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Joel G. Jorgensen[1,3], Stephen J. Brenner[1] and W. Ross Silcock[2]

[1]Nongame Bird Program, Nebraska Game and Parks Commission, 2200 N. 33rd, Lincoln, NE, 68503
[2]6810 Tournament Drive, Houston, TX, 77069
[3]Corresponding author: joel.jorgensen@nebraska.gov

On 2 November 1968 in northeastern Otoe County, Nebraska, Milton Muncie harvested a bird (herein referred to as the 1968 specimen), subsequently identified as an immature Barnacle Goose (*Branta leucopsis*), from a flock of about 40 Cackling Geese (*Branta hutchinsii*; Cortelyou 1969). The occurrence was reported not only as the first record of a Barnacle Goose for Nebraska, but also the first record for the North American Interior and West (Cortelyou 1969). Cortelyou's (1969) brief article also included a photograph of the mounted specimen.

At the time and when subsequently reviewed by various authors, the identity of the 1968 specimen as a Barnacle Goose was not a matter of debate. Questions about its provenance, however, led authors (Bray et al. 1986, Sharpe et al. 2001) to consider the species' occurrence as a wild bird in the state to be unproven, thus "hypothetical". Bray et al. (1986) noted an immature in fall was a likely age class and period for a genuine wild vagrant, but considered the Otoe County specimen an escapee, citing Ryff (1984). Johnsgard (2018) also acknowledged the possibility the 1968 specimen could be a true vagrant, referring to it as "apparently wild". Barnacle Goose has subsequently been reported four times in the state, but none of the reports are as well-documented as the 1968 specimen. Thus, no records have been accepted and Barnacle Goose does not appear on the Official List of the Birds of Nebraska (Brogie 2009).

Questions of provenance are often problematic for out-of-range waterfowl. Barnacle Goose reports from across North America were, until recently, generally considered to represent non-wild birds that originated from captive stock. These conclusions were primarily influenced by arguments advanced by Ryff (1984), who noted that the species is regularly kept in private collections and who also posited the species' range and migration patterns were not conducive for vagrancy to North America. This stance has subsequently been questioned (Sherony 2008, Howell et al. 2014, Burrell 2017) and numerous Barnacle Goose records have now been accepted by state or provincial records committees, especially from eastern North America (Sherony 2014). However, records from states as close to Nebraska as Colorado

(CBRC 2021) and Arkansas (Arkansas Audubon Society 2021) have also been recently accepted by state bird records committees.

In 2018, the lead author noticed that a specimen mount of an apparent Barnacle Goose at the Nebraska Game and Parks Commission headquarters in Lincoln appeared similar to the 1968 specimen depicted in Cortelyou (1969; Figure 1). Upon closer inspection, it was concluded the 1968 specimen and the one discovered in 2018 are one and the same. This discovery provided an opportunity to closely review the specimen as well as conduct stable isotope analysis of feathers, which has the potential to provide useful information about the 1968 specimen's provenance. In the article, we report our findings from our review and comment on how this new information should be used when considering other reports of Barnacle Geese from Nebraska and the Interior.

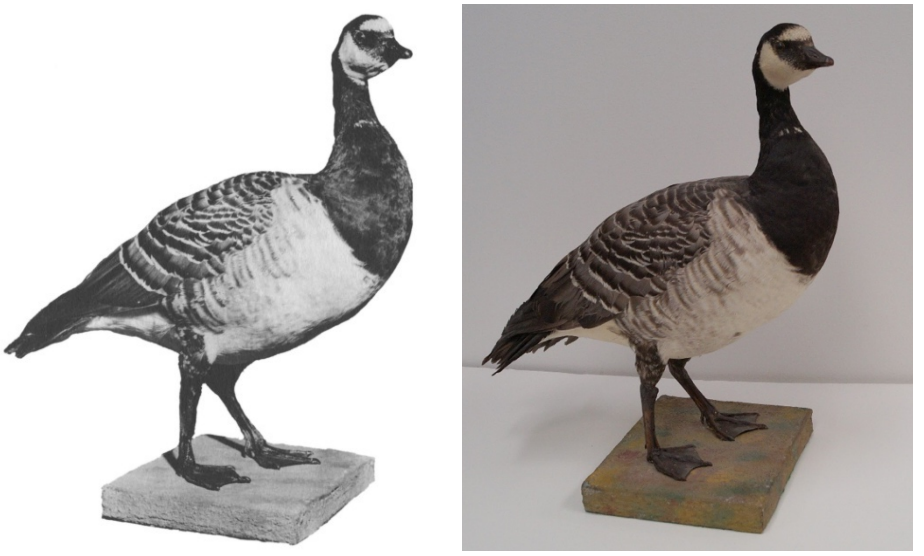

Figure 1. Original (left) published photograph from Cortelyou (1969) of the purported Barnacle Goose harvested in Otoe County 2 November 1968. Photograph (right) of the mounted specimen discovered at the Nebraska Game and Parks Commission headquarters in Lincoln, Nebraska. Markings and stance of the bird, as well as the base of the mount, all appear identical.

Methods

We visually inspected the 1968 specimen for field marks that would identify it to species. We also inspected the 1968 specimen for obvious signs of captivity (e.g. missing halluces, feather damage and wear). We solicited additional opinions about the age and identification of the specimen from individuals with extensive experience aging waterfowl, species identification or both. Randy Stutheit and Matthew Garrick with the Nebraska Game and Parks Commission have considerable skill handling, banding and aging waterfowl, and both physically inspected the specimen. Steven Mlodinow, Scott McWilliams (University of Rhode Island), and Joern Lehmhus (Institute for Plant Protection in Field Crops and Grassland, Germany) have wide-ranging experience identifying or aging geese or both, and they reviewed photographs of the 1968 specimen. Dr. Lehmhus has a substantial background in identifying European geese and goose hybrids. Photographic reviewers were limited to examination of general plumage and morphology of the 1968 specimen. We measured the culmen, bill width and tarsus on the specimen and compared results with selected geese species. Typically, these measurements are conducted on live animals, but we were constrained to a static mount that we could not damage excessively by removing the mounted base or adjusting any element of the body. Unlike feathers, which may shrink post-mortem, bare parts (e.g., bill) are less likely to do so (Engelmoer et al. 1983). We repeated each measurement three times and averaged the results.

We also collected samples from the secondary feathers for stable isotope analysis, following the approach used by McAlpine et al. (2020). Ratios of stable isotopes are used to determine origins of migratory animals because these ratios vary based on the food webs of an animal's diet. Deuterium is a heavy hydrogen isotope that is useful in determining an organism's origin because it varies with climatic conditions, namely precipitation. This results in predictable spatial variation in the signatures across continents. Feathers are composed of keratin which is metabolically inert after it is synthesized by an organism thus "fixing" the hydrogen isotope "signature" of an individual bird. Adult Barnacle Geese, similar to other goose species, undergo a wing molt and replace flight feathers while remaining in breeding areas after nesting (Larsson 1996). Hatch-year birds, of course, also grow their feathers in breeding areas (Larsson 1996). Thus, we were interested in hydrogen isotope levels in the flight feathers of this goose because they should provide evidence of whether the bird's feathers were grown at a northern or temperate latitude. A bird with a feather isotopic signature from a northern latitude would more likely represent a wild bird whereas a bird with an isotopic signature from temperate latitudes would more likely suggest a captive-reared bird that subsequently escaped.

Feather samples were sent to the U.S. Geological Survey's Reston Stable Isotope Laboratory where stable isotope analysis was conducted. The sample was cleaned with a 2:1 chloroform: methanol solution, dried and prepared for stable isotope analysis. The sample was then normalized to USGS42 (Tibetan hair), USGS43 (Indian hair), powdered Kudu Horn, and Caribou hoof, and the isotopic value (δ^2H) is reported (in parts per thousand, ‰) in relation to the Vienna Standard Mean Ocean Water-

Standard Light Antarctic Precipitation (VSMOW-SLAP) standard scale (Hobson et al. 2012, Toews et al. 2017, McAlpine et al. 2020). As there is not a 1:1 relationship between hydrogen isotopes in feathers (δ^2H_f) and in precipitation (δ^2H_p), previous studies have implemented transfer functions to create spatially explicit 'isoscapes' that match a biological sample to a location of origin (Hobson et al. 2012, Toews et al. 2017, and McAlpine et al. 2020). Previous studies used nearby or closely related known-origin samples to calibrate the transfer function for organic material such as feathers and claws (Toews et al. 2017, Asante et al. 2017). This was obviously not available to us as we do not possess other goose specimens from 1968. Therefore, we converted mean growing season precipitation δ^2H_p (Bowen et al. 2005, waterisotopes.org) to a spatial feather isoscape using a transfer function estimated for short distance ground foragers that was applied to samples from a vagrant Graylag Goose (*Anser anser*) [$\delta^2H_f = 0.95 * \delta^2H_p - 23$; Hobson et al. 2012, McAlpine et al. 2020].

We used a normal probability density function to create likelihood of origin for any spatial cell that matched the corrected feather isoscape (Asante et al. 2017, McAlpine et al. 2020). This function includes expected standard deviation between isotope measurements of samples from individuals from the same location. We had to utilize values reported from other published literature given our sample of one bird from more than 50 years ago. Hobson et al. (2012) reported variation up to 18‰ for ground-foraging short distance migrants, and this was similar to reported deviation for Lesser Scaup (*Aythya affinis*; 5.6-16.5‰; Hobson et al. 2009) and slightly higher than the 12.8‰ used for waterfowl in central Canada (Asante et al. 2017). We used 18‰ for our expected variation to allow for the highest amount of variation in our estimates given the uncertainty related to the provenance of the specimen and general paucity of relevant data from the 1960s. We used ArcGis Pro 2.8 to generate a likelihood of origin map.

Results

The 1968 specimen did not have any physical indications of being reared in captivity typically associated with domestic waterfowl (i.e. clipped halluces, feathers, and toes). The specimen possessed a black or blackish breast, neck, primaries and tail and extensive areas of white on the head and face, as well as the underparts (Figure 1). These general plumage characters are consistent with Barnacle Goose and the species has been described as unmistakable (Carboneras and Kirwan 2020). However, finer features were not consistent with Barnacle Goose, suggesting the bird may be a hybrid. Notably, the black areas in the loral region, hind-crown and distal portion of the head were more extensive than is typically observed in Barnacle Geese (Figure 2). Specifically, black extended completely behind the eye distally, connecting with the hind-crown. The black loral area also extended completely around the eye and encompassed the entire portion where the bill meets the lores. The neck had dark black plumage with a subtle demarcation of faint white feathering in mid neck leading to dark slate gray coloration from mid-neck down to the chest. Upperpart feathers also

appeared to possess warmer tones than expected in Barnacle Geese with subtly duskier markings on the sides and flanks. These plumage characters indicated the specimen was likely a hybrid, most likely with a Cackling Goose (*Branta hutchinsii*).

Measurements of the culmen and bill width were similar to available measurements of Barnacle and Cackling goose (Table 1). Tarsus measurement was greater than the reported range for Barnacle Goose, but within the range reported for Cackling Goose (*B. h. hutchinsii*). However, the utility of tarsus measurement may be of limited value in this case because of the fixed and manipulated position of the legs of the mounted specimen. All three measurements were outside of the range of reported values for Canada Goose subspecies *B.c. interior*. We used subspecies *interior* of Canada Goose and *hutchinsii* of Cackling Goose in these comparisons because both breed in western Greenland (Mowbray et al. 2020a, 2020b) where Barnacle Geese currently breed (Boertman 1994), and where there is at least the potential for hybridization between these two species.

Figure 2. Closer view of the head of the 1968 specimen that shows more extensive black areas on the lores and hindcrown than what is expected for an adult Barnacle Goose.

Reviewers (Mlodinow, McWilliams) concluded the 1968 specimen was a Barnacle Goose x Cackling Goose hybrid. However, one reviewer (Lehmhus) suggested the 1968 specimen may be a Barnacle Goose x hybrid (Barnacle Goose x Cackling Goose) backcross (herein, Barnacle Goose backcross hybrid). Canada Goose was also considered as a possibility but is considered an unlikely parent species based on measurements. Brant (*Branta bernicla*) was also considered as a possible parent

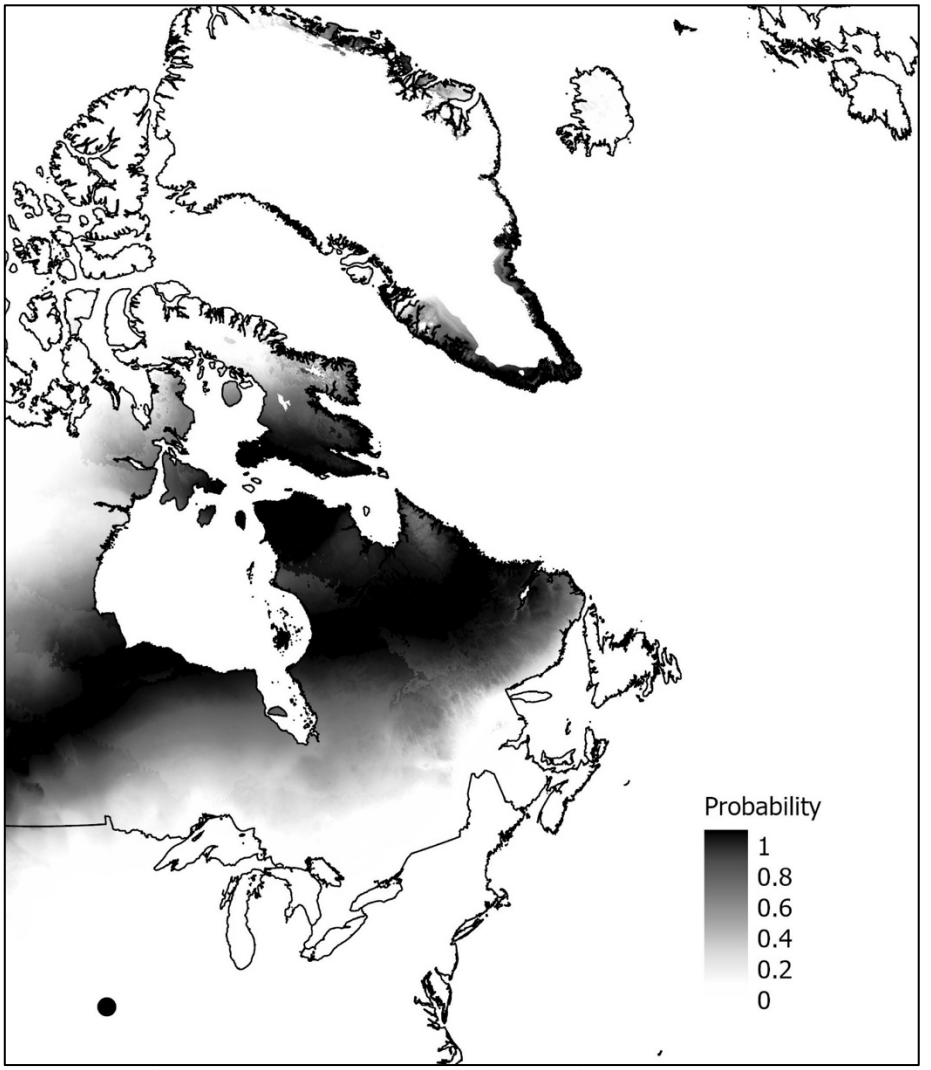

Figure 3. Likelihood of geographic origin of feather sample taken from 1968 specimen, with darker shades representing higher likelihoods. The graphic shows the northeastern United States, eastern Canada and Greenland. The large black dot is the approximate harvest location of the 1968 specimen.

species, but Brant x Barnacle Goose hybrids often have long undertail coverts (Joern Lehmhus, personal communication), a feature this bird did not possess. Based on our examination of the plumage and measurements, we conclude the 1968 specimen is most likely a Barnacle Goose x Cackling Goose hybrid or a Barnacle Goose backcross hybrid.

One photographic reviewer (McWilliams) suspected the 1968 specimen was an after hatch-year (AHY) bird based on heaviness of the side barring (slight to none in hatch-year (HY) birds, heavy in AHY), and the boldness of the wing covert edging (blurry and not as distinct in HY bird and sharply defined in AHY). Both individuals (Stutheit and Garrick) who physically examined the 1968 specimen concluded the 1968 specimen is an AHY based on the rounded shape and lack of obvious wear on the tail feathers. Thus, based on these opinions, and concurrence by Lehmhus, we conclude the 1968 specimen is an AHY bird rather than an immature as reported in Cortelyou (1969).

Stable isotope analysis provided a δ^2H value of 120.5 ‰ of the wing feather sample. After conversion using the transfer function, the assigned geographic likelihoods based on the isotopic reading of the feather sample are highest in the boreal or sub-Arctic regions of central and eastern Canada, the Ungava Peninsula, and limited areas in southern Baffin Island and Greenland (Fig 3).

Table 1. Culmen, bill width and tarsus measurements for the Nebraska goose specimen and reported ranges or averages for Barnacle (*B. leucopsis*), Cackling (*B. h. hutchinsii*), and Canada (*B.c. interior*) geese.

Metric	Nebraska specimen	Barnacle Goose[1]	Cackling Goose[2]	Canada Goose[3]
Culmen	39.0 (± 0.2)	38.1	37.2 – 39.2	49.9 – 51.6
Bill width	21.0 (± 0.2)	21.0	20.5 – 21.7	23.5 – 24.7
Tarsus	83.4 (± 0.7)	58.5 – 81	84.0 – 90.6	84.3 – 93.1

[1]Reported values from Owen and Ogilvie 1979.
[2]Reported values from Mowbray et al. 2020b.
[3]Reported values from Thompson et al. 1999.

Discussion

Our reexamination of the 1968 specimen provides three important corrections to the ornithological record. First, the 1968 specimen was originally misidentified as a Barnacle Goose and this identification was not questioned by various authors (including the authors of this article, until very recently) even though there was an extant published photo. Second, the 1968 specimen was incorrectly reported to be an immature or HY bird when it appears to be an AHY bird. Thirdly, it was assumed the bird originated from captive stock and was not a wild bird. Based on the evidence presented here, we conclude this bird is a wild AHY Barnacle Goose x Cackling Goose hybrid or Barnacle Goose backcross hybrid. This conclusion has important implications for other records of Barnacle Geese and Barnacle Goose hybrids in North

America, as well as other records of vagrant waterfowl from the Interior of North America.

The number of Barnacle Geese breeding in the Greenland population has increased markedly, from < 10,000 individuals in the 1960s to > 80,000 individuals by 2013 (Mitchell and Hall 2013). Much of this increase has been in western Greenland, where, as recently as 1994 (Boertman 1994) there were only four records of Barnacle Goose there. This, along with other evidence, is one reason why plausible arguments were made that a proportion of Barnacle Geese found in North America are wild vagrants (Sherony 2008), countering the earlier position advanced by Ryff (1984) that was widely accepted for many years.

Our likelihood map does indicate a possibility the feather was grown at more southerly latitudes than expected for Cackling Geese, namely in areas of boreal forest and boreal plains in south-central Canada (Fig. 3). However, much of this region is dominated by habitat that Cackling Geese are not known to utilize during the breeding season (i.e. forest), particularly during molt. Regions in the Intermountain West of North America at high elevations (>1500m) were also excluded, as geese are not known to use montane areas to molt, nor do we find it likely that there would be an exotic waterfowl collection at such altitudes in the 1960s given the extremely harsh weather conditions for the majority of the year. Even with these caveats, the highest probabilities given the isotopic signature of the feather are > 1200km from the harvest location and include known-breeding locations for Cackling Geese, we cannot completely exclude the possibility that a captive-reared goose could escape from captivity at a temperate latitude, flock and migrate with wild sub-Arctic or Arctic breeding geese in spring and then migrate south after completing a wing molt in fall. There is no evidence that there is a source of Cackling Goose x Barnacle Goose hybrids in North America, since Cackling Geese, unlike Barnacle Geese, are rarely kept in captivity in North America (Steven Mlodinow, personal communication). Furthermore, we are unaware of any documented examples of a captive-reared Barnacle Goose x Cackling Goose hybrid or Barnacle Goose backcross hybrid migrating to a northern latitude, molting its wing feathers, and flying south to Nebraska or the Midwest with Cackling Geese.

The key remaining question is where Cackling and Barnacle geese would interact in the wild and eventually breed to produce the hybrid or hybrid backcross that was harvested in Nebraska. The 1968 specimen occurred prior to the recent major increases of the Barnacle Goose populations at a time when the scarcity of Barnacle Geese in or near the established breeding range of western Greenland Cackling Geese (Boertman 1994) would be quite likely to produce hybrids and backcross hybrids between the two species.

Boertman (1994) described two breeding colonies of Cackling Goose subspecies *B. h. hutchinsii* breeding in western Greenland; this situation was mentioned only tangentially by Mowbray et al. (2020b) in their section entitled "Historical Changes to the Distribution". Apparently, these breeders had been present from the 1950s (Mowbray et al. 2020b), perhaps not surprisingly, since the Greenland

locations are about 600 miles from the Cackling Goose breeding locations in southern Baffin Island, Canada. On the other hand, Barnacle Goose, while breeding in numbers in eastern Greenland at the time, was only a vagrant to western Greenland, with only four records (Boertman 1994). Thus, given this imbalance in numbers, it is possible that hybrids could arise between the two species when one of the involved species has few options for a same-species mate choice (McCracken and Wilson 2011). It is thus probably not a coincidence that the Nebraska hybrid occurred in 1968. Subsequently, however, Barnacle Goose breeding numbers have increased in western Greenland (Mitchell and Hall 2013), which suggests hybridization would decline and become quite rare as breeding birds would easily find conspecific mates.

Barnacle Goose has been reported in Nebraska on at least four other occasions (Silcock and Jorgensen 2021); one was reported at a sandpit pond south of the Odessa bridge in Phelps Co 9 Mar 1995 (Gubanyi 1996), another with Cackling Geese at Massie Waterfowl Production Area (WPA), Clay Co 28 Mar-4 Apr 1998 (Brogie 1999), and a group of three was distantly photographed in Colfax Co Apr 2014 (Brogie 2015). In addition, one among a flock of geese at Harvard WPA, Clay Co 9 May 1998 (Jorgensen 2012) may have been the same individual observed at Massie WPA earlier in that spring. All of these reports were rejected by the Nebraska Ornithologists' Union's Records Committee (NOURC) because of questions of provenance (Gubanyi 1996, Brogie 1999, 2015), as was a record of a Pink-footed Goose (*Anser brachyrhynchus*), whose identity is not in dispute, at Harvard WPA 30 Jan 2006 (Brogie 2007). Pink-footed Goose also breeds in Greenland and is observed with increasing frequency in North America (Sherony 2008). Our results from stable isotopic analysis provide additional support that wild Arctic-breeding geese, potentially including Greenland breeders like Barnacle Goose or its hybrids with Cackling Goose, are quite capable of reaching North America and, specifically, Nebraska. Thus, we believe NOURC's precautionary approach, while defensible, is actually counterproductive because of the tendency for unaccepted records becoming footnotes in the ornithological record. Thus, we believe NOURC should re-review this record as well as that of the 2006 Nebraska Pink-footed Goose. With that said, we do not believe any of the other Barnacle Goose reports from Nebraska are supported by indisputable photographic or specimen evidence. This is important because without photographs we do not know if these reports excluded hybrids involving Barnacle Geese, such as the 1968 specimen. Thus, there are no other indisputable Barnacle Goose occurrences for Nebraska at this time.

Our study provides an entertaining conclusion to an important event in Nebraska ornithology. Interestingly, we would have been unable to identify the specimen discovered at the Nebraska Game and Parks Commission headquarters as the bird harvested in 1968 if a photograph of the latter was not published or available. We also do not know how the Commission came into possession of this mount. Finally, our study also emphasizes the importance of tangible evidence for significant bird records remaining extant for later examination. It seems likely that a written description, even a detailed one, of the 1968 specimen could have conclusively

identified the bird as a Barnacle Goose. It was only the availability of the photograph and specimen that allowed the actual identity (as a hybrid) be determined.

Acknowledgement

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