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ARTICLE

Interior ecosystem in the subarctic: wild, living, arthropod biodiversity in the University of Alaska Museum, Fairbanks, Alaska, United States of America

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Abstract

Outside of pest control reports, little attention has been paid to interior ecosystems in high-latitude regions. Opportunistic sampling of live arthropods captured inside the University of Alaska Museum Fairbanks, Alaska, United States of America allowed us to describe and analyse one such interior ecosystem. We document a minimum of 77 arthropod species over 18 years. Beetles, spiders, and booklice represented 80% of the total abundance. Of those captured, synanthropes consisted primarily of fungivores and detritivores, seasonals consisted primarily of predators and omnivores, and transients consisted primarily of predators and had greater diet and species diversity than the synanthropes and transients. January was the most common month for capturing synanthropes, September for capturing seasonals, and July for capturing transients. Four synanthropic species not previously known from Alaska, which appear to have breeding populations inside the museum, were found: *Dorypteryx domestica* (Smithers, 1958) (Psocodea: Psyllipsocidae), *Cartodere constricta* (Gyllenhal, 1827), *Dienerella filum* (Aubé, 1850), and *Corticaria serrata* (Paykull 1800) (Coleoptera: Latridiidae). Three transient and one synanthrope species previously unreported from Alaska, with no evidence of breeding populations, were also found: the click beetle *Danosoma obtectum* (Say, 1839) (Coleoptera: Elateridae), a spider in the genus *Phantyna*, probably the species *P. bicornis* (Emerton, 1915) (Araneae: Dictynidae), two *Colobopsis* sp. ant specimens (Hymenoptera: Formicidae), and the synanthropic spider *Oecobius cellariorum* (Dugès, 1836) (Araneae: Oecobiidae).

Introduction

Human-made habitats have rapidly expanded throughout the globe over an extremely short evolutionary time period, creating a vast and growing network of interior habitats (Martin *et al.* 2015; Bertone *et al.* 2016). Human movement, migration, and shipment of goods create an opportunity for human-associated arthropods to disperse throughout this emerging ecosystem. Despite the global ubiquity of indoor environments, the ecology, evolution, and distribution patterns of interior arthropod communities are largely understudied (Martin *et al.* 2015; Leong *et al.* 2016, 2017), with most publications focussed on the control of indoor pests.

Indoor arthropod communities include a spectrum of indoor associations, from organisms that become trapped indoors to their detriment (transients) to arthropods that can establish breeding populations inside (synanthropes) and that often benefit from association with humans and their dwellings. Many of these synanthropic species have evolved in close association with humans

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(Martin *et al.* 2015). Traits of synanthropes often include flightlessness, flattened bodies, parthenogenesis, prior cave-dwelling life histories (Balvín *et al.* 2012), and a diet that includes decaying organic matter such as vertebrate food particles, skin, and hair (detritivory, keratinophagy), or mould (mycophagy) (Martin *et al.* 2015). Nocturnal and thigmotactic activities are also common traits of synanthropes. However, outside of cities, the majority of arthropod species found indoors originate from the local exterior ecosystem: they become trapped in a building's envelope and are unable to feed or breed indoors (Leong *et al.* 2017).

High-latitude ecosystems have long winters, a time of inactivity for arthropods, which can remain dormant for up to eight months in a year. In Alaska, this requires freeze-tolerance or freeze-avoiding overwintering strategies (Sømme 1995; Barnes *et al.* 1996). An array of seasonally abundant species cannot establish breeding populations in buildings but repeatedly end up indoors as a result of their annual drive to seek thermal refugia to overwinter (Guarisco 1999; Sikes 2008). For example, there are numerous interior Alaska records in November, January, and February of the butterfly *Nymphalis l-album* (Esper 1781) (Lepidoptera: Nymphalidae), which overwinters as an adult and periodically is found flying indoors in winter.

The nonmarine arthropod fauna of Alaska has been documented with a dynamically updated online checklist of almost 9000 species (Sikes *et al.* 2017a). Given that Sweden, a country of similar latitude and about one-third the area of Alaska, has an insect fauna estimated to contain over 28 000 species (Karlsson *et al.* 2020), the current total for Alaska may represent less than one-third of the state's fauna. However, in contrast with lower-latitude American states and the Canadian provinces, Alaska appears to have relatively few established (79) nonnative nonmarine arthropod species. These have recently been summarised by Simpson *et al.* (2019), and a dynamic, growing list of these species (118) can be found at https://arctos.database.museum/saved/adventiveAKarthropods. Some of these nonnative species were detected as interceptions and appear to have not established breeding populations in the state, or are managed by people and are thus not on Simpson *et al.*'s (2019) list. Approximately 28 of these 118 species persist in Alaska only indoors or on the bodies of humans (as nonpets) these include *Thermobia domestica* Packard, 1873 (Zygentoma: Lepismatidae), *Cimex lectularius* Linnaeus, 1758 (Hemiptera: Cimicidae), *Demodex folliculorum* (Simon, 1842) (Trombidiformes: Demodicidae), and *Pholcus phalangioides* Füssli, 1775 (Araneae: Pholcidae) (Simpson *et al.* 2019). The indoor ecosystems of Alaska, centred around the shelter and food resources provided by the bipedal primate *Homo sapiens* Linnaeus (Primates: Hominidae) are amongst the least-studied ecosystems in the state. Just *et al.* (2019) found that the climate of the indoor ecosystems they studied, in an attempt to generalise globally, is most similar to that of the outdoor ecosystem of west–central Kenya.

One of the first records of this fauna in Alaska was published by Van Duzee (1921), who reported a population of *Blattella germanica* Linnaeus, 1767 (Blattodea: Ectobiidae) from St. George Island in the Bering Sea, a species that can survive in Alaska only if it is indoors with humans. This well-studied blattodean apparently can no longer be found outside of buildings throughout its range (Martin *et al.* 2015). Synanthropes likely existed in Alaska before European contact. Forbes *et al.* (2019) found subfossil remains of *Pediculus humanus* Linnaeus, 1758 (Psocodea: Pediculidae) in an archaeological Yup'ik site in Nunalleq, in southwestern Alaska. Given that humans have been living in Alaska longer than any other region of North America, with the oldest confirmed sites dating to over 14 000 years before present (Holmes 2001), and in Beringia far longer (~30 000 years before present; Hoffecker *et al.* 2016), some of these populations of synanthropic arthropods may be the oldest on the continent.

Museums strive to minimise or eliminate populations of synanthropes, many of which are considered pest species that can damage museum specimens and artefacts (Querner 2015). Arthropods can be introduced to a museum through organic materials brought in for exhibits, via shipping containers for specimen loans, or by employees. Most museums practise various integrated pest control measures that include freezing, cleanliness, and vigilance. Monitoring with sticky traps and hand-captures are currently the most common forms of vigilance. The use of

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chemical deterrents and toxins, which were popular methods in the 20th century, has declined due to human health concerns (Pinniger *et al.* 2011). The University of Alaska Museum Insect Collection, in Fairbanks, Alaska, United States of America, processes all incoming loans and donations through freezers at −40 °C for three days and tries to annually examine every pinned specimen for evidence of infestation.

This study was undertaken to try to answer the following questions: Which species of arthropods can be found alive inside the museum? How different is a high-latitude indoor ecosystem from those of lower latitudes? What are the diets and trophic roles of organisms found alive inside the museum? It is hoped that this information will help with pest control measures and expand the growing body of knowledge on the ecology of interior ecosystems.

Methods

Specimens were opportunistically collected alive by museum staff by using sticky traps, by freezing, and by hand, inside the University of Alaska Museum, in Fairbanks, Alaska, between 2001 and 2019. Specimens collected by freezing were found in containers of museum specimens that were frozen for decontamination; these specimens were assumed to have been alive before freezing. Many, but not all, of these have been prepared and added to the museum collection. The collection effort was not controlled, and smaller-bodied (*e.g.*, Acari, Collembola) and flying (*e.g.*, Diptera) organisms were likely undersampled. The floor, room, or hallway within the museum where each specimen was found was not consistently recorded, so this information was not included in the analysis.

Specimens were identified by the first author (DSS), using keys in Lindroth (1961, 1963, 1966, 1968, 1969a, 1969b), Hatch (1971), McAlpine *et al.* (1981), Anderson and Peck (1985), Gordon (1985), McAlpine *et al.* (1987), Goulet (1992), Mockford (1993), Larson *et al.* (2000), Newton *et al.* (2000), Marshall (2006), Bright and Bouchard (2008), Catling (2008), and Pelletier and Hébert (2019), and by the specialists listed in the acknowledgements. Some specimens await species-level identification. All names were checked for current validity against recent checklists (*e.g.*, Maw *et al.* 2000; Bousquet *et al.* 2013; Pohl *et al.* 2018) and taxonomic name servers (*e.g.*, World Spider Catalog 2020 and the Integrated Taxonomic Information System (ITIS), Washington, D.C., United States of America, https://www.itis.gov/).

The museum (64.858 °N, 147.8424 °W, 187 m elevation) is situated on the University of Alaska Fairbanks campus in interior, subarctic Alaska, within the boreal forest, which consists primarily of white spruce (*Picea glauca* (Moench) Voss (Pinaceae)), Alaskan paper birch (*Betula neoalaskana* Sarg. (Betulaceae)), trembling aspen (*Populus tremuloides* Michx. (Salicaceae)), and balsam poplar (*Populus balsamifera* Linnaeus (Salicaceae)). Unmanaged forest, shrub, and meadow habitats, beds of managed ornamental plants, and grass lawns surround and grow throughout the campus. Live ornamental plants are kept indoors on the ground floor of the museum, but none are allowed in the research and collections space. Between 1 January 2019 and 14 February 2020, the average temperature inside the collections space was 19.93 °C (67.88 °F), and the relative humidity based on the averages of four sensors was 39.29%. Humidity levels are controlled in this space, with a set-point in winter (35%) that is lower than in summer (45%).

Species of specimens caught alive in the museum were coded into one of three categories, using published ecological knowledge of each taxon, combined with our observed count data. Synanthropes are species that establish breeding populations indoors that potentially can survive over multiple years. Seasonals are species that regularly appear indoors as a result of their life history, such as organisms that seek overwintering refuges and accidentally end up inside but cannot survive inside over multiple years. Transients are species that are rarely found indoors and don't appear to have life-history characteristics that predispose them to be repeatedly found indoors.

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Data for these specimens were downloaded from Arctos, the online specimen data management system used by the University of Alaska Insect Collection, and can be retrieved from https://arctos.database.museum/saved/insideUAM.

Results

Table 1 shows the identifications, abundance, and our synanthrope scale categorisations for all arthropods caught alive in the museum and processed into the museum insect collection. A total of 267 specimens catalogued as 193 records, representing a minimum of 77 arthropod species in 44 families and 12 orders, have been documented alive inside the museum over 18 years. Just over one-half of the specimens were synanthropes, with seasonals and transients each comprising just under one-quarter of the specimens collected (Fig. 1). Beetles, spiders, and booklice represented 80% of the total abundance. The synanthropes collected were primarily fungivores and detritivores, the seasonals collected were primarily predators and omnivores, and the transients collected were primarily predators and had the greatest diet diversity (Fig. 2). The transients had the greatest species richness ($n = 41$), the seasonals the least ($n = 11$), and the synanthropes' species richness was in between ($n = 21$). The most common month for synanthrope capture was January, for seasonals, it was September, and for transients, it was July.

Amongst the taxa documented, the booklouse *Dorypteryx domestica* (Smithers, 1958) (Psocodea: Psyllipsocidae) and the click beetle *Danosoma obtectum* (Say, 1839) (Coleoptera: Elateridae) are reported from Alaska for the first time. The click beetle consisted of a single-transient specimen, whereas the booklouse appears to maintain a thriving population inside the museum. The latridiid beetles *Cartodere constricta* (Gyllenhal, 1827), *Dienerella filum* (Aubé, 1850), and *Corticaria serrata* (Paykull 1800) (Coleoptera: Latridiidae) were not listed from Alaska in the most recent checklist of beetles of Canada and Alaska (Bousquet *et al.* 2013) but were found in sufficient numbers inside the museum to suggest they were reproducing. Two ant specimens of the phragmotic genus *Colobopsis* were captured during routine freezing of incoming exhibit display bark of unknown provenance. Unlike the prior three beetle species, which are synanthropes breeding inside the museum, this ant species would not have been able to establish a breeding population in the museum. A single specimen, caught by hand by cleaning staff, of a spider in the genus *Phantyna*, probably the species *P. bicornis* (Emerton, 1915) (Araneae: Dictynidae), represents the first and only record of this genus for Alaska. A single specimen, caught by hand in the fish lab, of the synanthropic spider *Oecobius cellariorum* (Dugès, 1836) (Araneae: Oecobiidae) was documented and is the only record to date from Alaska of this genus. This is currently the only DNA-barcoded specimen of this species in the DNA Barcode of Life Data System (Ratnasingham and Hebert 2007).

Discussion

This study represents the first scientific inventory of the arthropod biodiversity of an interior ecosystem in the subarctic. Although indoor pest species in Alaska are often documented by the University of Alaska Fairbanks Cooperative Extension Service, less focus and identification effort have been spent on understanding the entire interior fauna as a food web, including the nonpest species that can be found indoors. The species richness in the museum was higher than expected, and several notable taxa were recorded. These specimens have been useful for research, and 25 of the 267 specimens found alive inside the museum, representing 21 species, were DNA barcoded as part of Sikes *et al.*'s (2017b) effort to build a DNA barcode library for the state.

The most common month of capture for each group was not surprising; however, given our inconsistent and opportunistic sampling methods, these seasonality data should be considered suggestive rather than conclusive. Seasonal patterns do not appear to have been noted in previous studies of indoor arthropods, which have tended to focus on samples in single seasons

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Table 1. Identification list, specimen counts, and indoor association (grey = synanthropes; orange = seasonals; blue = transients) of arthropod specimens collected inside the University of Alaska Museum from 2001 to 2018.

Order	Family	Identification	Count	Assoc.
Araneae	Agelenidae	*Agelenopsis utahana* (Chamberlin & Ivie, 1933)	1	
Araneae	Amaurobiidae	*Arctobius agelenoides* (Emerton, 1919)	1	
Araneae	Araneidae	*Araneus marmoreus* Clerck, 1757	1	
Araneae	Araneidae	*Araneus trifolium* (Hentz, 1847)	1	
Araneae	Araneidae	Araneidae	1	
Araneae	Dictynidae	*Phantyna bicornis* (Emerton, 1915)?	1	
Araneae	Linyphiidae	*Erigone arctica* (White, 1852)	10	
Araneae	Linyphiidae	Linyphiidae	1	
Araneae	Lycosidae	Lycosidae	9	
Araneae	Lycosidae	*Pardosa* sp.	1	
Araneae	Lycosidae	*Pardosa fuscula* (Thorell, 1875)	1	
Araneae	Lycosidae	*Pardosa hyperborea* (Thorell, 1872)	1	
Araneae	Oecobiidae	*Oecobius cellariorum* (Dugès, 1836)	1	
Araneae	Philodromidae	Philodromidae	1	
Araneae	Salticidae	*Eris militaris* (Hentz, 1845)	1	
Araneae	Theridiidae	*Steatoda borealis* (Hentz, 1850)	12	
Araneae	Thomisidae	Thomisidae	3	
Araneae	Thomisidae	*Xysticus* sp.	3	
Mesostigmata	Ascidae	*Proctolaelaps* sp.	22	
Coleoptera	Anthicidae	*Anthicus coracinus* LeConte, 1852	1	
Coleoptera	Buprestidae	*Buprestis nutalli* Kirby, 1837	2	
Coleoptera	Buprestidae	*Melanophila acuminata* (DeGeer, 1774)	1	
Coleoptera	Carabidae	*Amara interstitialis* Dejean, 1828	5	
Coleoptera	Carabidae	*Amara patruelis* Dejean, 1831	11	
Coleoptera	Carabidae	*Amara* sp.	2	
Coleoptera	Carabidae	*Bembidion grapii* Gyllenhal, 1827	1	
Coleoptera	Carabidae	*Bembidion obscurellum* (Motschulsky, 1845)	1	
Coleoptera	Carabidae	*Bembidion quadrimaculatum* (Linnaeus, 1761)	1	
Coleoptera	Carabidae	*Bembidion* sp.	3	
Coleoptera	Carabidae	*Calathus ingratus* Dejean, 1828	1	
Coleoptera	Carabidae	*Carabus chamissonis* Fischer von Waldheim, 1820	1	
Coleoptera	Carabidae	*Carabus vietinghoffii* Adams, 1812	2	
Coleoptera	Carabidae	*Dicheirotrichus cognatus* (Gyllenhal, 1827)	2	
Coleoptera	Carabidae	*Platynus decentis* (Say, 1823)	1	
Coleoptera	Carabidae	*Pterostichus adstrictus* Eschscholtz, 1823	5	
Coleoptera	Carabidae	*Syntomus americanus* (Dejean, 1831)	1	

(*Continued*)

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Table 1. (*Continued*)

Order	Family	Identification	Count	Assoc.
Coleoptera	Cerambycidae	*Monochamus scutellatus* (Say, 1824)	1	
Coleoptera	Coccinellidae	*Coccinella transversoguttata* Faldermann, 1835	1	
Coleoptera	Coccinellidae	*Coccinella trifasciata* (Walbaum, 1792)	1	
Coleoptera	Coccinellidae	*Anatis mali* (Say, 1824)	1	
Coleoptera	Coccinellidae	*Hippodamia parenthesis* (Say, 1824)	1	
Coleoptera	Cryptophagidae	*Cryptophagus acutangulus* Gyllenhal, 1827	11	
Coleoptera	Curculionidae	*Otiorhynchus ovatus* (Linnaeus, 1758)	3	
Coleoptera	Dermestidae	*Anthrenus verbasci* (Linnaeus, 1767)	1	
Coleoptera	Dermestidae	*Dermestes lardarius* Linnaeus, 1758	2	
Coleoptera	Dermestidae	*Dermestes maculatus* DeGeer, 1774	2	
Coleoptera	Dermestidae	Dermestidae (larvae)	8	
Coleoptera	Dermestidae	*Reesa vespulae* (Milliron, 1939)	8	
Coleoptera	Dermestidae	*Trogoderma variabile* Ballion, 1878	1	
Coleoptera	Dytiscidae	*Colymbetes dahuricus* Aubé, 1837	1	
Coleoptera	Dytiscidae	*Colymbetes sculptilis* Harris, 1829	1	
Coleoptera	Dytiscidae	*Dytiscus circumcinctus* Ahrens, 1811	1	
Coleoptera	Elateridae	*Danosoma obtectum* (Say, 1839)	1	
Coleoptera	Latridiidae	*Cartodere constricta* (Gyllenhal, 1827)	1	
Coleoptera	Latridiidae	*Corticaria serrata* (Paykull, 1798)	7	
Coleoptera	Latridiidae	*Corticaria* sp.	1	
Coleoptera	Latridiidae	*Corticarina minuta* (Fabricius, 1792)	1	
Coleoptera	Latridiidae	*Dienerella filum* (Aubé, 1850)	12	
Coleoptera	Latridiidae	Latridiidae	2	
Coleoptera	Nitidulidae	*Glischrochilus vittatus* (Say, 1835)	1	
Coleoptera	Ptinidae	*Stegobium paniceum* (Linnaeus, 1758)	2	
Coleoptera	Silphidae	*Aclypea opaca* (Linnaeus, 1758)	7	
Coleoptera	Silphidae	*Thanatophilus sagax* (Mannerheim, 1853)	1	
Coleoptera	Silphidae	*Nicrophorus investigator* Zetterstedt, 1824	1	
Coleoptera	Silvanidae	*Oryzaephilus surinamensis* (Linnaeus, 1758)	1	
Coleoptera	Staphylinidae	*Philonthina*	2	
Diptera	Empididae	*Rhamphomyia* sp.	1	
Diptera	Psychodidae	Psychodidae	6	
Diptera	Phoridae	Phoridae	2	
Diptera	Drosophilidae	*Drosophila* sp.	1	
Diptera	Scathophagidae	Scathophagidae	1	
Diptera	Sciaridae	Sciaridae	1	
Hemiptera	Rhyparochromidae	*Peritrechus convivus* (Stal, 1858)	2	

(*Continued*)

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Table 1. (*Continued*)

Order	Family	Identification	Count	Assoc.
Hymenoptera	Tenthredinidae	*Nematus* sp.	1	
Hymenoptera	Formicidae	*Colobopsis* sp.	2	
Lepidoptera	Noctuidae	*Euxoa ochrogaster* (Guenée, 1852)	1	
Lepidoptera	Tineidae	*Tineola bisselliella* (Hummel, 1823)	1	
Lepidoptera	Noctuidae	*Ufeus* sp.	3	
Lepidoptera		Gelechioidea	2	
Neuroptera	Chrysopidae	*Chrysoperla* sp.	1	
Opiliones	Phalangiidae	*Phalangium opilio* Linnaeus, 1758	1	
Orthoptera	Acrididae	*Melanoplus* sp.	1	
Psocodea	Psyllipsocidae	*Dorypteryx domestica* (Smithers, 1958)	20	
Psocodea	Sphaeropsocidae	*Badonnelia* sp.	19	
Zygentoma	Lepismatidae	*Thermobia domestica* Packard, 1873	4	

(*e.g.*, Bertone *et al.* 2016). Transients are most likely to be at peak population size and greatest activity level outdoors in midsummer and were indeed captured most often inside the museum in July. Seasonals seeking overwintering refugia were most often captured in September, as would be expected due to the cooling temperatures that occur at the end of the summer. Synanthropes, which breed indoors, might be captured in all months of the year. Finding synanthropes most often in January could be due to random chance, or the lack of transients and seasonals in the winter may increase the likelihood that museum staff notice synanthropes at that time of year.

Bertone *et al.* (2016) were perhaps the first to conduct an intensive survey of interior arthropod biodiversity that did not focus on pest control. They surveyed 50 homes in North Carolina, United States of America and estimated that an average of 93 arthropod species occurred per home. Their methods differed greatly from those of the current study and resulted in the capture of many taxa our methods likely undersampled (*e.g.*, mites, flies). Additionally, their sampling was conducted within a single year (May to October 2012), with each home visited just once. This makes it hard to compare our results with theirs, but given that our list of 77 species was assembled over 18 years and is smaller than their estimate of average species per home based on a single day of sampling each home (93 species), it is clear the richness of species found in homes in North Carolina vastly exceeds that richness of species found alive inside the museum. This is not surprising, given the well-known latitudinal species-richness gradient and the fact that transient species comprised the majority of the interior species richness. Additionally, homes in general have a greater diversity of accessible food resources for arthropods, such as pets and their dander, human food detritus, house plants, and sleeping humans, than museums do. Museums also have janitorial staff that perform more regular cleaning than takes place in most homes, thus reducing food resources for arthropods. One important difference between museums and homes is the large number of international shipments of specimens loaned to museums around the world. Various synanthropes, such as the booklice reported herein, are far more likely to occur inside museums than in typical homes for this reason, possibly making museums a distinct subset of interior ecosystems. Many species of synanthropes would be expected to be shared across latitudes, if similar structures were compared, because these organisms breed indoors and the interior climate is relatively stable across latitudes (Just *et al.* 2019). And, indeed, some of the same general synanthrope higher taxa

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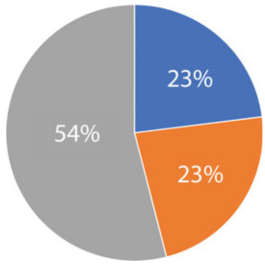

Fig. 1. The percentage of arthropod specimens categorised by indoor association (grey = synanthropes; orange = seasonals; blue = transients).

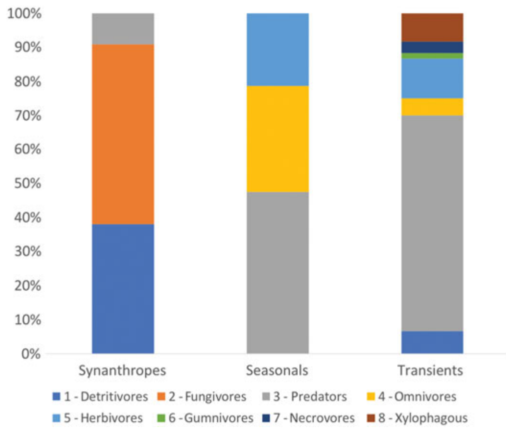

Fig. 2. The percent diet type of collected arthropods categorised by indoor association ranking.

identified in Bertone *et al.* (2016) also occur on our list (*e.g.*, Dermestidae, Psychodidae, Theridiidae, Zygentoma).

It appears no similar study focussed on the interior ecosystem of a single museum has been published, although many pest-specific "how to control" documents that list many commonly found arthropod taxa exist (*e.g.*, Blyth 1996; Querner 2015), and the website https://museumpests.net collates a considerable amount of useful information aimed at helping museums deal with pest species. Surveys have been conducted to assess integrated pest management practices in museums (*e.g.*, Linnie 1987; Deans 2017), and many museums maintain internal documents on animals captured alive inside their walls. New regional records have been published previously, based on specimens found alive in museums (*e.g.*, Huhta 1972). Publication of summaries of such data in the manner presented here would be valuable to the museum community and those interested in interior ecosystems.

Although Bertone *et al.* (2016) may have been the first to conduct a peer-reviewed scientific study of this nature, the basic idea – of treating human dwellings and the ecology of their unwanted arthropod occupants as an integral part of natural ecosystems – has been published on previously. Ordish (1960) described the natural history of a single 400-year-old Kentish farmhouse in England and included detailed descriptions of the life histories of the many arthropods found within.

The noctuid moth, *Ufeus* sp. (Lepidoptera: Noctuidae), is one curious find in the current study. A single *Ufeus* specimen in the museum's insect collection was captured outside in Fairbanks in 1970 by Kenelm Philip. Three other specimens were collected alive inside the museum in 2001, 2006, and 2019 (Table 1). These four specimens are the only the specimens of this taxon in the museum insect collection. We coded this species as a seasonal species because it appears to seek

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shelter for overwintering and thus is sometimes found indoors. It is unusual for a species that occurs in the wild in Alaska to be found more often indoors than out, but this is not the only such case. The latridiid beetle, *Dienerella filum*, is also known from more specimens caught inside the museum (12) than from specimens caught outdoors in Alaska (2). However, this is less surprising: this species is a known synanthrope (Bousquet 1990), and some synanthropes are occasionally found outside.

The booklice (Psocodea) *Dorypteryx domestica* and *Badonnelia* sp. (probably *B. titei* Pearman, 1953 (Psocoptera: Sphaeropsocidae) (Mockford 2005)) are taxa that have never been found outdoors in Alaska, with *B. titei* having never been found outside of buildings (Mockford 2005). In addition to being found inside the museum, these species have been found indoors in the Kenai National Wildlife Refuge headquarters building on the Kenai Peninsula, Alaska. They are well-known synanthropes that feed on moulds, and *D. domestica* is known from all continents except Asia and Antarctica (Cerdeña 2016). Both of these species are known museum synanthropes (Lienhard 1982). *Badonnelia titei* has been shown to feed on dried insect remains and may not require moulds for development (Bowser 2013). These two species maintain breeding populations inside the museum but to date are innocuous; however, they likely act as a food source for various other scavenger and predator species and thus could contribute to greater numbers of pest species, such as dermestid beetles.

Given their high abundance, small body size, and mould- and detrivorous-feeding habits, these booklice taxa probably form a significant portion of the arthropod base of the interior food web. If so, the animals of this interior food web may rely primarily on fungi rather than on plants. It is certainly the case that, like caves, this interior food web is necromass-based, with herbivory on live plants inside the museum representing a negligible energy source. As such, this food web adds to the growing number of examples of primarily allochthonous and necromass-based systems in Alaska. These include lotic water systems (Fellman *et al.* 2009), caves (Carlson 1994), islands after volcanic eruptions (Sikes and Slowik 2010), Arctic tundra, in which Koltz *et al.* (2018) calculated that 99.6% of the carbon processed by the invertebrate food web is from detrital sources, and snowfields, which accumulate dead arthropods that act as a food source for invertebrates and birds (Edwards 1972; Mullen *et al.* 2018).

We look forwards to future efforts to understand interior ecosystems from a scientific rather than an entirely pest control perspective. A global effort with more than 2000 volunteers to document biodiversity inside homes, led by Rob Dunn, is underway via an iNaturalist project called Never Home Alone: The Wild Life of Homes. Analysis of the data from this iNaturalist project, once completed, will provide a deeper context and understanding of our findings.

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