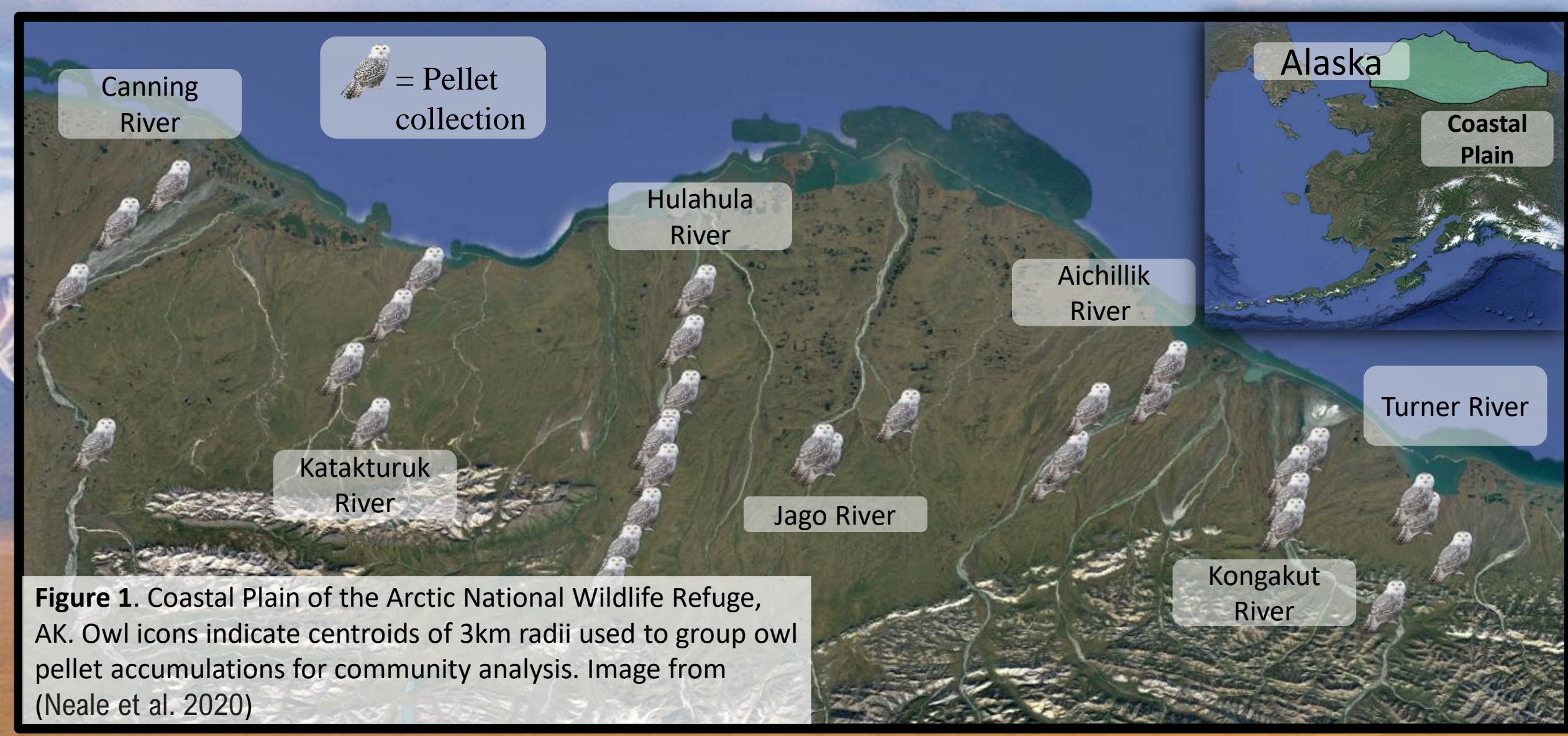


# Analysis of raptor pellets of the Arctic National Wildlife Refuge reveals multiple producers across the Coastal Plain

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**Figure 1.** Coastal Plain of the Arctic National Wildlife Refuge, AK. Owl icons indicate centroids of 3km radii used to group owl pellet accumulations for community analysis. Image from (Neale et al. 2020)

## Introduction

The Coastal Plain of the Arctic National Wildlife Refuge, AK is one of the last remaining, largely un-anthropogenically modified stretches of coastal plain in the United States. The Coastal Plain is a broad, largely flat region between the Brooks Range to the south and the Arctic Ocean to the north. While state and federal wildlife management focuses on understanding large mammal and migratory bird populations, we know less about the small mammals, which serve as the base of many mammalian and avian food chains. Predatory birds (raptors) generally eat their prey whole and subsequently regurgitate packets of undigested material in the form of pellets (Terry et al., 2018). These pellets are useful for evaluating the composition of small mammal communities across space and through time (Neale et al., 2020). Recent work used pellets (Figure 1) to establish the first survey of small mammals across the coastal plain (Neale et al., 2020). This study showed that the rodent community of the Coastal Plain shifted dramatically from lemming-dominated to vole-dominated across a west-to-east gradient. However, this work did not establish which raptor(s) produced the pellets, which is important for understanding the underlying patterns. To evaluate which pellet-producer(s) contributed to the pellet record, I measured the physical dimensions of the pellets (lengths and widths) and compared those frequency distributions to known pellet dimensions of candidate pellet producers that breed or summer along the Coastal Plain of the Arctic Refuge.

## Materials and Methods

Pellets were collected by Joshua Miller during surveys of antlers and other bones on *Dryas*-rich habitats across the Coastal Plain. Pellets analyzed here come from surveys conducted in 2018. In the lab, pellets were photographed, and maximum pellet lengths and widths are recorded (in millimeters) using digital calipers. To evaluate pellet dimensions, I generated frequency distributions for lengths and widths.

To aggregate data on pellet dimensions, pellet appearance, and diet preferences of candidate pellet generators, I used previously published literature and the Cornell Lab of Ornithology, Birds of the World website. I focused my search on pellet-producing birds that breed or summer on the Coastal Plain of the Arctic Refuge (USFWS, 2010). Birds that feed on fish, invertebrates, other birds, or have diets that otherwise do not correspond with the Coastal Plain's rodent-dominated pellets from were no longer considered. The remaining bird species were considered "Suspects" and the dimensions of their pellets were then compared to the dimensions of Coastal Plain pellets.

To determine which of the "Suspects" may have contributed to Coastal Plain pellets, I visually compared their pellet lengths and widths (means and standard deviations) to a histogram of Coastal Plain pellet lengths and widths.

Status	Definition
Permanent Resident	Present throughout the year and breeds in the area.
Summer Resident	Only present during the period from May to September.
Breeder	Documented as a breeding species.
Migrant	Travels through on the way to wintering or breeding areas.
Visitor	Present as a non-breeding species.
Abundance	Definition
Abundant	Very numerous in suitable habitats.
Common	Very likely to be seen or heard in suitable habitats.
Fairly Common	Numerous but not always present in suitable habitats.
Uncommon	Occurs regularly, but not always observed either because of lower abundance or secretive behaviors.
Rare	Occurs regularly but in very small numbers so not commonly observed.
Casual	Beyond its normal range but irregularly observed.
Accidental	Far from its normal range. Further observations unlikely.

**Table 1:** Terms used to describe the status and abundance of Coastal Plain bird species.

## Acknowledgements

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Coastal Plain Raptors	Species	Status	Abundance	Diet	
Suspects (potential contributors of Coastal Plain pellets)	Snowy Owl	<i>Bubo scandiacus</i>	permanent resident	uncommon	small and large mammals, birds, carrion, some insects, crustaceans, and amphibians
	Short-eared Owl	<i>Asio flammeus</i>	breeder	uncommon	majority small mammals; less frequently birds
	Northern Harrier	<i>Circus hudsonius</i>	summer resident	uncommon	small-medium sized mammals (usually rodents), birds, reptiles, and frogs
	Gyrfalcon	<i>Falco rusticolus</i>	permanent resident	uncommon	mostly birds, some small mammals (microtines to hares)
	Common Raven	<i>Corvus corax</i>	permanent resident/breeder	uncommon/rare	live meat, eggs, insects, grains, fruit, garbage, and carrion
	Sabine's Gull	<i>Xema sabini</i>	breeder and migrant	uncommon	zooplankton, crustaceans, fish
	Mew Gull	<i>Larus canus</i>	visitor and breeder	rare	omnivorous; crayfish, worms, larvae, insects, garbage
	Glaucous Gull	<i>Larus hyperboreus</i>	breeder and summer resident	common	opportunistic; varies with the season and breeding location.
	Arctic Tern	<i>Sterna paradisaea</i>	breeder (coastal/land) (inland coastal plain)	uncommon (coastal/rare)	small fish, crustaceans, insects, some invertebrates

**Table 2:** Relevant pellet-producing species sighted along the coastal plain, along with status and abundance taken from published literature. Shaded boxes represent pellet-producing birds that breed or reside on the Coastal Plain but are less likely to be the producers of the Coastal Plain pellets.

**Figure 2**

## Coast Plain Pellet Appearance

Pellets were generally long and oval-shaped or closer to spherical (see Figure 2). Most pellets were densely compacted and smooth. Few pellets had jagged edges. The color of most pellets was brown to gray. Bones were often visible on external pellet surfaces. Other pellets showed fur, or a fur-like matrix, with no sign of bones. Fur ranged from dull to shiny in appearance. Some pellets were light gray to white; these pellets were also smaller and had irregular shapes. This deviation in color and shape might indicate a specific producer pellet. However, reporting of these features was not recovered from the literature.

**Figure 2.1:** Long and oval-shaped pellet from the Arctic Refuge. Dark, rich brown color. Demonstrating a densely compacted, whole pellet.

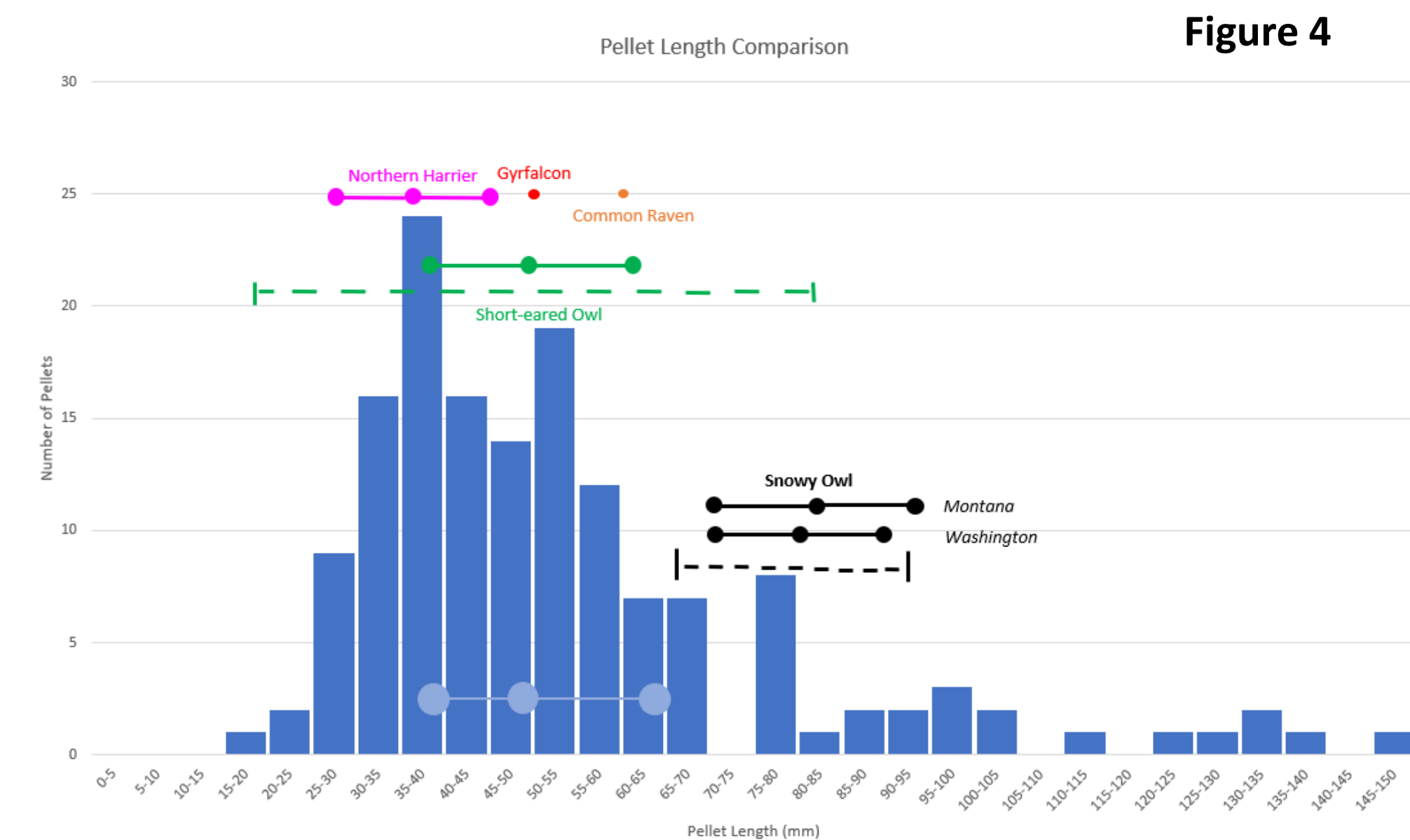
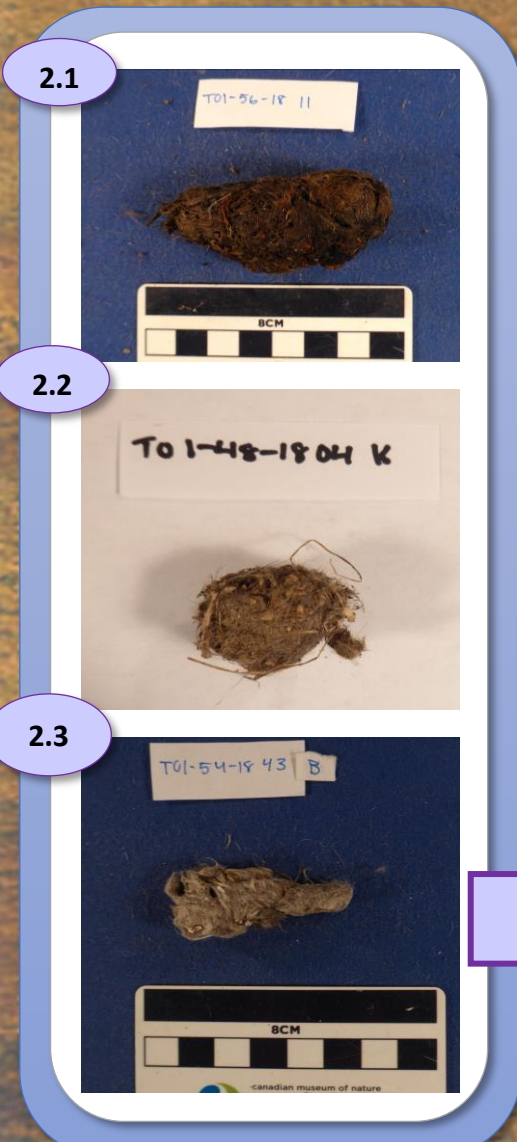
**Figure 2.2:** Spherical pellet from the Arctic Refuge. Spherical in shape. Color is dull-brown, which was the most common pellet color.

**Figure 2.3:** Pale gray-white, irregularly shaped pellet from the Arctic Refuge.

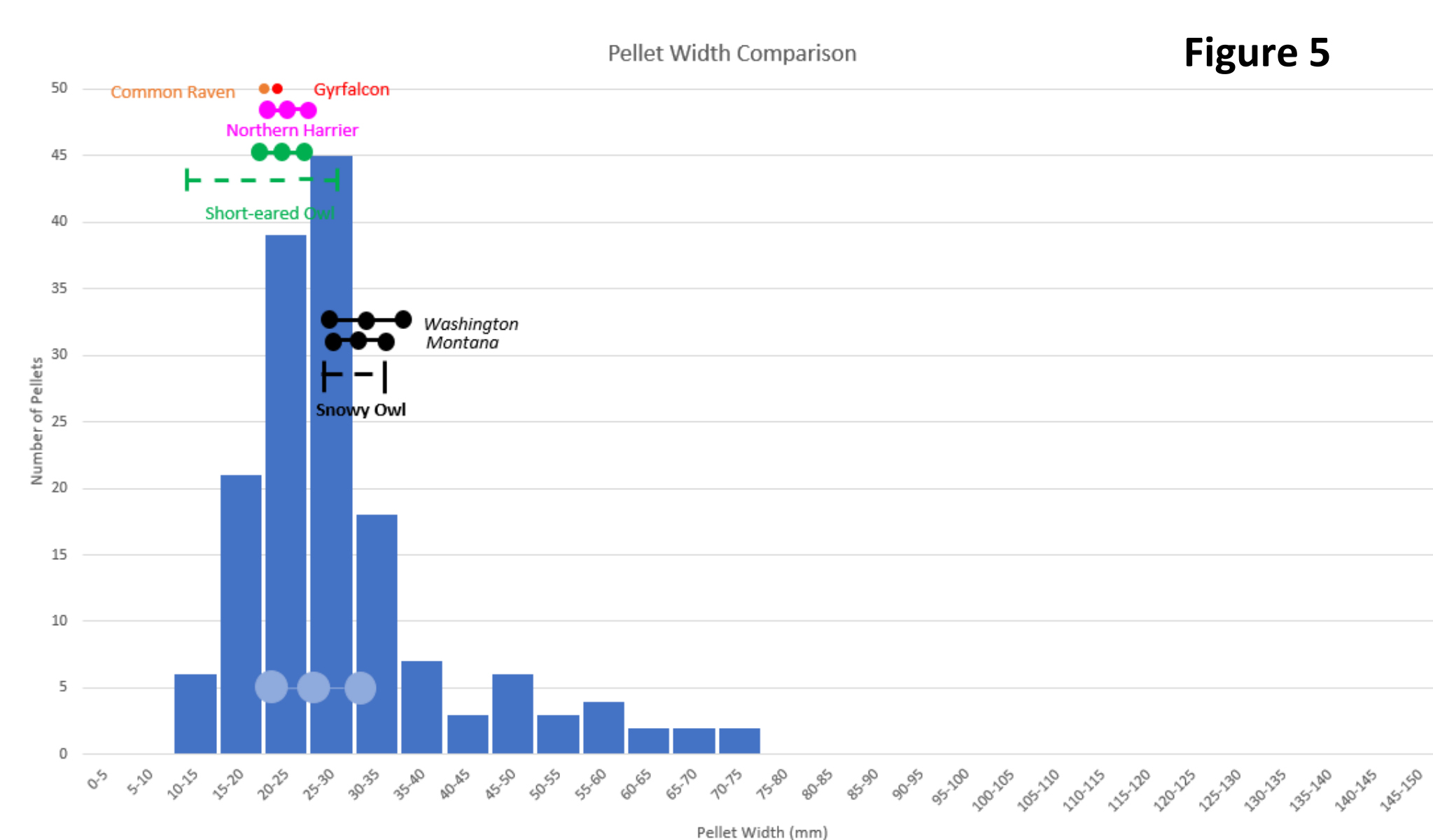


**Figure 3:** Map of the Arctic National Wildlife Refuge and the Coastal Plain. Image from: Alaska Department of Natural Resources

Caribou form large herds on the coastal plains north of the Brooks Range in the Arctic National Wildlife Refuge, Alaska. Photo: Florian Schulz



**Figure 4**



**Figure 5**

**Figures 4 & 5:** Histograms of pellets lengths (Figure 4) and widths (Figure 5) in millimeters. Pellet mean (points) +/- one standard deviation (solid line with dot at end) are shown for snowy owl, northern harrier, and short-eared owl. For short-eared owl and snowy owls, known range of pellets is also provided (dashed lines). Mean pellet sizes (dots) are provided for gyrfalcon and common raven. Species represented by colors (see Key). Median and interquartile range of Coastal Plain pellets (light blue dots and solid lines) provided near base of histograms.

### Key

Breeding and Permanent Residents	Color
Snowy Owl	Orange
Short-eared Owl	Purple
Northern Harrier	Red
Gyrfalcon	Green
Common Raven	Blue

## Suspects

**Snowy Owl**  
Snowy owl pellets are the largest of all potential pellet producers. Their pellets overlap with the higher range of Coastal Plain pellets in both length and width, though Coastal Plain pellets can be larger than known snowy owl pellets. Snowy owl pellet lengths are larger the 75<sup>th</sup> percentile of Coastal Plain pellets and generally higher than the median width of Coastal Plain pellets. The snowy owl is the most likely candidate of the largest pellets on the Coastal Plain.

**Short-eared Owl**  
Short-eared owls can be common breeders across the coastal plain and their pellet lengths and widths overlap a large portion of Coastal Plain pellets. For pellet lengths, the mean (+/- one standard deviation) for short-eared owls overlaps the middle peak of Coastal Plain pellets (Figure 4). Short-eared owl pellets can vary across a wide range of lengths and widths (Fig. 4 and 5, dashed green lines) which overlap a majority of Coastal Plain pellets. Their pellets are very compact and tend to be very consistent in appearance due to the short-eared owls' efficient digestive system (Stegman, 1957). This description is consistent with the appearance of Coastal Plain pellets.

**Northern Harrier**  
Northern harriers generate pellets with dimensions that overlap the dominant peak of Coastal Plain pellet lengths (Fig. 4) and a majority of Coastal Plain pellet widths. Northern harriers are uncommon summer residents to the coastal plain.

**Gyrfalcon**  
Gyrfalcon pellet lengths overlap those of short-eared owls and is consistent with the middle peak of Coastal Plain pellet lengths. Gyrfalcon pellet widths are within the interquartile range of Coastal Plain pellet widths. Gyrfalcon pellets are long and oval, consisting of feathers, fur, and small to medium sized bones (Booms et al., 2020). The gyrfalcon is an uncommon permanent resident of the Coastal Plain.

**Common Raven**  
Pellet dimensions for ravens are somewhat sparsely available, but median pellet length and widths are within the range of other "Suspects" and within the range of Coastal Plain pellets. Mean pellet length for the common raven does not overlap any of the peaks of Coastal Plain pellets (Fig. 4). Mean pellet width for the common raven is also more peripheral to the bulk of Coastal Plain pellet widths. The appearance of raven pellets is highly variable (Boorman and Heinrich, 2020), but available data are limited. Ravens are rare permanent residents or breeders on the coastal plain. Of all the "Suspects", ravens are rarest on the Coastal Plain.

Photos from: Cornell Lab or Ornithology, Birds of the World website

## Results

### (Identifying "Suspects")

Based on dietary preferences, sabine's gulls, mew gulls, glaucous gulls, are arctic terns are unlikely to produce the rodent-dominated pellets of the Coastal Plain. The diet of sabine's gull is mostly zooplankton, crustaceans, and fishes (Day et al., 2020). The Mew Gull is omnivorous, however their diet consist mostly of crustaceans, worms, larvae, insects, and garbage (Moskoff and Bevier, 2020). Arctic tern feed primarily on small fish, crustaceans, insects, and some invertebrates (Hatch et al., 2020). Glaucous gull are opportunistic, generalist feeders, with diets that vary considerably with season and breeding location (Weiser and Gilchrist, 2020), but are not known to include many rodents.

Remaining species of interest (our "Suspects") are snowy owl, short-eared owl, northern harrier, gyrfalcon, and common raven.

## Results (Coastal Plain Pellets & Raptor Comparisons)

Arctic Refuge pellet lengths range from 19.4 mm to 149.4 mm with a median and interquartile range of 48.2mm [37.4 mm, 64.0 mm] (Fig. 4). There are three peaks in pellet lengths: 35-40 mm, 50-55 mm, and 75-80 mm. Pellet widths range from 10.5 mm to 75.5 mm and have a median and interquartile range of 25.9 mm [22.2 mm, 31.5 mm] (Fig. 5).

The most dominant peak in Coastal Plain pellet lengths (35-40 mm) corresponds well with pellets produced by Northern Harriers. The peak at 75-80 mm corresponds well with snowy owl pellets. The middle peak (50-55 mm) corresponds well to short-eared owl pellets, but also to gyrfalcon pellets. Compared to short-eared owls and gyrfalcons, raven pellets are more offset relative to the 50-55 mm peak of Coastal Plain pellet lengths.

Variability in widths is more limited for both Coastal Plain pellets and pellet sizes of bird "Suspects". While this limits the discriminatory power of pellet widths, a combination of snowy owl, northern harrier, short-eared owls, raven, and gyrfalcon could generate the Coastal Plain pellet assemblage. Notably, many Coastal Plain pellets are much larger in length and width than reported in the literature (Figs. 4-5).

## Discussion

Pellets on the Arctic Refuge Coastal Plain likely come from multiple species. Prime suspects for the bulk of the pellets include short-eared owl, snowy owl, and northern harrier. Gyrfalcons and ravens are also possible contributors, though gyrfalcons generally consume more birds than observed in most Coastal Plain pellets nor was the breadth of raven diets (e.g., invertebrates, fruit, carrion).

A complication in our data is that pellet width was not particularly informative. Due to low variability, most pellet producers are consistent with widths of Coastal Plain pellets. Snowy owls are the only "Suspect" known to produce pellets on the large end of both length and width, which provides the clearest indication that they contributed at least some of the pellets recovered from the Coastal Plain.

Distinction between pellets of short-eared owls and northern harriers is notoriously difficult (Holt et al. 1987). Thus, while discrete peaks in Coastal Plain pellet lengths correspond nicely to northern harriers and short-eared owls, additional work is necessary to fully discriminate between these two species. For example, more detailed evaluation of pellet characteristics, including the percentage of bone vs. non-bone remains, can be used to differentiate pellets of different birds (e.g., Holt et al. 1987). See "Next Steps" for further details. For example, lengths of short-eared owl pellets are consistent with most of the pellets from the Coastal Plain.

## Next Steps

Future evaluations of Coastal Plain pellets should investigate additional pellet characteristics, as well as detailed analyses on the bones themselves. Such analyses will be particularly useful for discriminating Coastal Plain pellets of short-eared owls from those of northern harriers and gyrfalcons. For example, due to differences in diet and digestive efficiencies different bird species generate pellets containing different amounts of bone. For example, bones constitute ~37% of short-eared owl pellets by mass, as opposed to only ~18% of northern harrier pellets (Holt et al., 1987). Bones consumed by diurnal raptors can also be distinguish from those consumed by owls using differences in micro-fissures that form on bone surfaces during digestion (Terry et al., 2018). Finally differences in bone fragmentation can also be used to discriminate rodents consumed by diurnal raptors from those consumed by owls (Terry, 2007).

## Conclusion

Pellets on the Coastal Plain of the Arctic National Wildlife Refuge likely come from multiple birds including snowy owl, short-eared owl, and northern harrier. Ravens and gyrfalcons may also contribute to the pellet record. Evaluating pellet dimension is one way to determine which birds produced the pellets, but this method should be paired with others to more confidently determine the pellet-producers. While the pellet assemblage comes from multiple predators, there is no indication that bird populations change appreciably across the Coastal Plain, suggesting the impact on pellet-based rodent community data is likely minimal.

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