# ASSESSING THE TYPE AND FREQUENCY OF BAND RESIGHTING ERRORS FOR RAZORBILL *ALCA TORDA* WITH IMPLICATIONS FOR OTHER WILDLIFE STUDIES

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**SUMMARY**

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Visual markers are frequently used in wildlife studies to identify individual animals and to track their behaviour (including movement) and survival. These markers are useful because identification can be made without recapturing individuals, thus minimizing disturbance. However, studies have shown that errors associated with reading and recording markers adversely influence the estimation of population parameters. Using the example of triangular field-readable leg bands on Razorbill *Alca torda*, we developed a simple experimental protocol for quantifying band resighting error rates and identifying trends in digit misidentifications. The resighting error rate varied from 0.035 to 0.134 depending on observer distance and conditions under which the bands were read. Misidentification of the digits 3 and 5 accounted for more than 48% of all errors made. In our study, 94% of all misread bands corresponded to a valid entry in the banding data base (i.e. misread numbers coincidentally referred to other banded birds), probably because more than 12 000 Razorbills have been banded from one long sequence of band numbers between 1980 and 2007. We conclude that band reading error is a neglected phenomenon that has likely had profound effects on the accuracy of survival studies, and we provide suggestions for minimizing the frequency of such errors.

Key words: Band resighting error, capture–mark–recapture, Razorbill, *Alca torda*

## INTRODUCTION

The use of capture–mark–recapture/resight (CMR) techniques in wildlife studies has presented numerous challenges, including loss of or damage to bands, especially in long-lived species (Austin 1957, Lloyd & Perrins 1977, Lyngs 2006). A key component of CMR survival models is the adherence of recapture data to model assumptions, two of which are that tags are not lost and that individuals remain equally identifiable (Anderson *et al.* 1985, Pollock 1991). Band wear and loss clearly violate these assumptions and, as a result, have received much attention in the literature. However, an equally serious violation, here referred to as resighting error (misreading of one or more of the inscribed digits on a "field-readable" band), has rarely been addressed and is therefore the focus of this study.

For most long-lived animals, survival of breeding adults is a crucial parameter (Pfister 1998, Saether & Bakke 2000), and so accurate estimation of that survival is of critical importance. In seabirds, much data can be collected with minimal disturbance to breeding colonies through the resighting of marked individuals. As a result, this technique has become widely used (Lebreton 2001). However, errors associated with reading and recording of band combinations are not uncommon and have been shown to influence the estimation of population parameters (Weiss *et al.* 1991, Schwarz & Stobo 1999, Atkinson *et al.* 2001).

Recent advances have been made in modeling to incorporate factors such as band loss and band wear into survival analyses (Schwarz & Stobo 1999, Conn *et al.* 2004); it is therefore important to develop new ways to estimate this error. Here, we present a case study using Razorbills *Alca torda* to quantify band resighting error rates. The objectives of the study were to

- estimate band resighting error rates under controlled and natural conditions;
- to identify factors associated with resighting errors, including distance and digits used; and
- to recommend methods that may reduce resighting error in future studies.

## METHODS

### Study sites

The primary field study site was the Gannet Islands, Newfoundland and Labrador, Canada (53°56′N, 56°30′W), located in the northwest Atlantic Ocean, approximately 40 kilometres northeast of Cartwright, Newfoundland and Labrador. The Gannet Islands support the largest colony of Razorbills in North America—approximately 9800 breeding pairs (Chapdelaine *et al.* 2001). Banding of Razorbill adults and chicks began in 1996, and to date, more than 6000 birds have been banded. Additional data (experimental protocol only, see below) was collected on Machias Seal Island, New Brunswick, Canada (44°3′N, 67°06′W), and Tern Island, Hawaii (23°45′N, 166°10′W), USA.

**Band structure and combinations in use**

Captured Razorbills were banded with size 5 Canadian Wildlife Service (CWS) triangular stainless steel leg bands engraved with a three-digit prefix and five-digit suffix. The size of the prefix digits (1 mm) is such that they cannot be reliably read with a telescope at distances of more than 5–10 m, and for the purposes of this study, prefixes were not considered in our analyses. The five-digit suffix consists of stamped numbers 4 mm in height (Fig. 1).

Triangular field-readable Razorbill bands have been issued by the CWS bird banding office to researchers in Atlantic Canada and Quebec since 1995. Bands are typically issued in bundles of 50 or 100, and researchers can request 1000 bands or more annually. There are currently no measures in place to ensure that various banding locations receive band series that are significantly different from other sites (i.e. all Razorbill bands have an 895 prefix and, until 2006, all band suffixes began with the digit 1). For example, band strings 895-14001 to 895-14300 were used on Machias Seal Island and bands 895-14301 to 895-14500 were used on the Gannet Islands (Table 1). To date, more than 12 000 Razorbills have been banded (most as chicks) in Atlantic Canada and Quebec, and only a small number of bands issued to researchers are not currently placed on Razorbills (i.e. are still in the lab).

**Razorbill band reading and reliability trials**

To evaluate the type and frequency of band reading errors encountered with CWS size 5 triangular Razorbill bands, we employed two protocols:

- Our "natural conditions" protocol used banded birds at the Gannet Islands and Machias Seal Island.
- Our "experimental" protocol involving reading bands only under controlled conditions in St. John's, Newfoundland and Labrador, and on the Gannet Islands and Tern Island.


**Fig. 1.** Photo of a Canadian Wildlife Service size 5 Razorbill band used in this study.

*Natural conditions protocol*

Two participants at a time were asked to read band numbers on up to 30 marked Razorbills from a blind on the Gannet Islands while sharing the same Swarovski STS-80 HD spotting scope. All bands were read using 20× magnification. Razorbills were located no more than 15 m from the front of the blind. Each participant was given five seconds to view the band through the scope and then record the band number in private. Participants were asked to rank each resighting according to the following reliability scale:

- Excellent resight—participant is 100% confident that they accurately read and recorded the band number.
- Good resight—participant is more than 95% sure that they accurately recorded the band number; however, in a natural setting, they would have elected to follow the bird for a longer period of time
- Poor resight—participant is unsure of one or more digits in the band number.

Participants were then given time to make any additional comments, including a justification for each ranking (i.e. poor light reflection off the band, not enough lighting to view band, bird was in motion).

Resightings from both participants were compared and contradictory resighting events (i.e. the band number recorded by one participant did not match that recorded by the other participant) were identified. Because it was not possible to determine which of the recorded numbers was correct (or if both recorded numbers were incorrect), we developed an experimental protocol for which the correct band number was known.

*Experimental protocol*

Twenty-five participants were asked to resight 20 Razorbill bands (not attached to birds' legs) in carefully controlled conditions, at distances of 15 m and 22 m with the spotting scope set to 20× magnification. Because the probability of misreading a given band combination may not be equal for all bands, all test bands were selected at random to minimize bias. The examiner recorded the correct band number and placed the band on a flat platform facing directly toward the participant. The participant was then given five seconds to observe and record the band number. Additional time was given to allow participants to provide a ranking (as described above) and any additional comments. The band numbers recorded by each participant were then compared to the known band numbers and incorrect resightings were identified.

**TABLE 1**
**Banding records for Razorbills *Alca torda* in Atlantic Canada, showing how various banding locations are issued bands in close series**

| Band number | | Location used |
|---|---|---|
| From | To | |
| 895-14001 | 895-14300 | Machias Seal Island, New Brunswick |
| 895-14301 | 895-14500 | Gannet Islands, Newfoundland and Labrador |
| 895-14501 | 895-15105 | Gulf of St. Lawrence, Quebec |
| 895-16801 | 895-16825 | Hamilton Inlet, Newfoundland and Labrador |
| 895-16826 | 895-16976 | Witless Bay, Newfoundland and Labrador |

**Weather and participant data**

For both protocols, the dates on which all experiments were conducted were carefully selected to ensure consistent weather conditions. Weather data recorded included percent cloud cover, wind speed and direction, and temperature. Experiments were conducted over five days during May 2005 and July 2006 when observed wind speed was less than 10 km/h and cloud cover was below 20%. Participants were asked to provide information on the number of months or years during which they had experience in resighting birds and the type (i.e. color or metal) and size of bands resighted.

**Statistical analyses**

Statistical analyses were conducted using JMP (2005: SAS Institute, Cary, NC, USA). Resightings that received a poor reliability ranking from the participant were excluded from all calculations. Error rates were determined by calculating the number of bands or digits read incorrectly divided by the total number of bands or digits read. The number of errors and poor resights were calculated for each distance variable in the experimental protocol and statistical significance was determined using the Pearson chi-square test (Sokal & Rohlf 2000). We used a two-sample *t*-test to determine whether the number of incorrect recordings varied for observations ranked as good and excellent. Trends in digits that were consistently read incorrectly were identified, and the error rate per digit (0 through 9) was calculated by dividing the number of times the digit was misidentified by the total number of times the digit was available to be read (i.e. included in the band number being read by the participant).

## RESULTS

**Natural conditions protocol**

A total of 73 individual bands were read over four days. Each band was read by at least two participants with 24 bands being resighted in two or more stints. The total number of resightings was 228. Eight inconsistencies were identified, giving an apparent error rate of 0.035 [standard error (SE) = 0.01, n = 228, Table 2]. There was no bias in the errors for a particular band combination; the eight errors occurred with eight different bands. Of the errors made, the most common involved the digits 8 and 9. However, when considering the number of errors made per digit as a proportion of the total number of times the digit was available to be read, the digit 5 accounted for the highest number of errors (error rate = 0.27).

**Experimental protocol**

No bias in misreading rates for individual bands or participants was detected. For each participant, 20 bands were selected at random from a set of 41 bands at both 15 m and 22 m; therefore some bands were read twice by the same participant. Only four participants read the same band incorrectly twice (i.e. at both 15 m and 22 m), and the variation in misreading rates for each band was small, ranging from 0.041 to 0.136.

At 15 m a total of 406 resightings were recorded (excluding poor resights), and 24 errors (20 single-digit errors, 4 multiple-digit errors) were identified, generating an error rate of 0.059 (Table 2). At 22 m, 356 resightings were recorded, and 48 errors (45 single-digit errors, 3 multiple-digit errors) were identified for an error rate of 0.134. Only four of the 72 misreads recorded by participants did not correspond to a valid band number in the banding database.

Table 2 presents error frequencies for the most commonly misidentified band digits. Overall, the digits 5 (n = 17) and 3 (n = 16) were the most frequently misidentified, accounting for more than 48% of all errors made. Proportionately, however, the digits 5 and 6 were read incorrectly the greatest number of times (error rate = 0.51 and 0.46 respectively); 0 was read incorrectly the least number of times (error rate = 0.004).

**Ranking of resightings**

As stated earlier, all observations that received a poor ranking were excluded from the analyses; however, the frequency of these rankings and their relationship to resighting distance may be informative for some readers, and so the data are presented here. Participants gave a "poor" ranking to 45 observations at 15 m and 108 observations at 22 m. Observations that received a poor ranking accounted for 15.8% (n = 153) of all band readings. Overall, the number of incorrect resightings and rankings recorded as "poor" were significantly greater at 22 m than at 15 meters ($P < 0.001$, $\chi^2 = 12.71$).

For observations that were included in the analyses, a significantly larger number of the incorrect observations received a good ranking (n = 39) than received an excellent ranking (n = 11, $P = 0.004$, $t = 3.03$). All observations in which two digits were read incorrectly for the same band (n = 4) received a good ranking.

**Observer experience level**

The small sample size made it impossible to address the issue of the effect of past resighting experience on the error rate; however, from a simple review of the data, participant experience does not appear to be correlated with ability to correctly identify band numbers. Errors were detected for 21 of the 25 participants, with multiple errors being made by individuals with little and with extensive resighting experience.

**TABLE 2**
**The seven sets of digits most frequently associated with resighting errors made under natural and experimental conditions of Canadian Wildlife Service size 5 Razorbill bands**

| Digits mis-identified | Experimental conditions | | Natural conditions | Total |
|---|---|---|---|---|
| | 15 m | 22 m | 15 m | |
| 1 for 7 | 0 | 3 | 1 | 4 |
| 7 for 1 | 0 | 4 | 0 | 4 |
| 3 for 5 | 1 | 2 | 1 | 4 |
| 5 for 3 | 1 | 2 | 0 | 3 |
| 3 for 6 | 0 | 2 | 0 | 2 |
| 6 for 3 | 2 | 2 | 0 | 4 |
| 3 for 8 | 0 | 1 | 0 | 1 |
| 8 for 3 | 0 | 2 | 0 | 2 |
| 5 for 6 | 3 | 5 | 0 | 8 |
| 6 for 5 | 0 | 3 | 1 | 4 |
| 5 for 9 | 0 | 0 | 1 | 1 |
| 9 for 5 | 1 | 1 | 0 | 2 |
| 8 for 9 | 2 | 2 | 1 | 5 |
| 9 for 8 | 2 | 0 | 1 | 3 |

## DISCUSSION

Numerous studies have used CMR techniques to report parameter estimates for a variety of species (see Pollock 1991 and Lebreton *et al.* 1992 for reviews). However, only a few studies have examined the effects of resighting error on survival estimation, and they have produced somewhat conflicting results. For example, Weiss *et al.* (1991) found that 6.3% of resightings of neck-banded Canada Geese *Branta canadensis* were incorrectly made after the bird was recaptured without a neck band or was harvested. However, this error was not found to significantly influence the survival estimate. Schwarz & Stobo (1999) found that, for branded seals, misreads were infrequent and easily detected. The survival estimate was therefore only slightly inflated early in the study. And finally, Milligan *et al.* 2003 found that resighting error rates for color-banded passerines (using model birds under simulated natural conditions) ranged from 7% to 54% depending on observer experience, the amount of time allotted for resighting and the number of birds present.

Results of the experimental conditions protocol show that, overall, the resighting error rate was high (range: 0.035–0.134) and varied with observer distance. However, the experimental protocol likely proved a greater challenge for the observer than did the conditions under which resighting would naturally occur. For example, under typical resighting conditions, Razorbills walk around, allowing the observer to view the band from different angles, often providing lighting angles that maximize visibility of the numbers on the bands (J. Lavers & I. Jones pers. obs.). Furthermore, the observer is not usually limited to five seconds' observation time. We therefore feel that the error rate reported for the experimental protocol may be an overestimate.

We acknowledge the foregoing limitations and emphasize that the main purpose of this part of the study was not to precisely estimate error in the field but to identify trends in digit errors using known band numbers. Overall, we feel that the error rate calculated under natural conditions (0.035) is a closer approximation to the actual error generated when resighting live individuals. It is comparable to the error rate reported during the resighting of live birds by Weiss *et al.* (1991).

Trends in the misidentification of certain digits were identified. The most problematic digits were 5 and 6. In contrast to our study, the study by Weiss *et al.* (1991) found that the digit 6 had the lowest error rate. We initially expected that, given their similarity in structure, the digits 3 and 8 were the most likely to be confused. However, this combination of digits accounted for only 5% of the errors made. Weiss *et al.* (1991) and Clark *et al.* (2005) also reported distinct trends in the identification of certain letters used to code bands; yet, interestingly, the recommendations of each study are contradictory. That is, Weiss *et al.* (1991) recommend avoiding the letters J, P, and T; and Clark *et al.* (2005) strongly recommend their use. In addition, Milligan *et al.* (2003) found that certain color combinations, namely dark blue and light blue, were associated with a higher frequency of errors and missed band readings.

The results of the present study highlight a number of issues relating to the resighting and recording of band numbers. First, on two occasions, participants appeared to have correctly observed the band number presented, but recorded the digits in the wrong order. Thus errors in resighting data accumulated both from difficulties in observing and in recording band numbers. Although digit transpositions were infrequent and likely not a significant source of error for this study, we feel that transposition is a concern that must be addressed by researchers who are training individuals to resight bands. Second, because band numbers engraved on leg bands are not manufactured or distributed randomly, individuals banded at a common place or time have band numbers that often have many digits in common. Because researchers are often required to return to the same colonies multiple times to conduct resighting stints, repeated observations of similar band numbers may lead to complacency and assumptive behaviour. A final and perhaps more important issue is the fact that when one band is misread, it often generates two separate errors—as when the band number resighted is misidentified or recorded incorrectly, but matches another banded individual. In this case, the bird resighted will not be recorded as present in the population, and the bird that was not seen, but whose band number was recorded will appear in the dataset. In the present study, 94% of the bands that were misread during the experimental protocol corresponded to an existing band number in the database. That situation is likely the most troubling source of error, because it is difficult to detect and quantify, especially when hundreds or thousands of individuals are banded (Milligan *et al.* 2003).

In long-lived species, adult survival is the key parameter to which the population growth rate is the most sensitive (Lebreton & Clobert 1991), meaning that small deviations can have a huge effect on the status of a population. Band resighting error has the potential to seriously influence estimation of the survival rate; it is therefore essential to find a way to accurately incorporate resighting error into survival models. Because the size and type of band used—and the distances and conditions under which resighting is conducted—vary greatly, the resighting error rate should be estimated for studies on an individual basis.

Although we acknowledge that some (or all) of the following recommendations may not be feasible for some studies or for certain types of bands, we feel that it is important to suggest a variety of ways to minimize error so as to promote the development of new ideas and discussion between researchers, banding offices and band manufacturers.

- First, researchers should avoid placing bands in series on individuals in the same location and should attempt to avoid the use of the digits 3 and 5, where possible.
- In addition, as the present study showed, even when the observer reported a high level of confidence in a resighting (i.e. assigned a "good" ranking, thus 95% confident), errors are not uncommon. It is therefore essential that researchers develop and implement their own resighting ranking scheme and also establish minimum criteria for the number of times an individual band number must be resighted before it is considered confirmed.
- Another alternative would be for banders to use only some of the bands issued to them from the banding office. By randomly selecting the bands to be placed on birds and keeping the remaining bands in the lab, incorrect resightings can be more easily detected, and the resighting error rates can be estimated directly from the resighting data. Support for this idea comes from resighting data collected on Machias Seal Island, New Brunswick, where, since 1998, 13 band codes were reported to have been resighted in the field, but the bands were later located in the lab and had clearly not yet been placed on birds (J. Lavers pers. obs.).

Two final recommendations for band manufacturers involve the use of certain fonts and check digits:

- Read Regular fonts featuring improved readability (Frensch 2003) have been developed for individuals with dyslexia. And Clark et al. (2005) reported that Century Gothic gave a much clearer distinction between certain letters and numbers that might otherwise be mistaken for one another.
- A check digit is a form of redundancy check used for error detection. It consists of a single digit computed from the other digits in the message (Kirtland 2000). Check digits have been widely used in Universal Product Codes (UPCs) and International Standard Book Numbers (ISBNs). Both of these options may prove to be an effective (and easy) alternative for band manufacturers.

Although we were unable to statistically test for an effect of observer experience on error rate, a simple review of the data suggested that no effect was present. That finding contrasts with results presented by Milligan *et al.* (2003), who found that the average error rate for untrained observers was more than three times the rate recorded for trained observers (16% and 5% respectively). However, the main effect of observer experience was not statistically significant, and overall, the study suffered from low sample size ($n = 8$). Future studies should conduct an in-depth examination of the relationship between observer experience and resighting error rate.

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