighted	70.2 ^c	0.50	69.2	71.2
Artillery Simulators	2000	13	121.9	Cavity	W-weighted	65.8 ^b	1.70	62.1	69.5
Artillery Simulators	2000	13	121.9	Base	W-weighted	66.5 ^c	0.98	64.3	68.6
Artillery Simulators	2000	2	152.4	Cavity	W-weighted	54.6	1.50	35.5	73.7
Artillery Simulators	2000	2	152.4	Base	W-weighted	55.5	3.15	15.4	95.5
Artillery Simulators	1999	16	15.2	Cavity	W-weighted	93.9	0.91	91.9	95.8
Artillery Simulators	1999	16	15.2	Base	W-weighted	92.6	0.74	91.0	94.1
Artillery Simulators	1999	33	30.5	Cavity	W-weighted	92.0	0.61	90.7	93.2
Artillery Simulators	1999	33	30.5	Base	W-weighted	90.0	0.45	89.1	90.9
Artillery Simulators	1999	3	121.9	Cavity	W-weighted	77.2	0.33	75.8	78.6
Artillery Simulators	1999	3	121.9	Base	W-weighted	74.4	4.01	56.8	92.0

^a Significant noise level comparison between cavity versus base for the same stimulus type, distance, frequency weighting and year.

^b Significant noise level comparison between 1999 versus 2000 for the same stimulus type, distance and frequency weighting.

^c Significant noise level comparison between artillery simulator and blank fire testing for the same distance, frequency weighting and year.

Table C 12. Variation in .50-caliber blank fire noise levels based on year, stimulus distance, microphone position, and weighting function on Fort Stewart, GA, 1999-2000.

Noise Type	Year	Sample Size	Stimulus Distance (m)	Microphone Position	Weighting Function	Mean (dB)	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Blank Fire	2000	33	15.2	Cavity	Unweighted	113.7 ^a	0.51	112.6	114.7
Blank Fire	2000	33	15.2	Base	Unweighted	104.1	0.33	103.5	104.8
Blank Fire	2000	110	30.5	Cavity	Unweighted	111.0 ^a	0.34	110.3	111.7
Blank Fire	2000	110	30.5	Base	Unweighted	99.2	0.28	98.7	99.8
Blank Fire	2000	24	45.7	Cavity	Unweighted	109.9 ^a	0.63	108.6	111.2
Blank Fire	2000	24	45.7	Base	Unweighted	96.2	0.44	95.3	97.1
Blank Fire	2000	112	61.0	Cavity	Unweighted	106.0 ^a	0.40	105.2	106.8
Blank Fire	2000	112	61.0	Base	Unweighted	91.0	0.35	90.3	91.6
Blank Fire	2000	14	76.2	Cavity	Unweighted	103.0 ^a	1.38	100.0	105.9
Blank Fire	2000	14	76.2	Base	Unweighted	87.1	1.03	84.9	89.3
Blank Fire	2000	76	91.4	Cavity	Unweighted	99.6 ^a	0.69	98.3	101.0
Blank Fire	2000	76	91.4	Base	Unweighted	85.3 ^b	0.49	84.3	86.3
Blank Fire	2000	32	121.9	Cavity	Unweighted	98.1 ^a	0.99	96.1	100.2
Blank Fire	2000	32	121.9	Base	Unweighted	80.1 ^b	0.60	78.9	81.4
Blank Fire	2000	4	152.4	Cavity	Unweighted	87.9 ^a	0.50	86.3	89.5
Blank Fire	2000	4	152.4	Base	Unweighted	72.6	1.72	67.1	78.1
Blank Fire	1999	74	15.2	Cavity	Unweighted	113.0 ^a	0.51	112.0	114.0
Blank Fire	1999	74	15.2	Base	Unweighted	105.1	0.38	104.4	105.9
Blank Fire	1999	73	30.5	Cavity	Unweighted	110.4 ^a	0.66	109.1	111.7
Blank Fire	1999	73	30.5	Base	Unweighted	100.3	0.43	99.5	101.2
Blank Fire	1999	3	45.7	Cavity	Unweighted	101.5	2.21	92.0	111.0
Blank Fire	1999	3	45.7	Base	Unweighted	93.9	2.20	84.5	103.4
Blank Fire	1999	63	61.0	Cavity	Unweighted	105.3 ^a	0.72	103.8	106.7
Blank Fire	1999	63	61.0	Base	Unweighted	92.7	0.45	91.9	93.6
Blank Fire	1999	17	91.4	Cavity	Unweighted	104.7 ^a	1.06	102.4	106.9
Blank Fire	1999	17	91.4	Base	Unweighted	88.7	0.53	87.6	89.9
Blank Fire	1999	34	121.9	Cavity	Unweighted	97.6 ^a	0.80	96.0	99.3
Blank Fire	1999	34	121.9	Base	Unweighted	84.4	0.64	83.1	85.7
Blank Fire	2000	33	15.2	Cavity	W-weighted	91.8 ^a	0.69	90.4	93.2
Blank Fire	2000	33	15.2	Base	W-weighted	96.8	0.51	95.7	97.8
Blank Fire	2000	110	30.5	Cavity	W-weighted	88.1 ^a	0.31	87.5	88.7
Blank Fire	2000	110	30.5	Base	W-weighted	90.9 ^b	0.29	90.3	91.5
Blank Fire	2000	24	45.7	Cavity	W-weighted	85.5	0.59	84.2	86.7
Blank Fire	2000	24	45.7	Base	W-weighted	86.1	0.70	84.6	87.5
Blank Fire	2000	112	61.0	Cavity	W-weighted	82.9	0.36	82.2	83.7
Blank Fire	2000	112	61.0	Base	W-weighted	82.8 ^b	0.31	82.2	83.4
Blank Fire	2000	14	76.2	Cavity	W-weighted	80.8	1.08	78.5	83.2
Blank Fire	2000	14	76.2	Base	W-weighted	79.4	0.63	78.0	80.8
Blank Fire	2000	76	91.4	Cavity	W-weighted	78.4	0.43	77.5	79.2
Blank Fire	2000	76	91.4	Base	W-weighted	78.7	0.26	78.2	79.2
Blank Fire	2000	32	121.9	Cavity	W-weighted	74.6	1.07	72.4	76.8
Blank Fire	2000	32	121.9	Base	W-weighted	75.3	0.62	74.0	76.5

Blank Fire	2000	4	152.4	Cavity	W-weighted	63.3	1.98	57.0	69.6
Blank Fire	2000	4	152.4	Base	W-weighted	66.2	2.33	58.8	73.6
Blank Fire	1999	74	15.2	Cavity	W-weighted	92.4	0.50	91.4	93.4
Blank Fire	1999	74	15.2	Cavity	W-weighted	94.8	0.44	94.0	95.7
Blank Fire	1999	73	30.5	Cavity	W-weighted	88.7	0.60	87.5	89.9

Table C 12 (cont.)

Noise Type	Year	Sample Size	Stimulus Distance (m)	Microphone Position	Weighting Function	Mean (dB)	Std. Error	95% Confidence Interval	
								Lower Bound	Upper Bound
Blank Fire	1999	73	30.5	Base	W-weighted	88.7	0.47	87.7	89.6
Blank Fire	1999	3	45.7	Cavity	W-weighted	75.5	2.51	64.7	86.3
Blank Fire	1999	3	45.7	Base	W-weighted	77.5	2.43	67.0	87.9
Blank Fire	1999	63	61.0	Cavity	W-weighted	83.1	0.93	81.2	84.9
Blank Fire	1999	63	61.0	Base	W-weighted	79.9	0.62	78.6	81.1
Blank Fire	1999	17	91.4	Cavity	W-weighted	82.6	1.38	79.7	85.6
Blank Fire	1999	17	91.4	Base	W-weighted	76.9	0.58	75.7	78.1
Blank Fire	1999	34	121.9	Cavity	W-weighted	77.6 ^a	0.87	75.9	79.4
Blank Fire	1999	34	121.9	Base	W-weighted	72.7	0.63	71.4	73.9

^a Significant noise level comparison between cavity versus base for the same stimulus type, distance, frequency weighting and year.

^b Significant noise level comparison between 1999 versus 2000 for the same stimulus type, distance and frequency weighting.

^c Significant noise level comparison between artillery simulator and blank fire testing for the same distance, frequency weighting and year.

Appendix D: Source Spectra Examples

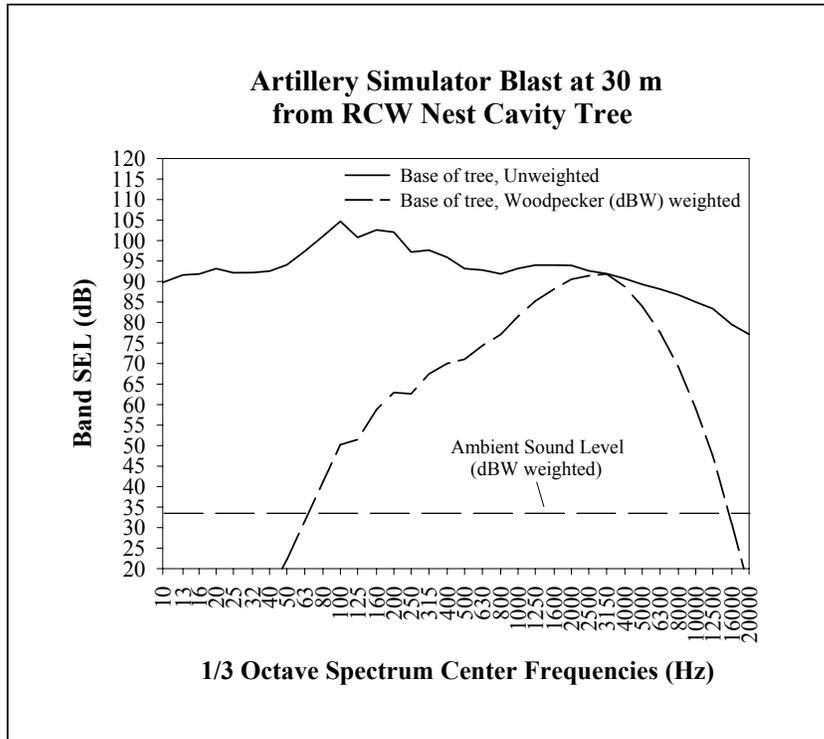


Figure D 1. Weighting comparison for experimental artillery simulator blast at cluster 47 on 5 June 2000 (post-fledging testing).

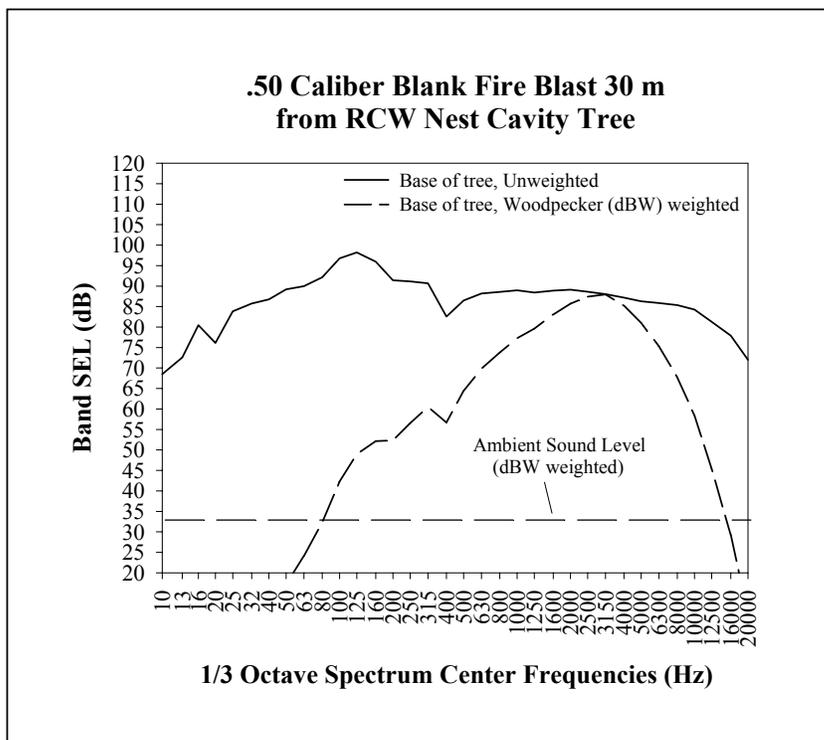


Figure D 2. Weighting comparison for experimental .50-caliber blank fire at cluster 47 on 5 June 2000 (post-fledging testing)

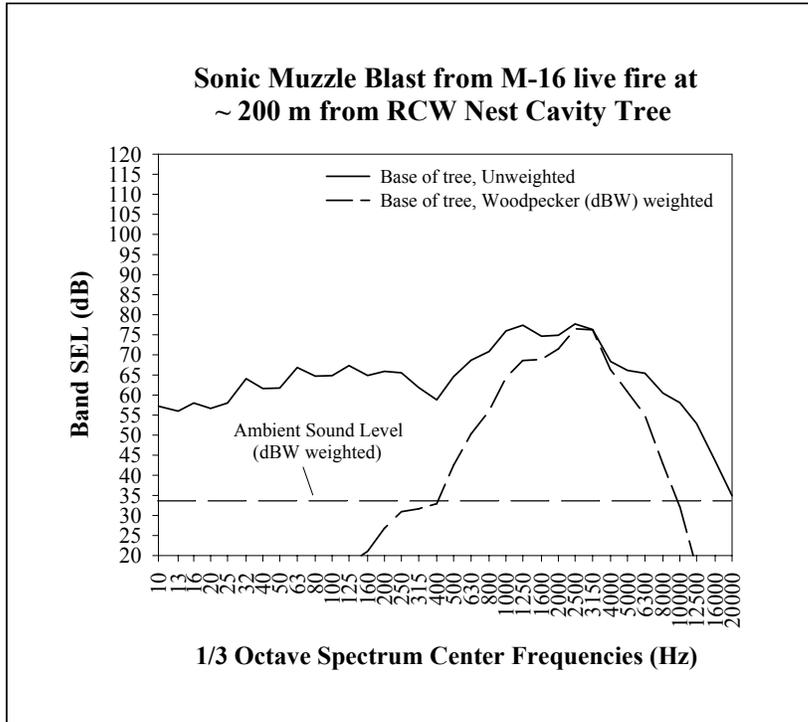


Figure D 3. Weighting comparison for passive M-16 live fire at cluster 103 on 6 May 2000.

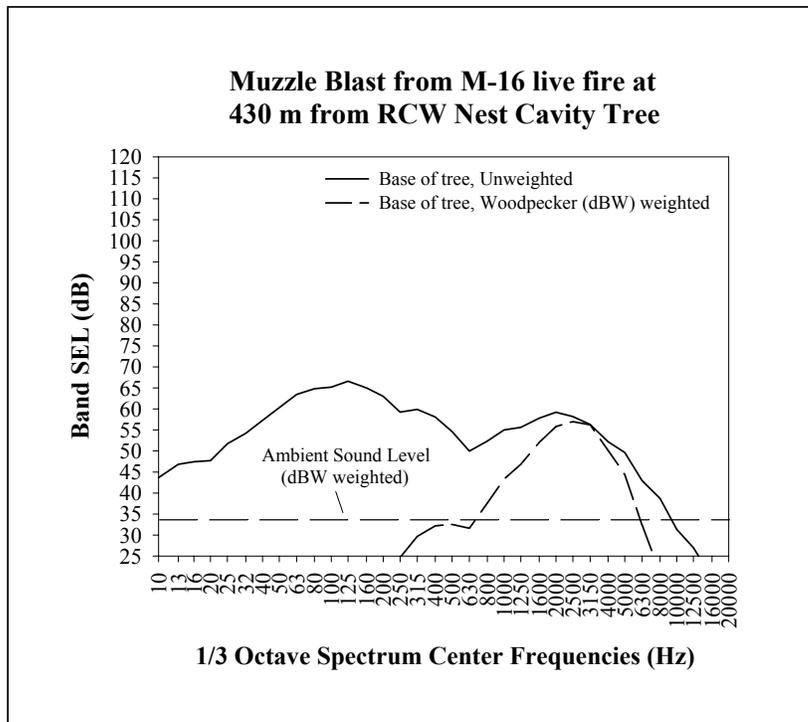


Figure D 4. Weighting comparison for passive M-16 live muzzle blast fire at cluster 103 on 6 May 2000.

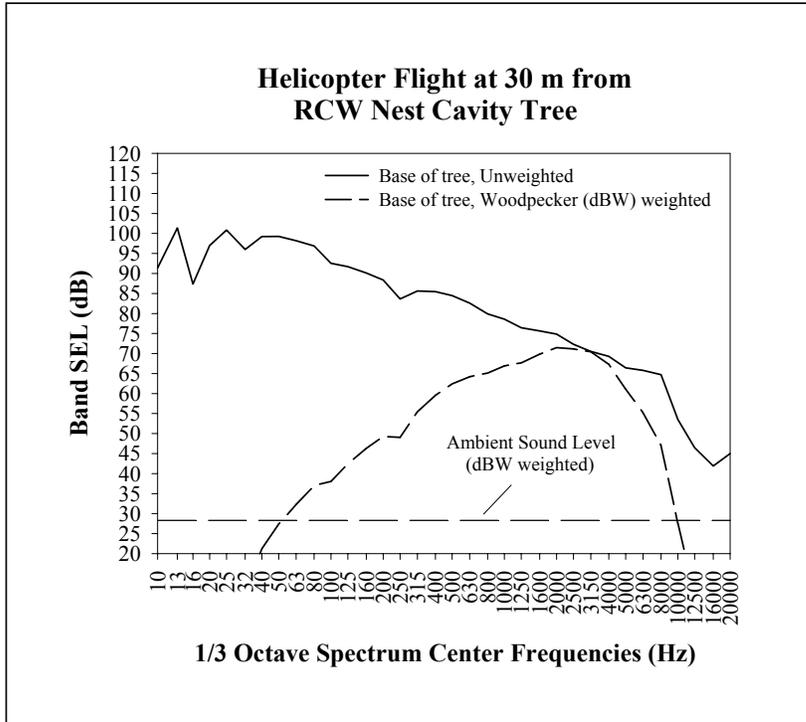


Figure D 5. Weighting comparison for a passive helicopter flight at cluster 206 on 25 May 2000.

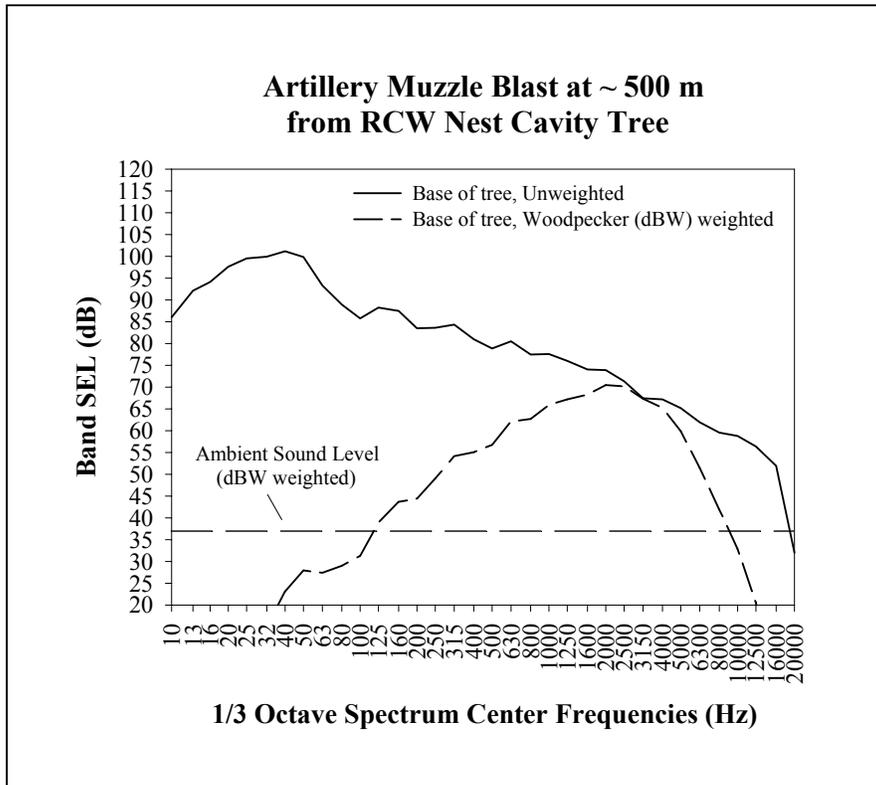


Figure D 6. Weighting comparison for passive artillery muzzle blast noise at cluster 83 on 21 May 1998. This blast elicited a flush response by the attending RCW.

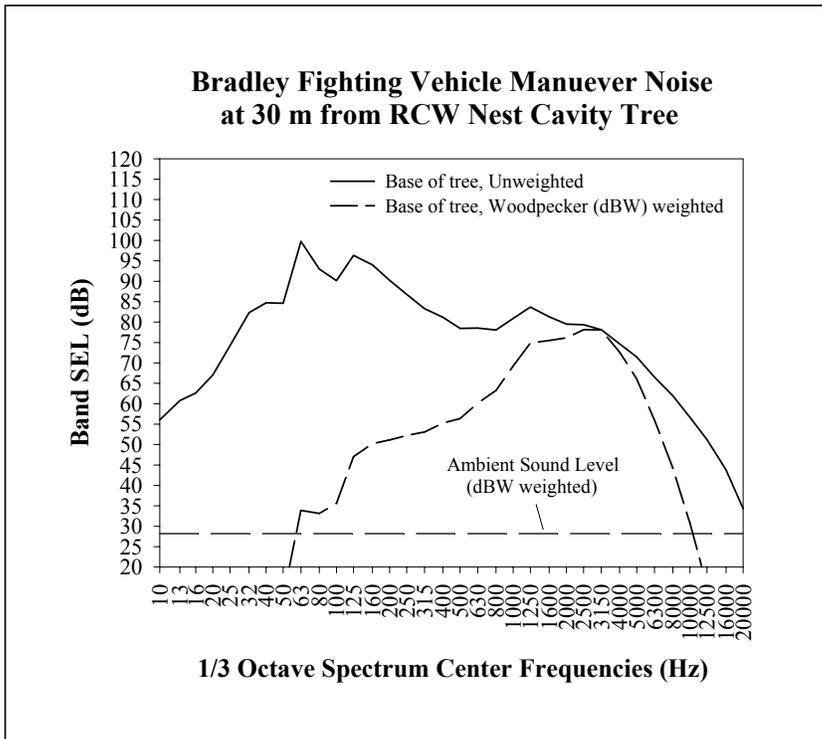


Figure D 7. Weighting comparison for a passive military vehicle noise event at cluster 216 on 8 May 2000. This event elicited a flush response by the attending RCW.

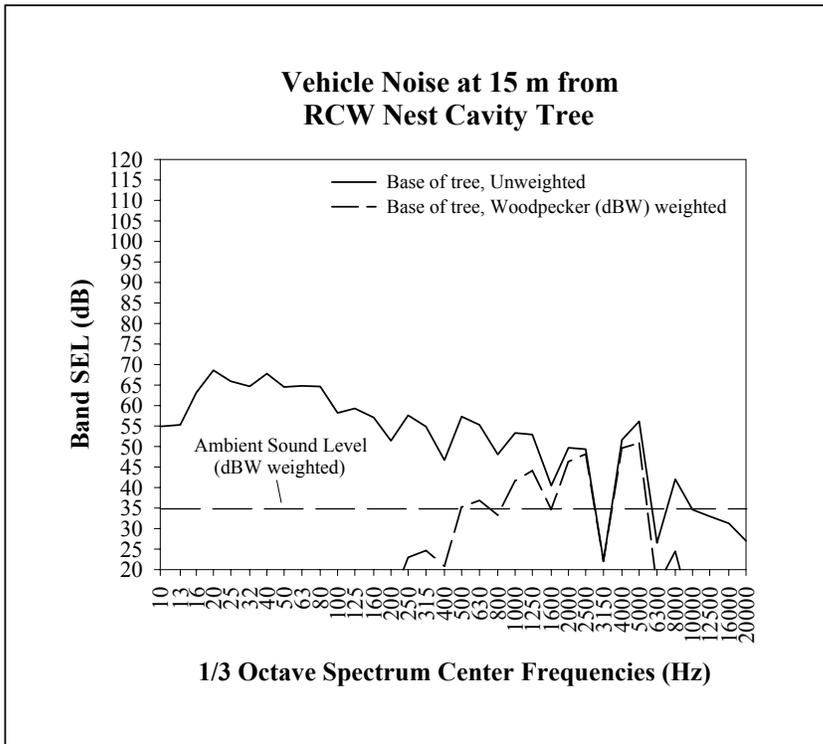


Figure D 8. Weighting comparison for passive vehicle noise at cluster 23 on 16 May 2000. This event elicited a flush response by the attending RCW.

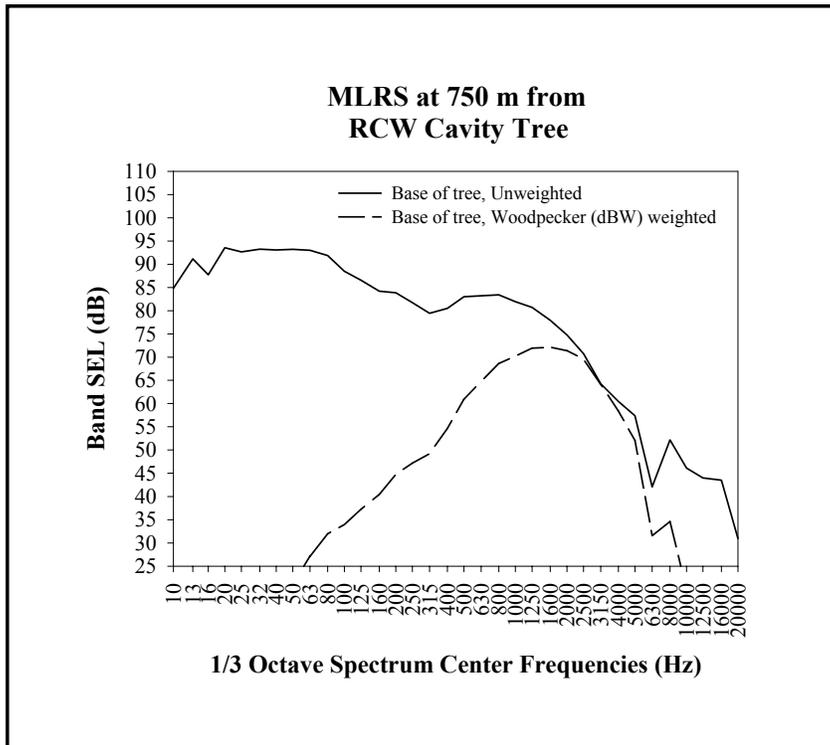


Figure D 9. Weighting comparison for passive MLRS fire at cluster 88 on 13 April 2000.

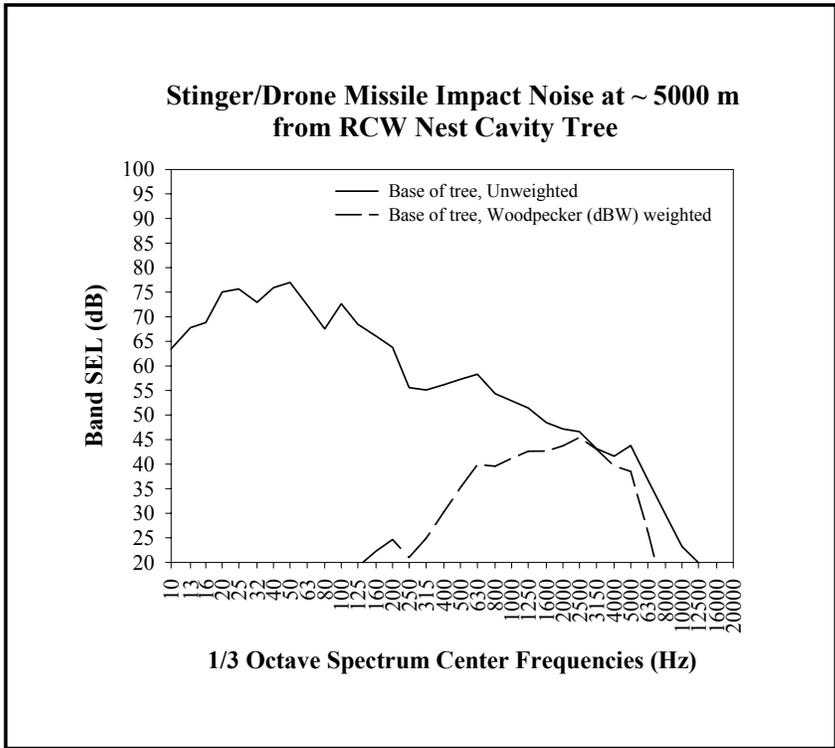


Figure D 10. Weighting comparison for passive Stinger/Drone Missile impact at cluster 83 on 16 May 2000.

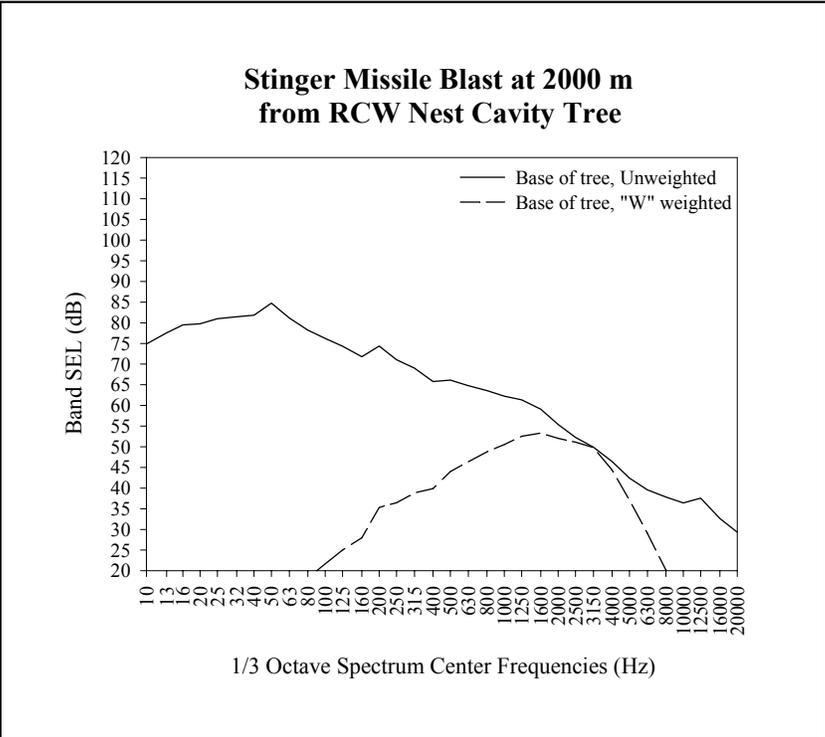


Figure D 11. Weighting comparison of passive Stinger Missile fire at cluster 83 on 16 May 2000.

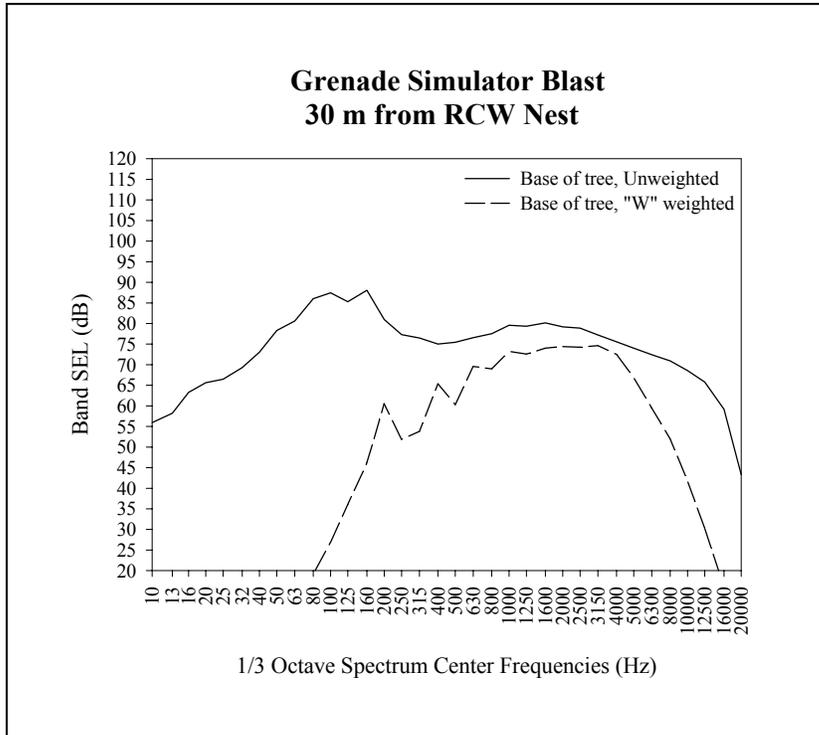


Figure D 12. Weighting comparison of a passive grenade simulator blast at cluster 221 on 23 June 2000.

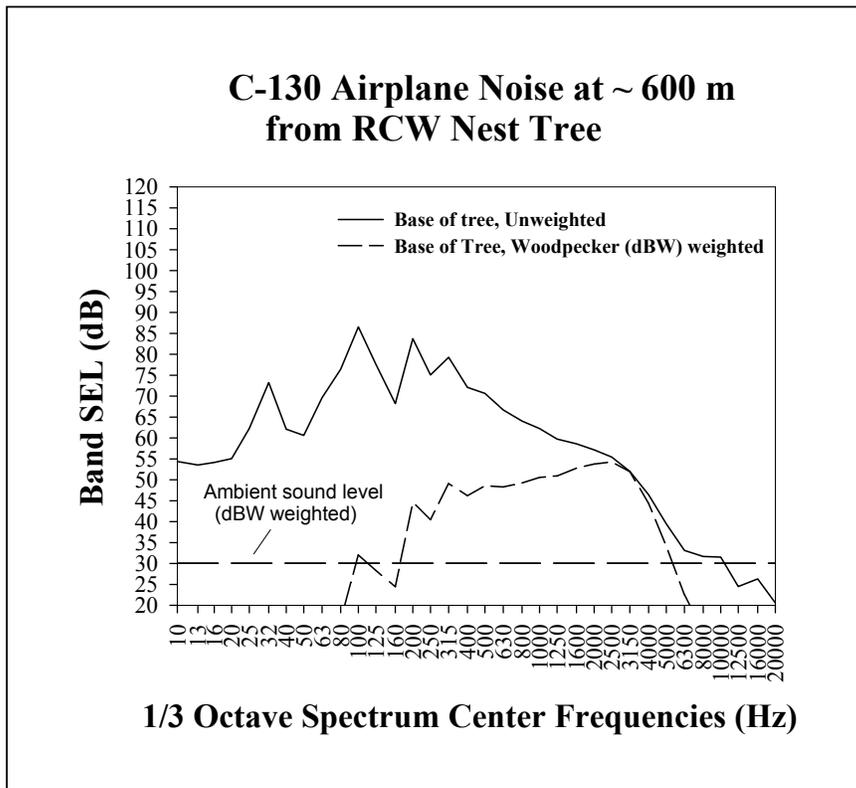


Figure D 13. Weighting comparison for passive C-130 airplane flight at cluster

Appendix E: Video Images from RCW Nests



Figure E 1. Red-bellied Woodpecker usurping a nest from a Red-cockaded Woodpecker in 2000 on Fort Stewart, GA.



Figure E 2. Rat snake leaving a Red-cockaded Woodpecker nest after consuming two eggs and two nestlings in 1998 on Fort Stewart, GA.



Figure E 3. Nest predation attempt by a Red-shouldered Hawk in 1998 on Fort Stewart, GA.



Figure E 4. Nest predation attempt by an American Crow in 2000 on Fort Stewart, GA.

Table C 13. Flush response of nesting Red-cockaded Woodpeckers versus the number, distance, and noise levels of passive M-16 live fire on Fort Stewart, GA, 1999-2000.

Stimulus Distance (m)	Cluster Tested	Number of Noise Events	Number of Data Sessions	Number of Flushes	Noise Levels, SEL (dB)		Typical Ambient LEQ (dB) "W" weighted
					Unweighted	"W" weighted	
200-300	103	284	6	0	76-96	75-89	34-43
400-600	3,51,103	1128	8	0	58-77	43-75	34-41
800-900	51	29	1	0	67	47-51	34
1200-2500	23,25,26,83	313	7	0	64-72	34-62	32-35
4000-5000	36,39,48,71,159,267	171	6	0	62-76	33-47	30-34
5001-7000	2	5	1	0	75-76	27-30	23-25
Totals	14	1930	29	0			

Table C 14. Flush response of nesting Red-cockaded Woodpeckers versus the number, distance, and noise levels of passive helicopter flights on Fort Stewart, GA, 1998-2000. Stimulus distances represent the closest estimated approach distance by a helicopter.

Stimulus Distance (m)	Cluster Tested	Number of Noise Events	Number of Data Sessions	Number of Flushes	Noise Levels, SEL (dB)		Typical Ambient LEQ (dB) "W" weighted
					Unweighted	"W" weighted	
30-50	8,53,57,83,206	11	5	0	103-110	84-92	33-35
51-100	23,53,57,60,206	11	5	0	96-101	79-84	33-37
101-200	2,6,23,48,53,57,60,83,206,207,216	21	12	0	90-104	68-81	23-37
201-300	2,6,10,23,44,48,53,60,83,143,151,206,218	25	16	0	87-99	61-74	31-36
301-500	2,25,26,53,142,206,216,218	15	7	0	73-85	40-64	25-34
Totals	19	83	45	0			

Table C 15. Flush response of nesting Red-cockaded Woodpeckers versus the number, distance, and noise level of passive large-caliber (> 20mm) live fire on Fort Stewart, GA, 1998-2000.

Stimulus Distance (m)	Cluster Tested	Number of Noise Events	Number of Data Sessions	Number of Flushes	Noise Levels, SEL (dB)		Typical Ambient LEQ (dB) "W" weighted
					unweighted	"W" weighted	
500-600	83	73	2	2	98-108	64-86	33-41
700-800	172	2	1	0	102-103	70-75	30
1000-3000	23,62,84,159,183,206,267	284	14	0	69-103	39-61	28-35
3001-5000	41,48,55,81,83,159,162,177,184	168	14	0	60-96	36-61	20-33
5001-7000	10,23,57,143,159,184	11	5	0	59-86	30-42	28-31
7001-9000	62,67,76,218	72	3	0	72-84	26-31	22-25
9001-11000	36,37,67,142,172,184	20	6	0	66	27-30	20-25
Totals	24	630	45	2			

