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THE EFFECTS OF RADIO WEIGHT AND HARNESSES ON TIME BUDGETS AND MOVEMENTS OF ACORN WOODPECKERS

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Abstract.—The effects of radio package weight and of the presence of a harness to attach radios were investigated in the Acorn Woodpecker (*Melanerpes formicivorus*). Time budgets and average distance traveled were recorded for individuals without radio packages, with 3-g radio packages, with 4.5-g radio packages, and with 3-g packages attached with a harness. Individuals with 4.5-g radios and with 3-g radios plus a harness showed decreased rates of behavior that involved flying. These individuals spent greater amounts of time preening and trying to remove the radio packages and were less mobile overall. Undetected, such effects could seriously bias the interpretation of radio tracking data. Time budget analysis allows a quantifiable evaluation of the effects of harnesses and of radio weight on behavior so that an acceptable radio package can be found for the species in question.

EL EFECTO DEL PESO DE RADIO TRANSMISORES Y ARNESES EN LA INVERSIÓN DEL TIEMPO Y LOS MOVIMIENTOS DE *MELANERPES FORMICIVORUS*

Sinopsis.—El efecto del peso de radio transmisores y arneses fue investigado en *Melanerpes formicivorus*. La inversión del tiempo y el promedio de área recorrida fueron estudiados para individuos que cargaron radio transmisores de 3, 4.5 y 3-g incluyendo el arnés. Individuos con transmisores de 4.5-g y de 3-g incluyendo el arnés, mostraron una reducción en los patrones de conducta que incluían vuelo. Estos individuos más sedentarios, utilizaron gran parte de su tiempo acicalándose y tratando de quitarse el transmisor. Estos efectos, si pasan desapercibidos, pueden intercalar sesgo y afectar la interpretación de datos obtenidos con radio transmisores. Un análisis de la inversión del tiempo permite una evaluación cuantitativa de los efectos de arneses y el peso de transmisores en la conducta de las aves, lo que induce a la búsqueda de un paquete con radio transmisor que sea aceptable para la especie.

Radio tracking allows the movements of free-ranging animals to be quantified in a manner unavailable by any other method. However, this technique is not without potential harmful effects on the study animal. For example, the attachment of radio transmitters to Woodcocks (*Philohela minor*) resulted in atypical breeding behavior and reduced courtship (Ramakka 1972), and Mallards (*Anas platyrhynchos*) and Blue-winged Teals (*A. discors*) preened more and exhibited a partial aversion to swimming when radios were attached (Greenwood and Sargent 1973). Vocalization rates of Mourning Doves (*Zenaida macroura*) were reduced following radio attachment (Sayre et al. 1981), and abnormal foraging rates were associated with the presence of radios in California Least Terns (*Sterna antillarum*) (Massey et al. 1988). In addition, harness mounted radios adversely affect plumage and survival in several species (Boag 1972, Johnson and Berner 1980, Karl and Clout 1987, Lance and Watson 1977, Nicholls and Warner 1968, Perry 1981, Small and Rusch 1985). Furthermore, harnesses may not noticeably affect behavior while birds are on the ground but they may adversely affect flying (Gessaman and Nagy 1988, Michener and Walcott 1966, Ramakka 1972).

Though heavier batteries provide longer radio life and a greater transmission range, a number of studies have shown detrimental effects from increased radio weight. For instance, Sibly and McCleery (1980) found decreased reproductive success for Herring Gulls (*Larus argentatus*) with heavier tags, and Warner and Etter (1983) found a decrease in the survival of Ring-necked Pheasants (*Phasianus colchicus*) as tag weight increased. Moreover, African Penguins (*Spheniscus demersus*) swim more slowly with larger radios (Wilson and Duffy 1986), and homing pigeons with radios and harnesses expend over 40% more energy during flight (Gessaman and Nagy 1988). Thus, in order to evaluate any possible behavioral abnormalities, the effects of radio packages should be investigated before starting a radio tracking or telemetry study. Here I evaluate the effects of varying radio weight and the presence or absence of harnesses on the behavior of free-ranging Acorn Woodpeckers (*Melanerpes formicivorus*).

STUDY SITE AND METHODS

Radio tracking studies on Acorn Woodpeckers were conducted at Hastings Natural History Reservation, 40 km southeast of the city of Monterey in the Santa Lucia Mountains of central coastal California. A color-banded population has been studied continuously at Hastings since 1971 (Koenig and Mumme 1987, MacRoberts and MacRoberts 1976). Data used in this study were taken March through August 1986. Subjects were caught in roosting holes and assigned randomly into the experimental groups. Individuals of both sexes weighing 76–84 g were used. Two studies were conducted. The first investigated the effects of radio weight and the second recorded the effects of wearing a harness. Three categories were used in the first study: no radio, a 3-g radio without a harness (3.5–3.9% of body weight), and a 4.5-g radio without a harness (5.1–5.9% of body weight). To test for harness effects in the second study I used two categories: a radio and harness package weighing 3 g and a 3-g radio without a harness. Each of five focal individuals were observed for 6 h for each category in both studies.

Harnesses were modified from the backpack design of Brander (1968) and were constructed of 0.32 cm tubular nylon webbing with the loops sewn together over the breastbone. Radios attached without harnesses were glued onto the backs of subjects using a cyanoacrylic glue. Due to the extra handling stress on birds when attaching harnesses, these individuals were allowed one day to acclimate before observations were begun.

Both continuous focal animal time budgets and positional data were taken during each watch. For focal animal time budgets the set of index behaviors chosen was both exclusive and exhaustive. A TRS Model 100 microcomputer was used to record the duration of each behavior. Twelve out of the total set of 28 behaviors were used in the following analysis. These were divided into "high energy" and "low energy" behaviors. High energy behavior was characterized by actions that included flight or movements that are more energetically costly (Bernstein et al. 1973, Fedak et al. 1974, Hails 1979, Utter and LeFebvre 1970). They include: (1) aggression (intraspecific aggression consisting of supplants, chases, or fighting), (2) defense (interspecific aggression, see 1), (3) flying, (4) moving (non-flight movements exclusive of those in other behaviors), (5) *waka* (an energetic social greeting consisting of vocalizations and a spread wing display), (6) flycatching (flights from perches during which flying insects are caught), and (7) working stores (moving acorns between holes). Low energy behavior includes: (1) preening, (2) eating, (3) gleaning (for acorn bits or oak catkins), (4) sitting and (5) vigilance (sitting and moving the head). The locations of radio-tracked birds were plotted every 15 min onto aerial photos using a coordinate system. Fifteen-minute sampling intervals were chosen to reduce the effects of autocorrelation. The distance moved was calculated as the shortest straight line between sequential points of observation, ignoring any changes in elevation. Individuals were tracked using hand-held three-element yagi antennas. Observers were commonly able to maintain continuous visual contact with focal birds due to their relatively short movements, strong territoriality, habituation to people and the openness of the vegetation. Radio-tagged individuals could be observed, on average, 79% of each watch while untagged individuals could be followed 58% of the time. The amount of time spent moving and flying may be underestimated for untagged birds. Data were not normally distributed and did not have equal variances, thus non-parametric tests were used in the analysis of data. Two-tailed P values were used except when noted.

RESULTS

Effects of radio weight.—Birds with 4.5-g radio packages showed significantly decreased rates of high energy behavior when compared to birds without a radio (Fig. 1, Kruskal-Wallis test, $H = 38.5$, df $= 6$, $P < 0.01$). These differences were individually significant for four high energy behaviors: flying (Mann-Whitney U test, $U = 1$, $P < 0.01$), moving ($U = 0$, $P < 0.01$), flycatching ($U = 0$, $P < 0.01$) and working stores ($U = 0$, $P < 0.01$). In addition, non-significant decreases were found in the rates of the remaining three high energy behaviors: aggression, defense and *waka* displays. There were no significant differences in the rates of any of the high energy behaviors between those individuals with 3-g radio packages and those without radios (Kruskal-Wallis test, $H = 5.8$, df $=$ 6, $P > 0.05$).

The rates of all low energy behaviors when combined differed significantly between radio packages (Fig. 1, Kruskal-Wallis test, $H = 13.9$, df $= 4$, $P < 0.05$). Radio packages weighing 4.5 g significantly increased three low energy behaviors: preening, eating, and sitting (Mann-Whitney U tests, all $P < 0.05$), but not gleaning or vigilance. Similar to high energy behavior, there were no significant differences in the rates of low energy behavior between those birds with 3-g radio packages and those without a radio (Kruskal-Wallis test, $H = 3.42$, df $= 6$, $P > 0.05$).

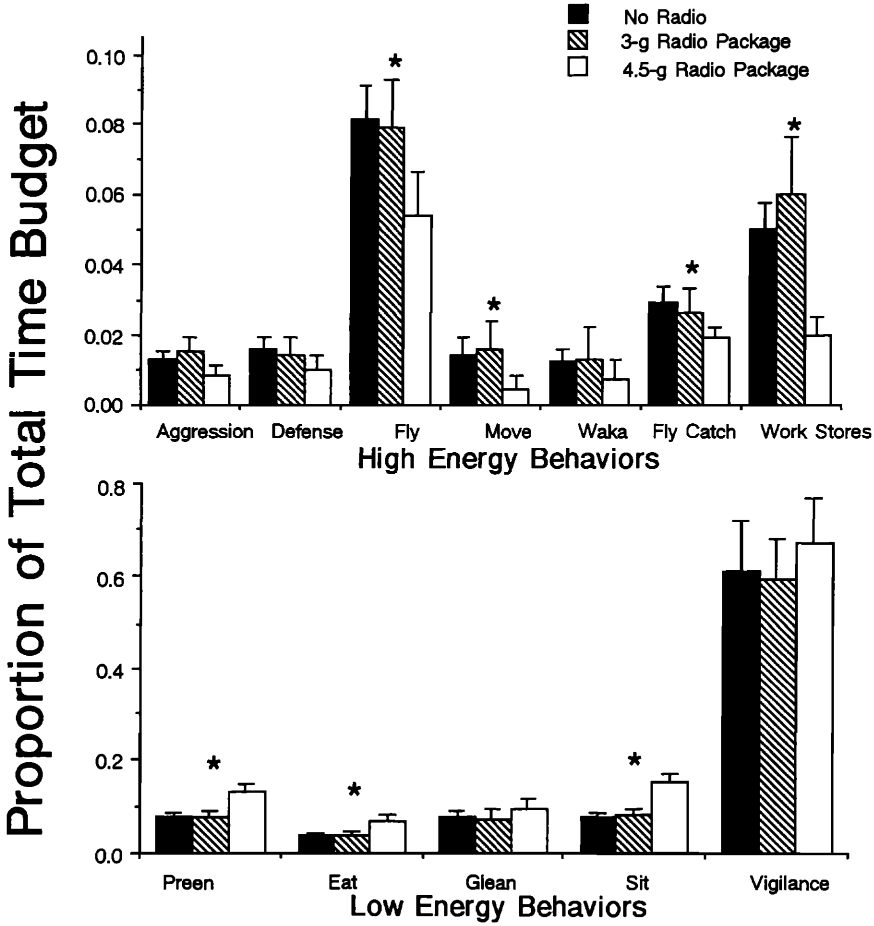

FIGURE 1. Proportion of total time budget spent in high and low energy behavior for individuals with no radio package, a 3-g radio, and a 4.5-g radio. Sample size is five for each category. Those behaviors that are starred were significantly different between the different weight categories (Mann-Whitney U test, $P < 0.05$ two-tailed).

Individuals with 4.5-g radios appeared to have more labored flight, such birds flapped their wings in a more continuous manner than did individuals without a radio or individuals with 3-g radios. The increased rate of preening found among birds with 4.5-g radios was mainly due to efforts directed at the radio packages. These individuals were often seen trying to pull off the radios several days after they were attached. In contrast, individuals with 3-g radios rarely directed preening efforts toward the radio packages (other than the antennas) after the first day they were attached.

The distances traveled during all 15-min periods were averaged for each individual over all watches (Fig. 2). Average distance traveled in

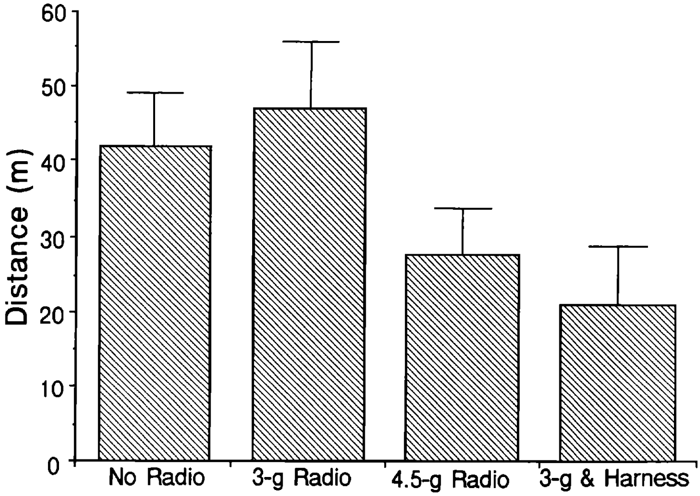

FIGURE 2. Average straight line distance (m) traveled in 15 min for individuals with no radio package, a 3-g radio, a 4.5-g radio and a 3-g radio with a harness. Sample size is five individuals for each category. Each individual was followed for 6 h.

each period was significantly less for individuals with 4.5-g radios compared to those not wearing a radio (Mann-Whitney U test, $U = 3$, $P < 0.05$). There were no significant differences between individuals without radios and those with 3-g radio packages (Mann-Whitney U test, $U = 10$, $P > 0.05$). All Acorn Woodpeckers with 4.5-g radios spent most of their time within the group territory whereas nonbreeding helpers with 3-g radios or without radios spent large amounts of time (>43%) outside of the group territory.

Effects of harnesses.—There was a significant difference in the rates of high energy behavior between individuals with and without a harness (Kruskal-Wallis test, $H = 15.54$, df = 6, $P < 0.05$). Radio packages attached with a harness rather than with an adhesive resulted in a significant reduction in the rates of two high energy behaviors (Fig. 3): flying (Mann-Whitney U test, $U = 4$, $P < 0.05$) and flycatching ($U = 0$, $P < 0.01$). There were also noticeable but non-significant decreases in aggression, defense and working stores. Moving and *waka* displays actually increased, but again not significantly.

The rates of low energy behavior varied significantly between categories (Kruskal-Wallis test, $H = 16.2$, df = 4, $P < 0.02$). Individuals with harnesses showed significant increases in the rates of two low energy behaviors: preening (Mann-Whitney U test, $U = 1$, $P < 0.01$) and sitting ($U = 0$, $P < 0.01$). The rates of eating, gleaning and vigilance were not significantly different between categories (Kruskal-Wallis test, $H = 0.5$, df = 2, $P > 0.05$). Individuals with harnesses spent more time preening and most of that preening was directed at the harnesses, similar to birds with 4.5-g radios.

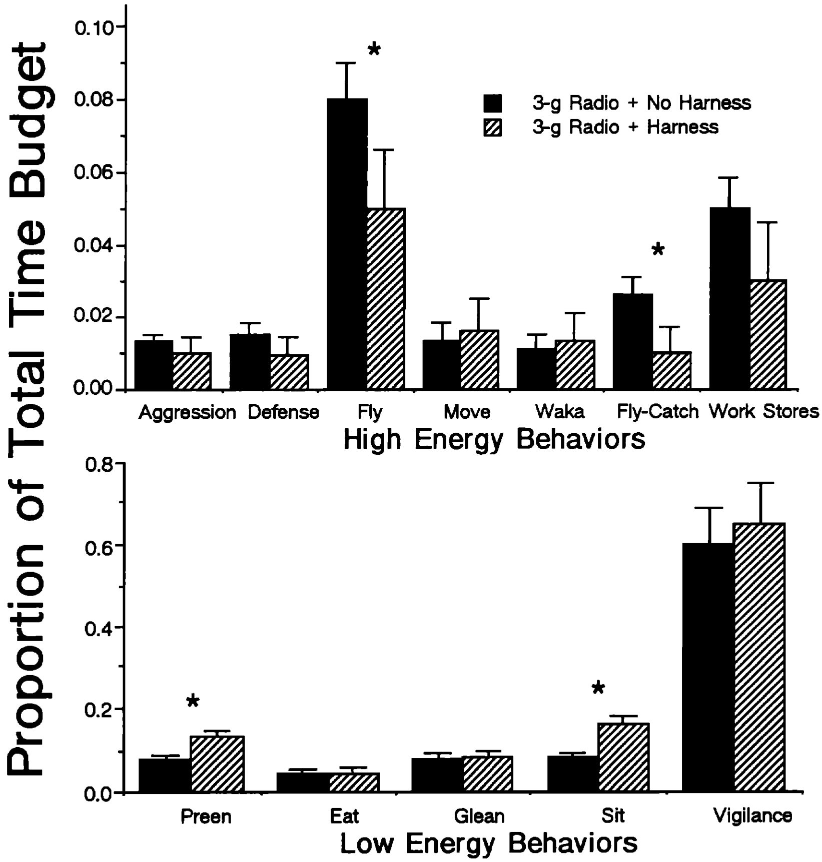

FIGURE 3. Proportion of total time budget spent in high and low energy behaviors for individuals with and without harnesses. Both groups had 3-g radios. Sample size is five for each category. Those behaviors that are starred were significantly different between the different harness categories (Mann-Whitney U test, $P < 0.05$ two-tailed).

An additional effect of wearing a harness was a decrease in average minimum distance traveled (Fig. 2). Individuals with 3-g radio packages with harnesses traveled significantly shorter distances than did individuals without harnesses or those without radios (Mann-Whitney U test, $U = 2$, $P < 0.05$). The distances traveled by individuals with harnesses were even shorter than the distances covered by individuals with the heavier 4.5-g radios that were glued on.

Further costs of harness use are the dangers of entanglement or constriction. The amount of slack in each harness had to be adjusted precisely for each Acorn Woodpecker. If the harnesses were too tight, respiration would be restricted, with obvious detrimental effects. Too much slack would enable an individual to insert its bill under the harness, which could result in death.

DISCUSSION

These results demonstrate that there are behavioral costs associated with certain radio packages. Increased radio weight was associated with a decrease in the rate of behavior involving flight. Accompanying the decrease in flight was an increase in the rate of behavior with low energy requirements such as preening and sitting. Additional evidence for increased energetic costs associated with heavier radios is the increased rate of feeding. Aggression and defense levels did not decrease significantly even though they involve a large flight component, but these behaviors were relatively rare.

The suggested maximum radio package weight for small birds over 50 g is 5% of body weight (Brander and Cochran 1971, Cochran 1980). However, this study indicates that radio packages close to this weight are associated with behavioral changes in Acorn Woodpeckers. The flycatching habits of Acorn Woodpeckers require low wing loading (Bock 1970). Data on bats indicate that species that require mobility when catching insects on the wing require lighter radios (Aldridge and Brigham 1988). Acorn Woodpeckers spend large amounts of time flycatching from perches, and thus they may be subject to similar constraints by radio weight. Thus not only mass (Caccamise and Hedin 1985) but also behavior and ecology of the target species must be considered when selecting the proper radio package. This study indicates that the 5% rule may be too liberal for some species.

The presence of harnesses reduced the rates of flying and flycatching in Acorn Woodpeckers even more than did the heavier 4.5-g radios. However, other high energy behaviors showed non-significant reductions or even increases (in contrast to 4.5-g radios), and thus harnesses appear primarily to interfere with flight. The decrease in the average flight distance associated with a harness is also indicative of the negative effects of harnesses on flight. These results are similar to the effects seen on homing Pigeons (*Columba livia*) (Gessaman and Nagy 1988, Michener and Walcott 1966) and Woodcocks (Ramakka 1972). The high levels of preening which were often observed several days after harness attachment also suggest that the harnesses may be causing some physical discomfort.

The use of harnesses had several other costs in addition to affecting behavior. They increased the weight of the total radio package such that the use of a smaller battery became necessary in order to reduce radio package weight. Harnesses also greatly increased the complexity of the radio packages. This increased the time required to attach the radio and thus sometimes necessitated the use of an anesthetic agent with a concomitant risk of overdose. Harnesses also increased the chance that a bird could become entangled in the radio package. For long-billed birds such as Acorn Woodpeckers this could be a cause of mortality.

Gluing provides a superior alternative to harnesses for small radio packages. Gluing simplifies attachment, reduces the need for anesthesia, decreases package weight and greatly reduces or eliminates the chances of entanglement. However, a problem arises in finding an adhesive that is strong, flexible and non-irritating to the integument of the bird. The use of cyanoacrylic glue provided adequate adhesion but lacked flexibility and there was an exothermic reaction on application. Gluing also involves feather loss when the radio package falls off. After 5 yr of radio tracking, we have not observed any mortality or behavior that could be attributed to this feather loss, and the longest recorded dispersal distances have been made by birds with glue-mounted radios.

The methodology used in this study provides a way to evaluate the effects of radio packages. With detailed time budgets, any behavioral changes associated with radio packages, or with attachment methods, can be quantified fairly rapidly. These behavioral changes might otherwise remain unnoticed or be attributed to an unrelated factor. This paper demonstrates that these effects need to be reduced or at least their biases be taken into account.

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