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EFFECTS OF HARNESS-STYLE AND ABDOMINALLY IMPLANTED TRANSMITTERS ON SURVIVAL AND RETURN RATES OF MALLARDS

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Abstract.—We evaluated the effects of harness-style and abdominally implanted transmitters on survival of ducklings, survival of attending females during the brood-rearing period, and female return rates in Mallards (*Anas platyrhynchos*). Eighty-three females were captured on their nests in late incubation in eastern Saskatchewan during 1990–1993. Transmitters were attached with harnesses on 34 females and 49 females had transmitters surgically implanted into their abdominal cavity. There was no difference in duckling survival ($P = 0.22$ from hatch–14 d, $P = 0.07$ for 15–30 d) or brood survival (one or more ducklings alive in brood; $P > 0.4$) to 30 d after hatching between broods accompanied by females with harnesses or implants. Female survival during late incubation and brood-rearing was high in 1990–1992 when only one of 61 females was killed over the 60-d period from the time of capture until the young fledged. Survival of brood-attending females was lower in 1993 when 5 of 16 females were killed during the brood-rearing period. Adjusted return rates were lower ($P < 0.025$) for females with harnesses (22.6%) than those with implants (55%). These findings provide further evidence of adverse effects of harness-style transmitters. Although implanted transmitters are recommended for use in studying reproductive ecology of waterfowl, better controls are needed before the effects of transmitters and attachment procedures can be fully evaluated.

EFECTOS DE LOS TRANSMISORES TIPO ARNÉS Y DE IMPLANTE ABDOMINAL EN LA SUPERVIVENCIA Y TASAS DE RETORNO DE *ANAS PLATYRHYNCHOS*

Sinopsis.—Evaluamos los efectos de los transmisores tipo arnés y de implante abdominal en la supervivencia de crías y de hembras cuidadoras durante el período de atender las crías y en tasas de retorno de hembras de *Anas platyrhynchos.* Se capturaron 83 hembras en sus nidos durante el final de la incubación en Saskatchewan oriental entre 1990–1993. Se colocaron transmisores de arnés en 34 hembras y se implantaron quirurgicamente transmisores en la cavidad abdominal de 49 hembras. No se halló diferencia en la supervivencia de crías ($P = 0.22$ desde nacimiento a 14 días, $P = 0.07$ para 15 a 30 días) o en la supervivencia de camadas (una o más crías vivas en la camada; $P > 0.4$) a 30 días después de eclosionar entre camadas acompañadas por hembras con arneses o implantes. La supervivencia de las hembras durante la incubación tardía y la crianza de la camada fué alta entre 1990 y 1992, cuando solo una de 61 hembras murió durante los 60 días entre el tiempo de la captura hasta que las crías se desarrollaron. La supervivencia de hembras que atienden camadas fué menor en 1993 cuando 5 de 16 hembras fueron muertas durante el período de atender las crías. Las tasas ajustadas de retorno fueron menores ($P < 0.025$) para hembras con arneses (22.6%) que para las que tenían implante (55%). Estos resultados añaden evidencia adicional sobre los efectos adversos de los transmisores tipo arnés. Aunque se recomienda el uso de transmisores implantados en

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estudios de ecología reproductiva de aves acuáticas, se necesitan mejores controles antes de evaluar de forma contundende el efecto de los transmisores y los métodos de ajustarlos.

Telemetry has been used extensively in waterfowl research to study nesting behavior (e.g., Cowardin et al. 1985), brood ecology (e.g., Ball et al. 1975, Orthmeyer and Ball 1990, Rohwer 1985, Rotella and Ratti 1992, Talent et al. 1982), and wintering ecology (e.g., Conroy et al. 1989). Back-mounted transmitters attached with harnesses (Dwyer 1972) have been commonly used in telemetry studies. However, a growing body of research indicates that harnesses adversely affect behavior (e.g., Greenwood and Sargeant 1973, Houston and Greenwood 1993), clutch size (Pietz et al. 1993), flight speed and metabolism (Gessaman and Nagy 1988), and return rates (Ward and Flint 1995) of birds. More recently, some researchers have used transmitters that are surgically implanted into the abdominal cavity of birds (e.g., Korschgen et al. 1984, Olsen et al. 1992). Rotella et al. (1993) compared nesting effort of female Mallards (*Anas platyrhynchos*) fitted with abdominal implants, harnesses, and sutured backpacks. They reported poor retention of the suture backpacks and fewer nest initiations by females with harness-style transmitters. Evaluation of these different methods of attachment is needed for other life-history stages.

As part of a four-year study investigating brood-rearing ecology of Mallards, we used harness-style or abdominally implanted transmitters on adult females. Because female Mallards are philopatric (reviewed by Arnold and Clark 1996), we were able to assess return rates through resighting and recapture of marked birds. Our objectives were to determine the effects of transmitter attachment method on (1) survival of ducklings and attending females during the brood-rearing period and (2) adult female return rates.

STUDY AREA AND METHODS

Brood survival was evaluated from 1990–1993, 40 km west of Yorkton in east-central Saskatchewan, Canada (51°12′N, 103°5′W). The area consisted of five managed nesting areas (63 ha each) in the aspen (*Populus tremuloides*) parkland zone of the prairie pothole region. The landscape was characterized by gently undulating topography, scattered aspen groves, and a moderate wetland density (range in mid-May, 27–49/km^2). The primary land use was the production of cereal and oilseed crops.

Mallard nests were located by searching on foot or using cable-chain drags (Klett et al. 1986). Nests were visited every 7–10 d, and stage of incubation was determined by candling the eggs (Weller 1956). Because nesting success of ducks in the prairie pothole region is typically low (Greenwood et al. 1995), fences were placed around nests to deter predators. Mallard nests that were not located in one of two 16-ha predator exclosure fences (similar design to Trottier et al. 1994) were surrounded by 100 m × 1-m high wire mesh fences if they survived to the late egg-laying or early incubation stage (Sargeant et al. 1974). Protecting nests does not affect the objectives of our study because we focus on events occurring after hatching. Females were captured on the nest at approximately 20 d of incubation using hand-carried mist nests (Bacon and Evrard 1990) or nest traps (Salyer 1962, Weller 1957). Females received leg bands, unique combinations of nylon nasal markers that varied in color and shape (Lokemoen and Sharp 1985), and radio transmitters. Birds were weighed to the nearest 5 g using spring scales; head length (mm) was measured using Vernier calipers and flattened wing chord (mm) was measured with a ruler. A body condition index was calculated as mass divided by the sum of head length and wing chord and was compared between transmitter treatment groups using ANOVA.

Females received a 22-g harness-style transmitter (28 mm × 18 mm × 8 mm, model CHP2H, Telonics Inc., Mesa, Arizona, USA) using a criss-cross modification (Smith and Gilbert 1981) of the traditional Dwyer (1972) harness or a 21-g cylindrical transmitter (23-mm diameter × 53-mm length, model IMP150, Telonics Inc.) implanted into their abdominal cavity. To reduce abandonment among females with harness-style transmitters, we anesthetized them with methoxyflurane in an induction chamber prior to being placed back on the nest (Rotella and Ratti 1990, Smith et al. 1980). Surgeries were conducted in a travel trailer within 500 m of nest sites. Surgical procedures followed Olsen et al. (1992). Females with implants were quickly returned to the nest when their breathing and heart rate stabilized and a swallowing reflex was evident, but prior to complete recovery from anesthesia.

Radio-equipped females were located 1–4 times daily using a truck-mounted or hand-held receiving system (White and Garrott 1990). Observations to count ducklings were conducted at least every 7 d until the young could fly (approximately 55 d, Bellrose 1976). Observations were made with binoculars and 15–60 power spotting scopes from sunrise to 1000 h and from 1800 h to dark, because these are periods when waterfowl broods were most active (Ringelman and Flake 1980). Brood observations were also made opportunistically while checking daily radio locations. The decision that a female had lost all young in her brood was based on direct observation and female behavior following guidelines of Orthmeyer and Ball (1990) and Rotella and Ratti (1992). Duckling survival was calculated for each brood separately using a modified Mayfield technique (Flint et al. 1995). The Mayfield method assumes constant survivorship, but mortality in ducklings is known to be higher in the first two weeks after hatching (e.g., Mauser et al. 1994, Orthmeyer and Ball 1990). Therefore we calculated daily survival probabilities (DSP) from hatch to 14 d and 15–30 d. For each time period we compared DSP values for broods accompanied by females with harnesses and implants using a Z-test (Johnson 1979). Survival for any period is DSP raised to the exponent of number of days in the interval (Johnson 1979). Survival to 30 d was calculated as the product of the survival rates for the two time periods. Because the probability of survival from 30 d to fledging is close to 1.0 (e.g., Orthmeyer and Ball 1990) we considered survival to 30 d as an approximation of duckling survival to fledging. Survival of ducklings in a brood may not be independent (Rotella and Ratti 1992, Winterstein

1992). Thus, we also calculated brood survival (≥1 duckling alive) to 30 d as an additional index of offspring survival that does not violate assumptions surrounding independence.

Clutch and brood size was manipulated in early incubation to ±50% of control size (n = 10 young) in 1991–1993 as part of another study (Dzus 1995). In years when harness-style and implant transmitters were used concurrently (1991 and 1992), treatments (transmitter style and brood size) were assigned randomly. While it would be desirable to evaluate the effects of these treatments simultaneously, the number of birds per treatment combination is not adequate for such a test. Here, we test for transmitter effects and present duckling survival for unmanipulated (1990) or control-sized (1991–1993) broods only, as attrition rates in reduced and enlarged broods was greater than control broods (Dzus 1995). There was no difference in rates of total brood loss between control and enlarged broods; therefore, we present brood survival data for these groups combined (Dzus 1995).

Adjusted return rates were calculated as the proportion of birds marked in year i that were resighted in years $\geq i + 1$ (Arnold and Clark 1996). Resightings were based on recaptures on nests and observations made either during pair and brood surveys or opportunistically on wetlands throughout the spring and summer. Females were excluded from this analysis (harness n = 3, implant n = 9) if they were unavailable for recapture (e.g., killed by predators, hunters, or as a result of anesthetic procedures). Three females implanted in 1991, recaptured in 1992 and subsequently re-implanted, are not included as newly marked females, thus maintaining independence of females within transmitter treatments for the recapture analysis. We used contingency tables (PROC FREQ; SAS Institute Inc. 1990) to compare adjusted return rates between females with harness-style and implant transmitters; for 2 × 2 tables we applied William's correction for continuity (G_{adj}; Sokal and Rohlf 1981:736–737).

This study was approved by the Animal Care Committee of the University of Saskatchewan on behalf of the Canadian Council for Animal Care.

RESULTS

Eighty-three females were captured over four years. Harness-style transmitters were placed on 34 females (24 in 1990, 9 in 1991, and 1 in 1992); of these one died in the methoxyflurane induction chamber prior to being placed back on the nest and four abandoned the nest ≤24 h after being captured. Forty-nine females had transmitters implanted into their abdominal cavity (13 in 1991, 19 in 1992 and 17 in 1993); four died during or soon after surgery and four abandoned their nests ≤24 h after surgery. Body condition indices did not differ ($F_{1,79} = 0.03$; $P = 0.86$) between females with harness-style transmitters ($\bar{x}$ = 2.38, SD = 0.11, n = 34) and those with abdominal implants ($\bar{x}$ = 2.38, SD = 0.13, n = 47).

Daily survival probabilities (DSP to 14 days; n less than above because we evaluated duckling survival for control-sized broods only, see methods for details) for young accompanied by females with backpacks ($\bar{x}$ = 0.956,

n = 17 broods, SE = 0.012) did not differ (Z = 1.24, P = 0.22) from that of ducklings attended by females with implants ($\bar{x}$ = 0.921, n = 11 broods, SE = 0.026). DSP from 15–30 d may have been lower (Z = 1.82, P = 0.07) for ducklings accompanied by females with harnesses ($\bar{x}$ = 0.975, n = 13 broods, SE = 0.008) than those young whose attending female carried an implant transmitter ($\bar{x}$ = 0.991, n = 7 broods, SE = 0.004). Despite this difference, duckling survival to 30 d is similar for young accompanied by harnessed females ($\bar{x}$ = 0.355) and those reared by implanted females ($\bar{x}$ = 0.275). Overall, brood survival to 30 d (control and enlarged broods combined) did not differ between broods attended by females with harness-style transmitters (11 of 17 broods surviving) and those with implants (11 of 18 broods surviving) (G = 0.048, df = 1, $P >$ 0.4). Based on a smaller sample in 1991, when both types of transmitters were used, brood survival to 30 d was similar between harness-style (2 of 3 broods surviving) and implant (3 of 6 broods surviving) females (Fisher's exact test, P = 1.0, two-tailed).

Survival of radio-marked female Mallards during the brood-rearing period was high and there was no evidence that mortality was influenced by transmitter type. From the time of capture (approximately 20 d incubation) until young fledged, only one of 61 females was killed (on day of hatch) from 1990–1992. Female survival was lower in 1993, when 5 of 16 females were killed (one before hatch, four within 8 d after hatch). Reasons for the increase in female mortality in 1993 are unknown.

Adjusted return rates were lower (G_{adj} = 5.39, df = 1, P = 0.02) for females fitted with harness-style transmitters (7 of 31 resighted) than for females with implanted transmitters (11 of 20 resighted). As nesting success may influence return rates (Johnson et al. 1992, Lokemoen et al. 1990), we compared the adjusted return rates for unsuccessful and successful females. No female with a harness (n = 6) or implant (n = 2) that experienced nest failure was resighted in the year $\geq i + 1$ after capture. Of the harnessed females (n = 25) that hatched eggs, 7 (28%) were known to return (2 recaptured on nests and 5 resighted). By contrast, 11 (61%) of 18 implant females that nested successfully were known to return (7 recaptured on nests and 4 resighted). Thus, for females that successfully hatched eggs, the adjusted return rate for females with implant transmitters was higher (G_{adj} = 4.64, df = 1, P = 0.03) than that of females with harness-style transmitters.

DISCUSSION

Radio telemetry is used frequently in studies of brood ecology of waterfowl and other species of bird. Harness-style transmitters adversely affect the behavior and nesting effort of Mallards (see Pietz et al. 1993, Rotella et al. 1993 and references therein). There is no evidence of serious effects of transmitters during brood-rearing for Mallards (e.g., Ball et al. 1975, Cowardin et al. 1985, Orthmeyer and Ball 1990, Pietz et al. 1995, Rotella and Ratti 1992). However, data from unmarked controls or comparisons with other types of transmitters have not been available.

Bergmann et al. (1994) found no difference in brood size by age class between females with harness-style transmitters and unmarked females (see also Ball et al. 1975). However, they were unable to evaluate brood survival in terms of total brood loss as this cannot be detected in unmarked broods. Gammonley and Kelley (1994) also found that female Wood Ducks (*Aix sponsa*) with harness-style transmitters hatched young and showed no difference in duckling survival compared to unmarked females. However, there was virtually no nesting effort when males *and* females were radio-marked prior to nest initiation. Offspring survival is lowest and ducklings are most dependent on parental care during the first two weeks after hatching. We found no evidence that harness-style transmitters affected duckling or brood survival in Mallards relative to broods attended by females with implanted transmitters. Females captured late in incubation may have already invested so much in the current year's reproduction that they are willing to tolerate capture and transmitter attachment. The apparent absence of adverse effects on duckling survival for females carrying harness-style transmitters does not mean that transmitters do not adversely affect females, but it does suggest that previous estimates of duckling survival based on following nest-trapped females fitted with harnesses were not seriously biased.

The deleterious effects of harness-style transmitters attached to females late in incubation appears to occur after the current reproductive event is completed. No renesting was observed for any females in this study. Bergmann et al. (1994) and Rotella et al. (1993) also reported no renesting for Mallard females carrying harness-style transmitters. The lack of renesting by females with implants in this study differs from Rotella et al. (1993). This may be related to different wetland conditions, which are known to affect Mallard nesting effort (Kaminski and Gluesing 1987, Krapu et al. 1983, Leitch and Kaminski 1985). Wetland density on the study area of Rotella et al. (1993) was better than those near Yorkton in 1991–1993 (E. H. Dzus, unpubl. data). Wetland density on the Yorkton area in 1990 was comparable to that of Rotella et al. (1993), but we did not use implant transmitters in 1990. One of five Mallard females equipped with abdominal implants in 1994 was known to renest twice under favorable wetland conditions on the St. Denis National Wildlife Area, Saskatchewan; four others raised ducklings and were thus unlikely to renest (R. G. Clark, unpubl. data). More work is necessary to evaluate abdominal implant transmitters in relation to renesting effort and timing of application of the transmitter.

Few studies have examined the effects of transmitter attachment on return rates. Gammonley and Kelley (1994) reported no difference in return rate between banded female Wood Ducks and females captured in late incubation that were equipped with harness-style transmitters. However, 72% of their recaptured females had lost their transmitters before they returned, thus any negative effects of transmitters may have been reduced by transmitter loss. Gilmer et al. (1974) found no difference in return rate for female Mallards with breast-mounted transmitters compared to females with leg bands. However, only 4% of "banded" females were recaptured (Gilmer et al. 1974), possibly because they captured most birds in July and August, and many may have been failed breeders, non-breeders, or non-residents which have a lower probability of return. Ward and Flint (1995) reported that color-banded Brant (*Branta bernicla*) returned to the breeding colony in the year following marking at a much higher rate (57–83%) than females marked with color bands and harness-style transmitters (4%). They also recorded no obvious effects of transmitters on female Brant during brood-rearing. The results with Brant are very similar to our findings. Our resighting rate of 0.55 for female Mallards with abdominally implanted transmitters was not significantly different ($G = 1.16$, df $= 1$, $P > 0.3$) from the adjusted return rate of 0.43 reported by Arnold and Clark (1996) for Mallards marked with nasal tags. Furthermore, our comparison showing higher adjusted return rates for female Mallards with implant transmitters compared to those with harness-style transmitters is conservative because there was an additional year available to recapture females with harness-style transmitters.

The use of transmitters implanted into the abdominal cavity of Mallards (and other ducks, see Korschgen et al. 1984, Olsen et al. 1992) has numerous advantages relative to harness-style transmitters. The combined biological information derived from females with implant transmitters in terms of nesting effort, offspring survival, and return rates makes these transmitters superior to externally mounted transmitters. There is no aerodynamic drag with implant transmitters as there is with any externally mounted transmitter (Caccamise and Hedin 1985, Gessaman and Nagy 1988). The addition of weight into the body cavity in the lower abdomen should not affect flight as fat stores normally accumulate in this region of the body (e.g., Bailey 1979). Placement of the transmitter in the right side of the abdominal cavity of birds is also suitable because most birds do not have a functioning ovary on this side of the body (Welty 1982: 161). In contrast to excessive amounts of preening, feather wear, skin abrasion, and loss of body mass among females with harness-style transmitters (e.g., Gilmer et al. 1974, Greenwood and Sargeant 1973, Perry 1981, Pietz et al. 1993), ducks receiving implant transmitters do not exhibit abnormal behavior (Korschgen et al. 1984, Olsen et al. 1992, E. H. Dzus, pers. obs.). Two disadvantages of using abdominal implant transmitters are (1) the time required for the surgical procedure, and (2) their reduced range (Korschgen et al. 1984, E. H. Dzus, unpubl. data). After evaluating methods and equipment, researchers should select techniques that minimize negative side effects (reviews by Calvo and Furness 1992, White and Garrott 1990).

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