IMPACTS DES CONDITIONS MÉTÉOROLOGIQUES SUR TROIS DÉTERMINANTS DE LA VALEUR ADAPTATIVE DE L'OURS NOIR AU QUÉBEC

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Composition du jury :

Dominique Berteaux, président du jury, Université du Québec à Rimouski

Martin-Hugues St-Laurent, directeur de recherche, Université du Québec à Rimouski

Christian Dussault, codirecteur de recherche, Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs

Fanie Pelletier, examinatrice externe, Université de Sherbrooke

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RÉSUMÉ

Les changements climatiques, tant passés, qu'actuels et futurs, ont le potentiel de modifier profondément les conditions environnementales rencontrées par la faune. Certains individus parviennent à s'y acclimater par des ajustements comportementaux, alors que d'autres se déplacent vers des régions où les conditions demeurent favorables, menant au déplacement de l'aire de répartition de l'espèce. Toutefois, les individus d'espèces plus tolérantes pourraient bénéficier des nouvelles conditions, notamment chez les espèces opportunistes comme l'ours noir (*Ursus americanus*). En raison de son régime alimentaire majoritairement herbivore, cette espèce pourrait tirer profit de conditions météorologiques favorisant une augmentation de la productivité végétale, lui offrant ainsi une plus grande disponibilité de nourriture pour constituer ses réserves de graisse avant la période de dormance hivernale. Afin de tester cette hypothèse, j'ai évalué les effets indirects des conditions météorologiques locales sur trois traits d'histoire de vie des ours noirs à partir d'une base de données rassemblant 1 824 individus provenant de huit sites d'études répartis le long d'un gradient allant des érablières aux pessières à mousses, et s'étendant sur une période de 41 ans (1983-2023). Mes résultats montrent que la masse corporelle ajustée pour l'âge, le segment de population et la date de capture, augmentait après une saison de croissance caractérisée par une forte productivité végétale, c.-à-d. un faible nombre d'heures de gel durant la floraison des plantes à fruits charnus et une grande disponibilité en eau durant l'été. La probabilité de primiparité augmentait quant à elle suivant une longue saison de croissance et un été caractérisé par une grande disponibilité en eau. Ces résultats suggèrent un effet indirect des conditions météorologiques favorables à une meilleure productivité végétale auxquelles les ours répondent par un investissement plus élevé en croissance pondérale et en reproduction. L'intervalle de temps entre les portées n'était quant à lui pas influencé par les conditions météorologiques locales, suggérant que les femelles échantillonnées n'ont pas été exposées à une très faible disponibilité de nourriture. Sur ces bases, mon étude montre que les variations météorologiques observées au cours des quatre dernières décennies auraient eu un effet indirect sur au moins deux traits d'histoire de vie de l'ours noir. Une analyse complémentaire a révélé que la masse corporelle ajustée des femelles accompagnées de jeune(s) d'un an et la probabilité de primiparité des femelles avaient augmenté au cours des 40 années couvertes par notre étude. Selon les tendances climatiques projetées, si ces dernières se traduisent par une diminution des gels printaniers tardifs, une augmentation des précipitations estivales et un allongement de la saison de croissance, cette espèce pourrait se révéler tolérante, voire favorisée, face aux changements climatiques à venir.

Mots clés : Changements climatiques; Condition corporelle; Conditions météorologiques; Étude à long-terme; Probabilité de primiparité; *Ursus americanus*.

ABSTRACT

Past, present and future climate change has the potential to deeply alter the environmental conditions faced by wildlife. While some individuals may adjust to these new conditions through behavioral responses, others could shift their range to regions where conditions remain favorable. Further, individuals from more tolerant species could even benefit from the new conditions, particularly for highly opportunistic species such as the American black bear (*Ursus americanus*). Due to their predominantly herbivorous diet, black bears could benefit from weather conditions that increase plant productivity, providing them with a greater food availability to build up fat reserves before the winter denning period. To test this hypothesis, I assessed the indirect effects of local weather conditions on three black bear life-history traits using a database of 1824 individuals from eight study sites distributed along a maple-black spruce forest gradient, covering a period of 41 years (1983–2023). My results show that the body mass, adjusted for age, demographic group, and date of capture, increased after a growing season characterized by high plant productivity, i.e., a low number of hours of frost during the flowering of fleshy fruit-bearing species and a high water availability during summer. The probability of primiparity increased following a long growing season and a summer characterized by high water availability. These results suggest an indirect effect of favorable weather conditions on plant productivity, to which bears respond with a higher investment in growth and reproduction. The interval between litters was not influenced by local weather conditions, suggesting that the females sampled were not exposed to very low food availability. On this basis, my study shows that weather variations observed over the last four decades may have indirectly affected at least two black bears life-history traits. Further investigations revealed that the adjusted body mass of females with yearling(s) and the females' probability of primiparity increased during the 40-year period covered by our dataset. If the projected climate trends result in a decrease in late spring frosts, an increase in summer precipitation, and a longer growing season, the black bear could prove to be tolerant, or even favored, in the face of future climate change.

Keywords: Body condition; Climate change; Long-term study; Probability of primiparity; *Ursus americanus*; Weather conditions.

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CONTEXTE DES CHANGEMENTS CLIMATIQUES

Depuis la fin du 18^{e} siècle, l'essor des activités impliquant la combustion d'énergies fossiles, la déforestation, ainsi que l'expansion de l'agriculture et de l'élevage intensif ont entraîné une hausse rapide des concentrations des gaz à effet de serre dans l'atmosphère, notamment le dioxyde de carbone (CO_2) et le méthane (CH_4; Crutzen 2006). Ces augmentations sont directement responsables de la modification du climat, défini comme la moyenne des conditions météorologiques sur une période de 30 ans ou plus (Intergovernmental Panel on Climate Change, IPCC 2023; World Meteorological Organization 2025). En conséquence, les températures globales ont augmenté en moyenne de 1,1°C (température de surface) pour la période 2011-2020 comparativement à la période 1850-1900 (IPCC 2023). Les régimes de précipitations ont également été profondément altérés, certaines régions observant une diminution marquée des quantités de pluie reçues, contrairement à d'autres où les précipitations ont plutôt augmenté (Ummenhofer & Meehl 2017; IPCC 2023). Ces transformations du climat ont également augmenté la fréquence des conditions météorologiques (p. ex. sécheresses et vagues de chaleur; voir IPCC 2023) favorables aux événements extrêmes, tels que les feux de forêt (Jones et al. 2022). Ces changements rapides imposent à la faune de nouvelles conditions environnementales souvent très différentes de celles ayant prévalu au cours de leur histoire évolutive.

RÉPONSES COMPORTEMENTALES DE LA FAUNE FACE AUX CHANGEMENTS CLIMATIQUES

Face aux perturbations environnementales, les organismes déploient une variété de réponses leur permettant de s'acclimater puis, ultimement, de s'adapter à ces nouvelles conditions (Johnson & St-Laurent 2011). L'ampleur et la nature de ces réponses sont

notamment déterminées par l'importance, la durée et l'étendue spatiale des perturbations. Elles sont d'abord exprimées à de fines échelles spatiales et sur de courtes périodes par des ajustements physiologiques et comportementaux. Cependant, plus les perturbations sont intenses et persistantes, et plus elles couvrent de vastes surfaces, plus les réponses de la faune se manifestent par une modification des taux vitaux et plus elles affectent durablement les populations. Des perturbations de plus grande amplitude spatiale ou temporelle peuvent affecter la dynamique des populations, en modifiant leur abondance et leur démographie (Johnson & St-Laurent 2011) ou en provoquant des extinctions locales (voir la méta-analyse de Wiens 2016).

Les ajustements comportementaux sont souvent les premières réponses exprimées, permettant aux individus de rapidement faire face aux changements (Johnson & St-Laurent 2011; Beever et al. 2017). Par exemple, lorsque les organismes sont exposés à des températures au-delà des seuils de préférence, ceux-ci peuvent répondre en adoptant des comportements favorisant la thermorégulation afin de maintenir une température corporelle relativement stable pour limiter les effets des variations environnementales (Hill et al. 2008; Terrien et al. 2011). La thermorégulation comportementale peut impliquer une modification de la sélection d'habitats, lorsque les individus se réfugient dans des endroits plus frais tels que sous une canopée dense ou dans un terrier (Terrien et al. 2011). Elle peut également s'exprimer par un changement dans le rythme d'activité journalier, lorsque les individus déplacent leur période d'activité aux heures les plus fraîches de la journée, tel qu'observé chez plusieurs espèces de lézards (Hill et al. 2008; López-Alcaide & Macip-Ríos 2011) et de mammifères (Aublet et al. 2009; Terrien et al. 2011; Borowick et al. 2020). Par exemple, chez l'éland (*Tragelaphus oryx*) des savanes africaines (Berry et al. 2023), les individus modifient leur rythme d'activité selon les périodes du jour lorsque les températures sont particulièrement élevées, réduisant l'activité diurne et augmentant l'activité nocturne. Cette réorganisation permet aux élands de maintenir un niveau d'activité suffisant pour la recherche de nourriture tout en minimisant les risques de stress thermique (Berry et al. 2023).

Lorsque les ajustements comportementaux ne permettent pas de réduire suffisamment les effets négatifs des changements climatiques, les individus peuvent quitter les régions où les conditions ne sont plus propices et s'établir dans les nouvelles régions où elles le sont devenues, modifiant ainsi l'aire de répartition des espèces (revue par Scheffers et al. 2016). En général, les individus des régions tropicales tendent à se déplacer vers le nord, dans les environnements précédemment dominés par des ceux des régions tempérées, adaptées à un climat plus froid (Vergés et al. 2014; Osland et al. 2021). Un phénomène similaire est observé dans les régions arctiques, alors que les individus des régions boréales se déplacent progressivement vers le nord, modifiant la composition des communautés locales avec une réduction de la présence d'espèces arctiques (Fossheim et al. 2015; Descamps & Strøm 2021). La méta-analyse de Chen et al. (2011) a révélé que l'aire de répartition de 1 367 espèces animales (arthropodes, mammifères, oiseaux, poissons, reptiles, amphibiens) s'était déplacée de 16,9 km en moyenne par décennie vers le nord au cours des dernières décennies. De même, en Finlande, Hällfors et al. (2024) ont observé un déplacement de la limite nord de l'aire de répartition de 87 espèces d'oiseaux, 57 espèces de papillons diurnes et 239 espèces de papillons nocturnes, avec des déplacements moyens respectifs de 33, 43 et de 24 km. Cependant, l'ampleur et la direction de ces déplacements varient considérablement entre les espèces et les individus. Ces différences peuvent s'expliquer par la mobilité des individus, leurs contraintes physiologiques ou encore leur tolérance aux conditions abiotiques locales (Chen et al. 2011; Wrensford et al. 2025). La capacité des populations à persister dans leur environnement dépend notamment de la taille de la niche climatique de l'espèce, définie comme l'ensemble des conditions climatiques sous lesquelles une espèce peut survivre et se reproduire en l'absence de facteurs limitants (Bates & Bertelsmeier 2021). Les espèces possédant une niche climatique étroite présentent souvent un déplacement plus marqué de leur aire de répartition que celles ayant une niche climatique plus large, ces dernières étant plus tolérantes aux variations climatiques et capables de se maintenir dans leur aire de répartition historique (Hällfors et al. 2024).

RÉPONSE DE LA FAUNE FACE AUX CHANGEMENTS CLIMATIQUES : CONDITION CORPORELLE, REPRODUCTION, SURVIE ET DYNAMIQUE DES POPULATIONS

Les modifications du comportement peuvent engendrer des coûts énergétiques supplémentaires, par exemple suite à une réponse physiologique ou à un changement dans la quantité ou la qualité des ressources alimentaires disponibles (Johnson & St-Laurent 2011). Conséquemment, ces ajustements peuvent, à leur tour, affecter la condition corporelle et le succès reproducteur des individus, par exemple le taux de conception ou encore l'âge à la première reproduction (aussi appelé âge à la primiparité), le succès reproducteur des femelles étant étroitement lié à leur condition corporelle en raison des coûts énergétiques élevés liés à la gestation et à la lactation, particulièrement chez les mammifères (Gittleman & Thompson 1988; Clutton-Brock et al. 1989). De tels mécanismes sont rapportés de plus en plus souvent dans le contexte des changements climatiques tel que le démontrent des études sur une variété de taxons (p. ex. oiseaux, reptiles, amphibiens, mammifères, arthropodes, poissons) et de niveaux d'organisation biologique (p. ex. génétique, physiologie, morphologie, phénologie, distribution des espèces, relations interspécifiques; revue par Scheffers et al. 2016).

À l'échelle individuelle, les changements climatiques sont fréquemment associés à une demande métabolique accrue ou à un stress thermique élevé, ce qui peut conduire à une dépense énergétique plus élevée et, ultimement, à une détérioration progressive de la condition corporelle des individus, tel qu'observé chez la pipistrelle de Kuhl (*Pipistrellus kuhlii* : Locatelli et al. 2019), la salamandre maculée (*Ambystoma maculatum* : Moldowan et al. 2022) et le chamois (*Rupicapra rupicapra* : Mason et al. 2014). Les effets des changements climatiques se répercutent également sur la survie des individus. Par exemple, dans le Haut-Arctique, l'avancement de la date de fonte des neiges observé au cours des dernières décennies est corrélé à une augmentation du taux de mortalité chez les bécasseaux maubèches juvéniles (*Calidris canutus canutus* : van Gils et al. 2016). Ce devancement entraîne une diminution de l'abondance et de la taille des arthropodes, principale nourriture des oisillons, conduisant à une réduction de la masse corporelle, de la taille corporelle et de la longueur du bec au moment de l'envol. La réduction de la longueur du bec entraîne des conséquences dans les aires d'hivernage, où les juvéniles à bec court ne peuvent se nourrir

des bivalves enfouis en profondeur dans le sable, et doivent se nourrir de proies ou d'herbes marines moins nutritives retrouvées près de la surface. Cette contrainte alimentaire se traduit par une mortalité plus élevée des jeunes bécasseaux à bec court entre leur premier et second hiver, contribuant possiblement au déclin de la population (van Gils et al. 2016). Des observations similaires ont été faites chez le lièvre d'Amérique (*Lepus americanus*), où le devancement de la fonte des neiges serait également associé à une mortalité accrue en raison d'une inadéquation temporelle entre la coloration blanchâtre du pelage et la disparition de la neige dans l'environnement, augmentant leur détectabilité par les prédateurs et accentuant le risque de mortalité (Zimova et al. 2016).

Dans certains cas, la dégradation de la condition corporelle due aux changements climatiques peut, à son tour, impacter d'autres traits d'histoire de vie, notamment la reproduction. Cette dynamique a, entre autres, été observée chez les lycaons (*Lycaon pictus*) où des températures ambiantes plus élevées étaient associées à une réduction du temps consacré à la recherche de nourriture, particulièrement durant la période d'élevage des chiots (Woodroffe et al. 2017). En conséquence d'un apport en nourriture moindre, une réduction de la survie des jeunes de moins d'un an et une diminution du taux de recrutement dans les populations de lycaons étaient observées. Des effets similaires ont été rapportés chez la mangouste rayée (*Mungos mungo*), où des températures élevées durant le mois précédent la naissance des nouveau-nés se traduisent par une réduction de la masse corporelle des jeunes (Khera et al. 2023). Cette diminution de la masse serait liée à une plus grande difficulté des femelles à dissiper la chaleur par temps chaud, les contraignant à limiter les processus exothermiques comme la lactation, ce qui réduit l'apport en ressources pour les petits. De même, chez le cratérope bicolore (*Turdoides bicolor*), les températures élevées durant l'incubation et l'élevage des oisillons augmentent significativement le risque de mortalité, notamment par surchauffe des œufs, qui deviennent alors non viables (Bourne et al. 2020).

EXEMPLE D'EFFETS POSITIFS DES CHANGEMENTS CLIMATIQUES SUR CERTAINES ESPÈCES

Bien que les impacts négatifs des changements climatiques soient souvent davantage connus et préoccupants, certaines études ont rapporté des changements environnementaux favorisant parfois quelques espèces. Par exemple, Zalewski et al. (2022) ont observé une corrélation positive entre les températures ambiantes hivernales et la masse corporelle des putois d'Europe (*Mustela putorius*). Selon leur étude, des hivers plus doux, caractérisés par des couvertures de neige et de glace moins épaisses, faciliteraient l'accès aux amphibiens hivernants, qui constituent la principale source de nourriture de cette espèce pendant la saison froide. Cette plus grande disponibilité des ressources, résultant d'une accessibilité accrue et combinée à une réduction de la durée de l'hiver, permettrait aux putois de limiter les pertes de masse corporelle durant l'hiver. Des observations similaires ont été rapportées chez d'autres espèces dont le blaireau européen (*Meles meles*) qui bénéficierait de l'augmentation des précipitations en raison d'un accès facilité aux invertébrés enfouis dans le sol, résultant en une augmentation de la masse corporelle (Byrne et al. 2015). De même, chez le bouquetin des Alpes (*Capra ibex*), des printemps plus précoces sont associés à une perte moindre de masse corporelle durant l'hiver, l'arrivée de la végétation printanière limitant la durée de la période de dépendance aux réserves de graisse stockées durant l'automne précédent (Brambilla et al. 2024).

Dans certains cas, la productivité végétale augmente par le biais de précipitations plus abondantes et de températures plus élevées (Marshall 1988; Wu et al. 2011), résultant en une meilleure condition corporelle des individus chez certaines populations d'espèces herbivores (p. ex. renne du Svalbard *Rangifer tarandus platyrhynchus* : Albon et al. 2017; cerf mulet *Odocoileus hemionus eremicus* : Marshal et al. 2008). Ces conditions climatiques favorables à une meilleure condition corporelle influencent également la reproduction, en particulier chez les femelles. Par exemple, des précipitations abondantes favorisent un verdissement hâtif de la végétation au printemps, offrant ainsi plus de nourriture aux femelles cerfs mulets durant leur gestation (Heffelfinger et al. 2018). Leur condition nutritionnelle s'en trouve améliorée, et elles peuvent allouer plus d'énergie et de ressources au développement de leurs petits, augmentant ainsi leur probabilité de survie.

Les liens entre les changements climatiques, le gain en masse et le succès reproducteur plus élevé noté chez certains herbivores s'expliquent par l'intermédiaire des effets des variations météorologiques sur la végétation. En effet, certaines combinaisons de température et d'humidité, deux variables météorologiques reconnues pour être influencées par les changements climatiques (Ummenhofer & Meehl 2017; IPCC 2023), sont déterminantes pour expliquer les variations de productivité végétale (Marshall 1988). Si l'eau est abondante, des températures plus élevées favorisent la respiration et la photosynthèse, ce qui entraîne une augmentation de l'absorption nette de carbone et de la production de biomasse aérienne et souterraine (Wu et al. 2011). À titre d'exemple, Glass et al. (2005) ont montré que des plants de bleuet nain (*Vaccinium angustifolium*) bien irrigués produisaient 50 % de fruits en plus que des plants soumis à des conditions plus sèches. À l'opposé, un stress hydrique combiné à des températures élevées est reconnu pour perturber le métabolisme et la structure cellulaire des végétaux, nuisant à des processus clés tels que la photosynthèse et la division cellulaire (Farooq et al. 2009; Anjum et al. 2017). Ces perturbations limitent la croissance des tissus, entraînant une réduction de la biomasse produite, des structures plus petites (p. ex. feuilles et tiges) et une sénescence accélérée (Farooq et al. 2009; Anjum et al. 2017).

Plusieurs variables météorologiques peuvent influencer la production de fruits, et ce, à différentes étapes du développement. En forêt boréale et tempérée, des conditions chaudes et arides durant la saison de croissance peuvent conduire à une diminution de la production de fruits charnus à la fin de la saison (Glass et al. 2005; Howe et al. 2012). La floraison et la pollinisation constituent des phases particulièrement critiques de la reproduction, mais aussi les plus vulnérables aux épisodes de gels (Centinari et al. 2016). Lorsque les températures sont suffisamment basses, des cristaux de glace peuvent se former dans les tissus végétaux, endommageant les membranes plasmiques cellulaires. Ces cristaux créent un gradient osmotique inversé qui entraîne une déshydratation des cellules, pouvant mener à leur rupture ou leur effondrement (Sakai & Larcher 1987; Jahed et al. 2023). Néanmoins, les plantes possèdent des mécanismes de résilience face au gel. Par exemple, l'exposition à des températures froides peut stimuler la production de molécules cryoprotectrices, telles que des protéines antigels, qui se lient aux cristaux de glace afin d'en inhiber la croissance et les

dommages qu'ils pourraient causer (Jahed et al. 2023). Ces mécanismes offrent toutefois une protection limitée, et des gels prolongés ou particulièrement intenses augmentent le risque de lésions (Olson & Steeves 1982; Hicklenton et al. 2002; CaraDonna & Bain 2016). Lorsque les dommages provoqués par le froid sont trop importants, le développement des fruits est compromis. Si plusieurs fleurs d'un plant sont touchées, cela peut entraîner une baisse significative de la biomasse de fruits produits (Hicklenton et al. 2002; Gezon et al. 2016).

Outre les herbivores, les omnivores opportunistes exploitent également les ressources végétales saisonnières et pourraient, eux aussi, tirer profit de conditions météorologiques plus favorables à la croissance des végétaux dans un contexte de changements climatiques. Des ressources alimentaires plus abondantes en raison des changements climatiques leur permettraient non seulement de tolérer, mais aussi de bénéficier de ces changements (Staudinger et al. 2013). Cette relation a notamment été observée chez le sanglier (*Sus scrofa*) au nord-est de la France, avec une proportion de femelles parturientes plus élevée (91 %) les années où les glands de chêne (*Quercus* sp.) sont abondants comparativement aux années de faible production où seulement 60 % donnaient naissance (Touzot et al. 2020). La variation de disponibilité de glands de chêne permettrait aux femelles de constituer de meilleures réserves de graisse avant l'hiver, augmentant leur succès reproducteur (Touzot et al. 2020) ainsi que le taux de survie de tous les individus (Vetter et al. 2015). Ces auteurs ont conclu leur étude par une simulation montrant une hausse notable de récurrence d'années de forte production de glands de chênes d'ici 2100 en raison des changements climatiques, suggérant une potentielle croissance des populations de sangliers (Touzot et al. 2020).

Les carnivores opportunistes pourraient également profiter d'une plus grande abondance de ressources végétales en réponse aux changements climatiques, puisqu'ils intègrent des végétaux (notamment des petits fruits) dans leur régime alimentaire (Willson 1993), une observation faite entre autres chez le coyote (*Canis latrans* : Samson & Crête 1997; Dumond et al. 2001), la martre d'Amérique (*Martes americana* : Weckwerth & Hawley 1962; Bull 2002) et le chacal à chabraque (*C. mesomelas* : Shikesho et al. 2024). Les fruits, riches en glucides et en lipides, représentent une ressource alimentaire saisonnière facilement accessible (Willson 1993) et fortement recherchée par les ursidés. Par exemple,

le régime alimentaire du grizzly (*Ursus arctos*) et de l'ours noir asiatique (*U. thibetanus*) inclut une grande proportion de fruits, de racines et de noix en fonction des variations saisonnières de leur disponibilité (Hwang et al. 2002; Fortin et al. 2013; Gunther et al. 2014; Nakajima et al. 2018).

L'OURS NOIR : UNE ESPÈCE SUSCEPTIBLE DE RÉPONDRE AUX CHANGEMENTS DANS LA PRODUCTIVITÉ VÉGÉTALE

L'ours noir (*U. americanus*) est un carnivore au régime alimentaire opportuniste composé en majorité de végétaux (~80 % de son alimentation; Bonin et al. 2020). Du printemps jusqu'au milieu de l'été, les ours consomment principalement des plantes herbacées, des graminées et des insectes, notamment des fourmis (Beeman & Pelton 1980; Boileau et al. 1994; Mosnier et al. 2008; Lesmerises et al. 2015). Ils peuvent également tuer et consommer, de façon opportuniste, les cervidés nouveau-nés durant cette période (Bastille-Rousseau et al. 2011). À partir du milieu de l'été jusqu'à la fin de l'automne, leur régime alimentaire se compose surtout de fruits principalement issus des genres *Vaccinium*, *Rubus*, *Ribes*, *Amelanchier*, *Prunus* et *Sorbus* (Boileau et al. 1994; Mosnier et al. 2008; Lesmerises et al. 2015). Ces espèces sont particulièrement abondantes dans les milieux en régénération suite à des perturbations d'origine naturelle (p. ex. feux de forêt ou épidémies d'insectes, Boileau et al. 1994; Costello & Sage 1994) ou anthropique (p. ex. coupes totales; Boileau et al. 1994; Costello & Sage 1994; Brodeur et al. 2008). Au cours de cette période, les ours consomment également des noix de certaines essences de feuillus matures, notamment les chênes (*Quercus* spp.), le hêtre d'Amérique (*Fagus grandifolia*) et les caryers (*Carya* spp.), lorsque ces ressources sont disponibles (Cottam et al. 1939; Beeman & Pelton 1980; Noyce & Garshelis 2011), et celles-ci peuvent constituer la majorité de leur alimentation lors des années de forte production (Cottam et al. 1939; Beeman et Pelton 1980). Les ours peuvent alors parcourir de longues distances hors de leur domaine vital estival pour localiser ces ressources (Samson & Huot 1995; Noyce & Garshelis 2011). En période de faible disponibilité des ressources naturelles, ils peuvent également exploiter les milieux agricoles

pour maximiser la consommation de ressources d'origine anthropique (p. ex. fourrage, grains) de même que l'accumulation de réserves en prévision de la dormance hivernale (Ditmer et al. 2016).

Les réserves de graisse accumulées avant l'hiver sont essentielles pour la survie et la reproduction des ours. Les ours entrent en tanière lorsque la nourriture se fait rare (Jonkel & Cowan 1971; Fowler et al. 2019). Ils entrent alors dans un état de torpeur caractérisé par une température corporelle minimale d'environ 31°C et une fréquence cardiaque réduite à environ 8 battements par minute (Vaughan et al. 2000). La durée de la période d'hivernation dépend de la durée du couvert neigeux (Fowler et al. 2019) et augmente avec la latitude (Tietje & Ruff 1980; Gámez-Brunswick & Rojas-Soto 2020). Pendant cette phase, les ours utilisent leurs réserves de graisse et perdent progressivement de la masse corporelle (Lessard et al. 2002; McLellan 2011). À l'émergence, les ours recommencent à s'alimenter, ce qui entraîne un maintien ou un gain de masse, bien que les femelles suitées et les mâles continuent de perdre du poids jusqu'au début de l'été en raison de la forte demande énergétique liée à la lactation et à la reproduction (Noyce & Garshelis 1998). C'est pendant la période d'hyperphagie, qui s'étend du milieu de l'été à la fin de l'automne, que les ours gagnent rapidement de la masse grâce aux ressources alimentaires riches en énergie telles que les fruits charnus et les noix (Jonkel & Cowan 1971; McLellan 2011).

Chez les femelles ours noirs, la masse corporelle à l'automne est positivement corrélée à leur probabilité de mettre bas l'hiver suivant (Elowe & Dodge 1989; Samson & Huot 1995). Bien que l'accouplement ait lieu en juin, l'implantation du blastocyste est retardée jusqu'en novembre et la mise bas survient en tanière, en janvier ou février (Vaughan et al. 2000). Ce délai d'implantation permet aux femelles de mettre bas à une période durant laquelle elles disposent des réserves énergétiques nécessaires pour assumer les coûts de la gestation et de la lactation (Robbins et al. 2012). Avant d'entrer en tanière, les femelles doivent donc atteindre un seuil minimal de masse corporelle permettant de mener à terme leur gestation (Rogers 1976; Samson & Huot 1995). À cet effet, une étude réalisée en Maurice (Québec, Canada) a montré que les femelles pesant moins de 56 kg à l'automne n'avaient produit aucun ourson, tandis que celles atteignant ou dépassant les 77 kg avaient toutes donné

naissance (Samson & Huot 1995). Les femelles qui atteignent ce seuil plus tôt dans leur vie peuvent donc débuter leur cycle de reproduction à un plus jeune âge (Stringham 1990). L'âge à la première reproduction se situe généralement entre 3 et 7 ans (Jolicoeur et al. 2006; Bridges et al. 2011), mais certaines femelles à croissance rapide peuvent devenir primipares à 2 ans lorsqu'elles ont un accès régulier à de la nourriture d'origine anthropique (Gould et al. 2021). De plus, l'accès à des ressources alimentaires abondantes ou de meilleure qualité augmente la probabilité de primiparité (Wightman et al. 2022) et réduis l'intervalle de temps entre deux événements de reproduction, pouvant ainsi atteindre le minimum biologique de l'espèce, soit deux ans d'intervalle (Stringham 1990).

OBJECTIF, HYPOTHÈSES, SURVOL DES MÉTHODES ET PRINCIPAUX RÉSULTATS

Les changements climatiques et les modifications de l'environnement qu'ils engendrent ont des répercussions sur la plupart des populations animales, certaines parvenant même à s'y acclimater. L'ours noir constitue un excellent modèle d'étude pour évaluer les effets potentiels des changements climatiques sur la faune, car son régime alimentaire opportuniste lui permet de s'ajuster à une vaste gamme de conditions environnementales, comme en témoigne sa vaste aire de répartition qui s'étend des régions arides du Mexique jusqu'à la toundra arctique du Canada (Scheick & McCown 2014).

L'objectif de mon projet de maîtrise était d'évaluer les relations entre les variations des conditions météorologiques et trois traits d'histoire de vie chez les ours noirs en forêt boréale : la masse, la probabilité de primiparité et l'intervalle de temps entre les portées. Considérant son régime alimentaire dominé par les végétaux, j'ai formulé l'hypothèse que des conditions météorologiques favorables à la croissance des plantes entraînent une augmentation de leur productivité et de leur disponibilité, offrant ainsi davantage de nourriture aux ours noirs. En conséquence, j'ai émis la prédiction voulant que lors des années avec des conditions propices à la croissance végétale, les ours aient une masse supérieure et que les femelles puissent allouer davantage d'énergie à la reproduction. Ultimement, ces

femelles auraient une probabilité plus élevée de mettre bas pour la première fois à l'hiver suivant et un intervalle de temps entre les reproductions plus près du minimum biologique, qui est de 2 ans. De plus, j'ai émis l'hypothèse qu'une période de disponibilité de nourriture plus longue permette aux ours de se nourrir plus longtemps, ce qui s'observerait par une augmentation de la masse et une probabilité de primiparité plus élevée pour un même âge, de même que par une réduction de l'intervalle de temps entre les portées jusqu'à atteindre le minimum biologique de 2 ans.

Afin de répondre à mon objectif, j'ai combiné les données de huit études sur l'ours noir menées à travers le Québec. J'ai regroupé des données sur 1 824 individus, dont beaucoup ont été suivis sur plusieurs années, couvrant ainsi un impressionnant gradient spatiotemporel allant des érablières du sud de la province jusqu'aux pessières à mousses au nord du Saguenay-Lac-Saint-Jean et s'échelonnant sur ~40 ans (1983 – 2023). Mes analyses de régressions linéaires mixtes ont révélé que la masse corporelle des ours, une fois ajustée en fonction de l'âge, du segment de population et de la date de capture, et en considérant les habitats disponibles, augmentait avec une diminution de la fréquence des gels pendant la floraison des espèces à fruits ainsi qu'une augmentation de la disponibilité en eau durant l'été précédent. En revanche, la masse corporelle ajustée des ours diminuait lorsque précédée d'une saison de croissance plus longue. Des régressions logistiques mixtes ont montré que la probabilité de primiparité des femelles augmentait lorsque les étés précédents étaient caractérisés par une plus grande disponibilité en eau et une saison de croissance plus longue. L'intervalle de temps entre les portées ne variait cependant pas entre les différents domaines bioclimatiques étudiés, suggérant que ces femelles n'étaient pas exposées à des conditions environnementales extrêmes puisqu'elles pouvaient acquérir les ressources nécessaires pour la reproduction la quasi-totalité des années suivant la primiparité. Mes résultats montrent que les conditions météorologiques locales ont un effet sur certains traits d'histoire de vie importants des ours. Face aux changements climatiques à venir, notamment si ces derniers se traduisent par une réduction des gelées tardives au printemps, une augmentation des précipitations estivales et un allongement de la saison de croissance, les populations de l'est du Canada pourraient s'avérer favorisées face aux changements climatiques à venir.

CHAPITRE 1
INFLUENCE DES CONDITIONS MÉTÉOROLOGIQUES LOCALES SUR DES TRAITS D'HISTOIRE DE VIE DES OURS NOIRS RÉVÉLÉE PAR QUATRE DÉCENNIES DE DONNÉES COLLECTÉES LE LONG D'UN GRAND GRADIENT SPATIAL

1.1 RÉSUMÉ EN FRANÇAIS DU PREMIER ARTICLE

Les changements climatiques modifient les conditions environnementales et entraînent souvent des répercussions négatives sur la faune. Cependant, les individus de certaines espèces pourraient bénéficier de ces changements grâce à une hausse de la disponibilité de nourriture ou à des conditions météorologiques plus clémentes. Prédire les réponses des espèces reste difficile, en particulier lorsque les changements des conditions météorologiques peuvent simultanément induire des coûts et des bénéfices. Les ours noirs (*Ursus americanus*) sont des carnivores opportunistes qui dépendent fortement des fruits, des noix et des plantes herbacées pour accumuler suffisamment de réserves de graisse avant la dormance hivernale, durant laquelle les femelles mettent également bas. À partir de 41 années (1983-2023) de données d'ours collectées sur 1 824 individus dans 8 sites d'étude distribués le long d'un gradient allant des forêts décidues à boréales, nous avons évalué comment les conditions météorologiques locales pourraient indirectement affecter la masse corporelle ajustée, la probabilité de primiparité et l'intervalle de temps entre les portées des ours noirs, tout en considérant les variations individuelles et d'habitat. Nos résultats suggèrent que la masse corporelle ajustée pour la date de capture, le segment de population et l'âge, utilisée comme indice de condition corporelle, était supérieure après des saisons de croissance caractérisées par une importante productivité végétale, c.-à-d. peu de dommages causés par le gel aux fleurs d'espèces à fruits charnus, ainsi qu'une grande disponibilité en eau durant l'été. Ceci suggère que malgré la flexibilité de leur régime alimentaire, les ours ont été sensibles aux

variations à grande échelle de la productivité végétale. De manière inattendue, nous avons également noté que de longues saisons de croissance étaient associées à une plus faible masse corporelle ajustée, suggérant des effets négatifs complexes de la durée de la période à s'alimenter. La probabilité de primiparité des femelles était positivement corrélée avec la disponibilité en eau et la longueur de la saison de croissance durant l'été précédent, indiquant que les conditions météorologiques favorables à la croissance végétale permettent aux ours de se reproduire à un âge plus précoce. L'intervalle de temps entre les portées moyen des femelles (2,1 ± 0,3 années, écart-type) était près de la fréquence optimale permettant de maximiser les opportunités de reproduction, suggérant que ni les conditions météorologiques ni l'habitat n'ont limité les événements de reproduction après la primiparité dans notre aire d'étude. Interprétés à la lumière des tendances décennales et des changements climatiques futurs, nos résultats peuvent renseigner sur les réactions potentielles des ours noirs aux changements climatiques anticipés. En effet, nous avons observé une diminution de la fréquence des gels pendant la floraison des espèces à fruits charnus, ainsi qu'une augmentation de la disponibilité en eau durant l'été et de la durée de la saison de croissance dans notre aire d'étude au cours des quatre dernières décennies. La masse corporelle ajustée des femelles accompagnées de juvéniles de 1 an et la probabilité de primiparité ont toutes deux augmenté au fil des décennies, suggérant que les ours se sont non seulement ajustés aux variations environnementales des dernières décennies, mais que certains individus en ont profité. L'intensité croissante des changements climatiques pourrait cependant mettre à l'épreuve leur résilience.

Mots clés : Changements climatiques; Condition corporelle, Conditions météorologiques; Étude à long-terme; Probabilité de primiparité; *Ursus americanus*.

J'ai corédigé cet article, intitulé « *Influence of local weather on life-history traits of American black bears revealed by four decades of data collected along a wide spatial gradient* », avec mon codirecteur, le chercheur Christian Dussault (MELCCFP), le chercheur Claude Samson (Parcs Canada) et mon directeur de recherche, le professeur Martin-Hugues St-Laurent (UQAR). Cet article sera soumis sous peu à la revue avec comité de révision par les pairs *Global Change Biology*, une fois les commentaires du jury du mémoire intégrés. En

tant que première auteure, ma contribution à ce travail a été l'essentiel de la recherche, du développement de la méthode, de l'exécution des analyses et de la rédaction de l'article. Le professeur Martin-Hugues St-Laurent et mon codirecteur Christian Dussault ont fourni l'idée originale du projet, coordonné son élaboration et son financement en plus de rassembler les données des différentes études compagnes réparties sur 41 ans. Mes trois coauteurs ont supervisé et révisé les analyses, commenté et édité les textes de l'article et approuvé son contenu en amont du dépôt.

1.2 INFLUENCE OF LOCAL WEATHER ON LIFE-HISTORY TRAITS OF AMERICAN BLACK BEARS REVEALED BY FOUR DECADES OF DATA COLLECTED ALONG A WIDE SPATIAL GRADIENT

ABSTRACT

Climate change alters environmental conditions in ways that often negatively impact wildlife. However, individuals of some species may benefit from these changes through increased food availability or milder weather conditions. Predicting species responses remains difficult, especially when shifts in weather patterns can simultaneously induce both costs and benefits. American black bears (*Ursus americanus*) are opportunistic carnivores that rely heavily on fruits, nuts, and herbaceous plants to accumulate sufficient fat reserves for the winter denning during which females also give birth. Using 41 years (1983–2023) of bear data collected on 1824 individuals in 8 study sites distributed along a deciduous-to-boreal forest gradient, we assessed how local weather could indirectly affect the black bear's adjusted body mass, probability of primiparity, and interbirth interval while accounting for habitat and individual variations. We found that the time-, demographic group-, and age-adjusted body mass, used as a body condition index, was higher following growing seasons characterized by high plant productivity, i.e., low frost damage to the flowers of fruit-bearing species and high water availability during summer. This suggests that despite their foraging flexibility, bears were sensitive to large-scale variations in plant productivity. Unexpectedly, we also found that longer growing seasons were associated with a lower adjusted body mass, suggesting complex negative effects of the duration of the foraging period. The probability of female primiparity correlated positively with water availability and growing season length during the preceding summer, indicating that suitable weather for plant growth accelerates reproductive onset in bears. The mean interbirth interval of females (2.1 ± 0.3 years, standard deviation) was close to the optimal frequency to maximize breeding opportunities, suggesting that neither the weather nor the habitat constrained reproduction events following primiparity in our study area. When interpreted in light of decennial trends and future climate change, our results can shed light on the potential reactions of the black bear to anticipated climate

changes. Indeed, we observed decreasing frequency of frost during the flowering of fruit-bearing species, and an increasing water availability during summer and growing season length within our study area over four decades. The adjusted body mass of females with yearlings and the probability of primiparity both increased over the four decades covered by our dataset, suggesting not only that bears adjusted to recent environmental variations but also that some individuals benefited from them. The growing intensity of climate change may, however, challenge their resilience.

Keywords: Body condition; Climate change; Long-term study; Probability of primiparity; *Ursus americanus*; Weather conditions.

INTRODUCTION

Over recent decades, we witnessed several changes in natural ecosystems, induced by increased human activity and referred to as human-induced rapid environmental changes (Sih 2013). Amongst all drivers, climate, defined as the long-term average of weather conditions over periods of 30 years or more (World Meteorological Organization 2025), is now rapidly changing, forcing wildlife to cope with conditions often far different from those under which they have evolved. Climate change is particularly evidenced by a rising average land and ocean surface temperature (Intergovernmental Panel on Climate Change 2023), an increased variability in precipitation patterns (Ummenhofer & Meehl 2017), and a higher frequency of extreme weather events, such as high temperatures and drought, which are likely to increase the risk of wildfires (Jones et al. 2022). The alteration of climatic conditions resulting from climate change has been associated with a poorer body condition in individuals of many animal species, potentially due to increased metabolic demands or thermal stress (e.g., Kuhl's pipistrelle *Pipistrellus kuhlii*: Locatelli et al. 2019; Spotted salamander *Ambystoma maculatum*: Moldowan et al. 2022; Alpine chamois *Rupicapra rupicapra*: Mason et al. 2014). In some species, climate change was also linked with reduced survival (e.g., camouflage mismatch in snowshoe hare *Lepus americanus*: Zimova et al. 2016) and lower reproductive success (e.g., extended interbirth intervals and lower pup recruitment in African wild dog *Lycaon pictus*: Woodroffe et al. 2017). However, climate change has also been associated with improved body condition, potentially due to increased prey availability (European polecat *Mustela putorius*: Zalewski et al. 2022), milder winters (European badger *Meles meles*: Byrne et al. 2015) or extended periods of food availability (Alpine ibex *Capra ibex*: Brambilla et al. 2024).

Some herbivore populations may benefit from climate change when it results in weather conditions more favorable to plant growth. Increased plant productivity due to favorable weather conditions allowed some species to reach a higher body mass (Svalbard reindeer *Rangifer tarandus platyrhynchus*: Albon et al. 2017) and to improve reproductive success (Mule deer *Odocoileus hemionus*: Heffelfinger et al. 2018). Plant productivity is influenced by the combination of water availability and temperature (Marshall 1988), two

climatic variables that are being altered by climate change. Warmer temperatures combined with increased precipitation can enhance plant biomass and productivity (Wu et al. 2011). Alternatively, low levels of soil moisture can cause plant desiccation and alter metabolic processes and cellular structure, which can reduce biomass production, accelerate senescence, and lead to smaller leaves (Farooq et al. 2009; Anjum et al. 2017). In wild fruit-bearing species, dry conditions and drought can also reduce fruit production (Glass et al. 2005; Howe et al. 2012). Freezing temperatures during the flowering and pollination period represents another critical constraint on plant reproduction (Olson & Steeves 1983; Inouye 2008; Xu et al. 2023). Low temperatures at this stage can damage reproductive structures, especially when flowers are exposed to cold for extended periods, increasing the likelihood of freezing injury and reducing fruit set (Hicklenton et al. 2002; CaraDonna & Bain 2016).

Many animals consume plant-based resources opportunistically or seasonally (e.g., grasses, fruits, or seeds) and may benefit from increased plant productivity. For instance, the breeding probability of female wild boars (*Sus scrofa*) rises with abundant acorn production (Touzot et al. 2020), and population growth rates have been positively associated with high beechnut availability (Vetter et al. 2015). Even carnivores may include plant matter in their diet, for example by consuming berries when seasonally available (Willson 1993), as observed for coyotes (*Canis latrans*: Samson & Crête 1997; Dumond et al. 2001) and American martens (*Martes americana*: Weckwerth & Hawley 1962; Bull 2002). Some members of the *Ursus* genus, such as the grizzly bear (*U. arctos*: McLellan 2011) and the American black bear (*U. americanus*), also eat a significant proportion of plant material.

For the black bear, individual body condition and female reproduction are strongly correlated with the abundance of food resources in their environment (Rogers 1976; Elowe & Dodge 1989; Stringham 1990; Wightman et al. 2022). Bears are opportunistic carnivores that feed on a variety of food sources (Beeman & Pelton 1980; Mosnier et al. 2008; Lesmerises et al. 2015), but their diet is predominantly composed of plant resources, which may constitute as much as 90% of their intake (Beeman & Pelton 1980; Mosnier et al. 2008; Lesmerises et al. 2015). Fat reserves accumulated before denning are critical for bears, since individuals typically lose body mass during denning and do not gain significant body mass

until the following period of hyperphagia (Jonkel & Cowan 1971; Noyce & Garshelis 1998; Lessard et al. 2002; McLellan 2011). For females, autumn body condition is positively correlated with their reproductive success the following spring (Elowe & Dodge 1989; Samson & Huot 1995). They must reach a minimal body mass threshold before the denning period (characterized by an overwinter torpor) to successfully produce cubs (Rogers 1976; Samson & Huot 1995), and those who reach this threshold at a younger age tend to reproduce earlier (Stringham 1990). Access to more abundant or higher quality food increases their probability of primiparity (Wightman et al. 2022) and is associated with shorter interbirth intervals (Stringham 1990). After the onset of reproduction, female black bears are usually available for reproduction every two years, because cubs remain with their mother for about 14–16 months, denning with her during their first winter (Stringham 1990).

From den emergence in spring until mid-summer, black bears primarily feed on grasses and herbaceous plants (Beeman & Pelton 1980; Boileau et al. 1994; Mosnier et al. 2008), insects (e.g., ants; Boileau et al. 1994; Lesmerises et al. 2015), and opportunistically on ungulate neonates (Bastille-Rousseau et al. 2011). Between mid-summer and late autumn, bears rapidly gain mass (Jonkel & Cowan 1987) by consuming fruits from common species of *Vaccinium*, *Rubus*, *Ribes*, *Amelanchier*, *Prunus*, and *Sorbus* genera (Boileau et al. 1994; Mosnier et al. 2008; Lesmerises et al. 2015) which are most abundant in regenerating forest stands following natural (e.g., wildfires, insect outbreaks: Boileau et al. 1994; Costello & Sage 1994) or anthropogenic (e.g., clearcuts: Boileau et al. 1994; Costello & Sage 1994; Brodeur et al. 2008) disturbances. In mature deciduous forests, bears also seek hard masts produced by oaks (*Quercus* spp.), beeches (*Fagus* spp.), and hickories (*Carya* spp.: Cottam et al. 1939; Beeman & Pelton 1980; Noyce & Garshelis 2011). They constitute most of the bears' autumn diet when available (Cottam et al. 1939; Beeman & Pelton 1980), and bears can travel far outside their summer home range to locate these resources (Samson & Huot 1998; Noyce & Garshelis 2011). In years of natural food scarcity, bears may forage in agricultural lands—when available—to maximize fat accumulation before denning (Elowe & Dodge 1989, Ditmer et al. 2016). Den entry typically occurs following the onset of snow cover and a marked decline in food availability (Jonkel & Cowan 1971; Fowler et al. 2019).

Therefore, the black bear is one species in which some populations could potentially benefit from increased plant productivity resulting from improved weather conditions following climate change.

Our objective was to evaluate the relationships between variations in local weather conditions and three key life-history traits (body mass, female probability of primiparity, and intervals between reproductions) in black bear populations across the boreal forest in eastern Canada. To do so, we integrated the data from eight studies conducted between 1983 and 2023 in Québec, Canada, to exploit temporal and spatial variations in weather conditions, as a proxy of varying climate, while accounting for variation in habitat-related food availability. We hypothesized that weather conditions favorable to plant growth would lead to increased plant productivity and fruit availability, thereby providing more food for bears. As a result, bears should attain a higher body mass, and females should be able to allocate more energy to reproduction, potentially rising the probability of primiparity and exhibiting a 2-year interval between successful reproductions. We also hypothesized that a longer period of food availability, potentially allowing prolonged access to high-quality food, would further increase body mass and the probability of primiparity, and reduce the interbirth interval to 2 years. We predicted that the age-, and sex- and reproductive status adjusted body mass of bears—used as an index of body condition—would increase when weather conditions were favorable to high plant productivity (i.e., no freezing temperatures during the flowering period, high water availability during summer) or with a longer period of food availability. We also predicted that weather conditions beneficial to plant development would enable females to reach primiparity at a younger age and shorten the delay between reproduction events. Although the temporal scope and structure of our analyses emphasize the effects of short-term weather variations, we interpret our results within the broader context of climate change.

METHODS

Study area

Our study was conducted in the province of Québec (eastern Canada; Figure 1). Bears were sampled in the six bioclimatic domains found in central and southern Québec, covering a wide range of environmental conditions. Bioclimatic domains are a provincial classification of the environment based on dominant tree species, type of natural disturbances, and climatic conditions (Table 1). The composition of the tree layer follows a latitudinal gradient with a dominance of deciduous species in the south, of coniferous forest in the north, and a mixed composition in the transition zone. Fleshy fruits, an important food source for bears, are available in all bioclimatic domains, but with varying biomass, species, and genera between them; the most abundant genera are *Vaccinium*, *Rubus*, *Prunus*, *Viburnum*, *Amelanchier*, *Ribes*, and *Sorbus*. Hard masts are also an important food item for bears (Beeman & Pelton 1980, Seger et al. 2013) but are only found in the maple (*Acer* spp.) bioclimatic domains. Hard masts are more precisely associated with red oak (*Quercus rubra*), white oak (*Quercus alba*), and American beech (*Fagus grandifolia*), which are mostly found in the maple – hickory (*Carya cordiformis*) bioclimatic domain and gradually decrease toward the northern limit of the maple – yellow birch (*Betula alleghaniensis*) domain. The growing season length is approximately 50 days shorter in the black spruce (*Picea mariana*) – mosses domain, the northernmost bioclimatic domain, compared to the maple – hickory domain (Robitaille & Saucier 1998). Commercial logging occurred in all bioclimatic domains during our study, at different levels of intensity, and agricultural lands are mainly found in the lowlands along the St. Lawrence River and in the south-western area (i.e., in the maple bioclimatic domains).

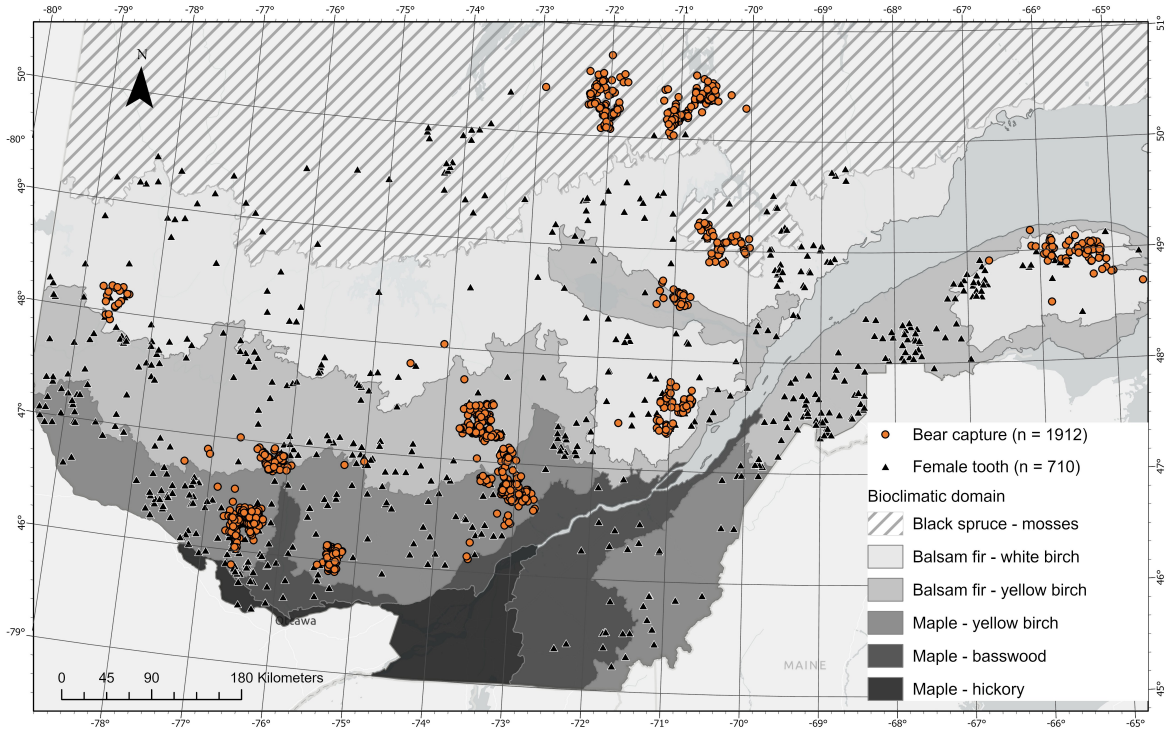

Figure 1. Map of the study area showing capture sites of black bears between 1983 and 2023 (orange circles, n = 1912 bear-captures), and harvest sites of females harvested through sport hunting or trapping between 2005 and 2022 (black triangles, n = 710 harvested females, 23 are from the bear-capture dataset). The shaded areas represent the different bioclimatic domains.

Table 1. Description of the bioclimatic domains where bear samples were collected for this study. Bioclimatic domains are named according to dominant tree species and defined by the plant communities and the climatic conditions (following Robitaille & Saucier 1998).

Bioclimatic domain	Companion species	Main natural disturbance	Mean annual temperature (°C)	Mean annual precipitation (mm)	Proportion of annual precipitation as snow (%)	Mean annual plant growing season length (day)
Black spruce (*Picea mariana*) – mosses	White birch Quaking aspen (*Populus tremuloides*) *Ericaceae* spp.	Wildfire	-1.2	1000	33	140
Balsam fir (*Abies balsamea*) – white birch (*Betula papyrifera*)	White spruce (*Picea glauca*)	Insect outbreak (Eastern part) Wildfire (Western part)	2.5	1200	40	145
Balsam fir – yellow birch (*Betula alleghaniensis*)	Maple	Insect outbreak Wildfire	2.5	900	30	170
Maple (*Acer* spp.) – yellow birch	Red oak (*Quercus rubra*) American beech (*Fagus grandifolia*)	Windthrow	3.0	950	25	175
Maple – basswood (*Tilia americana*)	White walnut (*Juglans cinera*) Oaks (*Quercus* spp.) American beech	Windthrow	4.0	1000	25	185
Maple – hickory (*Carya cordiformis*)	Hickories (*Carya* spp.) Oaks American beech	Windthrow	5.0	950	25	190

Data acquisition

Bear database

The data used for our analyses were separated into two major datasets from eight different research projects (see Figure 2). The first one combines data collected through seven projects investigating bear ecology across the province of Québec (Canada) between 1983 and 2023; we used these data to build our adjusted body mass analysis, hereafter referred as bear mass (details in Table 2). In these seven projects, body mass and the tooth samples needed to assess the age of the bears were collected through live capture or game and fur-bearer harvest (n = 1137 bears). Many of the live-captured bears were equipped with a GPS or VHF collar, and some of them could therefore be measured more than once, for example in their den. When combining these datasets, we removed the bears for which we had no information regarding capture location, mass, sex or age. One bear belonging to the MELCCFP dataset 1 was captured outside the study area in 1986, in Ontario, 32 km from the Québec's border, and was thus excluded from the bear body mass dataset. For the Massé et al. (2014) dataset, we only retained the bears captured in the northern part of the study area since the ones in the southern part had access to a feeding station. Our second dataset originates from the eighth database and contains information about the reproductive history of females harvested through hunting or trapping (n = 710 females) between 1999 and 2022. Age and breeding history were determined by tooth cement analysis (Matson's Laboratory LLC, Manhattan, Montana, USA; Coy & Garshelis 1992, Allen et al. 2017). The harvest location was known for all those bears, but body mass was available only for 23 females, and therefore this dataset could not be used for the body mass analysis.

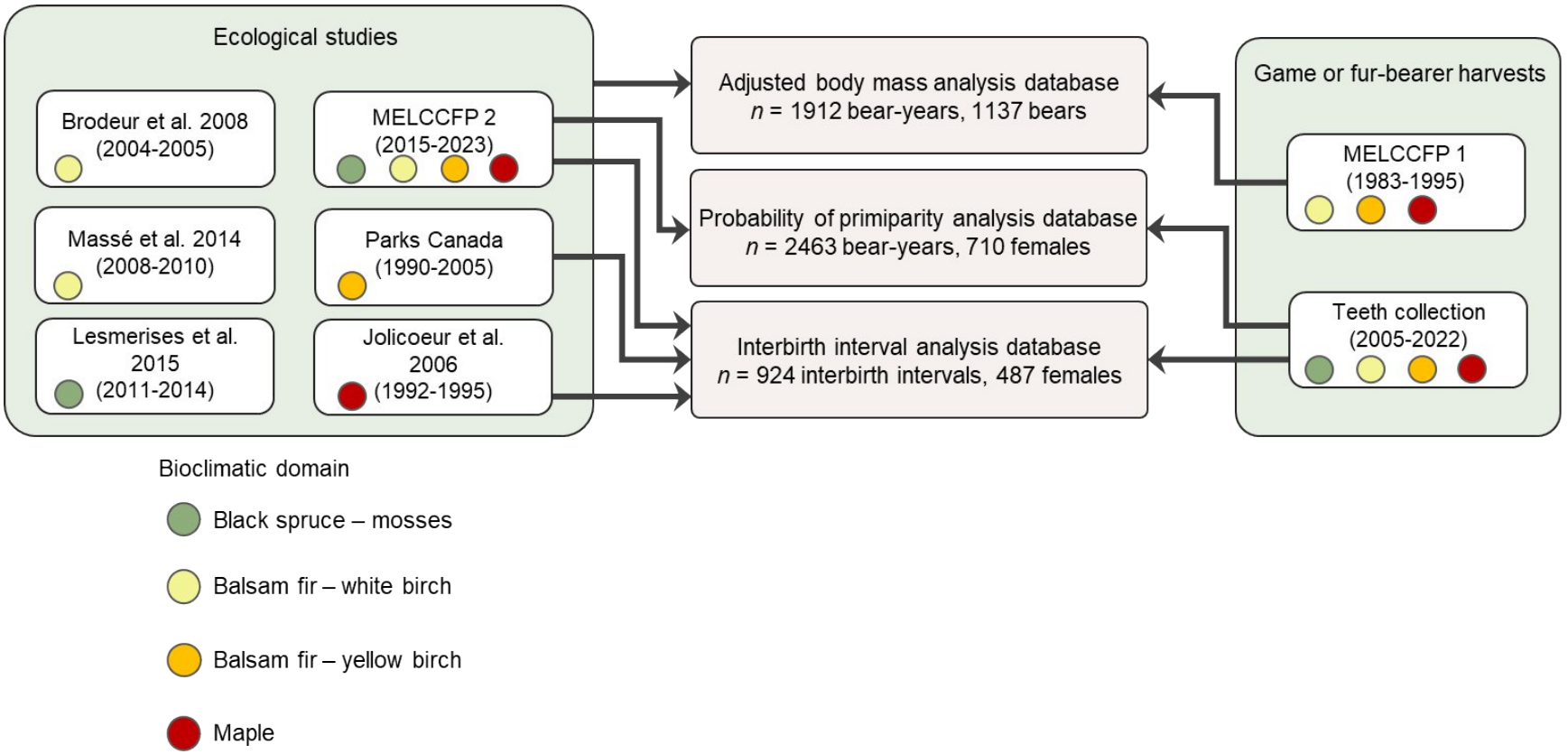

Figure 2. Diagram detailing which databases were used for the analyses of the three life-history traits of black bears in Québec (eastern Canada) from 1983 to 2023. For each dataset, we show the study period (in parentheses) and the bioclimatic domain (colored discs) in which bears were captured.

Table 2. Sources and characteristics of the different datasets gathered to test our hypotheses regarding the relationship between variations in black bear adjusted body mass and weather variables in Québec (Canada).

Dataset/ published papers	Study area	Bioclimatic domains	Time frame (months of captures)	Monitoring of bear movements	Winter den visits
Brodeur et al. (2008)	Laurentides Wildlife Reserve	Balsam fir – white birch	2004-2005 (March, May, June, July, September)	VHF	Yes
Parks Canada	La Mauricie National Park	Maple – yellow birch	1990-2005 (June to March)	VHF	Yes
Jolicoeur et al. (2006)	La Vérendrye & Pontiac Wildlife Reserves	Maple – yellow birch	1992-1995 (February, March, July to September)	VHF	Yes
Lesmerises et al. (2015)	Saguenay-Lac-St-Jean	Black spruce – mosses	2011-2014 (January to March, June-July)	GPS	Yes
Massé et al. (2014)	Saguenay-Lac-St-Jean	Balsam fir – yellow birch + Balsam fir – white birch	2008-2010 (June to September)	GPS	No
MELCCFP dataset 1	Abitibi, Gaspésie, Laurentides Wildlife Reserve (WR), Papineau-Labelle WF, Saint-Maurice WR, Mastigouche WF, La Vérendrye WR, Pontiac WR	Maple – yellow birch + Balsam fir – yellow birch + Balsam fir – white birch	1983-1996 (May to July, February, March)	No	No
MELCCFP dataset 2	Outaouais, Mauricie, Gaspésie, Saguenay-Lac-St-Jean	Maple – yellow birch + Balsam fir – yellow birch + Balsam fir – white birch + Black spruce – mosses	2015-2023 (February to August)	GPS	Yes

Capture and handling protocols

Live-capture, handling, and sampling protocols were largely similar between the studies. Bears were captured using foot snares and each trap site was visited at least once each day. Bears were immobilized either with tiletamine-zolazepam (Telazol, 5 mg/kg) alone, or with a mix of ketamine (10 mg/kg) and xylazine (5 mg/kg) or a mix of Telazol (1.5 mg/kg) and medetomidine (0.04 mg/kg). Bears were identified with an ear tag or a microchip implant and weighted (±0.2 kg). One or two premolars were extracted the first time a bear was captured. The teeth were sent to Matson's laboratory to determine the age and reproductive history of females when possible (Coy & Garshelis 1992; Allen et al. 2017). Handling procedures used during winter den visits were mostly the same as the ones used in summer, except that cubs or yearlings were sexed, weighted, and individually identified. For more details regarding live bear data collection methods, see Samson & Huot (1995), Jolicoeur et al. (2006), Brodeur et al. (2008), Massé et al. (2014) and Lesmerises et al. (2015). All protocols respected the Canadian Council on Animal Care Guidelines that prevailed at the time the study was conducted (certificate numbers are provided in Supporting Information 1 Table S1).

Remote sensing data

We obtained weather data from the ERA5-Land database (Muñoz-Sabater 2019) and vegetation index data from the Landsat Collection 2 Tier 1 Level 2 Enhanced Vegetation Index (EVI) Composite database (U.S. Geological Survey). ERA5-Land is a reanalysis of weather data from the European Center for Median Range Weather Forecast (ECMRWF). The data are available since 1950 and have a temporal resolution of 1 h and a spatial resolution of 81 km^2 (9 × 9 km pixels; Muñoz-Sabater 2019). The Landsat EVI Composite database is created from Tier 1 Level 2 orthorectified scenes with the near-infrared, red, and blue bands (Huete et al. 2002). It represents the photosynthetic activity and canopy structural variations of a pixel (Huete et al. 2002). This dataset has a temporal resolution of 8 or 16 days and a spatial resolution of 30 × 30 m, available from 1984 to the present (U.S. Geological

Survey). We gathered these data using cloud computing with Google Earth Engine (Gorelick et al. 2017), R software V4.2.0 (R Core Team 2022), and the R package *rgee* V1.1.7 (Aybar et al. 2020). This package allowed us to link the R environment to the Google Earth Engine API.

Time frame of weather and productivity variables

We integrated the weather and productivity variables most likely to influence the availability of plant food resources for black bears. We therefore focused on conditions prevailing during the flowering and fruit development periods, from spring to mid-summer, which could affect the quality and quantity of food resources available for bears during their hyperphagic period, from mid-summer to late autumn (Hicklenton et al. 2002, Glass et al. 2005, Howe et al. 2012). Bears store fat reserves in preparation for the denning and early spring periods, during which they lose weight, and regain most of it during the following mid-summer and autumn (Nelson et al. 1983, Bartareau et al. 2012). Therefore, the weather conditions most likely to affect the body condition of a bear are those that were prevailing during the development of the fruits consumed in the last hyperphagic period. For bears sampled from September 1st to December 31st of year x (e.g., 2000), we used weather data prevailing during the flowering and fruit development periods of the same year (i.e., 2000), while for those sampled between January 1st and August 31st we used the weather data of the previous year x_{-1} (1999 in this example).

Weather parameters

The production of fleshy fruits can be significantly reduced if a late frost occurs during the flowering period, damaging the flowers' tissues and thus affecting the development of fruits early in the season (Hicklenton et al. 2002; CaraDonna & Bain 2016; Hertel et al. 2018). We thus used the cumulative degree-days to determine the beginning and ending dates of the flowering period of fruit-bearing species for the specific location and year of each bear capture. The flowering period started and ended when 100 and 350 cumulative degree-days over 5°C thresholds were respectively met, corresponding to the dates when 10% of the

flowers were open on the earliest fruit-bearing species and when 50% of the flowers were open on the later-blooming species (see Supporting Information 2). We then determined the number of hours during which the temperature was below the freezing temperature (i.e., 0.0°C) within the estimated flowering period. We also considered a threshold of -3.5°C, the minimal temperature of resistance of blueberry flowers (*Vaccinium angustifolium*; Hicklenton et al. 2002), which is a widely available, important food item for black bears in our study area (Boileau et al. 1994; Samson & Huot 1995), but preliminary analyses revealed that models based on the 0.0°C threshold showed stronger support according to the Akaike's information criterion (AIC; Burnham & Anderson 2001).

The aridity of summers is known to influence the fruit productivity of fruit-bearing plants (Glass et al. 2005; Howe et al. 2012). We determined the water availability during the plant growing season using the August value of the 3-month Standardized Precipitation Evapotranspiration Index (SPEI: Vicente-Serrano et al. 2010; Beguería et al. 2013). This index was calculated using the precipitation and the potential evapotranspiration values recorded in June, July, and August. We calculated the potential evapotranspiration index using the R package *SPEI* (Vicente-Serrano et al. 2010), following a modified version of the Hargreaves method proposed by Droogers & Allen (2002), from Vicente-Serrano et al. (2010). The computation of SPEI required the monthly mean of the daily minimum temperature (°C), monthly mean of the daily maximum temperature (°C), mean daily sum of solar radiation (MJ/m^2), and monthly total precipitations (mm). We obtained these weather data from ERA5-Land daily aggregates database (Copernicus Climate Change Service, 2024).

Bears adjust the date of den entry based on the length of the growing season and period of food availability (Jonkel & Cowan 1971, Fowler et al. 2019). We assessed the length of the plant availability period (in Julian day) using the derivative method (Zhang et al. 2018) with the *phenofit* R package (Kong et al. 2022), which allowed us to determine the dates when green-up (beginning of growing season) and senescence (end of growing season) were the fastest. We first extracted time series of Enhanced Vegetation Index (EVI) from the Landsat database and included the presence or absence of a snow cover for each image to

reduce the noise in the data (Kong et al. 2022). We then calculated the length of the growing season by subtracting the Julian day of peak plant growth from the Julian day of peak plant senescence. When missing data prevented *phenofit* to identify the date of the start or end of the growing season (18% of the cases), we replaced missing values with the mean growing season length calculated over the study period allowing us to keep these records while preventing them to influence the results of statistical analyses.

Annual maps of land cover

We extracted land cover data from the SIFORT forest information system of the Ministère des Ressources naturelles et des Forêts (MRNF; MRNF 2017). SIFORT is a database of polygonal units (i.e., tiles) of 15 latitudinal seconds by 15 longitudinal seconds (ca. 14 ha) covering the entire province of Québec. This database is a simplification of the ecoforest map produced by the MRNF. The ecoforest map consists of polygons of forest stands or agricultural lands elaborated from 1:20,000 aerial photographs (MRNF 2015). Each forest stand is considered a homogeneous area in terms of cover type (coniferous, deciduous, or mixed), tree species composition, canopy density, height, age class, and soil type. The minimum mapping-unit size is 4 ha for forest stands and 2 ha for nonforested areas (agricultural lands, water bodies, bogs, etc.). In SIFORT, each tile receives the attributes of the polygon of the ecoforest map located at its centroid (MRNF 2017). Digital ecoforest map polygons begin to be available in 1990, but we opted for SIFORT maps instead of ecoforest maps to allow for consistency in land cover information throughout the study period (1983 to 2023). We used a 1:20,000 map of water bodies to remove the areas covered by water within each tile, thus improving the accuracy of the land area available within each tile. Ecoforest and SIFORT maps are produced approximately every 10 years. To cover the time frame of our dataset, we used four different maps (i.e., 1973, 1981, 1990, and 2001). We then built annual maps using these four decennial maps by adding the yearly natural (wildfires, windthrows, and insect outbreaks) and human (logging activities) disturbances. Annual maps of the disturbance polygon shapefiles were produced by the MRNF using the same aerial photographs as those used to elaborate ecoforest maps, but with a resolution of 10 m and a

minimum area of 0.1 ha. We removed disturbances when they reached 20 years old, assuming their potential to provide food to bears decreased rapidly from that age on (Brodeur et al. 2008). When a new SIFORT map became available, for example in 1990, we used it to update the attributes of the tiles and continued to add yearly disturbances.

Land cover classes

We used the land cover data of the SIFORT maps to identify the land cover types most likely to provide abundant fleshy fruits or anthropogenic food resources for bears during hyperphagia, based on Nielsen et al. (2004; 2020): ≤ 5-year-old clearcuts, 6–10-year-old clearcuts, 11–20-year-old clearcuts, ≤ 20-year-old forest fires (wildfires), ≤ 20-year-old insect outbreaks, ≤ 20-year-old windthrows, and agricultural lands. We intended to assess the availability of hard mast using the proportion of 40–100-year-old deciduous stands dominated by red and white oaks or American beech, but the occurrence of these species on maps was not available before 2001, as they were grouped with other species of hardwood trees as "shade-tolerant hardwoods". To consider the potential availability of these important hard mast-producing species, we used two different approaches. For oaks, we first trained a logistic regression on the 2001 ecoforest map to predict their occurrence based on variables that were available in all four SIFORT maps covering our time range (e.g., tree height class, tree density class). We evaluated the performance of the model using 10-fold cross-validations with the 2001 ecoforest map. We then used the model to predict the occurrence of oaks within 40–100-year-old deciduous forest stands in all four SIFORT maps, from 1973 to 2001, and later estimated their availability to individual bears (see details below in *Data analyses – Defining the bears' surrounding environment*). For American beech, we used the same approach as for oaks, but the model fit was low. We then decided to map the distribution area of beech and use a binary variable indicating whether each bear location buffer zone intersected (1) or not (0) with this area, indicating if the bear could potentially access beechnuts (details in Supporting Information 3).

Data analyses

Defining the bears' surrounding environment

A substantial proportion of individuals used in the body condition analysis (37.7%, n = 721 bear-years) and all individuals included in the age at primiparity analysis were not monitored using telemetry. Therefore, the only spatial reference we had for most individuals was their capture or harvest location. To characterize the surrounding environment in which bears lived prior to capture or harvest, we generated circular buffers centered on each capture or harvest point, assuming that this area was representative of the resources and meteorological conditions bears experienced during the previous year. We determined buffer sizes based on annual home-range sizes of bears within our dataset that were equipped with a GPS telemetry collar and monitored for an entire year (n = 485 bear-years). To do so, we first selected collared bears with a complete year of telemetry monitoring and calculated their annual home-range size using the 100% minimum convex polygon method (Mohr 1947). Then, we calculated the median home range size for each sex and bioclimatic domain, ending with buffer sizes varying from 25.5 km^2 to 613.3 km^2 (see Supporting Information 4 Table S4). Since we had no GPS telemetry data from the maple – hickory and maple – basswood bioclimatic domains, we used the same buffer size as the most similar domain (i.e., maple – yellow birch). We used the buffer zone approach for all bears, including those equipped with a telemetry collar, to standardize the method and ensure consistency between older and more recent data.

Relationships between weather variables and body mass

Body mass is recognized as a good indicator of bear body condition, but it needs to be adjusted for the time of the year (i.e., Julian day), as it fluctuates across seasons (Noyce & Garshelis 1998; McLellan 2011; Bartareau et al. 2012). Bears rapidly gain mass during the hyperphagia period (from late-summer to den entry in late-autumn) and loose mass during denning period (Lessard et al. 2002; McLellan 2011). Although some may gain or maintain their mass after den emergence, lactating females and males often loose mass until early

summer (Noyce & Garshelis 1998). Body mass also varies by age and sex; young males grow faster and reach a higher adult mass than females (Bartareau et al. 2012). The mass of females is also correlated with their reproductive status, as pregnant females or females with cubs have a higher body mass than those accompanied by yearlings or without young (Samson & Huot 1995; Noyce & Garshelis 1998). To account for these sources of variation, we modeled body mass as a function of date of capture, age, sex and reproductive status (hereafter referred as demographic group: male, female with cub(s), female with yearling(s), female alone), and used this adjusted value of body mass as an index of body condition. We pooled the rare cases of females with 2-year-old cubs (n = 2) during winter with those accompanied with yearlings. We also used an "unknown" demographic group category for females with missing reproductive information in our database (n = 471 bear-years).

We modeled the relationship between the body mass of bears and local weather using linear mixed models (R package *lme4*, Bates et al. 2015). For this analysis, we used all sampling occasions for which body mass data was available, resulting in 1912 bear-years ranging from 1 to 28 years old (n = 1137 individual bears). Before running the analysis, we standardized the continuous variables to directly compare their coefficients and improve the convergence of the models (Bates et al. 2015). We built nine candidate models, each representing a distinct underlying hypothesis (Table 3). The first one, the base model, included only the variables relative to individual bear characteristics, i.e., demographic group with the age and its quadratic term to account for rapid growth in early life and the slower growth as bears age (Bartareau et al. 2012), as well as potential senescence in older individuals (Nelson et al. 2024). We also included a quadratic term for the Julian day of capture to consider the seasonal variation of body mass (McLellan 2011; Bartareau et al. 2012). The bear ID was included as a random effect to control for repeated measurements of the same individual (Quinn & Keough 2024). We included an interaction between the demographic group and the age to consider the differences between males, lactating females, and non-lactating females (Noyce & Garshelis 1998; Bartareau et al. 2012; Bartareau 2019).

We also added latitude and longitude as well as their interaction to control for the spatial autocorrelation among samples, with individuals located closer together being more similar than those further apart (Murray & Sandercock 2020).

In addition to the variables included in our base model, our second candidate model also considered the availability of land cover types likely to provide high density of food resources for bears (Table 3). We thus calculated, as indices of food availability, the proportion of the buffer surrounding each bear's location occupied by the different land cover types likely to provide high food availability, along with a binary predictor indicating whether the bear location buffer intersected with the distribution area of the American beech. The last seven candidate models all included the individual covariates and land cover types likely to provide high food availability, but also different combinations of the weather variables likely to influence food productivity and accessibility, namely the number of hours below 0.0°C during the flowering period of fleshy fruit-bearing species, the 3-month SPEI of August, and the growing season length (in days) of the previous growing season (Table 3).

Table 3. Candidate models used to assess the variations of the adjusted body mass of black bears (linear mixed models) with the number of parameters (*k*) and the difference between the model and the most parsimonious model (no. 9; ΔAIC).

Model name	Explanatory covariates	*k*	ΔAIC
1 – Base model	Demographic group[a] + (Age + Age^2) + Demographic group*(Age + Age^2) + (Julian day + Julian day^2) + Latitude + Longitude + Latitude*Longitude + (1| ID-bear)	20	82.73
2 – Land cover	%Oak 40-100 years old + American beech presence/absence + %Agricultural land + %Clearcuts 0-5 years old + %Clearcuts 6-10 years old + %Clearcuts 11-20 years old + %Wildfires ≤ 20 years old + %Insect Outbreak ≤ 20 years old + %Windthrow ≤ 20 years old + Base model	29	55.65
3 – Spring frost	No. hours < 0.0°C + Land cover model	30	51.97
4 – Summer precipitation	3-month SPEI[b] of August + Land cover model	30	7.31
5 – Growing season length	Growing season length + Land cover model	30	47.29
6 – Spring frost + Summer precipitation	No. hours < 0.0°C + 3-month SPEI of August + Land cover model	31	1.61
7 – Spring frost + Growing season length	No. hours < 0.0°C + Growing season length + Land cover model	31	43.81
8 – Summer precipitation + Growing season length	3-month SPEI of August + Growing season length + Land cover model	31	5.46
9 – Spring frost + Summer precipitation + Growing season length	No. hours < 0.0°C + 3-month SPEI of August + Growing season length + Land cover model	32	0.00

[a] Demographic group: male, female with cub(s), female with yearling(s), female alone, female with unknown reproductive status.

[b] SPEI: Standardized Precipitation Evapotranspiration Index.

Relationships between weather variables and probability of primiparity

We modeled the probability of primiparity of bears as a function of land cover types, weather variables, and age of each female using mixed logistic regressions (R package *lme4*, Bates et al. 2015). We used the reproductive history dataset from the harvested females' teeth analyses (n = 710). As the earliest age of primiparity in our dataset was 2 years, we created a binary variable for each year a female was ≥ 2 years old until primiparity, indicating whether the female reproduced for the first time (1) or not (0) during that year (following Wightman et al. 2022). For example, for a female that gave birth for the first time at the age of 5 and was harvested in spring 2020 at 8 years old, the binary variable was set at 0 from 2 to 4 years old (2014 to 2016), to 1 at 5 years old (2017), and the subsequent years (6, 7 and 8 years old) were not included in the analysis. As explanatory variables, we used the land cover data measured around the harvest location, using the same buffer size as for the body mass analyses and weather data recorded during the active period preceding a potential birthing event ($year_{-1}$). As for the analysis on body mass, we standardized all numerical covariates to improve the convergence of models as well as to compare the effects of weather and land cover variables (Bates et al. 2015).

The base model for the probability of primiparity included only the individual predictors also included in all our candidate models: bear age in the current year, latitude and longitude of the harvest location, interactions between age and latitude and between latitude and longitude. We grouped females of age 6 and more (up to 9 years old) in the same 6+ age group because of the low sample size (n = 23 female with primiparity at age 7 and more). We also added the bear ID as a random factor. Age was log-transformed because older females have a higher probability of primiparity than younger ones (Wightman et al. 2022), and because the relationship between age and probability of primiparity is expected to reach 100%, as our dataset includes only females that eventually reproduced at least once.

The second candidate model considered both the land cover and individual variables of the base model. We decided to pool 0–5-year-old clearcuts with 6–10-year-old clearcuts to create the 0–10-year-old clearcuts category because too many bear buffers had null values.

We did the same by pooling wildfires, windthrows, and insect outbreaks to create the 0–20-year-old natural disturbances category. We also added an interaction between each land cover variables and log-transformed age to assess if the proportion of land cover types influenced the probability of primiparity at a given age (Table 4). The last seven candidate models included land cover types and individual covariates, as well as combinations of the following three weather variables: number of hours below 0.0°C during the flowering period of fruit-bearing species, 3-month SPEI of August, and growing season length, in addition with their interaction with the log-transformed age. We added an interaction between weather variables and the log-transformed age in the other candidate models for similar reasons as for land cover types (Table 4).

We verified the model assumptions of our statistical analyses with the *performance* (Lüdecke et al. 2021) and *DHARMa* (Hartig 2022) R packages. We used the Variance Inflation Factor (VIF; Graham 2003) to test the multicollinearity between covariates (all VIF values were ≤ 3.53 for the body mass models and ≤ 2.62 for the probability of primiparity models). We ranked models with the AIC and interpreted the coefficients of the most parsimonious model. We considered a variable statistically significant when the 95% confidence intervals of the coefficient did not overlap with zero. We compared the selected models to a model with non-linear effects of the included weather variables (log-transformed number of hours below 0.0°C, and quadratic effect of the 3-month SPEI of August and the growing season length) with the AIC. The model with linear effects received the greatest support for all weather variables. We determined the model fit with the marginal and conditional R^2. We conducted all statistical analyses in R 4.2.0 (R Core Team, 2022).

Table 4. Candidate models used to assess the variation in the probability of primiparity of female black bears with the number of parameters (*k*) and the difference between the model and the most parsimonious model (no. 8; ΔAIC).

Model name	Explanatory covariates	*k*	ΔAIC
1 – Base model	Log(Age) + Latitude + Longitude + Log(Age)*Latitude + Latitude*Longitude + (1|ID-bear)	6	18.19
2 – Land cover	%Oak 40-100 years old + American beech presence/absence + %Agricultural land + %Clearcuts 0-10 years old + %Clearcuts 11-20 years old + %Natural disturbances ≤ 20 years old + Log(Age)*%Oak 40-100 years old + Log(Age)*American beech presence/absence + Log(Age)*%Agricultural land + Log(Age)*%Clearcuts 0-10 years old + Log(Age)*%Clearcuts 11-20 years old + Log(Age)*%Natural disturbances ≤ 20 years old + Base model	18	14.16
3 – Spring frost	No. hours < 0.0°C + Log(Age)*No. hours < 0.0°C + Land cover model	20	17.30
4 – Summer precipitation	3-month SPEI[a] of August + Log(Age)*3-month SPEI of August + Land cover model	20	1.67
5 – Growing season length	Growing season length + Log(Age)*Growing season length + Land cover model	20	12.68
6 – Spring frost + Summer precipitation	No. hours < 0.0°C + 3-month SPEI of August + Log(Age)*No. hours < 0.0°C + Log(Age)*3-month SPEI of August + Land cover model	22	5.32
7 – Spring frost + Growing season length	No. hours < 0.0°C + Growing season length + Log(Age)*No. hours < 0.0°C + Log(Age)*Growing season length + Land cover model	22	15.83
8 – Summer precipitation + Growing season length	3-month SPEI of August + Growing season length + Log(Age)*3-month SPEI of August + Log(Age)*Growing season length + Land cover model	22	0.00
9 – Spring frost + Summer precipitation + Growing season length	No. hours < 0.0°C + 3-month SPEI of August + Growing season length + Log(Age)*No. hours < 0.0°C + Log(Age)*3-month SPEI of August + Log(Age)*Growing season length + Land cover model	24	3.55

[a] SPEI: Standardized Precipitation Evapotranspiration Index.

Relationships between weather variables and interbirth interval

We combined the body mass and the female reproductive history datasets, and selected females with two or more reproduction events, resulting in a dataset of 487 female bears. The variation in interbirth interval was too low to perform a regression analysis (91.8% of the females had a 2-year interbirth interval and 8.2% had an interval of ≥ 3 years). Instead, we performed a Chi-squared test to assess if the relative frequency of interbirth intervals varied with weather conditions and land covers at the regional scale using the following bioclimatic domains: Maple (including Maple – hickory, Maple – basswood, and Maple – yellow birch), Balsam fir – yellow birch, Balsam fir – white birch, and Black spruce – mosses (see Supporting Information 5 Table S5).

RESULTS

Relationships between weather variables and body mass

The most parsimonious model explaining variation in body mass included the three weather variables as well as the landcover types and other covariates (Model 9; Table 3). Variables included in the most parsimonious model are the number of hours below 0.0°C during flowering, the 3-month SPEI of August, and the growing season length. The model had a good fit to the data (marginal $R^2 = 0.84$, conditional $R^2 = 0.90$; Table 5). The base model had the lowest support (ΔAIC = 82.73; Table 3) followed by the model with the land cover variables only (ΔAIC = 55.65; Table 3). In contrast, models including at least one weather variable always had a greater support (ΔAIC ranging from 51.97 to 0.00; Table 3).

Bear body mass was significantly influenced by all weather variables we considered, and the weather variable with the strongest effect was the 3-month SPEI of August, followed by the number of hours below 0.0°C during flowering and finally the growing season length (Table 5). Bear mass decreased as the number of hours below 0.0°C during flowering increased, at a rate of 0.45 kg per hour below 0.0°C during flowering (Figure 3a, d). It increased with the 3-month SPEI of August (i.e., under more humid conditions) at a rate of 1.87 kg per unit (Figure 3b, e), and decreased with growing season length at a rate of -0.03 kg per growing season day (Figure 3c, f). Regarding the landcover types, bear mass increased with the availability of 40–100 year-old oak stands and agricultural lands (Table 5). The presence of American beech and the proportional availability of wildfires, windthrows, and clearcuts had no effect on mass (Table 5).

Notwithstanding the effect of weather and landcover variables, the mass of males was significantly higher than that of females (Table 5; Figure 3d-f), and among females, those with cubs had a higher mass than those accompanied by yearlings or lone females (Figure 3d-f) whereas the latter two groups did not differ. The bear mass gradually decreased from the beginning of the year until the end of May (Julian day 150), and gradually increased after that (Figure 4a, c). The mass of males and females increased rapidly at a young age, but this

growth gradually slowed, and the mass eventually reached an asymptote (Figure 4b, d). Males grew faster and reached a higher maximal mass than females.

Relationships between weather variables and reproduction indices

The probability of primiparity was best explained by the model including the 3-month SPEI of August and the growing season length (Model 8, Table 4) and showed a moderate fit to the data (marginal $R^2 = 0.56$, conditional $R^2 = 0.60$; Table 6). The base model had the lowest support among all models ($\Delta AIC = 18.19$; Table 4). The land cover only model ranked among the weather variable models ($\Delta AIC = 14.16$; Table 4).

The 3-month SPEI of August had a significant positive effect on the probability of primiparity, regardless of age, with the probability increasing from 10% to 24% between the lowest (less humid conditions) and highest (more humid) SPEI values (Figure 5a, c). The effect of growing season length varied with age. For 2- and 3-year-old females, the probability of primiparity did not change or slightly decreased with longer growing season (Figure 5b, d). For older females, the probability of primiparity increased by approximately 10–22% between the shorter and longer growing seasons (i.e., ca. between 70 and 180 days). The coefficient of the interaction between the growing season length and the log-transformed age was higher than that of the 3-month SPEI of August (Table 6). The availability of 40–100-year-old oak forest stands increased the probability of primiparity across all age classes (Table 6). The availability of agricultural lands, natural and anthropogenic disturbances, and the presence of American beech had no significant effect on the probability of primiparity. The relative frequency of interbirth intervals did not differ between bioclimatic domains ($\chi^2 = 5.4$, degrees of freedom = 3, $p = 0.15$).

Table 5. Coefficient estimates (β) and 95% confidence intervals (95% CI; [lower : upper]) of the most parsimonious linear mixed model used to assess the relationships between adjusted body mass and weather variables, land cover types, and individual characteristics of black bears (n = 1912 black bear captures) in Québec (eastern Canada) from 1983 to 2023. Variables in bold are considered to have a statistically significant effect on the adjusted body mass (i.e., 95% CI not overlapping zero). All continuous variables were scaled. The reference demographic group is Female – alone.

Groups of variables	Variables	β	95% CI
	Intercept	**47.188**	**[44.442 : 49.934]**
Weather			
	No. Hours < 0.0°C	**-0.832**	**[-1.404 : -0.260]**
	3-month SPEI of August	**1.822**	**[1.303 : 2.342]**
	Growing Season length	**-0.590**	**[-1.148 : -0.031]**
Land cover types			
	%Oak 40-100	**1.053**	**[0.288 : 1.818]**
	American beech presence/absence	-1.435	[-3.663 : 0.794]
	%Clearcuts 0-5	-0.178	[-0.756 : 0.399]
	%Clearcuts 6-10	0.397	[-0.191 : 0.986]
	%Clearcuts 11-20	0.179	[-0.568 : 0.926]
	%Wildfires ≤ 20	-0.092	[-0.797 : 0.613]
	%Windthrows ≤ 20	-0.039	[-0.597 : 0.520]
	%Insect outbreaks ≤ 20	0.465	[-0.135 : 1.065]
	%Agricultural land	**1.231**	**[0.667 : 1.794]**
Individual variation			
	Female - cub	8.093	[5.264 : 10.923]
	Female - unknown	4.134	[1.515 : 6.754]
	Female - yearling	-1.832	[-5.617 : 1.953]
	Male	40.236	[37.390 : 43.081]
	Age	21.221	[19.737 : 22.704]
	Age^2	-6.812	[-7.846 : -5.779]
	Julian Day	**-2.161**	**[-2.871 : -1.452]**
	Julian day^2	**3.674**	**[3.146 : 4.203]**
	Latitude	-0.772	[-2.107: 0.563]
	Longitude	-0.226	[-0.755 : 1.207]
	Female - cub * Age	**-7.972**	**[-12.038 : -3.906]**
	Female - unknown * Age	**-7.477**	**[-9.671 : -5.284]**
	Female - yearling * Age	**-9.824**	**[-15.560 : -4.089]**
	Male * Age	**25.009**	**[23.060 : 26.958]**
	Female - cub * Age^2	**3.869**	**[2.036 : 5.703]**
	Female - unknown * Age^2	**3.092**	**[1.758 : 4.427]**
	Female - yearling * Age^2	**3.572**	**[1.362 : 5.781]**
	Male * Age^2	**-6.950**	**[-8.515 : -5.384]**
	Latitude * Longitude	**1.320**	**[0.107 : 2.531]**
Model fit			
	Marginal R^2 = 0.84	Conditional R^2 = 0.90	

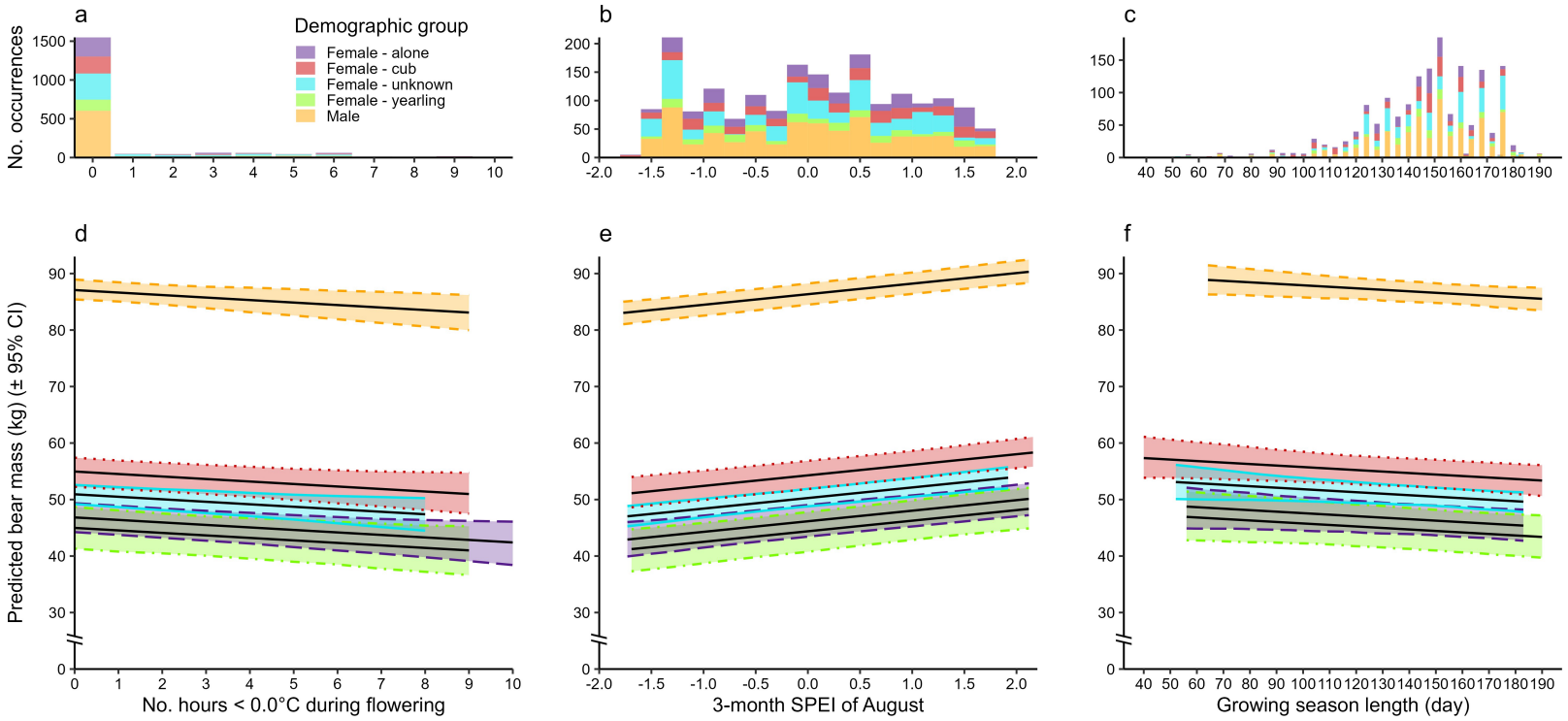

Figure 3. Top row: frequency histograms of (a) the number of hours below 0.0°C during the flowering period of fruit-bearing species, (b) the 3-month Standardized Precipitation Evapotranspiration Index (SPEI) of August, and (c) the growing season length, as recorded for demographic groups (represented by stacked bars) in the bear body mass database, for a total of 1912 bear-years. Bottom row: marginal effect of (d) the number of hours below 0.0°C during the flowering period of fruit-bearing species, (e) the 3-month SPEI of August, and (f) the growing season length, based on the most parsimonious model used to assess the relationships between bear adjusted body mass and weather variables, land cover types, and individual characteristics of black bears in Québec (eastern Canada), from 1983 to 2023. All effects are shown across the observed range of each variable, with other predictors fixed at their mean values. The model accounts for individual age, capture location, and capture date. Solid lines represent the predicted bear adjusted body mass, and shaded areas indicate the 95% confidence intervals. A different line is shown for each demographic group.

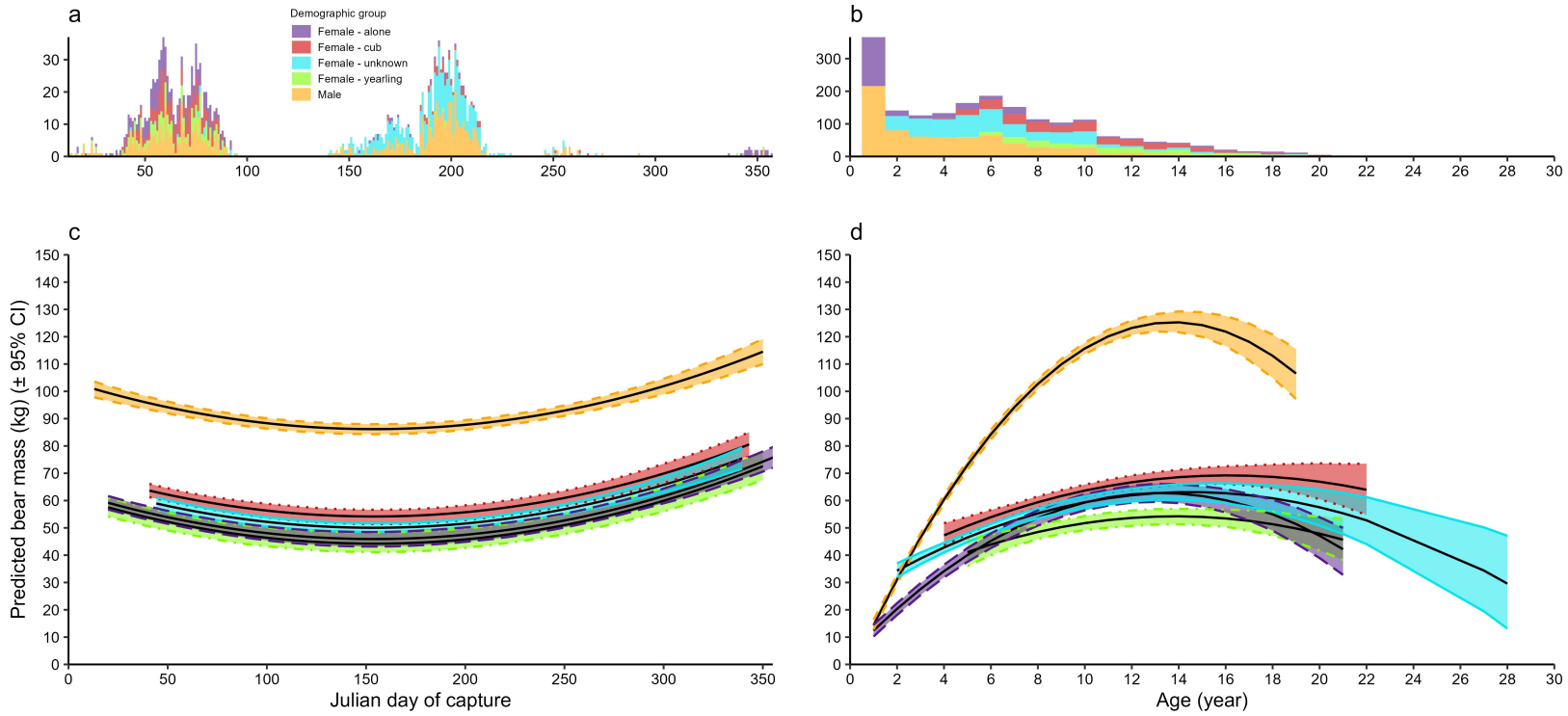

Figure 4. Top row: frequency histograms of (a) the Julian day of the capture date and (b) the individual's age, as recorded for the demographic groups (represented by stacked bars) in the bear body mass database, for a total of 1912 bear-years. Bottom row: marginal effect of (c) the Julian day of the capture date and (d) the individual's age, based on the most parsimonious model used to assess the relationships between the adjusted body mass and weather variables, land cover types, and individual characteristics of black bears in Québec (eastern Canada) from 1983 to 2023. All effects are shown across the observed range of each variable, with other predictors fixed at their mean values. Solid lines represent predicted bear adjusted body mass, and shaded areas indicate 95% confidence intervals. A different curve is shown for each demographic group.

Table 6. Coefficient estimates (β) and 95% confidence intervals (95% CI; [lower : upper]) of the most parsimonious model used to assess the relationships between probability of primiparity and weather variables, land cover types, and individual characteristics of black bears (n = 710 females) in Québec (eastern Canada) from 2005 to 2022. Variables in bold are considered to have a statistically significant effect on probability of primiparity (i.e., 95% CI not overlapping zero). All continuous variables were scaled.

Groups of variables	Variables	β	95% CI
	Intercept	**-1.735**	**[-2.002 : -1.468]**
Weather			
	SPEI	**0.202**	**[0.058 : 0.347]**
	SPEI * Log(Age)	0.062	[-0.099 : 0.223]
	Growing season length	-0.044	[-0.204 : 0.117]
	Growing season length * Log(Age)	**0.188**	**[0.018 : 0.358]**
Land cover types			
	%Clearcuts 0-10	0.042	[-0.116 : 0.200]
	%Clearcuts 0-10 * Log(Age)	0.140	[-0.055 : 0.334]
	%Clearcuts 11-20	0.091	[-0.070 : 0.252]
	%Clearcuts 11-20 * Log(Age)	-0.123	[-0.291 : 0.044]
	%Natural disturbances ≤ 20	0.017	[-0.161 : 0.196]
	%Natural disturbances ≤ 20 * Log(Age)	0.151	[-0.112 : 0.414]
	%Agricultural land	-0.018	[-0.175 : 0.139]
	%Agricultural land * Log(Age)	0.128	[-0.054 : 0.311]
	%Oaks 40-100	0.054	[-0.105 : 0.214]
	%Oaks 40-100 * Log(Age)	**0.270**	**[0.040 : 0.501]**
	American beech presence/absence	0.396	[-0.055 : 0.848]
	American beech presence/absence * Log(Age)	-0.103	[-0.575 : 0.370]
Individual variation			
	Log(Age)	2.136	[1.726 : 2.546]
	Latitude	-0.272	[-0.527 : -0.016]
	Longitude	**0.168**	**[0.016 : 0.319]**
	Latitude * Log(Age)	**0.257**	**[0.005 : 0.508]**
	Latitude * Longitude	0.129	[-0.054 : 0.312]
Model fit			
	Marginal R^2 = 0.56	Conditional R^2 = 0.60	

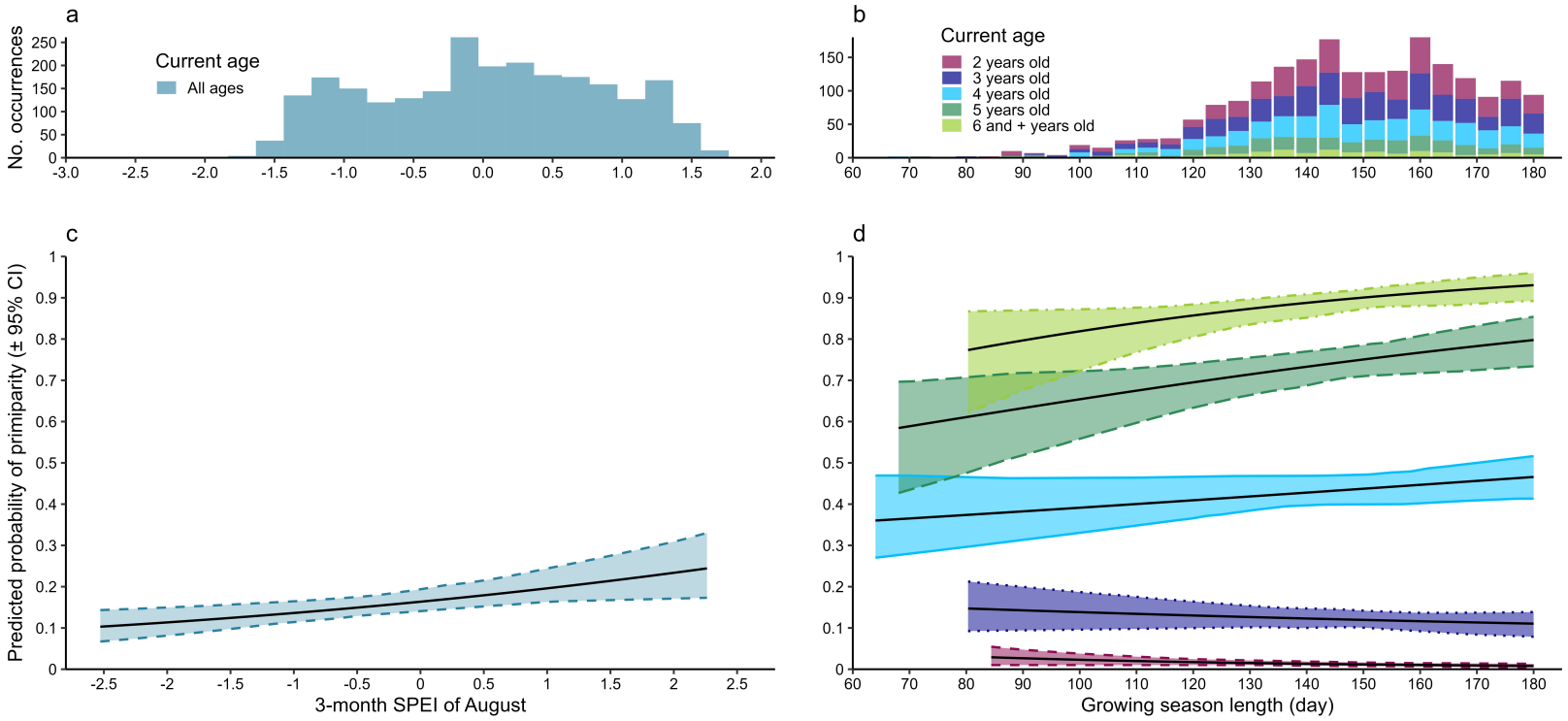

Figure 5. Top row: frequency histograms of (a) the 3-month Standardized Precipitation Evapotranspiration Index (SPEI) of August, and (b) the growing season length, as recorded for each age (represented by stacked bars) in the reproductive history database, for a total sample size of 2463 bear-years and 710 different females. Bottom row: marginal effect of (c) the 3-month SPEI of August, and (d) the growing season length, based on the most parsimonious model used to assess the relationships between probability of primiparity and weather variables, land cover types, and individual characteristics of black bears in Québec (eastern Canada), from 1986 to 2022. All effects are shown across the observed range of each variable, with other predictors fixed at their mean values. Solid lines represent predicted probability of primiparity, and shaded areas indicate 95% confidence intervals. Results are shown for each age category found in the dataset.

DISCUSSION

By combining data on 1824 individual black bears collected as part of 8 studies covering a vast latitudinal gradient and 41 years of surveys, we showed how three local weather variables, known to influence plant productivity or availability, strongly correlate with two of our three important life-history traits, namely the time-, demographic group-, and age-adjusted body mass (an index of body condition) and the females' probability of primiparity (an important determinant of reproductive success and fitness). We showed that a lower number of hours of frost during the flowering of fruit-bearing species and a higher water availability during summer were associated with an increase in body mass the following year. Also, a greater water availability during summer and a longer growing season were associated to a higher probability of primiparity the following year. Our results illustrate how weather can influence some key variables of black bear demography, paving the way for a better understanding of the potential impacts of climate change on an opportunistic omnivore.

Linking weather variables to body mass

We found a negative relationship between the body mass and the frequency of frost events during the flowering period of fruit-bearing species, with a body mass loss of 0.45 kg per hour of frost from 0 to 10 hours of frost. Flowering is a critical stage for fruit development, and frequent or intense frost events during this relatively short period of time can substantially reduce the availability of fruits and seeds the following autumn. Since bears in boreal forests accumulate most of their body fat during this period (Jonkel & Cowan 1971), reduced fruit production can negatively impact their body condition, with effects potentially lasting until the period of hyperphagia of the following year. Hertel et al. (2018) also found that low minimum temperatures during the flowering of bilberry (*V. myrtillus*) was correlated with low berry production, resulting in low body mass of female brown bears in autumn. Ruiz-Villar et al. (2019) previously suggested that late spring frost events and summer drought may have reduced acorn production at higher elevations, resulting in the unusual aggregation of brown bears at lower elevations during hyperphagia in the Cantabrian Mountains (Spain). Late spring frosts were also correlated with higher mortality from human-

bear conflicts possibly as a result of frost damage to flowers and fruits, inducing the loss of key food resources (Shoemaker et al. 2025).

Other fruit and hard mast consumers, such as deer (e.g., *O. virginianus*), turkeys (e.g., *Meleagris gallopavo*), and squirrels (e.g., *Sciurus carolinensis*) could be affected by frost in a similar way during the flowering of masting species (Inouye 2000). For instance, a severe frost that occurred in May 1966 damaged flowers and seeds of several species consumed by gray squirrels in southeast Ohio, reducing food availability the following autumn, and the body mass of adult females and subadults (Nixon & McClain 1969). Consequently, the squirrel population density declined by 83% in 1967 (Nixon & McClain 1969). Like other species with an omnivore diet, bears eat a great diversity of items and often shift to alternative food sources when availability is low due to unfavorable weather conditions (reviewed in Kurth et al. 2024). During years of hard mast failure, or where hard mast species are absent, bears were shown to rely predominantly on fleshy fruits to meet their nutritional needs (Kasbohm et al. 1995). In years of overall poor natural food availability, some bears may increase their use of urban and agricultural areas where they can find anthropogenic food to complete their fat reserves before denning (Baruch-Mordo et al. 2014; Ditmer et al. 2016). This behavior increases the occurrences of human-bear conflicts (Can et al. 2014; Obbard et al. 2014), with bears feeding on livestock and crops, and causing property damage (Davenport 1953; Miller et al. 2016; Doan-Crider et al. 2017). Moreover, such years of poor food availability were associated with higher bear mortality (Ryan et al. 2007), potentially threatening the long-term viability of small local populations (Can et al. 2014).

We showed that the body mass of bears was higher following summers characterized by a high water availability. An increase of one unit of the 3-month SPEI (i.e., one standard deviation of the long-term average, 30 years), meaning wetter summer conditions, was associated with a 1.87 kg increase of the body mass. Such conditions promote plant development (Wu et al. 2011) and increased fruit and seed production (Howe et al. 2012), leading to abundant food resources that favor mass gain for bears, especially during hyperphagia. Similar patterns were observed in herbivores, where increased rainfall and water availability led to improved body condition. For instance, increased water availability

during summer enabled female elks (*Cervus canadensis*) to gain more body fat by late autumn (November-December), likely due to enhanced plant digestibility and nutrient intake (Brown et al. 2025). Resource availability also has potentially long-term effects on individuals. In female Przewalski's horses (*Equus ferus przewalskii*), higher summer precipitation during the first year of life was associated with better body condition up to ages 3–4 (Rödel et al. 2023).

We found a negative relationship between body mass and the growing season length, contradicting our prediction that a longer growing season will result in higher body mass due to a longer period of food availability. A longer growing season could be associated with modifications in the fruiting and masting phenology rather than with an increase in food availability, requiring bears to adjust their foraging behavior to meet their nutritional requirements during the period where plants (and, to a lesser extent, fruits) are palatable, more digestible, and abundant. Several hypotheses could be put forward to explain this intriguing result. First, a longer growing season could lengthen the period between den emergence and the onset of hyperphagia, forcing bears to rely on lower quality or less abundant food during a longer period in spring and early summer, thus leading to mass loss or limited mass gain, mainly of fat. Noyce & Garshelis (1998) indeed showed that males and lactating females lose weight when feeding on low quality food during spring, while non-lactating females and young individuals may be able to maintain or even gain body mass. Second, a longer growing season may not necessarily result in increased foraging opportunities or access to abundant, high-quality food during late summer and autumn. For example, an extended growing season and earlier flowering can lead to earlier fruit maturation (Gallinat et al. 2015), potentially reducing net energy intake during the second half of hyperphagia. Moreover, some individuals, especially pregnant females, could enter their den early even if food is available (Schooley et al. 1994, Fowler et al. 2019), thereby avoiding possible periods of neutral or negative energy balance. Finally, a longer growing season could increase reproductive costs if earlier den emergence enhances cub survival, allowing mothers to successfully wean more cubs. However, we cannot investigate this potential relationship, as we did not consider cub survival. Moreover, this hypothesis would

not provide an explanation for males or non-reproductive females. Current knowledge on long-term fruiting phenology and how climate change affects it remains limited and likely varies greatly among species (Gallinat et al. 2015; Mendes et al. 2023), constraining our ability to identify the underlying drivers of fruiting timing. It is unclear whether fruiting is only controlled by intrinsic species-specific factors, causing it to advance in parallel with earlier flowering, or primarily by environmental cues, in which case fruiting would occur within a relatively consistent period regardless of shifts in the timing of flowering (Sandor et al. 2021). Understanding the mechanisms at play between variations in bear body mass and plant growing season length will thus require further investigations.

As previously reported (see Mahoney et al. 2001; Bartareau et al. 2012), bears in our study sites gained weight rapidly early in life, with growth gradually slowing and approaching an asymptote as they reached physical maturity. Body mass also varied seasonally, consistent with previous findings showing rapid weight gain from mid-summer until den entrance and weight loss thereafter (Noyce & Garshelis 1998; McLellan 2011; Bartareau et al. 2012). To account for individual and seasonal variations in body mass, we included age, sex, reproductive status, and Julian day of capture in our models, factors known to influence bear body mass (Samson & Huot 1995; Noyce & Garshelis 1998, McLellan 2011, Bartareau et al. 2012). The addition of these variables allowed us to isolate the effects of weather and land cover, a necessary step to assess the influence of climatic conditions on life-history traits, which was our main objective.

We detected a significant positive effect of the availability of mature oak forests and agricultural land on body mass. These results are consistent with previous studies showing that these land cover types provide high food density (Boileau et al. 1994; Noyce & Garshelis 2011; Ditmer et al. 2016). In contrast, other land cover types (i.e., the presence of American beech, the availability of clearcuts, wildfires, windthrows, and forest stands affected by insect outbreaks) did not significantly influence body mass and the probability of primiparity, even if previous studies showed that bears select these forest covers for food (Boileau et al. 1994; Samson & Huot 1995; Brodeur et al. 2008). These results may appear counterintuitive, as these four landcover types are known to provide foraging opportunities to bears (Costello

& Sage 1994; Brodeur et al. 2008). Windthrows are the main natural disturbance in the maple bioclimatic domains, and bears from these regions probably foraged in hard mast forest stands instead of windthrows. Forest stands affected by an insect outbreak were rare in our study areas, with most bears (~90%) not having access to them. While bears may feed in these stands, they may be too rare to have a detectable influence the bears' mass. Logging operations were generally widespread and abundant across our study area. Substantial variation nevertheless exists among clearcuts with respect to silvicultural treatments (e.g., proportion of trees harvested, planting, pre-commercial thinning) and the composition of early-successional vegetation. These factors, in turn, determine the species that regenerate and their potential value as a food resource for black bears. Our broad classification of logging activities likely was not detailed enough to capture this variability. For the American beech, the productivity fluctuates greatly each year, alternating between years of high and low mast production (Cleavitt & Fahey 2017). Consequently, any positive effects during productive years may be offset by poor mast years, potentially masking the relationship in our models.

Linking weather variables to the probability of primiparity

The probability of primiparity of females increased with the availability of water during the summer of the previous year, independently of their age. In agreement with the body mass analysis, this suggests that abundant plant resources following a summer of high primary productivity (see section above) allowed females to accumulate greater fat reserves before denning. Female bears need enough fat reserves to properly complete gestation and successfully produce cubs (Rogers 1976; Samson & Huot 1995), and those accumulating more fat, and thus reaching the necessary body mass threshold at a younger age, can reproduce earlier (Stringham 1990). Our results differ from those of Wightman et al. (2022), who found no significant relationship between total precipitation of the previous year and the probability of primiparity in black bears in Ontario. We suggest that the shorter time range of our water availability index (SPEI) could explain this difference, as it focuses on the period of fruit maturation only, and that precipitation alone cannot capture the entire

drought signal. Indeed, the 3-month SPEI also integrates the effects of potential evapotranspiration by considering temperature, an important variable in drought events (Vicente-Serrano et al. 2010). Thus, we argue that the SPEI may be seen as a better tool to estimate water availability for plants than total precipitation.

Some studies have proposed that the reproductive success of female bears is linked to resource availability, for example with females with a lower body mass (McLaughlin et al. 1994) having higher probabilities of unsuccessful reproduction (Costello et al. 2003; Bridges et al. 2011) in winters following a hard mast failure. In mammals, maternal condition significantly influences reproduction success because of its high energetic cost, particularly lactation (Gittleman & Thompson 1988, Clutton-Brock et al. 1989). Abundant food resources were shown to reduce the interbirth intervals of wolverines (*Gulo gulo*, with supplemental feeding: Persson 2005), lead to higher conception rates of Assamese macaques (*Macaca assamensis*: Heesen et al. 2013), and increase the probability of pupping and weaning success of Antarctic fur seal (*Arctocephalus gazella*: Lunn et al. 1994). Gould et al. (2021) reported that yearling female black bears with access to urban environments, likely linked with access to anthropogenic food, reached a higher body mass than their rural counterparts and could produce their first litter of cubs as early as 2 years old. A younger age at primiparity could lead to a longer active reproduction period and therefore a higher number of reproduction events during a female's life.

The growing season length had varying effects on the probability of primiparity depending on the age of the females. Although this result partially supports our prediction, it should be interpreted with caution. The weak relationship between the growing season length and probability of primiparity at 2 and 3 years old suggests that reproduction at these ages is relatively uncommon and might be influenced by variables not considered in our models (e.g., access to anthropogenic food: Gould et al. 2021). The positive relationship at an age of 4 years old (and more) could be explained by a longer out-of-the-den period allowing females to forage for a longer period and accumulate more body reserves prior to den entrance, although this interpretation is not supported by our body mass analysis. Pregnant females

could also enter the den earlier than other individuals (Fowler et al. 2019), possibly reducing energy expenditures while still benefiting from increased plant productivity.

Oak stands were the only land cover type having a significant effect on the probability of primiparity in our study area. Hard mast is an important food source for bears (Samson & Huot 1998, Noyce & Garshelis 2011), and its availability is known to influence the body mass and breeding success of females (Rogers 1976; Costello et al. 2003; Seger et al. 2013). In agreement with the body mass analysis, these results support that oak stands have a great positive impact on black bears in our study areas.

Linking weather variables to interbirth interval

We found no significant relationship between the interbirth interval and any of our regional-scale weather variables. In fact, most females (91.8%) in our dataset exhibited a 2-year interval between reproductive events, while 3-year interbirth intervals were exceptional across the study area. A 2-year reproductive cycle is also commonly reported in the literature when bears have access to relatively abundant and diverse food sources (Rogers 1987; Stringham 1990). The low frequency of > 2-year interbirth intervals suggests that most of the female black bears sampled were not exposed to extremely harsh environmental conditions.

Limitations

Assessing weather variables and available habitat components within a buffer zone around the capture locations rather than in the individuals' home ranges may have limited our ability to precisely characterize the conditions experienced by the bears. Our approach assumed that the capture location was in the center of an individual's range, while some individuals may have been captured while making an excursion outside their usual range. Although we had the telemetry data required to delimit the home range for some bears, we preferred to use the same approach with all individuals to preserve consistency across the dataset and keep a maximum number of available samples. We recognise that this approach

may have limited the precision of some explanatory variables and our ability to detect fine-scale effects.

We hypothesized that longer plant growing seasons, and therefore shorter winters, would extend the foraging period for bears, allowing them to accumulate greater fat reserves during hyperphagia. However, this relationship could be true only in certain regions, or the growing season length metric we used may not fully capture the fine-scale events or account for interactions with other environmental factors, such as photoperiod or pollinator phenology. While our approach provided a useful but relatively coarse indicator, future work could benefit from incorporating alternative or complementary indices reflecting the timing, duration, and quality of food available throughout the season at a finer scale.

Conclusions and potential implications of climate changes

Our study highlighted the influence of weather parameters on two fitness-related traits in black bears. Even after accounting for available habitat, we still detected significant effects of weather on the body mass, an index of body condition, and the females' probability of primiparity. We propose that favorable weather conditions, specifically a low frequency of frost events during flowering and a high-water availability during summer, can eventually promote plant productivity and lead to higher availability of fruits and hard masts in late summer and autumn. This higher food availability could, in turn, contribute to improved body condition, with effects extending into the following year until the next period of hyperphagia. Growing season length, however, had opposite effects on body mass and primiparity, thereby complicating the integration of its role into a broader understanding of black bear ecology and paving the way to future studies. While climate can strongly influence life-history and fitness, assessing the impacts of climate change requires considering co-occurring environmental changes, including habitat fragmentation, overexploitation, and the emergence of diseases or parasites, that may exacerbate their effects (Brook et al. 2008).

Within the broader context of climate changes, the long-term trend (1983–2023) of the number of hours below 0.0°C during the flowering of fruit-bearing species declined by an estimated 26% per decade in our study area (Supporting Information 6). Conversely, the

3-month SPEI of August and the growing season length increased by 0.12 units and 1.8 day per decade, respectively, reflecting a trend toward wetter summer conditions and progressively longer growing seasons over time (Supporting Information 6). Together, these results indicate a gradual shift in these three variables relative to past climatic norms, with potential consequences for black bears and their environment depending on the changing rate of each metric. The body mass of bears showed no significant linear trend over the 40-year period of this study, except for females accompanied by yearlings, whose mass increased on average by 0.74 kg per decade (Supporting Information 7 Table S7.2 and Figures S7a,c). Females with yearlings had the lowest body mass among all demographic groups (Figure 4b, d), reflecting the great energetic cost required to rear offspring (Gittleman & Thompson 1988, Clutton-Brock et al. 1989). We argue that these individuals could be more likely to benefit from a potential increase in food availability over time, allowing them to assume more easily the costs associated with parental care and dampen the decline in body condition, to the extent that their body mass became equivalent to that of non-reproductive females in recent years (Supporting Information 7, Figure S7a, c).

The absence of a temporal trend in body mass for the other demographic groups suggests that these individuals already reached their maximum foraging efficiency in the past or that the more recent conditions did not allow them to significantly increase their energy acquisition. Rather than maximizing energy reserves, some individuals may simply aim to reach sufficient reserves to meet their needs for winter survival and reproduction. In black (Schooley et al. 1994) and brown (Fowler et al. 2019) bears, the fact that pregnant females are the first to enter the den, and thus to stop foraging, supports this hypothesis. The probability of primiparity of females also showed a positive, albeit marginal, increase throughout the study period (1986–2023) (Supporting Information 7 Table S7.3), passing from +13% in 1986 to +21% in 2021 (Figure S7b, d). This suggests a trend toward earlier primiparity for females in recent years, potentially due to more beneficial environmental conditions, as reported by Wightman et al. (2022) and Metthé et al. (2025). The observed decrease in early frost frequency events and increased water availability should have favored higher food availability and might, at least partly, explain these long-term trends for two life-

history traits. However, despite the apparent benefits of long-term changes in average weather conditions, their detection in the field might be hindered by the substantial interannual variability in the weather parameters we studied (Supporting Information 6) and the confounding effect of land modifications resulting from the forestry industry or urbanization. In addition, the long-term trend of these weather variables remains uncertain and requires further investigation.

As climate extremes become more frequent, physiological or ecological thresholds could be met, and the potential benefits of increased plant productivity could be outweighed. For example, increased summer temperatures were previously associated with an increased autumn body condition of Svalbard reindeer (Albon et al. 2017). In contrast, Trondrud et al. (2023) reported that an extreme summer heat wave in Finland was associated with reduced autumn body mass in reindeer (*R. t. tarandus*), likely due to lower forage quality, heat stress, reduced foraging time, and increased insect harassment. In our study area, future projections suggest that air temperature is expected to rise between 1.5 and 4.5°C while mean annual precipitation is projected to increase by 6% to 13% (Houle et al. 2012; Yeung et al. 2019; Cholet et al. 2022). Despite these changes, the frequency of precipitation events is expected to remain similar to the current years' values but with increased intensity (Cholet et al. 2022). However, the severity and duration of soil water stress is projected to increase by 25% and 108% under RCP4.5 scenarios, respectively, relative to current conditions (Cholet et al. 2022). At the same time, the frost-free period is projected to increase from 89–124 days, historically, to 185–200 days by the end of the century, while the late frost risk after bud break may decline from 74–83% to 12–23% (under RCP 8.5: Marquis et al. 2022). Black bears are known for their behavioral flexibility, which could help them adjust to these future changes. Indeed, species distribution models predict an expansion of the northern latitude of their range by 2050 and 2070 (Pandey & Papeş 2018). Yet, the long-term effects of climate change remain difficult to anticipate, and the growing intensity of extreme climatic events may eventually challenge their resilience.

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SUPPORTING INFORMATION 1. ANIMAL CARE CERTIFICATES

Table S1. Animal care certificates delivered by the different animal care committees attesting that the handling protocols of the projects involving live capture of bears respected the guidelines of the Canadian Council on Animal Care prevailing at the time of the study.

Datasets/ published papers	Animal care certificates
Brodeur et al. 2008	Animal Care Committee of the MELCFFP (certificate #04-0002) and of the Université du Québec à Rimouski (certificate #17-04-22)
Parks Canada	Animal Care Committee of the Université Laval (#92-121)
Jolicoeur et al. 2006	Animal Care Committee of the MELCCFP (certificate #94-09)
Lesmerises et al. 2015	Animal Care Committee of the MELCCFP and of the Université du Québec à Rimouski (certificate #2011-30)
Massé et al. 2014	Animal Care Committee of the MELCCFP (certificates #2008-11, 2009-16, 2010-13, 2011-01)
MELCCFP dataset 1	NA – no live capture conducted
MELCCFP dataset 2	Animal Care Committee of the MELCCFP (certificates #2015-10, 2016-18, 2017-22, 2018-23, 2019-20, 2020-06 and 2021-02 for trapping and #2016-03, 2017-03, 2018-03, 2019-04, 2020-05, 2021-01 et 2022-01 for den visits).

SUPPORTING INFORMATION 2. IDENTIFYING THE FLOWERING PERIOD OF FRUIT-BEARING SPECIES

The beginning of the flowering period was defined as the date when 10% of the flowers were open on the earliest fruit-bearing species and ended when 50% of the flowers were open on the later-blooming species. We needed to identify the cumulative degree-days corresponding to these phenological stages to determine the beginning and ending dates of the flowering period relative to the location and year of the bear measurement sites.

To do so, we used unpublished data of Prof. Luc Sirois (Université du Québec à Rimouski, pers. comm.), ranging from 2008 to 2019, of daily temperature and phenological stage of multiple species from 3 sites in the Bas-St-Laurent and Gaspésie regions in Québec (eastern part of our study area). They developed a model to predict the phenological stage as a function of cumulative degree-days over 5°C (Sirois et al. unpublished):

$$PhenoStage = \alpha * (CDD)^{\beta}$$

PhenoStage is the phenological stage of the plant according to the BBCH scale (Hack et al., 1992), *CDD* is the cumulative degree-days over 5°C, α and β are constants unique to each species and site. We isolated *CDD* in this formula to determine the cumulative degree-days corresponding to *PhenoStage* no. 61 (10% of flowers open) and no. 65 (when 50% of flowers open) for each species:

$$\left(\frac{PhenoStage}{\alpha}\right)^{\left(\frac{1}{\beta}\right)} = CDD$$

We then used this formula to calculate the mean cumulative degree-days among the different sampling sites used by Sirois et al. (unpublished). We established these values for the most abundant fruit-bearing species found in our study sites: *Vaccinium angustifolium*, *Rubus idaeus*, *Prunus virginiana*, *Prunus pensylvanica*, *Amelanchier bartramiana*, *Ribes glandulosum*, *Rubus pubescens*, *Ribes lacustre*, and the genera *Vaccinium*, *Prunus*, *Amelanchier*, *Ribes*, *Rubus*, *Viburnum*, and *Sorbus*. We found the genus *Ribes* had the earliest

flowering period with 10% of its flower open at 100 cumulative degree-days, and *Rubus idaeus* had the latest flowering period, with 50% of its flowers open at 350 cumulative degree-days (Figure S2).

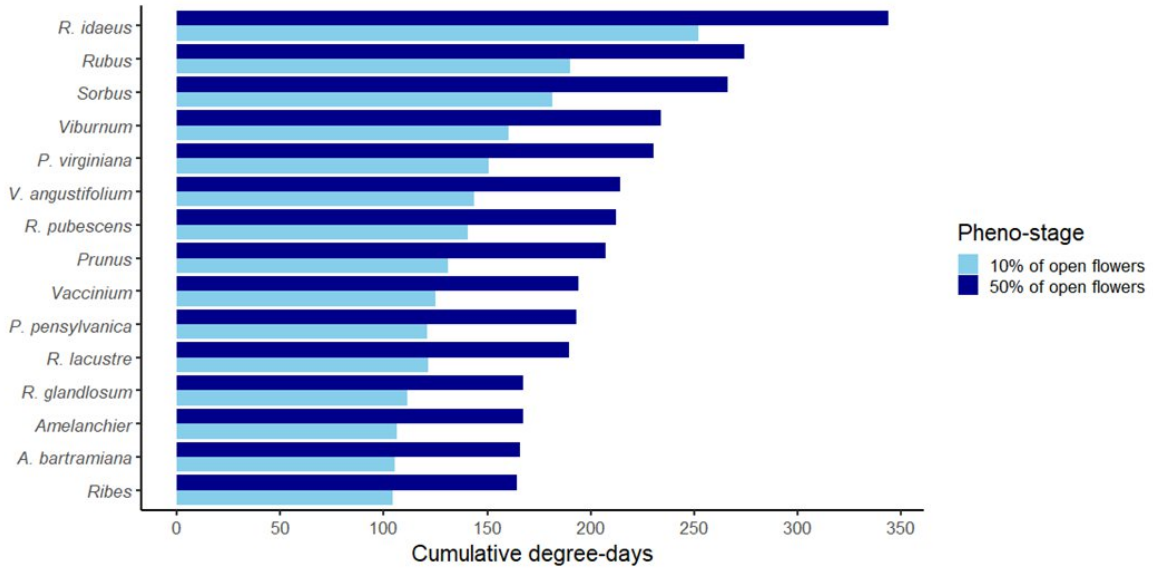

Figure S2. Cumulative degree-days required for 10% (light blue) and 50% (dark blue) of the flowers to be open for fruit-bearing species and genera in the Bas-St-Laurent and Gaspésie regions. Figure created with unpublished data from Luc Sirois, Université du Québec à Rimouski.

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SUPPORTING INFORMATION 3. PREDICTING THE PRESENCE OF OAK SPECIES AND AMERICAN BEECH IN OUR STUDY AREA

The abundance and availability of hard mast, an important food resource for bears, are likely to influence their body condition and reproduction (Costello et al. 2003). The availability of hard mast-producing species was not measured and had to be predicted to properly model the relationship between the food resources available in the environment and bear body condition and reproduction. Unfortunately, the presence of oaks (*Quercus* spp.) and American beech (*Fagus grandifolia*) was unavailable in the ecoforest maps of the Ministère des Ressources naturelles et des Forêts (hereafter MRNF) before 2001, and were grouped with other species of hardwood trees under the category "shade-tolerant hardwoods" (MRNF 2009). Given the lack of data prior to 2001, we developed a modeling approach to predict their presence in the 1983 to 2023 SIFORT maps based on data available in the 2001 ecoforest map. We used logistic regression models predicting the presence of oaks or American beech using other environmental variables available in the maps and geographic coordinates as explanatory variables (see details below).

Using the 2001 ecoforest map, we first selected all the forest stands where red oak (*Quercus rubra*), white oak (*Quercus alba*), or unknown oak species (*Quercus* sp.) were identified in the tree layer, and pooled them to create a distribution area to which we added a 5-km buffer. Within this distribution area, we selected all deciduous stands ≥ 20 years old. Many categories of the different map variables (e.g., ecological type) had no occurrence of oaks presence, we therefore only kept the polygons classed in categories with at least 10 occurrences of oak presence (Table S3.1). We ended with a total of 103,885 deciduous forest stands, among which only 7,310 contained oaks in the tree layer resulting in a ratio of approximately 1 presence : 14 absences. We randomly subsampled the polygons where oaks were absent in the tree layer to obtain a balanced ratio of 1 presence : 1 absence (He & Garcia 2009). Then, we fitted logistic regressions to predict the presence of oaks in the tree layer in relation with different combinations of the following variables: ecological type, tree density class, tree age class, tree height class, latitude, longitude, and the interaction between latitude and longitude (Table S3.2; Table S3.3). We verified multicollinearity with the Variance

Inflation Factor (VIF, Graham 2003) and selected the most parsimonious model with the Akaike's information criterion (AIC, Burnham & Anderson 2001). We found no problem of multicollinearity (all VIF values were ≤ 1.64). We visually validated that the model assumptions were met and evaluated the predictive power of the model with a 10-fold cross validation. We repeated the procedure 100 times, from the selection of the random polygons to the cross validation, and calculated the number of successful predictions. We then applied the model on the 2001 ecoforest map to predict oak presences in the original dataset to identify the threshold probability at which true oak presences began to appear.

We repeated this procedure for the American beech, but the predictive power of the selected model was considered too low to provide good predictions (61.2%; 95% CI [51.6 : 70.7]). This could be expected since the American beech is often grouped with other deciduous species in shade tolerant stand types (MRNF 2009), suggesting that the ecoforest map was not accurate to assess its range distribution. To delineate the distribution area of the American beech, we rather used data collected through ground surveys of permanent and temporary sample plots (n > 260,000) conducted by the MRNF (MRNF 2017). These plots are 400 m^2 circular units where a very detailed vegetation survey is made, including an estimate of the basal area of trees by species (MRNF 2017). Permanent plots have been in place since 1970 and are surveyed once per decade while a certain number of temporary plots are also surveyed each year (MRNF 2017). We delineated the American beech distribution area by merging all plots where the species was observed in the tree layer and adding a 5 km buffer around them to fill the gaps. Finally, we drew the northern limit of the distribution area by smoothing the edge of this northern limit. We conducted spatial analyses with ArcGIS pro V2.9.5 and statistical analyses in R V4.2.0 (R Core Team 2022).

Table S3.1. Variables and classification of the 2001 ecoforest map used in the candidate models to predict the presence of oaks (*Quercus* spp.) and American beech (*Fagus grandifolia*) with logistic regressions in our study area for the 1973, 1981, 1990, and 2001 SIFORT maps. Only the variables and their categories present in all versions of the SIFORT maps and with enough occurrences (≥ 10) of the presence of oaks or American beech were selected for the analyses. See MRNF (2015) for the definitions of the codes.

SIFORT & Ecoforest maps variables	Categories
Tree height class	1, 2, 3, 4
Tree age class	30, 50, 70, 90, 120
Tree density class	A, B, C, D
Ecological type	Oaks models: FC10, FC12, FE10, FE11, FE21, FE22, FE32, FE52, FE60, FE61, FE62 American beech models: FE20, FE21, FE22, FE23, FE30, FE32, FE32H, FE50, FE52, FE60, FE61, FE62

Table S3.2. Candidate models to predict the probability of oak (*Quercus rubra*, *Q. alba*, and *Quercus* sp.) presence, the number of parameters (*k*), and the difference between the model and the most parsimonious model (no. 3; ΔAIC).

Model	Explanatory variables	*k*	ΔAIC
1	Eco-type[a] + Density[b] + Height[b] + Age[b] + Latitude[c] + Longitude[c] + Latitude*Longitude	19	1.95
2	Eco-type + Density + Age + Latitude + Longitude	17	64.71
3	Eco-type + Density + Age + Latitude + Longitude + Latitude*Longitude	18	**0.00**
4	Eco-type + Density + Height + Age + Latitude + Longitude	18	66.19
5	Eco-type + Density + Height + Latitude + Longitude + Latitude*Longitude	18	6.88
6	Eco-type + Height + Age + Latitude + Longitude + Latitude*Longitude	16	12.77
7	Eco-type + Height +Age + Latitude + Longitude	15	78.00
8	Eco-type + Latitude*Longitude	14	16.29

[a]: Ecological type is a classification that considers both the physical characteristics of an environment and the ecological characteristics of the vegetation growing there;
[b]: Density, Height, and Age class of the dominant tree layer;
[c]: Coordinates (NAD83 Québec Lambert, m) of the forest polygon centroid.

Table S3.3. Candidate models to predict the probability of American beech (*Fagus grandifolia*) presence, the number of parameters (*k*), and the difference between the model and the most parsimonious model (no. 1; ΔAIC).

Model	Explanatory variables	*k*	ΔAIC
1	Eco-type + Density + Height + Age + Latitude + Longitude + Latitude*Longitude	19	**0.00**
2	Eco-type + Density + Age + Latitude + Longitude	17	266.28
3	Eco-type + Density + Age + Latitude + Longitude + Latitude*Longitude	18	107.60
4	Eco-type + Density + Height + Age + Latitude + Longitude	18	144.21
5	Eco-type + Density + Height + Latitude + Longitude + Latitude*Longitude	18	85.45
6	Eco-type + Height + Age + Latitude + Longitude + Latitude*Longitude	16	19.11
7	Eco-type + Height +Age + Latitude + Longitude	15	173.47
8	Eco-type + Latitude*Longitude	14	414.39

The most parsimonious model explaining the presence of oaks within deciduous forest stands included ecological type, tree density class, tree age class, latitude, longitude, and the interaction between latitude and longitude (Table S3.2). The 10-fold cross validation showed that the oak model had a mean accuracy (i.e., the percentage of correct predictions) of 90.0% (95% CI [85.3 : 96.6]). When applying this model to predict the presence of oaks in the 2001 ecoforest map, the threshold for the minimum predicted probability of true oak presence was approximately 70% (Figure S3.1). The distribution area of the American beech corresponded to the southern part of our study area (Figure S3.2).

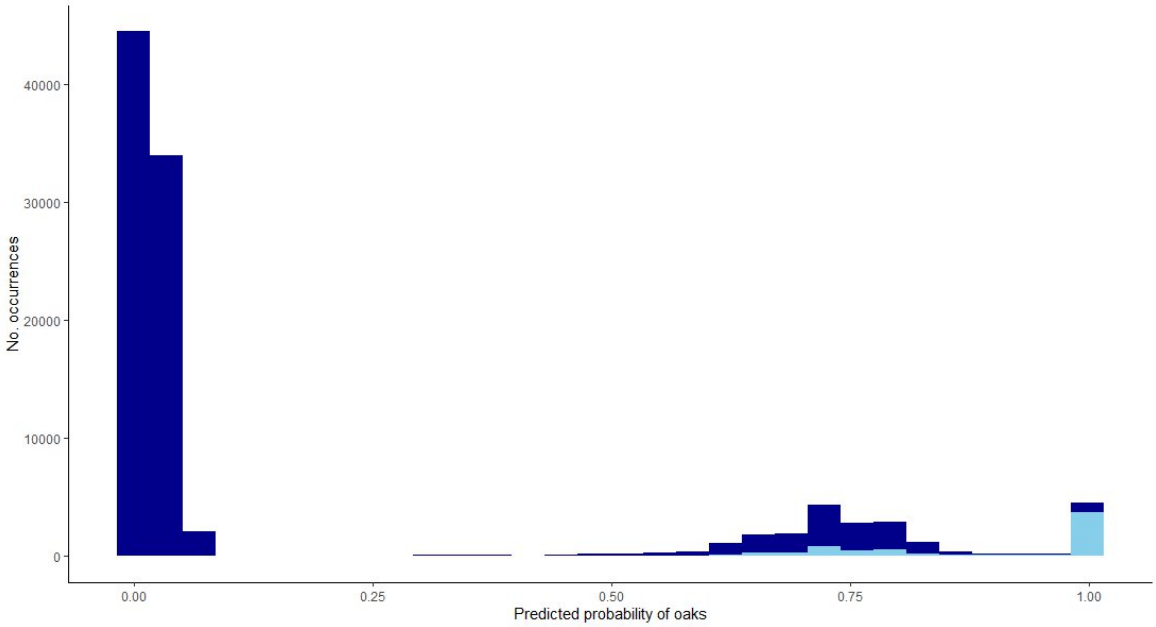

Figure S3.1. Frequency histogram of the probability of oak presence predicted by the most parsimonious model (logistic regression) for the 2001 ecoforest map polygons. The bars are divided by the number of true absences (dark blue) and true presences (light blue) of oaks. True presence of oaks appeared approximately at a predicted probability of oak presence of 70%.

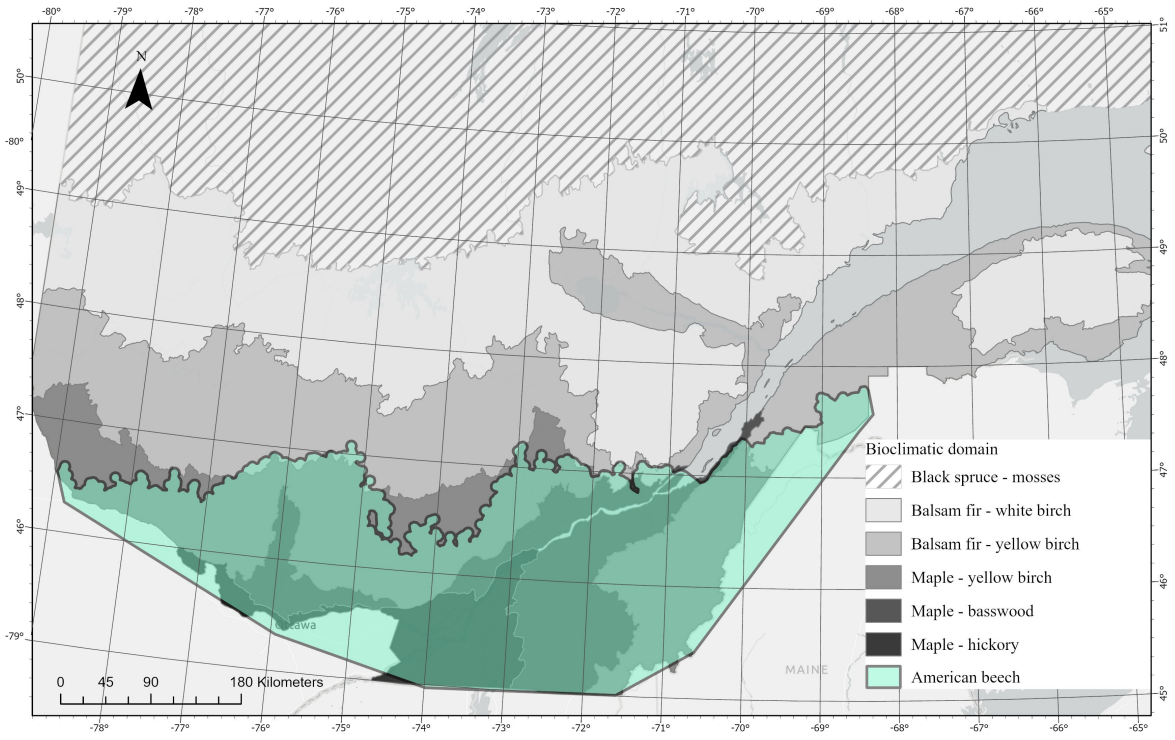

Figure S3.2. Distribution area of the American beech (light green) according to ground surveys of permanent and temporary sample plots of the MRNF (MRNF 2017). The gray filling patterns represent the different bioclimatic domains.

We considered that the oak model performance was high enough (90.0% of good predictions, 95% CI [85.3 : 96.6]) to predict the presence of oaks within the tree layer of 1973, 1981, 1990, and 2001 SIFORT maps. We only applied the model to the tiles that were within the area where the model was developed, and we identified tiles with a probability of presence ≥ 70% as having oaks. For the American beech, the model was not precise enough to assess the presence of the species at the forest-stand scale, so we rather determined if the bear's sampling location buffer intersected (1) or not (0) the distribution area of the American beech as an index of beech nut accessibility to sampled bears.

These methods allowed us to estimate the presence of hard mast-producing species in our study area. The predicted probability did not perfectly discriminate forest stands with and without oaks. Although this might have limited our ability to properly assess the effects of oak presence at a fine scale (e.g., exact bear capture or harvest location), this limitation is likely less important for large-scale effects (i.e., in the 25–613 km^2 buffer zone surrounding bear capture or harvest locations).

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SUPPORTING INFORMATION 4. BEAR ANNUAL HOME-RANGE SIZE

Table S4. Median annual home-range size of male and female black bears aged ≥ 2 years old according to the bioclimatic domain of their capture location. We calculated the values with the 100% minimum convex polygon method using telemetry data of bears with > 450 locations/year. The number in parentheses is the number of bear-year home ranges used to calculate the median (*n* = 485 bear-years, 235 unique bears).

	Median home-range size (km^2)			
	Maple – yellow birch (*n*)	Balsam fir – Yellow birch (*n*)	Balsam fir – White birch (*n*)	Black spruce – mosses (*n*)
Female	45.59 (71)	25.48 (88)	104.02 (23)	81.95 (131)
Male	414.33 (31)	313.90 (35)	601.84 (43)	613.31 (63)

SUPPORTING INFORMATION 5. FREQUENCY TABLE OF INTERBIRTH INTERVALS

Table S5. Frequency table of interbirth intervals (number of years between two reproduction events) for female black bears by bioclimatic domain (n = 924 interbirth interval, 487 unique female bears).

	2-years interbirth interval	3- and + years interbirth interval	Total
Maple	284	20	304
Balsam fir – yellow birch	285	21	306
Balsam fir – white birch	208	26	234
Black spruce - mosses	71	9	80
Total	848	76	924

SUPPORTING INFORMATION 6. DECENNIAL WEATHER TRENDS

We evaluated linear temporal trends of the weather variables we used as indices of food availability for bears across the study area and period (1983–2023) to investigate potential long-term changes in the environmental conditions experienced by bears. We first created a buffer with an 18 km radius around the centroid of the 12 main study sites of the body mass dataset (Figure S6.1). Within these buffer zones, we averaged the different values of the ERA5-Land tiles and extracted the annual number of hours with temperatures below 0.0°C during the flowering period of fleshy fruit-bearing species (n = 492), the 3-month Standardized Precipitation Evapotranspiration Index (SPEI) for August (n = 492), and the growing season length in days (n = 446). The extraction and calculation methods followed the same procedures used for the main analyses. Specifically, we used ERA5-Land hourly (Muñoz-Sabater 2019) and daily aggregates (Copernicus Climate Change Service 2024) data for the number of hours below 0.0°C and the 3-month SPEI calculation, and Landsat Collection 2 Tier 1 Level 2 8-day EVI composites (U.S. Geological Survey) for estimating the growing season length. The SPEI was calculated using the R package *SPEI* (Vicente-Serrano et al. 2010), and the growing season length was calculated using the *phenofit* package (Kong et al. 2022). Years with missing weather data were excluded from their respective analysis.

We evaluated the temporal trends in these weather variables using generalized linear models (GLM) or linear models (LM), depending on the distribution of the response variable: GLM with a negative binomial distribution for the number of hours below 0.0°C, and LM for both the 3-month SPEI of August and the growing season length. We included the year as the main predictor, with latitude, longitude and their interaction as covariables to account for potential spatial variation. We confirmed the absence of multicollinearity using the Variance Inflation Factor (VIF $\leq$ 1.46 for all models, Graham 2003). We verified model assumptions visually using the *performance* (Lüdecke et al. 2021) and *DHARMa* (Hartig 2022) packages in R V4.2.0 (R Core Team 2022).

The three weather variables showed a significant linear relationship with the year, while the effects of latitude, longitude, and their interaction were not statistically significant

(Table S6). The number of hours of frost during flowering decreased significantly over time, with an estimated decline of 2.9% per year, or 26% per decade, from 1983 to 2023 (Figure S6.2a). Concurrently, the 3-month SPEI of August and the growing season length showed significant increases of 0.012 standardized units per year (95% CI [< 0.001 : 0.019]) and 0.18 day per year (95% CI [0.030 : 0.333]), respectively (Figure S6.2b, c). Although statistically significant, the models had relatively low explanatory power (Table S6).

These analyses confirmed a gradual shift in regional climatic conditions potentially influencing the availability of food for bears over the past four decades within our study area. If these climatic trends continue, they could modify the environmental pressures acting on individuals. As such, these results provide an essential context for interpreting our results within the broader framework of climate change.

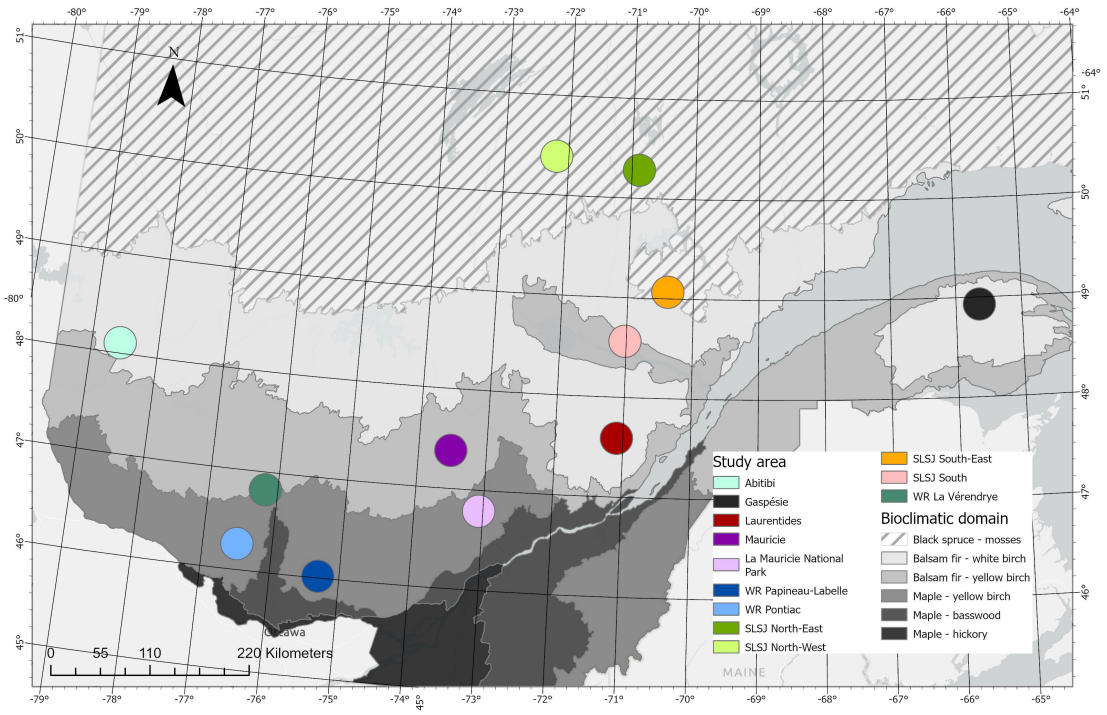

Figure S6.1. Centroid of study sites with an 18 km buffer, Québec (eastern Canada), in which we extracted the weather variables, i.e., the number of hours below 0.0°C, the 3-month Standardized Precipitation Evapotranspiration Index (SPEI), and the length of the growing season during our study period (1983–2023). The various shaded areas represent the different bioclimatic domains. WR = Wildlife Reserve; SLSJ = Saguenay-Lac-St-Jean.

Table S6. Coefficient estimates (β) and 95% confidence intervals (95% CI; [lower : upper]) of each weather variable examined: the number of hours below 0.0°C during the flowering of fruit-bearing species (n = 492, generalized linear model), the 3-month Standardized Precipitation Evapotranspiration Index (n = 492, linear model), and the growing season length (n = 446, linear model). Data were extracted from 12 study sites in Québec (eastern Canada) from 1983 to 2023. Variables in bold are considered to have a statistically significant effect on the weather variable (i.e., 95% CI not overlapping 1 in the case of the negative binomial GLM, and 0 for the LM).

Models	**Variables**	***β***	**95% CI**
No. hours < 0.0°C during flowering			
	Intercept	< 0.001	[< 0.001 : < 0.001]
	Year	**0.976**	**[0.956 : 0.995]**
	Latitude	2.876e+20	[0.142 : 882 196.6]
	Longitude	0.020	[0.001 : 3.404]
	Latitude * Longitude	1.082	[0.973 : 1.203]
3-month SPEI of August			
	Intercept	-45.80	[-174.36 : 82.75]
	Year	**0.012**	**[< 0.001 : 0.019]**
	Latitude	0.463	[-2.181 : 3.106]
	Longitude	-0.324	[-2.064 : 1.415]
	Latitude * Longitude	0.007	[-0.029 : 0.043]
Growing season length			
	Intercept	2020.33	[-556.64 : 4 597.30]
	Year	**0.182**	**[0.030 : 0.333]**
	Latitude	-47.108	[-100.15 : 5.93]
	Longitude	27.797	[-7.084 : 62.677]
	Latitude * Longitude	-0.586	[-1.309 : 0.136]
Model fit			R^2
	No. hours < 0.0°C during flowering		0.07
	3-month SPEI of August		0.02
	Growing season length		0.12

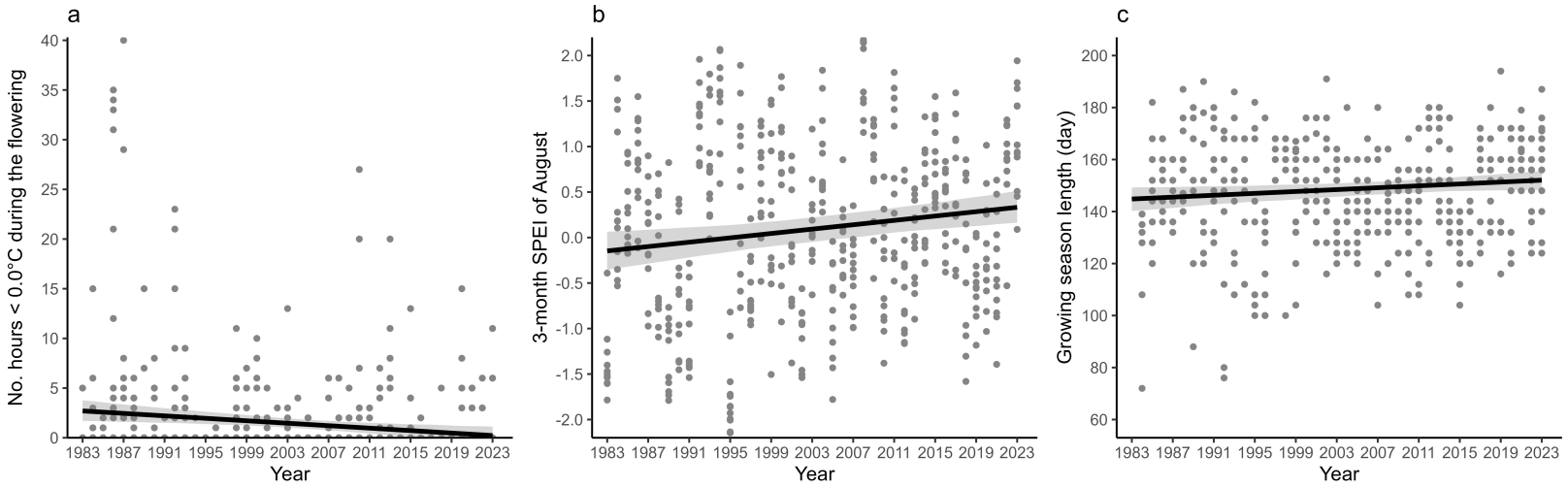

Figure S6.2. Marginal effects of (a) the number of hours below 0.0°C during the flowering period of fleshy fruit-bearing species, (b) the 3-month Standardized Precipitation Evapotranspiration Index (SPEI) of August, and (c) the growing season length, based on models used to assess the relationships between the weather variables and year, latitude, and longitude of 12 study sites in Québec (eastern Canada), from 1983 to 2023. Solid lines represent the predicted weather variable values, and shaded areas delineate the 95% confidence intervals. Points represent the raw data.

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SUPPORTING INFORMATION 7. LONG-TERM TRENDS IN ADJUSTED BODY MASS AND PROBABILITY OF PRIMIPARITY

We explored long-term temporal trends in the two life-history traits for which we found an influence of weather variables, namely the age-, demographic group-, and day of capture-adjusted body mass (hereafter referred as bear mass) of bears and the probability of primiparity of females. We used the same datasets as for the main analyses, i.e., $n = 1912$ bear-years for the body mass and $n = 710$ females for the probability of primiparity. We evaluated the existence of a linear temporal trend with a linear mixed model for the body mass and with a mixed logistic regression for the probability of primiparity (R package *lme4*, Bates et al. 2015). In addition to the year, we included the variables used to account for individual variation in each analysis (Table S7.1). We found no issue of multicollinearity among covariates (Variance Inflation Factors ≤ 2.46 for all models, Graham 2003). We verified model assumptions visually with *performance* (Lüdecke et al. 2021) and *DHARMa* (Hartig 2022) packages in R V4.2.0 (R Core Team 2022). All numerical variables were standardized.

Among all demographic groups, only females with yearlings showed a positive, statistically significant temporal trend in their body mass ($\beta = 3.042$, 95% CI [0.627 : 5.457]; Table S7.2), with a predicted increase of 0.74 kg per decade (Figure S7a, c). The probability of primiparity showed a marginally significant positive relationship with years ($\beta = 0.137$, 95% CI [-0.014 : -0.293]; Table S7.3), but we found no evidence of an interaction between the years and the female's age. The predicted probability of primiparity increased from 13% in 1986 to 21% in 2022, all age groups combined (Figure S7b, d). Both models had a good fit to the data (Table S7.2, Table S7.3).

Table S7.1. Models used to assess the long-term trend of the age-, demographic group-, and day of capture- adjusted body mass of black bears and the probability of primiparity of females, with number of parameters (*k*) included in each model.

Model	Explanatory variables	*k*
Adjusted body mass	Year + Year * Demographic group + Demographic group + Age + (Age^2) + Demographic group * (Age+ (Age^2)) + Julian day+ (Julian day^2) + Latitude + Longitude + Latitude * Longitude + (1|ID-bear)	25
Probability of primiparity	Year + Year * Log(Age) + Log(Age) + Latitude + Log(Age) * Latitude + Longitude + Latitude * Longitude + (1|ID-bear)	8

Table S7.2. Coefficient estimates (β) and 95% confidence intervals (95% CI; [lower : upper]) of the linear mixed model used to assess the relationships between adjusted body mass and year while accounting for individual characteristics of black bears (n = 1912 bear-years) in Québec (eastern Canada) between 1986 and 2023. Variables in bold are considered to have a statistically significant effect on the adjusted body mass (i.e., 95% CI not overlapping zero). All continuous variables were scaled. The reference demographic group is Female – alone.

Groups of variables	Variables	β	95% CI
	Intercept	**45.730**	**[43.081 : 48.379]**
Temporal variation			
	Year	0.595	[-0.987 : 2.177]
	Female - cub * Year	-0.076	[-2.169 : 2.016]
	Female - unknown * Year	-0.208	[-1.958 : 1.543]
	Female - yearling * Year	**3.042**	**[0.627 : 5.457]**
	Male * Year	0.509	[-1.288 : 2.306]
Individual variation			
	Female - cub	8.510	[5.632 : 11.388]
	Female - unknown	4.776	[2.085 : 7.466]
	Female - yearling	-1.677	[-5.522 : 2.168]
	Male	41.028	[38.127 : 43.929]
	Age	21.170	[19.660 : 22.674]
	Age^2	-6.710	[-7.769 : -5.651]
	Julian Day	**-2.313**	**[-3.031 : -1.595]**
	$Julian\ day^2$	**3.801**	**[3.266 : 4.337]**
	Latitude	-0.668	[-1.669 : 0.332]
	Longitude	0.117	[-0.735 : 0.969]
	Female - cub * Age	**-6.945**	**[-11.066 : -2.823]**
	Female - unknown * Age	**-7.148**	**[-9.388 : -4.909]**
	Female - yearling * Age	**-10.000**	**[-15.813 : -4.187]**
	Male * Age	**25.404**	**[23.415 : 27.392]**
	Female - cub * Age^2	**3.332**	**[1.470 : 5.194]**
	Female - unknown * Age^2	**2.978**	**[1.617 : 4.338]**
	Female - yearling * Age^2	**3.200**	**[0.944 : 5.455]**
	Male * Age^2	**-6.892**	**[-8.496 : -5.288]**
	Latitude * Longitude	**1.340**	**[0.351 : 2.329]**
Model fit			
	Marginal R^2 = 0.83	Conditional R^2 = 0.90	

Table S7.3. Coefficient estimates (β) and 95% confidence intervals (95% CI; [lower : upper]) of the logistic regression model used to assess the relationships between probability of primiparity and year while accounting for individual characteristics of female black bears (n = 710 females) in Québec (eastern Canada) between 2005 and 2022. Variables in bold are considered to have a statistically significant effect on the probability of primiparity (i.e., 95% CI not overlapping zero). All continuous variables were scaled.

Groups of variables	Variables	β	95% CI
	Intercept	**-1.621**	**[-1.845 -1.434]**
Temporal variation			
	Year	**0.137**	**[-0.014 : 0.293]**
	Year*Log(Age)	-0.093	[-0.258 : 0.069]
Individual variation			
	Log(Age)	2.040	[1.720 : 2.450]
	Latitude	-0.400	[-0.581 : -0.233]
	Longitude	0.192	[0.052 : 0.341]
	Log(Age)*Latitude	**0.187**	**[0.022 : 0.355]**
	Latitude*Longitude	**0.177**	**[0.013 : 0.349]**
Model fit			
	Marginal R^2 = 0.54	Conditional R^2 = 0.59	

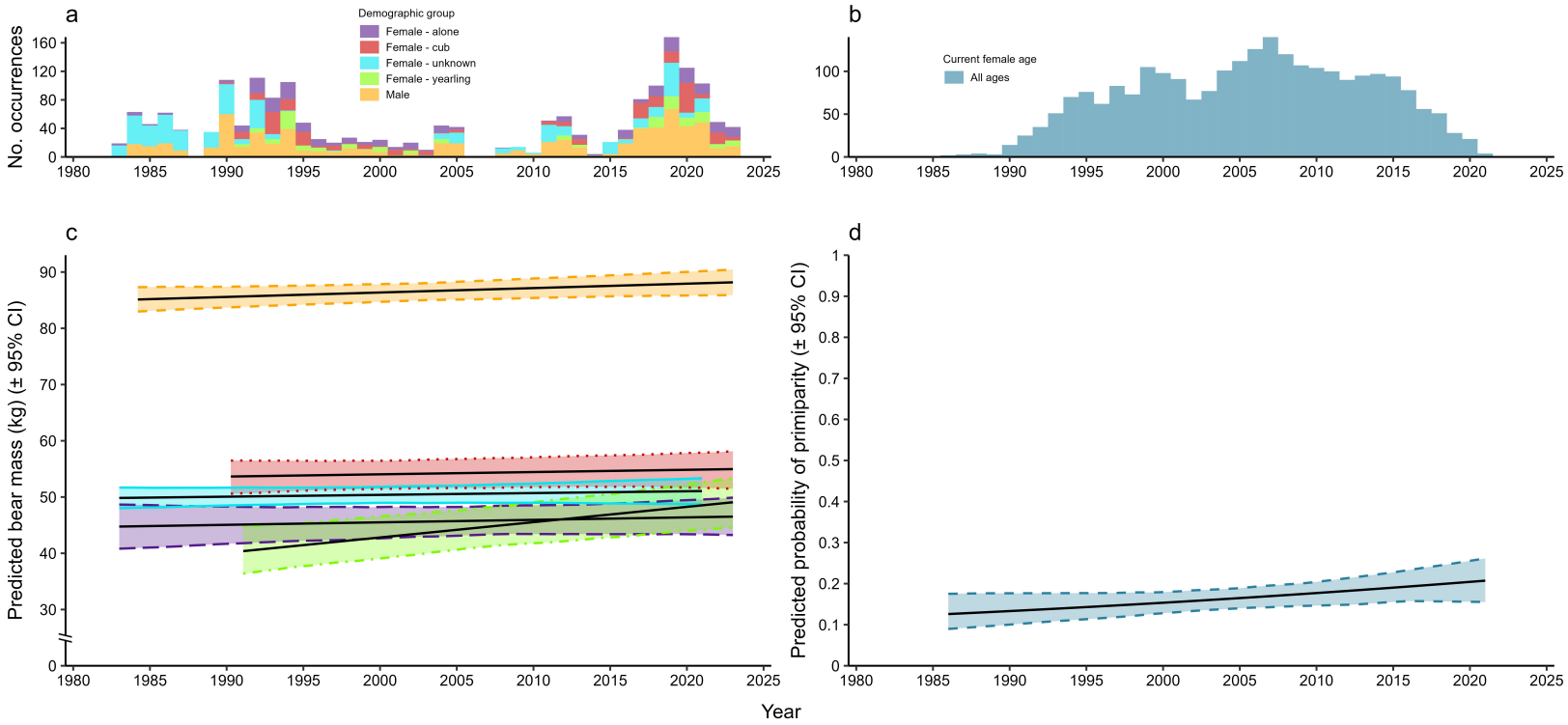

Figure S7. Top row: frequency histograms of (a) the adjusted body mass, as recorded for each demographic group represented by stacked bars (n = 1912 bear-years), and (b) the probability of primiparity (n = 2463 bear-years, 710 different females) in relation to year of data collection. Bottom row: marginal effect of the year for (c) the predicted adjusted body mass and (d) the predicted probability of primiparity, based on the models used to assess the relationships between the life-history traits and the year while accounting for individual characteristics of black bears in Québec (eastern Canada) between from 1983 and 2023. All effects are shown across the observed range of each variable, with other predictors fixed at their mean values. The adjusted body mass model (linear mixed model) accounts for individual age, capture location, and capture date. A different curve is shown for each demographic group. The probability of primiparity model (mixed logistic regression) was predicted for all ages combined since the interaction between year and female age was not statistically significant. Solid lines represent the predicted values of the life-history trait and shaded areas indicate the 95% confidence intervals.

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CONCLUSION GÉNÉRALE

RETOUR SUR LES OBJECTIFS ET PRINCIPAUX RÉSULTATS

L'objectif de mon projet était d'évaluer les effets des conditions météorologiques locales sur trois traits d'histoire de vie de l'ours noir (*Ursus americanus*) : 1) la masse corporelle ajustée pour l'âge, le segment de population et la date de capture (utilisée comme un indice de condition corporelle), 2) la probabilité de primiparité et 3) l'intervalle de temps entre les portées. À cette fin, j'ai combiné les données de 1 824 ours échantillonnés dans le cadre de huit études menées entre 1983 et 2023 sur un vaste territoire s'étendant des érablières aux pessières à mousses du Québec, afin d'exploiter une grande variation spatio-temporelle de conditions météorologiques et d'habitats.

Mes résultats montrent que les variations des conditions météorologiques locales ont indirectement affecté la masse corporelle ajustée des ours et la probabilité de primiparité des femelles, mais pas l'intervalle de temps entre les portées. La masse corporelle ajustée était négativement corrélée au nombre d'heures durant lesquelles la température était inférieure à 0,0°C durant la floraison des espèces à fruits charnus lors de la saison de croissance précédente. Les gels intenses et fréquents augmentent les risques de dommages aux tissus reproducteurs (Olson & Steeves 1982; Inouye 2008; Xu et al. 2023) ainsi que la mortalité des fleurs, ce qui réduit la production de fruits (Hicklenton et al. 2002; CaraDonna & Bain 2016). De ce fait, les ours ont accès à moins de nourriture durant la période d'hyperphagie, ce qui explique la diminution de masse observée. À l'opposé, la masse corporelle ajustée était positivement corrélée avec la disponibilité en eau durant les mois de juin, juillet et août de la saison de croissance précédente. Une grande disponibilité en eau favorise une plus grande productivité végétale (Wu et al. 2011; Howe et al. 2012), offrant ainsi plus de nourriture aux ours et expliquant le gain de masse supérieur. En revanche, la masse corporelle ajustée était négativement corrélée avec la durée de la saison de croissance précédente.

Contrairement à mon hypothèse, un allongement de la saison de croissance ne se traduit peut-être pas directement par un allongement de la période durant laquelle de la nourriture de qualité est disponible pour l'ours noir. Par exemple, si des températures plus élevées induisent une floraison plus hâtive, qui se traduit par une fructification plus hâtive, mais que la sénescence des feuilles est plus tardive (Gallinat et al. 2015), les ours ont peu de chance de bénéficier directement d'une saison de croissance plus longue. Ma revue de littérature ne m'a toutefois pas permis de confirmer ces liens potentiels entre la floraison et la fructification, la fructification étant possiblement plutôt influencée par des facteurs extrinsèques (Sandor et al. 2021).

La probabilité de primiparité était positivement corrélée avec la disponibilité de l'eau de juin à août pendant la saison de croissance précédente. Une grande disponibilité en eau favorise la productivité végétale (Wu et al. 2011; Howe et al. 2012), offrant ainsi aux femelles une disponibilité accrue des ressources alimentaires durant l'hyperphagie, ce qui leur permet d'accumuler davantage de réserves avant l'entrée en tanière et, éventuellement, la parturition. Ces réserves sont essentielles pour compléter la gestation (Rogers 1976; Samson & Huot 1995), et les femelles ayant eu accès à plus de ressources alimentaires devanceraient leur primiparité et augmenteraient ainsi la probabilité de primiparité de la population pour un âge donné. De plus, la probabilité de primiparité était positivement corrélée avec la durée de la saison de croissance chez les femelles âgées de 4 ans et plus, qui auraient potentiellement bénéficié d'une plus longue période pour accumuler des réserves avant l'hiver. Toutefois, ce résultat contredit celui de l'analyse de la masse ajustée, appelant à la prudence.

L'intervalle de temps entre deux portées chez les femelles ne différait pas significativement entre les domaines bioclimatiques. La majorité des femelles ayant un intervalle de temps équivalent à la valeur minimale observée chez cette espèce (2 ans), elles pouvaient probablement acquérir, dans la plupart des cas, suffisamment de ressources pour compléter leur gestation. Toutefois, celles-ci n'ont probablement pas été exposées à des conditions environnementales suffisamment difficiles pour manquer une année de reproduction en réponse à une faible disponibilité de nourriture. De plus, puisque ces

événements de reproduction manquée sont globalement très rares (environ 8 % des cas), il est possible que notre taille d'échantillon n'ait pas été suffisante pour détecter l'effet des variables d'habitat testées.

CONTRIBUTIONS APPLIQUÉES À L'OURS NOIR

Plusieurs études ont montré l'influence positive des habitats riches en nourriture sur les ours noirs, par exemple sur leur condition corporelle et leur reproduction (Rogers 1976; Elowe & Dodge 1989; Stringham 1990; Wightman et al. 2022). Les fruits charnus produits dans les milieux ouverts en régénération et les fruits durs des forêts matures de chênes (*Quercus* spp.) et de hêtres à grandes feuilles (*Fagus grandifolia*) constituent des ressources clés leur permettant d'accumuler des réserves avant l'entrée en tanière (Cottam et al. 1939; Beeman & Pelton 1980; Boileau et al. 1994; Mosnier et al. 2008; Noyce & Garshelis 2011; Lesmerises et al. 2015). La disponibilité de ces types d'habitats fournit donc un bon indicateur de la présence de ressources alimentaires, mais elle ne reflète pas nécessairement leur abondance réelle. En effet, les conditions météorologiques durant la saison de croissance influencent la production annuelle de fruits (Hicklenton et al. 2002; Glass et al. 2005; Howe et al. 2012; Gezon et al. 2016), et ignorer ces fluctuations pourrait conduire à surestimer la quantité de nourriture accessible aux ours durant certaines années. Si la production de fruits chute trop fortement, la condition corporelle des individus et leur investissement reproducteur peuvent être compromis (Elowe & Dodge 1989; Samson & Huot 1995; Costello et al. 2003). S'ils ne sont pas pris en compte, ces événements risquent de mener à une évaluation biaisée des fluctuations d'abondance et, à long terme, entraîner une surexploitation par la chasse ou le piégeage. De ce fait, intégrer l'effet des variables météorologiques influençant la production de nourriture, comme le nombre d'heures de gel au printemps et la disponibilité en eau à l'été, dans le suivi des populations permettrait donc d'obtenir une estimation plus réaliste des conditions environnementales auxquelles les ours sont confrontés, d'améliorer le suivi des populations et, éventuellement, d'ajuster les stratégies de gestion et de conservation. Il pourrait être intéressant, par exemple, de préciser,

pour une région donnée, à quelle fréquence on observe des années où les gels printaniers ou encore le manque d'eau en été sont susceptibles d'affecter l'accumulation de réserves de graisse et la probabilité de primiparité des ourses.

De plus, l'intégration des variables météorologiques dans le suivi des populations et dans les plans de gestion pourrait contribuer à mieux anticiper et gérer les conflits entre les ours et les humains. En période de faible disponibilité alimentaire en milieu naturel, certains individus se déplacent vers les zones urbaines ou agricoles afin d'y trouver des sources de nourriture (Baruch-Mordo et al. 2014; Ditmer et al. 2016). Ces secteurs, notamment les terres agricoles, offrent une nourriture abondante, riche et prévisible, permettant aux individus qui les utilisent d'atteindre une masse supérieure à ceux qui n'y ont pas accès (Beckmann & Berger 2003; Nelson et al. 2024). Cependant, cette proximité avec les installations humaines augmente la probabilité de rencontre et de conflits entre ours et humains (Obbard et al. 2014; Kurth et al. 2024), pouvant ainsi mener à des problèmes de cohabitation entre les deux espèces. Plusieurs études ont mis en évidence une corrélation positive entre la fréquence des conflits et les conditions météorologiques défavorables à la productivité végétale, notamment une faible disponibilité en eau durant la saison de croissance (Zack et al. 2003; Parchizadeh et al. 2023, mais voir Miller et al. 2016) ou des gels printaniers tardifs (Shoemaker et al. 2025). Mon projet montre que les ours répondent aussi à ces conditions en forêt boréale, avec une influence potentielle sur l'occurrence des conflits ours-humains dans ces écosystèmes. Ainsi, l'inclusion de variables météorologiques dans le suivi des populations pourrait potentiellement améliorer la gestion des conflits, voire aider à les anticiper.

CONTRIBUTIONS THÉORIQUES

Mon étude montre qu'une espèce animale largement reconnue pour sa grande capacité d'acclimatation et sa plasticité phénotypique, l'ours noir, peut répondre aux conditions météorologiques changeantes à l'échelle individuelle par une modification de certains traits d'histoire de vie. Ces résultats apportent un éclairage nouveau sur les mécanismes par

lesquels les changements climatiques ont le potentiel d'influencer la répartition et la dynamique des populations animales. Cependant, pour bien évaluer et comprendre les impacts potentiels des variations météorologiques, et ultimement des changements climatiques, sur les animaux, il est essentiel de considérer l'ensemble des facteurs limitants qui agissent en synergie avec les variations météorologiques. Les réponses des individus pour faire face aux variations météorologiques, et ultimement aux changements climatiques, par exemple, peuvent être limitées par la nécessité de faire des compromis pour les comportements de thermorégulation, comme c'est le cas chez le zèbre des plaines (*Equus quagga*) et l'oryx gazelle (*Oryx gazella*) qui privilégient l'évitement de leurs prédateurs nocturnes plutôt que le décalage de leur période d'activité vers les heures plus fraîches de la nuit, même lors de journée aux températures très élevées (Veldhuis et al. 2020). De plus, la résilience d'une espèce peut aussi être contrainte par d'autres types de perturbations, dont l'effet peut s'additionner à celui des conditions météorologiques. C'est le cas du caribou forestier (*Rangifer tarandus caribou*) au Québec dont le déplacement vers le nord de la limite sud de l'aire de répartition depuis 1850 n'est expliqué qu'à 17 % par les changements climatiques, le reste étant attribuable aux perturbations anthropiques (Morineau et al. 2023). Les conditions météorologiques peuvent également interagir avec d'autres processus environnementaux ou facteurs de stress et amplifier leurs effets. Par exemple, la combinaison de sécheresses extrêmes, de proies en mauvaise condition corporelle et d'une forte abondance de parasites a favorisé la propagation de la maladie de Carré dans les populations de lion (*Panthera leo*) du Serengeti et du Ngorongoro, entraînant la mortalité jusqu'au tiers de la population dans la région du Serengeti (Munson et al. 2008).

Mes résultats appuient le mécanisme proposé dans mon hypothèse, selon lequel les conditions météorologiques exercent des effets indirects sur la masse corporelle et la probabilité de primiparité des individus, par l'intermédiaire d'un effet direct sur la productivité leurs sources de nourriture. Ce mécanisme est susceptible de s'appliquer à d'autres espèces dont le régime alimentaire repose en grande partie sur les végétaux. Ainsi, de nombreuses espèces d'herbivores, frugivores ou granivores pourraient dépendre directement de la productivité végétale et indirectement des variations météorologiques, par

exemple les oiseaux (p. ex. Psittaciformes, Piciformes, Colliformes et Musophagiformes : Kissling et al. 2009) ou les chauves-souris (p. ex. Phyllostomidae, Pteropodidae : Fang et al. 2014; Osorio-Rodríguez et al. 2025). De telles relations ont été documentées chez le renne du Svalbard (*R. t. platyrhynchus*), le cerf mulet (*Odocoileus hemionus eremicus*) et le sanglier (*Sus scrofa*), chez lesquels des conditions météorologiques favorables à une forte productivité primaire étaient corrélées à une meilleure condition corporelle (Marshal et al. 2008; Albon et al. 2017; Touzot et al. 2020). Il serait également pertinent d'examiner de potentielles relations similaires chez les consommateurs saisonniers exploitant ponctuellement les ressources végétales, comme le coyote (*Canis latrans* : Samson & Crête 1997; Dumond et al. 2001) ou la martre d'Amérique (*Martes americana* : Weckwerth & Hawley 1962; Bull 2002), chez qui ces sources de nourriture, bien que consommées de façon opportuniste, pourraient représenter une ressource importante à certaines périodes de l'année. De plus, les effets indirects des conditions météorologiques pourraient se propager à travers plusieurs niveaux trophiques. Par exemple, dans les régions arides et semi-arides de l'ouest des États-Unis, une plus grande disponibilité en eau favorise la productivité végétale, ce qui a conduit à une augmentation de la densité des proies et, en conséquence, à une hausse de la densité des cougars (*Puma concolor*), elle aussi corrélée à une augmentation de la productivité végétale (Stoner et al. 2018). Ainsi, les conditions météorologiques locales peuvent influencer non seulement les producteurs primaires, mais aussi les consommateurs secondaires, soulignant l'importance d'intégrer les variations météorologiques dans les études en écologie animale et particulièrement dans le contexte des changements climatiques, bien que certains effets en cascade puissent être difficiles à anticiper.

LIMITES

Mes données proviennent de huit études couvrant un large gradient spatio-temporel et une grande diversité de conditions météorologiques. Une analyse à cette échelle exige cependant de faire certains compromis. Les cartes du Système d'information forestière par tesselle (SIFORT), les réanalyses d'ERA5-Land et l'imagerie satellitaire Landsat m'ont

permis d'utiliser une seule source d'information pour tout le territoire et toute la durée couverte par mon étude (de 1983 à 2023), mais au prix d'une réduction de la résolution des couches d'information numériques. De plus, puisque la majorité des ours n'étaient localisés qu'au point de capture, nous avons été contraints d'utiliser cette seule coordonnée pour estimer les habitats disponibles et les conditions météorologiques rencontrées par chaque individu. Idéalement, j'aurais caractérisé ces habitats et les conditions météorologiques dans le domaine vital réel de chaque individu délimité à l'aide de localisations télémétriques, ce qui aurait permis une description plus précise. La résolution spatiale relativement grossière de certaines variables explicatives utilisées dans mes modèles a ajouté de la variation dans mon jeu de données, ce qui a pu réduire ma capacité à mettre en évidence certains effets. Malgré ces contraintes, mes analyses sont robustes et le nombre très élevé d'échantillons d'ours mesurés dans ma base de données, tout comme la longueur du suivi dans le temps (soit 1 824 individus sur 41 ans) ont permis de montrer que les ours noirs répondent bel et bien aux variations météorologiques au Québec. Cette résolution relativement grossière était adéquate pour détecter des variations à des échelles spatiales et temporelles relativement grandes, mais tout de même raisonnables pour une espèce aussi mobile que l'ours noir. Par exemple, ERA5-Land est une réanalyse climatique dont la résolution spatiale est de de $0{,}1° \times 0{,}1°$ (~81 km^2) à l'intérieur desquelles les données météorologiques telles que la température, la radiation solaire ou les précipitations sont considérées homogènes (Muñoz-Sabater 2019). Une résolution spatiale supérieure m'aurait peut-être permis de révéler des relations à plus fine échelle.

Le large gradient spatio-temporel présent dans mes données rend également difficile la collecte de données environnementales compatibles pour tous les secteurs et disponibles pour toute la durée de l'étude. J'ai calculé des indices de disponibilité des ressources alimentaires pour pallier ce manque, notamment en utilisant un modèle prédictif pour estimer la présence de chênes. Toutefois, des données annuelles précises sur l'abondance des ressources alimentaires auraient pu me permettre de mieux considérer les variations interannuelles et spatiales de la disponibilité de nourriture. Chez le hêtre à grandes feuilles, par exemple, la production de faînes d'une année dépend de la production de l'année

précédente, créant une alternance entre les années de forte et de faible production (Cleavitt & Fahey 2017). Des informations sur la nourriture disponible avec une meilleure résolution temporelle et spatiale auraient peut-être permis de mieux contrôler cette source de variation et de préciser certaines relations ou même d'en détecter d'autres.

CONCLUSIONS ET PERSPECTIVES

Les changements climatiques se sont intensifiés au cours des deux derniers siècles (Crutzen 2006) et depuis, l'abondance d'environ 80 % des communautés terrestres et aquatiques a été modifiée (revue par Scheffers et al. 2016). Si la majorité des populations animales éprouvent des difficultés à s'acclimater à ces nouvelles conditions environnementales (p. ex. bécasseau maubèche *Calidris canutus canutus* : van Gils et al. 2016; lycaon *Lycaon pictus* : Woodroffe et al. 2017; cratérope bicolore *Turdoides bicolor* : Bourne et al. 2020; mangouste rayée *Mungos mungo* : Khera et al. 2023), certaines parviennent à s'y ajuster et même parfois à en tirer des bénéfices (p. ex. blaireau européen *Meles meles* : Byrne et al. 2015; renne du Svalbard : Albon et al. 2017; sanglier: Touzot et al. 2020; putois d'Europe *Mustela putorius* : Zalewski et al. 2022). À la lumière des résultats obtenus, les ours noirs de l'est du Canada pourraient tirer profit de certaines conditions découlant des changements climatiques en cours, telle qu'une réduction de l'occurrence des gels durant la floraison des espèces à fruits charnus, mais pas de toutes, comme une longue saison de croissance. Son adaptabilité et sa flexibilité alimentaire lui permettent d'exploiter une grande variété de ressources et de bénéficier indirectement des conditions météorologiques favorables à une forte productivité végétale. Cependant, mes résultats suggèrent également que les ours ne bénéficient pas directement d'un allongement de la saison de croissance, un effet anticipé des changements climatiques. Bien qu'une augmentation de la quantité de nourriture disponible puisse théoriquement avoir un effet bénéfique sur cette espèce qui doit accumuler de grandes réserves énergétiques en quelques mois, ces bénéfices pourraient être contrebalancés par des changements comportementaux ou dans la qualité de la nourriture, ou même par une augmentation des dépenses énergétiques.

Les changements climatiques impliquent également des bouleversements autres que ceux considérés par mon étude, et certaines variables pourraient atteindre un seuil au-delà duquel une augmentation de la productivité végétale n'apportera plus de bénéfices supplémentaires aux ours.

Mon étude constitue un premier pas important pour anticiper les effets potentiels des changements climatiques sur l'ours noir. J'encourage d'autres équipes de recherche à poursuivre cette démarche en évaluant comment les autres traits d'histoire de vie des ours ont changé au cours des dernières décennies, afin de préciser les tendances démographiques et la résilience de l'espèce face aux changements climatiques. Ces efforts de recherche devraient notamment s'attarder à tester les effets potentiels de futurs scénarios climatiques sur des populations fictives par modélisation. Pour la gestion de l'espèce, il est essentiel de poursuivre un suivi performant des populations, ce qui contribuera à consolider nos connaissances sur cette espèce emblématique de nos forêts nordiques, et ainsi à favoriser sa persistance dans un environnement en pleine transformation.

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