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Evaluation of nasal discs and colored leg bands as markers for Harlequin Ducks

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ABSTRACT. We evaluated nasal discs and colored leg bands for Harlequin Ducks (*Histrionicus histrionicus*) wintering in the Strait of Georgia, British Columbia, by comparing marker visibility and life span, and determining effects of nasal discs on behavior and pairing. Proportions resighted and frequency of sightings were higher for individuals marked with nasal discs than for those marked only with leg bands. Nasal disc loss followed a logistic function that predicted 50% loss by 396 d. Due to wear of leg bands, number of sightings per individual decreased with leg band age following a cubic function. We detected no effects of nasal discs on time spent in various behaviors, timing of pairing, or female pairing success. However, males with nasal discs had lower pairing success, and females with nasal discs were less likely to reunite with previous mates. We speculate that the effect of nasal discs on male pairing success may be due to a male-biased sex ratio and sexual selection on male appearance. Leg band wear should be considered for demographic models because its effects can violate assumptions and bias sighting and survival estimates.

SINOPSIS. **Evaluación de discos nasales y de bandas de colores parlas partas marcar individuos de *Histrionicus histrionicus***

Evaluamos el uso de discos nasales y de bandas coloreadas en las patas en individuos de *Histrionicus histrionicus* invernando en el Estrecho de Georgia, Columbia Británica, al comparar la visibilidad y el largo de vida de ambos marcadores, y al determinar los efectos de los discos nasales en la conducta y el apareamiento. La proporción revisualizada y la frecuencia de detección visual fueron mayores en individuos marcados con discos nasales que en los marcados solo con bandas en las patas. La pérdida de discos nasales siguió una función logística que predijo un 50% de pérdida a los 396 días. El número de detecciones visuales por individuo se redujo con la edad de la banda de pata según una función cúbica debido al desgaste de dichas bandas. No detectamos defectos de los discos nasales en el tiempo invertido en varias conductas, tiempo de aparearse, o de éxito femenino en aparearse. Sin embargo los machos con discos nasales tuvieron un menor éxito en aparearse y las hembras con discos nasales redujeron su probabildad de reunirse con parejas anteriores. Especulamos que el efecto de los discos nasales en el éxito en apareamiento de los machos puedo deberse a una razón de sexos viciada hacia los machos y a la selección sexual por apariencia masculina. Los efectos del uso de bandas en las patas debe ser considerado para modelos demográficos porque pueden violar aseveraciones y viciar las detecciones visuales y los estimados de supervivencia.

Key words: Histrionicus histrionicus, leg band wear, marker retention, nasal disc loss, pairing success, time budgets

Behavioral and demographic studies of birds often rely on markers that allow identification of individuals. Markers vary in life-span, visibility, and effect on individuals, and thus in their usefulness for different research objectives. However, marker induced changes in behavior or survival, or biases resulting from marker loss, are frequently not considered or accounted for (Calvo and Furness 1992). Markers can affect survival (Byers 1987; Schmutz and Morse 2000), pairing and breeding behavior (Frankel and Baskett 1963; Kinkel 1989; Metz and Weatherhead 1991), and time spent in different behaviors (Brua 1998; Pelayo and Clark 2000). Marker life-span may violate assumptions and bias estimates from mark-recapture analyses (Arnason and Mills 1981; Nichols and Hines 1993).

Colored tarsus markers (leg bands) and nasal markers (discs or saddles) are two common marking techniques for waterfowl (Bartonek and Dane 1964; Sugden and Poston 1968). Nasal markers allow identification during most behaviors, whereas leg bands can only be seen when the legs are exposed. Nasal markers are thus an attractive choice, especially when birds spend most of their time in the water or when they mix in flocks. Nasal markers may have the disadvantage of a short life-span (Sherwood 1966); however, leg bands also decline in usefulness over time due to loss or wear (Mills 1972; Spendelow et al. 1994). Some studies us-

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ing nasal markers have reported changes in behavior (McKinney and Derrickson 1979; Evrard 1996; Pelayo and Clark 2000), reduced pairing success (Koob 1981), delayed timing of breeding (Howerter et al. 1997), and injury or increased mortality from entanglement in netting and submerged vegetation (Erskine in Bartonek and Dane 1964; Sherwood 1966; Evrard 1986) and from icing (Greenwood and Bair 1974; Byers 1987), whereas others have reported no such effects (Bartonek and Dane 1964; Sugden and Poston 1968; Raveling 1969; Savard 1988).

We evaluated nasal discs and colored leg bands as markers for Harlequin Ducks (*Histrionicus histrionicus*) at coastal wintering areas in British Columbia. To our knowledge no information has been published evaluating markers for Harlequin Ducks, and few studies have evaluated markers for diving ducks at wintering areas. Our objectives were to compare marker visibility and life span, to determine if nasal discs affect behavior and pairing success, and, considering the life-span of leg bands, to test the assumption of mark-recapture analysis that all marked individuals have equal probability of being sighted (Cormack 1964).

METHODS

Study area and capture. As part of a larger study, over 2500 Harlequin Ducks were captured during their wing molt by corralling them into a drive trap erected along the shoreline (Clarkson and Goudie 1994) in July through September, 1994–2000. Primary capture locations were White Rock, Hornby Island, Quadra Island, and the east coast of Vancouver Island between Comox and Campbell River, in the Strait of Georgia, British Columbia, Canada.

Marking methods. All captured individuals were marked with a metal (aluminum before 1999; stainless steel in 1999–2001) United States Fish and Wildlife Service band on the left tarsus, and a laminated plastic 2-digit alphanumerically encoded color band with code cut out to expose the inner color layer (manufactured by Protouch Engraving, Saskatoon, Saskatchewan, Canada) on the right tarsus. Overlapping ends were glued with acetone. Worn leg bands were replaced on recaptured birds. Individuals were aged as adult (after-third year) or sub-adult (third-year and younger) by absence or presence of the Bursa of Fabricius (Kortwright 1943; Mather and Esler 1999).

In 1997–2000 we marked 457 individuals with nasal discs in addition to colored leg bands. Most (96%) were marked in 1998 and 1999. Discs of four shapes (circle, diamond, rectangle, triangle) and eight colors (aqua, black, blue, green, orange, red, white, yellow) were cut, 9 mm maximum diameter, from Darvic plastic (a PVC plastic resistant to UV light manufactured by A.C. Hughes Ltd., Middlesex, England). We attached disks using a 36 kg monofilament fishing line connector and marked each individual with a unique combination of two nasal discs attached on either side of the nares, as described by Bartonek and Dane (1964).

Resighting of marked individuals. Marked individuals were identified by spotting scope opportunistically throughout the fall, winter, and spring, 1997–2001. In addition, a large band-reading effort involving many researchers and volunteers was conducted each year at Hornby Island during March and April when large numbers of Harlequin Ducks congregated at Pacific herring (*Clupea pallasi*) spawning sites.

Marker visibility. We compared the visibility of colored leg bands and nasal discs during winter, when birds spend much of their time feeding (Goudie and Ankney 1986; Fischer and Griffin 2000) and their legs are infrequently exposed, and during the herring-spawning period in spring at Hornby Island, when birds frequently haul out. For each period we compared the probability that an individual was sighted, equal to the number of marked individuals that were seen at least once during that period out of the total number known to be alive (i.e., seen in that period or at a later date), and for those that were seen at least once, the number of sightings per individual. We included only sightings from 1998 to 2001 when both markers were in use, thereby equalizing observer effort for the two marker types.

Nasal disc loss. We recorded nasal disc loss when individuals previously marked with nasal discs were identified without them by their leg bands. Loss of both markers was unlikely because no individuals with nasal discs were seen with an illegible or missing leg band. We estimated date of loss as the midpoint between observations with and without discs. To calculate loss rate, we regressed number of individuals retaining discs on number of days after disc attachment. Individuals that were not resighted or whose nasal disc status could not be assessed at the end of the study were excluded.

Leg band wear. To estimate rate of leg band wear and test the assumption that sighting probability does not vary among marked individuals, we regressed number of sightings (>0) per individual on age (number of partial or full year since attachment) of their colored leg bands. We used data from the annual spring band-reading effort at Hornby Island, excluding individuals marked with nasal discs. We expected the number of sightings per individual to be highly variable and affected by many factors, such as bird behavior and location, as well as leg band age. However, we assumed that the effect of leg band age was independent, and that declines in numbers of sightings with leg band age could be attributed to leg band wear. New leg bands put on first-captured birds of various ages, and replacement leg bands put on some recaptured birds during each fall maintained new leg bands in the sample and ensured that neither bird age nor yearly fluctuations in observer effort were correlated with leg band age. However, because few years of data contributed to the oldest leg band ages, we examined the last two years separately to confirm that trends in leg band wear rates also held within years and were not biased by annual differences in observer effort.

We also compared proportions of colored leg bands that were worn and replaced on recaptured birds among leg band ages. These proportions did not equal the rate of leg band loss to the study because leg bands were frequently replaced before they were illegible. We considered recaptured individuals a representative sample of the marked population.

Effect of nasal discs on time budgets. We conducted 834 continuous, 30-min behavioral observation sessions on random individuals (Altman 1974), 450 on males and 384 on females from February to April in 1998 and 1999. Eighty-eight of these sessions were on individuals marked with nasal discs. Sampling from large numbers of birds throughout daylight hours and over a three-month period minimized the chance of repeatedly sampling the same individuals. We were unable to assess the effect of leg bands on behavior because during many behaviors it was not possible to distinguish leg-banded from unmarked individuals. We conducted observations using a 15–60 × spotting scope from a hidden or distant location to ensure that we did not affect behavior. We divided behavior into six categories: feeding, resting, maintenance, locomotion, defense, and courtship.

Effect of nasal discs on pairing behavior. Harlequin Ducks pair during winter and form long-term pair bonds (Robertson and Goudie 1999). We compared pairing success, timing of pairing, and the proportion reuniting with a previous mate between birds marked with nasal discs and birds marked only with leg bands. We included only adults in these analyses because pairing probability differs with age (Robertson et al. 1998). Birds were considered paired if they remained in close proximity, behaved synchronously, and exhibited defense behaviors such as mate guarding (Gowans et al. 1997). Our observations indicated that individuals behave contrary to their paired status for short periods of time but that 30 min was usually adequate to confidently assess paired status. We thus considered paired status confirmed if birds appeared paired or unpaired for most of a 30 min behavioral observation or if we had at least two consistent records from opportunistic sightings. We determined proportions of birds that successfully paired in a particular year only from observations and sightings made in spring (March, April, or May) to avoid bias caused by the fact that paired status could be confirmed throughout the winter but unpaired status could only be confirmed in the spring. We estimated pair date as the date of the first paired record. To ensure that pair dates were accurate within 30 d, we accepted all pair dates prior to 31 October, because pairing rarely occurs before the end of September, but required that individuals were seen unpaired no more than 30 d prior to a pair date after 31 October. Only pairs in which both partners were marked and known to be alive were considered to calculate proportions reuniting.

Statistical analyses. To compare proportions we used Fisher's Exact Test when more than 20% of cells had expected counts less than five, otherwise we used chi-squared tests. In our analysis of marker visibility we used ANCOVA, including the effect of leg band age, to test for

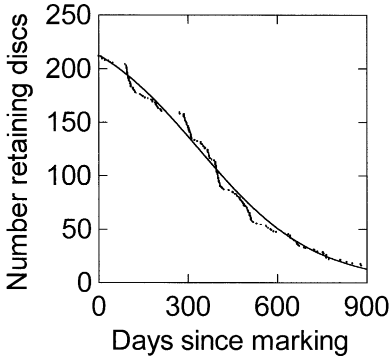

Fig. 1. Number of Harlequin Ducks retaining nasal discs for up to 900 d after attachment in the Strait of Georgia, British Columbia, 1997–2001.

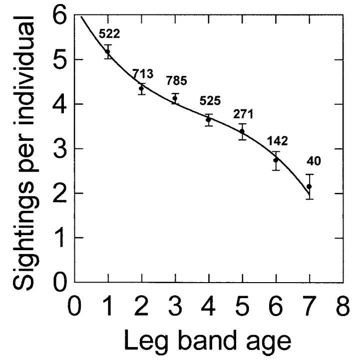

Fig. 2. Relationship between leg band age and the mean (±SE) number of sightings per individual of Harlequin Ducks known to be alive and marked only with color leg bands at Hornby Island, British Columbia, during the herring spawning period in March and April, 1997–2001. Sample size is given for each mean.

a nasal disc effect on numbers of sightings. We estimated rates of nasal disc loss and leg band wear using the Curve Estimation function in SPSS (1997) to test for curvilinear relationships, and compared model fit based on R^2 values and biological realism. To analyze the effect of nasal discs on time budgets we compared arcsine transformed (Sokal and Rohlf 1995) proportions of time spent in each behavior between individuals with and without nasal discs. Paired status, as well as location, date, sex, and the interaction of location and date, which were known to be important explanatory variables in time budget analyses (M. Rodway, unpubl. data), were included in General Linear Models (SPSS 1997). We used ANOVA to compare pair dates. We examined residuals from parametric tests to ensure that assumptions of normality and homoscedasticity were met. Type I error rate at was set at 0.05, except in the analysis of time budgets where we used a Bonferroni adjustment for five comparisons and accepted a type I error rate of 0.01. Adjusted means ± SE are reported.

RESULTS

Marker visibility. During winter, the proportion of marked individuals seen at least once was over three times greater for those marked with nasal discs (53.2%, $N = 356$) than for those marked only with leg bands (15.8%, $N = 441$; $\chi^2_1 = 427.3$, $P < 0.001$), and those identified were seen over twice as often if they had nasal discs (3.2 ± 0.1 times/winter) than if they did not (1.5 ± 0.1 times/winter; $F_{1,780} = 83.8$, $P < 0.001$). During spring the proportion of marked individuals that were seen at least once was also greater for those marked with nasal discs (63.2%, $N = 423$) than for those without nasal discs (56.4%, $N = 1576$; $\chi^2_1 = 10.4$, $P = 0.001$), and those with nasal discs were seen more frequently (7.0 ± 0.2 times/spring) than those without (4.1 ± 0.1 times/spring; $F_{1,1938} = 131.7$, $P < 0.001$).

Nasal disc loss. Of 212 individuals whose nasal disc fates were known 900 d after attachment, 196 individuals had lost their discs and 16 retained them. The rate of disc loss was best described by a logistic equation (number remaining = $1/(1/250 + (0.0007 * (1.0052^d)))$) ($R^2 = 0.99$, $F_{2,195} = 15{,}185.0$, $P < 0.001$; Fig. 1). This function predicted that half of all discs were lost by 396 d after attachment and that 6% remained after 900 d. Because nasal disc loss assessment depended on identification by leg bands, and because sighting probability was lower for leg banded than nasal marked birds, the true nasal disc loss rate was likely higher.

Leg band wear. The relationship between number of sightings per individual marked only with colored leg bands and leg band age was best described by a cubic relationship (number of sightings = $6.23 + (-1.35 * \text{leg band age}) + (0.28 * \text{leg band age}^2) + (-0.02 * \text{leg band age}^3)$) ($R^2 = 0.04$, $F_{4,2994} = 40.9$, $P < 0.001$; Fig. 2), predicting that a 6-yr-old leg band would be seen about 0.5 times as often, and an

8-yr-old leg band about 0.1 times as often, as a 1-yr-old leg band. This significant cubic relationship also held when data from 2000 ($R^2 = 0.04$, $F_{4,497} = 7.6$, $P < 0.001$) and 2001 ($R^2 = 0.04$, $F_{4,391} = 4.8$, $P = 0.003$) were analyzed separately. The proportion of colored leg bands replaced on recaptured individuals increased rapidly over six years. We replaced 11% ($N = 185$), 36% ($N = 92$), 66% ($N = 61$), 79% ($N = 38$), 93% ($N = 15$), and 100% ($N = 1$), of leg bands aged one, two, three, four, five, and six years, respectively.

Effect of nasal discs on time budgets. There were no significant differences in the percentage of time spent by individuals with and without nasal discs in feeding (49.2 ± 3.1 vs. 45.3 ± 1.2; $F_{1,825} = 1.83$, $P = 0.18$), resting (13.0 ± 2.8 vs. 16.8 ± 1.1; $F_{1,825} = 1.82$, $P = 0.18$), maintenance (17.9 ± 2.1 vs. 17.5 ± 0.8; $F_{1,825} = 0.00$, $P = 0.99$), locomotion (18.1 ± 2.0 vs. 17.9 ± 0.8; $F_{1,825} = 0.01$, $P = 0.91$), defense (0.2 ± 0.2 vs. 0.3 ± 0.1; $F_{1,825} = 0.76$, $P = 0.39$), or courtship behaviors (1.4 ± 0.6 vs. 2.2 ± 0.2; $F_{1,825} = 1.35$, $P = 0.25$). Power analysis revealed that differences in effect size of 6, 4, 3, 3, <1, and <1% could have been detected with a power of 0.8 for feeding, resting, maintenance, locomotion, defense, and courtship behaviors, respectively.

Effect of nasal discs on pairing behavior. Pairing success was lower for adult males with (28.1%, $N = 64$) than without (89.0%, $N = 309$; $\chi^2_1 = 116.6$, $P < 0.001$) nasal discs. We found no difference in the proportion of males reuniting with previous mates between males with (100%, $N = 5$) and without (96.6%, $N = 117$) nasal discs (Fisher's Exact Test, $P = 0.84$), although sample size of paired males with nasal discs was small. There was no difference in pairing success for adult females with (100%, $N = 113$) and without (99.6%, $N = 254$) nasal discs (Fisher's Exact Test, $P = 0.69$), although fewer females with (81.3%, $N = 16$) than without (98.2%, $N = 111$) nasal discs reunited with previous mates (Fisher's Exact Test, $P = 0.014$). The lower proportion of nasal-marked females reuniting was not due to nasal marking of their mates because all paired males with nasal disks reunited with previous mates. We did not detect any differences in pair dates for birds with and without nasal discs for either males (23 October ± 4.6 vs. 18 November ± 8.1; $F_{1,63} = 1.43$, $P = 0.24$) or females (11 November ± 6.2 vs. 30 October ± 5.9; $F_{1,95} = 1.89$, $P = 0.172$).

DISCUSSION

Nasal discs and colored alpha-numerically coded leg bands used as markers for Harlequin Ducks differed in visibility and life-span. More individuals were identified and those identified were sighted more frequently when marked with nasal discs than when marked with leg bands only, especially during winter when birds rarely haul out. However, the life-span of nasal discs was much shorter than that of leg bands. Half of all nasal discs were lost within 13 mo, while only 11% of 1-yr-old leg bands on recaptured individuals were replaced due to wear, and some of these would still have been legible when replaced and were not yet lost to the study.

Information on marker life-span is critical to many studies, particularly demographic studies in which marker wear or loss can bias survival, movement, and sighting estimates. Relatively long life-spans of colored leg bands in this study implicate these as suitable markers for demographic studies. However, our results indicate that leg band wear reduces sighting probabilities, thereby violating an important assumption in mark-recapture analysis. Severe leg band wear is equivalent to marker loss and is confounded with mortality and emigration. Known rates of marker wear and loss can be used to reduce biases and improve precision of the estimates (Arnason and Mills 1981; Nichols and Hines 1993).

Retention rates of nasal markers vary widely among published studies (Bartonek and Dane 1964; Sugden and Poston 1968; Greenwood 1977; Lokemoen and Sharp 1985), ranging from 20% retention in the first year for Canada Geese (*Branta canadensis*; Sherwood 1966) to 86% retention in over one year for Blue-winged Teal (*Anas discors*) and Mallards (*A. platyrhynchos*) (Evrard 1996). Retention rates likely vary due to differences in materials and attachment methods and differences in behavior among species. Rapid loss rates in Canada Geese have been explained by the abrasive action of sand, gravel, and mud on the nylon monofilament connector during feeding (Sherwood 1966). Similarly, Harlequin Ducks dive and probe for benthic invertebrates beneath small rocks and cobbles, often highly abrasive from barnacle growth (Robertson and Goudie 1999), which likely causes poor nasal disc retention. Use of stainless steel pins (Doty and Greenwood 1974; Lokemoen and Sharp 1985) could improve disc retention if loss is primarily caused by weakening of the monofilament connector (Greenwood 1977). However, wear of the plastic shapes was observed for some individuals, and exposure to sunlight eventually causes colors to fade.

High nasal disc visibility and short life span have both positive and negative aspects. High visibility make nasal discs attractive markers for winter studies when identification using leg bands is difficult, and for behavioral studies in which marked individuals must be identifiable during all behaviors. In contrast, the short life span of nasal discs make them less suitable for studies that require monitoring known individuals for extended periods of time. Rapid loss of a highly visible marker may, however, be an attractive quality for ethical and aesthetic reasons, particularly for species such as Harlequin Ducks, whose near-shore shore habitat and colorful plumage make them popular for wildlife viewing. Short retention times also ensure that any negative impacts on marked individuals, such as icing, entanglement, or decreased pairing success are minimized.

We did not detect a marker effect on the proportions of time spent in any of the behaviors measured in this study, possibly partly because our nasal markers were small relative to bill size. Proportion of time spent in maintenance did not increase and we observed no increase in bill scratching, which is frequently noted for nasal marked waterfowl (McKinney and Derrickson 1979; Koob 1981; Evrard 1996; Pelayo and Clark 2000). However, pairing success of males was reduced from 89 to 28% due to nasal marking, and fewer marked than unmarked females re-united with previous mates. Koob (1981) also observed that male Ruddy Ducks (*Oxyura jamaicensis*) with nasal saddles had low pairing success and rapidly lost their mates following marking. In contrast to our study, however, Ruddy Ducks with nasal markers decreased time spent in courtship and dramatically increased time spent in maintenance, the latter resulting almost entirely from maintenance behavior directed specifically at the nasal saddle (Koob 1981). Because nasal discs did not affect time budgets in our study, it seems likely that the effects of nasal discs on pairing success and repairing were not attributable to indirect effects, as was observed for Ruddy Ducks, but more likely reflect direct effects of nasal discs on appearance.

Colorful plumage of male Harlequin and other migratory ducks has been sexually selected and likely functions in female mate choice, male-male competition, or species recognition (Andersson 1994). Greater female choosiness due to a male-biased sex-ratio (Robertson and Goudie 1999) may explain why pairing success of male but not female Harlequin Ducks was reduced by nasal marking. Interestingly, even though female pairing success was unaffected by nasal markers, females with nasal discs were less likely to reunite with previous mates. Thus nasal discs may have reduced their attractiveness to experienced males, resulting in mate change, or affected individual recognition.

The impact that nasal discs had on pairing behavior suggests that nasal discs should not be used to study pairing success of males or repairing in either sex. However, because some aspects of courtship and pairing behavior may be relatively unaffected (e.g., timing of pairing, pairing success of females), and because pairing occurs during winter when birds rarely haul out, some such studies may benefit from nasal markers.

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