

Forum

Predators and scavengers: polar bears as marine carrion providers

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Scavenging is a foraging strategy widely used across the animal kingdom and apex predators provide a large amount of energy in a food web by provisioning carrion. In the harsh environmental conditions of the Arctic, apex predators such as polar bears *Ursus maritimus* can provide scavenging opportunities for many species. Carrion can act as a buffer when food resources are low, and some terrestrial species use the marine environment for cross-ecosystem resource subsidies. We present an overview of scavenging as a foraging strategy in the Arctic marine environment and examine the contribution of prey provided by polar bears to the Arctic scavenging assemblage. As obligate predators of seals, polar bears contribute a substantial amount of carrion to the marine ecosystem, particularly to the sea ice surface where it is accessible for seasonal scavenging opportunities. We estimated that an average polar bear kills approximately 1001 kg of marine mammal biomass annually and given preferential feeding of blubber and abandonment of carcasses, we estimate that 30% of the biomass is left as available carrion. Consequently, polar bears provision approximately 7.6×10^6 kg year⁻¹ of carrion biomass for scavengers across their range, equivalent to 3.93×10^7 MJ of energy. Eleven vertebrate species are known to scavenge polar bear kills, and an additional eight are possible scavengers. While foraging associations with polar bear kills for some species are better understood, others are scarce or undocumented. We provide an overview of what is known about the role of polar bears as carrion providers, the network of scavenging species on the sea ice, and the possible consequences of trophic downgrading in this ecosystem and recipient ecosystems.

Keywords: apex predator, carrion, cross-ecosystem resource subsidy, food web, scavengers, trophic downgrading, *Ursus maritimus*

Synthesis

Our paper takes a novel look at the impacts of climate change in the Arctic and the consequences for the ecosystem if polar bears are lost. We estimated that a single polar bear kills an average of 1000 kg of marine mammals each year to sustain their energy requirements. We estimate that polar bears provide 7 million kg year⁻¹ of carrion across their range, with up to 19 other vertebrate species benefiting from the resource. We highlight that polar bears are unique in the Arctic ecosystem in provisioning food on the sea ice surface and that no other process adequately replicates what polar bears are capable of.

Introduction

Apex predators shape ecosystems and influence biodiversity, and declines in their abundance are a conservation concern for ecosystem structure and function (Beschta and Ripple 2009, Ritchie et al. 2012). The influence of apex predators on trophic dynamics occurs through direct top-down numerical effects on prey populations and indirect interactions such as mesopredator control, prey behavioral responses, and altering spatial and temporal patterns of prey (Laundré et al. 2010, Ordiz et al. 2013, Johnson-Bice et al. 2023). Declines in the abundance of apex predators can cause trophic cascades (Ripple et al. 2016) and trophic downgrading (Estes et al. 2011, Ripple et al. 2024), the effects of which pervade through an entire ecosystem. Yet understanding the multifaceted role of apex predators has often only been possible after their removal from an ecosystem (Estes et al. 2011, Ritchie et al. 2012), especially the indirect effects, which are often unclear under equilibrium conditions and only noticeable once the change has occurred.

The provisioning of carrion by apex predators has important direct and indirect effects on ecosystems (Moleón et al. 2014, Johnson-Bice et al. 2023). Scavenging as a foraging strategy and source of energy is generally underestimated in

food web research (Wilson and Wolkovich 2011, Peers et al. 2020), yet is a common behavior among many taxa including large carnivores (Wirsing and Newsome 2021), mesocarnivores (Prugh and Sivy 2020), small mammals (Peers et al. 2018), birds (Moreno-Opo and Margalida 2013), reptiles (Lillywhite et al. 2002, Jessop et al. 2020), and detritivores (Dunlop et al. 2021). In areas where large carnivore abundance has changed (LaRue et al. 2012, Rosenblatt et al. 2014), consequent changes in carrion provided by predators may influence scavenger population dynamics.

Carrion can provide a buffer during periods of food scarcity and harsh environmental conditions in high-latitude ecosystems (Selva et al. 2019), yet few studies have assessed the role of carrion in the Arctic, especially marine systems. The Arctic is an intensely seasonal environment with large fluctuations in productivity and food resources (Stickney 1991, McKinnon et al. 2012) including migratory pulses of species that include predators, prey and facultative scavengers (Mullen and Pitelka 1972, Derocher et al. 2002, Galicia et al. 2016). Numerous Arctic species scavenge (Table 1), although the importance of scavenging for each species varies. For instance, species such as wolverine *Gulo gulo*, Arctic fox *Vulpes lagopus* and ravens *Corvus corax* receive significant dietary contributions from scavenging, and carrion abundance

Table 1. An overview of the common, rare, and potential members of the sea ice scavenging assemblage associated with carrion from polar bear *Ursus maritimus* kills.

Family	Common name	Scientific name	Scavenging activity	Source
Ursidae	polar bear	<i>Ursus maritimus</i>	common	Stirling 1974, Laidre et al. 2018, Lillie et al. 2019, Galicia et al. 2021
	grizzly bear	<i>Ursus arctos</i>	rare	MacHutchon and Wellwood 2003, Derocher 2012
Canidae	wolf	<i>Canis lupus</i>	rare	Stirling and Archibald 1977, Andriashek et al. 1985
	Arctic fox	<i>Vulpes lagopus</i>	common	Soper and Wilson 1928, Freuchen 1935, Chesemore 1968, Stirling and Archibald 1977, Roth 2003
Mustelidae	red fox	<i>Vulpes vulpes</i>	rare	Andriashek et al. 1985, Jung et al. 2020
	wolverine	<i>Gulo gulo</i>	potential	Magoun 1987, Magoun and Valkenburg 2001, Glass et al. 2022
Laridae	glaucous gull	<i>Larus hyperboreus</i>	common	Derocher et al. 2002, Selva et al. 2019
	herring gull	<i>Larus argentatus</i>	common	Barnas et al. 2024, Gamblin et al. unpubl.
Corvidae	ivory gull	<i>Pagophila eburnea</i>	common	Derocher et al. 2002, Spencer et al. 2014, Hamilton et al. 2017
	Ross's gull	<i>Rhodostethia rosea</i>	potential	Divoky 1976
	Iceland gull	<i>Larus glaucoides</i>	potential	Moorhouse 2021
	common raven	<i>Corvus corax</i>	common	Stirling and Archibald 1977, Smith 1980, Derocher et al. 2002, Matley et al. 2012
Accipitridae	rough-legged hawk	<i>Buteo lagopus</i>	rare	Gomo et al. 2020
	eagles	<i>Haliaeetus</i> spp., <i>Aquila chrysaetos</i>	potential	Erskine 1968, Utekhina et al. 2000, Killengreen et al. 2012, Gomo et al. 2020
Strigidae	snowy owl	<i>Bubo scandiacus</i>	rare	Therrien et al. 2011, Allen et al. 2019, Dybas 2024
Procellariidae	northern fulmars	<i>Fulmarus glacialis</i>	potential	Hobson and Welch 1992b
Stercorariidae	jaegers	<i>Stercorarius</i> spp.	potential	Magoun and Valkenburg 2001
Falconidae	falcons	<i>Falco</i> spp.	potential	Court et al. 1988, Burnham and Newton 2011

can elicit a numeric response in some of their populations (Temple 1974, Roth 2003, Mattisson et al. 2016). Other species, such as the snowy owl *Bubo scandiacus*, switch to a more generalized diet seasonally when primary prey resources are low and opportunistically use carrion (Boxall and Lein 1982, Dybas 2024).

The Arctic's apex marine predator, the polar bear *Ursus maritimus*, preys largely on Arctic ice-breeding seals but is also a facultative scavenger (Stirling 1974, Laidre et al. 2018). Polar bear diets are dominated by ringed seals *Pusa hispida*, but they also prey on larger, energy-rich prey items such as bearded seals *Erignathus barbatus*, harp seals *Pagophilus groenlandicus*, hooded seals *Cystophora cristata*, walrus *Odobenus rosmarus*, beluga whales *Delphinapterus leucas* and narwhals *Monodon monoceros* (Smith and Sjare 1990, Thiemann et al. 2008, Hamilton and Derocher 2019). In addition to scavenging and intraspecific kleptoparasitism, polar bears scavenge from alternative sources including natural strandings of beluga whales, narwhals, gray whales *Eschrichtius robustus*, bowhead whales *Balaena mysticetus*, carcasses from killer whale *Orcinus orca* predation events, and remains left by Inuit harvesters (Thiemann et al. 2008, Galicia et al. 2016, Laidre et al. 2018, Lillie et al. 2019). Scavenging is important for all demographic groups of polar bears but may be particularly significant for the survival of subadult bears. Younger bears that are less experienced at catching prey can benefit from scavenging carcasses left by older, dominant bears (Stirling 1974, Galicia et al. 2016). Despite being competitively subordinate, younger bears are often found in the same habitat as dominant individuals to scavenge on available carcasses (Pilfold et al. 2014b).

Facultative scavenging places polar bears among the species in the Arctic scavenging assemblage, but their primary predatory feeding behavior demonstrates their key role in provisioning resources to other species. Polar bears have evolved foraging behaviors that maximize energy gained by feeding primarily on the high-energy fat content of their prey (Stirling 1974, Stirling and McEwan 1975, Pagano et al. 2018). The energy-dense blubber is consumed preferentially, while the remainder of the carcass is often abandoned (Stirling and Archibald 1977, Stirling and Derocher 1990). Polar bears rarely cache, defend, or hoard kills (Stirling et al. 2020), leaving carcasses available for scavengers. Abandonment of carcasses can result in a substantial amount of carrion deposited on the sea ice by polar bears (Stirling and Archibald 1977), particularly during spring when polar bears are hyperphagic in response to ringed seal availability (Pilfold et al. 2012, 2015). Polar bear productivity and seal populations are linked, with higher predation rates, reproductive success, and adult survival of bears corresponding to years with high seal productivity (Stirling and McEwan 1975, Stirling 2002, Pilfold et al. 2012). During the peak of hunting over the hyperphagic period, it is estimated that a single bear will kill one seal every three to five days (Stirling and Øritsland 1995). This high predation rate and partial consumption of kills creates scavenging opportunities and highlights the resource provisioning role polar bears play as the Arctic's apex predator.

Our primary objective is to review the role of polar bears as carrion providers to the scavenging assemblage while on the sea ice. Specifically, we aim to 1) highlight the characteristics that distinguish scavenging in the Arctic sea ice ecosystem from other biomes, 2) describe the prey polar bears provide to scavengers and estimate the amount of carrion polar bears produce annually, 3) identify species that scavenge carrion left by polar bears, and 4) discuss future research needs and conservation implications. Many subpopulations of polar bears are vulnerable to the effects of climate change, with some subpopulations already experiencing declines (Stirling and Derocher 2012, Hamilton and Derocher 2019). By presenting an overview of scavenging in the Arctic marine environment, we aim to provide an understanding of the indirect effects of an apex predator and explore the possible consequences of trophic downgrading on a wide variety of scavenging species.

What distinguishes sea ice scavenging opportunities provided by polar bears?

Seasonality of the ecosystem

With mean temperatures ranging between -39°C in winter and 20°C in summer (Walsh 2008), the Arctic undergoes a transformation between seasons to which few species are adapted. With just 2% of the global total of fauna (Callaghan et al. 2004), the Arctic is one of the least biodiverse regions (Killengreen et al. 2012). Resident Arctic species are adapted to withstand intense seasonal variation, particularly low winter temperatures, while migratory species escape the winter conditions (Callaghan et al. 2004). As Scholander et al. (1950) noted: "It is quite obvious that the Arctic mammals are adapted to withstand cold or they would freeze to death."

These low temperatures support the sea ice biome, which includes a diversity of habitats ranging from thick multiyear ice to thinner annual ice that undergoes a seasonal freeze-thaw cycle (Comiso et al. 2008, Lin et al. 2022). This dynamic ice environment includes shore leads and recurrent polynyas, which are areas of open water surrounded by ice that are kept from freezing over by currents, winds and upwellings (Stirling 1980). During autumn, the onset of the ice freeze-up creates a complex habitat that consists of fast ice attached to land and the ocean floor and floating pack ice that expands throughout the winter and reaches its maximum extent in March (Jacobs et al. 1975, Comiso et al. 2008). The melt season begins as temperatures rise throughout spring and summer, leading to an entirely ice-free period in some regions as the ice thins and declines in cover, with the Arctic ice minimum extent occurring in September (Stroeve and Notz 2018).

As a sea ice-obligate species, polar bear foraging is influenced by the seasonality of ice availability (Stirling and McEwan 1975). All 20 of the recognized subpopulations of polar bears throughout the circumpolar Arctic (Hamilton and Derocher 2019, Laidre et al. 2022) depend on the sea ice as their primary habitat (Rode et al. 2015, Stern and Laidre 2016). Polar bears prefer active ice habitat that includes

shallow (< 300 m) ice-covered waters nearshore, shore leads, and polynyas, as these areas contribute roughly 50% of productivity in Arctic waters (Amstrup et al. 2008, Pilfold et al. 2014b). Polar bears will remain on the sea ice provided there is suitable ice cover (Cherry et al. 2013, McGeachy et al. 2024), and in some subpopulations they follow the ice as it retreats northward (Cherry et al. 2013, Pongracz and Derocher 2017, Thelin et al. 2025). Polar bears in regions with seasonal ice experience an ice-free period where they are forced ashore for several months with limited access to marine prey, resulting in an annual feeding/fasting regime that corresponds with ice availability (Stirling and McEwan 1975, Pagano et al. 2018). When sea ice is present and hunting opportunities are available, bears become hyperphagic in spring to build fat reserves needed to survive the ice-free period (Stirling and McEwan 1975, Pilfold et al. 2012, Galicia et al. 2020) (Fig. 1). During the ice-free season when bears are restricted to land, they fast and rely on stored energy reserves until freeze-up (Stirling and Parkinson 2006, Rode et al. 2015, Pagano et al. 2024).

As a pulsed resource (sensu Yang et al. 2008), carrion provided by polar bears can be substantial during the hyperphagic period of their feeding/fasting regime. The primary feeding period for polar bears follows the ringed seal

reproductive and molting period, creating a seasonal pulse in carrion when seal pups are born (Ramsay and Stirling 1988, Pilfold et al. 2012, 2014a). As opposed to the year-round availability of carrion to scavengers in other ecosystems, scavenging opportunities on the sea ice are limited to when ice is available to facilitate polar bear predation. As in other ecosystems, carrion may occur through other natural causes such as senescence, starvation, unfavorable environmental conditions or disease (Kalxdorff 1998, Selva and Fortuna 2007, Moleón et al. 2014). For example, ringed seals have been found dead and frozen outside of their breathing holes and lairs (Smith 1987). Disease outbreaks can also cause unusual mortality events that can lead to significant strandings (NOAA 2018). However, seals spend much of their life underwater (Kelly et al. 2010b), and throughout most of the year, seal mortalities would result in the carcass in the water column or sinking rather than being available on the surface of the sea ice for vertebrate scavengers.

In addition to the seasonality of carrion, the Arctic experiences temporal variation in the species composition within the scavenging assemblage. Few Arctic vertebrate species are resident, but several undergo long- or short-distance migrations between seasons (Callaghan et al. 2004). This seasonal



Figure 1. Polar bear *Ursus maritimus* with a recently killed bearded seal *Erignathus barbatus* pup. Polar bears feed primarily on the high-energy fat content of their prey to build fat reserves and often abandon large amounts of carrion biomass.

transition brings an influx of migratory species, particularly birds, that overwinter in temperate climates to avoid the harsh winter and early spring conditions (Callaghan et al. 2004). Some marine mammal species, such as the harp seal, hooded seals, and beluga whales, are also migratory and therefore only available at certain periods (Bailleul et al. 2012, Smith and Stirling 2019, Thelin et al. 2025). Seasonality produces a dynamic scavenging assemblage and prey base in the Arctic influenced by three key components: 1) polar bears as a specialist apex predator for provisioning carrion, 2) the presence of sea ice habitat suitable for polar bear foraging and other scavengers, and 3) the influx of migratory species that fill roles as prey and scavengers.

Transfer of energy between marine and terrestrial Arctic species

Scavengers facilitate the transfer of energy, and to a lesser extent nutrients, between marine and terrestrial ecosystems through carrion provisioned by polar bears. The benefits

of energy transfer in a typical scavenging framework often emphasize apex predators providing lower trophic levels access to resources without additional prey death or exertion of consumer energy (Wilson and Wolkovich 2011, Pereira et al. 2013). Polar bears extend these benefits by providing nutrients that would otherwise be unattainable for many terrestrial and avian species, as seals are mostly invulnerable to terrestrial predators with the limited exception of Arctic foxes preying on newborn ringed seal pups in their subnivean birth lairs (Smith 1976). Sea ice provides a platform for polar bears to transfer food resources from the pelagic environment to the ice surface in large, reliable quantities (Fig. 2), and for most species, polar bears are the link to marine resource acquisition on the ice. The cross-ecosystem transfer of nutrients between the marine and terrestrial environment is well documented in sandy beach ecosystems from carrion washed ashore (Behrendorff et al. 2016, Hyndes et al. 2022), but this type of food resource is spatially and temporally infrequent (Britton and Morton 1994). Cross-ecosystem

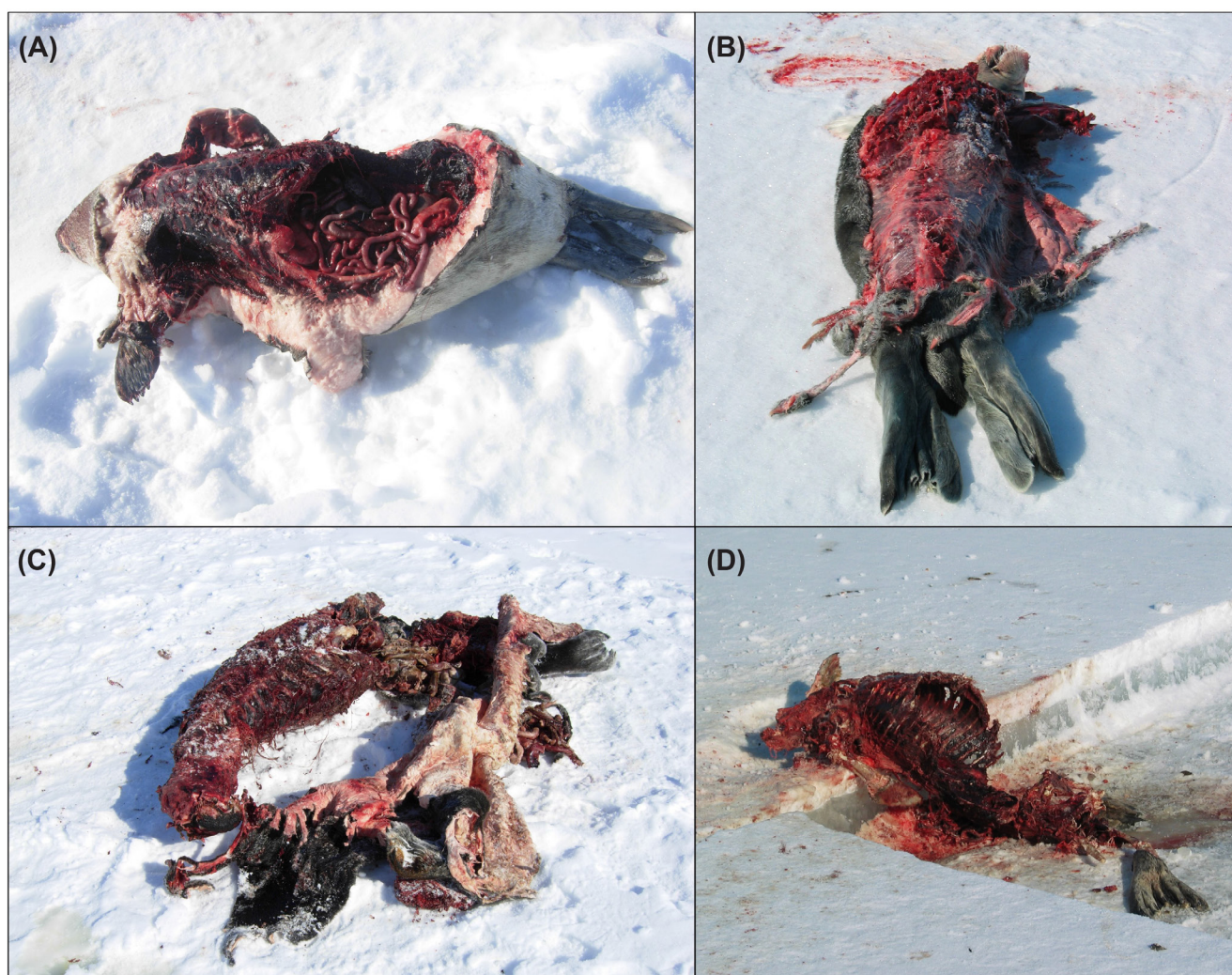


Figure 2. Abandoned prey remains from four different polar bear *Ursus maritimus* predation events: (A) adult ringed seal *Pusa hispida*, (B) bearded seal *Erignathus barbatus* pup, (C) well-scavenged adult bearded seal, and (D) well-scavenged adult ringed seal.

resource subsidies are donor-controlled resources transferred from one habitat to a recipient consumer from a different habitat (Polis et al. 1997), and predators can act as donors prompting nutrient movement from marine to terrestrial environments. For example, brown hyenas *Parahyaena brunnea* deposit Cape fur seal *Arctocephalus pusillus* carcasses along the coast of Namibia through predation and surplus killings (Wiesel 2010). Similarly, the partial consumption and surplus killing of salmon *Oncorhynchus* spp. by grizzly bears *Ursus arctos* provides carrion, although this resource lasts for just one to two months and prey abundance fluctuates annually (Hilderbrand et al. 1999, Lincoln and Quinn 2019). For polar bears, a key difference is that the marine resources they provision do not leave the marine environment but are rather made available for terrestrial and avian species on the sea ice surface. Nutrients may be transferred as feces and stored energy brought back to land by scavengers, while any other non-consumed remains enter the water column when the sea ice melts or turns over (Fig. 3).

Apex predators may reduce carrion availability by food caching or rapidly consuming large quantities of the prey (Vander Wall 1990, Allen et al. 2015), but this behavior is not typical for polar bears (Stirling and Derocher 1990,

Stirling et al. 2020). Caching is consistent with optimal foraging theory, which posits that animals make choices on which food items to prioritize and where to forage to optimize their net energy gained (MacArthur and Pianka 1966, Krebs 1977). Therefore, it is energetically beneficial for apex predators to maximize carcass consumption through caching when the cost of acquiring new prey is high (Lincoln and Quinn 2019). Contrasting with these caching behaviors, polar bears often consume only the energy-dense blubber and abandon the remainder of the carcass (Stirling and Archibald 1977, Stirling and Derocher 1990, Stirling et al. 2020). Polar bears have the stomach capacity to consume a meal the size of approximately 15–20% of their body mass (Best 1977, Derocher and Wiig 2002). For large prey items, this limit can produce substantial carrion. For example, a 300 kg bearded seal could produce > 200 kg of carrion after the first feeding bout by an adult male polar bear. Prioritizing blubber consumption of seals allows polar bears to access the most energy-dense portion of the carcass and reduces the water requirements that would be needed to excrete the byproducts of consuming protein-rich tissues (Nelson et al. 1983). Access to energetically efficient freshwater is limited in the Arctic since the consumption of snow or ice imposes an

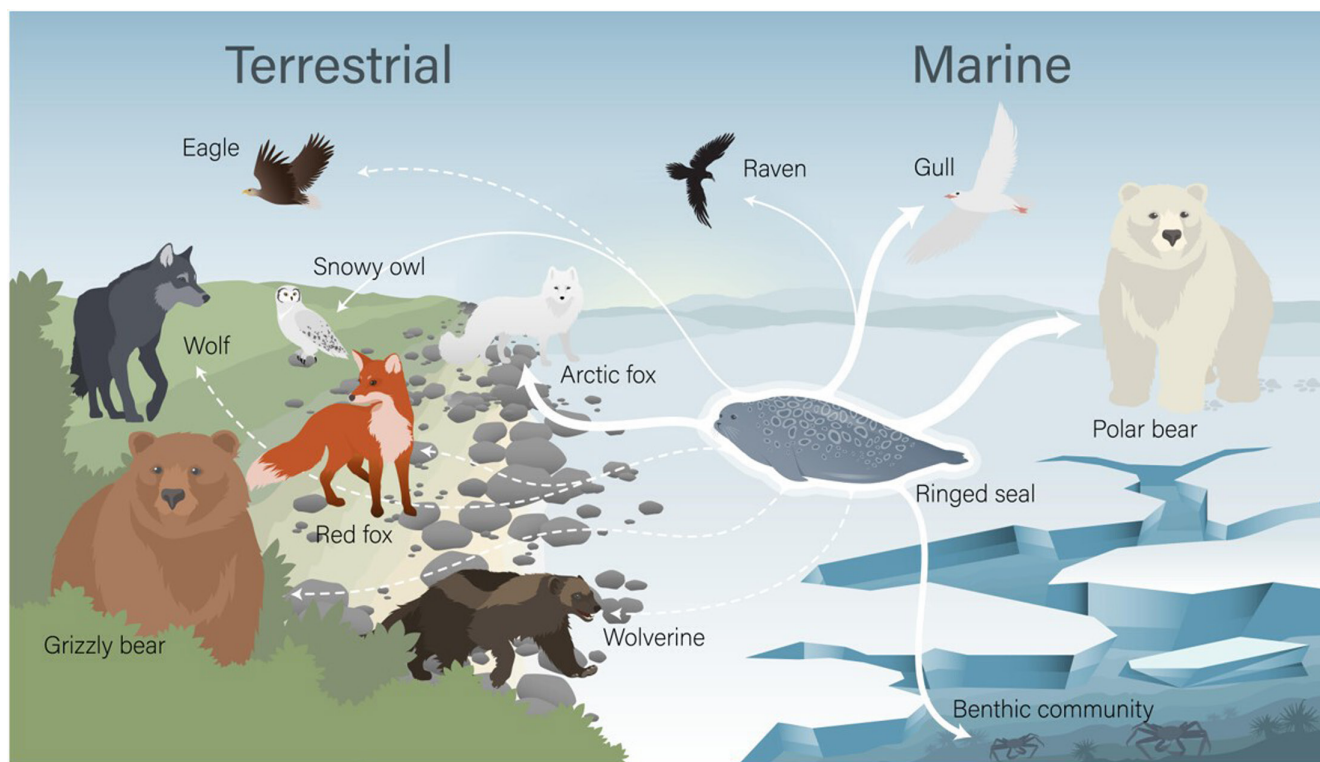


Figure 3. Diagram illustrating a subset of known and potential members of the sea ice scavenging assemblage associated with carrion from polar bear *Ursus maritimus* kills. Arrow thickness represents the strength of energy flow between carrion and scavengers, as well as the spatial and temporal variation in energy flow. Thick solid arrows denote known primary scavengers with broad overlap, thin solid arrows denote secondary scavengers that may not be present in all regions, and thin dashed arrows denote species that have rarely been observed scavenging on the sea ice or potential scavengers that have been observed scavenging in the terrestrial Arctic landscape but not yet on the sea ice. Ringed seals *Pusa hispida* are depicted as the representative carrion species in this diagram for simplicity since they are the most abundant Arctic pinniped and the primary prey of polar bears. However, the diagram can also represent other marine mammals that may be a source of marine-based energy and nutrients.

energetic cost, but the catabolism of fat produces metabolic water that can aid water balance in polar bears (Nelson et al. 1983).

The availability of marine resources is also facilitated by polar bears opening the carcass after depositing it onto the sea ice (Stirling and Archibald 1977, Smith 1980). The act of opening thick-skinned carcasses to the benefit of other species has been observed elsewhere (Moleón et al. 2014), and this phenomenon is especially important in colder climates where smaller species, such as ravens and other birds, have difficulty tearing the hard-frozen skin (Selva et al. 2003). Carcass availability is also a function of the spatial distribution of seal kills. Arctic seals are generally more abundant in nearshore areas (Frost et al. 2004), and continental shelf areas are important foraging zones for polar bears (Hamilton and Derocher 2019). The high availability of carcasses in nearshore areas on stable ice facilitates the link between terrestrial and marine environments, and carcasses deposited farther from shore may pose a limit on which species can access areas that are often in active ice zones with broken ice and open water.

The abiotic environment can limit or prolong scavenging opportunities

The intense seasonality in abiotic conditions in the Arctic can influence scavenging opportunities in complex ways, both by freezing carrion in extreme cold, while also simultaneously prolonging carcass availability by delaying degradation. During winter, only resident species that are physiologically adapted to withstand cold conditions and can tear and masticate the frozen flesh of carcasses benefit from carrion provisioning on the sea ice (Stirling 1974, Ainley et al. 2003, Fuglestad et al. 2006). Observations of seal carcasses with significant remaining biomass frozen to the sea ice in -25°C conditions suggest that there may be lower temperature bounds to the availability of the remains (Stirling and Øritsland 1995). There are also likely energy tradeoffs and induced physiological stress from heating consumed frozen tissue to equilibrium with internal body temperature (Nelson et al. 1983).

Decay rates, nutrient transport to different groups (i.e. insects, soil microbes and vertebrates), and carcass size influence the quantity of biomass available in an ecosystem (Moleón et al. 2015, Barton et al. 2019). In many terrestrial environments, rapid decomposition rates can render a carcass useless to scavengers within days, and in some climates invertebrates and bacteria can outcompete scavengers in as little as 24 h (Coe 1978, Beasley et al. 2012). Carcass persistence in extreme and moderately cold environments is prolonged, primarily due to reduced competition with microbial and invertebrate communities that are limited or absent due to cold temperatures (Turner et al. 2017). Ambient temperature influences decomposition rates and bacteria growth, with warmer, moister climates promoting faster decomposition rates than colder, dryer climates (Parmenter and MacMahon 2009, Beasley et al. 2012). As the Arctic transitions from the winter environment to the moderately cold

spring temperatures, the abiotic environment and the sea ice platform create a refrigerator effect (sensu van der Veen et al. 2020) that delays carcass degradation by prolonging the frozen condition of the carcass. In addition, the Arctic receives as little precipitation as a desert ecosystem (Callaghan et al. 2005), providing conditions that preserve tissue. Depending on the size of the carcass, the refrigerator effect could prolong scavenging opportunities for months.

On the sea ice, the speed at which carcasses are removed from the surface is primarily controlled by the timing of ice turnover and melt. When seal carrion is left, avian and terrestrial scavengers may access it until the sea ice platform becomes unstable, at which point the carrion is transferred below-ice to epontic, pelagic and benthic scavengers (Dunlop et al. 2021). Similar to the sea ice surface, the temperatures of the ocean floor limit bacterial growth and carcass decomposition (Beasley et al. 2012), so the use of polar bear kills may extend well beyond the time carcasses are available to the terrestrial community (Hobson and Welch 1992a). The link between the sea ice and scavengers in the water column is poorly understood.

What can be scavenged?

Types of scavenging resources

Many scavenging resources in the Arctic are marine-driven, although carcasses of large herbivores are available in terrestrial ecosystems near the subarctic boreal forest tree line and on the tundra (Selva et al. 2019). With a global population estimate of approximately 26 000 polar bears (PBSG 2024), polar bears are the primary provider of marine carrion on the sea ice throughout the circumpolar Arctic. Arctic foxes are the only other predator that could deposit carrion on the sea ice, but their foraging behavior likely produces few remains for scavenging (Smith 1976). Arctic foxes can enter subnivean lairs to kill ringed seal pups, often remaining within the lair until the whole carcass has been consumed (Smith 1976). Killer whales are another top predator and are becoming more common in Arctic waters (Ferguson et al. 2010, Barratclough et al. 2025), providing carrion to scavengers in open water, along the shore and below the ice.

The ringed seal is the most abundant Arctic pinniped and the primary prey of polar bears and Arctic foxes on the sea ice (Smith and Stirling 1975, Smith 1980, Thiemann et al. 2008), and as such they represent the majority of carrion available. Ringed seals are a sea ice-obligate species and exhibit different periods throughout the year: the open-water foraging period, the subnivean foraging and reproductive period, and the basking period when molting occurs (Kelly et al. 2010b). Ringed seals are particularly vulnerable to predation during and after pups are born (Smith and Stirling 1975, Pilfold et al. 2012, 2015). During this time pups remain in subnivean lairs for approximately 5–8 weeks for nursing and thermoregulation due to their limited tolerance for cold water immersion (Smith et al. 1991, Lydersen and Kovacs 1999). When pups are weaned subnivean lairs are abandoned, the mating season

begins, and ringed seals enter a basking period where they are exposed on the sea ice without cover to facilitate molting until the ice breaks up (Kelly et al. 2010a, 2010b). Ringed seal behavior during this period keeps them on or near the surface of the sea ice and therefore vulnerable to predation (Smith 1976, 1980, Hammill and Smith 1991, Pilfold et al. 2015), resulting in a significant increase in kills by polar bears (Pilfold et al. 2012) and increased scavenging opportunities.

In addition to ringed seals, polar bears prey on several ice-associated marine mammal species (Thiemann et al. 2008, Hamilton and Derocher 2019). The diversity of prey species whose ranges overlap with each subpopulation ranges from three to nine marine mammal species (Fig. 4), yet the use of each species depends on hunting abilities of polar bear demographic groups and regional availability (Thiemann et al. 2008, Hamilton and Derocher 2019). Sexual size dimorphism and age influence prey acquisition in polar bears, as juveniles and females are roughly half the size of adult males (Derocher et al. 2005, Thiemann et al. 2008). Bearded seals, for instance, are important prey for polar bears, although their large size may limit smaller bears from making successful adult kills (Stirling and Archibald 1977). Bearded seals are roughly five times the size of adult ringed seals, weighing on average 33 kg at birth and 250–300 kg as adults, although they can reach sizes over 425 kg (Kovacs 2018). Adult bearded seals are most frequently preyed on by large, adult male polar bears, while smaller females and young bears can predate juveniles (Stirling and Archibald 1977, Thiemann et al. 2008, 2011). Although bearded seal kill rates are lower than ringed seals, they contribute a substantial portion of kill biomass available for scavenging due to their large size (Derocher et al. 2002,

Pilfold et al. 2012). Other larger prey items such as narwhal and beluga whales are also more prevalent in the diets of larger, older males (Thiemann et al. 2008).

Regionally, harp seals are a significant dietary contribution in areas associated with the North Atlantic Ocean, and harbor seals *Phoca vitulina* are an important prey resource for younger age classes where available (Thiemann et al. 2008). Although not as common as other prey species, polar bears kill and cannibalize conspecifics and these carcasses can provide scavenging opportunities (Amstrup et al. 2006). Ribbon seals *Histiophoca fasciata* and spotted seals *P. largha* may be opportunistic prey, although there is little evidence of predation by polar bears (Boveng et al. 2009, 2013).

Quantifying carrion biomass

Few studies provide quantitative data on carrion biomass, although recent efforts have identified methods for extrapolating population and ecosystem-level estimates from individual carcasses (Barton et al. 2019). Following Barton et al. (2019), we developed a framework for using carcass-level data and population metrics to generate annual biomass input rates at the subpopulation scale and for the entire polar bear range. To generate annual subpopulation and global seal biomass input rates, we used the body mass of ringed seals as the representative model input because they are the primary prey of polar bears (Stirling 1974, Smith 1980, Thiemann et al. 2008).

We first estimated the total ringed seal biomass required annually for a single polar bear using polar bear kill rates and ringed seal mass by age class. We used the kill rates estimated in Stirling and Øritsland (1995) to identify the number

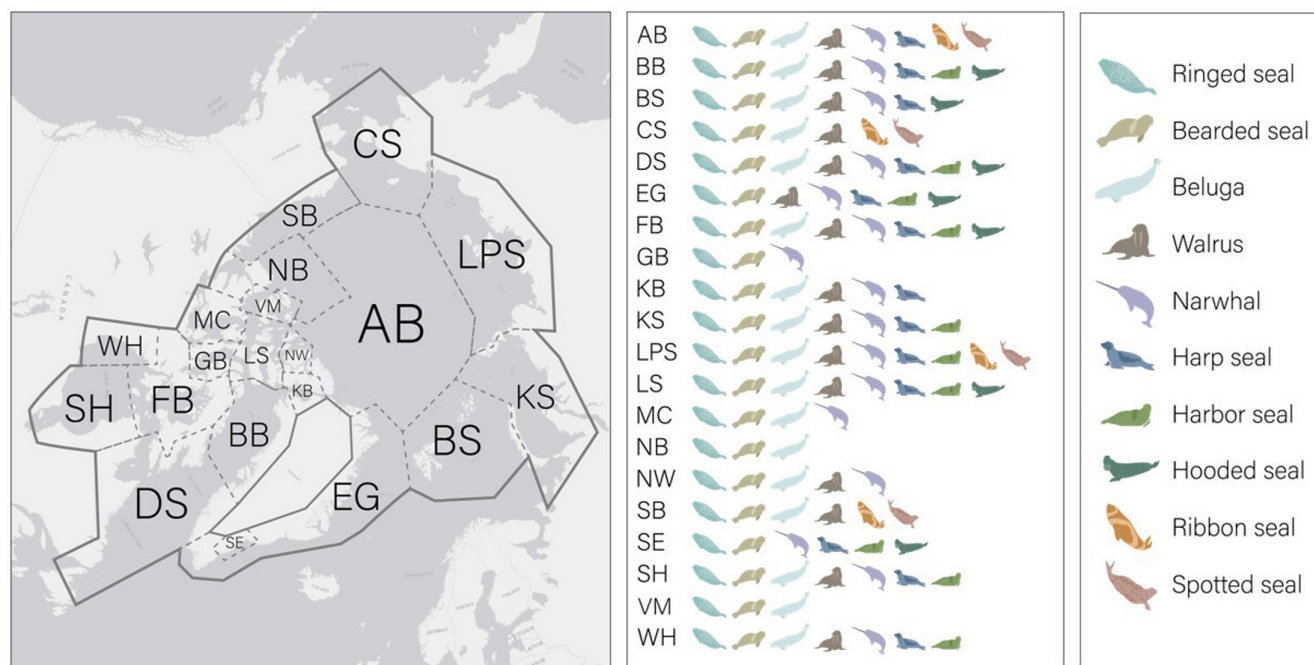


Figure 4. Overview of the 20 polar bear *Ursus maritimus* subpopulations recognized by the Polar Bear Specialist Group (PBSG 2024) and the marine mammal species that are potential and documented prey for polar bears.

of seals killed annually in each seal age class. Stirling and Øritsland (1995) used direct field observations and assumptions based on polar bear predatory behavior to estimate that an average polar bear requires and likely consumes 6 newborn ringed seal pups (< 2 months old), 18 young-of-the-year (2–11 months old), 11 subadults (1–2 years old), and 8 adults annually. Following Stirling and McEwan (1975), we calculated the mean mass of each age-class of seal as 23.6 kg for young-of-the-year, 19.2 kg for subadults, and 45.7 kg for adults. We then multiplied the kill rate of each age class of seal by their respective mean mass to estimate the total seal biomass produced per bear annually. We ignored newborn pups from the biomass calculation due to their small size (~4 kg). The derived estimate for ringed seal biomass requirements for an average bear was 1001 kg year⁻¹ (Eq. 1):

$$\begin{aligned} \text{Seal biomass (kg year}^{-1}\text{) per bear} \\ = \sum \text{kills} \times \text{mean mass per seal age class} \end{aligned} \quad (1)$$

We then generated subpopulation-level biomass estimates by multiplying the polar bear subpopulation sizes (Hamilton and Derocher 2019, PBSC 2024) by the biomass requirements per average bear (Eq. 2).

$$\begin{aligned} \text{Seal biomass (kg year}^{-1}\text{) per subpopulation} \\ = \text{Subpopulation size} \times 1001 \text{ kg year}^{-1} \end{aligned} \quad (2)$$

Lastly, we used estimates of polar bear dietary preferences and ringed seal body composition to calculate the biomass available to scavengers after a polar bear abandons a kill. Polar bears are estimated to eat a diet composition that is 80% blubber and 20% muscle (Best 1985, Cherry et al. 2011), although some estimates report diet composition as low as 66–74% blubber for wild bears and 60% blubber for captive bears (Rode et al. 2021). To create a conservative estimate of remaining biomass after a polar bear has fed on a ringed seal, we assumed that the bear eats all the blubber and enough muscle to fulfill the 80/20 high-fat diet mix. Ringed seal body composition is approximately 40% blubber, 40% muscle, and 20% skeletal mass (Best 1985, Ryg et al. 1990). For a 46 kg adult ringed seal, the body mass composition breakdown is therefore 18.4 kg blubber, 18.4 kg muscle, and 9.2 kg skeletal mass. Following the 80/20 blubber to muscle diet mix, if a polar bear consumes 18.4 kg of blubber from a 46 kg ringed seal and that represents 80% of the total biomass eaten (18.4 kg/0.80 = 23 kg), then 4.6 kg of muscle is consumed from the remaining 23 kg of mass (23 kg × 0.20 = 4.6 kg). Therefore, approximately 50% (23/46 kg) of the biomass is left as carrion. The remaining biomass is a mixture of 13.8 kg of muscle and 9.2 kg of skeletal mass. We assumed that the remaining muscle biomass (13.8/23 kg) represents the available biomass available for scavenger consumption, or approximately 60% of the carrion.

Using this model, the biomass remaining for other scavengers is calculated as 50% of the total biomass produced per subpopulation after polar bears abandon their kills, and 60% of the remaining biomass represents the available biomass when skeletal mass is removed (Eq. 3).

$$\begin{aligned} \text{Available carrion biomass (kg year}^{-1}\text{)} \\ = (\text{Seal biomass} \times 0.5) \times 0.6 \end{aligned} \quad (3)$$

To determine the energy contribution of carrion, we multiplied the available carrion biomass by the energy estimate of 5.15 MJ kg⁻¹ of raw ringed seal meat derived from Kuhnlein and Soueida's (1992) nutritional composition values for ringed seals (Eq. 4).

$$\begin{aligned} \text{Energy contributed (MJ year}^{-1}\text{)} \\ = \text{Available carrion biomass} \times 5.15 \text{ MJ kg}^{-1} \end{aligned} \quad (4)$$

Estimates of the available carrion biomass produced varied by subpopulation and ranged from 48 363 to 882 245 kg year⁻¹ (Table 2). Polar bear abundance within a subpopulation ultimately relies on the productivity of the seal population (Stirling 2002), with areas of higher prey diversity often associated with larger subpopulations in better condition (Rode et al. 2012). In total, we estimated that polar bears produce approximately 7.6 × 10⁶ kg year⁻¹ of carrion biomass, equivalent to 3.93 × 10⁷ MJ of energy across their range.

Variations in carrion biomass

The provisioning of carrion by polar bears is subject to numerous factors that a simplified model cannot precisely account for without further empirical data. We used the period of one year across all subpopulations using a single prey species to ameliorate conditional variations and provide a basis for future empirical assessment. The kill rates in Stirling and Øritsland (1995) were based on direct observations and polar bear predatory behavior, and our model built on these estimates to provide a conservative estimation of carrion deposition rates. However, factors such as the seasonality of polar bear resource acquisition, different prey types (e.g. age class, size and species), surplus killing events, sea ice availability, as well as subpopulation area and demographics influence carrion availability.

Polar bears acquire most of their annual energetic needs during the hyperphagic period in late spring and early summer (Ramsay and Stirling 1988, Pilfold et al. 2012) and it is estimated that a kill rate of one adult ringed seal every 9–10 days is needed for adult females to balance their energetic needs during this period (Pagano et al. 2018). However, hyperphagic polar bears are gaining mass to prepare for the upcoming period of low prey availability and will kill and consume as much as possible. Polar bears have been observed on multiple occasions surplus killing at productive hunting

Table 2. Quantification of seal biomass deposited on the sea ice by polar bears in each subpopulation and globally. Biomass represents the amount of seal biomass produced annually per subpopulation, available biomass reflects the amount available to scavengers after polar bear consumption and skeletal mass is removed, and energy contributed demonstrates the number of megajoules made available to the scavenging assemblage.

Subpopulation	Subpopulation size ¹	Biomass ³ (kg year ⁻¹)	Available biomass ⁴ (kg year ⁻¹)	Energy contributed ⁵ (MJ year ⁻¹)
AB ²	489	489 636	146 891	7.56×10^5
BB	2826	2 829 674	848 902	4.37×10^6
BS	2644	2 647 437	794 231	4.09×10^6
CS	2937	2 940 818	882 245	4.54×10^6
DS	2015	2 017 620	605 286	3.11×10^6
EG/SG ²	991	992 288	297 686	1.53×10^6
FB	2585	2 588 361	776 508	4.00×10^6
GB	1525	1 526 983	458 095	2.36×10^6
KB	357	357 464	107 239	5.52×10^5
KS ²	989	990 286	297 086	1.53×10^6
LPS ²	812	813 056	243 917	1.26×10^6
LS	2541	2 544 303	763 291	3.93×10^6
MC	716	716 931	215 079	1.11×10^6
NB	980	981 274	294 382	1.51×10^6
NW	203	203 264	60 979	3.14×10^5
SB	900	901 170	270 351	1.39×10^6
SH	1119	1 120 455	336 136	1.73×10^6
VM	161	161 209	48 363	2.49×10^5
WH	618	618 803	185 641	9.55×10^5
Global total	25 408	25 441 030	7.6×10^6	3.93×10^7

¹Estimates taken from the Polar Bear Specialist Group (PBSG 2024) for subpopulations with estimates, and extrapolated from Hamilton and Derocher (2019) for subpopulations without estimates

²Subpopulation size unknown – extrapolated from Hamilton and Derocher (2019) based on the relationship between prey diversity and polar bear density

³Calculated using the estimate of 1001.3 kg year⁻¹ of seal biomass per bear derived from Stirling and McEwan (1975) and Stirling and Ortisland (1995)

⁴Biomass available to scavengers after 50% consumption of carcass by bears and skeletal mass subtracted; calculated using Best (1985) and Stirling and McEwan (1975) estimates of bear consumption ratios

⁵Energy estimated from 5.15 MJ kg⁻¹ of raw ringed seal meat (Kuhnlein and Soueida 1992)

grounds with individual bears taking far more prey than consumable, including multiple seals (Amstrup 2003, Stirling and Derocher 1990, Smith and Stirling 2019) and even multiple cetaceans (Lowry et al. 1987, Aars et al. 2015, Derocher 2012). The demographic composition of ringed seal kills in Stirling and Øritsland (1995) is also weighted toward young-of-the-year, and empirical evidence shows the importance of older adult seals and larger sized individuals in the diet of polar bears (Derocher et al. 2002, Pilfold et al. 2012, 2015). Larger kills often exceed the stomach capacity of a single bear, leaving more carrion than the same biomass divided into multiple smaller kills in which the digestive constraints on consumption would be reduced (Best 1985). Therefore, our model is likely a conservative estimate of the carrion biomass produced by polar bears, especially when bears are killing at rates necessary for mass gain.

Our model assumed that all blubber is removed from the available carrion biomass to meet polar bear energetic needs and preference for fat, but the nutrient composition of carrion will vary across seasons and prey species (Fig. 2). Larger kills in which substantial blubber is left behind increases the energetic value of the carrion because seal blubber is five times as calorically dense as muscle by wet weight (Stirling and McEwan 1975, Best 1985). Seasonal changes in prey body composition and mass also influence carrion energy.

Northern seals are generally at their lowest body condition following their reproductive and molting period and gain lost mass and blubber through hyperphagic feeding, the timing of which varies by species (McLaren 1958, Stirling and McEwan 1975, Ryg et al. 1990, Nilssen et al. 1997, Rosen et al. 2021). Variations in prey distribution and diversity lead to subpopulation differences that likely influence the quantity of carrion biomass provisioned. For example, the Gulf of Boothia subpopulation in the Canadian Arctic (Fig. 4) supports the highest known density of polar bears, and bears in this region consume more bearded seals than the nearby Baffin Bay subpopulation between Canada and Greenland (Galicía et al. 2015, Dyck et al. 2023). As a result, the carrion provisioned in the Gulf of Boothia may be more concentrated than in other areas. Differences in prey, sea ice conditions, and the scavenging species that are present to benefit from those resources could also influence energy transfer between regions.

What species are part of the Arctic scavenging assemblage?

Interspecific foraging associations occur when multiple species forage in association with each other (Ward and Zahavi

1973, Powell 1985, Sazima et al. 2007). Typically, one species acts as the leader of the interaction, providing resources for one or more follower species (Strand 1988, Barnas et al. 2024). These interactions can have a positive or neutral effect on the leader (i.e. mutualism or commensalism) or can take the form of parasitism (Tomita 2024). On the sea ice, scavenging represents a network of inter- and intraspecific foraging associations, where polar bears act as the leader species and the scavenging assemblage consists of numerous follower species. The sea ice scavenging assemblage represents a commensal relationship, where follower species benefit from food subsidies and the leader experiences no net effect (Tomita 2024). Adult polar bears can kleptoparasitize subordinates (Stirling 1974), but generally, the intraspecific foraging association between scavenging bears and predatory bears that abandon carcasses is thought to be commensal (Pilfold et al. 2014b). Interspecific foraging associations between polar bears and herring gulls *Larus argentatus* were described in terrestrial ecosystems (Barnas et al. 2024), but no assessments have examined their foraging associations on sea ice. Here, we describe the scavenging assemblage of polar bear kills on the sea ice by identifying species that are known to scavenge on them and potential scavengers (Table 1). Using primary and secondary literature, personal observations, life history traits and ranges of species considered, we identified common scavengers as species well-documented using polar bear kills on the sea ice, rare scavengers as those species infrequently noted, and potential scavengers as species who are known to scavenge in Arctic terrestrial environments and who have been documented using the sea ice but not yet scavenging on polar bear kills.

Common and rare scavengers

The Arctic fox is a terrestrial species that often benefits from marine carrion subsidies provided by polar bears (Soper and Wilson 1928, Freuchen 1935, Chesemore 1968, Stirling and Archibald 1977), particularly when terrestrial prey availability is low (Roth 2003). Arctic foxes are opportunistic predators and scavengers, relying on arvicoline rodent populations as primary prey throughout most of their range, as well as marine resources, migratory birds, eggs, and facultative scavenging (Jepsen et al. 2002, Angerbjörn et al. 2013, McDonald et al. 2017). The marine environment is particularly important for Arctic foxes in winter and spring, where sea ice excursions provide opportunities to predate ringed seal pups in subnivean birth lairs and scavenge seal remains from polar bear kills (Smith 1976, Roth 2003). Marine dietary inputs may compose up to 2/3 of the winter diet of Arctic foxes, and during years of low primary terrestrial prey Arctic fox abundance is influenced by the hunting success of polar bears and seal availability (Roth 2003, Johnson-Bice et al. 2025). The implications of carrion in the food web extend beyond the scavenger consuming the carcass and may have cascading effects on lower trophic levels when predator populations are subsidized (Rees et al. 2020, Johnson-Bice et al. 2025).

Among avian species, there are numerous accounts of ravens and gulls scavenging polar bear kills on the sea ice, with ravens representing a common scavenger in many regions (Stirling and Archibald 1977, Smith 1980, Derocher et al. 2002, Hamilton et al. 2017). Scavenger gull species, including the glaucous gull *Larus hyperboreus*, ivory gull *Pagophila eburnea* and herring gull, utilize marine mammal carrion facultatively (Hamilton et al. 2017, Spencer et al. 2014) and can be the most abundant visitor at carcass sites (Young et al. 2022). Rare scavengers with documentation of limited forays onto the sea ice for scavenging include grizzly bears, wolves *Canis lupus*, red foxes *Vulpes vulpes*, snowy owls and rough-legged hawks *Buteo lagopus* (Stirling and Archibald 1977, Andriashek et al. 1985, Derocher 2012, Jung et al. 2020).

Potential scavengers

The acquisition of carrion by scavengers is influenced by differences in morphology and behavior, with certain species better adapted to exploit carrion than others (Allen et al. 2015, Gomo et al. 2020). Unequal access to carrion is evident in all ecosystems, but is particularly important on the sea ice. One common feature among known sea ice scavengers is their ability to access the sea ice for marine-feeding bouts, whereas primarily terrestrial-feeding scavengers may be limited by the nature of the sea ice environment. For instance, red foxes are primarily a terrestrial-feeding species, as evident from their predominant use of boreal forest habitat in the subarctic and tundra habitat in the low Arctic (Warret Rodrigues and Roth 2023). In contrast, the high mobility and physiological adaptations of Arctic foxes, such as a reduction of basal metabolic rates and an increase in fur by up to 200% during winter (Underwood 1971, Fuglestad et al. 2006), allow them to exploit marine resources when ice conditions are suitable for travel (Warret Rodrigues and Roth 2023). Similarly, the high mobility of avian species allows them to access the marine environment for food subsidies irrespective of ice conditions (Therrien et al. 2011).

Scavenging is an important strategy for terrestrial-feeding species associated with the tundra and subarctic boreal forest (Killengreen et al. 2012, Peers et al. 2020), yet the extent of sea ice use by these species is unknown. Potential sea ice scavengers that have been observed scavenging in the tundra or boreal forest and have made forays onto the ice include wolverines (Magoun 1987, Magoun and Valkenburg 2001, Glass et al. 2022), eagles (*Haliaeetus* spp., *Aquila chrysaetos*; Erskine 1968, Utekhina et al. 2000, Killengreen et al. 2012, Gomo et al. 2020), jaegers *Stercorarius* spp. (Magoun and Valkenburg 2001), Ross's gull *Rhodostethia rosea* (Divoky 1976), Iceland gull *Larus glaucoideus* (Moorhouse 2021), northern fulmars *Fulmarus glacialis* (Hobson and Welch 1992b), and falcons *Falco* spp. (Court et al. 1988, Burnham and Newton 2011) (Table 1).

Although this list of potential scavengers is not comprehensive, it highlights the species that may scavenge polar bear kills and illustrates the knowledge gaps surrounding sea ice scavengers. The number of Arctic species, particularly

terrestrial vertebrates, that are subsidized by polar bear carrion is not well documented. Even for common sea ice scavengers, such as Arctic foxes, information on the proportion of their diet acquired by scavenging and the frequency of scavenging events is unknown.

Future research needs

Our review highlights what is known about the role of polar bears as carrion providers and the network of scavenging species on the sea ice. While scavenging associations with polar bear kills for some species are documented, others are scarce or lack documentation. Documenting scavengers on the sea ice will be an important step in identifying the species that use this resource, but additional research is needed to increase our understanding of the temporal and spatial species composition of the scavenging assemblage, the environmental and biological cues that drive carrion acquisition, the importance of carrion to facultative scavengers, and its links to the terrestrial food web. Other research avenues could include species-specific carcass removal rates, the succession of scavengers, and competition or dominance hierarchies that may exist around carcasses. The potential for carrion to act as a vector for disease and parasite transmission is another unexplored area. Climate change has increased pathogen exposure in polar bears, and the consumption of infected marine prey has been identified as a key pathway for transmission (Penk et al. 2021, Pilfold et al. 2021, Biddlecombe et al. 2025). Similarly, avian scavengers are exposed to pollutants from polar bear kills (Buckman et al. 2004, Lucia et al. 2017), which further highlights the importance of understanding scavenging ecology.

Experimental research on scavenging in the subarctic and Arctic is growing, with studies demonstrating techniques for addressing these knowledge gaps. Killengreen et al. (2012) investigated scavenger guilds on the tundra and how those change across a gradient of neighboring ecosystems. Gomo et al. (2020) explored the scavenging assemblages across an environmental gradient of boreal forest and tundra. Peers et al. (2020) focused on scavenging dynamics in the boreal forest and how that changes across spatial and temporal gradients. All these studies used remote-sensing cameras to monitor experimentally placed carcasses, providing examples of the experimental design and modeling techniques to investigate scavenging. Coupled with experimentally placed carcass stations, monitoring of natural kills may also provide insight on scavenging. There are no published examples of experimental studies on scavenging in the Arctic sea ice environment, likely owing to the logistical challenges that exist (e.g. drifting ice, ice turnover, barriers to human access). Most of the knowledge of these scavenger assemblages exists within natural history notes or anecdotal observations.

Additional research is also needed to refine our spatial and temporal understanding of the carrion biomass and energy contributed by polar bears to these scavenger assemblages. Our simplified biomass model relied on annual kill rates described in Stirling and Øritsland (1995), where empirical

kill rate data was limited to observations in April, May and July, while the remaining months were subjectively estimated based on polar bear foraging ecology. Empirical data is needed for kill rates and nutritional requirements of various polar bear demographic groups, subpopulations, and times of year to more accurately estimate carrion provisioning. We call on a systematic research effort to clarify the potentially important role that polar bears have in facilitating the energy intake of sympatric species.

Conservation implications

Habitat loss and degradation is one of the primary threats to apex predators and biodiversity worldwide (Ripple et al. 2014, Jantz et al. 2015), and this threat is evident in the Arctic where climate change has influenced phenology and species composition (Post et al. 2013, Ramírez et al. 2017, Lannuzel et al. 2020). The Arctic is experiencing amplified warming at least four times that of the global average (You et al. 2021), with the number of ice-covered days declining at 7–41 days per decade (Stern and Laidre 2016). These ongoing declines are predicted to lengthen as the climate continues to warm, resulting in an earlier ice melt onset and a delay in autumn freeze-up (Stroeve et al. 2014). Several subpopulations of polar bears have experienced declines that have been linked to the loss of sea ice habitat (Stirling and Derocher 2012, Bromaghin et al. 2015, Obbard et al. 2015, Lunn et al. 2016) and many are expected to be extirpated with continued warming (Durner et al. 2009, Castro de la Guardia et al. 2013, Hamilton and Derocher 2019, Molnár et al. 2020, Stroeve et al. 2024).

The sea ice influences ecological dynamics in both the marine environment associated with the ice platform as well as in adjacent terrestrial ecosystems (Post et al. 2013). The direct effects of an extended ice-free period include increased mortality and declines in the reproductive success of polar bears, ringed seals, and other species that depend on the sea ice for foraging, reproduction and resting (Molnár et al. 2010, Post et al. 2013). However, there is also the potential for indirect effects of sea ice loss that influence multiple trophic levels across biomes mediated by scavenging. If polar bear abundance declines, or if they are extirpated, the opportunities for scavenging on marine carrion would be reduced. For example, the Western Hudson Bay subpopulation declined 32% between 1987–2011 (Lunn et al. 2016), and the Southern Beaufort Sea subpopulation declined 44% between 2004–2010 (Bromaghin et al. 2015). These declines would result in an estimated loss of 113 848 kg year⁻¹ of carrion biomass (5.86×10^5 MJ of energy year⁻¹) in Western Hudson Bay, and 210 273 kg year⁻¹ of carrion biomass (1.08×10^6 MJ of energy year⁻¹) in the Southern Beaufort Sea. Lower density polar bear subpopulations also reduces the density of carrion sites, likely requiring further travel and energy expenditure by scavengers to locate carcasses. While Arctic foxes are not obligate scavengers, losing carrion from polar bears would be significant (Johnson-Bice et al. 2025).

The sea ice platform is essential for terrestrial scavengers to access carrion provided by polar bears, especially for mammals

that are less mobile than avian species. Even with stable polar bear populations, changes in sea ice dynamics including reductions in extent, increased fragmentation, speed of drift, and rates of turnover may decrease access to marine carrion subsidies. In combination with declines in polar bear and seal populations, continued warming in the Arctic is likely to reduce carrion provisioning and influence the fitness of facultative scavengers. Our review highlights an underappreciated aspect of Arctic marine ecosystems through scavenging opportunities provided by an apex predator. Declines in polar bear populations will have functional consequences for these ecosystems. It is vital that we examine the magnitude of these potential changes by providing the necessary baseline information.

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Author contributions

Holly E. L. Gamblin: Conceptualization (equal); Visualization (lead); Writing – original draft (lead); Writing – review and editing (lead). **Andrew E. Derocher:** Conceptualization (equal); Writing – original draft (supporting); Writing – review and editing (supporting). **Evan S. Richardson:** Conceptualization (supporting); Writing – original draft (supporting); Writing – review and editing (supporting). **David McGeachy:** Conceptualization (supporting); Writing – original draft (supporting); Writing – review and editing (supporting). **James D. Roth:** Conceptualization (supporting); Writing – original draft (supporting); Writing – review and editing (supporting). **Nicholas W. Pilfold:** Conceptualization (equal); Writing – original draft (supporting); Writing – review and editing (supporting).

Data availability statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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