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LETTERS AND COMMENTS

# Conservation implications of misidentification and killing of protected species

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Killing protected species mistaken for morphologically similar quarry species, or species with weaker protection, can hinder their conservation. Despite policy aims to reduce threats from illegal killing, information is lacking on susceptible species, conservation impacts and the identification accuracy of hunters. We examined the ability of hunters ($n$ = 232) in Arctic Russia to identify the endangered Northwest European Bewick's swan *Cygnus columbianus bewickii* using photographs. Only 14% ($n$ = 33) identified this species correctly and distinguished it from sympatric and congeneric whooper swans *C. cygnus* and mute swans *C. olor*, with 15% of individuals admitting to accidentally hunting a Bewick's swan in the previous 3 years. We conclude that there is a risk of Bewick's swans being shot accidentally when mistaken for similar species with less legal protection. Improving hunters' skills in discerning protected from legitimate quarry species is likely to be an effective tool for conservation of morphologically similar species.

**KEYWORDS**
identification accuracy, illegal killing, misidentification of protected species, mitigation, Russia

## 1 | INTRODUCTION

Accidentally killing protected species mistaken for legitimate quarry species presents a problem to threatened wildlife (Agreement on the Conservation of African-Eurasian Migratory Waterbirds [AEWA], 2015). For populations subject to legal hunting, accurate identification is important to ensure sustainable exploitation and avoid impacts on non-target species (Christensen, Madsen, Asferg, Peder Hounisen, & Haugaard, 2017; European Commission, 2008). The ability of hunters to shoot selectively may vary with species, environmental conditions, and hunter experience (European Commission, 2008). Examples of avian species affected by shooting mortality include the critically endangered slender-billed curlew *Numenius tenuirostris* (Gallo-Orsi et al., 2002) and the vulnerable lesser white-fronted goose *Anser erythropus* (AEWA, 2015; Jones, Martin, Barov, & Nagy, 2008). More widely, misidentification of wildlife species may reduce ability or willingness to engage in monitoring and conservation (Robinson, Inger, & Gaston, 2016), have implications for public health (e.g., distinguishing poisonous and nonpoisonous species) and have serious conservation impacts (e.g., removal of native species when mistaken for invasive) (Somaweera, Somaweera, & Shine, 2010).

Despite international attention (e.g., AEWA, 2015; European Commission, 2008; Madsen et al., 2015), information on birds susceptible to misidentification and potential impacts on these species is surprisingly lacking (AEWA, 2015). Though scarce, evaluations of hunters' species-

  

identification skills have mixed outcomes. One study assessing hunters' ability to identify five quarry goose species in Denmark found that 14.5% of 2,160 identifications were incorrect (Christensen et al., 2017). While most hunters on the Mississippi Flyway were able to recognize common waterfowl, females of taxa rarely encountered were frequently misidentified (Wilson & Rohwer, 1995). Globally, few countries grant hunting licenses on the condition of passing a species identification test. In northern Europe, there are notable exceptions including Denmark (Danish Hunters' Association, 2008), Norway (Directorate for Nature Management Trondheim, 2018), Sweden (Svenska Jagareforbundet, 2005), Finland (Hunters' Central organization, 2018), Germany (Deutscher Jagdschutz-Verband, 2003), the Netherlands, Belgium, and Luxembourg (Koninklijke Nederlandse Jagers Vereniging, 2004).

We examined the ability of hunters in the Russian Arctic to identify correctly the endangered Northwest European Bewick's swan *Cygnus columbianus bewickii* (BirdLife International, 2015), which has been protected from hunting under national and international legislation throughout its range since 1954 and 1976, respectively (Rees, 2006), but is still hunted illegally (Gurtovaya, 2000; Mineyev & Mineyev, 2014; Nagy et al., 2012; Newth, Brown, & Rees, 2011). In their Russian Arctic breeding grounds, Bewick's swans may be confused with mute swans *C. olor* (AEWA, 2015), and in particular, whooper swans *C. cygnus*, which are similar in appearance (Figure 1) and distribution (Mineyev & Mineyev, 2011, 2014; Rees, 2006).

Bewick's swan has been included in the Red Data Book of the Russian Federation (and previously the Soviet Union) since 1978, giving it legal protection from hunting across Russia (Mineyev & Kondratiev, 2001). The species is additionally listed in Red Data books for its breeding and moulting areas in the Nenets Autonomous Okrug (NAO) (Gurtovaya & Litvin, 2006) and the Arkhangelsk Oblast (AO) (Novoselov, 2008), emphasizing its protected status in these regions. Further south, it is also protected across staging and wintering areas, yet embedded shot was detected in 31% of individuals x-rayed between winters 1970/1971 and 2008/2009, highlighting the frequent occurrence of shooting this species within the flyway (Newth et al., 2011). Such shooting may have a significant impact on Bewick's swan survival rates (Wood et al., 2018) and is considered a potentially high threat for the population (AEWA, 2015; Nagy et al., 2012). Although whooper swans and mute swans are omitted from huntable species lists in the NAO and AO (Mineyev & Mineyev, 2014), their absence from the Russian Red Data Book means that they have weaker legal protection. Moreover, although whooper swans are included in the regional Red Data Book of the AO (Novoselov, 2008), they are not included for the NAO (Gurtovaya & Litvin, 2006). Mute swans are not listed for either region. The penalty for killing these two species therefore is less severe, and the legal deterrent weaker, than for Bewick's swans (Decree of the Ministry of Natural Resources and Ecology of Russian Federation No. 107 April 28, 2008).

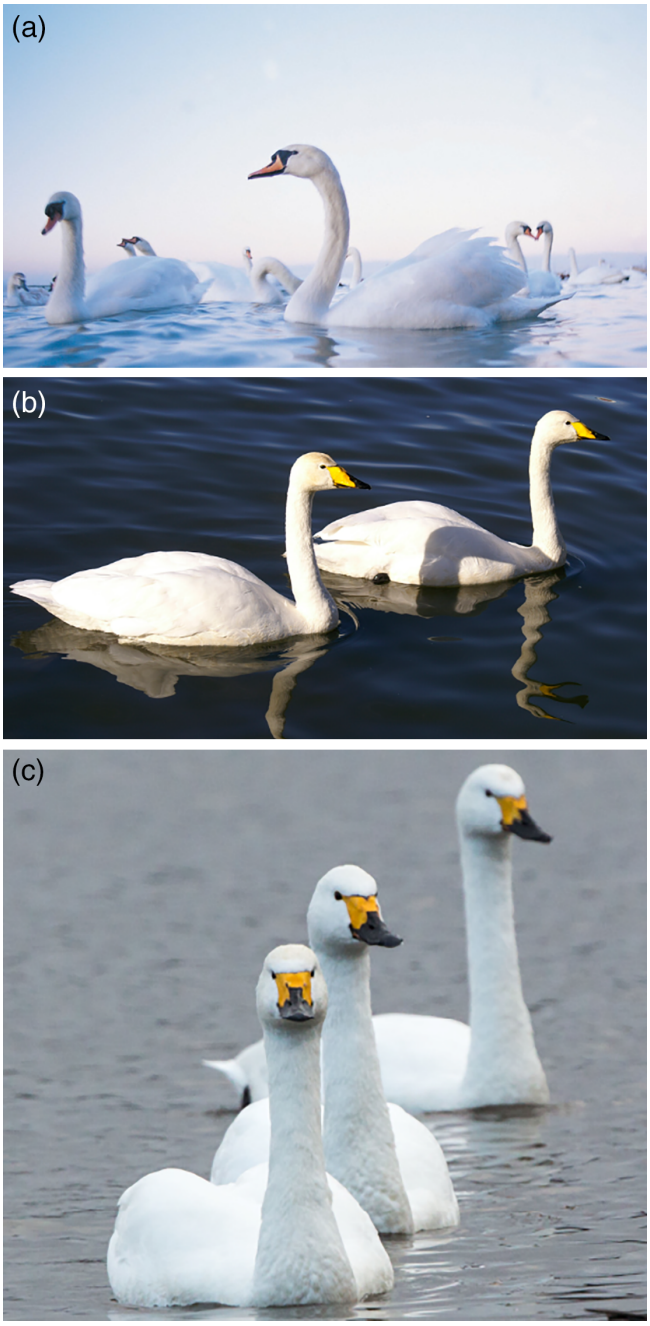


**FIGURE 1** Photographs of adult (a) mute swans, (b) whooper swans and, (c) Bewick's swans used to assess species identification accuracy (photo credit: WWT)

We predicted that Bewick's swans are shot at when deliberately targeted, when mistaken for one of the two morphologically similar and sympatric swan species or through inaccurate targeting of quarry species in close proximity. Given the prevalence of Bewick's swans carrying shot, and that they spend circa 40% of the year in northern Russia (May–September inclusive; Rees, 2006), we tested the ability of a large sample of hunters in European Arctic Russia to distinguish the Bewick's swan from two other swan species

and examined the influence of sociodemographic variables on identification success. Thus we explored the potential role of species misidentification in the illegal killing of Bewick's swans and prospective mitigation measures.

## 2 | METHODS

Hunters from seven settlements in European Arctic Russia (six in the NAO; one in the AO; Figure 2) were surveyed between June 27 and July 16, 2016. The population of the NAO is ethnically diverse, comprising Russians, indigenous Nenets, Komi, and other nationalities, while that of the AO is predominantly Russian (Russian Federal State Statistics Service, 2015). Identities of settlements and participants are not reported to preserve anonymity. Settlements were selected on the basis of: (a) proximity to areas used by Bewick's swans when summering on the tundra or during migration (Mineyev, 1991; Rees, 2006), (b) ethnic heterogeneity of the populations (ensuring all main ethnicities were sampled across the settlements), and (c) ease of access. Questionnaires were administered by three trained facilitators, all Russian speakers, in interviews with participants at a time and location of their convenience. Only those regarding themselves as "hunters" were asked to participate. For each settlement, 2.5% of the total population (based on numbers for 2015; range = 10–88 participants per settlement) was included in the survey.

Given the sensitive nature of illegal killing, snowball sampling was used to recruit participants (Newing, Eagle, Puri, & Watson, 2011). Although it is not possible to make statistical inferences from the sample to the population using this method, information can be gathered from groups that are ordinarily less easily accessed, and influential factors may be identified. Recruitment continued until a sufficient number of individuals had been identified to meet the desired sample for each settlement. All participants were aged 18 years or over. Survey methods were approved by the College of Life and Environmental Sciences (Penryn Campus) Ethics Committee at the University of Exeter (reference 2016/1496) and each respondent gave their free and informed consent prior to participation.

The questionnaire comprised 52 questions; question wording and methods were refined following a pilot survey of 50 inhabitants from one settlement in the NAO between June 24 and July 1, 2015. Only interviews conducted in 2016 are used in the analyses (S1). Participants were asked about their sociodemographic status, residence, hunting frequency and hunter identity (i.e., reason for regarding oneself


**FIGURE 2** Study regions in the Russian Arctic. Grey shading denotes the Nenets autonomous Okrug (NAO) and white shading, Arkhangelsk oblast (AO). In AO, only hunters on the mainland (and not the island of Novaya Zemlya) were surveyed

as a "hunter"), and knowledge about Bewick's swan ecology and the laws protecting them (Table S1; European Commission, 2008; Robinson et al., 2016; Christensen et al., 2017).

To test respondents' ability to distinguish between three swan species, they were shown (in turn) a color photograph (sized 29 × 20 cm) of an adult Bewick's swan, whooper swan, and mute swan (each printed on a separate sheet), and asked to identify each one by their Russian or colloquial name (Appendix S1, Question 7). The participants had the opportunity to view all three photographs at the same time. Previous studies (e.g., Keane, Andriamahatsiaro, Jones, & Milner-Gulland, 2011) have found visual tools useful for ascertaining species identification. Respondents were also asked whether they had hunted Bewick's swans in the region within the previous 3 years (Appendix S1, Question 12).

### 2.1 | Statistical analysis

All analyses were conducted in R 3.1.1 (R Development Core Team, 2016). A generalized linear model (GLM) with binomial error distribution and logit link function was used to assess the effects of the explanatory variables on the hunters' ability to identify a Bewick's swan (0 = incorrect, 1 = correct). Generalized Variance Inflation Factors (GVIFs) checked for multicollinearity between explanatory variables. All variables (Table S1) were within acceptable norms (i.e., GVIFs <3) (Thomas, Vaughan, & Lello, 2013) and therefore were retained in the global model.

An Information Theoretic approach was applied (Burnham, Anderson, & Huyvaert, 2011). Full subset model selection was performed using the MuMIn package in R (R Development Core Team, 2016), to test all possible combinations of effects (Table S1). Models were ranked according to the value of Akaike's information criteria, corrected for small sample size (AICc). The model with the lowest AICc value was regarded as our best supported model and the relative likelihood, Akaike weight, and evidence ratio were also used to assess support. $R^2_{mod}$ values (Tjur, 2009) assessed the percentage of the variance in hunters' ability to identify Bewick's swans explained by each model. Model averaging across our best supported models (i.e., those where ΔAICc ≤2.0) was undertaken using the MuMIn package (R Development Core Team, 2016), to estimate the effect sizes associated with each variable. Chi-squared tests determined whether or not hunters' ability to identify swans differed significantly across species. To assess whether hunters' ability to identify each species differed from that expected by chance (i.e., random selection), we used a two-sample binomial test for equality of proportions.

## 3 | RESULTS

A total of 256 people were approached and 8% ($n = 20$) declined to participate. Four participants did not complete the questionnaire and their responses were omitted from the analysis. Therefore, 232 questionnaires were completed and used in the analysis. Respondents came from eight ethnic groups (Table S1) and 98% ($n = 228$) were male. 14% (n = 33) of the respondents correctly identified (named) a Bewick's swan from its color photograph (Table 1). Identification accuracy was similar for whooper swans (14%; $n = 33$) and for mute swans (12%; $n = 27$), and hunters' ability to identify swans did not differ significantly between species ($X^2_2 = 0.894$, $p = 0.64$ for three species) (Table 1). No other species aside from Bewick's, whooper and mute swans were suggested by the participants during the identification test. Those able to identify Bewick's swans were significantly more likely also to be able to identify whooper swans (16 of 33; 49%) than those that were not (17 of 199; 9%) ($X^2_2 = 33.81$, $p \leq 0.001$). A two-sample binomial test for equality of proportions indicated that identification accuracy was, in every case, worse than that expected by chance (Table 1).

Identification accuracy was best explained by a model (of averaged effects associated with our best supported models; that is, those models where ΔAICc ≤2.0), including employment sector, the distance of hunters' settlement to the nearest key Bewick's swan site, region of residence, hunting frequency, hunter identity, knowledge of Bewick's swan migration and monogamy, perceptions of population trends, knowledge of protective laws and age (Tables 2 and 3). Those able to identify Bewick's swans correctly were

**TABLE 1** Identification accuracy and the probability of accurate identification expected following random selection, of three swan species by 232 hunters in the Russian Arctic

| Species | Identification accuracy (n) | Probability of accurate identification following random selection (n) | Two-sample binomial test for equal proportions ($\chi^2$) | $p$ Value |
|---|---|---|---|---|
| Identification of Bewick's swan only | 0.14 (33) | 0.33 (77) | 22.03 | <0.001 |
| Identification of whooper swan only | 0.14 (33) | 0.33 (77) | 22.03 | <0.001 |
| Identification of mute swan only | 0.12 (27) | 0.33 (77) | 29.76 | <0.001 |
| Identification of both Bewick's and whooper swans | 0.07 (16) | 0.17 (39) | 9.98 | <0.001 |
| Identification of both Bewick's and mute swans | 0.05 (12) | 0.17 (39) | 14.89 | <0.001 |
| Identification of both whooper and mute swans | 0.06 (13) | 0.17 (39) | 13.54 | <0.001 |
| Identification of all three swan species | 0.05 (11) | 0.17 (39) | 16.34 | <0.001 |

**TABLE 2** A summary of effects on the ability of 232 hunters in the Russian Arctic to correctly identify a Bewick's swan. We present model averaged effects associated with our best-supported models (i.e., all models where ΔAICc ≤2.0). A GLM with a binomial error distribution and logit link function was used to assess the effects of the explanatory variables on the ability of hunters to identify a Bewick's swan (0 = incorrect identification, 1 = correct identification)

| Parameter[c] | Estimate | *SE* | *Z* | *p* |
|---|---|---|---|---|
| Intercept | *−2.047* | *350.075* | *0.006* | *0.995* |
| Employment (unlikely to involve interaction with natural environment) | −1.238 | 0.488 | 2.522 | 0.012 |
| Employment (other[a]) | −1.670 | 0.685 | 2.424 | 0.015 |
| Distance to nearest key Bewick's swan site | −0.555 | 0.452 | 1.224 | 0.221 |
| Hunting frequency[b] | −0.022 | 0.147 | 0.149 | 0.882 |
| Knowledge of migration (correct) | 0.039 | 0.196 | 0.198 | 0.843 |
| Region of residence (Nenets Autonomous Okrug) | 0.072 | 0.259 | 0.278 | 0.781 |
| Unsure of population trends for Bewick's swans | 1.239 | 350.074 | 0.004 | 0.997 |
| Perceive Bewick's swan population is increasing | 1.271 | 350.075 | 0.004 | 0.997 |
| Perceive Bewick's swan population is stable | 1.336 | 350.078 | 0.004 | 0.997 |
| Age | 0.017 | 0.143 | 0.120 | 0.905 |
| Knowledge of monogamous behavior (correct) | 0.013 | 0.153 | 0.086 | 0.931 |
| Knowledge of laws protecting Bewick's swans (correct) | 0.027 | 0.215 | 0.125 | 0.901 |
| Knowledge of laws protecting Bewick's swans (incorrect) | 0.068 | 0.355 | 0.186 | 0.852 |
| Hunter identity: Reason for regarding oneself as a hunter (did not know) | 0.003 | 0.189 | 0.015 | 0.988 |
| Hunter identity: Reason for regarding oneself as a hunter (appreciation of the natural world) | 0.024 | 0.139 | 0.173 | 0.863 |

*Note.* Italics represent intercept values.
[a]Includes pensioners, the unemployed, and respondents for whom employment sector is unknown.
[b]Number of days spent hunting per annum.
[c]The reference factor levels are: Employment (likely to involve interaction with the natural environment); knowledge of migration (incorrect); region (Arkhangelsk Oblast); perceive Bewick's swan population is decreasing; knowledge of monogamous behavior (incorrect); knowledge of laws protecting Bewick's swans (did not know), and hunter identity (reasons for regarding oneself as a hunter are not related to an appreciation of the natural world).

significantly more likely to be employed in a sector that involved interaction with the natural environment than those that were not (33 and 13%, respectively; Table 2). Identification accuracy was highest among those employed in reindeer herding and the fishing industry (38 and 33%, respectively). Respondents living in closer proximity to key Bewick's swan sites were also more likely (albeit marginally so) to be able to identify Bewick's swans (Table 2). Those who spent fewer days hunting per year were marginally *more* likely to be able to identify a Bewick's swan, as were those with greater knowledge of Bewick's swan migration and monogamy (Table 2). Participants noting an appreciation of the natural world as a reason for regarding themselves as hunters were more likely to be able to identify a Bewick's swan. Bewick's swan identification accuracy was more likely to be higher among those living in the NAO than in AO (Table 2). Those with knowledge that Bewick's swans were protected by law were marginally less likely to be able to identify the species. Perception of population trends was a poor predictor of identification accuracy ($SE = 350$; Table 2).

Overall, 12% ($n = 27$) of participants admitted to hunting what they believed to be a Bewick's swan in the previous 3 years, 15% ($n = 35$) admitted to accidentally hunting them, 72% ($n = 168$) stated that they had not hunted Bewick's swans, and 0.8% ($n = 2$) did not want to answer the question. Of those able to identify a Bewick's swan correctly ($n = 33$), 12% ($n = 4$) admitted to hunting the species and 18% ($n = 6$) admitted to accidentally hunting them. Most (82%; $n = 190$) respondents were aware that it was not legal to hunt Bewick's swans while 8% ($n = 19$) thought that it was permissible and 10% ($n = 23$) did not know.

## 4 | DISCUSSION

Photographs of the Northwest European Bewick's swan, a protected species susceptible to illegal shooting (Newth et al., 2011), were generally not distinguished from photographs of two other swan species with lower legal protection by hunters in parts of the Russian Arctic. Poor identification accuracy for Bewick's, whooper and mute swans (14, 14, and 12%, respectively) suggests an overall inability by hunters to separate these species. Hunters familiar with the identifying features of Bewick's swans were significantly more likely to identify whooper swans than those that were not. Given the physical similarities between these particular swans, specific knowledge is required to distinguish them. Accurate distinction of morphologically similar species may challenge even the most experienced ornithologist. This has important implications for the effectiveness of conservation rules and for understanding sources of uncertainty surrounding their implementation (Hunt, 2013).

Low identification rates may be attributable to subtle-specific differences (Christensen et al., 2017). In addition to sharing similar morphological traits, Bewick's and whooper swans also exhibit similar behavior (including vocalizations) and ecology (Rees, 2006), coexist at certain times in sizeable numbers (Mineyev & Mineyev, 2011, 2014; Rees, 2006), and use similar habitats. Given that whooper and mute swans are afforded weaker legal protections than Bewick's swans in Russia, with lower penalties incurred for their killing, it is plausible that they are targeted for shooting. Enforcement of severe penalties serve as a deterrent and, among other measures, reduce the illegal killing of protected wildlife (e.g., Martin, Martin, & Vigne, 2013). Moreover, penalties are a key tool deployed by the Russian Government to deter poaching (e.g., Federal Law No. 91 07.05.2013). Both whooper and mute swans may be included on hunting lists and shot in other regions of Russia

**TABLE 3** A comparison of the relative support and explanatory power of our best-supported models relating to the ability of 232 hunters in the Russian Arctic to correctly identify a Bewick's swan. *K* refers to the number of parameters within the model. Model parameters: *i* = intercept, *E* = employment sector, *D* = distance of settlement to the nearest key Bewick's swan site, *Hf* = hunting frequency, *Km* = knowledge of migration, *Ppop* = perception of population trend, *A* = age, *Kp* = knowledge of monogamous behaviour, *Kl* = knowledge of laws, *Hi* = hunter identity and *R* = region of residence. The best supported models (for which model-averaging of parameter estimates was undertaken; Table 2) are indicated in bold

| Model | *K* | AICc | ΔAICc | Relative likelihood | Akaike weights | Evidence ratio | $R^2_{mod}$ (%) |
|---|---|---|---|---|---|---|---|
| ***i + E + D*** | **3** | **186.467** | **0.0** | **1.00** | **0.2068** | **1.00** | **5.8** |
| ***i + E*** | **2** | **188.040** | **1.6** | **0.46** | **0.0942** | **2.20** | **4.2** |
| ***i + E + Hf + D*** | **4** | **188.152** | **1.7** | **0.43** | **0.0890** | **2.32** | **6.1** |
| ***i + km + E + D*** | **4** | **188.205** | **1.7** | **0.42** | **0.0867** | **2.38** | **5.8** |
| ***i + E + D + R*** | **4** | **188.215** | **1.7** | **0.42** | **0.0863** | **4.40** | **6.0** |
| ***i + E + R*** | **3** | **188.236** | **1.8** | **0.41** | **0.0854** | **2.42** | **4.9** |
| ***i + E + Ppop + D*** | **4** | **188.307** | **1.8** | **0.40** | **0.0824** | **2.51** | **8.0** |
| ***i + E + A + D*** | **4** | **188.33** | **1.9** | **0.39** | **0.0815** | **2.54** | **6.0** |
| *i + E + D + Kp* | 4 | 188.441 | 2.0 | 0.37 | 0.0071 | 2.68 | 5.9 |
| *i + E + D + kl* | 4 | 188.995 | 2.5 | 0.28 | 0.0584 | 3.54 | 6.6 |
| *i + E + D + hi* | 4 | 189.217 | 2.7 | 0.25 | 0.0523 | 3.95 | 6.1 |

(Solokha & Gorokhovsky, 2017). Under these circumstances, it seems likely that Bewick's swans are shot on being mistaken for whooper and mute swans. Mute swans are less likely to coincide with Bewick's swans during the summer because they occur in lower numbers in the arctic tundra (Mineyev & Mineyev, 2014). Those living in the AO were not as likely to identify a Bewick's swan correctly in comparison to those living in the NAO. The risk of hunters who are aware of protective laws mistakenly shooting Bewick's swans when whooper swans are targeted is perhaps lower in the AO, as here whooper swans are also listed in the regional Red Data Book (i.e., afforded the strongest legal protection), whereas in the NAO they are not. Higher penalties are therefore incurred for the hunting of whooper swans in the AO which may serve as a deterrent and reduce the likelihood that they are targeted for hunting in the first place. Furthermore, hunters in the AO may regard that legal protections simply encompass swan species with yellow and black bills, thus making the ability to distinguish Bewick's from whooper swans less relevant. It is likely that shooting is the main method of hunting for all three swan species.

Higher identification accuracy was found for hunters employed in sectors more likely to involve interaction with the natural environment and among those living closer to key Bewick's swan sites. These hunters are perhaps more likely to encounter Bewick's swans and thus be familiar with their identifying characteristics. Among American duck hunters, highest identification accuracy occurred for species regularly seen in the field (Wilson & Rohwer, 1995). Hunting frequency also plays an important role and has been found to depend upon the training and experience of the hunter (e.g., European Commission, 2008). In this study, however, those spending more days hunting annually were significantly less likely to be able to identify Bewick's swans. The number of years rather than days spent hunting may be more influential in this case.

Identification accuracy may be higher under field conditions than from photographs, because other cues are available to hunters such as the comparative size, behavior and occurrence of swans in the area (Austen, Bindemann, Griffiths, & Roberts, 2016; Christensen et al., 2017). Given that Bewick's and whoopers swans are particularly similar morphologically, size differences may be one of several distinguishing features used to identify them. However, adverse field conditions including weather, lighting and observation distance can in turn reduce the ability of hunters to recognize species (European Commission, 2008), so inspecting a photo closely, without time constraints and in a well-lit room, might be expected to improve some aspects of identification accuracy. We should also consider that, as in other wildfowl (Christensen et al., 2017; Wilson & Rohwer, 1995), identification of juveniles is likely to be less accurate than for adult birds because interspecific differences in morphology are more subtle at that age (Christensen et al., 2017; Wilson & Rohwer, 1995). Finally, those unable to identify Bewick's swans may not have been aware of their existence and this warrants further investigation.

We conclude that the risk of Bewick's swans being shot arises in part when they are mistaken for two morphologically similar swan species, particularly when they spatially and temporally coincide. Interventions may help reduce the accidental shooting of misidentified species, for instance by informing hunters of the consequences of accidental shooting for wild bird populations and improving their identification abilities (AEWA, 2015; Madsen et al., 2015). Hunters should be encouraged by government agencies, hunting organizations, hunting tourism agencies and respected and influential community leaders and groups, to avoid shooting a bird unless they are confident of its identity (AEWA, 2015; European Commission, 2008). Government-supported proficiency tests and traditional ways of educating would ensure that an adequate level of knowledge is reached

(AEWA, 2015; Madsen et al., 2015). Identification keys, which help to reduce the risk of confusion (e.g., Poyarkov et al., 2011), are a useful resource (AEWA, 2015; European Commission, 2008). Financial, practical, and communications support from government agencies and hunting bodies for the design and dissemination of resources for hunters, is likely to be required for a successful awareness-raising campaign. For example, the Italian Hunters' Association (Associazione Cacciatori Migratoristi Acquatici) was instrumental in preparing and distributing visual guides for hunters which addressed the possible confusion of Ruff *Philomachus pugnax* and Ferruginous Duck *Aythya nyroca* with morphologically similar species (AEWA, 2015). While most hunters in this survey understood that it was not permissible to hunt Bewick's swans, 18% thought that it was legal or did not know. Some hunters therefore may benefit from further information on protection accorded to different species. Printed and digital memos for hunters that comprise a visual guide on protected and quarry species, information on areas where hunting is forbidden and penalties for non-compliance, may be an effective method of dissemination. Overall, 15% of participants admitted to having accidentally hunted what they believed to be a Bewick's swan in the previous 3 years. Given that the ability of hunters to distinguish between the swan species was poor, it is possible that some of those reporting to have hunted a Bewick's swan may have in fact hunted a whooper or mute swan and vice versa. However, of those able to identify a Bewick's swan correctly, 18% admitted to accidentally hunting the species. It should also be considered that 8% of hunters asked to participate in the survey declined to take part, some of whom may have done so in fear of incriminating themselves if they had hunted a Bewick's swan previously. The number of hunters who admitted hunting a Bewick's swan may therefore be an underestimate. Further investigation should determine the risk of birds being accidentally shot when in close proximity to inaccurately targeted quarry species. In some circumstances, it may be necessary for governments to strengthen the legal protection of nonprotected species at high risk of being mistaken for protected species (e.g., Knobel, 2015), or to amend opening and closing dates of hunting seasons when both protected and nonprotected species coincide (European Commission, 2008). Countries that are signatories to multilateral environmental agreements can utilize relevant guidance and resolutions (e.g., AEWA Resolution 6.4: Conservation and Sustainable Use of Migratory Waterbirds; AEWA, 2016) that provide frameworks within which interventions can be initiated and undertaken and political support can be garnered. Given that illegal shooting of Bewick's swans occurs throughout their range (Rees & Bowler, 2002), measures should be implemented at other sites where accidental shooting is considered a risk (AEWA, 2015). Given that 12% of hunters admitted to the nonaccidental hunting of (what they believed to be) a Bewick's swan previously, further studies are required to establish whether this species is at significant risk from purposeful as well as accidental hunting, and if so, the motivations for such behavior. Understanding the role and impact of hunters within the wider social-ecological landscape is crucial for reducing the uncertainty of implementing regulations for conserving wildlife (Hunt, 2013). Improving hunters' skills in discerning protected from quarry is likely to be an effective tool for conservation of morphologically similar species.

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### Authors' contributions

Study design: J.L.N., A.N., I.S.; fieldwork: A.C., G.M.; data analysis and writing the article: J.L.N.; critical review: A.N., R.M., K.W., E.R., S.B., R.C., P.G., A.B.

## CONFLICT OF INTEREST

The authors declare no potential conflict of interests.

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## REFERENCES

Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA). (2015). *Guidance for dealing with the accidental shooting of look-alike species in the Western Palearctic* (AEWA/MOP Inf. 6.1). 6th Session of the Meeting of the Parties, November 9–14, 2015, Bonn, Germany. Retrieved from: http://www.unep-aewa.org/sites/default/files/document/mop6_inf_1_guidance_look_alike_species.pdf.

Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA). (2016). *Resolution 6.4. Conservation and sustainable use of migratory Waterbirds* (*Inf.* 4.0). Inter-Governmental Meeting on the Establishment of a European Goose Management Platform under the Auspices of AEWA. May 11–12, 2016, Paris, France.

Austen, G. E., Bindemann, M., Griffiths, R. A., & Roberts, D. L. (2016). Species identification by experts and non-experts: Comparing images from field guides. *Scientific Reports*, *6*, 33634. https://doi.org/10.1038/srep33634

BirdLife International. (2015). *European red list of birds*. Luxembourg: Office for Official Publications of the European Communities.

Burnham, K. P., Anderson, D. R., & Huyvaert, K. P. (2011). AIC model selection and multimodel inference in behavioral ecology. Some background, observations, and comparisons. *Behavioral Ecology and Sociobiology*, *65*, 25–35. https://doi.org/10.1007/s00265-010-1029-6

Christensen, T. K., Madsen, J., Asferg, T., Peder Hounisen, J. P., & Haugaard, L. (2017). Assessing hunters' ability to identify shot geese: Implications for hunting bag accuracy. *European Journal of Wildlife Research*, *63*, 20. https://doi.org/10.1007/s10344-017-1080-y

Danish Hunters' Association (2008). *Hunting in Denmark.* Retrieved from: http://www.face.eu/sites/default/files/denmark_en_2.pdf.

Deutscher Jagdschutz-Verband e.V (2003). *Hunting in Germany*. Retrieved from: http://www.face.eu/sites/default/files/germany_en.pdf.

Directorate for Nature Management Trondheim. (2018). *Hunting in Norway.* Retrieved from: https://www.face.eu/sites/default/files/norway_en.pdf.

European Commission. (2008). *Guidance document on hunting under Council Directive 79/409/EEC on the conservation of wild birds 'The Birds Directive'*. Retrieved from: http://ec.europa.eu/environment/nature/conservation/wildbirds/hunting/docs/hunting_guide_en.pdf.

Gallo-Orsi, U. & The Slender-billed Curlew Working Group. (2002). *International Action Plan for the Slender-billed curlew* (*Nemenius tenuirostris*) (CMS/ScC.11/Doc.14). Paper presented at the Eleventh Meeting of the CMS Scientific Council, September 14–17, 2002, Bonn, Germany.

Gurtovaya, E. N. (2000). Aggressive interactions between Bewick's swans and other Anseriformes in the breeding period. *Casarca*, *6*, 167–176.

Gurtovaya, E. N., & Litvin, K. E. (2006). Bewick's swan *Cygnus bewickii* Yarell, 1830. In N. V. Matveeva (Ed.), *Red data book of the nenets Autonomous okrug* (pp. 305–307). Nar'Yan-Mar, Russia: Nenets Information Analysis Center (in Russian).

Hunt, L. M. (2013). Using human-dimensions research to reduce implementation uncertainty for wildlife management: A case of moose (*Alces alces*) hunting in northern Ontario, Canada. *Wildlife Research*, *40*(1), 61–69. https://doi.org/10.1071/WR12185

Hunters' Central Organization. (2018). *Hunting in Finland.* Retrieved from: http://www.face.eu/sites/default/files/finland.en_2009.pdf.

Jones, T., Martin, K., Barov, B., & Nagy, S. (2008). *AEWA international single species action plan for the conservation of the western palearctic population of the lesser white-fronted goose Anser erythropus* (AEWA Technical Series No. 36), Bonn, Germany. Retrieved from: http://www.unep-aewa.org/sites/default/files/publication/lwfg_ssap_130109_0.pdf.

Keane, A., Andriamahatsiaro, R. A., Jones, J. P. G., & Milner-Gulland, E. J. (2011). Evidence for the effects of environmental engagement and education on knowledge of wildlife laws in Madagascar. *Conservation Letters*, *4*, 55–63. https://doi.org/10.1111/j.1755-263X.2010.00144.x

Knobel, J. C. (2015). The bald and golden eagle protection act, species-based legal protection and the danger of misidentification. *PER: Potchefstroomse Elektroniese Regsblad*, *17*(7), 2605–2641.

Koninklijke Nederlandse Jagers Vereniging. (2004). *Hunting in the Netherlands.* Retrieved from: https://www.face.eu/sites/default/files/netherlands_en.pdf.

Madsen, J., Bunnefeld, N., Nagy, S., Griffin, C., Defos du Rau, P., Mondain-Monval, J.Y., … Noe, O. (2015). *Guidelines on sustainable harvest of migratory Waterbirds* (AEWA Conservation Guidelines No. 5, AEWA Technical Series No. 62). Bonn, Germany.

Martin, E., Martin, C., & Vigne, L. (2013). Successful reduction in rhino poaching in Nepal. *Pachyderm*, *54*, 66–76.

Mineyev, Y. N. (1991). Distribution and numbers of Bewick's Swans *Cygnus bewickii* in the European Northeast of the USSR. *Wildfowl*, (Vol. Special Supplement (No. 1), pp. 62–67).Retrieved from https://wildfowl.wwt.org.uk/index.php/wildfowl/article/view/1364/pdf_10

Mineyev, Y. N., & Kondratiev, A. Y. A. (2001). Bewick's swan. In D. S. Pavlov, L. N. Mazin, V. V. Rozhnov, & V. E. Flint, et al. (Eds.), *Red data book of the Russian Federation, Animals* (p. 862). Balashikha, Moscow: Astrel (in Russian).

Mineyev, Y. N., & Mineyev, O. Y. (2011). The Ecology of whooper swans (Cygnus cygnus) in the European north east of Russia. Institute of Biology, Komi Scientific Centre, Ural Department. *Russian Academy of Science*, *4*(8), 42–47 (in Russian).

Mineyev, Y. N., & Mineyev, O. Y. (2014). *Swans of the European North-east of Russia*. Syktyvkar, Russia: Institute of Biology of the Komi Scientific Centre, Ural Dept, Russian Academy of Sciences (in Russian).

Nagy, S., Petkov, N., Rees, E.C., Solokha, A., Hilton, G., Beekman, J., & Nolet, B. (2012). *International single species action plan for the Northwest European Population of Bewick's Swan (Cygnus columbianus bewickii)* (AEWA Technical Series No. 44). Bonn, Germany.

Newing, H., Eagle, C. M., Puri, R. K., & Watson, C. W. (2011). *Conducting research in conservation: A social science perspective*. Abingdon, England: Routledge.

Newth, J. L., Brown, M. J., & Rees, E. C. (2011). Incidence of shotgun pellets in Bewick's swans *Cygnus columbianus bewickii* and whooper swans *Cygnus cygnus* wintering in the UK. *Biological Conservation*, *144*, 1630–1637. https://doi.org/10.1016/j.biocon.2011.02.014

Novoselov, A. P. (Ed.). (2008). *Red data book of the Arkhangelsk Oblast*. Arkhangelsk, Russia: Committee for Ecology of the Arkhangelsk Oblast, 351 pp. (in Russian).

Poyarkov, N. D., Kondratyev, A. V., Litvin, K. E., Syroechkovskiy, E. E., Koblik, E. A., Blokhin, Y. Y., … Volkov, S. V. (2011). Field guide of Anseriformes of Russia. In E. E. Syroechkovsky (Ed.), *Redakcia* (p. 223). Moscow, Russia: Redakcia Print Design (in Russian).

R Development Core Team. (2016). *R: A language and environment for statistical computing. [3.3.0]*. Vienna, Austria: R Foundation for Statistical Computing.

Rees, E. C. (2006). *Bewick's swan*. London, England: T & A.D Poyser Ltd.

Rees, E. C., & Bowler, J. M. (2002). Bewick's swan *Cygnus columbianus*. In C. V. Wernham, M. P. Toms, J. H. Marchant, J. A. Clark, G. M. Siriwardena, & S. R. Baillie (Eds.), *The migration atlas: Movements of the birds of Britain and Ireland* (pp. 149–153). London, England: T.&A.D Poyser Ltd..

Robinson, B. S., Inger, R., & Gaston, K. J. (2016). A rose by any other name: Plant identification knowledge & socio-demographics. *PLoS One*, *11*(5), e0156572. https://doi.org/10.1371/journal.pone.0156572

Russian Federal State Statistics Service. (2015). *The population of the Russian Federation for municipalities as of January 1, 2015.* Moscow, Russia: Russian Federal State Statistics Service (in Russian).

Solokha, A., & Gorokhovsky, K. (2017). Estimating waterbird harvest in Russia. *Suomen Riista*, *63*, 43–52.

Somaweera, R., Somaweera, N., & Shine, R. (2010). Frogs under friendly fire: How accurately can the general public recognize invasive species? *Biological Conservation*, *143*(6), 1477–1484. https://doi.org/10.1016/j.biocon.2010.03.027

Svenska Jagareforbundet. (2005). *Hunting in Sweden.* Retrieved from: https://www.face.eu/sites/default/files/sweden_en.pdf.

Thomas, R., Vaughan, I., & Lello, J. (2013). *Data analysis with R statistical software: A guidebook for scientists*. Cardiff, Wales: Eco-explore.

Tjur, T. (2009). Coefficients of determination in logistic regression models – A new proposal: The coefficient discrimination. *The American Statistician*, *63* (4), 366–372. https://doi.org/10.1198/tast.2009.08210

Wilson, B. C., & Rohwer, F. C. (1995). In-hand duck identification by hunters at Mississippi flyway public hunting areas. *Wildlife Society Bulletin*, *23*, 472–480.

Wood, K. A., Nuijten, R. J. M., Newth, J. L., Haitjema, T., Vangeluwe, D., Ioannidis, P., … Rees, E. C. (2018). Apparent survival of an Arctic-breeding migratory bird over 44 years of fluctuating population size. *Ibis*, *160*, 413–430. https://doi.org/10.1111/ibi.12521

## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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