

**INVESTIGATING THE DRIVERS AND  
CONSEQUENCES OF INDIVIDUAL DIETARY  
SPECIALIZATION IN AN ARCTIC MARINE TOP  
PREDATOR**

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## **Abstract**

Due to climate warming, reduced sea-ice extent and concentration in the Arctic has altered prey availability and limited foraging opportunities for polar bears (*Ursus maritimus*). My thesis examined individual foraging patterns across the Foxe Basin and Davis Strait subpopulations to identify drivers and consequences of dietary specialization. Using quantitative fatty acid signature analysis and proportional similarity (PSi) scores, I assessed how dietary specialization varies across intrinsic and extrinsic factors, and its relationship to body condition. Results revealed distinct diets and differing levels of specialization influenced by intrinsic and extrinsic variables. Sea-ice metrics were linked to variations in prey choice and individual specialization, suggesting altered access to preferred prey. Differences in individual specialization corresponded to variations in body condition, suggesting demographic groups experience energetic costs differently. These findings emphasize the role of individual-level variation in a warming Arctic, and underscore the importance of continued monitoring for polar bear conservation and management.

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## Chapter I - General Introduction

### Apex Predators and Ecosystem Functioning

“Apex” or “top” predators refers to large predators found at the top of their respective trophic ladder (Wallach et al. 2015). Top predators play a crucial role in a variety of ecosystem functions, including the maintenance of prey populations through the limitation of intermediate level (meso-)predators, helping to reduce total predation within an ecosystem (Wallach et al. 2015; Ripple et al. 2014). The resulting trophic effects may cascade downward through the ecosystem promoting food web connectivity, species abundance and richness, and altering disease dynamics, animal behaviour and large-scale processes such as carbon sequestration (Wallach et al. 2015, 2016; Ripple et al. 2014; Atwood et al. 2015). In addition, it has been shown that top predators are effective indicators of ecosystem biodiversity and functioning (Natsukawa & Sergio 2022). The impacts of these “trophic cascades” are most visible when top predators are removed/excluded from their environment or if they are introduced into an areas with no top predator present (Rao 2018).

One notable case study on the effect of these trophic cascades is increased orca (*Orcinus orca*) predation on sea otters (*Enhydra lutris*) and its influence on herbivorous sea urchins and kelp forests (Estes et al. 1998). Initially, recovering sea otter populations limited the abundance and distribution of herbivorous sea urchins, thus increasing kelp forest development in the North Pacific (Estes & Duggins 1995). However, due to a change in prey availability for orca populations, increased predation on sea otters allowed for the rapid proliferation of sea urchin species, leading to the collapse of kelp forests due to overgrazing, impacting multiple trophic levels (Estes et al. 1998). Additionally, these trophic effects directly influenced climate

processes, with increased sea otter predation on sea urchin species producing a large effect on carbon sequestration, with continued predation leading to a 4.4 to 8.7-teragram increase in carbon storage in an ecosystem spanning  $5.1 \times 10^{10} \text{m}^2$  (Wilmers et al. 2012).

### **Optimal Foraging Theory**

Depending on the foraging behaviour of top predators, the ecological impacts of the resultant cascades may vary as different individuals may select different prey. One of the ways foraging behaviour can be quantified is using optimal foraging theory (OFT). This theory is a cost-benefit function of behaviours that influence encounter rates and, behaviours that alter the probability of consumption (Stephens & Krebs 1986; Sih 2011). Based on optimal foraging theory, it is predicted that an individual will choose a foraging strategy that will optimize the net rate of energy intake or maximize a characteristic related to biological fitness (MacArthur & Pianka 1966; Schoener 1971; Pyke 2010, 2019). Often, due to challenges in directly measuring biological fitness, a proxy or alternate “currency” must be used (e.g. body mass, female reproductive success, offspring survival, energy intake) and the foraging behaviour which maximizes this value would then be found (Alif et al. 2022; Pyke 2019). In order to optimize net energy intake or fitness, most predators will tend to select the most profitable prey under high abundance conditions (Bagchi et al. 2003; Karanth & Sunquist 1995; Sih 1993, 2011; Schluter 1981). However, predators may also select prey species based on available biomass instead of population abundance (Naef-Daenzer et al. 2000). For example, Naef-Daenzer et al. (2000) found that when selecting prey, the Great Tit (*Parus major*) opted for spiders until the biomass of available caterpillar species surpassed that of the available spider biomass. Additionally, increased frequency in encounters with prey species of low profitability did not influence a predator’s consumption of that prey item (Schluter 1981; Sih 1993; Barkan & Withiam, 1989).

Dependent on the strategy employed by an individual, the foraging behaviours used and resultant dietary niche may vary greatly from the overall population in an effort to maximize fitness.

## **Dietary Specialization**

### *General Overview*

Dietary specialization occurs when an individual demonstrates a narrower or altered foraging niche compared to the overall population (Sargeant 2007). The idea of niche width variation has been around as early as the 1960s, and individuals may be labelled as a “generalist” or a “specialist” depending on how they exploit their niche (Van Valen 1965; Pagani-Núñez et al. 2016). Many “generalist” species may in fact be composed of multiple specialist individuals (Bolnick et al. 2002). West (1988) showed that individuals of the intertidal snail species, *Nucella melones*, often ignored preferred prey species of its conspecifics, consuming only a fraction (1-5 taxa) of the total 21 prey taxa recorded. Alternatively, McAulay et al. (2021) found that stoats (*Mustela erminea*), although considered to be a generalist species, exhibited a substantial degree of individual specialization within the populations found in three different New Zealand national parks. Previously, Bolnick et al. (2003) utilized overlap among individuals to identify three cases of dietary specialization: (1) pure generalists, showing totally overlapping diets, (2) functional specialists, showing partially overlapping diets and (3) pure specialists, showing non-overlapping diets. An even more precise categorization was suggested by Pagani-Núñez et al. (2016), which utilized four alternate categories: (1) Obligate specialists, which are morphologically and behaviourally adapted to exploiting a single resource, (2) Facultative specialists, which are adapted to exploit single food sources but may opportunistically exploit additional resources, (3) Facultative generalists, which can develop specializations but prefer to exploit alternative

resources and (4) Obligate generalists, which are limited in developing novel foraging behaviours and thus exploit a wide variety of resources.

Individual dietary specialization may be measured in a multitude of ways, including: Total niche width (TNW; Roughgarden 1972; Bolnick et al. 2002; Zaccarelli et al. 2013), proportional similarity ( $PS_i$ ; Schoener 1968; Bolnick et al. 2002; Zaccarelli et al. 2013), and mean likelihood ( $W_i$ ; Petraitis 1979; Bolnick et al. 2002; Zaccarelli et al. 2013). TNW is comprised of the within-individual component ( $WIC$ ), which shows the variation in resource use within individuals; and the between-individual component ( $BIC$ ), which shows the variation between individuals (Roughgarden 1972; Bolnick et al. 2002; Zaccarelli et al. 2013). The level of individual specialization can be measured by determining the proportion of TNW explained by WIC (i.e. Individual specialization =  $WIC/TNW$ ; Roughgarden 1972; Bolnick et al. 2002; Zaccarelli et al. 2013). Proportional similarity (adapted from Schoener 1968 and Feinsinger et al. 1981) is measured as dietary overlap between an individual and the overall population, with a generalist individual showing greater overlap (Roughgarden 1972; Bolnick et al. 2002; Zaccarelli et al. 2013). The prevalence of specialization within the population can then be measured as the average of individual  $PS_i$  values (Bolnick et al. 2002; Zaccarelli et al. 2013). Similarly, mean likelihood (adapted from Petraitis 1979) measures individual specialization as the probability an individual's diet may be drawn randomly from the population distribution, with mean  $W_i$  score serving as the metric of individual specialization within the population (Bolnick et al. 2002; Zaccarelli et al. 2013). All three measures provide a proportion between 0 and 1, with 1 equal to generalization and 0 equal to specialization (Bolnick et al. 2002; Zaccarelli et al. 2013).

## *Causes of Individual Specialization*

Based on optimal foraging theory, an individual should adopt a foraging strategy that optimizes the net rate of energy gain (MacArthur & Pianka 1966; Schoener 1971; Pyke 2010, 2019). Individual dietary specialization may occur when individuals alter foraging behavior to maximize a characteristic related to fitness, such as energy intake (Pulliam 1974; Schoener 1971). In response to pressure from high intraspecific competition, individuals with populations have shown increased dietary specialization to help offset greater demands on specific prey species (Svanbäck & Bolnick 2005; Tinker et al. 2008; Svanbäck & Persson 2004). Alongside intraspecific competition, habitat characteristics associated with reduced prey diversity and abundance play a crucial role in the determining the presence and degree of dietary specialization within a population (Newsome et al. 2015; Tinker et al. 2008). Phenotypic changes in response to variable environmental conditions may also affect the degree of specialization, where individuals with high phenotypic plasticity are more likely to shift towards novel foraging strategies (i.e. increased dietary specialization), potentially aiding in longer persistence times in habitats affected by climate warming (Evans & Moustakas 2018). Previous work has found evidence of high phenotypic plasticity in foraging behavior and prey consumption of polar bears (*Ursus maritimus*), following changes in prey availability in areas with high prey diversity (Galicía et al. 2021a).

## **Quantitative Fatty Acid Signature Analysis - QFASA**

Dietary fatty acid analysis is a well-established method for exploring dietary habits across a variety of large, free-ranging species in various ecosystems (Iverson et al. 2004; Thiemann et al. 2008, Galicía et al. 2021a, Remili et al. 2023). For most wide-ranging predators, direct observation of feeding is not feasible. The typical response is to use indirect methods of analysis

of calcified prey structures from scat or stomach contents, or more advanced techniques such as quantitative fatty acid signature analysis (QFASA), stable isotope mixing models and DNA analysis (Fitch & Brownell, 1968; Iverson et al. 2004; Bowen & Iverson, 2013; Nilsen et al. 2012). Although each method provides valuable insights into dietary habits, there are limitations. For example, when using scat or stomach contents, the dietary history of the predator is limited to the last few meals, while soft bodied prey may be underrepresented due to their fast rate of digestion, and the hard calcified structures may undergo varying degrees of erosion, limiting the effectiveness of prey size or species identification (Bowen & Iverson 2013; Iverson et al. 2004).

Developed by Iverson et al. (2004), QFASA is a statistical model that is used to estimate the proportion of prey species in a predator's diet by analyzing predator and prey fatty acid compositions. QFASA analyzes the fatty acid composition or "signature" of a predator and compares it to the mean signature of each potential prey species to determine the proportional combination of prey that minimizes the statistical distance between predator and prey profiles (Iverson et al. 2004). The fatty acids (FA) selected for modelling are based on dietary relevance and metabolic behaviour, with trace and/or biosynthesized fatty acids removed to improve accuracy (Budge et al. 2002). Additionally, the model uses calibration coefficients derived from feeding experiments (e.g. Kirsch et al. 2000; Thiemann et al. 2008) to account for any metabolic modification of fatty acid that occurs in the predator (Iverson et al. 2004). The output of this model is an estimate of an individual's diet composition in the form of proportion of prey species consumed, in the days to months prior to sampling (Iverson et al. 2004; Bowen & Iverson, 2013).

## Polar Bear Foraging Behaviour

Spanning 20 relatively discrete subpopulations in the northern hemisphere (IUCN/SSC Polar Bear Specialist Group 2024), polar bears are reliant on annual sea ice as a platform to travel and hunt (Sahanatien & Derocher 2012). In parts of their range where sea ice melts annually, polar bears are forced to migrate on land and undergo a period of fasting until freeze-up occurs and they can return to ice-covered areas to hunt (Stirling & Parkinson 2006; Stirling et al. 1999). Considered by some as “lipovores”, meaning a marine predator that targets lipid-rich prey items (Derocher 2012), polar bears are able to withstand long fasting periods due to the deposition of fat after consumption (Stirling & Derocher 1993, 2012). Current sea ice loss and earlier sea-ice break-up has been linked to a reduction in optimal foraging area for polar bears in the Canadian Arctic (Sahanatien & Derocher 2012; Stirling et al. 1999; Stirling & Parkinson 2006). This has directly influenced predator-prey relationships between polar bears and their main prey source, the ringed seal (*Pusa hispida*; Hamilton et al. 2017; Luque et al. 2014).

Additionally, sexual size dimorphism has a significant effect on the foraging strategies employed by polar bears, with older male bears showing increased predation on larger prey species such as bearded seal (*Erignathus barbatus*) and walrus (*Odobenus rosmarus*), whereas smaller prey choices such as ringed seals and harbour seals (*Phoca vitulina*) were consumed more often by younger age classes (Thiemann et al. 2008). Although primarily feeding on ringed seal and bearded seal (Thiemann et al. 2008; Stirling & Øritsland 1995), locally abundant species, including harp seal (*Pagophilus groenlandicus*), beluga whale (*Delphinapterus leucas*) and bowhead whale (*Balaena mysticetus*) are also an important source of prey (Thiemann et al. 2008; Galicia et al. 2015). As changes to sea ice occur, the distribution of polar bears which are typically centered around profitable prey habitat, may change, increasing intraspecific

competition for available prey species (Derocher et al. 2004). Moreover, due to the correlation between polar bear foraging behavior, prey distribution and sea-ice conditions, dietary analysis may serve as a useful tool for monitoring changes in population distribution and ecosystem functioning (Galicia et al. 2021b)

### **Body Condition Estimates in Polar Bears**

Optimal foraging theory predicts an individual will choose a foraging strategy that will maximize a character related to biological fitness or one that will optimize the net rate of energy gain (MacArthur & Pianka 1966; Schoener 1971; Pyke 2010, 2019). More often than not, challenges in directly measuring biological fitness lead researchers to use proxies or alternate “currencies” (Alif et al. 2022; Rode et al. 2020; Pyke 2019). In mammals, adipose tissue serves as a storage site for energy, and may also act as a source of insulation during periods of low temperature (Young. 1976; Pond et al. 1992). Adipose tissue also influences many life history characteristics such as juvenile growth and adult mass gain, the probability and outcome of pregnancy, along with body condition and over winter survival (Parker et al. 2009). In vertebrate species, adipose tissue is comprised of numerous fat cells called adipocytes, which shrink or swell as lipid is mobilized or stored, respectively (Schemmel 1976; Iverson et al. 1995). For this reason, adipose tissue may serve as a useful proxy for biological fitness and body condition, with analysis providing important ecological and physiological information.

Consisting primarily of fatty acids acquired from their diet, polar bear adipose tissue is stored in a subcutaneous layer (Pond et al. 1992; Colby et al. 1993). However, unlike other marine mammals that possess a specialized subcutaneous blubber layer for thermal insulation, polar bears have a subcutaneous adipose tissue layer that functions as the primary site for energy storage (Pond et al. 1992). There are several ways to estimate fat stores in polar bears including:

various combinations of morphometric measurements and estimated weights (e.g. Quetelet Index; Ganong 1991; Stirling et al. 2008), bioelectrical impedance analysis (Sciullo et al. 2016), subjective indices (Stirling et al. 2008, 1989; Rode et al. 2020), and adipose tissue lipid content (Thiemann et al. 2006; McKinney et al. 2014).

Due to concerns of over-harvest of polar bears, the Agreement on the Conservation of Polar bears was established in 1973, with subsistence harvest being an exclusive right of Indigenous peoples located in Canada's northern provinces and territories (Government of Nunavut 2022). Currently, adipose tissue lipid content, which quantifies the amount of extracted lipid from subcutaneous tissue samples, along with a subjective fatness index are the two available options for use in harvested bears. Due to the limitations of alternate techniques for measuring fat stores in polar bears in the field (see Sciullo et al. 2016), techniques utilizing harvested polar bear samples and the observations of hunters and trappers (e.g. fatness index scores) provide valuable information on a larger number of individuals, while actively including Indigenous communities in the monitoring process. The subjective fatness index uses qualitative observations of the amount of subcutaneous fat on a bear and then assigns a score based on a 1 to 5 scale (1: leanest, 5: Obese; Stirling et al. 1989; Stirling et al. 2008; Rode et al. 2020). Although this index is one of the most easily accessible methods of estimating fat stores (Stirling et al. 2008), varying degrees of accuracy along with observations by untrained individuals may skew data. However, FI now also serves as a way for non-researchers such as hunters and trappers to provide information regarding body condition of subsistence harvested bears from areas or seasons where live-capture is not feasible (Stirling et al. 2008). As local communities and territorial governments become increasingly hesitant to support capture-based methods, harvest-

based methods and/or other non-invasive forms of research may present the most feasible alternatives for continued monitoring.

Body condition has been assumed to affect the health and fitness of polar bears, and is an indicator of nutritional stress and reproductive potential, with increased fat stores associated with better body condition (Sciullo et al. 2016; Lindstedt & Boyce 1985; Atkinson & Ramsay 1995; Stevenson & Woods 2006). It is suggested that the lipid content of adipose tissue taken from any large superficial depot (e.g. belly, rump or baculum) is a good indicator of total superficial adipose store, and when compared against other condition indices are reasonably accurate and precise measures of body condition (Thiemann et al. 2006; McKinney et al. 2014). Maternal mass has been shown to be the most critical measure of reproductive success, with body weight found to be heavily associated with stored fat before denning (Atkinson & Ramsay, 1995). During fasting periods, female polar bears have been shown to utilize 93% of their stored fat reserves while losing up to 43% of their total body mass with reproductive success largely depending on the amount of stored energy and nutrients prior to fasting (Atkinson & Ramsay, 1995). Specifically in pregnant female polar bears, adipose tissue lipid content may serve as an indicator of reproductive status and cub production as females are reliant on stored resources for gestation and lactation during the denning period (Thiemann et al. 2006; Derocher & Stirling 1996, 1998). Additional results show that adipose tissue lipid content has been quantitatively linked to fatness index scores and is a good indicator of body condition in polar bears regardless of age or sex characteristics (Stirling et al. 2008).

### **Effects of Climate Change**

Since 1979, the Arctic ecosystem has been disproportionately affected by climate change, warming at a rate up to four times higher than the global average (Rantanen et al. 2022). This

phenomenon known as “Arctic amplification” (Rantenen et al. 2022) has contributed to an increase in sea-ice loss over the past few decades, with recent estimates showing an approximate 12-13% per decade reduction in September ice extent (Hwang et al. 2020) with an estimated decline in total ice extent of 42% compared to the 1980s (Maslanik et al. 2007). The Arctic melt season has also seen an estimated increase in length of 5 days per decade (Stroeve et al. 2014), with a significant decrease in the age and thickness of the multiyear ice pack (Maslanik et al. 2007). Recent data suggest that regardless of global emission scenarios, we may see a seasonally ice-free Arctic between 2030 and 2050 (Kim et al. 2023). Additionally, changing sea ice characteristics including break-up date, reduced total ice coverage, and reduced ice thickness have disrupted effects on the quality and quantity of primary production in the Arctic, ultimately affecting animals at a higher trophic level (Darnis et al. 2012; Ji et al. 2013; Leu et al. 2011). Due to longer ice-free periods and reduced sea ice concentration, Arctic trophic systems have been heavily affected by increased sea surface temperature from higher heat absorption in the upper ocean (Yang et al. 2023). A warming climate has also led to a poleward shift in many boreal fish species, disturbing Arctic fish distribution and abundance (Fossheim et al. 2015; Florke et al. 2021). Further, there has been a reduction in sea ice choke points due to climate warming, partially removing the physical barriers of entry into the Arctic for killer whales (*Orcinus orca*) and other large predators (Higdon & Ferguson 2009). This may cause a decline in Arctic prey populations due to top-down regulatory effects exerted by increased predation from killer whales (Estes et al. 1998; Ferguson et al. 2010; Higdon & Ferguson 2009). Understanding the effect that an increasingly ice-free Arctic and disproportionate climate warming has on organisms reliant on sea ice is the key to developing lasting and impactful management and conservation strategies.

## Thesis Objectives and Organization

The Arctic ecosystem has been disproportionately affected by climate change in comparison to the rest of the world. With rapidly receding sea-ice extent, altered predator-prey dynamics and reduced foraging habitat, the long-term climate effects on marine predator fitness are relatively unknown. Using harvest-based sampling in two adjacent polar bear subpopulations with highly seasonal sea ice conditions – Foxe Basin and Davis Strait – I intend to study the effect of long-term climate warming on polar bear diet and fitness. Combining sea-ice measurements, body condition estimates and dietary fatty acid analysis, I will examine the drivers and consequences of dietary specialization on polar bear body condition, as a proxy for fitness. This thesis will be organized into three chapters, starting with an introductory chapter (*Chapter I – General Introduction*) and finishing with a concluding chapter (*Chapter III – General Conclusions*). *Chapter II – Drivers and consequences of dietary specialization among polar bears in Foxe Basin and Davis Strait* is an evaluation of the intrinsic (e.g. sex and age-class) and extrinsic (e.g. sea-ice break-up date, open water period length, and maximum sea-ice extent) drivers of dietary specialization and how it relates to overall polar bear fitness. As a marine mammal apex predator, polar bears are an integral part of the Arctic marine ecosystem. Occupying the upper trophic levels, changes to ecosystem functioning and prey availability/health as a result of climate warming may be reflected in the diet and body condition of these animals (See Rode et al. 2021) making them an important tool for assessing the health and resilience of the Arctic ecosystem. The use of harvested bears not only allows for increased sample collection and analysis across a wider geographic area, but also allows the hunters and trappers reliant on polar bears for food and economic gain to take part directly in the scientific process that may affect changes in subsistence harvesting regulations. Understanding how

climate warming has impacted polar bear populations is necessary to ensure successful conservation and to provide Indigenous communities with continued access to an important socioeconomic and cultural resource.

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## **Chapter II – Drivers and consequences of dietary specialization among polar bears in Foxe Basin and Davis Strait**

### **Introduction**

Animal foraging behaviour has been widely studied throughout time. According to optimal foraging theory, a predator will seek to optimize the net rate of energy intake or measure of biological fitness while foraging (MacArthur & Pianka 1966; Schoener 1971). Specific foraging behaviour, such as individual specialization, whereby an individual utilizes a narrower or altered foraging niche, or has reduced niche overlap compared to the overall population (Sargeant 2007) has shown to be an adaptive response to help reduce pressure from high intraspecific competition (Svanbäck & Bolnick 2005; Tinker et al. 2008). Additionally, varying habitat characteristics which influence prey diversity/abundance and foraging strategies, as well as phenotypic changes in response to variable environmental conditions play a crucial role in the degree of specialization within a population (Newsome et al. 2015; Tinker et al. 2008; Evans & Moustakas 2018). In more recent history, there has been a shift away from the binary categorisations of populations as definite generalists or definite specialists. Variations in individual foraging behaviour have allowed for more heterogenous populations, with the coexistence of both specialist and generalist individuals (Bolnick et al. 2003; Svanbäck & Bolnick, 2007; Thiemann et al. 2011). The extent of dietary specialization may be measured using a proportional similarity index ( $PS_i$ ), calculating the interspecific overlap in diet between individuals. This index has been widely used in diet studies (e.g. Sánchez-Hernández et al. 2025; Woo et al. 2008) as a way to measure individual-level foraging behaviour as well as population

level trends.  $PS_i$  functions on the idea that a specialist individual exploits different resources than other individuals and has an overall niche width that does not overlap with the rest of the population (Sargeant, 2007), whereas an individual with greater overlap is deemed to be a more generalist individual (Roughgarden 1972; Bolnick et al. 2002; Zaccarelli et al. 2013). In general, specialist individuals tend to have a more difficult time switching between available resources in comparison to generalist individuals, however the overall adaptability of a population may depend on the degree of individual specialization within (Bolnick et al. 2003; Jory et al. 2021). Under certain circumstances, foraging strategies employed by an individual may endure over time, potentially transferring to their offspring (Estes et al. 2003; Lillie et al. 2018; Schindler et al. 1997).

Intrinsic factors (e.g. sexual dimorphism and phenotypic variation) may influence the degree of individual dietary specialization within a population (Stephens & Krebs, 1986). Intrinsic factors influencing foraging behaviour may include age, sex and/or body size, all of which potentially impact an individual's access to prey species (Thiemann et al. 2011). The extent of dietary specialization in a population may also serve as an adaptive response to help alleviate pressure from high intraspecific competition (Svanbäck & Bolnick 2005; Tinker et al. 2008). Research in the black amur bream (*Megalobrama terminalis*) has shown that intraspecific competition was reduced more through individual dietary specialization than through a shift in the timing and occurrence of feeding activity (Xia et al. 2020). Additionally, Holbrook & Schmitt (1992) demonstrated that due to a strong competitive hierarchy in striped surfperch (*Embiotoca lateralis*), individual dietary specialization occurred as a passive process, resulting from selective use of available foraging patches and not an active process, arising from an individual's selection of specific prey taxa. Furthermore, increased population density also has an effect on individual

dietary specialization, with the associated decline in prey availability leading to increased specialization and population niche width (see Ratcliffe et al. 2018; Svanbäck & Bolnick, 2007). Not only does intraspecific competition influence individual specialization, but high levels of interspecific competition have been found to reduce individual specialization by constraining resource use (Bolnick et al. 2010).

As a top predator species that is reliant on sea-ice to travel, hunt and mate, polar bears may be valuable indicators of environmental change (Stirling & Derocher 1993; Peacock et al. 2010; Amstrup 2003). Warmer temperatures have forced longer ice-free periods (i.e. earlier break-up and/or later freeze-up; Lam et al. 2022) and reduced total sea-ice extent (Hwang et al. 2020; Maslanik et al. 2007)) thus reducing availability of optimal foraging habitat. During the summer months when sea-ice melts, polar bears are forced to utilize multiyear ice or move to land, where they undergo a period of fasting, relying on accumulated fat stores for energy (Bromaghin et al. 2015; Derocher et al. 2004). Polar bears are known to prey mainly on ringed seal and bearded seal, even exhibiting a noticeable correlation between ringed seal and polar bear abundance (Thiemann et al., 2008a; Stirling & Archibald 1977; Stirling & Øritsland 1995). Longer ice-free periods have not only reduced access to ringed seals by reducing spatial overlap (Derocher et al. 2004; Hamilton et al. 2017), but it has also reduced ringed seal quality, abundance, and availability by lowering their pregnancy and birth rates, decreasing their body condition, and increasing their cortisol levels (Ferguson et al. 2017). Additionally, there has been predicted median declines in ringed seal population sizes between 50 to 99% by the year 2100 (Reimer et al. 2019). Due to constant fluctuations in health and abundance of ringed seal populations in a warming climate, relying on them as a primary source of prey may be detrimental to polar bear health. However polar bears exhibiting more flexible foraging

behaviour have been found switching to alternative food sources, which helped to reduce the effects of depleted/altered primary prey sources (Thiemann et al. 2008a; Galicia et al. 2021a). There has been an indication that changes to sea-ice metrics may introduce novel foraging opportunities, such as more scavenging opportunities on bowhead whales as a result of increased predation from killer whales (Galicia et al. 2016), potentially mediated by the removal of physical barriers of entry into the Arctic (e.g. sea-ice choke points) for larger predators (Higdon & Ferguson 2009). Worsening sea-ice conditions as a result of continued climate warming may promote a greater diversity of foraging behaviours in an effort to offset the effects of depleted and/or altered prey availability and abundance, thus increasing the population niche width and consequently reducing the degree of specialization within the population. Understanding the link between environmental conditions and changes to predator foraging behaviour is a valuable tool to use when assessing the impact of climate change on Arctic ecosystems.

Furthermore, polar bears exhibit strong sexual size dimorphism with males reaching sizes 2.1 times larger than females, while also exhibiting prolonged growth periods (Ralls & Mesnick 2009; Derocher et al. 2005). Previous work has shown sexual dimorphism has an important effect on polar bear foraging behaviour, as large male bears more often fed on larger prey species such as bearded seal (*Erignathus barbatus*) and walrus (*Odobenus rosmarus*), with smaller and/or younger individuals often opting for alternate prey such as ringed seal (*Pusa hispida*) and harbour seal (*Phoca vitulina*, Thiemann et al. 2008a). Specifically, male bears often exhibit the greatest dietary diversity and flexibility, while smaller and/or younger bears along with adult females exhibit lower associated dietary flexibility (Thiemann et al. 2011). When measuring dietary specialization using the proportional similarity index, increased dietary diversity and

flexibility amongst male bears may lead to foraging behaviours outside of the population niche, thus increasing specialization.

When access to prey is limited, polar bears will switch to a period of fasting relying primarily on fat stores for energy (Derocher et al. 2004; Messier et al. 1992; Stirling & Øritsland, 1995). The main site of energy storage in polar bears is subcutaneous adipose tissue (Thiemann et al. 2006; McKinney et al. 2014). Individual fat cells, known as adipocytes, swell or shrink during lipid deposition or mobilization (Schemmel 1976; Iverson et al. 1995) and therefore the proportion of lipid in adipose tissue increases/decreases as an individual accumulates/uses energy stores. Adipose tissue lipid content can thus serve as an effective tool in monitoring the body condition of polar bears (McKinney et al. 2014; Thiemann et al. 2006; Sciullo et al. 2016).

Alongside adipose tissue lipid content, a variety of other methods have been used to measure body condition in polar bears. Some of these methods include varying combinations of morphometric measurements (e.g. length, body mass, skull size and girth; Rode et al. 2010; McKinney et al. 2014), bioelectrical impedance analysis (Sciullo et al. 2016) and subjective indices (Stirling et al. 1989, 2008; Rode et al. 2020). The subjective fatness index is a qualitative rating from 1 (most lean) to 5 (obese) based on the observed amount of subcutaneous fat (Stirling et al. 1989, 2008; Rode et al. 2020). Fatness index (SFI) scores are a reliable measure of assessing polar bear body condition in the field (Stirling et al. 2008), although there are some limitations. However, research has shown that the fatness index scores have been quantitatively linked to adipose tissue lipid content, lending itself to be a useful indicator of body condition (Stirling et al. 2008). However, as a result of decreased willingness from territorial governments and local communities to participate in capture-based methods of assessing body condition (e.g.

adipose tissue lipid content), non-invasive procedures such as the subjective fatness index, are becoming increasingly important.

Fatty acid analysis has been used extensively to study the foraging habits of polar bears (e.g. Thiemann et al. 2008a, 2011; Galicia et al. 2016, 2021a) and has become an important tool for monitoring dietary shifts within a population (see Galicia et al. 2016). Due to the limited synthesis of fatty acids in polar bears, dietary fatty acids are largely deposited directly into the adipose tissue without modification (Budge et al. 2006; Iverson et al. 2004). Thus, the fatty acid composition of a polar bear's fat stores reflects the fatty acid composition of its composite prey. Quantitative fatty acid signature analysis (QFASA), a statistical model developed by Iverson et al. (2004), models the fatty acid profile of a predator as a linear combination of its potential prey, and estimates diet composition as the combination that minimizes the distance between the observed and modelled predator (Iverson et al. 2004, Budge et al. 2006, Bromaghin et al 2017). Fatty acid signatures in polar bears typically reflect integrated diet composition over the preceding 30-90 days (Iverson et al. 2004, Thiemann et al. 2022).

Despite drastic declines in sea-ice conditions, polar bear populations within Foxe Basin and Davis Strait have been relatively stable, while neighbouring subpopulations, such as Western Hudson Bay, have shown decreases in population estimates (Dunham et al. 2024; IUCN Polar Bear Specialist Group 2024). A key attribute separating these subpopulations from the others is the diversity and abundance of accessible prey species. While declines in sea-ice extent/concentration have been associated with a reduction in access to primary prey (Derocher et al. 2004; Hamilton et al. 2017), it has been suggested that changes in sea-ice conditions has lead to greater consumption of bowhead whale carcass by polar bears within Foxe Basin as a result of increased killer whale predation (Galicia et al. 2016), therefore providing foraging

opportunities not as readily available to other subpopulations. Furthermore, Atlantic walrus have been found distributed across Davis Strait, Foxe Basin and the connecting Hudson Strait throughout both winter and summer seasons (North Atlantic Marine Mammal Commission, 2021), providing continued access to a prey species relatively unavailable to other subpopulations. In addition to high prey diversity among these two subpopulations, the use of pack ice as a whelping patch by harp seals within Davis Strait has supported incredibly high abundance of the primary prey type (Fisheries and Oceans Canada 2025) thus allowing for continued access to the preferred prey of individuals within this subpopulation, not seen elsewhere. As these two subpopulations are connected through Hudson Strait, there is an opportunity for additional prey movement across boundaries, leading to variations in prey availability and consequently foraging behaviour (see Galicia et al. 2021a) therefore allowing for the study of potentially unique cases of individual specialization. Furthermore, the two subpopulations exhibit varying degrees of annual sea-ice coverage, with Foxe Basin reaching complete coverage during the winter months, while the maximum extent within Davis Strait varies between years. The contrast between the sea-ice conditions within these two subpopulations provides valuable insight into how variations in sea-ice extent may alter predator-prey dynamics, influence individual specialization and affect body condition/fitness. Additionally, if climate warming severely alters sea-ice conditions in Foxe Basin, ice-free periods may arise in the winter months and results from Davis Strait may help predict changes in foraging behaviour and body condition/fitness under environmental extremes.

The objective of this study was to use QFASA to identify the dietary composition and degree of dietary specialization in relation to changing sea-ice conditions and their effect on body condition in polar bears in Foxe Basin and Davis Strait. I sought to address the following

hypotheses: (1) That male bears will show the highest degree of individual dietary specialization due to sexual size dimorphism which allows for the exploitation of prey unavailable to smaller sexes and age classes; (2) Earlier sea-ice break-up, longer ice-free periods and, in Davis Strait, reduced maximum extent, will be associated with less specialization as bears are forced to move to land earlier, reducing access to preferred prey and limiting selective feeding; (3) That greater individual dietary specialization is predicted to have a negative impact on body condition in adult female polar bears as morphometric limitations (i.e. maximum body size) reduce the success of capturing alternate prey species, thus reducing foraging efficiency, as inferred from adipose tissue lipid content and subjective fatness index ratings.

## **Methods**

### *Study Area*

This study used adipose tissue samples from subsistence harvested bears across two adjacent polar bear subpopulations – Davis Strait and Foxe Basin. The most recent population estimate for Foxe Basin was completed using mark-recapture distance-sampling (Stapelton et al. 2016) and estimates a total of 2585 (CI = 2096-3189) individuals and suggests a likely stable population (IUCN Polar Bear Specialist Group, 2024). Recent population estimates for Davis Strait using genetic capture-recapture and physical sampling (Dunham et al. 2024) suggest a population size of 1,944 (95% CRI = 1593 -2366) and a likely decreasing population (IUCN Polar Bear Specialist Group, 2024).

### *Polar Bear Sample Collection*

I analyzed adipose tissue samples from 461 individual subsistence harvested polar bears from 2018 to 2023 within two subpopulations: Foxe Basin and Davis Strait. Additionally, I

included previously published data for 704 bears harvested from 1999 to 2003 (Foxe Basin [ $n = 82$ ]) and 2010 to 2018 (Foxe Basin [ $n = 397$ ] and Davis Strait [ $n = 225$ ]; Thiemann et al. 2008a; Galicia et al. 2021a), for a total of 1165 individual polar bears (Table 2.1). No samples were available in Foxe Basin between 2003 and 2010. Samples were collected with the assistance of local Inuit communities (Figure 2.1), and were contributed by hunters in 19 communities: Anderson Brook, Arviat, Baker Lake, Chesterfield Inlet, Coral Harbour, East Bay, Ell Bay, Igloodik, Iqaluit, Kimmirut, Kinngait, Naujaat, Nuluqjuaq Bay, Pangnirtung, Qairusuk Bight, Rankin Inlet, Sanirajak and Whale Cove. Samples were collected year round following a cyclical pattern with the lowest harvest occurring during the summer months (June and July), while the largest harvest occurred during the spring (March and April). It is illegal to harvest females with dependent cubs, which are typically weaned at 2.5 years. Thus, the samples included independent male and female bears from two different age classes: adults (5+ years old) and subadults (3-4 years old) (Table 2.1). Body condition was estimated by hunters using a subjective fatness rating between 1 (leanest) and 5 (obese; Stirling et al. 2008) and as the percentage of lipid extracted from adipose tissue samples (Thiemann et al. 2006; McKinney et al. 2014) as previous research has shown a quantitative link between the two indices (Stirling et al. 2008). Subjective fatness index scores were not recorded for every harvested polar bear, and therefore only bears with available data ( $n = 876$ ) were used during analysis. Similarly, adipose tissue lipid content was not available for all bears previously analyzed, therefore only bears with recorded values ( $n = 683$ ) were included in the analysis. Locations of harvested bears were provided using the decimal degrees (DD) system for latitude and longitude, however data were not available for some bears ( $n = 89$ ; Figure 2.1). Subcutaneous adipose tissue samples (ca. 6 cm x 3 cm) were taken from the rump of each bear, wrapped in foil, and stored in a labeled Ziploc bag at  $-20^{\circ}\text{C}$  until analysis.

### *Prey Species Sample Collection*

I analyzed 75 marine mammal blubber samples from bearded seal, harbour seal, harp seal, ringed seal and walrus. These samples were taken from subsistence harvests during the 2019-2023 harvest periods in Foxe Basin, Davis Strait. Due to the limited availability of recent (2019-2023) harbour seal samples, I included samples from animals harvested in Western Hudson Bay. Blubber subsamples were from the skin, through the full depth of the layer and placed into a 4 mL Cryovial. Samples were stored at -80°C until shipped to York University, where they were stored at -20°C until analysis. In addition to these prey samples, I used data from 351 marine mammals across Foxe Basin, Davis Strait and surrounding subpopulations from a previously published prey library (Thieman et al. 2008b (var); Galicia et al. 2016; Galicia 2022) containing bearded seals, ringed seals, harp seal, harbour seal, beluga whale, bowhead whale, and walrus for a total of 426 marine mammal samples (Table 2.2).

### *Laboratory Analyses*

A 0.5 g subsample of adipose tissue (polar bear) or blubber (marine mammal) was taken from the center of the adipose tissue/blubber as this area is protected against oxidation (Budge et al. 2006). The constituent lipids were extracted and isolated from the subsample using a modified Folch method (Folch et al. 1957; Iverson et al. 2001; Budge et al. 2006). Once extracted, adipose tissue lipid content was recorded as percent total sample wet weight. Isolated lipid was transesterified into fatty acid methyl esters (FAME) using a sulfuric acid catalyst through the Hilditch procedure (Thiemann et al. 2004; Budge et al. 2006; Hilditch & Williams, 1947). The analysis of FAME was completed using temperature-programmed gas-liquid chromatography (Budge et al. 2006) at Dalhousie University – Department of Process Engineering and Applied Science. Individual FAs were identified based on retention time and manually verified using

Compass CDS software (Version 3.9, Bruker Daltonics Inc., Germany). FA data were reported as the mass percent of the total FA  $\pm$  1 SEM (Table 2.3) and were named using the nomenclature A:Bn – X, where A references the carbon chain length, B is the number of double bonds and X is the position of the first double bond relative to the terminal methyl group. Only fatty acids that occurred at a proportion of  $>0.1\%$  of the total FAs were used for analysis (Budge et al. 2012).

### *Diet Estimation*

Polar bear diets were estimated using quantitative fatty acid signature analysis (QFASA; Iverson et al. 2004). QFASA combines prey signatures to create a model predator signature and estimates predator diets such that a distance measure between the observed and modelled predator signatures is minimized (Bromaghin 2017; Iverson et al. 2004). I used the Aitchison distance between observed and modelled predator signatures in my analysis (outlined in Bromaghin et al. 2015, 2016). Additionally, because fatty acids may be catabolized, modified, or biosynthesized in addition to coming from the diet, calibration coefficients are used to account for metabolic processes within the predator (Iverson et al. 2004). Calibration coefficients are typically based on the ratio between the quantity of FA present in the adipose tissue of a predator and the quantity of FA present in a controlled diet (Iverson et al. 2004). I used calibration coefficients derived from feeding studies on captive mink, fed a marine-based diet (Thiemann et al. 2008a). These calibration coefficients have been widely used in the literature and shown to produce reliable diet estimates in polar bears (Bromaghin et al. 2017; Thiemann et al. 2022; Galicia et al. 2021a). The fatty acid suite used for diet modeling was in line with previous work on polar bear dietary specialization (see Galicia et al. 2021a), however the calibration coefficients excluded the previously used fatty acid, 22:1n-9, due to confounding in the prey library (Florko et al. 2020). The estimated diets reflect the consumption of lipid biomass in the

preceding weeks to months prior to sample collection (Iverson et al. 2004; Thiemann et al. 2022). Diet estimates were generated using the R package qfasar (version 1.2.1; Bromaghin 2017)

In order for QFASA to accurately predict predator diets, a prey library containing the FA information of all known prey types consumed by the predator must be used. Although the prey species are different, similarities within fatty acids profiles can create confounding effects, affecting diet estimation accuracy (Bromaghin et al. 2017). Prior to utilizing QFASA, I performed a principal component analysis (PCA) in R (version 4.5.1, R Foundation for Statistical Computing, Vienna, Austria) on the prey library FA profiles (Table 2.4) to look for overlap between and within prey types and between and within harvest locations. When available, prey species were taken from within the subpopulations used in this study, however to increase sample size and overall library reliability, additional prey samples taken from outside the study locations were also used to model predator diets (see Table 2.2). Within the R package qfasar, I utilized the following two diagnostic functions to determine if there was any confounding of prey types or significant clustering within prey types: (1) Leave-one-prey-out (LOPO) analysis and (2) divisive magnetic clustering (DIMAC).

LOPO analysis is a diagnostic function that helps determine if there is any prey confounding within the prey library. LOPO analysis functions by first temporarily removing one signature from the library, then recalculating the mean signatures for each prey type and determining the mixture of prey signatures that best matches the removed signature (i.e. same as diet estimation), and then the removed signature is added back to the library and this process is repeated for every prey signature in turn. After the entire library has undergone this process, a mean diet estimate is calculated for each prey type, with a “perfect” prey library achieving a

100% match to the corresponding prey type. However, as prey types are not always estimated perfectly, the proportion of prey signatures that are not correctly attributed can be considered as the degree of confounding prey (Bromaghin 2017).

Within prey types, clusters can appear when a group of individuals are more similar to each other than to other members of the same prey type. These clusters may be formed due differences in fatty acid composition based on to spatial variability, temporal variability or physical attributes (e.g. age, sex or size classes) within a species. In order to investigate the presence of clusters within the prey species, DIMAC clusters individuals more similar to one another than the overall population. If there is significant clustering, the prey library may be partitioned so that individual clusters within a species are formed into respective prey types, thus increasing the libraries performance (Bromaghin et al. 2017).

FA analysis of marine lipids can often produce >70 individual FAs, all of which are not relevant for diet estimation (see table 2.3). In order to estimate diets using QFASA, you must provide a set (also known as a suite) of FAs to be used. Polar bear diets for this study were estimated using a fatty acid suite of 29 dietary FA, as outlined by Florko et al. (2021).

Additionally, certain FAs may be synthesized *de novo* from non-lipid precursors, while ingested FAs may be modified or utilized prior to deposition in the adipose tissue of polar bears. In order to account for this phenomenon, calibration coefficients must be provided during diet estimation (Budge et al. 2012). The consistency of signatures and calibration coefficients were assessed using the `pred_beyond_pre()` function in the `qfasar` package. During diet estimation, the predator signatures are modeled under the assumption that they are a linear mixture of mean prey signatures (Iverson et al. 2004) and therefore should fall within the range of prey proportions. `Pred_beyond_pre()` determines the proportion of predator signatures that fall outside the range

of prey proportions. If the model returns large values outside the range of prey proportions, it is indicative of a violation of model assumptions and the library is either incomplete or the calibration coefficients are not precise (Bromaghin 2017; Bromaghin et al. 2015, 2016). The results of `pred_beyond_pre` can be used to investigate problematic FAs by comparing a number of FAs with the highest sum of predator-beyond-prey values for each calibration coefficient. Problematic FAs would be removed in order to improve the identification of prey items and predator diet estimation would then be done over.

### *Sea-ice Metrics*

The metrics used to assess the effect of changing environmental conditions in this study were annual sea-ice break-up date, the length of the ice-free period (in days) and in Davis Strait, the maximum sea-ice extent (in km<sup>2</sup>). Maximum sea-ice extent was not used as a metric in Foxe Basin as sea-ice covered the entire geographic area of the sea each year, and therefore there was no variation in extent conditions. Daily sea-ice concentrations from 1999-2003 (Foxe Basin) and 2010-2023 (Foxe Basin and Davis Strait) were downloaded in a spatial resolution of 25 km x 25 km (625 km<sup>2</sup> per pixel) grid cells from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data (DiGirolamo et al. 2022) available from the National Snow and Ice Data Center in Boulder, CO, USA. I used R (version 4.5.1) to extract the sea-ice concentration raster images, with each cell having an associated sea-ice concentration (i.e. the estimated amount of sea-ice covering the individual cell; DiGirolamo et al. 2022).

I used sea-ice extent and concentration to calculate annual break-up date and the length of the ice-free period as outlined in McGeachy et al. (2024). Annual break-up date was defined as the first of three consecutive ordinal dates where the average sea-ice concentration was below 50% within the area of maximum extent of the respective subpopulation. The length of the ice-

free period was defined as the difference between the ordinal retreat date and the ordinal freeze up date, where retreat date was equal to the date sea-ice extent was  $\leq 10\%$  of the winter maximum and freeze up date was equal to the ordinal date sea-ice extent returned to 10%. All analysis was done using a combination of the terra package (version 1.8-60; Hijmans 2025), the sf package (version 1.0-21; Pebesma 2025) and the lubridate package (version 1.9.4; Spinu et al. 2024) in R (version 4.5.1).

In both Foxe Basin and Davis Strait sea-ice conditions dictated the start and end of each season. For Foxe Basin, I utilized the seasons outlined in Galicia et al. (2021a) in order to maintain consistency across the literature, while also allowing for better degree of comparability between results. As there is a variation in sea-ice conditions, between Foxe Basin and Davis Strait, I utilized seasons adapted from Thelin et al. (2025) when analyzing Davis Strait. More specifically, I created four (4) total seasons for Davis Strait based on sea-ice conditions listed above; (1) Freeze-up - the mean date of sea-ice freeze-up until mean date of maximum extent; (2) Winter - the mean date of maximum extent until the mean start date of break-up; (3) Break-up - the mean start date of break-up until the mean date of retreat; (4) Summer – the mean date of retreat to the mean date of freeze-up.

### *Statistical Analysis*

I used a series of generalized linear mixed effect models (GLMMs) to explore the intrinsic and extrinsic factors influencing diet composition and their effect on individual dietary specialization and body condition of polar bears across age and sex. The GLMMs were performed using a beta regression on account of the continuous proportional outputs of the dietary estimates being bound between 0 and 1, and a logit link function to ensure all predicted values stay within the 0 and 1 constraints. To understand how dietary habits differed, I utilized

prey species as the response variable, with age, sex and their interaction as intrinsic fixed variables, along with harvest year, break-up date, length of the ice-free period and, in Davis Strait, maximum sea-ice extent as extrinsic fixed variables. Season was included as a random effect.

The extent of individual dietary specialization was estimated using the proportional similarity index ( $PS_i$ ) in the R package *RInSp* (version 1.2.5, Zaccarelli et al. 2022). Based on Czekanowski's proportional similarity index ( $PS$ ),  $PS_i$  measures the overlap of an individual's diet with the rest of the population and follows the equation:

$$PS_i = 1 - 0.5 \sum_j |p_{ij} - q_j|$$

where  $i$  is the individual,  $p_{ij}$  is the frequency of prey type  $j$  in the individual's diet, and  $q_j$  is the frequency of prey type  $j$  in the entire population (Schoener 1968; Zaccarelli et al. 2013). The prevalence of individual specialization (IS) in the population was then measured as the mean  $PS_i$  of the population (Zaccarelli et al. 2013).  $PS_i$  scores are bound between values of 0 and 1, with smaller individual overlap with the overall population producing lower values (i.e. closer to 0), and high overlap producing greater values (i.e. closer to 1). Individuals who are more specialized should show reduced overlap with the overall population and therefore return lower  $PS_i$  values, with generalist individuals showing increased overlap, and therefore higher  $PS_i$  values (Bolnick et al. 2002; Zaccarelli et al. 2013). For the purpose of this study, I used a threshold  $PS_i$  value of < 0.50 to consider an individual a dietary specialist. I chose the value 0.50 based on the fact that as individuals stray from this point, under the concept of  $PS_i$  they will become either more specialized or more similar to the overall population based on the increase or decrease in value

and therefore the mid-point is the best indicator for the transition from generalist to specialist individual.

To determine the effect of intrinsic and extrinsic drivers on individual dietary specialization, I performed a series of GLMMs using  $PS_i$  as the response variable. The GLMMs were completed based on subpopulation, and utilized sex, age, sea-ice break-up date, and the length of the ice-free period as fixed effects, with harvest year and season as random effects. The GLMM performed for Davis Strait also included maximum extent as a fixed effect. Break-up date and length of the ice-free period included for each polar bear was dependent on the date of harvest. For example, if a polar bear was harvested in January, however break-up date did not occur until July, I used the previous year's break up date since that individual had not yet experienced the current year's break-up at the time of harvest. Similarly, if a polar bear was harvested before the last day of the ice-free period, the previous year's ice-free period length was used instead. Individuals harvested after their current years break-up date and/or ice-free period utilized the current-year values. In Davis Strait, the same principle applied to maximum extent values.

A final series of GLMMs was used to explore the relationship between dietary specialization, prey type and body condition in polar bears across age and sex classes. Adipose tissue lipid content was used as the response variable, while the fixed effects were age, sex, their interaction and  $PS_i$  with year and season as a random effects. To determine if any individual prey types contributed significantly to body condition, I also performed a series of GLMMs with prey type as the fixed effect and harvest year and season as random effects. However, since the subjective fatness index is an ordinal categorical variable, a cumulative link mixed model (CLMM) was created using the ordinal package in R (Version 2023.12-4.1; Christensen 2024).

The response variable was the subjective fatness index rating, while the fixed effects were age, sex and  $PS_i$ , with year and season as random effects. Similarly, I completed a series of CLMMs with prey type as the fixed effect to determine if any individual prey type predicted SFI scores. Additionally, I performed a Spearman's rank correlation on individuals with both subjective fatness index scores and adipose tissue lipid content values to determine the relationship between body condition indices.

Using the performance package in R (Lüdecke et al. 2021), I tested all models for assumption violations, including multicollinearity, over dispersion and singularity. The level of significance I used was  $\alpha = 0.05$  unless alternatively stated.

## **Results**

### *Prey Library and Diet Estimate Model Evaluation*

In order to test the efficacy and reliability of the prey library I performed a leave-one-prey-out (LOPO) analysis and divisive magnetic clustering (DIMAC). The LOPO analysis resulted in 84.66% for the mean proportion of prey that were correctly identified across all prey types (unweighted by sample size), with the proportion of correctly estimated signatures regardless of prey type equaling 81.72%. Bowhead resulted in the highest accuracy at 99.88%, with bearded seal showing the lowest at 71.14%. Walrus and harbour seal showed 93.81% and 93.21% respectively, with beluga (82%), harp seal (77.46%) and ringed seal (75.05%) showing lower scores. The DIMAC function found no evidence of substantial substructure within the prey library, indicating no significant variation in fatty acid composition within prey types and therefore eliminating the need for a partitioned library.

### *Dietary Composition*

Overall, ringed seal was found to be the most significant prey item within Foxe Basin, accounting for an average of  $40.34 \pm 1.06\%$  of polar bear diet. Bearded seal contributed the second most to diet composition with an average of  $18.86 \pm 0.67\%$ , while harp seal ( $17.57 \pm 0.79\%$ ) and walrus ( $13.96 \pm 0.67\%$ ) contributed slightly less. Harbour seal ( $4.03 \pm 0.27\%$ ) and beluga ( $4.99 \pm 0.43\%$ ) contributed minimally, with bowhead contributing nearly nothing to diet ( $0.5 \pm 0.08\%$ ). The largest contribution of each prey type to any individual's diet was bearded seal (89%), beluga (83%), bowhead (26%), harbour seal (50%), harp seal (99%), ringed seal (99%) and walrus (97%). Distribution of diet proportions across years can be seen in figure 2.3, while mean proportions across age and sex classes can be found in table 2.5.

Among Foxe Basin bears, sex was a strong predictor for bearded seal, ringed seal, harp seal and walrus in diet. Adult male polar bears showed significantly higher consumption of bearded seal, harp seal and walrus in comparison to adult females ( $p < 0.05$ ). In contrast, adult male bears were predicted to eat significantly less ringed seal than adult females ( $p < 0.001$ ). There was a significant interaction between age and sex for bearded seal with subadult males predicted to eat significantly less bearded seal in comparison to other age and sex classes ( $p < 0.001$ ). Additionally, there was a significant age and sex interaction found in ringed seal proportion as subadult males had higher levels of modeled ringed seal in diet in comparison to their adult male counterparts. Extrinsicly, break-up date significantly influenced the amount of harp seal in diet with later break-up associated with lower predicted proportions of harp seal ( $p < 0.001$ ). Year was a strong predictor for all prey types except for bowhead and walrus ( $p < 0.001$ ). A Kendall's rank correlation found that between 1999 and 2023 there was a significant increase in bearded seal, harp seal and bowhead in diet, with a significant decrease in the proportion of

beluga, ringed seal and harbour seal (Figure 2.5). Season accounted for little variance across the models, with the greatest variance associated with harp seal proportion (0.128, SD = 0.358) and the lowest among beluga and bowhead ( $<0.001$ , SD  $<0.001$ ). There were no significant intrinsic or extrinsic factors that predicted the amount of bowhead in an individual's diet within Foxe Basin. Although there was a slight trend towards earlier break-up dates and increased open water periods over the course of the study period within Foxe Basin, the results from the linear model used were not significant ( $p > 0.05$ ; Figure 2.2). A summary of results from the GLMM on predicted prey dietary proportions within Foxe Basin can be found in table 2.6.

Within Davis Strait, harp seal was the most substantial prey type, accounting for a mean proportion of  $49.95 \pm 1.01\%$ . Ringed seal was found to be the second most abundant prey species ( $24.69 \pm 1.37\%$ ) with bearded seal ( $10.54 \pm 0.62\%$ ) and walrus ( $10.39 \pm 0.54\%$ ) occurring at similar levels. Harbour seal ( $2.97 \pm 0.33\%$ ), Beluga ( $1.02 \pm 0.28\%$ ), bowhead ( $0.44 \pm 0.18\%$ ) accounted for less than 5% of the overall diet combined. The largest contribution of each prey type for a given individual was harp seal (99%), ringed seal (98%), bearded seal (52%), beluga (47%), walrus (63%), bowhead (45%) and harbour seal (35%). Distribution of diet composition across years can be found in figure 2.4, with mean compositions across age and sex class found in table 2.5.

Overall, certain trends in dietary composition within Davis Strait were predicted best by sex. Adult male bears exhibited significantly higher predicted proportions of bearded seal, harbour seal, harp seal in comparison to adult females ( $p \leq 0.05$ ; Table 2.6). Significant differences in dietary composition between sexes occurred within walrus and ringed seal, with adult males predicted to have higher proportions of walrus ( $p < 0.001$ ) and lower proportions of ringed seal ( $p < 0.001$ ) in comparison to adult females (Table 2.6). The model showed significant

age-sex interactions for bearded seal and walrus indicating that the effect of sex was dependent on age class ( $p < 0.05$ ; Table 2.6).

Extrinsically, maximum sea-ice extent was the greatest predictor for changes in dietary composition in Davis Strait. An increase in maximum extent was significantly associated with predicted decreased proportions of walrus and bearded seal diet, while also associated with higher levels of harbour seal ( $p < 0.05$ ). The length of the ice-free period had a significant effect on bearded seal and walrus proportions, with longer periods predicting higher dietary proportions ( $p < 0.05$ ). Conversely, later break up date was negatively associated with predicted ringed seal proportion ( $p = 0.014$ ). The GLMM suggested the later the harvest year, the smaller the modeled proportion of bearded seal, harbour seal and walrus in diet, however a Kendall's rank correlation found no significant increases or decreases in prey proportion between 2010 and 2023 (Figure 2.6). Season accounted for little variance among prey proportion within Davis Strait, with modest variance associated with ringed seal (0.167, SD = 0.409), and the lowest variance associated with beluga, bowhead and harbour seal ( $<0.001$ , SD = 0.001). There were no significant intrinsic or extrinsic factors that predicted the amount of bowhead or beluga in an individual's diet within Davis Strait. Additionally, the linear model investigating changes in break-up date, length of the open water period and maximum extent found no significant trends across the study period within Davis Strait ( $p > 0.05$ ; Figure 2.2) A summary of results from the GLMM on predicted prey proportions in diet within Davis Strait can be found in table 2.6.

### *Extent of Dietary Specialization*

The total incidence of specialization (IS) within the Foxe Basin population was  $0.58 \pm 0.005$ . Out of the 818 polar bears analyzed, 224 (27%) were found to have a proportional similarity index ( $PS_i$ ) value  $< 0.5$ , indicating that just over one quarter of the sample population

adopted more specialist foraging behaviours. The individuals displaying more specialist foraging behaviour ( $n = 224$ ;  $PS_i < 50$ ) were comprised of 38 subadult females, 45 subadult males, 31 adult females and 109 adult males (Figure 2.8). The top 10 most specialized individuals within Foxe Basin, consisted of 3 subadult males, 3 subadult females, 3 adult males, and 1 adult female (Figure 2.10). Amongst subadults, high proportions of dietary beluga were found in half the individuals, with two of three males (GF298, GF465) exhibiting proportions over 0.8, and one female exhibiting a proportion of 0.71 (P0336; Figure 2.10). The second associated prey for specialized subadults was walrus, with one male exhibiting a proportion of 0.97 (GF358), while one female had a proportion of 0.53 (GF258; Figure 2.10). Increased specialization resulting from an almost complete diet of harp seal was seen only within females, with a subadult female showing a proportion of 0.97 (GF244), while the adult female showed a proportion of 0.99 (Figure 2.10). The prey choices responsible for increased dietary specialization amongst adult males was bearded seal, found at proportions of 0.68 (P1237) and 0.75 (P1397) and walrus, found at a proportion of 0.91 (P1397; Figure 2.10). The individual with the greatest specialization was a subadult, male bear (GF298) harvested during the freeze-up period in 2020 displayed the lowest  $PS_i$  value of 0.11, with a diet consisting of primarily beluga (83%), and harbour seal (15%) (Figure 2.10). The other 595 individuals all displayed a  $PS_i$  value  $\geq 0.5$ , indicating that 73% of the sample population adopted more generalist foraging behaviours. Of the 595 individuals displaying more generalist foraging behaviour ( $PS_i \geq 0.5$ ), there was a total of 114 subadult females, 139 subadult males, 96 adult females and 246 adult males (Figure 2.8). Two individuals displayed the largest  $PS_i$  value (0.90). The first, an adult female bear (GF414) was harvested during the winter season in 2022, was estimated to consume mainly ringed seal (45%), followed by substantial amounts of harp seal (21%), bearded seal (20%) and walrus

(14%). The second individual was a subadult female (GF411) also harvested during the winter of 2022. She exhibited similar foraging behaviour, consuming mostly ringed seal (40%), followed by bearded seal (24%), harp seal (18%) and walrus (17%) .

Within Davis Strait, the IS of the sample population was  $0.693 \pm 006$ . Across the 347 bears sampled in Davis Strait, only 26 individuals (8%) were found to have a more specialist diet composition. Of these 26 individuals, there were 8 adult females, 13 adult males, 3 subadult females and 2 subadult males (Figure 2.9). Out of the top 10 most specialized individuals, there was 1 subadult male, 2 subadult females, 3 adult males and 4 adult females (Figure 2.11). The individual with the lowest  $PS_i$  value was an adult, male bear (P1892) harvested during the winter of 2018 who had a  $PS_i$  of 0.148 with a diet composed primarily of walrus (48%), bowhead (21%), harbour seal (16%) and beluga (15%) (Figure 2.8). The second most specialized individual was also an adult male bear (GF040) who showed almost equal dietary proportions of beluga (0.39) and bearded seal (0.38; Figure 2.11). The remaining 8 individuals all exhibited proportions of dietary ringed seal in excess of 0.84, suggesting that some degree of dietary specialization within Davis Strait is partially due to the increased exploitation of ringed seal by an individual (Figure 2.11). The individuals who adopted more generalist feeding strategies ( $n = 321$ ;  $PS_i \geq 0.5$ ) were comprised of 62 adult females, 181 adult males, 35 subadult females and 43 subadult males (Figure 2.9). The individual with the largest  $PS_i$  value (0.948) was an adult, female bear (P0181) harvested during the freeze-up season in 2012. Her diet consisted of primarily harp seal (49%), followed by ringed seal (30%), and walrus (10%) (Figure 2.8).

A suite of beta GLMMs testing the effects of intrinsic and extrinsic variables on  $PS_i$  scores in Foxe Basin, Davis Strait, predicted that sex had a significant effect on  $PS_i$  within Foxe Basin, with adult males showing consistently lower predicted  $PS_i$  values (mean  $0.575 \pm 0.006$ )

than adult females (mean  $0.597 \pm 0.008$ ,  $p = 0.025$ ; Table 2.7). Later sea-ice break-up was also a significant predictor of  $PS_i$  scores in Foxe Basin, with later break-up dates associated with a decrease in  $PS_i$  values ( $p = 0.016$ , Table 2.7). There were no significant predictors of  $PS_i$  within Davis Strait. Across both subpopulations, a Kendall's rank correlation test showed no significant trends in mean  $PS_i$  across years (Figure 2.7).

### *Factors Influencing Body Condition*

Two measures of body condition, a fatness index (SFI) score and percent of extracted adipose tissue lipid (LIPP), were modeled to determine the effect of intrinsic and extrinsic variables on individual fitness. A subset of 609 individuals from Foxe Basin were used for modelling fatness index scores (261 adult males, 98 adult females, 133 subadult males and 117 subadult females), while only 474 individuals had associated LIPP values (197 adult males, 76 adult females, 108 subadult males and 93 subadult females). Within Davis Strait, only 264 individuals had available SFI scores (145 adult males, 58 adult females, 35 subadult males and 26 subadult females), while 209 individuals had available LIPP values (117 adult males, 50 adult females, 24 subadult males and 18 subadult females). Of the individuals studied, 648 had both an SFI score and LIPP value. A Spearman's rank correlation test found that there was a weak, but statistically significant positive association between SFI and lipid content within Davis Strait (spearman  $\rho = 0.19$ ,  $p = 0.008$ ), however there was substantial overlap between SFI categories (Figure 2.12). Foxe Basin demonstrated a moderate, significant positive association between SFI scores and LIPP values (spearman  $\rho = 0.28$ ,  $p < 0.001$ ) and while overlap between categories did occur, there was a clearer rank order than in Davis Strait (Figure 2.12). A Kendall's rank correlation test found no significant trends in body condition across either subpopulation within the study period (Figure 2.7).

Across the Foxe Basin population, there were no intrinsic or extrinsic factors significantly predicting SFI scores (Table 2.9). The GLMM modeling adipose tissue lipid content (LIPP) showed that subadult females tended to have lower predicted LIPP than adult females, although this age effect was insignificant ( $p = 0.058$ ) and did not differ between sexes (Table 2.8). Additionally, subadult females showed a weak, non-significant increase in predicted LIPP as  $PS_i$  increased in comparison to adult females ( $p = 0.075$ ; Table 2.8).

The results from the CLMM on SFI scores in Davis Strait indicated that there was a significant sex effect, with adult males displaying higher predicted SFI scores than adult females ( $p = 0.013$ ; Table 2.10). There was a marginal age and age\*sex effect, where subadult females showed slightly higher predicted SFI scores than adult females ( $p = 0.052$ ), however this effect may be reduced within subadult males ( $p = 0.052$ , Table 2.10). There was a slight, yet non-significant trend that adult male bears exhibit lower predicted LIPP scores than adult females ( $p = 0.068$ ; Table 2.8). However, there was a significant age\*sex effect on LIPP scores, where subadult males showed higher predicted LIPP values than expected based on only sex differences ( $p = 0.039$ ; Table 2.8). Additionally, there was a three-way effect between age\*sex\*  $PS_i$  on LIPP, with subadult males showing a non-existent relationship between  $PS_i$  on LIPP ( $p = 0.044$ ; Table 2.8), different from the other age- and sex-classes. Two extrinsic factors had a positive effect on LIPP, with later sea-ice break up date ( $p = 0.014$ ) and longer ice-free periods ( $p = 0.045$ ) associated with higher predicted LIPP (Table 2.8). There were no other effects on body condition within Davis Strait.

Within Foxe Basin, it was found that ringed seal was positively associated with LIPP, with higher ringed seal in diet leading to higher predicted LIPP ( $p < 0.001$ ; Table 2.11). Conversely, bearded seal ( $p = 0.002$ ), walrus ( $p < 0.001$ ) and beluga ( $p = 0.043$ ) were negatively

associated with LIPP, as increased dietary proportions were associated with lower predicted LIPP scores (Table 2.11). Regarding SFI scores, there was a negative effect on SFI as bearded seal proportion increased ( $p < 0.001$ ), along with a positive effect as ringed seal proportion increased ( $p = 0.042$ ; Table 2.11). No other trends were present across Foxe Basin. Similarly, when testing for the effect of individual prey types on body condition in Davis Strait, it was found that bearded seal proportion was negatively associated with LIPP ( $p < 0.001$ ; Table 2.11). There was also a positive effect on predicted LIPP as ringed seal proportion increased ( $p = 0.04$ ; Table 2.11). There was no significant effects of prey proportions on SFI scores in Davis Strait.

## **Discussion**

As the Arctic experiences drastic ecological shifts in response to climate warming, understanding top predator dietary habits provides an opportunity to assess the resiliency and changes in the ecosystem and its functioning. Although consisting of majority generalist foragers, polar bears still demonstrate a degree of individual-level specialization amongst populations, similar to other documented “generalist” populations (Bolnick et al. 2002). Dietary specialists arise in a population in many ways, such as after changes to prey diversity and/or abundance, as a way to help reduce inter- and intraspecific competition, and as a result of phenotypic changes in response to variable environmental conditions (Svanbäck & Bolnick 2005; Tinker et al. 2008; Newsome et al. 2015; Evans & Moustakas 2018). Although it is known that polar bears exhibit dietary flexibility within populations (see Galicia et al. 2021a), the effect of individual specialization on fitness is not well understood.

The results of this study have provided deeper insights into the effects of climate change and individual specialization on body condition and fitness in an Arctic top predator. This study helped to identify intrinsic and extrinsic drivers of dietary specialization and their effect on polar

bear body condition and fitness across Foxe Basin and Davis Strait. As expected, sex had the biggest influence on individual specialization, with adult male bears exhibiting greater dietary specialization within Foxe Basin, however no significant differences arose in Davis Strait. Extrinsic factors, later break-up date was associated with increased specialization in Foxe Basin, consistent with the initial hypothesis. No other extrinsic factors affected  $PS_i$  in Foxe Basin, while none of the sea-ice metrics influenced  $PS_i$  in Davis Strait, highlighting the unique relationships each subpopulation has with climatically altered ecosystems. Polar bear body condition within Foxe Basin was not related to any intrinsic or extrinsic factors, suggesting no single driver effects overall fitness. Whereas in Davis Strait, longer ice-free periods and conversely later sea-ice break up date both positively influenced LIPP as a measure of body condition, indicative of an intricate relationship between changing sea-ice conditions and polar bear fitness. Contrary to the original hypothesis,  $PS_i$  had no detectable effect on adult female body condition across both subpopulations. However, in Davis Strait the age pattern in LIPP was different for males and females. Subadult females had lower predicted LIPP than adult females, while subadult males had higher predicted LIPP than their adult counterparts, creating a reversed age pattern between the sexes and showcasing the different costs and benefits to dietary specialization across age and sex classes.

### *Diet Composition*

Ringed seal is consistently found to be the most common prey type within the Foxe Basin region (see Thiemann et al. 2008a; Galicia et al. 2021a), most likely due to their high abundance and extensive distribution across the Arctic (Stirling & McEwan 1975). Although I used individuals previously analyzed by Galicia et al. (2021a), there were a few methodological differences, including the removal of 22:1n-9 as a dietary fatty acid due to prey confounding

(See Florko et al. 2020, 2021), along with the addition of new prey samples in the library. When compared to diet estimates of bears previously analyzed by Galicia et al. (2021a), my estimates for individuals from Foxe Basin between 1999-2003 returned slightly higher mean levels of ringed seal, with lower levels of dietary beluga, however the overall trend was consistent as ringed seal was the dominant prey choice followed by beluga for those years. When looking at individuals from Foxe Basin between 2010-2018 analysed by both this study and Galicia et al. (2021a), my estimates returned slightly higher mean levels of ringed seal, along with slightly lower mean estimates for beluga, bearded seal and bowhead, however the overall trends were still the same across this time period. Previous research from Florko et al. (2020) has shown that the fatty acid 22:1n-9 resulted in increased confounding between bearded seal, beluga whale, bowhead whale and ringed seal during QFASA. Between 2010 and 2023 ringed seal was the preferred prey choice in Foxe Basin followed by bearded seal and harp seal, consistent with previous work in the area (see Galicia et al. 2021a). Most likely, the slight differences in diet estimates between this study and previous research by Galicia et al. (2021a) are a result of the removal of a problematic fatty acid, along with the addition of new prey individuals in the prey library leading to slight variations in overall prey FA profiles.

Amongst individuals from Davis Strait, harp seal was the dominant prey in diet followed by ringed seal, with bowhead contributing the least to diet which aligns with previously reported trends (Galicia et al. 2021b). The Northwest Atlantic harp seal stock is found distributed throughout Davis Strait, with estimated abundances of 7.5 million seals (95% CI=6.75-8.42) in 1998, declining to 5.6 million seals (95% CI=4.78-6.63) in 2019 and 4.4 million (95% CI=3.65-5.35) in 2024 (Fisheries and Oceans Canada 2025). Although harp seal populations have shown a decline in abundance throughout the study period, the total estimated abundance is still

extremely high relative to other prey species. Additionally, harp seals show a lack of predator escape response, which combined with increased regional availability from on-ice whelping patches (Thiemann et al. 2008a; Galicia et al. 2021a) and substantial population abundance is likely the reason harp seal is consistently the primary prey choice within Davis Strait.

Across both subpopulations, adult males showed significantly less dietary ringed seal in comparison to adult females and subadult bears. Sexual and age-based size dimorphisms allow for larger, adult male bears to actively hunt and forage larger prey types (e.g. walrus and bearded seal; Derocher et al. 2005), allowing for decreased reliance on ringed seals. Ringed seal pups are abundant each year until around the time of annual ice break-up, and along with their small size and lack of experience being predated, offer an easier catch for inexperienced subadult and smaller adult female bears (Stirling & Lunn 1997). The ease at which ringed seals are captured, allows for less energy expenditure during foraging, therefore increasing the energetic return and is most likely the reason for continued preference for this prey type across polar bear populations, but more specifically younger and/or smaller individuals.

Adult male bears exhibited higher levels of bearded seal and walrus in estimated diet, in agreement with previous findings that sexual size dimorphisms play a role in foraging behaviour on larger prey (Thiemann et al. 2008a). Walrus in diet occurred at much lower levels within females across both age groups, suggesting that size dimorphisms have restricted females to primarily scavenging this prey, therefore reflected as lower proportions of walrus in diet, whereas male bears have been successful at actively hunting walrus (Calvert & Sterling 1990). Additionally, adult male polar bears have been known to frequent pack ice (Stirling et al. 1993), an area consistently used by larger bearded seal (Chambellant et al. 2012; Pilfold et al. 2014) which may allow for increased spatial overlap and consequently more foraging opportunities.

Lower levels of bearded seal amongst adult females and subadult bears, suggest that smaller body size limits the ability to effectively hunt bearded seal. Additionally, low levels of dietary bowhead and the lack of any significant intrinsic or extrinsic predictors are consistent with previous findings, suggesting that individuals are limited to opportunistic foraging of carcasses and remains from subsistence harvesting (Galicia et al. 2021a).

Within Foxe Basin, there was a significant increase in bearded seal, harp seal and bowhead consumption between 1999 and 2023. The Eastern Hudson Bay (EHB) beluga population, which overlaps, in part, with the Foxe Basin polar bear population, has seen dramatic declines in abundance dropping from an estimated 6,600 (95% CI=4,800-9,300) in 1974 to 3,400 (95% CI = 2,200 – 5,000) individuals in 2016 (Hammill et al. 2017). This indicates a substantial reduction in regional availability and abundance between 1999 and 2010, most likely influencing the dietary proportions within Foxe Basin at this time. Additionally, later sea-ice break-up, and consequently longer periods of consolidated ice, has been associated with increased beluga whale in diet (Florko et al. 2020), whereas bearded seal are more prevalent in areas of pack ice (Breed et al. 2018; McCarthy et al. 2025). Although insignificant, sea-ice break-up dates did trend towards earlier occurrences within the study period, with later break-up occurring in the earlier years (i.e. 1999-2003; figure 2.2), potentially facilitating a shift in diet away from beluga and towards bearded seal.

Although diet composition was variable across years, a Kendall's rank correlation test showed no significant changes in individual prey types within Davis Strait. This suggest relatively stable prey populations and continued high abundance have allowed for continued selection of preferred prey types in the region, even under fluctuating environmental conditions.

### *Extent of Dietary Specialization*

Overall, both Foxe Basin and Davis Strait demonstrated more “generalist”  $PS_i$  scores ( $\geq 0.5$ ) than “specialist” scores ( $< 0.5$ ) with Davis Strait found to be composed of a larger number of generalist individuals, achieving a mean incidence of specialization of  $0.69 \pm 0.02$ , while Foxe Basin, although still composed primarily of generalist individuals, resulted in a mean incidence of specialization of  $0.58 \pm 0.01$ . Differences between subpopulations were likely due to variations in the spatiotemporal distribution of marine mammals within Foxe Basin (see Galicia et al. 2021b), resulting in a larger variety of diets throughout and therefore increasing the extent of specialization. Furthermore, substantial marine mammal diversity (Stewart & Lockhart 2025) along with novel foraging opportunities as a result of increased predation from killer whales (see Galicia et al. 2016) has resulted in a high prey diversity for individuals within Foxe Basin. Additionally, estimated population sizes for Foxe Basin ( $n = 2585$ , CI = 2096-3198; Stapleton et al. 2016) indicate a larger number of individuals present across a smaller geographic area (1.18mill. km<sup>2</sup>; Vongraven & Peacock 2011) in comparison to Davis Strait ( $n = 1944$ , CI = 1593-2366; 2.62 mill km<sup>2</sup>; Dunham et al. 2024; Vongraven & Peacock 2011). Increased specialization has been previously associated with greater population density as prey availability and abundance is reduced under heightened foraging pressure (see Ratcliffe et al. 2018; Svanbäck & Bolnick, 2007). Potentially, an increased likelihood for intraspecific competition as a result of reduced prey abundance and increased population density, in conjunction with higher prey diversity has driven increased levels of dietary specialization in the area.

Within Foxe Basin, a “generalist” diet composition across the population consisted of primarily ringed seal (~40%), with similar parts (~20%) bearded seal and harp seal second, followed by walrus (~15%). Across the top 10 most specialized individuals, there were no

individual prey types driving specialization. The three most specialized adult male bears showed increased preference towards larger prey types (i.e. bearded seal and walrus), while two of the four most specialized females showed a preference for the smaller harp seal, consistent with findings on the effect of adult male size dimorphisms and foraging behaviour. Interestingly, five of the six most specialized subadult bears exhibited diets containing primarily larger prey (i.e. beluga and walrus). However, scavenging of beluga and walrus has been recorded across the Arctic (Smith & Sjare 1990; Rugh & Shelden 1993; Calvert & Stirling 1990), and these findings are most likely reflective of increased scavenging behaviour amongst subadult bears as they learn to forage and hunt on their own. Overall, adult male bears were found to be more specialist than other age and sex categories, consistent with findings that larger male bears are able to exploit a wider variety of larger prey types that females and subadults are unable to consume due to morphological constraints. Additionally, energetic and fat requirements for females prior to denning and/or successful cub-rearing (see Atkinson & Ramsay 1995; Pagano 2021; Thiemann et al. 2006; Derocher & Stirling 1996, 1998) may limit these individuals to forage on readily available, highly abundant and more easily captured prey such as ringed seal and harp seal, in order to maintain healthy fat levels and increase individual and cub survival. These findings are consistent with the original hypothesis that adult male bears will exhibit a higher degree of individual specialization in comparison to other age and sex classes.

The “generalist” diet composition within Davis Strait was primarily harp seal (~50%), followed by ringed seal (~30%), then similar levels (~10%) of walrus and bearded seal. The two most specialized individuals were both adult males who fed primarily on larger prey types, including walrus, beluga, bowhead and bearded seals, consistent with findings on the relationship between adult male size dimorphisms and foraging behaviour. Notably, the

remaining eight of the ten most specialized individuals exhibited the same foraging strategy, with ringed seal accounting for over 80% of dietary composition. This behaviour aligns with the established importance of ringed seals as the primary prey type across most polar bear subpopulations and as a common secondary prey source within Davis Strait. Across the entire subpopulation there was no significant difference in  $PS_i$  across age and sex, and therefore does not support the original hypothesis. Presumably, the high abundance of harp seal within Davis Strait provides a substantial primary prey source, most likely reducing the amount of intraspecific competition and consequently decreasing the need for specialized foraging behaviour.

#### *Effect of Dietary Specialization on Body Condition and Fitness*

Two measures of body condition indices – a subjective fatness index and adipose tissue lipid content - were used to test the effect of dietary specialization on polar bear fitness. Most notably, the 1 (most lean) to 5 (obese) FI scale is a subjective rating established at the time of harvest, and given by minimally- or potentially un-trained hunters and trappers, which may lead to unintended inflation of certain categories due to individual differences in assessment and procedural knowledge. Although the extreme ends of the scale may be easily distinguished, bears in category three may see increased mis-identification with categories immediately below or above, potentially skewing population results. Although there are some limitations in using the fatness index, the results from my Spearman's rank correlation test found that the subjective fatness index scores and adipose tissue lipid content were quantitatively linked, in line with previous research (see Stirling et al. 2008) and suggesting that SFI scores are a valuable and effective tool for measuring body condition.

Contrary to the hypothesis, decreased specialization in lone adult females was not significantly associated with increased body condition in Foxe Basin; however, there was an indication that this trend may be present among subadults. Among subadults, females may exhibit lower overall LIPP relative to adult females, as decreased specialization was slightly associated with higher LIPP. Previous work in the neighbouring Western Hudson Bay polar bear population found relatively high dietary diversity within subadult polar bears, most likely due to their smaller size and inexperience hunting (Sciullo et al. 2017). Presumably, the small size and inexperience of subadult female bears has restrained foraging behaviour to more readily accessible prey types (e.g. ringed seal pups) in order to maintain better body condition. Results from the model using fatness index scores as a measure of body condition show no relationship between age, sex, dietary specialization and body condition within Foxe Basin. This is most likely due to the previously listed limitations and inaccuracies in using SFI scores as body condition estimates.

Although non-significant, adult males tended to have lower LIPP values than adult females in Davis Strait. Adult males do not benefit from increased fat stores to the same extent as adult females, as they do not experience the same energetic demands of denning, pregnancy, prolonged fasting, lactation and cub rearing. As a result, the need for excess energy stores (i.e. increased adipose tissue lipid content) is substantially lower in adult males; thus, lower LIPP values would make ecological sense. Overall, subadults exhibited higher LIPP values than adults, also exhibiting a significant the age\*sex interaction. The difference in LIPP values between males and females was reduced in subadults, with subadult males exhibiting LIPP values higher than expected based on sex differences alone, bringing them closer to those of their female counterparts. Subadults exhibit higher energetic demands associated with continued growth and

increased intraspecific competition, due to their smaller size, while the energetic requirements of cub rearing do not yet constrain subadult female bears. Additionally, subadult bears are at greater risk of starvation, particularly during ice-free periods (Pagano et al. 2024). Presumably, these conditions have promoted intensive foraging in subadults whenever food is available, as consistent access to high-quality habitats is not always guaranteed. As a result, increased fat stores may be more beneficial to subadults than adults, increasing overall LIPP values, while the inability for subadult females to get pregnant may result in closer LIPP values between sexes among subadults.

Similar to Foxe Basin, adult female bears did not show any association between *PSi* and LIPP content. Subadult females and adult males both demonstrated non-significant trends where increased dietary specialization was associated with decreased LIPP content. However, the significant age\*sex\**PSi* interaction shows that among subadult males, this trend did not persist, with no relationship between body condition and dietary specialization. The lack of relationship between LIPP and *PSi* in subadult males suggests that the exploitation of primary prey types does not lead to better body condition, presumably because increased energetic requirements during this rapid growth phase promote a wide array of foraging behaviours to meet physiological needs. A similar lack of association was observed in adult females, indicating that body condition was not strongly related to specific foraging behaviours. Instead, adult females may rely on foraging strategies that reflect prey availability at a given time. This pattern suggests greater flexibility in adult females and subadult males, potentially enabling them to meet the energetic demands of denning and cub rearing for females and more rapid growth in males.

Fatness index scores in Davis Strait showed a strong sex effect, with adult males exhibiting significantly higher SFI scores than adult females, most likely due to increased size

and associated mass during adulthood. Subadult females tended to have higher SFI scores than adult females, though the difference was marginal. Ecologically, this pattern may reflect the fact that younger females have access to abundant, predictable, and easy-to-capture prey, while not yet constrained by the energetic demands of gestation and lactation, and therefore accumulate body reserves more easily than adult females. Additionally, the model indicated a marginal increase in SFI scores in subadult males relative to adult females; however, this increase was smaller than that in subadult females. Seemingly, increased energetic demands associated with faster growth in subadult male bears have affected their ability to accumulate and maintain fat stores. However, because of limitations in using the fatness index as a body condition estimate, these trends must be interpreted cautiously.

It was found that as the consumption of bearded seal in both subpopulations, and beluga and walrus in Foxe Basin, increased, there was a significant decrease in the quantity of lipid extracted from the adipose tissue, whereas increased consumption of ringed seal in both subpopulations was associated with a significant increase in the quantity of lipid extracted. The model for dietary composition in this study, showed both bearded seal and walrus found at higher levels in adult males. As previously mentioned, adult male bears do not benefit from excess fat storage in the same way as other age and sex classes, while also being able to exploit larger prey types such as bearded seals and walruses which could explain the marginally reduced adipose tissue lipid content observed in these individuals in Davis Strait. Although there were no intrinsic factors influencing the consumption of beluga, the model suggests that individuals who consumed greater proportions of beluga exhibited decreased adipose tissue lipid content. There have been documented cases of polar bears actively hunting beluga whales; however, most often, bears scavenge on the remains of stranded belugas (Smith & Sjare, 1990). The limited

availability of beluga whale carcasses, along with the increased physical demands associated with the successful hunt and capture of belugas, may cause individuals that specialize on this prey type to expend more energy than they receive, consequently reducing body condition. The model investigating the influence of prey consumption on subjective fatness index (SFI) scores showed similar results in Foxe Basin only: lower SFI scores associated with increased bearded seal proportions and higher SFI scores associated with increased ringed seal proportions. Interestingly, adult males in Foxe Basin were not found to be in worse condition, as measured by a fatness index, while still maintaining higher levels of bearded seal. Presumably, the limitations of using fatness index scores as body condition indices have overshadowed the logical negative relationship between the two models. There were no significant trends in Davis Strait, most likely due to low/no samples across certain age- and sex-classes. Results obtained utilizing SFI scores should be taken with caution due to methodological limitations.

When comparing the results from the initial diet composition model with those of the body condition models, there is an indication that increased bearded seal proportions may be associated with decreases in adipose tissue lipid content in adult male bears in Davis Strait; however, the direction of the association is not clear. Adult male bears are both less dependent on excess fat stores and more capable of exploiting large prey such as bearded seal due to their size, meaning that higher bearded seal proportions and lower lipid content likely co-occur as parallel outcomes of age- and sex-specific foraging behaviour instead of direct dietary effects on body condition. Additionally, the original hypothesis that female bears exhibiting lower degrees of individual specialization will be in better body condition cannot be supported with results from either subpopulation. Interestingly, in Foxe Basin, subadult females, rather than adult females, adopting more generalist foraging strategies, may have higher adipose tissue lipid content,

potentially due to reduced constraints imposed by the energetic demands of gestation and lactation.

### *Environmental influences*

My results suggest an intricate relationship among sea-ice conditions, predator-prey interactions, and, consequently, body condition, with the most notable effects in Davis Strait. Presumably, as Foxe Basin reaches complete sea-ice coverage each year, polar bears and their prey may still, to a degree, exhibit typical predator-prey relationships, likely reducing the overall effects of climate warming. As the maximum extent varies from year to year in Davis Strait, any reduction in overall extent, compounded with earlier break-up dates and longer ice-free periods, may amplify changes in predator-prey dynamics, thereby generating more noticeable changes. Although interannual variability in environmental conditions did occur, there were no long-term trends.

Later break-up date was the most significant predictor of changes in dietary composition and, consequently, specialization within Foxe Basin. Consistent with the original hypothesis, later sea-ice break-up was significantly associated with increased specialization within Foxe Basin. When looking at diet composition, later breakup was associated with a significant reduction in the proportion of harp seals in the diet. Previous literature indicates that reductions in sea-ice coverage have enabled increased expansion of harp seal into the central Arctic, including Foxe Basin (Stephenson & Hartwig 2010), thus in years with later break-up, there should be limited expansion. Additionally, work in a neighbouring subpopulation has indicated that the core-use areas of polar bears overlap minimally with those of harp seals during break-up (Thelin et al. 2025), suggesting that foraging opportunities are likely reduced during this period. Presumably, during years with increased sea-ice coverage associated with later break-up, there

has been a reduction in harp seal expansion into Foxe Basin along with reduced spatial overlap during the break-up period, which has lowered the proportion of harp seal in diet. As harp seals are a significant component of the population's dietary niche, in years with later break-up, changes in availability and abundance have most likely led to the exploitation of alternate prey sources, driving increased specialization within Foxe Basin.

In contrast to trends seen in Foxe Basin, extrinsic factors heavily influenced prey proportions in diet, and adipose tissue lipid content in Davis Strait, but did not influence dietary specialization. Proportions of prey in the diet were influenced the most by maximum sea-ice extent, with significant decreases in predicted bearded seal and walrus, and a notable increase in predicted harbour seal as maximum extent increased. Appropriately, increased length of the ice-free period was associated with significant increases in predicted bearded seal and walrus. Both walrus and bearded seal prefer relatively shallow waters (<100 m), with bearded seals preferring areas of intermediate ice concentration (~15%) and areas along the ice edge, while walrus utilize terrestrial or pack ice as haul-out areas (Breed et al. 2018; McCarthy et al. 2025; Cameron et al. 2018; Stephenson & Hartwig 2010). As extent increases, access to pack ice and intermediate ice concentrations (if present) is limited to deeper water off the coast and outside the preferred range of these two prey species. As a result, it is likely that foraging opportunities are decreased in years of greater extent, while subsequently increased in years with longer ice-free periods, as preferred prey habitat is more accessible, thereby explaining the present trends. Harbour seal proportions show an opposite trend, with higher proportions in years of maximum extent, yet there is no effect from the lengthening ice-free period. Although harbour seals are primarily coastal species, they often exhibit offshore foraging behaviour, travelling more than 100 km from their haul-out sites (Vance et al. 2021). During years of increased ice extent, it is possible that

during these offshore foraging trips, there is increased overlap with polar bears, thereby increasing the proportion in diet. The last extrinsic factor – break-up date – was negatively associated with ringed seal proportions, with later break-up dates leading to decreased predicted ringed seal in diet. Ringed seals are reliant on stable sea-ice for breeding and haul-out, with a preference for land-fast ice along coastlines and within fjords (Kovacs et al. 2011; Lydersen & Kovacs 1999). However, low ovulation rates and subsequently ovulation failure have been associated with later sea-ice clearance (Harwood et al. 2020). Reduced ringed seal population abundance, as a result of decreased ovulation rates and ovulation failure in years with later sea-ice breakup, has presumably led to decreased proportions in diet.

Oddly enough, the substantial extrinsic effects on individual prey types in diet within Davis Strait did not influence *PSi* scores. Individuals in Davis Strait showed, on average, less specialization, with harp seals as the preferred and most abundant prey species. From my model on diet proportions, harp seal proportions were not significantly affected by any extrinsic factors, indicating that consumption is relatively consistent across changing environmental conditions and therefore does not influence overall specialization within this population.

Although there were no extrinsic factors influencing the degree of dietary specialization within Davis Strait, break-up date and the length of the ice-free period did significantly influence adipose tissue lipid content. Contrasting trends indicate later sea-ice break-up and longer ice-free periods, both associated with increased adipose tissue lipid content. Contrary to this trend, the proportion of ringed seal in diet was the only prey type linked to increased lipid percentage, while also showing decreased proportions in years with later break-up; thus, it should be expected that break-up date would be negatively associated with lipid percentage. Most likely, in years with later sea-ice break-up, individuals exhibit greater flexibility in foraging behaviour,

exploiting alternative prey to maintain body condition. Additionally, later sea-ice break-up means that individuals have greater access to and more time within preferred foraging habitat, presumably allowing for greater lipid accumulation in adipose tissue. Similarly, bearded seal proportions in diet were significantly associated with lower adipose tissue lipid content, but were higher during years with longer ice-free periods. This would suggest that we would see decreased body condition in years with longer ice-free seasons; however, the results indicate otherwise. One potential explanation for this trend is that higher levels of walrus in diet during these years help increase lipid stores, as longer ice-free periods are associated with greater walrus abundance in diet. However, both bearded seals and walrus are larger prey types, often restricted to larger adult males or, when available, scavenged by other age and sex classes; therefore, they may not be applicable to the entire population. Additionally, the negative association between bearded seals and adipose tissue lipid content may result from smaller individuals in worse body condition opportunistically scavenging bearded seals at higher levels to replenish energy stores, or from co-occurring outcomes of age- and sex-specific foraging ecology. Due to the contradictory evidence provided by these results, any conclusions about the relationship between body condition and sea-ice metrics cannot be made with confidence, and further work is needed.

Within Foxe Basin, changing sea-ice conditions had little influence on diet and, consequently, no effect on either adipose tissue lipid content or fatness index scores. While Davis Strait exhibits more variable environmental conditions, which were shown to influence diet to a greater extent, their effects on adipose tissue lipid content are contradictory and yield no clear conclusions, and they also show no significant effect on fatness index scores. These results highlight the complex relationships among extrinsic drivers, prey choice, dietary specialization, and body condition in polar bears in Foxe Basin and Davis Strait.

## Conclusion

This study aimed to examine the intrinsic and extrinsic drivers of dietary specialization and their effect on body condition and fitness of polar bears in Foxe Basin and Davis Strait. The findings show that foraging behaviours are changing across time, while localised prey availability and abundance within Foxe Basin have driven increased individual dietary specialisation, the readily abundant and temporally stable harp seal populations in Davis Strait have allowed for continually less. Intrinsically, sexual size dimorphisms and the associated increase in intraspecific competition had the greatest influence on prey choice, specialization and body condition. Extrinsically, environmental conditions only influenced the degree of specialization within Foxe Basin, while only influencing body condition of individuals within Davis Strait. The results of this study showcased the intricate relationships between an Arctic top predator and its habitat under dynamic environmental conditions. Future research should continue to model the individual and population-level effects of climate change on ice-dependent polar bear populations, as environmental conditions continue to worsen and these Arctic top predators are forced to adapt.

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**Table 2.1** – Distribution of harvested polar bear adipose tissue samples used to analyze the diet composition of polar bears across two subpopulations: Davis Strait and Foxe Basin.

<b>Subpopulation</b>	<b>Total (<i>n</i>)</b>	<b>Adult</b>		<b>Subadult</b>	
		<i>Male</i>	<i>Female</i>	<i>Male</i>	<i>Female</i>
Davis Strait	347	194	70	45	38
Foxe Basin	818	355	127	184	152
Total	1165	549	197	229	190

**Table 2.2** – Distribution of harvested prey species collected from 2000-2023. Bolded subpopulation indicates samples taken from outside the study area (i.e. Western Hudson bay – WH; Gulf of Boothia – GB; Baffin Bay – BB; Lancaster Sound; LS) to increase sample size and prey library reliability.

<b>Species</b>	<b>Total (n)</b>	<b>Subpopulation</b>	<b>Sample (n)</b>
Bearded Seal	33	DS	1
		FB	11
		<b>GB</b>	<b>3</b>
		<b>WH</b>	<b>18</b>
Beluga	56	DS	13
		FB	32
		WH	11
Bowhead	51	DS	2
		FB	43
		<b>GB</b>	<b>1</b>
		<b>LS</b>	<b>5</b>
Harbour Seal	23	FB	1
		<b>WH</b>	<b>22</b>
Harp Seal	84	FB	2
		<b>BB</b>	<b>7</b>
		DS	75
Ringed Seal	142	DS	72
		FB	70
Walrus	37	DS	3
		FB	31
		<b>LS</b>	<b>3</b>
<b>Total (n)</b>	<b>426</b>		<b>426</b>

**Table 2.3** – Fatty Acid composition (mean % mass of total FA  $\pm$  SEM) of adipose tissue samples collected in Foxe Basin and Davis strait between 1999 – 2003 (Foxe Basin) and 2010 – 2023 (Foxe Basin and Davis Strait). FA’s used for final diet estimation are found bolded.

Fatty Acid	Davis Strait ( <i>n</i> = 347)			Foxe Basin ( <i>n</i> = 818)		
12:0	0.027	$\pm$	0.001	0.034	$\pm$	0.001
13:0	0.045	$\pm$	0.007	0.012	$\pm$	0.000
i-14:0	0.023	$\pm$	0.001	0.030	$\pm$	0.001
14:0	2.961	$\pm$	0.024	3.066	$\pm$	0.023
14:1n-9	0.063	$\pm$	0.001	0.058	$\pm$	0.001
14:1n-7	0.035	$\pm$	0.001	0.047	$\pm$	0.001
14:1n-5	0.496	$\pm$	0.008	0.690	$\pm$	0.008
i-15	0.180	$\pm$	0.003	0.222	$\pm$	0.007
ai-15	0.088	$\pm$	0.003	0.147	$\pm$	0.004
15:0	0.199	$\pm$	0.003	0.251	$\pm$	0.002
i-16	0.082	$\pm$	0.002	0.111	$\pm$	0.002
16:0	6.135	$\pm$	0.070	7.354	$\pm$	0.060
16:1n-11	0.212	$\pm$	0.006	0.221	$\pm$	0.003
16:1n-9	0.464	$\pm$	0.005	0.511	$\pm$	0.003
16:1n-7	10.014	$\pm$	0.167	14.187	$\pm$	0.119
16:1n-5	0.186	$\pm$	0.003	0.235	$\pm$	0.002
17:1a	0.027	$\pm$	0.001	0.038	$\pm$	0.001
i-17	0.154	$\pm$	0.002	0.204	$\pm$	0.002
<b>16:2n-6</b>	0.031	$\pm$	0.001	0.036	$\pm$	0.000
ai-17:0	0.083	$\pm$	0.003	0.100	$\pm$	0.004
<b>17:1b</b>	0.122	$\pm$	0.002	0.133	$\pm$	0.001
<b>16:2n-4</b>	0.320	$\pm$	0.005	0.322	$\pm$	0.003
17:0	0.137	$\pm$	0.003	0.176	$\pm$	0.002
<b>16:3n-4</b>	0.048	$\pm$	0.001	0.049	$\pm$	0.001
17:1	0.181	$\pm$	0.003	0.234	$\pm$	0.002
<b>16:4n-3</b>	0.027	$\pm$	0.001	0.041	$\pm$	0.001
<b>16:4n-1</b>	0.056	$\pm$	0.002	0.049	$\pm$	0.001
18:0	1.943	$\pm$	0.023	2.276	$\pm$	0.025
18:1n-13	0.033	$\pm$	0.003	0.058	$\pm$	0.002
18:1n-11	5.313	$\pm$	0.071	3.211	$\pm$	0.049
18:1n-9	21.650	$\pm$	0.131	21.521	$\pm$	0.109
18:1n-7	4.370	$\pm$	0.041	5.928	$\pm$	0.046
18:1n-5	0.458	$\pm$	0.004	0.546	$\pm$	0.003
18:2d5,11	0.055	$\pm$	0.001	0.054	$\pm$	0.001

<b>Fatty Acid</b>	<b>Davis Strait (n = 347)</b>			<b>Foxe Basin (n = 818)</b>		
18:2n-7	0.067	±	0.001	0.082	±	0.001
<b>18:2n-6</b>	1.531	±	0.018	2.206	±	0.022
18:2n-4	0.099	±	0.001	0.126	±	0.001
<b>18:3n-6</b>	0.085	±	0.001	0.108	±	0.001
<b>18:3n-4</b>	0.156	±	0.002	0.185	±	0.002
<b>18:3n-3</b>	0.365	±	0.004	0.412	±	0.008
<b>18:3n-1</b>	0.051	±	0.001	0.052	±	0.001
<b>18:4n-3</b>	0.414	±	0.009	0.380	±	0.006
<b>18:4n-1</b>	0.104	±	0.003	0.128	±	0.002
20:0	0.089	±	0.002	0.075	±	0.001
20:1n-11	4.137	±	0.064	2.436	±	0.034
<b>20:1n-9</b>	14.010	±	0.175	8.048	±	0.106
<b>20:1n-7</b>	1.107	±	0.021	1.327	±	0.029
20:2nmid1	0.050	±	0.003	0.047	±	0.003
20:2n-9	0.027	±	0.001	0.066	±	0.002
20:2nmid2	0.050	±	0.002	0.065	±	0.003
<b>20:2n-6</b>	0.310	±	0.004	0.369	±	0.004
20:3nmit	0.041	±	0.002	0.044	±	0.001
<b>20:3n-6</b>	0.114	±	0.001	0.134	±	0.001
<b>20:4n-6</b>	0.234	±	0.004	0.338	±	0.005
<b>20:3n-3</b>	0.051	±	0.001	0.052	±	0.001
<b>20:4n-3</b>	0.353	±	0.005	0.376	±	0.004
<b>20:5n-3</b>	2.039	±	0.063	2.672	±	0.045
22:0	0.014	±	0.003	0.035	±	0.010
<b>22:1n-11</b>	3.650	±	0.086	1.503	±	0.040
22:1n-9	1.012	±	0.019	0.521	±	0.009
<b>22:1n-7</b>	0.127	±	0.003	0.090	±	0.001
22:2nmid1	0.042	±	0.002	0.056	±	0.002
22:2nmid2	0.023	±	0.002	0.029	±	0.002
22:3nmit	0.026	±	0.002	0.025	±	0.002
22:2n-6	0.028	±	0.001	0.027	±	0.001
<b>21:5n-3</b>	0.347	±	0.004	0.394	±	0.003
23:0	0.011	±	0.001	0.011	±	0.001
<b>22:4n-6</b>	0.139	±	0.003	0.214	±	0.005
<b>22:5n-6</b>	0.118	±	0.002	0.152	±	0.002
<b>22:4n-3</b>	0.081	±	0.001	0.071	±	0.001
<b>22:5n-3</b>	5.751	±	0.060	6.614	±	0.049
24:0	0.025	±	0.002	0.012	±	0.001
<b>22:6n-3</b>	6.764	±	0.072	8.257	±	0.065
24:1n-9	0.125	±	0.003	0.079	±	0.001

**Table 2.4** - Fatty Acid composition (mean % mass of total FA  $\pm$  SEM) of marine mammal prey blubber samples collected between 2000 – 2023. FA's used for final diet estimation are found bolded.

Fatty Acid	Bearded Seal (n = 33)	Beluga (n = 56)	Bowhead (n = 51)	Harbour Seal (n = 23)	Harp Seal (n = 84)	Ringed Seal (n = 142)	Walrus (n = 37)
12:0	0.118 $\pm$ 0.007	0.719 $\pm$ 0.040	0.079 $\pm$ 0.003	0.128 $\pm$ 0.005	0.072 $\pm$ 0.003	0.085 $\pm$ 0.008	0.102 $\pm$ 0.011
13:0	0.011 $\pm$ 0.002	0.036 $\pm$ 0.002	0.012 $\pm$ 0.001	0.020 $\pm$ 0.001	0.021 $\pm$ 0.001	0.014 $\pm$ 0.001	0.011 $\pm$ 0.001
i-14	0.013 $\pm$ 0.001	0.136 $\pm$ 0.025	0.099 $\pm$ 0.004	0.033 $\pm$ 0.002	0.022 $\pm$ 0.001	0.017 $\pm$ 0.001	0.012 $\pm$ 0.001
14:0	2.590 $\pm$ 0.057	5.221 $\pm$ 0.103	3.234 $\pm$ 0.060	3.326 $\pm$ 0.119	5.363 $\pm$ 0.092	4.076 $\pm$ 0.083	3.088 $\pm$ 0.084
14:1n9	0.069 $\pm$ 0.005	0.677 $\pm$ 0.046	0.063 $\pm$ 0.002	0.081 $\pm$ 0.007	0.187 $\pm$ 0.005	0.115 $\pm$ 0.004	0.126 $\pm$ 0.009
14:1n7	0.093 $\pm$ 0.012	0.521 $\pm$ 0.036	0.044 $\pm$ 0.001	0.147 $\pm$ 0.012	0.042 $\pm$ 0.003	0.083 $\pm$ 0.005	0.080 $\pm$ 0.004
14:1n5	0.627 $\pm$ 0.046	1.495 $\pm$ 0.093	0.655 $\pm$ 0.025	0.969 $\pm$ 0.104	0.523 $\pm$ 0.030	1.176 $\pm$ 0.038	0.543 $\pm$ 0.070
i-15	0.124 $\pm$ 0.008	0.741 $\pm$ 0.085	0.030 $\pm$ 0.002	0.270 $\pm$ 0.013	0.159 $\pm$ 0.004	0.142 $\pm$ 0.003	0.075 $\pm$ 0.003
ai-15	0.111 $\pm$ 0.013	0.106 $\pm$ 0.006	0.022 $\pm$ 0.001	0.117 $\pm$ 0.009	0.062 $\pm$ 0.003	0.074 $\pm$ 0.004	0.520 $\pm$ 0.060
15:0	0.310 $\pm$ 0.010	0.272 $\pm$ 0.010	0.172 $\pm$ 0.002	0.308 $\pm$ 0.012	0.230 $\pm$ 0.004	0.203 $\pm$ 0.004	0.402 $\pm$ 0.018
15:1n8	0.009 $\pm$ 0.005	0.017 $\pm$ 0.002	0.032 $\pm$ 0.001	0.009 $\pm$ 0.002	0.019 $\pm$ 0.001	0.004 $\pm$ 0.001	0.000 $\pm$ 0.000
15:1n6	0.033 $\pm$ 0.005	0.037 $\pm$ 0.005	0.041 $\pm$ 0.001	0.000 $\pm$ 0.000	0.021 $\pm$ 0.002	0.009 $\pm$ 0.001	0.000 $\pm$ 0.000
i-16	0.135 $\pm$ 0.010	0.224 $\pm$ 0.047	0.069 $\pm$ 0.001	0.131 $\pm$ 0.008	0.056 $\pm$ 0.002	0.050 $\pm$ 0.003	0.127 $\pm$ 0.013
16:0	8.792 $\pm$ 0.350	6.630 $\pm$ 0.167	5.056 $\pm$ 0.088	10.274 $\pm$ 0.339	7.964 $\pm$ 0.154	6.494 $\pm$ 0.166	10.299 $\pm$ 0.332
16:1n11	0.313 $\pm$ 0.013	1.203 $\pm$ 0.052	0.395 $\pm$ 0.014	0.379 $\pm$ 0.016	0.318 $\pm$ 0.008	0.509 $\pm$ 0.017	0.261 $\pm$ 0.010
16:1n9	0.376 $\pm$ 0.008	1.310 $\pm$ 0.062	0.285 $\pm$ 0.006	0.540 $\pm$ 0.026	0.214 $\pm$ 0.005	0.509 $\pm$ 0.014	0.443 $\pm$ 0.021
16:1n7	19.391 $\pm$ 0.604	22.009 $\pm$ 0.592	19.892 $\pm$ 0.311	18.042 $\pm$ 0.990	13.722 $\pm$ 0.328	20.184 $\pm$ 0.290	18.440 $\pm$ 0.857
16:1n5	0.280 $\pm$ 0.005	0.274 $\pm$ 0.005	0.022 $\pm$ 0.001	0.301 $\pm$ 0.006	0.249 $\pm$ 0.004	0.306 $\pm$ 0.004	0.301 $\pm$ 0.013
17:1a	0.064 $\pm$ 0.004	0.064 $\pm$ 0.003	0.276 $\pm$ 0.004	0.115 $\pm$ 0.006	0.055 $\pm$ 0.003	0.043 $\pm$ 0.002	0.021 $\pm$ 0.001
i-17	0.037 $\pm$ 0.014	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.086 $\pm$ 0.033	0.004 $\pm$ 0.003	0.040 $\pm$ 0.005	0.162 $\pm$ 0.033
<b>16:2n6</b>	0.047 $\pm$ 0.002	0.055 $\pm$ 0.001	0.052 $\pm$ 0.002	0.065 $\pm$ 0.004	0.061 $\pm$ 0.001	0.058 $\pm$ 0.002	0.068 $\pm$ 0.003
ai-17	0.262 $\pm$ 0.025	0.131 $\pm$ 0.007	0.085 $\pm$ 0.017	0.225 $\pm$ 0.027	0.096 $\pm$ 0.003	0.059 $\pm$ 0.003	0.296 $\pm$ 0.043
<b>17:1b</b>	0.278 $\pm$ 0.022	0.242 $\pm$ 0.007	0.579 $\pm$ 0.009	0.524 $\pm$ 0.031	0.190 $\pm$ 0.012	0.121 $\pm$ 0.005	0.100 $\pm$ 0.006
<b>16:2n4</b>	0.302 $\pm$ 0.008	0.455 $\pm$ 0.009	0.000 $\pm$ 0.000	0.195 $\pm$ 0.017	0.573 $\pm$ 0.014	0.568 $\pm$ 0.010	0.311 $\pm$ 0.015
17:0	0.235 $\pm$ 0.015	0.088 $\pm$ 0.005	0.072 $\pm$ 0.002	0.186 $\pm$ 0.012	0.099 $\pm$ 0.004	0.058 $\pm$ 0.002	0.257 $\pm$ 0.012
<b>16:3n4</b>	0.096 $\pm$ 0.005	0.097 $\pm$ 0.003	0.187 $\pm$ 0.005	0.082 $\pm$ 0.007	0.353 $\pm$ 0.010	0.222 $\pm$ 0.009	0.083 $\pm$ 0.006

<b>Fatty Acid</b>	<b>Bearded Seal</b> (n = 33)	<b>Beluga</b> (n = 56)	<b>Bowhead</b> (n = 51)	<b>Harbour Seal</b> (n = 23)	<b>Harp Seal</b> (n = 84)	<b>Ringed Seal</b> (n = 142)	<b>Walrus</b> (n = 37)
17:1	0.482 ± 0.025	0.214 ± 0.007	0.032 ± 0.005	0.519 ± 0.025	0.154 ± 0.005	0.210 ± 0.007	0.330 ± 0.017
<b>16:4n3</b>	0.042 ± 0.003	0.142 ± 0.018	0.106 ± 0.003	0.162 ± 0.010	0.071 ± 0.004	0.060 ± 0.003	0.024 ± 0.001
<b>16:4n1</b>	0.119 ± 0.007	0.094 ± 0.004	0.321 ± 0.012	0.068 ± 0.008	0.625 ± 0.027	0.357 ± 0.025	0.188 ± 0.016
18:0	1.558 ± 0.096	1.015 ± 0.055	1.078 ± 0.036	1.182 ± 0.056	1.094 ± 0.033	0.643 ± 0.019	2.044 ± 0.113
18:1n13	0.272 ± 0.032	0.053 ± 0.001	0.035 ± 0.002	0.135 ± 0.017	0.071 ± 0.003	0.053 ± 0.003	0.302 ± 0.036
18:1n11	0.904 ± 0.160	3.821 ± 0.092	4.345 ± 0.120	0.498 ± 0.082	2.533 ± 0.087	3.121 ± 0.152	0.170 ± 0.053
18:1n9	16.734 ± 0.365	16.122 ± 0.217	10.476 ± 0.219	18.354 ± 0.331	10.106 ± 0.244	15.703 ± 0.235	15.771 ± 0.575
18:1n7	8.806 ± 0.227	4.098 ± 0.062	3.198 ± 0.072	5.109 ± 0.148	3.187 ± 0.087	4.872 ± 0.074	10.276 ± 0.296
18:1n5	0.615 ± 0.015	0.521 ± 0.009	0.605 ± 0.010	0.629 ± 0.020	0.545 ± 0.010	0.589 ± 0.011	0.424 ± 0.012
18:2d5,11	0.052 ± 0.005	0.037 ± 0.001	0.000 ± 0.000	0.097 ± 0.007	0.046 ± 0.001	0.066 ± 0.001	0.040 ± 0.005
18:2n7	0.074 ± 0.004	0.049 ± 0.002	0.000 ± 0.000	0.096 ± 0.008	0.036 ± 0.001	0.082 ± 0.003	0.126 ± 0.010
<b>18:2n6</b>	1.879 ± 0.081	1.553 ± 0.039	0.862 ± 0.023	2.094 ± 0.110	1.145 ± 0.033	1.349 ± 0.049	0.949 ± 0.056
18:2n4	0.191 ± 0.005	0.099 ± 0.002	0.119 ± 0.004	0.097 ± 0.004	0.113 ± 0.003	0.133 ± 0.002	0.332 ± 0.013
<b>18:3n6</b>	0.159 ± 0.007	0.083 ± 0.002	0.136 ± 0.003	0.162 ± 0.011	0.123 ± 0.003	0.169 ± 0.005	0.110 ± 0.006
<b>18:3n4</b>	0.164 ± 0.005	0.106 ± 0.003	0.162 ± 0.008	0.098 ± 0.004	0.108 ± 0.003	0.115 ± 0.002	0.311 ± 0.012
<b>18:3n3</b>	0.402 ± 0.022	0.223 ± 0.006	0.316 ± 0.008	0.969 ± 0.062	0.398 ± 0.017	0.442 ± 0.010	0.272 ± 0.016
<b>18:3n1</b>	0.116 ± 0.007	0.066 ± 0.004	0.028 ± 0.001	0.170 ± 0.009	0.057 ± 0.002	0.058 ± 0.002	0.059 ± 0.003
<b>18:4n3</b>	0.611 ± 0.033	0.376 ± 0.016	0.761 ± 0.025	1.708 ± 0.120	1.382 ± 0.065	1.134 ± 0.043	0.732 ± 0.043
<b>18:4n1</b>	0.139 ± 0.006	0.119 ± 0.005	0.431 ± 0.019	0.045 ± 0.004	0.210 ± 0.008	0.158 ± 0.004	0.306 ± 0.014
20:0	0.055 ± 0.004	0.040 ± 0.003	0.109 ± 0.002	0.043 ± 0.005	0.089 ± 0.002	0.036 ± 0.003	0.081 ± 0.011
20:1n11	0.925 ± 0.074	2.363 ± 0.052	3.580 ± 0.098	0.414 ± 0.031	1.612 ± 0.057	1.264 ± 0.063	1.107 ± 0.059
<b>20:1n9</b>	2.808 ± 0.289	8.869 ± 0.295	16.093 ± 0.325	2.016 ± 0.184	13.625 ± 0.358	5.912 ± 0.279	1.914 ± 0.108
<b>20:1n7</b>	1.259 ± 0.065	0.659 ± 0.024	1.932 ± 0.037	0.472 ± 0.021	0.906 ± 0.033	0.508 ± 0.016	4.039 ± 0.263
20:2n9	0.095 ± 0.009	0.051 ± 0.006	0.119 ± 0.002	0.011 ± 0.003	0.078 ± 0.005	0.022 ± 0.001	0.310 ± 0.029
<b>20:2n6</b>	0.439 ± 0.017	0.198 ± 0.006	0.162 ± 0.004	0.376 ± 0.011	0.194 ± 0.003	0.232 ± 0.004	0.752 ± 0.026
<b>20:3n6</b>	0.117 ± 0.004	0.068 ± 0.003	0.121 ± 0.002	0.085 ± 0.009	0.065 ± 0.002	0.085 ± 0.002	0.240 ± 0.009
<b>20:4n6</b>	1.149 ± 0.045	0.248 ± 0.009	0.285 ± 0.006	0.842 ± 0.065	0.255 ± 0.007	0.384 ± 0.013	0.668 ± 0.041
<b>20:3n3</b>	0.076 ± 0.004	0.031 ± 0.002	0.038 ± 0.002	0.134 ± 0.009	0.048 ± 0.002	0.056 ± 0.001	0.095 ± 0.009
<b>20:4n3</b>	0.504 ± 0.020	0.368 ± 0.013	0.422 ± 0.018	0.781 ± 0.054	0.464 ± 0.013	0.376 ± 0.006	0.761 ± 0.026

<b>Fatty Acid</b>	<b>Bearded Seal</b> (n = 33)	<b>Beluga</b> (n = 56)	<b>Bowhead</b> (n = 51)	<b>Harbour Seal</b> (n = 23)	<b>Harp Seal</b> (n = 84)	<b>Ringed Seal</b> (n = 142)	<b>Walrus</b> (n = 37)
<b>20:5n3</b>	8.671 ± 0.286	3.598 ± 0.140	5.734 ± 0.197	6.537 ± 0.346	6.849 ± 0.186	9.098 ± 0.175	6.701 ± 0.357
22:0	0.001 ± 0.001	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.003 ± 0.000	0.009 ± 0.002
<b>22:1n11</b>	0.395 ± 0.054	3.978 ± 0.230	9.213 ± 0.370	0.256 ± 0.067	8.373 ± 0.306	1.158 ± 0.118	0.080 ± 0.014
22:1n9	0.215 ± 0.016	0.783 ± 0.047	2.024 ± 0.076	0.173 ± 0.018	1.363 ± 0.055	0.388 ± 0.026	0.142 ± 0.012
<b>22:1n7</b>	0.075 ± 0.009	0.123 ± 0.007	0.368 ± 0.015	0.044 ± 0.007	0.207 ± 0.010	0.063 ± 0.004	0.105 ± 0.010
22:2n6	0.012 ± 0.004	0.000 ± 0.000	0.020 ± 0.001	0.004 ± 0.002	0.013 ± 0.002	0.024 ± 0.003	0.007 ± 0.002
<b>21:5n3</b>	0.383 ± 0.011	0.150 ± 0.008	0.040 ± 0.002	0.312 ± 0.012	0.392 ± 0.007	0.414 ± 0.008	0.702 ± 0.031
<b>22:4n6</b>	0.292 ± 0.023	0.094 ± 0.034	0.015 ± 0.001	0.250 ± 0.027	0.055 ± 0.003	0.083 ± 0.003	0.533 ± 0.092
<b>22:5n6</b>	0.218 ± 0.013	0.068 ± 0.010	0.025 ± 0.002	0.234 ± 0.012	0.077 ± 0.002	0.088 ± 0.003	0.137 ± 0.016
<b>22:4n3</b>	0.066 ± 0.003	0.040 ± 0.002	0.056 ± 0.001	0.131 ± 0.011	0.089 ± 0.003	0.075 ± 0.004	0.100 ± 0.008
<b>22:5n3</b>	4.464 ± 0.137	2.034 ± 0.104	1.942 ± 0.071	4.701 ± 0.170	4.174 ± 0.087	5.533 ± 0.093	6.844 ± 0.279
<b>22:6n3</b>	8.845 ± 0.384	4.496 ± 0.218	3.136 ± 0.098	13.134 ± 0.459	8.059 ± 0.183	9.271 ± 0.169	4.982 ± 0.241
24:1n9	0.065 ± 0.007	0.146 ± 0.009	0.107 ± 0.004	0.082 ± 0.012	0.240 ± 0.010	0.165 ± 0.015	0.049 ± 0.008

**Table 2.5** – Mean prey proportions estimated by QFASA for each age and sex class across Foxe Basin and Davis Strait. Proportions are presented as mean %  $\pm$  1 SEM.

Prey type	Foxe Basin				Davis Strait			
	Male		Female		Male		Female	
	<i>Adult</i>	<i>Subadult</i>	<i>Adult</i>	<i>Subadult</i>	<i>Adult</i>	<i>Subadult</i>	<i>Adult</i>	<i>Subadult</i>
Bearded Seal	22.73 $\pm$ 1.12	14.59 $\pm$ 1.14	16.49 $\pm$ 1.56	16.96 $\pm$ 1.49	11.95 $\pm$ 0.88	10.49 $\pm$ 2.06	7.82 $\pm$ 1.00	8.43 $\pm$ 1.45
Beluga	5.19 $\pm$ 0.62	5.31 $\pm$ 1.10	3.73 $\pm$ 0.89	5.19 $\pm$ 1.00	1.01 $\pm$ 0.34	0.74 $\pm$ 0.58	0.59 $\pm$ 0.57	2.21 $\pm$ 1.39
Bowhead	0.61 $\pm$ 0.12	0.29 $\pm$ 0.12	0.42 $\pm$ 0.16	0.58 $\pm$ 0.26	0.50 $\pm$ 0.26	0.89 $\pm$ 0.89	0.07 $\pm$ 0.07	0.30 $\pm$ 0.30
Harbour Seal	3.75 $\pm$ 0.37	3.71 $\pm$ 0.58	4.19 $\pm$ 0.76	4.91 $\pm$ 0.69	4.40 $\pm$ 0.53	1.25 $\pm$ 0.51	0.65 $\pm$ 0.26	1.94 $\pm$ 0.73
Harp Seal	17.80 $\pm$ 0.87	19.70 $\pm$ 1.39	16.93 $\pm$ 1.74	13.64 $\pm$ 1.13	52.41 $\pm$ 1.24	51.38 $\pm$ 2.88	42.74 $\pm$ 2.32	49.00 $\pm$ 3.44
Ringed Seal	30.31 $\pm$ 1.53	42.99 $\pm$ 2.12	49.84 $\pm$ 2.67	52.65 $\pm$ 2.29	17.47 $\pm$ 1.53	28.75 $\pm$ 4.24	39.86 $\pm$ 3.26	28.80 $\pm$ 4.29
Walrus	19.61 $\pm$ 1.20	13.41 $\pm$ 1.25	8.40 $\pm$ 1.08	6.07 $\pm$ 0.95	12.26 $\pm$ 0.80	6.49 $\pm$ 1.17	8.27 $\pm$ 0.96	9.33 $\pm$ 1.23

**Table 2.6** – A summary of significant fixed effects from GLMM models evaluating the influence of intrinsic and extrinsic variables on the proportion of each prey type in the diet within Foxe Basin and Davis Strait. Prey types not included resulted in no significant fixed effects. All estimates are relative to the intercept baseline of adult females.

Subpopulation	Model	Response	Fixed Effect	Model Output				
				$\beta$	SE	z-value	p-value	
Foxe Basin	Diet	Bearded Seal	Adult Male	0.419	0.115	3.638	<0.001	
			Subadult:Male	-0.595	0.168	-3.539	<0.001	
			Year	0.057	0.007	8.145	<0.001	
			Beluga	Year	-0.037	0.007	-5.314	<0.001
			Harbour Seal	Year	-0.023	0.007	-3.488	<0.001
		Harp Seal	Adult Male	0.254	0.114	2.231	0.026	
			Break-up Date	-0.028	0.008	-3.452	<0.001	
Year	0.055		0.007	7.543	<0.001			
Ringed Seal	Adult Male	-0.833	0.131	-6.339	<0.001			
	Subadult:Male	0.481	0.192	2.507	0.012			
	Year	-0.051	0.009	-5.975	<0.001			
	Walrus	Adult Male	0.596	0.114	5.249	<0.001		
Davis Strait	Diet	Bearded Seal	Adult Male	0.31	0.155	1.999	0.046	
			Subadult:Male	-0.865	0.291	-2.9666	0.003	
			Length of Ice-free Period	0.008	0.004	2.059	0.039	
			Maximum Extent	-0.151	0.056	-2.701	0.007	
			Year	-0.041	0.018	-2.316	0.021	
		Harbour Seal	Adult Male	0.328	0.144	2.276	0.023	
			Maximum Extent	0.108	0.051	2.116	0.034	
			Year	-0.036	0.016	-2.19	0.029	
			Harp Seal	Adult Male	0.251	0.128	1.96	0.05
		Ringed Seal	Adult Male	-0.718	0.173	-4.146	<0.001	
			Break-up Date	-0.017	0.007	-2.462	0.014	
		Walrus	Adult Male	0.491	0.149	3.305	<0.001	
Subadult:Male	-1.21		0.283	-4.275	<0.001			
Length of Ice-free Period	0.008		0.004	2.087	0.037			
Maximum Extent	-0.154		0.053	-2.921	0.003			
	Year	-0.036	0.016	-2.21	0.027			

**Table 2.7**– Summary of GLMM results for individual dietary specialization (*PSi*) in Foxe Basin and Davis Strait. Significant fixed effects are found bolded. Estimates are interpreted relative to the intercept baseline of adult females.

Subpopulation	Response	Effects	Estimate	SE	z-value	p-value
Foxe Basin	<i>PSi</i>	<b>Fixed</b>				
		<b>Intercept</b>	<b>2.463</b>	<b>0.866</b>	<b>2.844</b>	<b>0.005</b>
		Subadult Female	0.023	0.7	0.336	0.737
		<b>Adult Male</b>	<b>-0.134</b>	<b>0.06</b>	<b>-2.242</b>	<b>0.025</b>
		Subadult Male	0.135	0.087	1.551	0.121
		<b>Break-up Date</b>	<b>-0.011</b>	<b>0.005</b>	<b>-2.407</b>	<b>0.016</b>
		Length of Ice Free period	-0.002	0.002	-1.203	0.229
		<b>Random</b>				
		<i>Effect</i>	<i>Variance</i>		<i>SD</i>	
		Season	0.002		0.042	
Year	0.009		0.097			
Davis Strait	<i>PSi</i>	<b>Fixed</b>				
		Intercept	0.911	0.825	1.105	0.269
		Subadult Female	0.056	0.121	0.464	0.642
		Adult Male	0.053	0.083	0.635	0.525
		Subadult Male	-0.173	0.154	-1.128	0.259
		Break-up Date	-0.004	0.004	-1.202	0.229
		Maximum Extent	-0.008	0.038	-0.217	0.828
		Length of Ice Free period	0.004	0.002	1.641	0.101
		<b>Random</b>				
		<i>Effect</i>	<i>Variance</i>		<i>SD</i>	
Season	0.003		0.045			
Year	< 0.001		< 0.001			

**Table 2.8** – Summary of GLMM results evaluating the effect of intrinsic and extrinsic factors on adipose tissue lipid content in Foxe Basin and Davis Strait. Significant p-values are found bolded, while marginal trends are denoted by an asterisk. Estimates are relative to the adult female intercept.

Subpopulation	Response	Effects	Estimate	SE	z-value	p-value
Foxe Basin	Lipid percentage	<b>Fixed</b>				
		Intercept	0.241	1.109	0.217	0.828
		Subadult Female*	-0.763	0.402	-1.899	0.058*
		Adult Male	-0.387	0.354	-1.094	0.274
		Subadult:Male	0.391	0.475	0.822	0.411
		<i>PSi</i>	-0.067	0.504	-0.134	0.894
		Subadult Female: <i>PSi</i> *	1.169	0.657	1.780	0.075*
		Adult Male: <i>PSi</i>	0.303	0.575	0.526	0.599
		Subadult:Male: <i>PSi</i>	-0.543	0.783	-0.694	0.488
		Break-up Date	0.006	0.006	1.115	0.265
		Length of Ice Free period	0.003	0.002	1.379	0.168
		<b>Random</b>				
		<i>Effect</i>	<i>Variance</i>		<i>SD</i>	
		Season	0.013		0.114	
Year	0.007		0.086			
Davis Strait	Lipid percentage	<b>Fixed</b>				
		Intercept	-1.385	1.125	-1.231	0.218
		Subadult Female	-1.414	0.919	-1.539	0.124
		Adult Male*	-1.119	0.614	-1.822	0.068*
		<b>Subadult:Male</b>	<b>2.536</b>	<b>1.227</b>	<b>2.067</b>	<b>0.039</b>
		<i>PSi</i>	-0.148	0.682	-0.217	0.828
		Subadult Female: <i>PSi</i>	2.117	1.277	1.657	0.097
		Adult Male: <i>PSi</i>	1.433	0.868	1.652	0.099
		<b>Subadult:Male:<i>PSi</i></b>	<b>-3.540</b>	<b>1.760</b>	<b>-2.011</b>	<b>0.044</b>
		<b>Break-up Date</b>	<b>0.012</b>	<b>0.005</b>	<b>2.457</b>	<b>0.014</b>
		<b>Length of Ice Free period</b>	<b>0.007</b>	<b>0.004</b>	<b>2.009</b>	<b>0.045</b>
		Maximum Extent	0.018	0.046	0.387	0.699
		<b>Random</b>				
		<i>Effect</i>	<i>Variance</i>		<i>SD</i>	
Season	0.021		0.145			
Year	< 0.001		< 0.001			

**Table 2.9** - Summary of CLMM results evaluating the effect of intrinsic and extrinsic factors on fatness index scores in Foxe Basin. Estimates are relative to the adult female intercept.

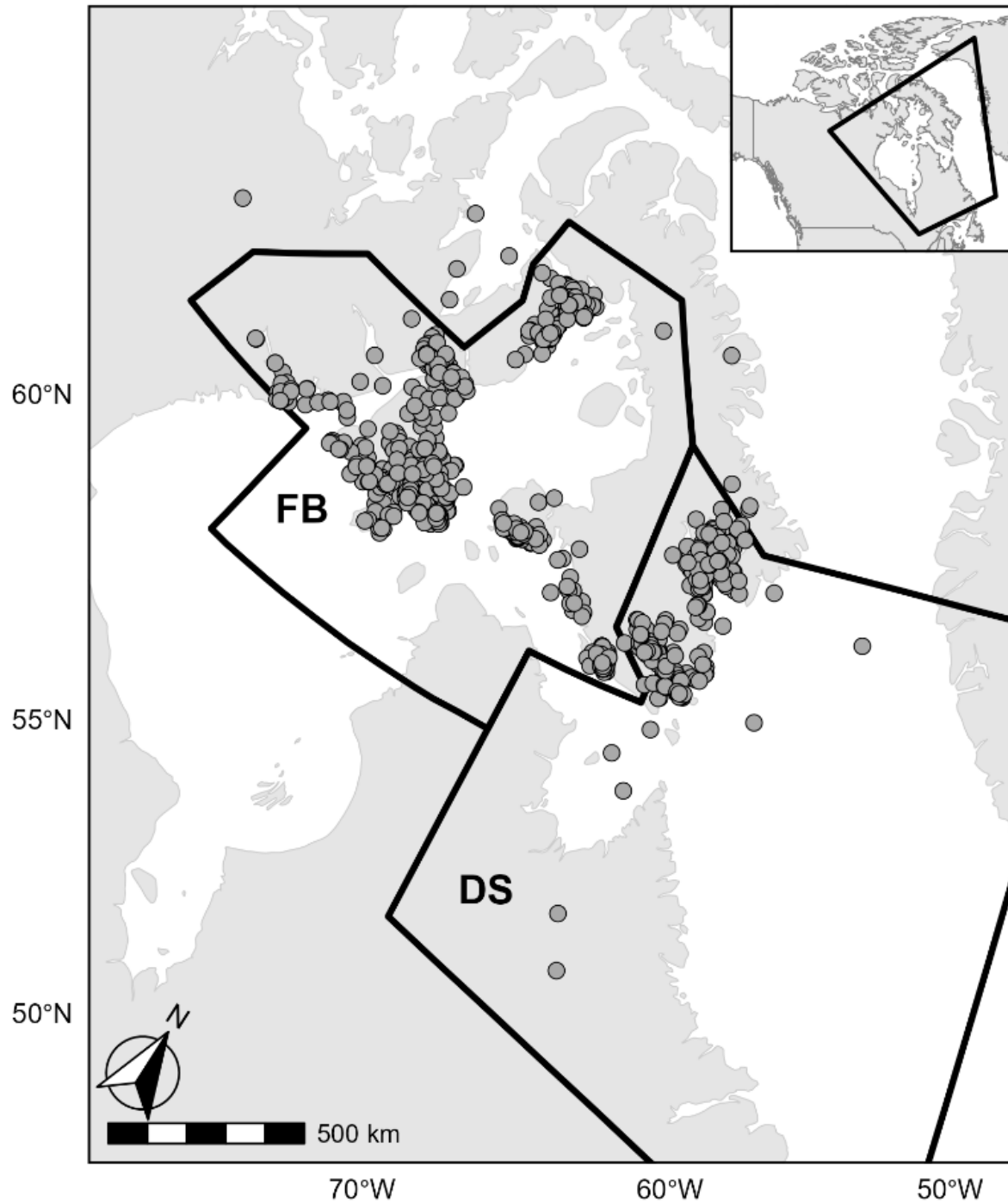
Subpopulation	Response	Effects	Estimate	SE	z-value	p-value
Foxe Basin	Fatness Index Score	<b>Fixed</b>				
		Subadult	-0.151	0.261	-0.578	0.563
		Adult Male	0.390	0.229	1.704	0.088
		Subadult:Male	-0.467	0.328	-1.422	0.155
		<i>PSi</i>	-0.067	0.212	-0.314	0.754
		Subadult Female: <i>PSi</i>	0.019	0.277	0.070	0.944
		Adult Male: <i>PSi</i>	-0.057	0.244	-0.235	0.815
		Subadult:Male: <i>PSi</i>	0.032	0.343	0.092	0.926
		Break-up Date	-0.019	0.100	-0.193	0.847
		Length of Ice Free period	0.063	0.106	0.591	0.554
		<b>Random</b>				
		<i>Effect</i>	<i>Variance</i>		<i>SD</i>	
		Season	0.409		0.639	
		Year	0.045		0.213	
		<b>Threshold coefficients</b>				
		<i>Boundary</i>	<i>Estimate</i>	<i>STE</i>	<i>z-value</i>	
		1 2	-3.392	0.428	-7.390	
		2 3	-1.650	0.367	-4.499	
		3 4	0.640	0.362	1.770	
		4 5	2.723	0.382	7.129	

**Table 2.10** – A summary the CLMM results evaluating the effect of intrinsic and extrinsic factors on fatness index scores in Davis Strait. Significant p-values are found bolded, while marginal trends are denoted by an asterisk. Estimates are relative to the baseline adult female intercept.

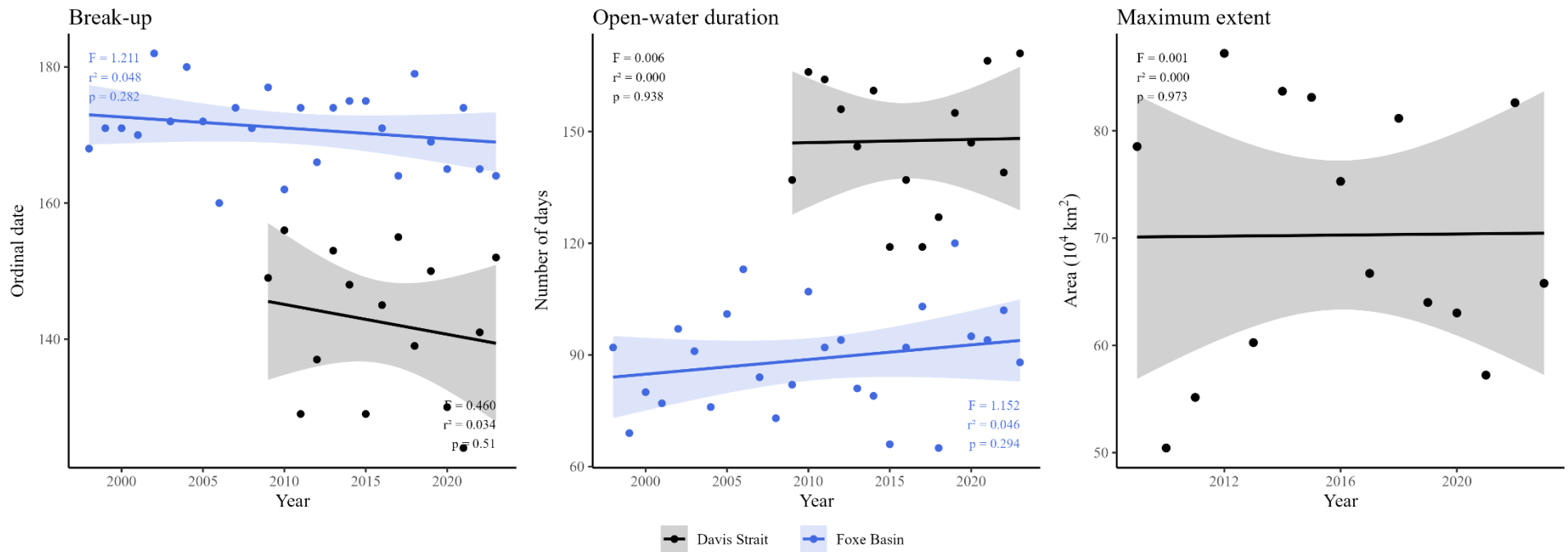
Subpopulation	Response	Effects	Estimate	SE	z-value	p-value
Davis Strait	Fatness Index Score	<b>Fixed</b>				
		Subadult Female*	0.924	0.476	1.943	0.052*
		<b>Adult Male</b>	<b>0.791</b>	<b>0.318</b>	<b>2.492</b>	<b>0.013</b>
		Subadult:Male*	-1.169	0.601	-1.945	0.052*
		<i>PSi</i>	-0.119	0.235	-0.506	0.613
		Subadult Female: <i>PSi</i>	0.027	0.429	0.063	0.950
		Adult Male: <i>PSi</i>	-0.057	0.297	-0.191	0.848
		Subadult:Male: <i>PSi</i>	-0.123	0.621	-0.198	0.843
		Break-up Date	-0.161	0.143	-1.125	0.260
		Maximum Extent	-0.132	0.145	-0.914	0.361
		Length of Ice Free period	-0.025	0.158	-0.157	0.875
		<b>Random</b>				
		<i>Effect</i>	<i>Variance</i>		<i>SD</i>	
		Season	0.274		0.524	
		Year	0.084		0.291	
		<b>Threshold coefficients</b>				
		<i>Boundary</i>	<i>Estimate</i>	<i>STE</i>	<i>z-value</i>	
		1 2	-4.666	0.803	-5.813	
		2 3	-2.222	0.438	-5.070	
		3 4	0.807	0.403	2.000	
4 5	3.440	0.480	7.173			

**Table 2.11** – A summary of GLMM (for Lipid Percentage) and CLMM (for Fatness Index Scores) outputs assessing the effect of individual prey types on body condition estimates within Foxe Basin and Davis Strait. Each prey type was modeled separately as the fixed effect. Significant p-values are found bolded.

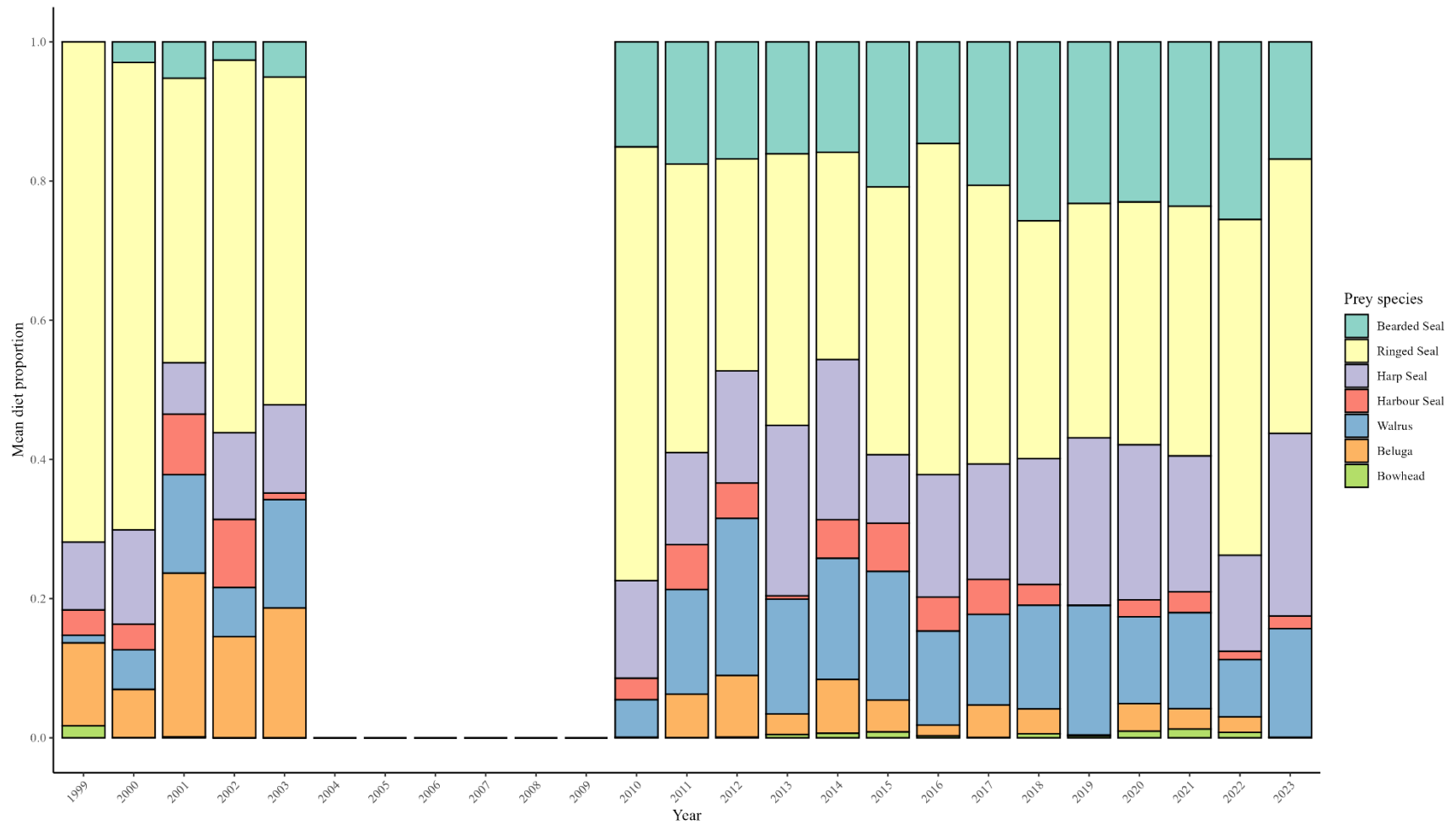
Subpopulation	Response Variable	Fixed Effect	Model Output			
			Estimate	STE	z value	p-value
Foxe Basin	Lipid Percentage	<b>Bearded Seal</b>	<b>-0.386</b>	<b>0.125</b>	<b>-3.102</b>	<b>0.002</b>
		<b>Beluga</b>	<b>-0.438</b>	<b>0.216</b>	<b>-2.025</b>	<b>0.043</b>
		Bowhead	-1.308	0.922	-1.419	0.156
		Harbour Seal	0.295	0.391	0.755	0.450
		Harp Seal	-0.052	0.150	-0.350	0.726
		<b>Ringed Seal</b>	<b>0.462</b>	<b>0.087</b>	<b>5.336</b>	<b>&lt;0.001</b>
		<b>Walrus</b>	<b>-0.454</b>	<b>0.125</b>	<b>-3.616</b>	<b>&lt;0.001</b>
	Fatness Index Score	<b>Bearded Seal</b>	<b>-8.908</b>	<b>0.402</b>	<b>-2.216</b>	<b>0.027</b>
		Beluga	-0.477	0.687	-0.964	0.487
		Bowhead	-4.358	3.504	-1.244	0.214
		Harbour Seal	0.273	1.033	0.264	0.792
		Harp Seal	-0.530	0.481	-1.102	0.270
		<b>Ringed Seal</b>	<b>0.519</b>	<b>0.256</b>	<b>2.031</b>	<b>0.042</b>
		Walrus	0.173	0.414	0.417	0.677
Davis Strait	Lipid Percentage	<b>Bearded Seal</b>	<b>-1.483</b>	<b>0.399</b>	<b>-3.715</b>	<b>&lt;0.001</b>
		Beluga	-1.508	0.925	-1.631	0.103
		Bowhead	-0.350	1.051	-0.333	0.739
		Harbour Seal	0.057	1.056	0.054	0.957
		Harp Seal	0.050	0.268	0.188	0.851
		<b>Ringed Seal</b>	<b>0.401</b>	<b>0.195</b>	<b>2.057</b>	<b>0.040</b>
		Walrus	-0.408	0.488	-0.837	0.403
	Fatness Index Score	Bearded Seal	-0.219	1.023	-0.214	0.830
		Beluga	-2.314	2.368	-0.977	0.328
		Bowhead	2.395	2.842	0.843	0.399
		Harbour Seal	0.304	2.426	0.125	0.900
		Harp Seal	0.854	0.653	1.309	0.191
		Ringed Seal	-0.287	0.471	-0.610	0.542
		Walrus	-0.661	1.280	-0.516	0.606



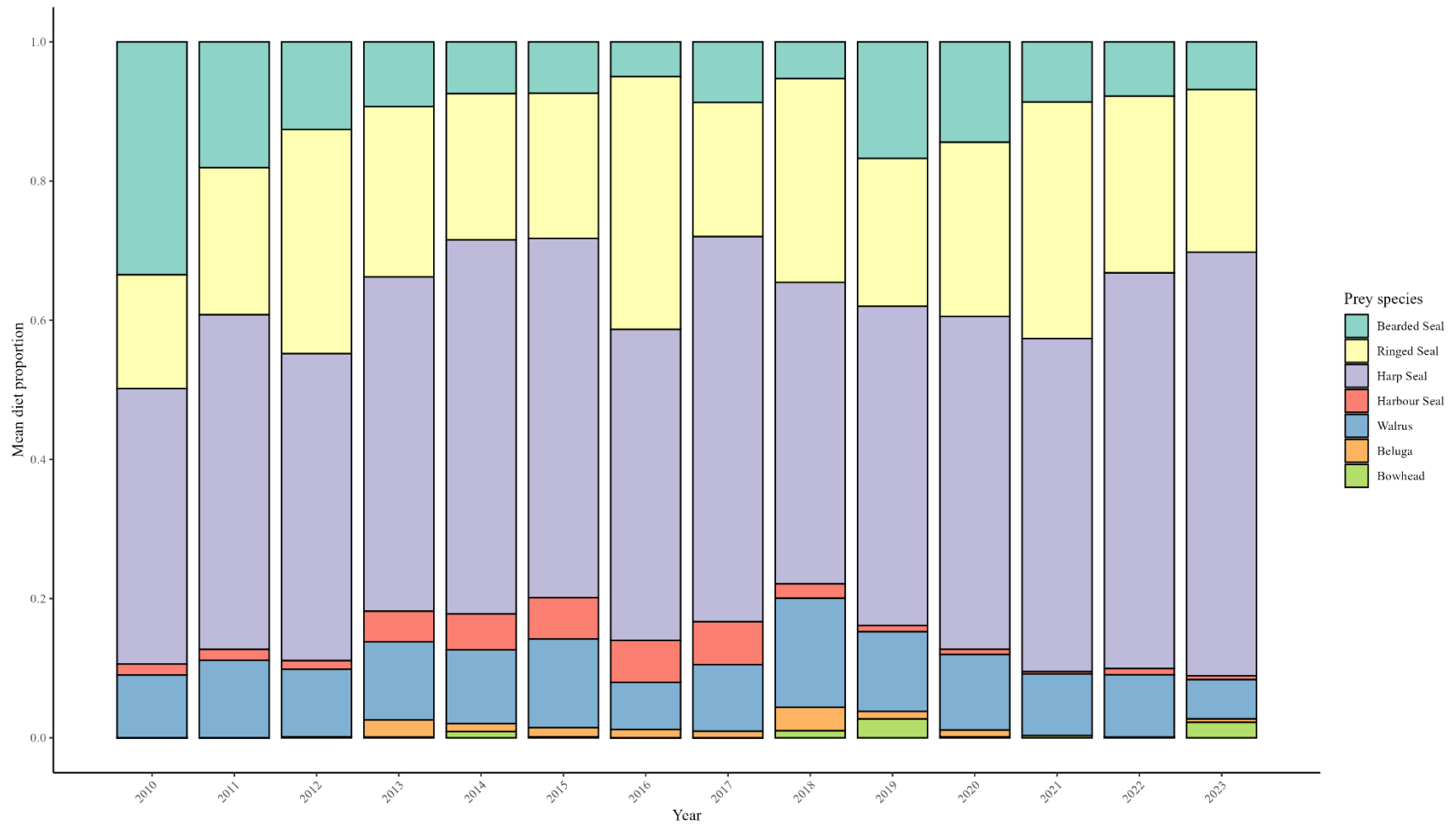
**Figure 2.1** – Location of polar bears ( $n = 1076$ ) harvested in Foxe Basin (FB) and Davis Strait (DS) by Inuit hunters and trappers from 1999-2003 (FB) and 2010-2018 (FB and DS). Bears missing latitude and/or longitude data ( $n = 89$ ) were not included.



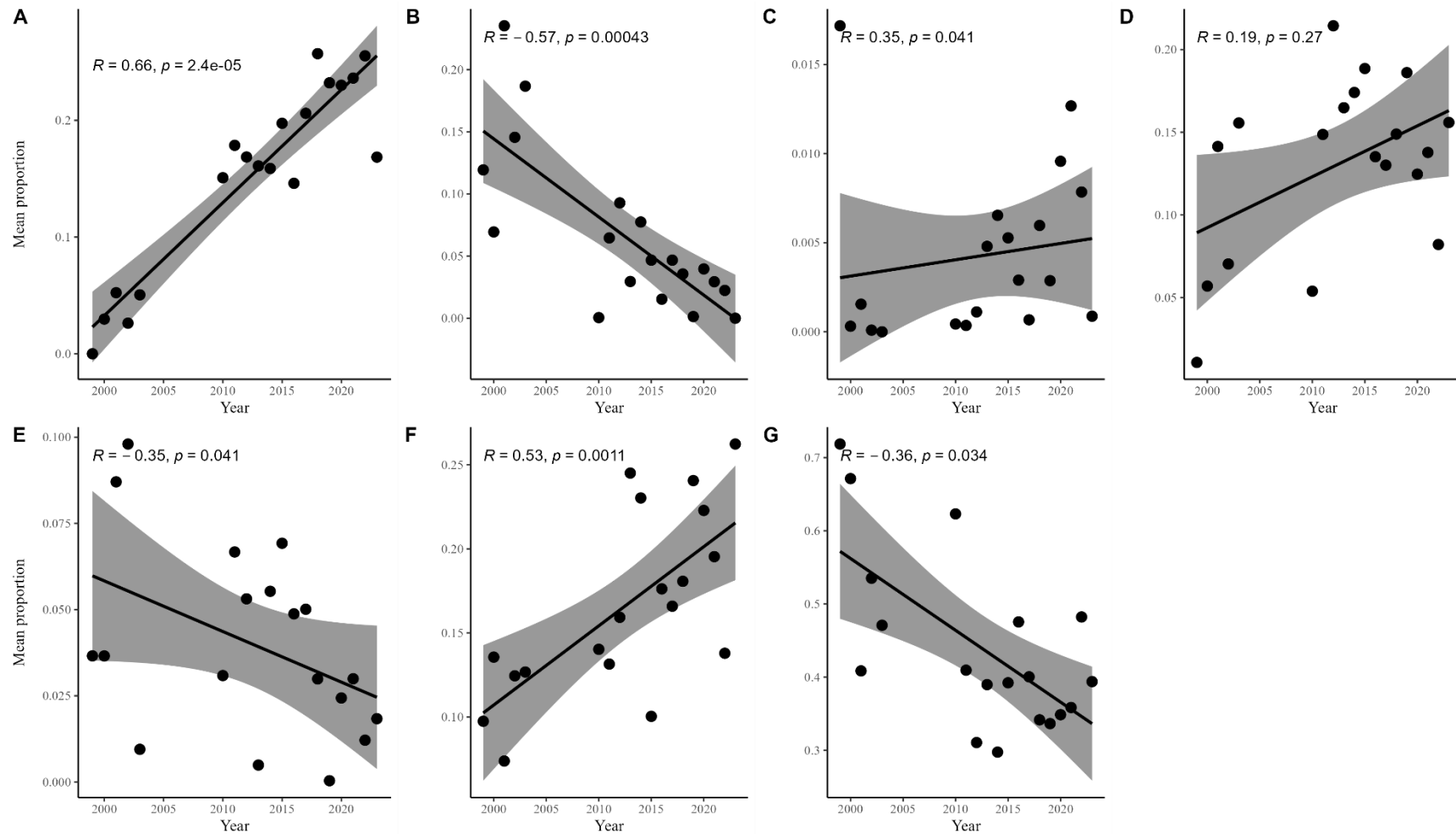
**Figure 2.2** – Temporal trends in sea-ice metrics for Davis Strait (Black) and Foxt Basin (Blue) subpopulations. Panels show sea ice break-up ordinal date, open water duration (in days) and maximum extent for Davis Strait ( $\times 10^4 \text{ km}^2$ ). Sea ice metrics for Foxt Basin were taken annually from 1998 to 2023, while Davis Strait were taken from 2009 to 2023. Results from the linear regressions (F-statistic,  $R^2$  and p-value) are reported in each panel.



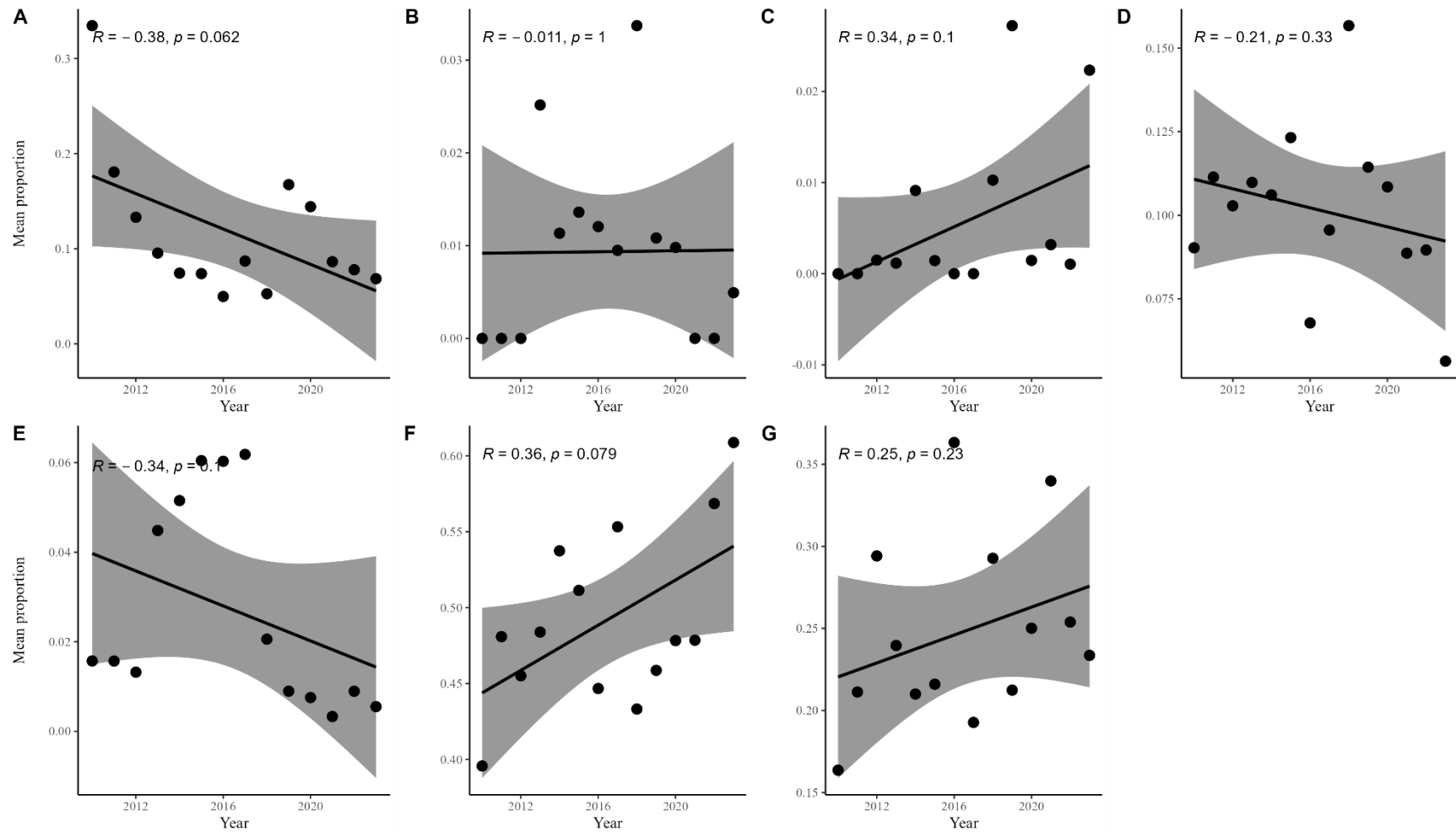
**Figure 2.3** – Mean annual diet composition of the Foxt Basin polar bear subpopulation from 1999–2003 and 2010–2023 (n = 818). Stacked bars show the proportional contribution of bearded seal, ringed seal, harp seal, harbour seal, walrus, beluga, and bowhead whale to the QFASA estimated mean population diet for each year. No sampling was conducted between 2003 and 2010.



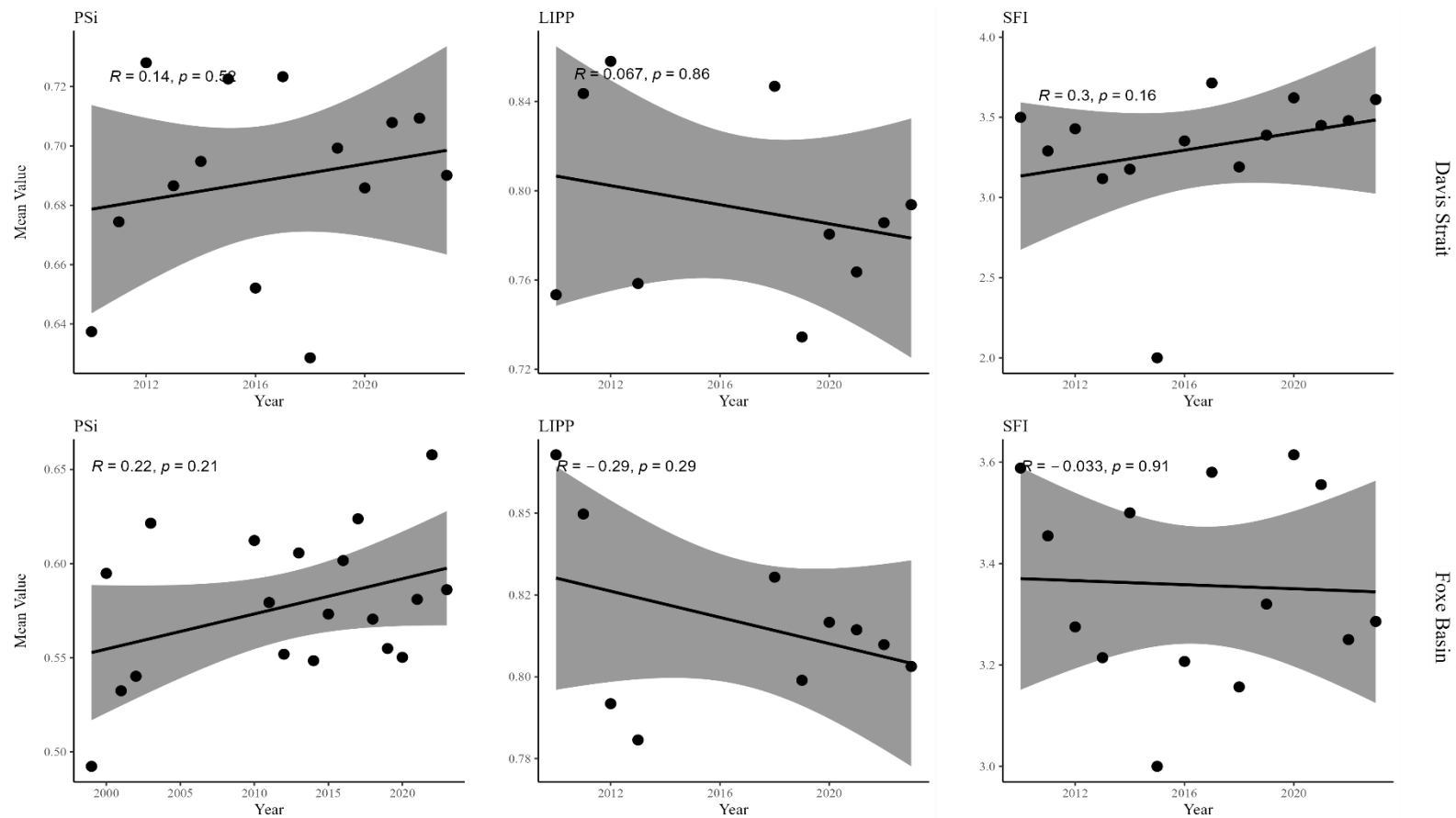
**Figure 2.4** - Mean annual diet composition of the Davis Strait polar bear subpopulation from 2010–2023 (n = 347). Stacked bars show the proportional contribution of bearded seal, ringed seal, harp seal, harbour seal, walrus, beluga, and bowhead whale to the QFASA estimated mean population diet for each year.



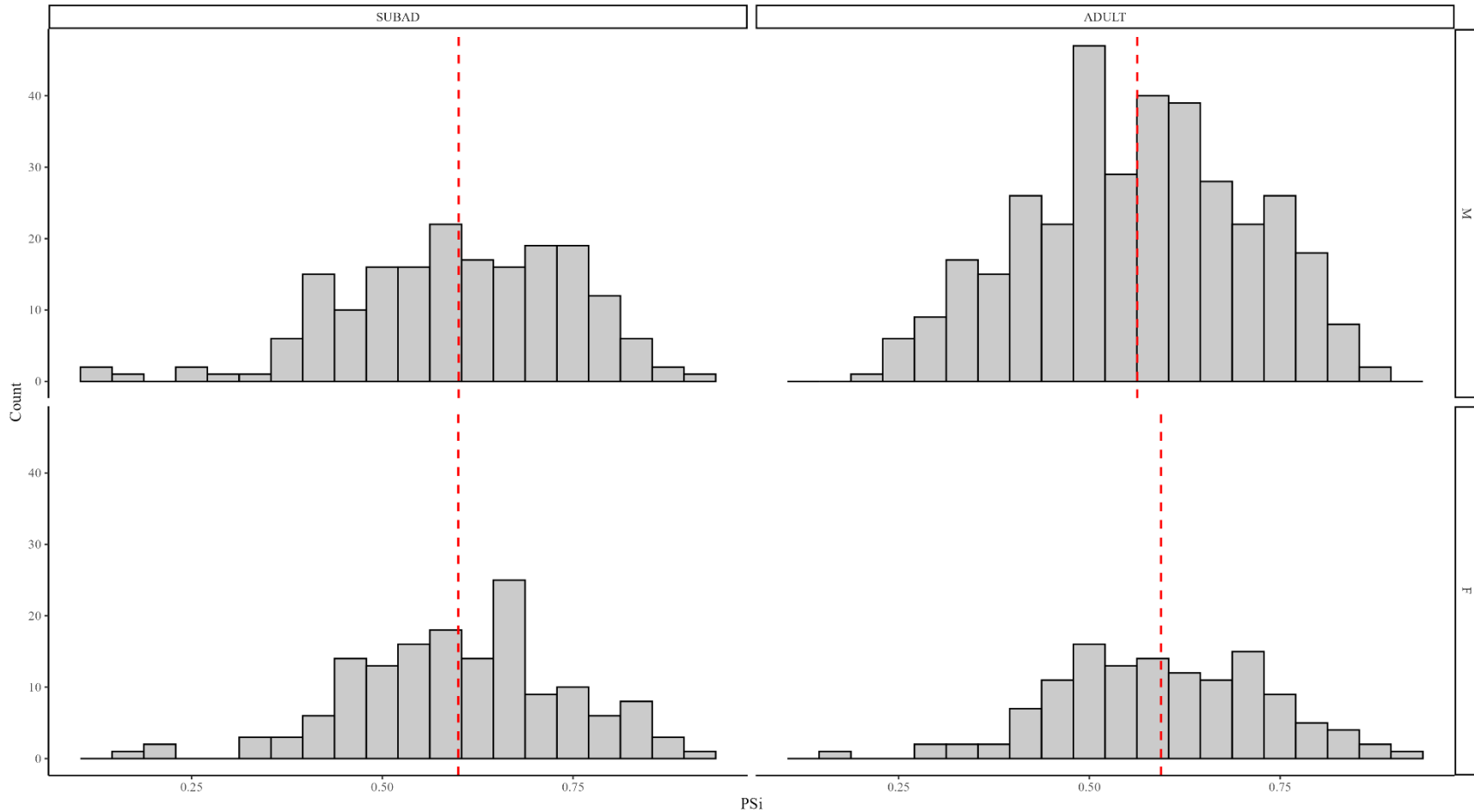
**Figure 2.5** - Temporal trends in mean annual estimated diet proportion of prey species in the Foxe Basin polar bear subpopulation from 1999–2003 and 2010–2023. A fitted regression line, and associated 95% confidence interval are included, along with the Kendall's rank correlation coefficient ( $R$ ) and associated p-value. Panels correspond to (A) bearded seal, (B) beluga, (C) bowhead whale, (D) walrus, (E) harbour seal, (F) harp seal, and (G) ringed seal.



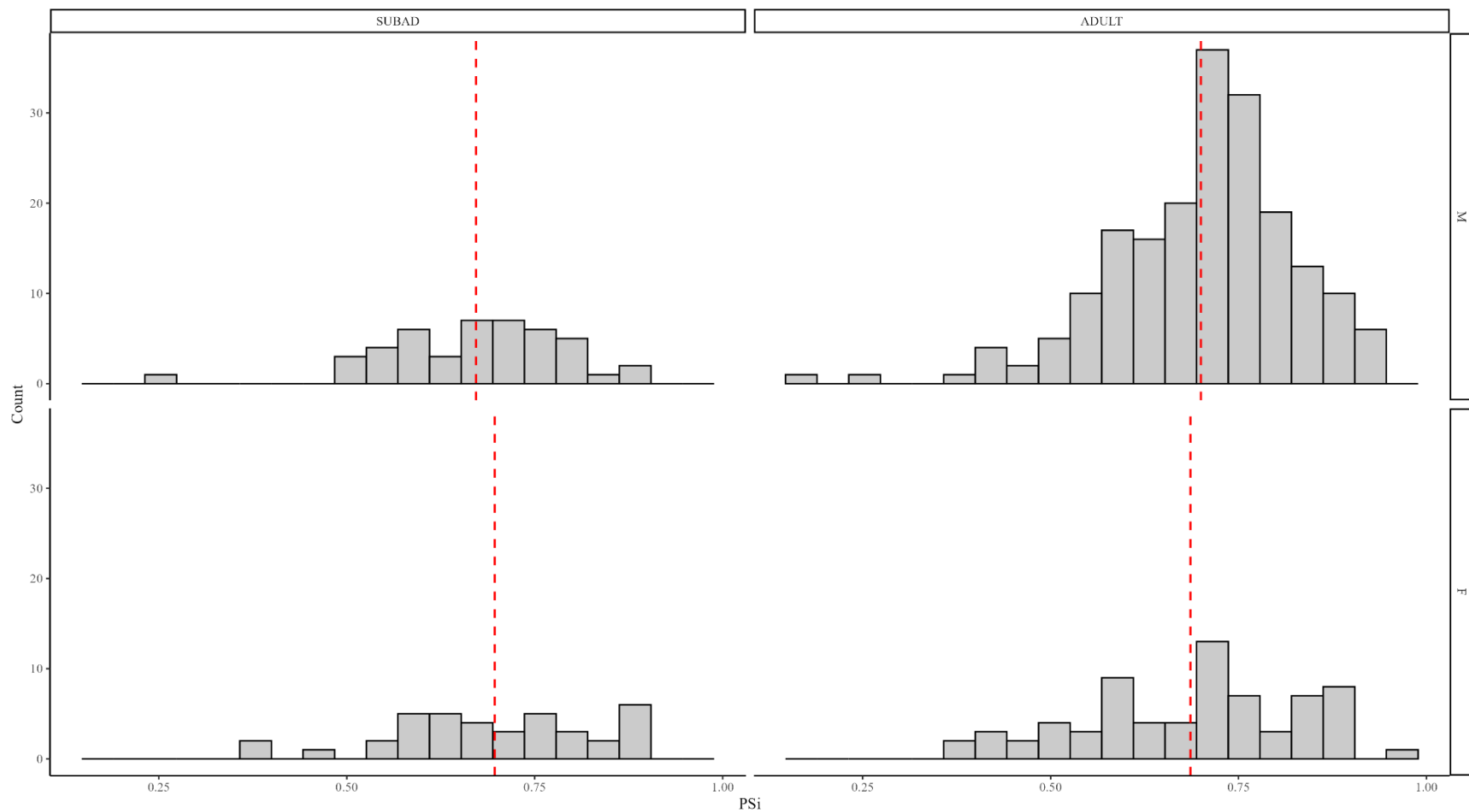
**Figure 2.6** - Temporal trends in mean annual estimated diet proportion of prey species in the Davis Strait polar bear subpopulation between 2010–2023. A fitted regression line, and the associated 95% confidence interval are included, along with the Kendall's rank correlation coefficient ( $R$ ) and associated  $p$ -value. Panels correspond to (A) bearded seal, (B) beluga, (C) bowhead whale, (D) walrus, (E) harbour seal, (F) harp seal, and (G) ringed seal.



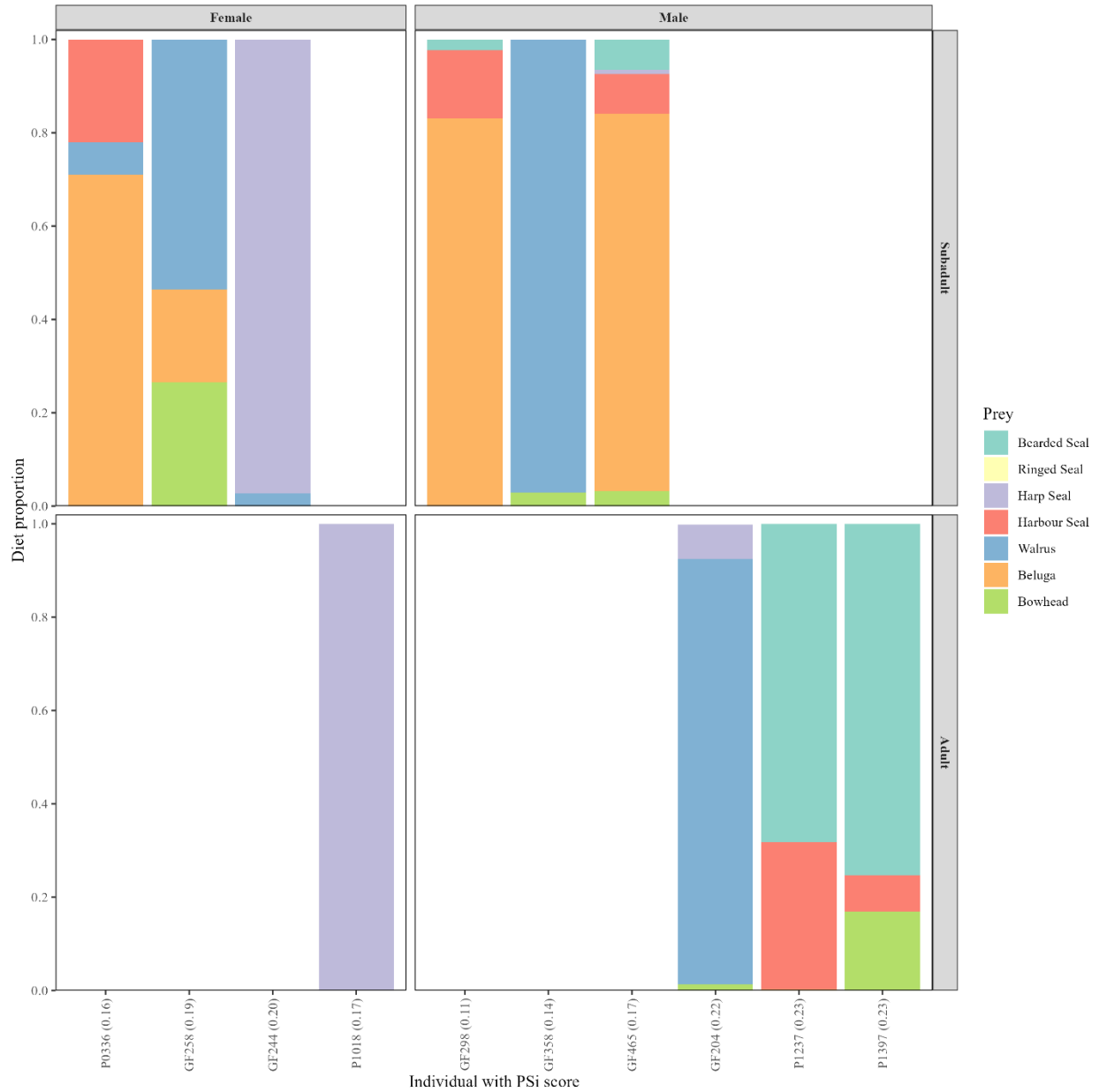
**Figure 2.7** – Temporal trends in mean annual individual-level foraging and body condition metrics in Davis Strait (2010 – 2023; Top) and Foxe Basin (1999-2023; Bottom). Panels show annual mean values individual specialization measured as proportional similarity ( $PSi$ ) and body condition measured as adipose tissue lipid content (LIPP) and subjective fatness index (SFI) scores. Points represent the annual mean value, with the solid line representing a fitted regression line and the associated 95% confidence intervals in grey. Kendall’s rank correlation coefficients ( $R$ ) and associated  $p$ -values are found within each panel. Across all metrics, there were no significant differences across years. Body condition estimates for Foxe Basin were not available prior to 2010.



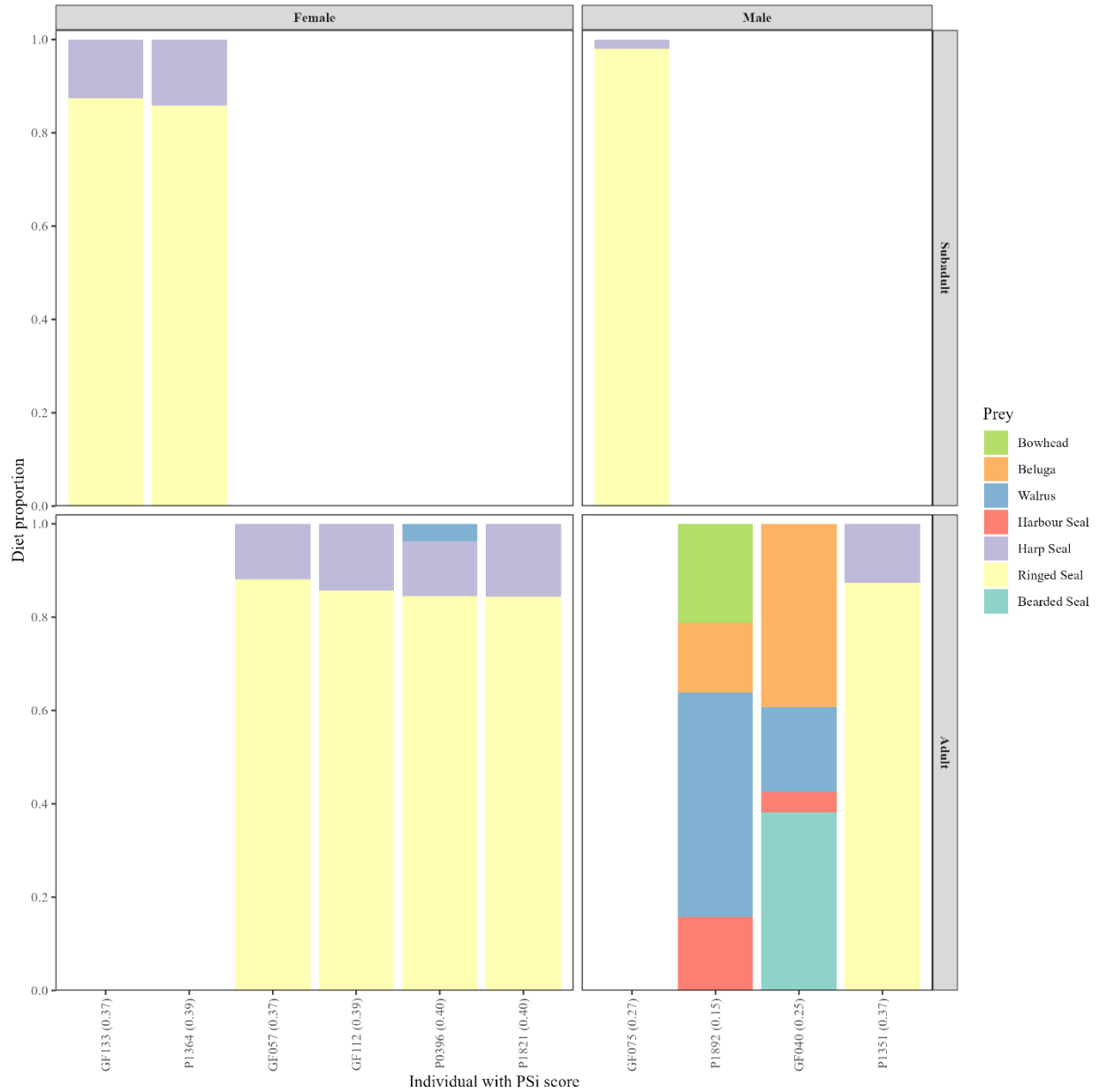
**Figure 2.8** – Histogram illustrating the distribution of proportional similarity index ( $PS_i$ ) scores and the extent of dietary specialization ( $PS_i < 0.50$ ) and dietary generalization ( $PS_i \geq 0.50$ ) within the Foxe Basin polar bear subpopulation. Data are separated by age class with subadults in the left panels and adults in the right panels, and sex, with females in the top panels, and males in the bottom panels. The vertical red dashed line represents the mean  $PS_i$  for each age–sex group.



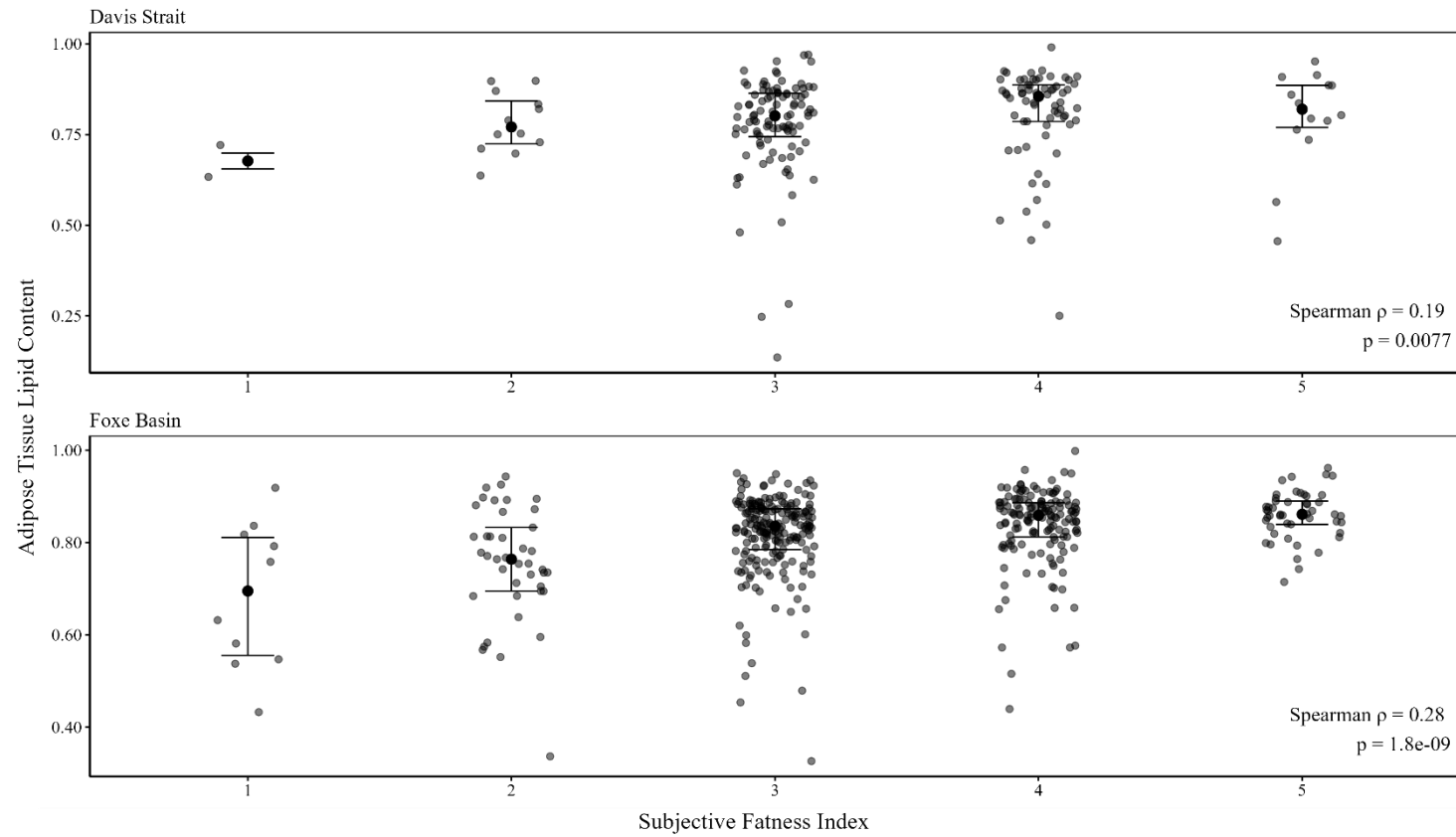
**Figure 2.9** – Histogram detailing the distribution of proportional similarity index ( $PS_i$ ) scores within Davis Strait and the extent of dietary specialization ( $PS_i < 0.50$ ) and dietary generalization ( $PS_i \geq 0.50$ ). Data are separated by age class with subadults in the left panels and adults in the right panels, and sex, with females in the top panels, and males in the bottom panels. The vertical red dashed line represents the mean  $PS_i$  for each age–sex group.



**Figure 2.10** - Comparison of individual diet composition for the top 10 individuals with the greatest specialist foraging behaviours within Foxe Basin. Individuals are labelled with their lab ID and their respective *PSi* score in parentheses. The frames are organized by sex and age class, with 3 subadult females, 3 subadult males, 1 adult female and 3 adult males. The most specialized individual (GF298; *PSi* = 0.11) was a subadult male consuming primarily beluga whale.



**Figure 2.11** – A comparison of individual diet composition for the top 10 specialist individuals within Davis Strait. The frames are organized by sex and age class, with 1 subadult male, 2 subadult females, 3 adult males and 4 subadult females. The most specialized individual (P1892;  $PSi = 0.15$ ) was an adult male consuming primarily walrus and bowhead. Cases of increased specialization were most commonly associated with high levels of ringed seal in diet.



**Figure 2.12** – Results of a Spearman’s rank correlation test on the relationship between subjective fatness index scores and adipose tissue lipid content in Foxe Basin and Davis Strait. Individual points represent lipid content for individual bears, while the black points represent the median values for each subjective fatness index category. Davis Strait exhibited a weak but statistically significant ( $\rho = 0.19$ ,  $p = 0.0077$ ) positive association, whereas in Foxe Basin the positive association was stronger and highly significant ( $\rho = 0.28$ ,  $p = 1.8 \times 10^{-9}$ ).

## Chapter III – General Conclusions

### Summary

It is well known that the primary prey for most polar bear subpopulations is ringed seal, yet at the individual level, there are visible differences in foraging strategies. Some individuals may exhibit generalist foraging strategies, consuming prey typical for the population, whereas others may display unique foraging strategies, specialized on atypical prey types (Thiemann et al. 2011). These behaviors arise as the result of a multitude of factors including, the level of intraspecific competition within a population (Bolnick et al. 2003; Parent et al. 2014), the abundance and distribution of prey (Galicía et al. 2021b), and sexual- and/or age-based size dimorphisms (find the cite for this), all of which may be influenced by changes in environmental conditions. This thesis investigated the drivers and consequences of individual specialization over time in response to climate change in Foxe Basin and Davis Strait. It aimed to address the following hypotheses: (1) That male bears will show the highest degree of individual dietary specialization due to sexual size dimorphism which allows for the exploitation of prey unavailable to smaller sexes and age classes; (2) earlier sea-ice break up, longer ice-free periods and, in Davis Strait, reduced maximum extent, will be associated with less specialization as bears are forced to move to land earlier, reducing access to preferred prey and limiting selective feeding; (3) Greater individual dietary specialization is predicted to have a negative impact on body condition in adult female polar bears as morphometric limitations reduce the success of capturing alternate prey species, thus reducing the accumulation of adipose tissue and therefore lowering lipid content.

Diet composition was estimated for each individual as a combined proportion of 7 prey types, and final estimates were used to calculate the proportional similarity index (*PSi*) for each individual. *PSi* was used to quantify individual specialization and was compared across intrinsic and extrinsic factors. Intrinsic drivers consisted of age (i.e. adult and subadult) and sex classes (i.e. male or female), while extrinsic drivers included the timing of sea-ice break-up, the length of the ice-free period and, in Davis Strait, the maximum extent. Adipose tissue lipid content and fatness index scores were used as proxies for body condition and fitness, and their relationship with *PSi* was evaluated alongside the listed intrinsic and extrinsic factors. The results of this thesis added to the growing body of literature on the effect of climate warming on Arctic marine mammal foraging behaviour, while highlighting the effect of individual specialization on body condition and fitness within two adjacent subpopulations - Foxe Basin and Davis Strait. Understanding the drivers and consequences of dietary specialization on body condition and fitness in this Arctic top predator is necessary for understanding the extent to which climate warming has affected ecosystem structure and functioning, while providing important insights into the health and stability of a vulnerable species.

Previous studies utilizing quantitative fatty acid signature analysis (QFASA) to estimate polar bear diet showed a preference for ringed seal (*Pusa hispida*) as primary prey within Foxe Basin (Thiemann et al. 2008; Galicia et al. 2021a), while harp seal (*Pagophilus groenlandicus*) was the prey of choice within Davis Strait (Galicia et al. 2021b). My results indicate similar trends, with ringed seal and harp seal as the primary prey in Foxe Basin and Davis Strait, respectively. Bearded seal (*Erignathus barbatus*), ringed seal (in Davis Strait) and harp seal (in Foxe Basin) were secondary prey types within the study areas, with walrus (*Odobenus rosmarus*), bowhead (*Balaena mysticetus*), harbour seal (*Phoca vitulina*) and beluga

(*Delphinapterus leucas*) all contributing minimally. Beluga in diet within Foxe Basin showed a significant reduction in the proportion after 2003, replaced by bearded as the secondary prey type, consistent with previous work (Galicia et al. 2021a). Although it has been suggested that with expected increases in length to the open-water period, there may be a preference for open-water species such as the harbour seal (Stirling & Derocher 1993), my results indicate a continued shift away from harbour seal in diet, highlighting the complex effects environmental conditions have on predator-prey dynamics. Further, in years with reduced proportions of primary prey in diet, there was a noticeable increase in secondary prey proportions, suggesting some degree of dietary flexibility when preferred prey is unavailable.

Polar bears exhibit extreme age- and sexual-size dimorphisms, with younger males growing more rapidly, while adult males reach masses up to twice those of their female counterparts (Ralls & Mesnick 2009; Derocher et al. 2005). This intrinsic factor has had an important effect on foraging behaviour, as male bears can successfully feed on larger prey species, while younger/smaller individuals are often restricted to smaller, more accessible prey (Thiemann et al. 2008). This was reflected in the results from Foxe Basin, where adult male bears consumed greater quantities of bearded seal and walrus, and females consumed greater quantities of ringed seal. Additionally, age-based size dimorphisms were reflected in Foxe Basin as younger male bears exhibited increased proportions of ringed seal in diet compared to their adult conspecifics. Temporally and spatially variable prey within Foxe Basin (see Galicia et al. 2021b), along with age and sexual size dimorphisms, have driven increased specialization amongst adult male bears, as seen in this research. Interestingly, Davis Strait did not exhibit the same expected trends, as there were no age or sex specific differences in harp seal proportions, suggesting harp seal populations may be relatively stable and maintained abundance has resulted

in reduced intraspecific competition, allowing for the continued selection as the primary prey choice by both sexes and age classes, thus reducing the need for increased specialization.

As morphometric limitations in adult female polar bears may reduce the success of capturing alternate prey species, it was expected that increased specialization would result in decreased adipose tissue lipid content, lower fatness index scores and therefore worse body condition. However, contrary to this hypothesis, the degree of dietary specialization an individual exhibited did not influence overall body condition in either subpopulation. Instead, lower adipose tissue lipid content and fatness index scores were associated with increased amounts of bearded seal, beluga (Foxye Basin) and walrus (Foxye Basin), while increased amounts of ringed seal had the opposite effect. My results instead suggest that the overall degree of specialization does not have the biggest influence on polar bear body condition, but that specific prey choice may be a larger factor.

Over recent history, we have seen drastic changes in the Arctic ecosystem. Warming at rates unseen anywhere else in the world (Rantanen et al. 2020), there have been unprecedented changes to sea-ice dynamics, including reduced extent (Hwang et al. 2020; Maslanik et al. 2007), earlier sea-ice breakup, and increased length of the open water period (McGeachy et al. 2024). For an ice-dependent species such as the polar bear, these changes have been associated with reduced access to primary prey (ringed seals; Stirling & Derocher 1993; Derocher et al. 2004), negative effects on cub production and survival (Stirling & Derocher 2012) and reduced availability of optimal foraging habitat. It was thought that worsening sea-ice conditions would be associated with decreased specialization as bears have reduced access to preferred prey and therefore are limited in selectively feeding. However, only Foxye Basin displayed a relationship between changing sea-ice conditions, specifically later break-up, and individual specialization,

exhibiting the opposite of what was expected. Extrinsic influences were more significantly associated with prey selection and body condition in polar bears from Davis Strait. This highlights the complex interactions among changing environmental conditions, foraging behaviour, and body condition in two distinct, highly variable subpopulations.

Together, these findings underscore that the consequences of climate warming are neither uniform nor easily predicted, but instead arise from the complex relationships between environmental conditions, sexual- and age-specific size dimorphisms, and prey availability and abundance. While dietary specialization was expected to decline under deteriorating sea-ice conditions, this thesis shows that specialization persists and in some cases increases in ways that differ markedly between Foxe Basin and Davis Strait. Not to mention, body condition was influenced more by the specific prey consumed than by the degree of specialization itself, emphasizing that not all foraging strategies provide equal energetic consequences. Ultimately, these results highlight the importance of individual variation in polar bear foraging ecology and must be considered when assessing the environmental effects on top predator foraging behaviour in a rapidly changing Arctic. By assessing changes in diet composition and individual specialisation along with the intrinsic and extrinsic drivers across two ecologically distinct subpopulations, this research provides important insight into how a vulnerable apex predator responds to altered ecosystem dynamics and adds to the growing body of literature on predicting future challenges to polar bear health, fitness, and conservation.

### **Conservation Implications**

Polar bears are ice-reliant animals, utilizing sea-ice platforms as a place to travel, hunt and mate (Stirling & Derocher 1993; Stirling et al. 1999; Amstrup 2003). However, changes to sea-ice conditions under a warming climate also affect their most important prey species – the

ringed seal. Longer ice-free seasons have reduced spatial overlap with ringed seals (Derocher et al. 2004; Hamilton et al. 2017), while also reducing prey quality and abundance through lower birth rates and decreased body condition (Ferguson et al. 2017), leading to predicted declines in mean abundance up to 99% by the end of the century (Reimer et al. 2019). Individuals who choose to forage on predominantly ringed seals may experience detrimental effects to body condition and fitness, as annual variations in sea-ice conditions decrease prey quality and reduce available foraging habitat. At the same time, individuals adopting more specialist foraging niches (i.e. less overlap with the population) and exhibiting flexible foraging strategies may be more resilient to these altered predator-prey dynamics (Thiemann et al. 2008; Galicia et al. 2021a).

Even though specialist foraging behaviour may help to reduce the impacts of climatically altered prey abundance and availability, not all individuals have the opportunity to adapt to these behaviours. Sexual- and age-specific size dimorphism significantly affects what prey an individual may consume. Older and bigger males are able to exhibit a wider dietary niche, exploiting larger prey types such as walrus and bearded seal (Thiemann et al. 2008), whereas younger individuals and smaller adult females are more restricted in their foraging behaviour, associated with lower dietary flexibility and a narrower dietary niche (Thiemann et al. 2011). As climate warming continues to reduce available foraging habitat, present size dimorphisms will compound with unfavourable sea-ice conditions to increase the level of intraspecific competition amongst subadults and smaller adult female bears, driving changes in individual dietary specialization. Individuals who are unable to exhibit flexible foraging behaviours may experience drastic changes to body condition and fitness, thus influencing the overall health and stability of the population.

This study helped to identify the influence of variable sea-ice conditions, age and sex on individual specialization and its influence on body condition and fitness within Foxe Basin and Davis Strait. The results aid in understanding the complex relationship between foraging behaviour and polar bear health, while providing insights into how changing environmental conditions have altered predator-prey dynamics. Determining the intrinsic and extrinsic factors associated with reduced body condition will help contribute to the continued management and conservation of polar bears within the Foxe Basin and Davis Strait subpopulations. It is important that these and other subpopulations undergo continuous monitoring, as climate change continues to affect populations at the individual level, and changes in overall population health and abundance may worsen over time.

### **Suggested Future Research**

My research was one of the first aimed at quantifying the drivers of individual specialization and their effect on body condition and fitness within polar bear subpopulations. Although I studied 2 of the 20 distinct polar bear subpopulations, changes in environmental conditions, predator-prey dynamics and ecosystem functioning vary greatly across spatial and temporal scales (Thiemann et al. 2008; Galicia et al. 2021a, 2021b). Research should continue to address and document the changes to individual specialization, and its relation to body condition across the remainder of the Arctic. Additionally, work across a broader temporal scale is necessary to build a solid foundation for modelling the effects of climate change on ecosystem health and functioning, as it is more difficult to detect statistically meaningful trends over shorter time periods.

This study was limited to only a few extrinsic factors associated with climate warming in the Arctic, and it is likely that other environmental factors, such as snow depth and ice thickness

may drive changes in predator-prey dynamics, thus influencing individual dietary specialization. Previous work with ringed seals has demonstrated the importance of deep snow and thick sea-ice for denning success and reduced predation (Furgal et al. 1996; Iacozza & Ferguson 2014). In areas with reduced snow depth, seal pups were often exposed to the elements sooner and at greater risk of predation than those born in areas with greater snow depth, thereby increasing mortality (Furgal et al. 1996; Iacozza & Ferguson 2014). As polar bear abundance has been previously linked to ringed seal abundance (Stirling & Øritsland 1995), increased mortality in areas with reduced snow depth may cause a shift away from ringed seal in diet, increasing individual specialization. However, there is also the chance that reduced snow depth may increase the proportion of ringed seals in diet, as pups, which have been found to constitute a large portion of kills during the spring (Stirling & Archibald 1977), become more easily accessible. For this reason, the inclusion of additional extrinsic factors may provide a clearer picture of the relationship between polar bears and their prey in climatically altered ecosystems.

Furthermore, this study analyzed samples taken from subsistence-harvested bears, limiting research to only independent individuals within two age classes. Prior to the 2019/2020 harvest season, there was a 2:1 male-to-female harvest ratio in Nunavut, which has since been changed to a 1:1 sex ratio (Obbard et al. 2025). This may have allowed for an over-representation of males within the population before this time period, and consequently, potentially influenced the results on body condition and dietary specialization within the study group. Further research should focus on maintaining even sex ratios during analysis to provide meaningful insights into any sex differences that may arise. Additionally, it has been illegal to harvest female bears with dependent cubs, which are typically weaned from their mothers at 2.5 years old. This has led to the inclusion of only independent bears over 2.5 years old (i.e., subadults) and independent

adults in the study, thereby misrepresenting the current population structure. Additionally, increased fat stores (and by proxy, body condition) are critically important for female bears undergoing denning and birthing. Increased fat stores prior to denning were associated with greater reproductive success, larger and healthier offspring, and a higher likelihood of surviving lactation during the denning period (Atkinson & Ramsay 1995; Robbins et al. 2012). As successful reproduction is crucial to the maintenance of healthy polar bear subpopulations, the use of samples from harvested bears excludes a subset of the population which would provide the greatest insights into the current and future state of these populations under extreme climate stress. While lone adult female bears may be pregnant when harvested, this is typically not recorded by the individual harvesting, and therefore cannot be accounted for during analysis. \

Therefore, any further research and sample collection should aim to include more information on reproductive status while including samples from female bears with dependent cubs, obtained through biopsies or alternative methods.

These results indicated substantial variation in prey selection at the individual level, highlighting the variability in polar bears' foraging behaviour. This study was limited to 7 previously documented polar bear prey types in Foxe Basin and Davis Strait, including bearded seal, beluga, bowhead, harp seal, harbour seal, ringed seal, and walrus (see Galicia et al. 2021a, 2021b; Thiemann et al. 2008). Limited by access to a significant number of prey samples and fatty acid information, the inclusion of previously known prey types, such as hooded seal and narwhal (see Thiemann et al. 2008), was not possible. Future research should aim to expand the existing prey library, as an abundant and diverse prey library encompassing both previously used and novel prey types is necessary to provide a more complete estimate of polar bears' dietary habits in the Arctic. One novel prey type may include Arctic Charr (*Salvelinus alpinus*), which

has been proposed as a potential terrestrial food source for polar bears during the ice-free period (Dyck & Romberg 2007; Dyck & Kebraab 2009); however, it has never been confirmed as a substantial energy source.

In summary, my work provided evidence for the intrinsic drivers of individual specialization and valuable insights into the role climate warming has played in shaping Arctic ecosystem structure and functioning. This study was one of the first to quantify the effect of individual specialization on polar bear body condition in two discrete, highly variable polar bear subpopulations – Foxe Basin and Davis Strait. These findings highlight the importance of understanding how flexibility in foraging behaviour, prey availability, and shifting sea-ice dynamics interact to influence individual foraging strategies and ultimately population health. As the Arctic ecosystem continues to undergo rapid environmental change, incorporating a broader suite of extrinsic factors, expanding prey libraries, and including currently underrepresented demographic groups, particularly reproductive females, will be essential for generating accurate models of population health and functioning. By addressing these remaining gaps, future research can better inform conservation and management strategies, helping to preserve vulnerable polar bear subpopulations in the face of unprecedented climatic stress.

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