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# Using $\delta^2H$ stable isotope analysis to identify the origin of a first winter Red-breasted Goose *Branta ruficollis* caught in Norway

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*Abstract.* We analysed hydrogen stable isotopes ($\delta^2H$) in first generation median wing covert feathers sampled from a free-flying first winter Red-breasted Goose *Branta ruficollis* caught at Storøya, Norway in late April 2019. Highly depleted $\delta^2H$ values corresponded to those predicted if these feathers were grown in the Russian Arctic breeding areas of this species, too highly depleted compared to predicted values for a bird raised in captivity in Norway or elsewhere in western Europe. Although these data do not provide irrefutable proof of the individual's wild origin, they strongly suggest that even records outside the normal range for this species can potentially constitute a genuinely wild-reared individual.

**Keywords:** Deuterium, hydrogen, isoscapes, Red-breasted Goose, stable isotopes

## INTRODUCTION

Ducks, geese and swans are highly attractive species that adapt well to being kept and bred in captivity (Kear 1990). Inevitably, such birds often escape, even establishing self-sustaining non-native breeding populations (e.g. Ogilvie et al. 2004), making it difficult to confirm whether individuals seen away from their regular range are genuine itinerant wild birds or merely escapes from captivity. The Red-breasted Goose *Branta ruficollis* is widely kept in captivity, but since the 1970s has shifted its natural wintering areas from the Caspian Sea to the Western Black Sea, making it increasingly likely that wild vagrants would turn up in Western Europe (Kear 2005).

Elemental stable isotopes in feathers grown as pulli offers a potential method to distinguish first winter waterbirds of native origin from those reared on the winter quarters in different chemical isoscapes. The hydrogen stable isotope ratio (the ratio of the heavy atom deuterium to the more common lighter form, D/H or $^2H/^1H$, generally conventionally written as $\delta^2H$) in groundwater varies across the globe, dependent upon that of local precipitation. Heavier deuterium tends to be depleted more rapidly in precipitation from the atmosphere than its lighter counterpart. Hence, strong gradients in $\delta^2H$ occur across continental Europe and North America with increasing distance from oceans, the source of recharge for atmospheric water vapour supplying precipitation to both continents (Hobson & Wassenaar 1997, Hobson et al. 2004), adjusting for altitude effects that also affect precipitation isotope ratios. Groundwater $\delta^2H$ correlates with precipitation, which plants take up and incorporate into their tissues, so when eaten by other consumer organisms, the $\delta^2H$ ratios in the biota of a given area reflect that of local precipitation. Consequently, bird feather stable isotope ratios correlate strongly, through the local diet, with that in precipitation where those feathers were grown. No matter where the bird travels, that feather carries a record of the $\delta^2H$ ratios in the environment where the bird was when the specific feather was grown. Hence, breeding female Scaly-sided Mergansers *Mergus squamatus* could be assigned to the Far Eastern Russia river catchments where they raised their offspring, because each river basin has a distinctive $\delta^2H$ ratio (Solovyeva et al. 2016). $\delta^2H$ ratios in older tail feathers grown on the brood rearing areas (showing notched tips) from a Danish-shot first winter Baikal Teal *Sibirionetta formosa* contained depleted $\delta^2H$ ratios (characteristic of Siberian breeding areas), relative to new grown tail feathers (grown locally in Europe), which confirmed the bird to be a genuine vagrant to western Europe (Fox et al. 2007).

As of 2015, there had been 24 records of Red-breasted Geese in Norway; of these, five were considered escapes (Norwegian Rarity Committee, unpublished data). All records have been of single birds, except for a report of three individuals together in 1997, when many were reported in Sweden, and three individuals in 2014, which were considered escapes. In 2019, a first winter Red-breasted Goose turned up in southern Norway and was subsequently captured, enabling feathers to be sampled to verify its natal origin.

## METHODS

We analysed $\delta^2H$ in first year wing coverts taken from a Red-breasted Goose captured at Storøya, Norway (59°53'N, 10°36'E) on 24 April 2019 by the first author. The bird was first reported on 21 April at Storøya, from where it moved 50 km south on 26 April where it remained until 29 April. It was caught with a 1 m diameter monofilament noose while grazing on short grass turf. The monofilament was 1 mm thick to ensure no harm came to the bird during capture.

Two first generation median wing covert feathers were plucked from the bird on capture and stored for later analysis by Iso-Analytical Ltd (Crewe UK). Feathers were washed in 0.25M sodium hydroxide solution followed by two separate washes in purified water and oven-dried overnight at 60 °C. Washed feathers were finely chopped with surgical scissors and small amounts (1 ± 0.1 mg) were weighed into silver capsules (8 x 5 mm) for hydrogen isotope analysis using an Elemental Analyser - Isotope Ratio Mass Spectrometry (EA-IRMS). Samples and references in silver capsules were loaded into an auto-sampler. Samples were equilibrated with moisture in the laboratory air for 14 days prior to analysis before being dropped into a furnace at 1080 °C and thermally decomposed to $H_2$ and CO over glassy carbon, removing water with magnesium perchlorate and $CO_2$ with a Carbosorb™ trap. $H_2$ was resolved by a packed column gas chromatograph maintained at 35 °C. The resultant chromatographic peak enters the ion source of the IRMS where it is ionized and accelerated. Gas species of different mass (in this case masses 2 and 3 for $H_2$) were separated in a magnetic field then simultaneously measured on a Faraday cup universal collector array. The reference material used for $\delta^2$H analysis of the feather samples was IA-R002 (mineral oil, $\delta^2$HV-SMOW = -111.2 ‰). IA-R002 is an in-house standard calibrated against and traceable to NBS-22 (mineral oil, $\delta^2$HV-SMOW = -120 ‰), an inter-laboratory comparison standard distributed by the International Atomic Energy Agency (IAEA). Samples of IA-R002, IAEA-CH-7 (polyethylene foil, $\delta^2$HV-SMOW = -100.3 ‰), and IA-R072 (mineral oil, $\delta^2$HV-SMOW = -148.61 ‰) were also measured along with the samples as quality control check samples. IA-R072 is an in-house standard calibrated against and traceable to NBS-22 (mineral oil, $\delta^2$HV-SMOW = -120 ‰). IAEA-CH-7 is an inter-laboratory comparison standard distributed by the IAEA. Five non-exchangeable hydrogen standards were comparatively equilibrated and analysed alongside the feather samples as controls. The four standards used for calibration were USGS42 (human hair, non-exchangeable $\delta^2$HV-SMOW = -44.4 ‰), USGS43 (human hair, non-exchangeable $\delta^2$HV-SMOW = -72.9 ‰), USGS CBS (caribou hoof, non-exchangeable $\delta^2$HV-SMOW = -156.41 ‰) and USGS KHS (kudu horn, non-exchangeable $\delta^2$HV-SMOW = -35.3 ‰). The fifth standard, measured as a quality control check sample, was Eurofins 11/2/C (casein, non-exchangeable $\delta^2$HV-SMOW = -113.37 ‰). USGS42, USGS43, USGS CBS and USGS KHS are inter-laboratory comparison standards distributed by the United States Geological Survey (USGS). Eurofins 11/2/C is an inter-laboratory quality check sample provided by Eurofins Scientific. $\delta^2$H results are presented here as measure values following correction for exchangeable hydrogen using a four-point linear calibration with USGS42, USGS43, USGS CBS and USGS KHS.

## RESULTS AND DISCUSSION

The analysis of two samples from the same covert feather returned $\delta^2$HV-SMOW non-exchangeable values of -135.97 ‰ and -136.13 ‰. Such values are more depleted in deuterium relative to what would be expected from western Europe. Substituting our feather values in the regression models of Hobson et al. (2004, Figures 2a & b), they generate mean annual $\delta^2$H values of 124.25 ‰ and 124.43 ‰ and mean detrended growing season values of 101.22 ‰ and 101.34 ‰. These values are well outside values predicted for any region in western Europe or indeed western Russia (see the contour maps of these groundwater measures in Figures 1a & b of Hobson et al. 2004). These values fall within those mapped for the Taimyr Peninsula in Arctic Russia where Red-breasted Geese breed (see Figure 14 in Terzer et al. 2013, after correction for partitioning of $\delta^2$H values from ground water, via vegetation into feather tissue). The gradients in depleted $\delta^2$H annual and monthly precipitation across Eurasia are available at: http://wateriso.utah.edu/waterisotopes/pages/data_access/figure_pgs/global.html). Although not proven beyond doubt that this bird was a wild individual, the feather analysis provides considerable support for the hypothesis that this was not a bird reared in captivity in Europe, because the $\delta^2$H ratio could not be the result of exposure to artificial food or rainfall typical of Western Europe. Rather, we consider it more likely to have been natively reared, because the values more closely reflected those expected if raised in the wild in its normal breeding area.

The Red-breasted Goose discussed here was present in a park area, which might normally increase the probability of the bird having been raised in captivity. The Barnacle Geese *Branta leucopsis* flock with which it grazed was relatively tame and allowed human approach. The Red-breasted Goose behaved as the rest of this flock, allowing approaches down to about 5 metres. Despite this, the stable isotope ratio suggests it may have been a wild-reared bird. Barnacle Geese exhibit strong parent-offspring bonds, which tend to persist through the first winter in all *Branta* species, probably to teach juvenile birds the migration routes (Black & Owen 1989) so it is likely that first-winter Red-breasted Geese which have lost contact with parents and siblings may show abnormal behaviour, including migration routes and timing. They then might end up following a different flock of a different species northwards, thereby ending up away from the normal range. Together, these features suggest prudence in rejecting vagrant goose records as being not genuinely wild, just because they are seen in areas and at times of the year, which are not typical for the species without further evidence.

There remains no doubt that there are many escaped Red-breasted Geese in Europe, evident from the number of individuals of obvious captive origin that show up in the wild and the fact that they are easy to find for sale online. Therefore, judging the true origin of any single individual in Europe requires to the best possible extent, determination of how, and from where, the bird may have arrived. Genuine wild Red-breasted Geese are most likely to reach Western Europe with flocks of either Greater White-fronted Geese *Anser albifrons* or Dark-bellied Brent Geese *Branta bernicla bernicla* from Siberia in autumn and early winter, although having reached western Europe, such birds may shift between goose flocks and associate with other species, particularly small *Branta* species. The individual in question most likely arrived in Norway with a flock of Barnacle Geese, potentially wintering in the Netherlands, in the same areas as wild White-fronted and Brent Geese spend their winter.

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