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One health implications of fur farming

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Fur farming involves the captive-breeding, rearing, and killing of between 85 – 100 million animals annually for their pelts. The purpose of this report is to summarise key areas of significance and concern regarding fur farming, and discuss these matters and their one-health considerations. We conducted primary literature searches using Google Scholar and PubMed that focused on issues of animal welfare, zoonoses and public health, and environmental impacts of fur farming, and examined 280 reports. We identified that at least 15 species are farmed for fur across at least 19 countries. We found 16 categories of animal welfare concern (e.g., deprivation, stress, abnormal behaviours, insanitary conditions, forced obesity, and high morbidity and mortality), 18 reported endemic pathogens and diseases with confirmed or potential zoonotic and cross-species implications (e.g., bacterial n = 6, viral n = 5, and parasitic n = 7), and four main categories of environmental concern (e.g., greenhouse gas emissions, invasive alien species, toxic chemicals, and eutrophication) associated with fur farming. Despite numerous efforts to systematically monitor and control animal welfare at fur farms, practices continue to fail to meet normal scientific principles and models used in other animal welfare situations. In our view, limited available data does not currently indicate that fur farms are major sources of zoonotic epidemics and pandemics. The environmental problems caused by fur farming are significant, and relate mainly to invasive species, toxic chemical release and eutrophication of water bodies. We offer some recommendations for monitoring and controlling particular fur farming practices, in line with many governments and other investigators we conclude that inherent problems are essentially unresolvable and advocate complete prohibitions on the sector.

KEYWORDS

animal welfare, zoonoses, public health, cross-species transmission, greenwashing, carbon emissions, invasive species

Introduction

Fur farming involves the captive-breeding, rearing, and killing of animals for their pelts, although byproducts include fur, skin, and meat (Gremmen, 2014; Halliday and McCulloch, 2022; Linzey and Linzey, 2022). Whilst 'farming' implies that animals are bred and raised within a closed-cycle system, the wild-capture of animals is also reported to constitute part of the supply chain (Gremmen, 2014); thus, the term 'farm' may be subject to broad use. Precise historical commencement of organised fur farming is unclear. However, mink (*Neogale* [formerly *Neovison*] *vison*), for example, were farmed in the USA as early as the 1860s (International Fur Trade Federation, 2011), and in the case of coypu (nutria) (*Myocastor coypus*) as early as 1913 (Colpitts, 1997). Currently, there are at least 11,000 fur farms across Europe, North America, and China alone (Fenollar et al., 2021). The global value of fur farming has been estimated at $40bn (ActAsia, 2019), and the industry directly employs around 60,000 people (Gremmen, 2014). Presently, fur farming may involve between 85 and 100 million animals per year (Pluda, 2020; Halliday and McCulloch, 2022; Linzey and Linzey, 2022), with the main production regions being Europe, the United States, and China (Gremmen, 2014).

Production, marketing, and consumption of fur has raised longstanding key concerns from nongovernmental organisations (NGOs) and the surveyed public regarding, notably, animal welfare (Picket and Harris, 2015; ActAsia, 2019; Halliday and McCulloch, 2022), zoonoses and public health (Picket and Harris, 2015; ActAsia, 2019), environmental issues, carbon emissions and footprint (ActAsia, 2019), and ethics (Sun, 2013; Picket and Harris, 2015; Thubron, 2017; ActAsia, 2019; Gorbach, 2021; Arney, 2022; Linzey and Linzey, 2022). Leading NGOs, academics, and public opinion have called for the development and implementation of legislation to alleviate or, in particular, completely prohibit fur farming practices that involve harm to animals, people, and the environment (Laatu, 2013; Sun, 2013; Picket and Harris, 2015; ActAsia, 2019; Arney, 2022; Fur Free Alliance, 2020; Pluda, 2020). The scientific community has also provided numerous studies documenting issues and concerns that broadly support the messages of the NGO reports, and this information will be presented later. Whilst NGOs have produced some detailed and evidence-based reports, such as those above, our data collation focused primarily on the peer-reviewed scientific literature.

In this report, we aim to summarise three key areas of significance and concern regarding fur farming, in particular, animal welfare, public health, and environmental issues, and discuss these matters within the one-health theme. We also apply a precautionary principle throughout, in which we adopt the position that where data may be lacking, priority of concern and protection is assumed in favour of animal welfare, public health, and environmental issues.

Methods

We conducted six primary literature searches using Google Scholar and PubMed since 2010. We selected Google Scholar for its search breadth capabilities, and we selected PubMed for its specificity regarding health-related issues. Subject searches were: 1. animal welfare, 2. zoonoses, 3. environment/climate, 4. environment/invasive alien species, 5. environment/toxic chemicals, and 6. environment/eutrophication. The results are presented in Box 1.

To determine the major environmental effects of fur farming to investigate further, an initial scoping literature search was carried out in Scholar, using the terms ["environmental issues" "fur farming"] and ["environmental impacts" "fur farming"]. The results were sorted by relevance. The first 20 documents were scanned to identify the major environmental issues related to fur farming. These were invasive species, eutrophication, and toxic chemicals. These terms were used to build more specific searches. [Greenhouse gasses and CO2 were flagged for consideration for examination at the request of the funder.]

The literature review followed the guidelines for rapid reviews (Khangura et al., 2012; Dobbins, 2017), and considered papers from 2010 to present although the papers may cite work done earlier.

Search 1.

Scholar search: "fur farm" (welfare OR stereotypy) - 387 results.

PubMed search: "fur farm" AND (welfare OR stereotypy) - 0 relevant results.

Search 2.

Scholar search: "fur farm" ("public health" OR disease OR zoono*) - 523 results.

PubMed search: "fur farm" ("public health" OR disease OR zoono*) - 4 results (3 new and 1 duplicate).

Search 3.

Scholar search: ("CO2 emissions" OR "greenhouse gas" OR "carbon footprint") "climate change" "fur farming" - 106 results.

PubMed search: ("CO2 emissions" OR "greenhouse gas" OR "carbon footprint") "climate change" "fur farming" - 0 results.

Scholar search: "mink manure" "greenhouse gas" - 30 results.

PubMed search: "mink manure" "greenhouse gas" - 0 results.

Search 4.

Scholar search: "fur farming" "invasive alien species" - 164 results.

PubMed search: "fur farming" "invasive alien species" - 0 results.

Search 5.

Scholar search: "fur farming" "toxic chemicals" - 37 results.

PubMed search: "fur farming" "toxic chemicals" - 0 results.

Search 6.

Scholar search: "fur farming" "eutrophication"- 93 results.

PubMed search: "fur farming" "eutrophication" - 0 results.

Additional items (animal welfare = 42, zoonoses and public health = 28, environment = 1) were supplemented from authors' libraries. Reports were excluded on the basis of low relevance, for example, duplication of same information, articles focused on history of fur farming, or specific laboratory-based infection of animals.

The summary information contained in Tables 1–12 is derived from reviewed published reports and may not include all examples of otherwise known species and countries involved in fur farming, animal welfare issues, pathogens and diseases, or environmental considerations.

Results

Box 1 provides the results for the search terms and strings.

Overview

Currently, at least 15 species are farmed for fur across at least 19 countries (Table 1). Across all 15 species identified as fur farmed animals, the biological obligate dietary categories and representations were noted: carnivores $n = 7$; omnivores $n = 5$; herbivores $n = 3$. However, the most frequently cited fur farmed species (mink [*Neogale vison*], raccoon dogs [*Nyctereutes procyonoides*], and foxes [*Vulpes vulpes* & *Alopex lagopus*]) are all carnivores.

Numerous countries were identified that formerly permitted fur farming and that have now prohibited the practice, which include: Austria, Belgium, Bosnia and Herzegovina, Croatia, Czech Republic, Estonia, France, Northern Ireland, Luxembourg, North Macedonia, Norway, Serbia, Slovakia, Slovenia, The Netherlands, and United Kingdom (Arney, 2022). Currently, the European Union is considering a ban on fur farming across its membership, and if introduced then this would add Bulgaria, Denmark, Finland, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Poland, Romania, Spain, and Sweden to those countries that have already prohibited the practice. Such a ban would raise the minimum total number of nations banning fur farming to 31, and reduce the number of practicing countries to a minimum of six, these being Canada, China, Iceland, Japan, Russia, and the USA.

Animal welfare

From the literature review of current fur farming operations, we identified at least 16 categories of animal welfare issues and concerns (Table 2), which were categorised on the basis of negative reporting and itemisation for these factors within the literature.

Public health, zoonoses, and cross-species infections

From the literature we identified at least 18 reported endemic pathogens and diseases with confirmed or potential zoonotic and cross-species implications that were associated with fur farmed animals (Table 3). Of these pathogens and diseases, their categorisations were bacterial $n = 6$, viral $n = 5$, and parasitic $n = 7$. Across all 18 endemic pathogens and diseases, those with recorded confirmed or potential categories of zoonotic, cross-species/spillover, or reverse zoonotic were $n = 15$, $n = 16$, and $n = 2$ respectively. The information contained in Table 3 may under represent the diversity of pathogens, diseases, and affected species. For example, whilst there was a lack of reports directly associating Lissavirus, canine Parvovirus, and SARS-CoV-2 with farmed cats and dogs, these animals are potentially linked to these issues.

BOX 1 Search results.

Welfare (Search 1): 387 results	
Unavailable, irrelevant or not in English	305
Downloaded	82
Added from authors' libraries	42
Irrelevant after reading or duplicates	52
Used in review	72
Zoonoses (Search 2): 527 results	
Unavailable, irrelevant or not in English	388
Downloaded	139
Added from authors' libraries	28
Irrelevant after reading or duplicates	59
Used in review	108
Environment/climate (Search 3): 136 results	
Unavailable, irrelevant or not in English	67
Downloaded	69
Irrelevant after reading or duplicates	59
Used in review	10
Environment/invasive alien species (Search 4): 164 results	
Unavailable, irrelevant or not in English	48
Downloaded	116
Added from authors' libraries	1
Irrelevant after reading or duplicates	41
Used in review	76
Environment/toxic chemicals (Search 5): 37 results	
Unavailable, irrelevant or not in English	10
Downloaded	27
Irrelevant after reading or duplicates	21
Used in review	6
Environment/eutrophication (Search 6): 93 results	
Unavailable, irrelevant or not in English	24
Downloaded	69
Irrelevant after reading or duplicates	60
Used in review	9

Environment

From the literature we identified four main categories of environmental concern (greenhouse gas emissions, invasive alien species, toxic chemicals, and eutrophication) (Tables 4–12). Across

TABLE 1 Species currently farmed globally by species name, common name, and region.

Scientific name	Common name	Region farmed	References
Neogale vison	American mink	CAN, CHN, BUL, DNK, ESP, FIN, GER, GRE, HUN, ISL, ITA, JAP, LVA, LTU, POL, ROU, RUS, SWE	(Honjo, 2014; Picket and Harris, 2015; Brash et al., 2016; Firlej et al., 2018; ActAsia, 2019; Klockiewicz et al., 2021)
Mephitis mephitis	Striped skunk	USA	(Sobey et al., 2019)
Mustela putorius furo	Ferret	CHN, JAP	(Firlej et al., 2018)
Martes zibellina	Sable	RUS	(Firlej et al., 2018)
Marmota bobak bobak	Bobcat marmot	RUS	(Plotnikov, 2012)
Marmota camtschatica camtschatica	Black-capped marmot	RUS	(Plotnikov, 2012)
Chinchilla lanigera	Chinchilla	CHN, DNK, GER, HUN, ITA, LVA, LTU, POL, ROU, RUS	(Firlej et al., 2018)
Vulpes vulpes	Red and silver fox	CAN, CHN, DNK, FIN, ISL, ITA, LVA, LTU, POL, ROU, RUS	(Firlej et al., 2018; ActAsia, 2019; Klockiewicz et al., 2021)
Alopex lagopus	White and blue fox	CHN, FIN, POL, RUS	(Picket and Harris, 2015; Mustonen et al., 2017; Firlej et al., 2018)
Nyctereutes procyonoides	Raccoon dog	CHN, FIN, POL	(Firlej et al., 2018; Koistinen and Korhonen, 2018; ActAsia, 2019; Klockiewicz et al., 2021)
Oryctolagus cuniculus	Rabbit	CHN, RUS	(Firlej et al., 2018)
Myocastor coypus	Coypu (nutria)	RUS,	(Firlej et al., 2018)
Canis lupus familiaris	Dog	CHN, POL	(ActAsia, 2019; DEFRA, 2021)
Felis catus	Cat	CHN	(ActAsia, 2019; DEFRA, 2021)

BUL, Bulgaria; CAN, Canada; CHN, China; DNK, Denmark; FIN, Finland; GER, Germany; GRE, Greece; HUN, Hungary; ISL, Iceland; ITA, Italy; JAP, Japan; LVA, Latvia; LTU, Lithuania; POL, Poland; ROU, Romania; RUS, Russia; ESP, Spain; SWE, Sweden; USA, United States of America.

all four categories, the numbers of cited examples of concern regarding greenhouse gas emissions, invasive alien species, toxic chemicals, and eutrophication were $n = 9$, $n = 57$ (7 species), $n = 13$, and $n = 9$, respectively.

It is estimated that between 15% and 38% of all invasive mammal species originate from fur farming (Genovesi et al.,

TABLE 2 Animal welfare issues identified in literature.

Issues	References
Basic environmental deprivation = absence of bedding, animals forced to stand or rest on floors of bare wire cages.	(Sun, 2013; Picket and Harris, 2015; ActAsia, 2019; Arney, 2022; Linzey and Linzey, 2022)
Enrichment deprivation = absence of areas for seclusion.	(Sun, 2013; Picket and Harris, 2015; ActAsia, 2019; Arney, 2022; Linzey and Linzey, 2022)
Spatial deprivation = absence of space consistent with normal movement and exercise, including inability to stand or straighten bodies.	(Sun, 2013; Picket and Harris, 2015; ActAsia, 2019; Arney, 2022; Linzey and Linzey, 2022)
Inability to perform normal behaviours – digging, climbing, nest building, running, jumping, scent tracking, absence of areas for seclusion.	(Sun, 2013; Picket and Harris, 2015; ActAsia, 2019; Arney, 2022; Linzey and Linzey, 2022)
Enrichment deprivation = mentally and behaviourally understimulating conditions.	(Sun, 2013; Picket and Harris, 2015; ActAsia, 2019; Polanco et al., 2021; Arney, 2022; Linzey and Linzey, 2022)
Social deprivation = absence of close contact with individuals of same species.	(Picket and Harris, 2015; ActAsia, 2019; Arney, 2022; Linzey and Linzey, 2022)
Social stress = co-occupant aggression and injuries, including bites and cannibalism.	(Sun, 2013; Picket and Harris, 2015; ActAsia, 2019; Linzey and Linzey, 2022)
Abnormal and stereotypic behaviours = pacing, scrabbling (scratching at enclosure boundaries), fearfulness, self-mutilation, fur-chewing, learned helplessness, infanticide.	(Sun, 2013; Picket and Harris, 2015; Polanco et al., 2018; Arney, 2022; Linzey and Linzey, 2022)
Exposure to potential anxiety = stress behaviours of individuals easily detectable by others.	(Plotnikov, 2012; Picket and Harris, 2015; ActAsia, 2019; Arney, 2022; Linzey and Linzey, 2022)
Exposure to insanitary and bio-insecure conditions = lack of clean and absorbent substrates, rusty and contaminated wire as regular surfaces, faecal and urinary matters contaminated surroundings, risk of infection due to close proximity of others.	(Noah, and Animalia, 2015; Picket and Harris, 2015; ActAsia, 2019; Linzey and Linzey, 2022)
Obesity or forced obesity = overfeeding to produce larger pelts.	(Picket and Harris, 2015; Mustonen et al., 2017)
Morbidity = (e.g., in mink, foxes, racoon dogs, raccoons, & marmots) numerous bacterial/protozoan/viral/ectoparasite infections, causing conditions including enteric disease, necrotic pyoderma, pneumonia, obesity, leg weakness, negative mobility, abrasions, pressure lesions, skeletal pathology (carpal joint laxity and locomotor deficits), periodontal disease, eye disease, and negative genetic traits and associated conditions.	(Kempe et al., 2010; Plotnikov, 2012; Ellick et al., 2013; Picket and Harris, 2015; Brash et al., 2016; Hammer et al., 2016; Kempe and Strandén, 2016; Moisander-Jylhä et al., 2016; Nordgren et al., 2016a; Nordgren et al., 2016b; Smura et al., 2016; Mustonen et al., 2017; Kempe, 2018; Devaux et al., 2021; Klockiewicz et al., 2021; Linzey and Linzey, 2022)
High premature mortality = e.g., 15 - 50% mortality to weaning among foxes, 99% mortality among mink kits.	(Picket and Harris, 2015; Linzey and Linzey, 2022)
Physical mistreatment and abuse = rough treatment of animals during handling and	(Picket and Harris, 2015; Arney, 2022; Linzey and Linzey, 2022)

(Continued)

TABLE 2 Continued

Issues	References
processing, use of injurious grasping tongs, bruises, generalised injuries, artificial insemination injuries, trampling, strangling, and bone fractures, animals thrown, beaten.	
Inhumane transportation = live animals shipped over large distances (e.g., Denmark to China) in highly restrictive and containers under deprived conditions.	(Picket and Harris, 2015; Arney, 2022)
Inhumane killing methods = live skinning – hanging (head down) of animals during insertion of knife and flaying of skin (larger animals, e.g., raccoon dogs); cerebral concussion (rabbits), cervical dislocation (smaller animals, e.g., mink); decapitation (chinchillas), gassing using CO or CO_2 (smaller animals, e.g., mink); electrocution (medium-sized animals, e.g., foxes).	(Sun, 2013; Picket and Harris, 2015; Ramchandani and Coste-Maniere, 2017; ActAsia, 2019; Linzey and Linzey, 2022)

2009; Tedeschi et al., 2022). Although there have historically been other reasons for introduction of furbearers to non native habitats, those introductions were smaller in scale, and there is a large body of evidence, including genetic single nucleotide polymorphisms (SNP) studies that trace back the origins of several problematic invasive species directly to escapes or releases from fur farms. Indeed, the fur species American mink, racoon dog and muskrat, are the most widespread invasive species in Europe, spanning 27 countries (Tedeschi et al., 2022). A study in South America for example, showed that whilst some invasive species were imported for hunting such as hares and rabbits, deer, antelope and chital, or for biological control (grey foxes), American mink, muskrats and North American beavers were imported for specifically for fur. Nutria and the American mink are cited by IUCN's Global Invasive Species Database as originating from fur farming escapes or releases (IUCN, 2023). Furthermore, widespread populations of the American mink and racoon dog have their origins clearly traced to releases in the Russian Federation from fur farms, where the species were first recorded (Balakirev and Tinaeva, 2001). A study in

TABLE 3 Confirmed and potential zoonotic and cross-species infections associated with fur farmed animals (ordered by pathogen type and then alphabetically by disease).

Pathogens Bacterial = (B) Viral = (V) Parasitic = (P) Toxin = (T)	Diseases	Signs and/or symptoms shared among human and nonhuman animals (e.g.)	Fur farm animals involved	Transmission Zoonotic = ZN Cross-species/ spillover = CS Reverse zoonotic = RZ confirmed/ potential/probable	References
Arcanobacterium phocae (B)	Fur animal epidemic necrotic pyoderma	Dermatitis, lethargy, anorexia, death.	Mink (*Neogale vison*) White and blue fox (*Alopex lagopus*) Raccoon dog (*Nyctereutes procyonoides*)	CS confirmed	(Nordgren et al., 2016a; Nordgren et al., 2016b; Nordgren, 2017)
Chlamydia spp. (B)	Chlamydiosis	Conjunctivitis, rhinitis, respiratory, cough, gastrointestinal, fever, anorexia, lethargy, urogenital disease, death.	Mink (*Neogale vison*) Fox (unspecified) Raccoon dog (*Nyctereutes procyonoides*)	ZN confirmed, CS confirmed	(Li et al., 2018; Edling, 2023)
Clostridium botulinum (B)	Botulism	Gastrointestinal, paralysis, anorexia, weight loss, blepharospasm, photophobia, tetany, depression, death.	Mink (*Neogale vison*) White and blue fox (*Alopex lagopus*) Red and silver fox (*Vulpes vulpes*) Ferret (*Mustela putorius furo*)	ZN confirmed, CS confirmed; ZN confirmed, CS confirmed ZN confirmed, CS confirmed	(Myllykoski et al., 2011; Anniballi et al., 2013)
Escherichia coli (B)	E. coli infection	Gastrointestinal, malaise, fever, septicaemia, death.	Mink (*Neogale vison*) Mammals general	ZN confirmed, CS confirmed	(Zheng et al., 2019)
Methicillin-resistant Staphylococcus aureus (B)	MRSA infection	Dermatological, abscessation, fever.	Mink (*Neogale vison*)	ZN confirmed, CS confirmed	(Larsen et al., 2016)

(Continued)

TABLE 3 Continued

Pathogens Bacterial = (B) Viral = (V) Parasitic = (P) Toxin = (T)	Diseases	Signs and/or symptoms shared among human and nonhuman animals (e.g.)	Fur farm animals involved	Transmission Zoonotic = ZN Cross-species/ spillover = CS Reverse zoonotic = RZ confirmed/ potential/probable	References
Salmonella spp.	Salmonellosis	Gastrointestinal, malaise, fever, death.	Mink (*Neogale vison*)	ZN confirmed, CS confirmed	(Finnish Food Authority, 2022)
Canine distemper virus (V)	Distemper	Pulmonary, death.	Raccoon dog (*Nyctereutes procyonoides*)	CS confirmed	(Cheng et al., 2015)
Carnivore amdoparvovirus/ Parvovirus spp. (V)	Aleutian disease	Hepatic lesions, periportal fibrosis, hepatocyte necrosis, vascular degeneration, renal damage, myocarditis, pneumonia, neurological, death.	Mink (*Neogale vison*) Striped skunk (*Mephitis mephitis*) Raccoon dog (*Nyctereutes procyonoides*) White and blue fox (*Alopex lagopus*)	ZN potential, CS confirmed	(Valdovska and Pilmane, 2011; LaDouceur et al., 2015; Fernaíndez-Antonio et al., 2016; Zhang et al., 2016; Virtanen, 2022)
Influenza A virus (V)	Influenza/avian flu	Fever, lung lesions, rapid respiration, interstitial pneumonia, cough, shortness of breath/difficulty breathing, fatigue, muscle body aches, loss of taste and/or smell, weight loss, death, malaise, lung lesions, rapid respiration, interstitial pneumonia, inappetence, weight loss, ocular discharge, sneezing, death.	Mink *(Neogale vison)* Cat (*Felis catus)* Dog (*Canis lupus familiaris*) Raccoon dog (*Nyctereutes procyonoides*) Red and silver fox (*Vulpes vulpes*) Striped skunk (*Mephitis mephitis*) Ferret (*Mustela putorius furo*)	ZN confirmed (via intermediary poultry); RZ potential/probable; CS confirmed	(Suarez, 2017; Sidik, 2023)
Lissavirus (V)	Rabies	Neurological, excitation, ataxia, paralysis, loss of consciousness, death.	Striped skunk (*Mephitis mephitis*) Raccoon dogs (*Nyctereutes procyonoides*) Foxes (unspecified)	ZN confirmed, CS confirmed	(Liu et al., 2015)
SARS-CoV-2 (V)	Severe acute respiratory syndrome/ COVID-19	Fever, lung lesions, rapid respiration, interstitial pneumonia, cough, shortness of breath/difficulty breathing, fatigue, muscle body aches, loss of taste and/or smell, weight loss, death, malaise, lung lesions, rapid respiration, interstitial pneumonia, inappetence, weight loss, ocular discharge, sneezing, death.	Mink (*Neogale vison*) Raccoon dog (*Nyctereutes procyonoides*) Mammals general.	ZN confirmed, CS confirmed, RZ confirmed ZN confirmed, RZ confirmed ZN potential, CS confirmed, RZ potential	(Aguiló-Gisbert et al., 2021; Ekstrand et al., 2021; Goraichuk et al., 2021; Roger et al., 2021; Shriner et al., 2021; Rajendran and Babbitt, 2022; Roy et al., 2023)
Eimeria spp., *Isospora* spp. (P)	Coccidiosis	Gastrointestinal, hemorrhagic enteritis, catarrh, intestinal necrosis, weight loss, death.	Mink (*Neogale vison*) Red and silver fox (*Vulpes vulpes*)	ZN confirmed, CS confirmed	(Molenaara and Jornaa, 2016; Klockiewicz et al., 2021; Kuznetsov et al., 2021)

(Continued)

TABLE 3 Continued

Pathogens Bacterial = (B) Viral = (V) Parasitic = (P) Toxin = (T)	Diseases	Signs and/or symptoms shared among human and nonhuman animals (e.g.)	Fur farm animals involved	Transmission Zoonotic = ZN Cross-species/ spillover = CS Reverse zoonotic = RZ confirmed/ potential/probable	References
Cryptosporidium spp. (P)	Cryptosporidiosis	Gastrointestinal, fever, weight loss, pain, anorexia, malaise, septicaemia, meningitis, death.	Mink (*Neogale vison*) Raccoon dog (*Nyctereutes procyonoides*) Red and silver fox (*Vulpes vulpes*)	ZN confirmed; CS confirmed	(Klockiewicz et al., 2021; Sengupta et al., 2021)
Leishmania infantum (P)	Leishmaniasis	Haemorrhagic pneumonia, enteritis, malaise, death.	Mink (*Neogale vison*)	ZN confirmed; CS confirmed	(Azami-Conesa et al., 2021; Klockiewicz et al., 2021)
Microsporidia/ Enterocytozoon bieneusi (P)	Microsporidiosis	Gatrointestinal, malaise, fever, weight loss, death.	Mink (*Neogale vison*) Raccoon dog (*Nyctereutes procyonoides*) White and blue fox (*Alopex lagopus*)	ZN confirmed; CS confirmed	(Klockiewicz et al., 2021)
Neospora caninum (P)	Neosporosis	Meningitis, ataxic, dysphagic, coma, abortions, Multifocal abscessation, death.	Red and silver fox (*Vulpes vulpes*)	CS confirmed	(Klockiewicz et al., 2021)
Toxoplasma gondii (P)	Toxoplasmosis	Gastrointestinal, malaise, anorexia, weight loss, pain, fever, systemic disease, death.	All fur farmed animals.	ZN confirmed; CS confirmed	(Shamaev et al., 2020; Klockiewicz et al., 2021)
Trichinella nativa (P)	Trichinellosis	Gatrointestinal, malaise, fever, weight loss, death.	White and blue fox (*Alopex lagopus*)	ZN potential, CS confirmed	(Uspensky et al., 2019; CDC, 2020)

Issues of transmission (column 5) are conveyed using the following keys and meanings: ZN = pathogen or disease of known zoonotic nature; CS = cross-species/spillover known to involve the relevant pathogen(s); RZ = pathogen or disease of known for reverse zoonotic; confirmed/potential/probable = describes the status of key elements to species listed as farmed for fur. Example: for American mink SARS-CoV-2 is a confirmed zoonoses (ZN), is confirmed to cross species barriers (spillover) (CS), confirmed as a reverse zoonosis (RZ), and confirmed among fur farmed animals.

Denmark on the invasive racoon dog, (Nordgren, 2017) used 4000 SNPs to show that the species originated from Danish fur farm escapes and releases. Genetic studies have shown that often animals from different fur farms have genetically distinct profiles so it is possible to track their spread. Once the animals are released or escaped there is often considerable admixture, which increases genetic diversity and makes the populations more adaptable and difficult to control (Zalewski et al., 2009).

The literature review identified the following taxa as major alien species, primarily originating from fur farming, that cause environmental damage, damage to infrastructure and biodiversity loss: coypu/nutria (*Myocastor coypus*); American mink (*Neogale vison*); muskrat (*Ondatra zibethicus*); racoon dog (*Nyctereutes procyonoides*); raccoon (*Procyon lotor*) and to a lesser extent red foxes (*Vulpes vulpes*) and the North American beaver (*Castor canadensis*). For this report, we presumptively consider that where a species has been recognised as an invasive organism it holds an inherent potential to invade local ecologies from fur farms, whether or not a release has occurred.

Coypu (*Myocastor coypus*) also called nutria, are native to South America, and are semi-aquatic rodents since introduced to Asia, Europe, Africa and North America for fur farming (Carter and Leonard, 2002; Bertolino and Genovesi, 2007; Liordos et al., 2017; IUCN, 2023). The rodent has a very high reproductive rate, and a wide range of acceptable habitats, hence accidental and deliberate releases have allowed its spread in the wild; it is now listed as one of the world's worst invasive alien species (Lowe et al., 2000; IUCN, 2023).

American mink (*Neogale vison*) were introduced into Europe, South America and Asia via fur farming (Balakirev and Tinaeva, 2001; IUCN, 2023), and the species is now established in the wild in 28 countries. Mink are highly mobile with a high rate of reproduction, and are one of the most invasive and damaging

TABLE 4 The results of the literature search on greenhouse gas (GHG) emissions from fur farming and mink manure.

Major Findings	References
A real mink coat and mink trim have four times the impact on climate change compared to a faux mink coat or faux trim. The real coat would have to last at least four times as long as the faux coat to mitigate this impact.	(Bijleveld, 2013)
A single piece of mink (28 kg CO_2-eqv/pelt) or fox pelt (83 kg CO_2-eqv/pelt) produces a carbon footprint from the production chain, equivalent to one to three days' average consumption of a consumer. When comparing fur garments with faux fur or acrylic garments, GHG emissions and acidifying emissions were both worse for the fur coats than for the other clothing items, even when the fur was assumed to last considerably longer.	(Silvenius et al., 2012)
Discussed the use of animal fat, including fur farm waste, to produce biodiesel, which could potentially mitigate some of the environmental damage from fur farming. However, producing biodiesel from plants directly would still be more sustainable. This was a pilot study and the method is not in general usage.	(Sirviö et al., 2018)
The hazardous manure waste from fur farms could be mitigated by mixing with peat and biochar which decrease the greenhouse gas pollution from manure as well as the nutrient content. The biochar mixture could be used as organic fertiliser. This was a pilot study and the method is not in general usage.	(Tyhtilä, 2016)
Manure makes up 5% of total N_2O emissions in Latvia, with most of this coming from cattle poultry and pigs. Mink are a minor source of N_2O emissions.	(Aplocina et al., 2015)
Peat can be used to cover manure to reduce the gaseous (GHG) emissions such as Methane and Ammonia. However, peat is non-renewable so biochar was tested and found to be a good alternative to peat, reducing emissions and needing replacement every 10 days. This was a pilot study and the method is not in general usage.	(Hellstedt and Regina, 2016)
Ammonia (NH_3) emissions in the Netherlands were lower from mink than other species because of the lower numbers farmed.	(Van Bruggen et al., 2012)
Mink manure could be made into biogas (Methane CH_4), a potentially useful product. This was a pilot study and the method is not in general usage.	(Awais et al., 2016)
Leachate from mink farms had considerably higher concentrations of ammonia, nitrates and phosphates when compared to poultry, fish farm, domestic and brewery effluents. Only dairy production had higher concentrations than mink farming.	(Khademi et al., 2014)

species in Europe (Zuberogoitia et al., 2010). Part of the success of the spread of the America mink relates to its opportunistic generalist predation habits, selecting a variety of available and vulnerable prey.

Muskrat (*Ondatra zibethicus*) are medium-sized semi-aquatic, omnivorous rodents that are seasonal breeders, and native to North America. Through fur farming, the muskrat has spread to Europe, Asia, and South America, with the preferred habitat being wetlands in a variety of climates (Keddy, 2010).

Racoon dogs (*Nyctereutes procyonoides*) are omnivorous canids with Far Eastern origins, that were introduced into the area comprising the former Union of Soviet Socialist Republics, and

TABLE 5 The environmental effects of invasive coypu/nutria (*Myocastor coypus*) by country.

Country/ region	Major findings	References
Iran	Recorded in 1995 for the first time, modelled future spread. Expected to spread further into uncolonised areas of Iran and beyond. Negative effect on biodiversity.	(Farashi and Najafabadi, 2015)
Kenya	Introduced in 1950 for fur farming. Escapes into lake produced large population that has now mainly died out due to hunting. Isolated occurrence.	(Gherardi et al., 2011)
Greece	Damage to crops and disease transmission are the main concerns. Looked at acceptability of various scenarios for the control of the invasive coypu species. Farmers and hunters were more in favour of lethal control methods than the general public. Present all over Europe, has caused extensive damage to crops, river ecosystems and has spread disease (leptospirosis). Successfully eradicated in UK but eradication attempts in mainland Europe have not been successful, despite high costs.	(Adamopoulou and Legakis, 2016; Liordos et al., 2017)
USA	A semi aquatic animal, coypu can cause devastation to water bodies and terrestrial habitat, including degrading vegetated marshland into open water ponds due to their high consumption of vegetation. Their burrows weaken levees and other infrastructure and they are major crop pests. Kruse, 2012 compared Louisiana (USA) with England (UK) as England has eradicated coypu. Factors such as inadequate knowledge of the location of the coypu populations and lack of funding to address the issue make eradication challenging.	Fall et al., 2011; Kruse, 2012; Poland et al., 2021
Italy	Colonised from Slovenia but origin is fur farms. Monitoring of the feral population and extrapolation of numbers estimated around a million feral coypu, calling in to question the effectiveness of eradication attempts. One study showed coypu have a habitat preference for reed beds (Phragmites) over rush beds, and they increase in density in late summer and autumn, which could be important in controlling the species.	(Marini et al., 2011; Bertolino et al., 2015; Balestrieri et al., 2016)
Ireland	Small numbers of coypu (nutria) found in Ireland but no large populations. Monitoring is continuing.	(Marnell et al., 2019)
Brazil	Native only to the very southern Pampas biome in Brazil there are reports of the species causing damage to waterways, vegetation and ecosystems elsewhere in the country, and this spread has been attributed to the production of meat, deliberate introductions to watercourses and fur farm escapes.	(Pereira et al., 2020)
South Korea	Coypu spread from fur farms along rivers and tributaries. A coordinated strategy is needed to control the spread.	(Hong et al., 2015)

(Continued)

TABLE 5 Continued

Country/region	Major findings	References
Japan	In Japan, 150 individuals were introduced from the USA in 1939, and their feral populations are currently causing serious problems to aquatic ecosystem and agriculture. Genetic analysis of microsatellite markers suggests that coypu in Okayama Plain originated from downstream fur farms in Yoshii and Takahashi Rivers and have expanded their range through the tributaries. Coypu affect ecosystem stability for example, one study found coypu fed on medium to large mussels and leave only smaller ones that may affect the stability of the population.	(Kawamura et al., 2018; Nagayama et al., 2020)
EU	Collected 24,232 coypu records between 1980 and 2018 from a range of sources in 28 European countries, modelled against 4 different climate change scenarios, showed that the coypu has, by far, not yet reached all potentially suitable regions and there is potential for further range expansion.	(Schertler et al., 2020)

TABLE 6 The environmental effects of invasive American mink (*Neogale vison*).

Country/region	Major findings	References
Scotland, UK	Since introduction for fur farming mink have spread in range and impacted native bird and mammal populations. Landscape and habitat features affect the spread. Targeted intervention at the invasion front is needed.	(Fraser et al., 2013)
Europe-wide	Due to competition with the invasive American mink The European mink (*Mustela lutreola*) is critically endangered with less than 5000 individuals remaining in the wild. Those populations that remain are fragmented and localised. The species is listed as critically endangered it is expected that the European mink will become extinct unless action is taken.	(Maran et al., 2016)
Italy	American mink naturalised in Friuli Venezia Giulia and several other regions of N. Italy. Mink mainly restricted to N. Italy but modelling shows they have the potential to spread much more widely within Italy.	(Iordan et al., 2012; Iordan et al., 2017)
Spain	Invasive American mink are reservoirs of native European parasites and contribute to the spread of these parasites with unpredictable environmental consequences. The mink also caused extensive environmental damage causing Spain to pass strict regulations in 2016 and a ban on new mink farms.	(Martínez-Rondán et al., 2017; Linzey and Linzey, 2022)
Islands, Galicia, Spain	Discusses the eradication programme on islands in Galicia, Spain. The mink there in 2000's were not the same population that were released in earlier decades but came from more recent releases.	(Velando et al., 2017)
Greece	American mink is naturalised in the country, and negatively affecting avifauna by predation and also competing with the European mink and other native carnivores such as otter and polecat. Damage to poultry farming and aquaculture. In certain areas, control of the American mink is required, hunting them as game is suggested. American mink is the most damaging of all invasive species in Europe affecting 47 native species by predation and competition. Attempts to control the invasion have had limited success in Greece and range expansion is ongoing.	(Adamopoulou and Legakis, 2016; Galanaki and Kominos, 2022)
Italy	Surveyed American mink in the Lazio region – 11 of 12 fur farms in the area had escaped or liberated mink, security of the farms was low.	(Bartolommei et al., 2013)
Iceland	Self-sustaining populations occupied all available habitats and culling programs failed to reduce the populations significantly. Negative impact on bird and fish populations. However recently populations are declining possibly due to climate change affecting aquatic food webs.	(Stefansson et al., 2016)
Japan	Invasive species in Japan, which passed a law in 2006 making it illegal to build new fur farms among other measures. The last remaining fur farm received repeated official warnings due to breaches of this act and closed in 2016.	(Linzey and Linzey, 2022)
UK	Genetic study found that gene flow can be halted by landscape features such as mountains and management efforts could use this information to break down connectivity. The case has been made for eradication rather than control, due to the costly and ongoing nature of control efforts. Eradication would be cheaper and more effective over the longer term and would be more successful in protecting wildlife. Significant contributor to the decline in water vole populations, ground nesting birds and fishes. Monitoring in Thames Valley shows increase of colonised sites from 7% to 46% in a 20-year period. American mink has devastated ground nesting wetland bird populations as well as rodents, amphibians and native mink. Responsible for the near extinction of the water vole (*Arvicola terrestris*) in the UK.	(Barrat et al., 2010; Newman and Macdonald, 2015; Martin and Lea, 2020)
Romania	Reports on 13 new occurrences from central Romania (Braşov County, Transylvania).	(Ionescu et al., 2019)
Bulgaria	Comments on the high number of mink escaping from fur farms in Bulgaria and establishing feral populations.	(Koshev, 2019)

(Continued)

TABLE 6 Continued

Country/region	Major findings	References
Nordic countries	Predation on ducks and nests causing population declines. Smaller ducks are disproportionately affected. However, removal of mink (e.g., from a Finnish island) sees swift recovery of duck populations.	(Fox et al., 2015; Jordán, 2017)
Spain	Between 1985–2012 the distribution area of non-native mink in Spain increased 17-fold to occupy a quarter of mainland Spain to the detriment of native mink - conservation measures are urgently needed.	(Põdra and Gómez, 2018)
Uruguay	Already established in Argentina and Chile, this paper provides evidence of a new invasion near a fur farm in Uruguay and potential risks to the pampas biome.	(Laufer et al., 2022)
China	Genetic admixture between feral populations and farmed mink. No trace of bottle necks. High genetic diversity promotes the invasiveness and rapid evolution in the wild.	(Zhang et al., 2021)
Sardinia	A 2011 model greatly underestimated the spread of feral mink on the Island. Their colonisation is more widespread than previously recorded, including colonisation of the entire River Tirso, the longest (152 km) Sardinian river.	(Dettori et al., 2016)
Belarus	Microsatellite markers confirm a continued influx of farmed mink into already established feral populations.	(Valnisty et al., 2020)
Chile	Trapping campaigns can remove up to 70% of the invasive mink in an area.	(Medina-Vogel et al., 2022)
Poland	Commented on high genetic diversity of feral mink. This is unusual in invasive species due to founder effects. Mink are able to quickly recolonise areas from where they have been previously eradicated. More than 3% of the mink examined were infected with *Trichinella* parasites. Wildlife adversely affected for example two bird species in the Masurian Lake District in northeastern Poland were detrimentally affected by the appearance of American mink in the area – they declined in both distribution and abundance – coots (*Fulica atra*) and great crested grebes (*Podiceps cristatus*).	(Brzeziński et al., 2012; Dziech et al., 2023)
Spain	American mink populations have spread across 12,530 km of rivers with a population of over 30,000 individuals and is a major contributor to the decline of the European mink as well as other native species including European polecats (*Mustela putorius*), stoats (*Mustela erminea*), and sea birds.	(Sidorovich et al., 2010; Newman and Macdonald, 2015; Maran et al., 2016; Goicolea et al., 2023)
Chile	There are differences in genetic structure and diversity within different populations of American mink in Chile, and these can add to the problem by admixture.	(Mora et al., 2018)
Argentina	In 2011, the American mink became the most acute threat to the critically endangered hooded grebe (*Podiceps gallardoi*) when the mink killed 4% of the population, hence control methods were put in place, with partial success.	(Fasola et al., 2011; Fasola and Roesler, 2016)
Portugal	Established throughout several river basins in Portugal via border crossings from Spain. Eradication not possible due to new individuals crossing, so control is the only option.	(Rodrigues et al., 2015)
Germany	Fish stocks seem relatively unaffected by mink predation despite this being a major part of the diet but high rates of predation on breeding waterfowl have had a negative effect on the population.	(Zschille et al., 2014)

then spread throughout Europe (Geacu, 2019). The species' preferred habitat is water, marshland, swampland, reedbeds, and hardwood forests (Geacu, 2019).

North American raccoons (*Procyon lotor*) are invasive mesocarnivores and the species' success relates to its adaptability to a wide range of habitats and resources, even becoming commensal with humans in cities and feeding on refuse. The spread of raccoons is also due to a lack of predators and competition in its size range (Salgado, 2018).

There is a higher concentration of nitrogen (N) and phosphorus (P) in the manure of mink compared to certain livestock. When these N and P salts are washed into water courses, aquatic plants and algae overgrow, which leads to eutrophication (Vaitkunas, 2000), and a subsequent depletion of oxygen and degradation of the ecosystem.

Discussion

Animal welfare

Numerous scientific principles and models have been developed and regularly refined regarding the consideration and assessment of animal welfare, and are in common use across a variety of situations, including research, guidelines, general practice, and the law (Warwick, 2022). Key examples of these principles and models are summarised in Table 13. Some of these principles and models (e.g., the Five Freedoms, the Five Welfare Needs, and the Three Fs [Freedoms]), are essentially designed to inspire or require that certain provisions are met and stresses prevented; thus, they relate largely to human responsibility over animals in their care. Other principles and models (e.g., Motivation and preference, the Five Domains, Positive and negative states, Sentience, and If it leaves, does it come back?), are animal-centred; thus, they relate largely to the way that animals may feel and implicit obligations to ensure they have a good life.

TABLE 7 The environmental effects of invasive muskrat (*Ondatra zibethicus*) by region.

Country/region	Major findings	References
Italy	Introduced in 1990s from North America as escapees from fur farms.	(Bertolino et al., 2015)
Lithuania	Negative impact on ecosystems (especially water embankment) and crop plants. Undermines banks, dams and road and railway embankments causing ecological and economic losses. Devastated populations of reed type plants such as *Phragmites* and *Typha angustifolia.* In some cases, though this increases biodiversity as species dominance is reduced. Impacts native rodents and he aquatic species *Anodonta, Unio*, and the freshwater pearl mussel *Margaritifera*.	(Skyrienė and Paulauskas, 2012)
Baltic Sea Region	By digging and feeding on plant roots the muskrat undermines the structure of river banks and disturbs the ecosystem and the vegetation, causing flooding, mudflats and destroying the habitat of fishes and nesting birds.	(Olenin et al., 2017)
Russia, Germany	Intensive grazing changes vegetation dynamics and threaten fish, shellfish and ground nesting birds. Crop damage, weakened infrastructure. Threats to endangered species such as the Russian desman (*Desmana moschata*). Vectors/reservoirs of pathogens such *as* liver fluke, leptospirosis or alveolar echinococcosis (as the intermediate host of *Echinococcus multilocularis*). In Germany damage to infrastructure and biosecurity costs have been estimated as €12.4 million.	(Barrat et al., 2010)
Nordic countries	Causes considerable damage to the environments, reservoir for potentially lethal zoonotic microorganism such as *Francisella tularensis.* Predation on ducks and nests causes population declines.	(Fox et al., 2015; Macieira, 2019)
Poland	Declining in Poland due to predation by American mink.	(Dziech et al., 2023)
Mongolia	Muskrats were released in 1967 in Mongolia and from 415 introduced individuals, the spread has been exponential for example, there are estimates of 80,000 individuals around a single lake (Lake Khar-Us). Due to the damage inflicted on ecosystems, hunting for fur was proposed as a control measure.	(Otgonbaatar et al., 2018)

TABLE 8 The environmental effects of invasive racoon dog (*Nyctereutes procyonoides*) by country.

Country/region	Major findings	References
Siberia	Native frogs and birds are preyed on, and the species is a vector for parasitic diseases and rabies.	(Tsiamis et al., 2021)
Poland	Originally escaped from fur farms and colonised much of Poland, at a density of 1–5 individuals per km^2 and covering 89% of Poland. Threat to ground nesting waterbirds and frogs including several endangered species. Population thought to be increasing.	(Dziech et al., 2023)

Captivity-stress, environmental enrichment, morbidity, and mortality

Comparison between reports summarised in Table 2 and the scientific principles and models summarised Table 13 clearly indicates that traditional safeguards for animal welfare are comprehensively not being met at fur farms.

Most studies of stress among fur farmed animals appear to have involved mink (*Neogale vison*). Environmental enrichment (e.g., provision of elevated 'getaway bunks') in mink cages, where adult females can periodically avoid offspring, have shown benefits to parent health and welfare; although apparent increased mortality was noted that could be linked to incidental invasive study observation (Dawson et al., 2013). Nevertheless, environmental enrichment in general (e.g., increased space and climbing and hiding facilities) has been found to reduce stereotypical behaviour (e.g., abnormal repetitive behaviours) in fur farmed mink (Dallaire et al., 2012; Campbell et al., 2013; Díez-León and Mason, 2016; Díez-León et al., 2016); although, enrichment did not significantly affect growth rates. Importantly, whether or not an animal actively uses a particular environmental enrichment feature, they may still benefit from its presence (Decker et al., 2023). However, space relating to cage ceiling height requirements may be relevant to specific behaviours, such as reaching for food, and individual specific preferences (Díez-León et al., 2017). Understimulation (boredom-like) states and stereotypical behaviours among fur farmed animals (although potentially not inter-related) have also been shown to rapidly reduce where environmental enrichment (e.g., extra space and toys) is improved (Polanco et al., 2021). Captivity-stress among fur farmed mink is recognised in the literature as a persistent issue warranting intervention (Wlazlo et al., 2022). One aspect of such intervention involves addition of natural tranquilisers (valerian [*Valeriana officinalis* L.] and passion flower [*Passiflora incarnata*]) extracts, which were found to be effective based on both physiological (blood cell counts and cortisol) and behavioural (fearfulness and aggression) parameters (Wlazlo et al., 2022).

Studies of foxes (*Alopex lagopus*) have identified genetic traits that are implied in conditions including high growth rates and body weights, leg weakness, and negative mobility, which were found to be common, and indicated that improved selective breeding is required (Kempe et al., 2010). Similarly, this same fox species has been reported to experience skeletal pathology such as carpal joint laxity and locomotor deficits that may be attributable to inadequate nutrition, housing, and genetic background (Mustonen et al., 2017). A number of health issues are endemic to fur farms that involve frequently occurring pathogens, immunocompromisation, disease risks, diseases, and injuries. For example, the proceedings of an international congress on fur farming includes at least 18 health concerns endemic to fur farming (Larsen et al., 2016).

Inevitably, mortality is a condition of fur farming because all animals are intentionally culled. However, in addition to

TABLE 9 The environmental effects of invasive North American raccoon (*Procyon lotor*) by region.

Country/region	Major findings	References
Germany	Invasive racoon species are vectors for a number of parasites and spread disease among domestic animals, livestock and humans in the case of racoon ringworm.	(Peter et al., 2023)
Italy	Initially only found in the north of the country, the range of the species is increasing and spreading southward in recent years. A total of 53 occurrence points were collected from observation sites in the Lombardy area. Modelling showed Alpine regions were of low suitability for the species and they were unlikely to have been introduced via the Swiss route. There is a potential for colonisation of new areas.	(Mori et al., 2015; Boscherini et al., 2019)
USA	Crop damage, declines of waterfowl and tortoise, spread of infections such as *Gnathostoma procyonis,* a nematode in the stomach, and *Crenosoma globlei*, which infects the lungs, leptospirosis and tularemia and a reservoir for rabies.	(Barrat et al., 2010)
Cyprus	Present on Cyprus due to fur farming – threat to biodiversity.	(Peyton et al., 2020)
Germany	Looked at urban areas in Germany (Berlin). Biodiversity loss.	(Genovesi et al., 2013)
Spain	Feral populations have been introduced multiple times and founders can be between 2 and 4 individuals. Mixing between populations keeps genetic diversity high and makes populations more adaptable, increasing their invasive potential.	(Alda et al., 2013)
E.U.	Since the 1990s racoon populations have grown exponentially and the problem is now out of control in Europe due to growing populations, range expansion and inadequate management strategies.	(Salgado, 2018)

generalisable disease-related mortalities are also those associated with outbreaks such as SARS-CoV-2, which resulted in many millions of animals (e.g., 17 million mink in Denmark alone) being culled (Linzey and Linzey, 2022). Mink are especially susceptible to SARS-CoV-2, and outbreaks have occurred in an estimated 400 mink farms in Europe and North America (Linzey and Linzey, 2022), including in Denmark, France, Greece, Italy, Lithuania, Poland, Spain, Sweden, The Netherlands, Canada, and United States, (Fenollar et al., 2021).

Whilst fur farmed dogs and cats can be categorised as domesticated animals, several species, notably mink, sable, foxes, raccoons, raccoon dogs, and coypus, should be considered wild animals. Also, other species, for example, ferrets, rabbits, and chinchillas, despite long histories of captive use, cannot be regarded as biologically domesticated (Décory, 2019; Arney, 2022). Although varying degrees of domestication and husbandry challenge may be involved among fur farmed species, all animals across the domesticated-to-wild spectrum should be regarded as having complex welfare needs, and farmed wild species may be

TABLE 10 Other species of concern.

Country/region	Species	Major findings	References
USA	Red foxes (*Vulpes vulpes*)	Red foxes are not native to California, multiple introductions occurred through fur farming. Recolonisation is cancelling out eradication programs. Red foxes are also spreading throughout the mid-Atlantic region with the Appalachian Mountains acting as a corridor for gene flow from the northern (native) source to admix with the fur farmed sources, enabling range expansion.	(Kasprowicz, 2016; Sacks et al., 2016)
E.U.	North American beaver (*Castor canadensis*)	Negative impacts on ecosystems and native species by predation (e.g., fishes, amphibians), competition and interbreeding (with native carnivores), alters hydrology damaged infrastructure, and provides a reservoir for disease.	(Hollander et al., 2017)

regarded as particularly sensitive to captive conditions that essentially deprive animals of natural, or even naturalistic, environments. Further, an expert scientific committee of the European Commission has long acknowledged that fur animal species are unsuitable for farming (SCAHAW, 2001).

Zoonoses and public health

Table 3 summarises pathogens and diseases associated with fur farms and relevant species, and also indicates wide-ranging potential for zoonotic, cross-species, endemic and emergent diseases. However, based on available information persistent or significant transmission has not been established for all of these infections. For some pathogens and resultant diseases, notably SARS-CoV-2, substantial work has been done that indicates the importance of this disease in both fur farmed animals and humans. For other pathogens, for example, influenza viruses, these hold potential for devastating cross-species epidemics and pandemics, despite little current data regarding seroprevalence or manifested disease. Further research is needed to more precisely ascertain potential levels of risk associated with each known pathogen associated with fur farms. Accordingly, Table 3 presents issues of transmission by utilising keys and meanings that describe the involvements of pathogens and diseases that are confirmed as being associated with fur farmed species, indicates the species of relevance regarding these pathogens and diseases, and clarifies whether a pathogen or disease is confirmed only for the species in general or is also confirmed among fur farmed animals. For example, regarding American mink, SARS-CoV-2 is a confirmed

TABLE 11 Toxic chemicals used in the fur processing industry.

Toxins	Major Findings	References
Sulphuric acid, toluene, ammonia, zinc, chlorobenzene, chlorine, lead, naphthalene	Used in the preservation of farmed fur, all of these substances are harmful to the environment and public health.	(Linzey and Linzey, 2022)
Chromium	Chromium compounds are used in fur processing and preservation and are toxic to both the environment and public health. Almost ten chromium substances are listed on ECHA's Candidate List of Substances of Very High Concern (SVHC). Chromium in the environment can stunt crop growth and reduce yields and can affect human health and fertility.	(Chandrasekaran, 2018; Prasad et al., 2021; Hossini et al., 2022; Linzey and Linzey, 2022)
Nonylphenol (NP) and nonylphenol ethoxylates (NPE)	Used in processing fur. Persistent in the environment and very toxic to aquatic life. Presence of NP found in human tissues. Reproductive and developmental effects in fishes. Endocrine disruptors.	(Chandrasekaran, 2018)
Mercury and persistent organic pollutants (POP's)	Mercury, polychlorinated biphenyls (PCB), dichlorodiphenyltrichloroethane (DDT), hexachlorocyclohexane (HCH), and dieldrin found to be present in mink feed and mink waste in Nova Scotia. Lakes in the catchment of mink farms had higher THg flux and ΣPCB flux than lakes with no mink farms nearby. Mercury is toxic to both the environment and public health.	(Gregory et al., 2022)
Azo-dyes (Organic chemicals with a functional nitrogen containing group with aryl and substituted aryl groups.)	Azo dyes are used in the processing of fur and have been shown to cause allergic contact dermatitis in workers. Some of the cleavage products of the breakdown of azo dyes are unregulated and have been shown to be mutagens, with unknown public health consequences,	(Brüschweiler and Merlot, 2017; Uitti, 2020)

TABLE 12 The eutrophication effect of nutrient enrichment on water bodies in the vicinity of fur farms.

Findings	References
Developed a novel phosphate loading model to assess the drivers of eutrophication and the contribution of mink farming to this issue. Mink farming was found to be a primary driver of phosphate deposition, contributing to cultural eutrophication of several lakes in Novia Scotia, Canada. Modelling scenarios indicated mink farming was much worse for eutrophication than aquaculture run off due to fish farming in the same area.	(Van Heyst et al., 2022)
Reported the severe eutrophication of lake downstream from mink farm causing changes in zooplankton assemblages.	(Jones et al., 2022)
Constructed a nitrogen loading model, showing that contributions from fur farming and seafood processing disproportionately affected smaller water bodies rather than larger ones. Where water turnover is low or in small water bodies localised industry such as fur farming and be a significant cause of eutrophication.	(Kelly et al., 2021)
Aquatic midges can be an indicator of eutrophication. By comparing midge assemblages it was possible to establish a baseline (before mink farming) and found that mink farming has cause deterioration of benthic habitat. Found that midges associated with low dissolved oxygen had increased, which was correlated to fur farming in the vicinity.	(Campbell and Kurek, 2019)
Although lakes were eutrophic or hypereutrophic over time, midge composition had remained stable and may have adapted or become tolerant to the high levels of nutrient influx over decades of fur farming.	(Pereira et al., 2020; Campbell et al., 2022a; Campbell et al., 2022b)
For each mink pelt, 20.5 kg of manure and 18 L of urine are produced, corresponding to 1 kg of N (nitrogen) and 0.3 kg of P (phosphorus), which can be extrapolated to 455 tonnes of phosphorus and 910 tonnes of nitrogen per year in Nova Scotia.	(MacEachern, 2018)
Evaluated the trophic status of Gozna and Secu reservoirs from Semenic Mountains, they were found to be mesotrophic (containing the correct level of nutrients) but with a tendency to eutrophication due to anthropogenic activities including fur farming.	(Zsolt et al., 2016)

zoonosis, is confirmed to cross species barriers (spillover), is confirmed as a reverse zoonosis, and is further confirmed among fur farmed animals. While a particular pathogen or disease that is confirmed among fur farmed animals becomes a clear issue of concern, the presence of a pathogen or disease in a species under non-farmed conditions involves potential concerns due proven occurrence and transmissibility.

Microbiome and virome pathogens of animals harbour potential in any country for the emergence of epidemics and pandemics. Numerous studies already describe major outbreaks of highly pathogenic and pandemic related animal and zoonotic diseases, two-way transmission of pathogens, and rapid dissemination within fur farming establishments. The international nature of fur farming, and of human travel generally, harbours significant – and historically demonstrated – risks of pathogenic infiltration and spillover between humans, fur farmed animals, and vice-versa causing and continuously inviting animal based, zoonotic, and public health crises. However, there appears to be little data to allow for estimate of relative risk for zoonotic outbreaks linked to fur farming. Nevertheless, significant zoonoses and public health issues are confirmed, as are itemised in Table 3, and below.

Bacteria and diseases

Fur animal epidemic necrotic pyoderma is a frequently observed disease of fur farmed mink (*Neogale vison*) foxes (*Alopex lagopus*), and raccoon dog (*Nyctereutes procyonoides*) (Nordgren et al., 2016a; Nordgren et al., 2016b; Nordgren, 2017). Botulism has been reported to affect several fur farmed species including mink (*Neogale vison*) white and blue fox (*Alopex lagopus*) red and silver fox (*Vulpes vulpes*) ferret (*Mustela putorius furo*), and frequently has a high mortality rate (Myllykoski et al., 2011; Anniballi et al., 2013). Chlamydia bacteria, which cause chlamydiosis, has been reported among fur farmed mink, farmed foxes, and raccoon dogs (Li et al., 2018). The study found that all foxes and raccoons, and 5% of mink harboured Chlamydia (Li et al., 2018). However, the presence of these pathogens appears to be

TABLE 13 Summary of frequently used animal welfare principles and model.

Principle/ Model	Summary description	Reference
The Five Freedoms	Freedom from hunger and thirst. Freedom from discomfort. Freedom from pain, injury. Freedom to express normal behaviour. Freedom from fear and distress.	(Farm Animal Welfare Council, 1979)
Motivation and preference	The ability to express preferences – to choose according to motivation. For example, habitat selection or performing exploratory behaviours.	(Dawkins, 1990)
Control over environment	Welfare is linked to the animal's control over its interactions with the environment and, thus, homeostasis and survival. Animals lacking control over their environment frequently develop a raft of negative states, including stereotypies, aggression, sedentarism, learned helplessness, hyperactivity, exploratory and escape activities, stress, immunosuppression and disease.	(Dawkins, 1990; Broom, 1991)
The Three Fs (Freedoms)	Freedom - animals should lead natural lives. Feelings - animals should feel well and experience normal pleasures. Function - animals should function well.	(Fraser et al., 1997)
The Five Welfare Needs	Need for a suitable environment. Need for a suitable diet. Need to be able to exhibit normal behaviour patterns. Need to be housed with or apart from other animals. Need to be protected from pain, suffering, injury and disease.	(RSPCA, 2006)
Controlled deprivation	Regardless of enrichment, captive animals probably experience inferior conditions when compared to nature. Essentially, even the best conditions equate to a basic "life-support system" rather than meeting holistic biological needs.	(Burghardt, 2013)
The Five Domains	Nutrition (negative versus positive). Environment (negative versus positive). Health (negative versus positive). Behaviour (negative versus positive). Mental (negative versus positive). = "A life worth living"	(Mellor, 2016)
Positive and negative states	The promotion of positive states (favourable feelings, stimulation, pleasure, comfort, quiescence, good mental, emotional and physical health, good welfare) and avoidance of negative states (thwarting of positive states, stress, pain, suffering, understimulation, unfavourable stimulation and poor welfare).	(Mellor, 2015)
Our control, our responsibility	In nature, animals have control over their own welfare, whereas in captivity, humans are in control of their welfare and thus hold high responsibility.	(Mendl et al., 2017)
Sentience	Sentience recognises and embraces the capacity to feel positive, neutral and negative experiences (such as pleasure, pain, enjoyment and suffering, etc.), as well as to experience consciousness and self-awareness.	(Mendl et al., 2017)
If it leaves, does it come back?	If opening a cage door results in the animal leaving and returning, then captive conditions and welfare may be favourable (or is it merely dependent on basic sustenance)?. If the animal does not return, then welfare may be unfavourable.	(Peng and Broom, 2021)
Crypto-overcrowding	The inability for all animals in an enclosure to simultaneously use any facility or furnishing. For example, all animals must be able to occupy a water vessel or basking site at the same time.	(Arena and Warwick, 2023)

[Adapted from Warwick, 2022 (Warwick, 2022)].

limited to host carriers rather than disease transmission (Li et al., 2018). *Escherichia coli* infection has been identified among fur farmed mink (Zheng et al., 2019), and its potential importance as a ubiquitous contagion for many species is well known, although there appear to be few reports of this disease in the farming sector. *E. coli* infections are widespread among humans and other animal species, including fur farmed mink, and are caused by opportunistic bacteria that are commonly isolated from soil and water (OIE, 2018; Zheng et al., 2019; Turner, 2022). Studies have detected *E. coli* isolates in over 90% of fur farmed mink and feed, with antibiotic-resistant strains also being identified (Agga et al., 2021). Methicillin-resistant *Staphylococcus aureus* (MRSA) is a widely-acknowledged 'super-bug' affecting human and non-human species, and has been isolated from approximately one-third of fur farmed mink (Larsen et al., 2016). Salmonellosis has been reported to significantly affect mink kits in Finland (Finnish Food Authority, 2022).

Viruses and diseases

Canine distemper virus may affect various mammalian species with high consequential mortality, and has been known to cause a severe outbreak in racoon dogs at a fur farm among vaccinated animals (Cheng et al., 2015). Aleutian disease is a highly debilitating infection associated with fur farmed mustelids (LaDouceur et al., 2015). However, outbreaks involving 5% of mink at Danish farms has been recorded (Hjulsager et al., 2016). Rabies has been identified via serology at least in relation to one farm in China, with 2.78% of animals providing positive results (Liu et al., 2015). SARS-CoV-2 (Covid 19) is an exemplar virus, disease, and pandemic with relevance to fur farming. At least 33 mammalian species have been highlighted as being at risk of contracting SARS-CoV-2 (Suarez, 2017; Akimova et al., 2021; Goraichuk et al., 2021). Influenza virus is a highly contagious and concerning infection of fur farmed animals (notably mink), that causes high mortality (Åkerstedt et al., 2012; Sun et al., 2021). However, numerous species are also susceptible to influenza virus infection (Suarez, 2017).

Parasites and diseases

Coccidiosis has been identified in fur farmed mink, although the causal parasites may affect diverse species (Kuznetsov et al., 2021). Prevalence rates for coccidia at fur farms have been recorded at 56 – 69% (Molenaara and Jornaa, 2016; Kuznetsov et al., 2021). Increased mortality has been noted among affected mink kits and a mortality rate of 50% has been recorded among fox puppies (Klockiewicz et al., 2021). Cryptosporidiosis is caused by microparasites, and one study at a fur farm found that prevalence was low (Sengupta et al., 2021). However, another study detected variable prevalence rates for Cryptosporidium spp. of up to 31% among fur farmed raccoon dogs, foxes, and mink (Klockiewicz et al., 2021). Leishmaniasis is a significant, commonly vector-borne, cross-species and zoonotic disease that also affects fur farmed mink (Śmielewska-Łoś et al., 2003). High mortality of 38% has been recorded among mink kits (Śmielewska-Łoś et al., 2003). Microsporidiosis results in gastrointestinal disorders, malaise and can affect various fur farmed animals (Śmielewska-Łoś et al., 2003). The prevalence of the pathogens at a Chinese fur farm was found to be low to moderate at approximately 16% of foxes and 4% of raccoon dogs (Zhao et al., 2015). Neosporosis appears to affect mainly foxes where fur farms are concerned and prevalence seems to be low at approximately 4% (Śmielewska-Łoś et al., 2003). Toxoplasmosis is caused by microparasites, and is one of the most important global parasitic diseases of fur farmed animals (Klockiewicz et al., 2021). Three seroprevalence studies have found between 32% and 41% of sampled fur farmed mink to be positive (Shamaev et al., 2020), and mortality among kits as high as 90%-100% (Klockiewicz et al., 2021). Whilst various routes of transmission may be implied, contaminated offal feed is an important route (Śmielewska-Łoś et al., 2003). Trichinellosis is a parasitic disease that can affect many species, although the available information appears only to document seroprevalence at 4% among fur farm workers (Uspensky et al., 2019).

Toxins and diseases

Whilst nonmetallic and metallic deposits have been reported among fur farmed foxes, for example, carbon (C), sodium (Na), aluminium (Al), and phosphorous (P), there appears to be insufficient information to indicate the specific problems that might be associated with significant toxicoses (Filistowicz et al., 2011). However, environmental and human health implications associated with fur farm-related toxin contamination warrant further targeted research.

Contaminated feed

Contaminated feed has been indicated as a source of botulism (mink, ferrets, and foxes) (Myllykoski et al., 2011) and influenza virus (Sun et al., 2021). One study found that 10% of raccoon dogs at a farm in China that experienced fatal respiratory and gastrointestinal diseases had succumbed to H5N1 from chicken carcases (Suarez, 2017). Recycled fur farm animals as well as offal from types of livestock farms are also used as feed (Myllykoski et al., 2011), creating a potential for perpetual recontamination.

Environment

There are few studies that have looked directly at the impact of fur farming on climate change and greenhouse gas emissions (GHG). Whilst it is recognised that livestock and intensive farming make an enormous contribution to GHG and climate issues (e.g., [Garnier et al., 2019; Zubir et al., 2022]), fur farming comprises a relatively small percentage of this total and as such the issue of "intensive animal farming" is usually considered as a whole, not separated by species or use. However, the initial literature review showed that fur farming may produce disproportionately large emissions due to nitrous oxide (N_2O) in manure that is a more potent greenhouse gas than CO_2 (Bijleveld, 2013). Hence a further search was carried out specifically on the GHG emissions from mink manure.

During this literature review, we confirmed that fur animal manure produces disproportionately more, N, P and GHG than other species (Dubrovskis et al., 2009; Khademi et al., 2014). It is also clear that the environmental impact of fur is greater than that of other textiles, but again, fur comprises a smaller proportion of the total textile industry. Although declining in Europe and the USA, fur production is holding steady in China. The disproportionately high GHG emissions from fur bearing animals compared to livestock is an issue of concern.

The environmental impact of invasive alien species released from fur farms

Invasive alien species (IAS) are animals and plants introduced accidentally or deliberately into a natural environment where they are not normally found, with serious negative effects on either ecosystems or native species (Tsiamis et al., 2021). Invasive carnivores and mesocarnivores introduced by fur farming are opportunistic generalists, meaning they can exploit a large range of habitats and natural resources (Salgado, 2018; Weiskopf et al., 2020). Many animals were released from fur farms over the past century due to escape, deliberate release in times of low prices, and occasionally releases by animal rights groups. Invasive species originating from fur farms are often small, mobile, forms with a high reproductive rate, which allows for rapid spread. For example, American mink are now considered an invasive species in 28 European countries (Martínez-Rondán et al., 2017). The spread of such species is one of the most serious threats to ecosystems globally (Early et al., 2016; Ielmini and Sankaran, 2021).

It is clear that the release of small carnivorous fur animals into the non-native environment continues to have devastating impacts on native species, biodiversity, and the spread of disease. These animals may also cause physical damage to ecosystems by burrowing, which leads to erosion at terrestrial - aquatic boundaries (Harvey et al., 2019).

Eradication efforts are costly, often logistically difficult, and only partially successful

Whilst fur farms operate, there remain the possibilities of deliberate or accidental releases and establishment of invasive carnivores (Hollander et al., 2017); in particular because three species American mink, coypu, and muskrats, are able to opportunistically exploit a variety of habitats and diets (Liordos et al., 2017). Several studies show that the genetic diversity of feral populations is being kept high by admixture from fur farms. Until fur farms are phased out, eradication attempts for invasives will likely at best be only partially successful. Eradication of invasives is costly and often requires many years. Thus, phasing out fur farming would be the most efficient way to ensure that invasive populations are controlled or eliminated. On the Eurasian continent a fur farm ban would be of limited use because feral populations spread across borders; thus, global agreement would be the most effective approach.

The environmental impact of chemical pollution from fur farming

Fur is a natural material subject to decomposition; thus, chemical treatment is necessary for its preservation (Linzey and Linzey, 2022). These chemicals are toxic to the environment and human health (Linzey and Linzey, 2022).

Toxic chemicals from processing fur

Often, the environmental processing of fur and leather are considered together in the literature. Situations where it is possible to evaluate the chemicals used in, particularly, fur processing are shown in Table 12.

Eutrophication from manure

Eutrophication can be defined as the extraordinarily high nutrient enrichment of an aquatic ecosystem, occurring when nitrogen (N) and phosphorus (P) cause accelerated and abnormal growth of autotrophic organisms, such as plants and algae (Cervantes-Astorga et al., 2021). The increase in respiration from the breakdown of this plant matter by microorganisms depletes the oxygen in the water, leading, ultimately to die offs of heterotrophic organisms such as fishes. In extreme cases the water body can no longer support life (Bailey et al., 2012).

Although fur farms make up a small proportion of nutrient run offs in terms of global numbers their effects are disproportionate because the manure is much higher in N and P than certain mammalian livestock (Vaitkunas, 2000; Van Bruggen et al., 2012). Furbearers are often kept outdoors with the pens sitting on the ground, so the manure is more easily able to leach into the soil than with traditionally housed livestock (Harding, 1979). Most studies on eutrophication in relation to fur farming have been done on the Lakes of Southwest Nova Scotia, Canada, where there are 1.4 million mink on approximately 40 mink farms, located near the headwater of the Carleton River. There are many eutrophic and hypereutrophic lakes in the area including Nowlans, Placides, and Hourglass Lakes (Taylor, 2009; Taylor, 2010). Other areas of concern include the Baltic Sea, which suffers from eutrophication due to human activities in the area including fur farming. The literature reviewed indicates that fur farms are often clustered in particular areas, causing localised eutrophication of watercourses. Small water bodies with low turnover are likely to be more affected.

One-health

The term ‘one-health’ summarises a paradigm where the environment, animals, and people are considered to be interconnected (Rabozzi et al., 2012; Cantas and Suer, 2014; Broom, 2022b; CDC, 2022; Jacobs et al., 2022). The fur farming sector impacts animal welfare, public health, and environmental issues; thus, the one-health paradigm can be regarded as a relevant coalescent theme within this review. The term ‘one-welfare’ summarises the relationship between animal welfare, human wellbeing, and the physical and social environment (García Pinillos, 2021).

Captivity-stress can directly impact animal welfare and result in potentially increased susceptibility to disease and pathogen-shedding, which in turn may increase zoonotic transmission. Anthropogenic habitat loss, and bottlenecking of species into smaller and less stable ecosystems, may promote pathogen spillover, outbreaks of disease, and public health threats (Jones et al., 2008; Allen et al., 2017). SARS-CoV-2 is an example of where habitat loss, highly restricted confinement of animals, large-scale fur farming, and human interactions may have acted concomitantly to produce severe outbreaks and consequences, leading to calls for a future one-health approach to investigate such diseases (Goraichuk et al., 2021). Moreover, at least 19 major epidemics or pandemics with links to use of animals have emerged since 1918, including, for example, Spanish flu, human immunodeficiency virus/acquired immune deficiency syndrome (HIV/AIDS), avian influenza H5N1, swine flu, SARS-CoV-1, Middle-East respiratory syndrome, SARS-CoV-2, and others. Collectively, these issues have resulted in hundreds of millions of infections and millions of deaths among humans (Warwick and Steedman, 2021). As indicated earlier, some of these major global pandemics, for example, avian influenza H5N1 and SARS-CoV-2, involve fur farms, and are subject to cross-species infections and spillover human zoonoses events. The World Health Organisation concluded that the risk of transmission of SARS-CoV-2 from fur farms to susceptible wildlife populations is considered ‘high’ in Europe and ‘moderate’ in Asia and the Americas, and that “spillover from fur farm animals to humans poses a serious public health and socio-economic threat and requires a One Health approach to manage” (GLEWS+, 2021).

In issues such as fur farming, individual themes, such as animal welfare and health, zoonoses and public health, and environment and ecology, can be clearly identified, although these elements are overall inseperable. Accordingly, their amelioration or resolution may require a multidisciplinary approach (Rabozzi et al., 2012; Cantas and Suer, 2014; García Pinillos, 2021; Gorbach, 2021; Jo et al., 2021; Broom, 2022a; Broom, 2022b). Part of this multidisciplinary approach, requires objective considerations that are less human-centred, recognise moral obligations to animals that are used for human purposes, and ackowledge that effects of sector practices should not simply be presently sustainable, but also for the long-term future (Broom, 2022a; Broom, 2022b).

People increasingly reject production methods that are either immediately harmful or unsustainable. For example, public exposure to inhumane fur production practices has resulted in people dismissing future acquisitions (Global Times, 2017; Material Innovation Initiative, 2021). However, public attitudes and responses to information about fur farming can follow targeted messaging whether for or against the practice (Lee, 2014). Ultimately, it is in the interests of businesses to act to pre-empt product boycotts, and constantly review practices with an eye for problems related to animal welfare and health, public health and safety, and environmental harm individually, as well as one-health issues generally. Failure to address practices that the public find unacceptable may cause businesses to become unsustainable (Broom, 2022a; Broom, 2022b).

Fur farming involves all the acknowledged elements (animal welfare, human health, and environment) associated with the remit of the one-health (and one-welfare) paradigm. Accordingly, the issues outlined herein that are associated with fur farming, especially those of a problematic nature, are multifactorial. Whilst they can be considered individually, they are also entangled. Consistent with the one-health paradigm, whilst improvements to problematic situations of fur farming may be achievable in some respects, overall resolution of the significant concerns presented in this report require actions to address all issues.

Legal and governance

In the European Union (EU), all animals are theoretically protected as 'sentient beings' in the Lisbon Treaty (2007) (EUR-Lex, 2023a). Welfare legislation applying to fur farms includes Council Directive 98/58/EC (1998), the European Convention (1999) recommendation concerning fur animals, and Council Regulation 1099/2009 (2009). Nevertheless, the current EU regulatory framework is not adequately safeguarding animal welfare in fur farms (Gremmen, 2014). The European Union has banned imports of certain fur products for animal welfare reasons, such as cat and dog fur from China, wild caught animal fur from countries where steel leg hold traps are legal (EUR-Lex, 2023b), as well as seal fur from Canada and Norway. European Union-based fur farms are also covered by other EU regulatory frameworks, such as the EU Common Agricultural Policy, as well as member specific government legislation, recommendations, and codes of practice issued by the European Fur Breeders Association, and other national fur federations. Compliance to existing welfare regulations and codes of practice throughout the EU is varied, and not all farmed species are covered (Gremmen, 2014).

In China there is no national legal protection for animal welfare. Industry-led fur farming guidelines covering management, welfare, disease, and environmental protection exist (International Fur Federation, 2023), although as in other fur producing nations, lack of compliance is reported throughout the industry (ActAsia, 2019). Despite the lack of nationwide animal welfare laws in China, Chinese citizens ranked "environmental protection, sustainable development, and animal protection" as the most important social issues to them (Sinclair and Phillips, 2017).

Canada has no federal laws specifically governing fur-farms. The National Farm Animal Care Council's industry-led code of practice for fur farmed mink has been enforced by particular provinces (McSheffrey, 2015). Individual states, such as British Columbia and Nova Scotia, which are historically large producers of fur, have their own regulations and guidelines for fur farming (Province of Nova Scotia, 2013; Province of British Columbia, 2015), and from April 2023 mink farming is prohibited in British Columbia (The Fur-Bearers, 2023). However, as for Europe, there is a lack of consistency and compliance across Canada in regards to fur farming regulations (McCague Borlack LLP, 2019). Fur farms appear to be declining in Canada, with 347 being reported in 2011 and 97 reported in 2021 (We Animals Media, 2022), and three quarters of Canadians support the proposed national ban on fur farming (Bill C-247) introduced in 2022 (The Fur-Bearers, 2022).

The United States has no federal law governing fur farms, although there is a ban on the trade in cat and dog fur, as well as a Fur Products Labelling Act (Peterson, 2010) and the Marine Mammals Protection Act prohibits trade in fur products from protected wild mammals (NOAA Fisheries, 2023). Individual states can impose restrictions and codes of conduct regarding fur farming, and notably California has banned the sale and manufacturing of all new fur produce within the State since January 2023 (California Legislative Information, 2019).

As outlined previously, fur farming involves multifactorial problematic issues regarding animal welfare, public health, environment, and ethics. These issues individually and collectively attract strong concerns and criticisms, and by direct extension also invite negative reputational impacts for commercial, consumer, and governmental actors (Müller et al., 2021). Thus, the reputational health of sectors within a nation can also be considered negatively affected by harmful industries and any parties to such commodification of nature. Pro-fur co-actors undertake endeavours to dissociate their activities from reported harms and related public perceptions using, for example, tactical and strategic marketing messages involving greenwashing, assurance branding techniques, self-produced surveys, messaging regarding responsible and sustainable practices, and emphasising employment and economic benefits (e.g., [Noah, and Animalia, 2015; Rosenqvist, 2017; Müller et al., 2021]). For example, the fur industry suggests that its use of animal byproducts indicates the sustainable use within the sector (Gremmen, 2014).

Concerns regarding animal welfare have led the fur industry to develop and promote dedicated assessment protocols for farmed animals, in particular blue foxes (*Vulpes lagopus*), silver foxes (*Vulpes vulpes*), and mink (*Neogale vison*) (Mononen et al., 2012). Promoted as the WelFur Project, this approach utilises established assessment principles and criteria (i.e., Welfare Quality®) to monitor on-farm welfare using 12 categories relevant to physical, behavioural, mental, and housing conditions (Botreau et al., 2012; Mononen et al., 2012; Møller et al., 2015; WelFur, 2015). The WelFur Project appears to successfully identify and document persistent animal welfare problems (Møller et al., 2015; WelFur, 2015). However, the effectiveness of the WelFur Project has been criticised for its adherence to industry best practice models, which have been considered as essentially compounding unacceptable minimalist standards, rather than promoting animal welfare as a central requirement and objective, and thus does not prevent poor welfare (Fur Free Alliance, 2020; Linzey and Linzey, 2022). Some studies indicate that consumers preferred the idea of fur products from farmed rather than trapped wild animals (Sun, 2013). Despite the various fur farming-associated promotional messages and management initiatives, public disapproval for fur production methods largely persists due to the aforesaid problems. For example, in Finland, which has a long history of fur farming, a recent initiative showed strong public support calling on the government to ban commerce (Laatu, 2013), and a UK survey found that approximately four-fifths of respondents opposed the fur industry, and 78% supported a legal prohibition on fur farming (Halliday and McCulloch, 2022).

Major fashion brands have banned the use of fur products (e.g., Burberry, Gucci, and Prada) as have fashion shows such as Stockholm's Fashion Week and London Fashion Week. The increasing number of people wishing to avoid products that involve animal suffering has led to a surge of companies purely focusing on "next-Gen materials" that mimic animal products such as fur (Material Innovation Initiative, 2021).

As indicated previously, bans on fur farming are variously in place and under wider consideration. Investigations into trade bans on both wild-caught and farmed wildlife and derived products have reported such measures to be highly effective, 'gold-standard', protocols especially when combined with strong enforcement (e.g., [Toland et al., 2012; Reino et al., 2017; D'Cruze et al., 2020a; D'Cruze et al., 2020b; Green et al., 2020; Toland et al., 2020; Peng and Broom, 2021]). Another analysis of prohibitions for wildlife trades indicated that bans are an important preventative approach to avoiding pathogenic spillovers and curtailing potential pandemics (Fischer, 2021).

Brief comparison of fur farming with livestock farming

In terms of scale, fur farming involves approximately 85 to 100 million animals annually (Pluda, 2020; Halliday and McCulloch, 2022; Linzey and Linzey, 2022). In comparison, terrestrial livestock farming for protein consumption involves an estimated 74 billion animals annually (Our world in data, 2020). Whilst overall volume of fur farmed animals is relatively low compared with chicken production, herein the fur industry is being compared against the largest relevant sector.

Animal welfare

An issue of some compatibility with fur farming may be indoor intensive and semi-intensive factory production methods, such as for chickens (*Gallus gallus domesticus*). Globally, 70 billion chickens are factory farmed and consumed annually (Our world in data, 2020). Clearly, this volume is substantially greater than animals farmed for fur. Animal welfare concerns for factory-farmed chickens are considerable, with common issues of mental stress, abnormal behaviour, aggression-related injuries, limb fractures, disease, and death all being reported in the scientific literature (D'Silva, 2006; Friedrich and Wilson, 2015; Martin, 2015; Moen and Devolder, 2022). Accordingly, in terms of scale, factory farming of chickens might be regarded as a greater concern. In terms of animal welfare, these might be considered broadly compatible in several respects.

Zoonoses and public health

Zoonotic and public health issues of fur farming and chicken farming share several commonalities, but also several differences. For example, of the 18 reported zoonotic pathogens and diseases associated with fur farmed animals (Table 3), 10 issues [*Chlamydia* spp. (Marchino et al., 2022), *Clostridium botulinum* (Souillard et al., 2021), *Escherichia coli* (Azza et al., 2018), Methicillin-resistant *Staphylococcus aureus* (Benrabia et al., 2020), *Salmonella* spp. (Duc et al., 2019), *Influenza A virus* (Gobbo et al., 2022), Eimeria (Mesa-Pineda et al., 2021), *Cryptosporidium* spp. (Lin et al., 2022), *Leishmania infantum* (Alexander et al., 2002), and *Microsporidia* spp. (Reetz et al., 2002)], are also widely reported in chicken farming. However, eight issues of reported zoonotic pathogens and diseases associated with fur farmed animals (*Arcanobacterium phocae*, canine distemper virus, carnivore amdoparvovirus/Parvovirus, Lissavirus, SARS-CoV-2, *Neospora caninum, Toxoplasma gondii*, and *Trichinella nativa*) appear not to be associated with the comparative example (chickens), although several of these pathogens have been used during experimental infections of chickens. Accordingly, fur farming does involve several specific pathogenic threats related to the sector. In addition, fur farming mostly involves carnivorous species, which may harbour greater numbers of more potential pathogens than chickens and other obligate herbivores and obligate omnivores due to the diets of these species including other animals (Warwick et al., 2012).

Environment

In terms of environmental impacts, on issues relating to greenhouse gas emissions, toxic contamination, and eutrophication, fur farming might be considered a significant but less substantial contributor than mainstream livestock farming. However, pollution from, for example, ammonia run-off and other powerful contaminants from fur farms may be less monitored and controlled than other use sectors, highly pervasive, and involve disproportionately greater environmental contamination. The issue of invasive species is highly significant, with the introduction of wild animal species and associated ecological harm being frequently associated with fur farming, with disproportionately problematic consequences.

General comment

In terms of scale, on most animal welfare, public health, and environmental issues, fur farming may overall reasonably be assumed to represent a smaller, although significant, contributor to these recognised harms than the main livestock industries. However, product justification should be considered a key overarching issue concerning relevant harms. Such consideration requires balancing the importance of non-essential products (fur-based luxury or casual wear clothing) *versus* products that feed society. In this balancing scenario, manifestly fur-based products are disproportionately harmful.

Conclusions

At least 35 nations are known to have farmed animals for fur since 1917. In recent years, welfare assessment methods have been developed to objectively better protect animals from harms. However, even using welfare assessment criteria developed in association with the fur farming sector, there remains clear industry and independently reported evidence of persistent significant and major animal welfare problems, including psychological stress, abnormal behaviour, environmental deprivation, understimulation, co-occupant aggression, self-harming injuries, insanitary conditions, disease, husbandry-related morbidities and mortalities, and human imposed physical abuse and inhumanities. Despite numerous efforts to systematically monitor and control animal welfare at fur farms, practices continue to fail to meet the normal scientific principles and models used in other animal welfare situations. At least 17 nations have introduced total or partial prohibitions within their borders, primarily for animal welfare reasons. Manifestly, prohibitions are accepted by numerous national governments as primary measures for controlling fur farming and preventing stress or suffering among animals. In our view, fur farming is incompatible with acceptable standards for animal welfare, and documented concerns provide strong grounds to support historical and proposed bans on fur farming.

In our view, the limited available data does not currently indicate that fur farms are major sources of zoonotic epidemics and pandemics. However, there are many well documented examples of major epidemics and pandemics emerging suddenly from animal production and handling sectors with devastating consequences, sometimes as a result of highly subtle triggers. Thus, there are no grounds for complacency towards fur farming as a possible further source of globally significant disease. Cross-species transmission within both global and fur farm contexts has been well demonstrated with the advent of SARS-CoV-2, and many possible spillover events involving diverse pathogens can be considered as potentially emergent at any one time. Epidemics and pandemics could arise from single contact episodes. Centres at which large numbers of animals of known vulnerable backgrounds are held can be considered important hubs for emergent infections that are zoonotic, cross-species, and reverse zoonotic in nature; fur farms represent hubs for multi-factorial transmission. Whilst evidentially limited, we consider spillover risks for zoonotic disease related to fur farming to be relevant because the transmission routes are clearly established, and a precautionary principle should be applied to control. Manifestly, strong examples exist where fur farms can act as infection hubs, and our main concern resides in the 'what if' factor (Warwick, 2020) - i.e., that fur farms harbour clear potential for rapid emergence of epidemic and pandemic disease. Accordingly, application of the precautionary principle should be a primary consideration in decisions on fur farming in respect of public health, which could justify further prohibitions.

The environmental problems caused by fur farming are significant, and relate mainly to invasive species, toxic chemical release and eutrophication of water bodies. Eutrophication is a problem in areas where many fur farms are clustered such as Nova Scotia or the Baltic Sea. It is anticipated that as demand for fur decreases, these environmental issues will eventually reduce. However, with regard to invasive species, even reduction or abolition of fur farming will not resolve inherent problems. Combined responses, including humane eradication of already established populations, are used to control invasive organisms, although there are significant logistical, financial, and ethical barriers to this approach. Most efforts so far have been aimed at control by trapping, which is a labour-intensive method. For example, a team of volunteers was required for three years to remove 376 mink from 4,081 mi^2 in Scotland (Lambin et al., 2017). Establishing control or eradication programmes without addressing the existence of fur farms and their releases, is largely counterproductive because it has been shown that new releases provide additional recruits and increased genetic diversity to established populations. Genetic diversity makes invasive populations more resilient to environmental change and more adaptable, for example, in colonising new areas with increases in their invasive potential (Alda et al., 2013). However, the species' high adaptability and potential to cross land borders and establish new populations (Rodrigues et al., 2015), means that unilateral eradication attempts would only be partially effective unless international cooperation was agreed. Hence, to date, most successful eradications have occurred on Islands (Lambin et al., 2017). In our view, the comprehensive revisions regarding practices inherent to fur farming that would be necessary to significantly improve the identified environmental problems are incompatible with the sustainable continuance of the sector.

Recommendations

Based on the results of the literature review we provide the following recommendations:

1. Animal welfare issues. Complete prohibition of fur farming is required in order to resolve inherent animal welfare problems.
2. Zoonoses and public health issues. Intensive government mandated regular inspection and screening should be adopted for all animals and workers at fur farms for the presence of relevant (zoonotic or cross-species) pathogens, diseases, or toxic contaminants. Using the precautionary principle, where any farm manifests an outbreak or occurrence of any relevant pathogen, disease or toxic contaminant, the facility should face compulsory permanent closure.
3. Environmental issues. Existing fur farms should, under mandatory governmental conditions, adopt proper management and treatment of manure (e.g., with biochar) including potential use for agricultural fertiliser in controlled settings away from water bodies. Containment of manure must be so controlled that it does not escape into the environment. Strict government approved biosecurity measures should be implemented to control escapes of potentially invasive species.
4. Wider awareness should be raised regarding animal welfare, zoonoses and public health (including biosecurity), and environmental issues and risks associated with fur farming in order to further reduce product demands.
5. International cooperation should be increased to develop consensus for a legal framework on fur farming consistent with the one health umbrella.

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Concept and design: CW and RG; Literature research: RG and CW; Analysis and writing: CW, AP, CS, and RG. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

ActAsia (2019) *China's fur trade and its position in the global fur industry*. Available at: https://www.actasia.org/wp-content/uploads/2019/10/China-Fur-Report-7.4-DIGITAL-2.pdf (Accessed 11 March 2023).

Adamopoulou, C., and Legakis, A. (2016). First account on the occurrence of selected invasive alien vertebrates in Greece. *BioInvasions Rec* 5, 189–196. doi: 10.3391/bir.2016.5.4.01

Agga, G. E., Silva, P. J., and Martin, R. S. (2021). Third-generation cephalosporin- and tetracycline-resistant escherichia coli and antimicrobial resistance genes from metagenomes of mink feces and feed. *Foodborne Pathog. Dis.* 18 (3), 169–178. doi: 10.1089/fpd.2020.2851

Aguiló-Gisbert, J., Padilla-Blanco, M., Lizana, V., Maiques, E., Muñoz-Baquero, M., Chillida-Martínez, E., et al. (2021). First description of SARS-coV-2 infection in two feral american mink (Neovison vison) caught in the wild. *Anim. (Basel)* 11 (5), 1–13. doi: 10.3390/ani11051422

Åkerstedt, J., Valheim, M., Germundsson, A., Moldal, T., Lie, K. I., Falk, M., et al. (2012). Pneumonia caused by influenza A H1N1 2009 virus in farmed American mink (Neovison vison). *Vet. Rec* 170 (14), 362. doi: 10.1136/vr.100512

Akimova, T., Semakina, V., Mitrofanova, M., Zhiltsova, M., Vystavkina, E., Isakova, D., et al. (2021). SARS-CoV-2 spread in humans and animals. *Ветеринария сегодня*. 2, 88–96. doi: 10.29326/2304-196X-2021-2-37-88-96

Alda, F., Ruiz-López, M. J., García, F. J., Gompper, M. E., Eggert, L. S., and García, J. T. (2013). Genetic evidence for multiple introduction events of raccoons (Procyon lotor) in Spain. *Biol. invasions* 15, 687–698. doi: 10.1007/s10530-012-0318-6

Alexander, B., de Carvalho, R. L., McCallum, H., and Pereira, M. H. (2002). Role of the domestic chicken (Gallus gallus) in the epidemiology of urban visceral leishmaniasis in Brazil. *Emerg. Infect. Dis.* 8 (12), 1480–1485. doi: 10.3201/eid0812.010485

Allen, T., Murray, K. A., Zambrana-Torrelio, C., Morse, S. S., Rondinini, C., Di Marco, M., et al. (2017). Global hotspots and correlates of emerging zoonotic diseases. *Nat. Commun.* 8 (1), 1124. doi: 10.1038/s41467-017-00923-8

Anniballi, F., Fiore, A., Löfström, C., Skarin, H., Auricchio, B., Woudstra, C., et al. (2013). Management of animal botulism outbreaks: from clinical suspicion to practical countermeasures to prevent or minimize outbreaks. *Biosecur Bioterror* 11 Suppl 1, S191–S199. doi: 10.1089/bsp.2012.0089

Aplocina, E., Aboltins, A., and Priekulis, J. (2015). "Manure management systems and nitrogen emissions in Latvia," in *Proceedings of the 7th International Scientific Conference Rural Development* (Lithuania: Aleksandras Stulginskis University) 5. doi: 10.15544/RD.2015.047

Arena, P. C., and Warwick, C. (2023). "Spatial and thermal considerations," in *Health and welfare of captive reptiles, 2nd ed.* Eds. C. Warwick, P. C. Arena and G. M. Burghardt (Cham, Switzerland: Springer), 417–445.

Arney, D. (2022). "Farming non-domesticated and semi-domesticated terrestrial species," in *Routledge handbook of animal welfare*. Eds. A. Knight, C. Phillips and P. Sparks (London, UK: Taylor & Francis), 103–114.

Awais, M., Alvarado-Morales, M., Tsapekos, P., Gulfraz, M., and Angelidaki, I. (2016). Methane production and kinetic modeling for co-digestion of manure with lignocellulosic residues. *Energy Fuels* 30 (12), 10516–10523. doi: 10.1021/acs.energyfuels.6b02105

Azami-Conesa, I., Sansano-Maestre, J., Martínez-Díaz, R. A., and Gómez-Muñoz, M. T. (2021). Invasive Species as Hosts of Zoonotic Infections: The Case of American Mink (Neovison vison) and Leishmania infantum. *Microorganisms* 9 (7). doi: 10.3390/microorganisms9071531

Azza, A., Dahshan, A. H. M., El-Nahass, E.-S., and Abd El-Mawgoud, A. (2018). Pathogenicity of Escherichia coli O157 in commercial broiler chickens. *Beni-Suef Univ. J. Basic Appl. Sci.* 7 (4), 620–625. doi: 10.1016/j.bjbas.2018.07.005

Bailey, K., Codd, R., Holm, K., O'Brien, K., and Yarber, M. (2012). Comparative water quality study of cozine, gooseneck, and mill creeks. *Paper ENVS 385* (Oregon USA: Research Methods, Linfield University), pp. 28.

Balakirev, N., and Tinaeva, E. (2001). Fur farming in Russia: the current situation and the prospects. *Scientifur* 25 (1), 7–10.

Balestrieri, A., Zenato, M., Fontana, E., Vezza, P., Remonti, L., Caronni, F., et al. (2016). An indirect method for assessing the abundance of introduced pest M yocastor coypus (Rodentia) in agricultural landscapes. *J. Zoology* 298 (1), 37–45. doi: 10.1111/jzo.12284

Barrat, J., Richomme, C., and Moinet, M. (2010). The accidental release of exotic species from breeding colonies and zoological collections. *Rev. Sci. Tech* 29 (1), 113–122. doi: 10.20506/rst.29.1.1968

Bartolommei, P., Bonesi, L., Guj, I., Monaco, A., and Mortelliti, A. (2013). First report on the distribution of the American mink Neovison vison (Mammalia: Mustelidae) in central Italy. *Ital. J. zoology* 80 (3), 455–461. doi: 10.1080/11250003.2013.804126

Benrabia, I., Hamdi, T. M., Shehata, A. A., Neubauer, H., and Wareth, G. (2020). Methicillin-resistant staphylococcus aureus (MRSA) in poultry species in Algeria: long-term study on prevalence and antimicrobial resistance. *Vet. Sci.* 7 (2), 1–11. doi: 10.3390/vetsci7020054

Bertolino, S., Colangelo, P., Mori, E., and Capizzi, D. (2015). Good for management, not for conservation: an overview of research, conservation and management of Italian small mammals. *Hystrix* 26 (1), 1–11. doi: 10.4404/hystrix-26.1-10263

Bertolino, S., and Genovesi, P. (2007). "Semiaquatic mammals introduced into Italy: case studies in biological invasion," in *Biological invaders in inland waters: Profiles, distribution, and threats*. Ed. F. Gherardi (Cham, Switzerland: Springer), 175–191.

Bijleveld, M. (2013). *Natural mink fur and faux fur products, an environmental comparison* (Delft: CE Delft).

Boscherini, A., Mazza, G., Menchetti, M., Laurenzi, A., and Mori, E. (2019). Time is running out! Rapid range expansion of the invasive northern raccoon in central Italy. *Mammalia* 84 (1), 98–101. doi: 10.1515/mammalia-2018-0151

Botreau, R., Gaborit, M., and Veissier, I. (2012). "Applying Welfare Quality® strategy to design a welfare assessment tool for foxes and mink farms," in *Proceedings of the X th International Scientific Congress in fur animal production: Scientifur* (The Netherlands: Wageningen Academic Publishers) 36 (3/4), 460–468.

Brash, M. L., Martin, E. A., Heal, J. D., and Hildebrandt, H. H. (2016). "Pediculosis (Stachiella larseni) in farmed mink in Ontario, Canada," in *Proceedings of the XI th International Scientific Congress in fur animal production: Scientifur* (Helsinki, Finland: International Fur Animal Scientific Association) 40 (3/4), 45–48.

Broom, D. M. (1991). Animal welfare: concepts and measurement. *J. Anim. Sci.* 69 (10), 4167–4175. doi: 10.2527/1991.69104167x

Broom, D. M. (2022a). "Animal welfare concepts," in *Routledge handbook of animal welfare*. Eds. A. Knight, C. Phillips and P. Sparks (London, UK: Taylor & Francis), 12–21.

Broom, D. M. (2022b). Animal welfare in relation to human welfare and sustainability–a review paper. *Veterinarski arhiv* 92 (5), 541–547. doi: 10.24099/vet.arhiv.2011

Brüschweiler, B. J., and Merlot, C. (2017). Azo dyes in clothing textiles can be cleaved into a series of mutagenic aromatic amines which are not regulated yet. *Regul. Toxicol. Pharmacol.* 88, 214–226. doi: 10.1016/j.yrtph.2017.06.012

Brzeziński, M., Natorff, M., Zalewski, A., and Żmihorski, M. (2012). Numerical and behavioral responses of waterfowl to the invasive American mink: A conservation paradox. *Biol. Conserv.* 147 (1), 68–78. doi: 10.1016/j.biocon.2011.11.012

Burghardt, G. M. (2013). Environmental enrichment and cognitive complexity in reptiles and amphibians: concepts, review, and implications for captive populations. *Appl. Anim. Behav. Sci.* 147 (3-4), 286–298. doi: 10.1016/j.applanim.2013.04.013

California Legislative Information (2019) *Assembly bill no. 44 chapter 764* (State of California Government). Available at: https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200AB44 (Accessed 15 March 2023).

Campbell, D. L., Dallaire, J. A., and Mason, G. J. (2013). Environmentally enriched rearing environments reduce repetitive perseveration in caged mink, but increase spontaneous alternation. *Behav. Brain Res.* 239, 177–187. doi: 10.1016/j.bbr.2012.11.004

Campbell, J. M., and Kurek, J. (2019). Assessing the effects of eutrophication on lakes in Nova Scotia, Canada, using subfossil midges. *Atlantic Geology* 55. doi: 10.4138/atlgeol.2019.005

Campbell, J., Libera, N., Smol, J., and Kurek, J. (2022a). Historical impacts of mink fur farming on chironomid assemblages from shallow lakes in Nova Scotia, Canada. *Lake Reservoir Manage.* 38 (1), 80–94. doi: 10.1080/10402381.2021.2018631

Campbell, J., Libera, N., Smol, J., and Kurek, J. (2022b). Stability of midge assemblages in productive shallow lakes exposed to point and diffuse nutrient inputs. *J. Paleolimnol.* 67 (3), 259–272. doi: 10.1007/s10933-021-00230-9

Cantas, L., and Suer, K. (2014). Review: the important bacterial zoonoses in "one health" concept. *Front. Public Health* 2. doi: 10.3389/fpubh.2014.00144

Carter, J., and Leonard, B. P. (2002). A review of the literature on the worldwide distribution, spread of, and efforts to eradicate the coypu (Myocastor coypus). *Wildlife Soc. Bull.* 30 (1), 162–175.

CDC (2020) *Parasites - tricheinellosis* (Centers for Disease Control and Prevention, U.S. Department of Health & Human Services) (Accessed 11 March 2023).

CDC (2022) *One health basics* (Centers for Disease Control and Prevention, U.S. Department of Health & Human Services). Available at: https://www.cdc.gov/onehealth/basics/index.html (Accessed 4 March 2023).

Cervantes-Astorga, E., Aguilar-Juárez, O., Carrillo-Nieves, D., and Gradilla-Hernández, M. S. (2021). A GIS methodology to determine the critical regions for mitigating eutrophication in large territories: the case of jalisco, Mexico. *Sustainability* 13 (14), 8029. doi: 10.3390/su13148029

Chandrasekaran, V. (2018). *Substitution of hazardous chemicals in fur processing industry* (Kaunas, Lithuania: Masters, Kaunas University of Technology).

Cheng, Y., Wang, J., Zhang, M., Zhao, J., Shao, X., Ma, Z., et al. (2015). Isolation and sequence analysis of a canine distemper virus from a raccoon dog in Jilin Province, China. *Virus Genes* 51 (2), 298–301. doi: 10.1007/s11262-015-1236-3

Colpitts, G. (1997). Conservation, science and Canada's fur farming industry 1913-1945. *Histoire Sociale/Social History*. 30 (59).

Dallaire, J. A., Meagher, R. K., and Mason, G. J. (2012). Individual differences in stereotypic behaviour predict individual differences in the nature and degree of enrichment use in caged American mink. *Appl. Anim. Behav. Sci.* 142 (1-2), 98–108. doi: 10.1016/j.applanim.2012.09.012

Dawkins, M. S. (1990). From an animal's point of view: motivation, fitness, and animal welfare. *Behav. Brain Sci.* 13 (1), 1–9. doi: 10.1017/S0140525X00077104

Dawson, L., Buob, M., Haley, D., Miller, S., Stryker, J., Quinton, M., et al. (2013). Providing elevated 'getaway bunks' to nursing mink dams improves their health and welfare. *Appl. Anim. Behav. Sci.* 147 (1-2), 224–234. doi: 10.1016/j.applanim.2013.04.001

D'Cruze, N., Green, J., Elwin, A., and Schmidt-Burbach, J. (2020a). Trading tactics: Time to rethink the global trade in wildlife. *Animals* 10 (12), 2456. doi: 10.3390/ani10122456

D'Cruze, N., Paterson, S., Green, J., Megson, D., Warwick, C., Coulthard, E., et al. (2020b). Dropping the ball? The welfare of ball pythons traded in the EU and north america. *Animals* 10 (3), 413. doi: 10.3390/ani10030413

Decker, S., Lavery, J. M., and Mason, G. J. (2023). Don't use it? Don't lose it! Why active use is not required for stimuli, resources or "enrichments" to have welfare value. *Zoo Biol.* 42 (4), 467–475. doi: 10.1002/zoo.21756

Décory, M. S. M. (2019). A universal definition of "Domestication" to unleash global animal welfare progress. *dA. Derecho Animal (Forum of Animal Law Studies)* 10 (2), 39–55. doi: 10.5565/rev/da.424

DEFRA (2021) *The fur market in great britain* (Department for Environment, Food & Rural Affairs). Available at: https://consult.defra.gov.uk/animal-welfare-in-trade/fur-market-in-great-britain/ (Accessed 14 February 2023).

Dettori, E., Balestrieri, A., Ruiu, A., Capelli, E., Prigioni, C., Zapata-Perez, V., et al. (2016). "Recent spread of invasive American mink Neovison vison in Sardinia," in *Atti del III Congresso Nazionale Fauna Problematica* (Italy: Cesena), 88.

Devaux, C. A., Pinault, L., Delerce, J., Raoult, D., Levasseur, A., and Frutos, R. (2021). Spread of mink SARS-coV-2 variants in humans: A model of sarbecovirus interspecies evolution. *Front. Microbiol.* 12. doi: 10.3389/fmicb.2021.675528

Díez-León, M., Bursian, S., Galicia, D., Napolitano, A., Palme, R., and Mason, G. (2016). Environmentally enriching American mink (Neovison vison) increases lymphoid organ weight and skeletal symmetry, and reveals differences between two sub-types of stereotypic behaviour. *Appl. Anim. Behav. Sci.* 177, 59–69. doi: 10.1016/j.applanim.2015.12.002

Díez-León, M., and Mason, G. (2016). Effects of environmental enrichment and stereotypic behavior on maternal behavior and infant viability in a model carnivore, the American mink (Neovison vison). *Zoo Biol.* 35 (1), 19–28. doi: 10.1002/zoo.21249

Díez-León, M., Quinton, M., and Mason, G. (2017). How tall should a mink cage be? Using animals' preferences for different ceiling heights to improve cage design. *Appl. Anim. Behav. Sci.* 192, 24–34. doi: 10.1016/j.applanim.2017.03.002

Dobbins, M. (2017). Rapid review guidebook. *Natl. Collab Cent Method Tools* 13, 25.

D'Silva, J. (2006). Adverse impact of industrial animal agriculture on the health and welfare of farmed animals. *Integr. Zoology* 1 (1), 53–58. doi: 10.1111/j.1749-4877.2006.00013.x

Dubrovskis, V., Plume, I., and Straume, I. (2009). "Investigation of biogas production from mink and cow manure," in *Proceedings of the 8th International Scientific Conference, Engineering for rural development* (Jelgava, Latvia: Latvia University of Agriculture), 253–256.

Duc, V. M., Nakamoto, Y., Fujiwara, A., Toyofuku, H., Obi, T., and Chuma, T. (2019). Prevalence of Salmonella in broiler chickens in Kagoshima, Japan in 2009 to 2012 and the relationship between serovars changing and antimicrobial resistance. *BMC Vet. Res.* 15 (1), 108. doi: 10.1186/s12917-019-1836-6

Dziech, A., Wierzbicki, H., Moska, M., and Zatoń-Dobrowolska, M. (2023). Invasive and alien mammal species in Poland—A review. *Diversity* 15 (2), 138. doi: 10.3390/d15020138

Early, R., Bradley, B. A., Dukes, J. S., Lawler, J. J., Olden, J. D., Blumenthal, D. M., et al. (2016). Global threats from invasive alien species in the twenty-first century and national response capacities. *Nat. Commun.* 7, 12485. doi: 10.1038/ncomms12485

Edling, T. (2023) *Chlamydiosis in animals* (MSD Veterinary Manual). Available at: https://www.msdvetmanual.com/generalized-conditions/chlamydiosis/chlamydiosis-in-animals (Accessed 4 March 2023).

Ekstrand, K., Flanagan, A. J., Lin, I. E., Vejseli, B., Cole, A., Lally, A. P., et al. (2021). Animal transmission of SARS-coV-2 and the welfare of animals during the COVID-19 pandemic. *Anim. (Basel)* 11 (7), 1–38. doi: 10.3390/ani11072044

Ellick, R. M., Fitzgerald, S. D., Link, J. E., and Bursian, S. J. (2013). Comparison of destructive periodontal disease in blue iris mink to PCB 126–induced mandibular and maxillary squamous epithelial proliferation in natural dark mink. *Toxicologic Pathol.* 41 (3), 528–531. doi: 10.1177/0192623312457270

EUR-Lex (2023a) *Consolidated version of the Treaty on the Functioning of the European Union - Article 13* (European Union). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A12016E013 (Accessed 14 March 2023).

EUR-Lex (2023b) *Council regulation (EEC) No 3254/91*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31991R3254 (Accessed 20 March 2023).

Fall, M. W., Avery, M. L., Campbell, T. A., Egan, P. J., Engeman, R. M., Pimentel, D., et al. (2011). "Rodents and other vertebrate invaders in the United States," in *Biological invasions: economic and environmental costs of alien plant, animal, and microbe species*. Ed. D. Pimentel (Boca Raton: CRC Press), 381–410.

Farashi, A., and Najafabadi, M. S. (2015). Modeling the spread of invasive nutrias (Myocastor coypus) over Iran. *Ecol. complexity* 22, 59–64. doi: 10.1016/j.ecocom.2015.02.003

Farm Animal Welfare Council (1979) *Farm animal welfare council press statement*. Available at: https://webarchive.nationalarchives.gov.uk/20121010012428/http://www.fawc.org.uk/pdf/fivefreedoms1979.pdf (Accessed 23 February 2020).

Fasola, L., Muzio, J., Chehébar, C., Cassini, M., and Macdonald, D. W. (2011). Range expansion and prey use of American mink in Argentinean Patagonia: dilemmas for conservation. *Eur. J. Wildlife Res.* 57, 283–294. doi: 10.1007/s10344-010-0425-6

Fasola, L., and Roesler, I. (2016). Invasive predator control program in Austral Patagonia for endangered bird conservation. *Eur. J. Wildlife Res.* 62 (5), 601–608. doi: 10.1007/s10344-016-1032-y

Fenollar, F., Mediannikov, O., Maurin, M., Devaux, C., Colson, P., Levasseur, A., et al. (2021). Mink, SARS-coV-2, and the human-animal interface. *Front. Microbiol.* 12. doi: 10.3389/fmicb.2021.663815

Fernaíndez-Antonio, R., Prieto, A., Diíaz-Cao, J. M., Loípez, G., Loípez, C., Peírez-Creo, A., et al. (2016). "Evaluation by qPCR of personal protective equipments for visitors against AMDV," in *Proceedings of the XI th International Scientific Congress in fur animal production: Scientifur* (Helsinki, Finland: International Fur Animal Scientific Association) 40 (3/4), 81–84.

Filistowicz, A., Dobrzański, Z., Przysiecki, P., Nowicki, S., and Filistowicz, A. (2011). Concentration of heavy metals in hair and skin of silver and red foxes (Vulpes vulpes). *Environ. Monit Assess.* 182 (1-4), 477–484. doi: 10.1007/s10661-011-1891-3

Finnish Food Authority (2022). *Animal diseases in Finland 2021* (Livsmedelsverket, Finland: Finnish Food Authority publications), pp74.

Firlej, C., Firlej, K., and Kubala, S. (2018). *The influence of fur farming on the local economy in Poland* (Czech Republic: University of Hradec Kralove).

Fischer, S. (2021). Post-disaster spillovers: Evidence from Iranian provinces. *J. Risk Financial Manage.* 14 (5), 193. doi: 10.3390/jrfm14050193

Fox, A. D., Jónsson, J. E., Aarvak, T., Bregnballe, T., Christensen, T. K., Clausen, K. K., et al. (2015). Current and potential threats to Nordic duck populations—a horizon scanning exercise. *Annales Zoologici Fennici (BioOne)*. 52 (4), 193–220. doi: 10.5735/086.052.0404

Fraser, E. J., Macdonald, D. W., Oliver, M. K., Piertney, S., and Lambin, X. (2013). Using population genetic structure of an invasive mammal to target control efforts–an example of the American mink in Scotland. *Biol. Conserv.* 167, 35–42. doi: 10.1016/j.biocon.2013.07.011

Fraser, D., Weary, D. M., Pajor, E. A., and Milligan, B. N. (1997). A scientific conception of animal welfare that reflects ethical concerns. *Anim. Welfare* 6, 187–205. doi: 10.1017/S0962728600019795

Friedrich, B., and Wilson, S. (2015). Coming home to roost: How the chicken industry hurts chickens, humans, and the environment. *Anim. L.* 22, 103.

Fur Free Alliance (2020). *Why WelFur fails to stop the suffering of animals on fur farms* (Amsterdam: Fur Free Alliance), pp59.

Galanaki, A., and Kominos, T. (2022). The distribution of American mink (Neovison vison) in Greece. *Mammalia* 86 (1), 57–65. doi: 10.1515/mammalia-2020-0067

García Pinillos, R. (2021). One welfare impacts of COVID-19–A summary of key highlights within the one welfare framework. *Appl. Anim. Behav. Sci.* 236, 105262. doi: 10.1016/j.applanim.2021.105262

Garnier, J., Le Noë, J., Marescaux, A., Sanz-Cobena, A., Lassaletta, L., Silvestre, M., et al. (2019). Long-term changes in greenhouse gas emissions from French agriculture and livestock, (1852-2014): From traditional agriculture to conventional intensive systems. *Sci. Tot. Environ.* 660, 1486–1501. doi: 10.1016/j.scitotenv.2019.01.048

Geacu, S. (2019). On the presence of the Racoon-Dog (Nyctereutes procyonoides Gray 1834) in the galați county (Romania). *Rev. Silvicul. si Cinegetica* 24 (44), 79–81.

Genovesi, P., Bacher, S., Kobelt, M., Pascal, M., and Scalera, R. (2009). "Alien mammals of Europe", in *Handbook of Alien Species in Europe* (Dordrecht: Springer), 119–128. doi: 10.1007/978-1-4020-8280-1_9

Genovesi, P., Scalera, R., and Van Ham, C. (2013). *Invasive alien species: the urban dimension: case studies on strengthening local action in Europe* (Brussels, Belgium: International Union for Conservation of Nature (IUCN)).

Gherardi, F., Britton, J. R., Mavuti, K. M., Pacini, N., Grey, J., Tricarico, E., et al. (2011). A review of allodiversity in Lake Naivasha, Kenya: Developing conservation actions to protect East African lakes from the negative impacts of alien species. *Biol. Conserv.* 144 (11), 2585–2596. doi: 10.1016/j.biocon.2011.07.020

GLEWS+. (2021). *SARS-CoV-2 in animals used for fur farming. Risk assessment report*. (Paris, France: Food and Agriculture Organization of the United Nations, World Organisation for Animal Health and World Health Organization).

Global Times (2017) *Chinese fur farms see their profits plummet* (ECNS.CN). Available at: http://www.ecns.cn/experience/2017/12-15/284668.shtml (Accessed 15 March 2023).

Gobbo, F., Zanardello, C., Bottinelli, M., Budai, J., Bruno, F., De Nardi, R., et al. (2022). Silent infection of highly pathogenic avian influenza virus (H5N1) clade 2.3.4.4b in a commercial chicken broiler flock in Italy. *Viruses* 14 (8), 1–16. doi: 10.3390/v14081600

Goicolea, T., Lewison, R. L., Mateo-Sánchez, M. C., and Jennings, M. K. (2023). Dynamic habitat suitability and connectivity analyses to inform management of an invasive species and conservation of its native competitor, the European mink. *Biol Invasions* 25, 3583–3601. doi: 10.1007/s10530-023-03128-x

Goraichuk, I. V., Arefiev, V., Stegniy, B. T., and Gerilovych, A. P. (2021). Zoonotic and reverse zoonotic transmissibility of SARS-coV-2. *Virus Res.* 302, 198473. doi: 10.1016/j.virusres.2021.198473

Gorbach, R. (2021). Fur farming. Skin for skin? *Anim. Ethics Rev.* 1 (1), 45–52.

Green, J., Coulthard, E., Norrey, J., Megson, D., and D'Cruze, N. (2020). Risky business: Live non-CITES wildlife UK imports and the potential for infectious diseases. *Animals* 10 (9), 1632. doi: 10.3390/ani10091632

Gregory, B. R. B., Kissinger, J. A., Clarkson, C., Kimpe, L. E., Eickmeyer, D. C., Kurek, J., et al. (2022). Are fur farms a potential source of persistent organic pollutants or mercury to nearby freshwater ecosystems? *Sci. Tot. Environ.* 833, 155100. doi: 10.1016/j.scitotenv.2022.155100

Gremmen, K. (2014). *Safeguarding animal welfare in the European fur farming industry* (Enschede, The Netherlands: Bachelor Thesis University of Twente).

Halliday, C., and McCulloch, S. P. (2022). Beliefs and attitudes of british residents about the welfare of fur-farmed species and the import and sale of fur products in the UK. *Animals* 12 (5), 538. doi: 10.3390/ani12050538

Hammer, A. S., Andresen, L., Larsen, S. V., Dalsgaard, K., Damborgog, P. P., and Aalbek, B. (2016). "Experimental infection with Arcanobacterium phocae and Streptococcus halichoeri in farm mink (Neovison vison)" in *Proceedings of the XI th International Scientific Congress in fur animal production: Scientifur* (Helsinki, Finland: International Fur Animal Scientific Association) 40 (3/4), 39–341.

Harding, A. R. (1979). *Fur farming. A book of information on raising furbearing animals for profit* (Columbus, Ohio, USA: A. R. Harding Publishing Co).

Harvey, G. L., Henshaw, A. J., Brasington, J., and England, J. (2019). Burrowing invasive species: An unquantified erosion risk at the aquatic-terrestrial Interface. *Rev. Geophys.* 57 (3), 1018–1036. doi: 10.1029/2018RG000635

Hellstedt, M., and Regina, K. (2016). "The effect of biochar-peat mixture on the gaseous emissions from fur animal manure," in *Proceedings of the XI th International Scientific Congress in fur animal production: Scientifur* (Helsinki, Finland: International Fur Animal Scientific Association) 40 (3/4), 247–251.

Hjulsager, C. K., Ryt-Hansen, P., Hagberg, E. E., Chrieíl, M., Struve, T., Krarup, A., et al. (2016). "Outbreaks of Aleutian mink disease in farmed mink (Neovison vison) in Denmark: molecular characterization by partial NS1 gene sequencing," in *Proceedings of the XI th International Scientific Congress in fur animal production: Scientifur volume 40 (3/4* (Helsinki, Finland: International Fur Animal Scientific Association), 85–87.

Hollander, H. D., van Duinen, G., Branquart, E., Hoop, L.d., De Hullu, P., Matthews, J., et al. (2017). "Risk assessment of the alien North American beaver (Castor canadensis)," in *Netherlands centre of expertise for exotic species (NEC-E), bargerveen foundation, dutch mammal society, service public de wallonie and radboud university* (The Netherlands: Institute for Water and Wetland Research, Department of Environmental Science).

Hong, S., Do, Y., Kim, J. Y., Kim, D.-K., and Joo, G.-J. (2015). Distribution, spread and habitat preferences of nutria (Myocastor coypus) invading the lower Nakdong River, South Korea. *Biol. Invas.* 17, 1485–1496. doi: 10.1007/s10530-014-0809-8

Honjo, M. (2014). "Japanese animal advocates get creative-to close mink fur farm. *dA. Derecho Animal (Forum of Animal Law Studies)* 5 (3), 1–3. doi: 10.5565/rev/da.237

Hossini, H., Shafie, B., Niri, A. D., Nazari, M., Esfahlan, A. J., Ahmadpour, M., et al. (2022). A comprehensive review on human health effects of chromium: insights on induced toxicity. *Environ. Sci. pollut. Res. Int.* 29 (47), 70686–70705. doi: 10.1007/s11356-022-22705-6

Ielmini, M. R., and Sankaran, K. (2021). "Invasive alien species: A prodigious global threat in the anthropocene," in *Invasive alien species: observations and issues from around the world*. Eds. T. Pullaiah and M. R. Ielmini (New York, USA: Wiley Online Library), 1–79. doi: 10.1002/9781119607045.ch1

International Fur Federation (2023) *Sustainable fur - asia regulations*. Available at: https://www.wearefur.com/responsible-fur/farming/fur-farming-asia/ (Accessed 15 March 2023).

International Fur Trade Federation (2011). *The socio-economic impact of international fur farming*. (Ile-de-France, France: IFF), pp26.

Ionescu, D., Hodor, C., and Drugă, M. (2019). "Recent occurrence of the American Mink (Neovison vison) in the central Romania," in *Proceedings of the Biennial*

International Symposium "Forest and sustainable development (Brașov, Romania: Transilvania University Press), 25–32.

Iordan, F., Lapini, L., Pavanello, M., Polednik, L., and Rieppi, C. (2017). Evidence for naturalization of the American mink (Neovison vison) in Friuli Venezia Giulia, NE Italy. *Mammalia* 81 (1), 91–94. doi: 10.1515/mammalia-2015-0044

Iordan, F., Rushton, S., Macdonald, D., and Bonesi, L. (2012). "Predicting the spread of feral populations of the American mink in Italy: is it too late for eradication?," in *Biological invasions*, vol. 14. , 1895–1908. doi: 10.1007/s10530-012-0200-6

IUCN (2023) *Global invasive species database*. Available at: http://www.iucngisd.org/gisd/index.php (Accessed 20 September 2023).

Jacobs, B., Rally, H., Doyle, C., O'Brien, L., Tennison, M., and Marino, L. (2022). Putative neural consequences of captivity for elephants and cetaceans. *Rev. Neurosci.* 33, 439–465. doi: 10.1515/revneuro-2021-0100

Jo, W. K., de Oliveira-Filho, E. F., Rasche, A., Greenwood, A. D., Osterrieder, K., and Drexler, J. F. (2021). Potential zoonotic sources of SARS-CoV-2 infections. *Transbound Emerg. Dis.* 68 (4), 1824–1834. doi: 10.1111/tbed.13872

Jones, A., Labaj, A., Campbell, J., Libera, N., and Kurek, J. (2022). Zooplankton assemblage and body size responses to severe lake eutrophication from agricultural activities near mink farms in Nova Scotia, Canada. *J. Plankton Res.* 44 (3), 464–474. doi: 10.1093/plankt/fbac022

Jones, K. E., Patel, N. G., Levy, M. A., Storeygard, A., Balk, D., Gittleman, J. L., et al. (2008). Global trends in emerging infectious diseases. *Nature* 451 (7181), 990–993. doi: 10.1038/nature06536

Jordán, D. P. (2017). Waterbirds in a changing world: Effects of climate, habitat and conservation policy on European waterbirds. *Acad. dissertat. Univ. Helsinki*. (Helsinki, Finland), pp146.

Kasprowicz, A. E. (2016). *The origin and expansion of the eastern red fox* (New Orleans, USA: University of New Orelans, Theses and Dissertations 2143).

Kawamura, K., Kaieda, S., Kato, M., and Kobayashi, S. (2018). Invasion genetics of nutria (Myocastor coypus) in Okayama, Japan, inferred from mitochondrial and microsatellite markers. *Eur. J. Wildlife Res.* 64, 1–13. doi: 10.1007/s10344-018-1185-y

Keddy, P. A. (2010). *Wetland ecology: principles and conservation* (New York, USA: Cambridge university press).

Kelly, N. E., Guijarro-Sabaniel, J., and Zimmerman, R. (2021). Anthropogenic nitrogen loading and risk of eutrophication in the coastal zone of Atlantic Canada. *Estuar. Coast. Shelf Sci.* 263, 107630. doi: 10.1016/j.ecss.2021.107630

Kempe, R. (2018). *Selection for welfare and feed efficiency in Finnish blue fox* (Finland: University of Helsinki).

Kempe, R., Koskinen, N., Mäntysaari, E., and Strandén, I. (2010). The genetics of body condition and leg weakness in the blue fox (Alopex lagopus). *Acta Agricul. Scand. Section A* 60 (3), 141–150. doi: 10.1080/09064702.2010.515241

Kempe, R., and Strandén, I. (2016). Breeding for better eye health in Finnish blue fox (Vulpes lagopus). *J. Anim. Breed Genet.* 133 (1), 51–58. doi: 10.1111/jbg.12170

Khademi, F., Yıldız, İ., Yıldız, A. C., and Abachi, S. (2014). "An assessment of microalgae cultivation potential using liquid waste streams: Opportunities and challenges," in *Proceeding of 13th international conference on clean energy ICCE* (Istanbul, Turkey), 2084–2097.

Khangura, S., Konnyu, K., Cushman, R., Grimshaw, J., and Moher, D. (2012). Evidence summaries: the evolution of a rapid review approach. *Systematic Rev.* 1 (1), 1–9. doi: 10.1186/2046-4053-1-10

Klockiewicz, M., Długosz, E., and Jakubowski, T. (2021). A review of the occurrence and clinical consequences of protozoan infections in carnivorous fur farm animals. *Ann. Agric. Environ. Med.* 28 (2), 199–207. doi: 10.26444/aaem/120974

Koistinen, T., and Korhonen, H. T. (2018). Juvenile Finnraccoons (Nyctereutes procyonoides ussuriensis) choose to allohuddle on the cage floor instead of resting on a platform. *Appl. Anim. Behav. Sci.* 201, 102–110. doi: 10.1016/j.applanim.2017.12.015

Koshev, Y. S. (2019). Occurrence of the american mink neovison vison (Schreber 1777)(Carnivora: mustelidae) in Bulgaria. *Acta Zoologica Bulgarica* 71 (3), 417–425.

Kruse, R. C. (2012). *The impact of nutria (Myocastor coypus) as an invasive species and its possible distribution in washington state* (Washington, USA: Evergreen State College).

Kuznetsov, Y. E., Belova, L., Gavrilova, N., Kuznetsova, N., Muromcev, A., and Efremov, A. Y. (2021). Epizootic monitoring of protozoozes in the fur farms of the Kaliningrad region, (2018-2020). *Agric. Biol.* 56 (4), 718–729. doi: 10.15389/agrobiology.2021.4.718eng

Laatu, S. (2013). *The development of animal welfare in Finland and how people perceive animal welfare: case study: animals in tourism: zoos* (Vaasa, Finland: Vaasa University of Applied Sciences).

LaDouceur, E. E., Anderson, M., Ritchie, B. W., Ciembor, P., Rimoldi, G., Piazza, M., et al. (2015). Aleutian disease: an emerging disease in free-ranging striped skunks (Mephitis mephitis) from california. *Vet. Pathol.* 52 (6), 1250–1253. doi: 10.1177/0300985814560234

Lambin, X., Horrill, J., and Raynor, R. (2017). "Achieving large scale, long-term invasive American mink control in northern Scotland despite short term funding," in *Island invasives: scaling up to meet the challenge*. Eds. C. R. Veitch, M. N. Clout, A. R. Martin, J. C. Russell and C. J. West (Gland, Switzerland: Occasional Paper SSC) 62, 651–657.

Larsen, G., Chrieíl, M., and Pedersen, K. (2016). MRSA in mink (Neovision vision)", in: *Proceedings of the XI th International Scientific Congress in fur animal production: Scientifur volume 40 (3/4)* (Helsinki, Finland: International Fur Animal Scientific Association), 119–121.

Laufer, G., González, E. M., Cravino, A., Gobel, N., Montenegro, F., Nión, G., et al. (2022). A potential threat to the Pampas Biome: the introduction of American mink, Neovison vison (Schreber 1777) in Uruguay. *Neotropical Biodiversity* 8 (1), 178–182. doi: 10.1080/23766808.2022.2061820

Lee, M. (2014). *The effects of product information on consumer attitudes and purchase intentions of fashion products made of fur, leather, and wool* (Iowa, USA: Graduate Theses and Dissertations, Iowa State University).

Li, Z., Liu, P., Cao, X., Lou, Z., Zaręba-Marchewka, K., Szymańska-Czerwińska, M., et al. (2018). First report of chlamydia abortus in farmed fur animals. *BioMed. Res. Int.* 2018, 4289648. doi: 10.1155/2018/4289648

Lin, X., Xin, L., Qi, M., Hou, M., Liao, S., Qi, N., et al. (2022). Dominance of the zoonotic pathogen Cryptosporidium meleagridis in broiler chickens in Guangdong, China, reveals evidence of cross-transmission. *Parasit Vectors* 15 (1), 188. doi: 10.1186/s13071-022-05267-x

Linzey, A., and Linzey, C. (2022). *An ethical critique of fur factory farming* (Cham: Palgrave Macmillan).

Liordos, V., Kontsiotis, V. J., Georgari, M., Baltzi, K., and Baltzi, I. (2017). Public acceptance of management methods under different human-wildlife conflict scenarios. *Sci. Tot. Environ.* 579, 685–693. doi: 10.1016/j.scitotenv.2016.11.040

Liu, C. N., Lou, Z. Z., Li, L., Yan, H. B., Blair, D., Lei, M. T., et al. (2015). Discrimination between E. granulosus sensu stricto, E. multilocularis and E. shiquicus Using a Multiplex PCR Assay. *PloS Negl. Trop. Dis.* 9 (9), e0004084. doi: 10.1371/journal.pntd.0004084

Lowe, S., Browne, M., Boudjelas, S., and De Poorter, M. (2000). *100 of the world's worst invasive alien species: a selection from the global invasive species database* (New Zealand: Invasive Species Specialist Group University of Auckland).

MacEachern, C. (2018). *Assessment of the potential of minkery wastewaters for the production of dunaliella salina and B-carotene* (Canada: Dalhousie University Nova Scotia).

Macieira, M. R. (2019). *Screening of diseases in swedish muskrats* (Portugal: University of Porto).

Maran, T., Skumatov, D., Gomez, A., Põdra, M., Abramov, A., and Dinets, V. (2016). *Mustela lutreola. The IUCN red list of threatened species 2016: e. T14018A45199861*. doi: 10.2305/IUCN.UK.2016-1.RLTS.T14018A45199861.en

Marchino, M., Rizzo, F., Barzanti, P., Sparasci, O. A., Bottino, P., Vicari, N., et al. (2022). Chlamydia species and related risk factors in poultry in north-western Italy: possible bird-to-human transmission for C. gallinacea. *Int. J. Environ. Res. Public Health* 19 (4), 1–20. doi: 10.3390/ijerph19042174

Marini, F., Ceccobelli, S., and Battisti, C. (2011). Coypu (Myocastor coypus) in a Mediterranean remnant wetland: a pilot study of a yearly cycle with management implications. *Wetlands Ecol. Manage.* 19 (2), 159–164. doi: 10.1007/s11273-010-9208-9

Marnell, F., O'Flynn, C., and O'Keeffe, D. (2019). Coypu (Myocastor coypus) confirmed as breeding in the wild in Ireland. *Irish Naturalists' J.* 36 (2), 165–167.

Martin, A. M. (2015). "Factory farming and consumer complicity," in *Philosophy comes to dinner*. Eds. A. Chignell, T. Cuneo and M. C. Halteman (London, UK: Taylor & Francis), 203–214.

Martin, A. R., and Lea, V. J. (2020). A mink-free GB: perspectives on eradicating American mink Neovison vison from Great Britain and its islands. *Mammal Rev.* 50 (2), 170–179. doi: 10.1111/mam.12178

Martínez-Rondán, F., De Ybáñez, M. R., Tizzani, P., López-Beceiro, A., Fidalgo, L., and Martínez-Carrasco, C. (2017). The American mink (Neovison vison) is a competent host for native European parasites. *Veterinary Parasitol.* 247, 93–99. doi: 10.1016/j.vetpar.2017.10.004

Material Innovation Initiative (2021). *State of the industry report: next-gen materials*. (California, USA), pp65.

McCague Borlack LLP (2019) *An overview of the regulation of fur farming in Canada [Online]*. Available at: https://mccagueborlack.com/emails/articles/fur-farming-regulations.html (Accessed 15 March 2023).

McSheffrey, E. (2015) *Behind bars: Canada's fur-farmed mink and fox* (Canada's National Observer). Available at: https://www.nationalobserver.com/2015/11/18/behind-bars-Canadas-fur-farmed-mink-and-fox (Accessed 15 March 2023).

Medina-Vogel, G., Muñoz, F., Moeggenberg, M., Calvo-Mac, C., Barros-Lama, M., Ulloa, N., et al. (2022). Improving trapping efficiency for control of american mink (Neovison vison) in patagonia. *Anim. (Basel)* 12 (2), 1–15. doi: 10.3390/ani12020142

Mellor, D. J. (2015). Positive animal welfare states and reference standards for welfare assessment. *New Z. Veterinary J.* 63 (1), 17–23. doi: 10.1080/00480169.2014.926802

Mellor, D. J. (2016). Updating animal welfare thinking: Moving beyond the "Five Freedoms" towards "a Life Worth Living. *Animals* 6 (3), 21. doi: 10.3390/ani6030021

Mendl, M., Mason, G., and Paul, E. S. (2017). "Animal welfare science," in *APA handbook of comparative psychology*. Eds. G. M. B. J. Call, I. M. Pepperberg, C. T. Snowdon and T. Zentall (Washington, DC: American Psychological Association), 793–811.

Mesa-Pineda, C., Navarro-Ruíz, J. L., López-Osorio, S., Chaparro-Gutiérrez, J. J., and Gómez-Osorio, L. M. (2021). Chicken coccidiosis: from the parasite lifecycle to control of the disease. *Front. Vet. Sci.* 8. doi: 10.3389/fvets.2021.787653

Moen, O. M., and Devolder, K. (2022). Palliative farming. *J. Ethics* 1-19, 543–561. doi: 10.1007/s10892-022-09404-7

Moisander-Jylhä, A.-M., Aaltonen, K., and Sironen, T. (2016). "Blue fox parvovirus in semen," in *Proceedings of the XI th International Scientific Congress in fur animal production: Scientifur volume 40 (3/4)* (Helsinki, Finland: International Fur Animal Scientific Association), 43–44.

Molenaara, R., and Jornaa, I. (2016). "Eimeria vison on Dutch mink farms," in *Proceedings of the XI th International Scientific Congress in fur animal production: Scientifur volume 40 (3/4)* (Helsinki, Finland: International Fur Animal Scientific Association), 49–52.

Møller, S. H., Hansen, S. W., Malmkvist, J., Vinke, C. M., Lidfors, L., Gaborit, M., et al. (2015). *WelFur-Welfare assessment protocol for mink* (Brussels, Belgium: European Fur Breeders' Association).

Mononen, J., Møller, S., Hansen, S., Hovland, A., Koistinen, T., Lidfors, L., et al. (2012). The development of on-farm welfare assessment protocols for foxes and mink: the WelFur project. *Anim. Welfare* 21 (3), 363–371. doi: 10.7120/09627286.21.3.363

Mora, M., Medina-Vogel, G., Sepúlveda, M. A., Noll, D., Álvarez-Varas, R., and Vianna, J. A. (2018). Genetic structure of introduced American mink (Neovison vison) in Patagonia: colonisation insights and implications for control and management strategies. *Wildlife Res.* 45 (4), 344–356. doi: 10.1071/WR18026

Mori, E., Mazza, G., Menchetti, M., Panzeri, M., Gager, Y., Bertolino, S., et al. (2015). The masked invader strikes again: the conquest of Italy by the Northern raccoon. *Hystrix* 26 (1), 1–5. doi: 10.4404/hystrix-26.1-11035

Müller, F. C., Kleibert, J. M., and Ibert, O. (2021). Hiding in the spotlight: commodifying nature and geographies of dissociation in the fur-fashion complex. *Economic Geogr.* 97 (1), 89–112. doi: 10.1080/00130095.2020.1858713

Mustonen, A.-M., Lawier, D., Ahola, L., Koistinen, T., Jalkanen, L., Mononen, J., et al. (2017). Skeletal pathology of farm-reared obese juvenile blue Foxes (Vulpes lagopus). *J. Veterinary Anat.* 10 (2), 51–74. doi: 10.21608/jva.2017.45445

Myllykoski, J., Lindström, M., Bekema, E., Pölönen, I., and Korkeala, H. (2011). Fur animal botulism hazard due to feed. *Res. Vet. Sci.* 90 (3), 412–418. doi: 10.1016/j.rvsc.2010.06.024

Nagayama, S., Kume, M., Oota, M., Mizushima, K., and Mori, S. (2020). Common coypu predation on unionid mussels and terrestrial plants in an invaded Japanese river. *Knowledge Manage. Aquat. Ecosyst.* 421), 37. doi: 10.1051/kmae/2020029

Newman, C., and Macdonald, D. W. (2015). "Biodiversity climate change impacts report card Technical paper 2," in *The implications of climate change for terrestrial UK Mammals. UK Natural Environment Research Council* (Oxford, UK: WildCRU, Zoology, University of Oxford).

NOAA Fisheries (2023) *Laws & Policies: marine mammal protection act* (US National Oceanic and Atmospheric Administration). Available at: https://www.fisheries.noaa.gov/topic/laws-policies/marine-mammal-protection-act (Accessed 28 March 2023).

Noah, and Animalia (2015). Case Saga Furs. Nordic fur trade - marketed as responsible business. Available at: https://respectforanimals.org/nordic-fur-trade-marketed-as-responsible-business/ (Accessed 10 April 2023).

Nordgren, H. (2017). *Fur animal epidemic necrotic pyoderma: pathology, etiology, and epidemiology* (Finland: Faculty of Veterinary Medicine of the University of Helsinki).

Nordgren, H., Aaltonen, K., Raunio-Saarnisto, M., Sukura, A., Vapalahti, O., and Sironen, T. (2016a). Experimental infection of mink enforces the role of arcanobacterium phocae as causative agent of fur animal epidemic necrotic pyoderma (FENP). *PloS One* 11 (12), e0168129. doi: 10.1371/journal.pone.0168129

Nordgren, H., Vapalahti, K., Sukura, A., Vapalahti, O., and Virtaa, A.-M. (2016b). "Epidemiologic study on fur animal epidemic pyoderma in Finland," in *Proceedings of the XI th International Scientific Congress in fur animal production: Scientifur volume 40 (3/4)* (Helsinki, Finland: International Fur Animal Scientific Association), 23–25.

OIE (2018). "Verocytotoxigenic escherichia coli," in *OIE terrestrial manual 2018*, vol. 11. (Paris, France: World Organisation for Animal Health).

Olenin, S., Gollasch, S., Lehtiniemi, M., Sapota, M., and Zaiko, A. (2017). "Biological invasions," in *Biological oceanography of the baltic sea*. Eds. P. Snoeijs-Leijonmalm, H. Schubert and T. Radziejewska (Netherlands: Dordrecht: Springer), 193–232.

Otgonbaatar, M., Shar, S., and Saveljev, A. P. (2018). Fifty years after introduction: muskrat Ondatra zibethicus population of Khar-Us Lake, Western Mongolia. *Russian J. Theriol.* 17 (1), 32–38. doi: 10.15298/rusjtheriol.17.1.03

Our world in data (2020) *Yearly number of animals slaughtered for meat, World 1961 to 2020* (Food and Agriculture Organization of the United Nations). Available at: https://ourworldindata.org/grapher/animals-slaughtered-for-meat (Accessed 15 March 2023).

Peng, S., and Broom, D. M. (2021). The sustainability of keeping birds as pets: should any be kept? *Animals* 11 (2), 582. doi: 10.3390/ani11020582

Pereira, A. D., Pires Adelino, J. R., Garcia, D. A. Z., Rodrigues Casimiro, A. C., Vizintim Marques, A. C., Vidotto-Magnoni, A. P., et al. (2020). Modeling the geographic distribution of Myocastor coypus (Mammalia, Rodentia) in Brazil: establishing priority areas for monitoring and an alert about the risk of invasion. *Stud. Neotropical Fauna Environ.* 55 (2), 139–148. doi: 10.1080/01650521.2019.1707419

Peter, N., Dörge, D. D., Cunze, S., Schantz, A. V., Skaljic, A., Rueckert, S., et al. (2023). Raccoons contraband – The metazoan parasite fauna of free-ranging raccoons in central Europe. *Int. J. Parasitol.: Parasites Wildlife* 20, 79–88. doi: 10.1016/j.ijppaw.2023.01.003

Peterson, L. A. (2010) *Brief summary of fur laws and fur production* (Michigan State University College of Law). Available at: https://www.animallaw.info/intro/fur-production-and-fur-laws (Accessed 15 March 2023).

Peyton, J. M., Martinou, A. F., Adriaens, T., Chartosia, N., Karachle, P. K., Rabitsch, W., et al. (2020). Horizon scanning to predict and prioritize invasive alien species with the potential to threaten human health and economies on Cyprus. *Front. Ecol. Evol.* 8, 566281. doi: 10.3389/fevo.2020.566281

Picket, H., and Harris, S. (2015). *The case against fur factory farming: A scientific review of animal welfare standards and 'WelFur* (Nottingham, UK: Respect for Animals).

Plotnikov, I. (2012). "Cage housed marmot's diseases," in *Proceedings of the X th International Scientific Congress in fur animal production: Scientifur* (The Netherlands: Wageningen Academic Publishers) 36 (3/4), 177–179. doi: 10.3920/978-90-8686-760-8

Pluda, M. E. (2020). End the lockdown for animals–reflecting and campaigning on three key arenas of human-animal interaction linked to zoonotic diseases. *dA. Derecho Animal (Forum of Animal Law Studies)* 11 (4), 171–176. doi: 10.5565/rev/da.543

Põdra, M., and Gómez, A. (2018). Rapid expansion of the American mink poses a serious threat to the European mink in Spain. *Mammalia* 82 (6), 580–588. doi: 10.1515/mammalia-2017-0013

Polanco, A., Díez-León, M., and Mason, G. (2018). Stereotypic behaviours are heterogeneous in their triggers and treatments in the American mink, Neovison vison, a model carnivore. *Anim. Behav.* 141, 105–114. doi: 10.1016/j.anbehav.2018.05.006

Polanco, A., Meagher, R., and Mason, G. (2021). Boredom-like exploratory responses in farmed mink reflect states that are rapidly reduced by environmental enrichment, but unrelated to stereotypic behaviour or 'lying awake'. *Appl. Anim. Behav. Sci.* 238, 105323. doi: 10.1016/j.applanim.2021.105323

Poland, T. M., Patel-Weynand, T., Finch, D. M., Miniat, C. F., Hayes, D. C., and Lopez, V. M. (2021). *Invasive species in forests and rangelands of the United States: A comprehensive science synthesis for the United States forest sector* (London, UK: Springer Nature).

Prasad, S., Yadav, K. K., Kumar, S., Gupta, N., Cabral-Pinto, M. M. S., Rezania, S., et al. (2021). Chromium contamination and effect on environmental health and its remediation: A sustainable approaches. *J. Environ. Manage* 285, 112174. doi: 10.1016/j.jenvman.2021.112174

Province of British Columbia (2015) *Fur farm regulation*. Available at: https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/8_2015 (Accessed 15 March 2023).

Province of Nova Scotia (2013) *Fur industry regulations*. Available at: https://novascotia.ca/just/regulations/regs/furindustry.htm (Accessed 15 March 2023).

Rabozzi, G., Bonizzi, L., Crespi, E., Somaruga, C., Sokooti, M., Tabibi, R., et al. (2012). Emerging zoonoses: the "one health approach". *Saf. Health Work* 3 (1), 77–83. doi: 10.5491/shaw.2012.3.1.77

Rajendran, M., and Babbitt, G. A. (2022). Persistent cross-species SARS-CoV-2 variant infectivity predicted via comparative molecular dynamics simulation. *R Soc. Open Sci.* 9 (11), 220600. doi: 10.1098/rsos.220600

Ramchandani, M., and Coste-Maniere, I. (2017). To Fur or not to fur: Sustainable production and consumption within animal-based luxury and fashion products. in *Textiles and Clothing Sustainability*. Ed. S. S. Muthu (Singapore: Springer), 41–60. doi: 10.1007/978-981-10-2131-2_2

Reetz, J., Rinder, H., Thomschke, A., Manke, H., Schwebs, M., and Bruderek, A. (2002). First detection of the microsporidium Enterocytozoon bieneusi in non-mammalian hosts (chickens). *Int. J. Parasitol.* 32 (7), 785–787. doi: 10.1016/s0020-7519(02)00045-0

Reino, L., Figueira, R., Beja, P., Araújo, M. B., Capinha, C., and Strubbe, D. (2017). Networks of global bird invasion altered by regional trade ban. *Sci. Adv.* 3 (11), e1700783. doi: 10.1126/sciadv.1700783

Rodrigues, D. C., Simões, L., Mullins, J., Lampa, S., Mendes, R. C., Fernandes, C., et al. (2015). Tracking the expansion of the American mink (Neovison vison) range in NW Portugal. *Biol. Invas.* 17 (1), 13–22. doi: 10.1007/s10530-014-0706-1

Roger, F., Delabouglise, A., Roche, B., Peyre, M., and Chevalier, V. (2021). Origin of the Covid-19 virus: the trail of mink farming. *Conversat.* 14, 1–6.

Rosenqvist, R. (2017). *Creating an ethical checklist for clothing business: european perspective* (Kokkola, Finland: Centria University of Applied Sciences Business Management).

Roy, H. E., Tricarico, E., Hassall, R., Johns, C. A., Roy, K. A., Scalera, R., et al. (2023). The role of invasive alien species in the emergence and spread of zoonoses. *Biol. Invas.* 25, 1249–1264. doi: 10.1007/s10530-022-02978-1

RSPCA (2006) *The five welfare needs*. Available at: https://www.rspca.org.uk/whatwedo/endcruelty/changingthelaw/whatwechanged/animalwelfareact (Accessed 22 February 2020).

Sacks, B. N., Brazeal, J. L., and Lewis, J. C. (2016). Landscape genetics of the nonnative red fox of California. *Ecol. Evol.* 6 (14), 4775–4791. doi: 10.1002/ece3.2229

Salgado, I. (2018). Is the raccoon (Procyon lotor) out of control in Europe? *Biodiversity Conserv.* 27 (9), 2243–2256. doi: 10.1007/s10531-018-1535-9

SCAHAW (2001). "The welfare of animals kept for fur production," in *European commission directorate C - scientific opinions* (Brussels, Belgium: Scientific Committee on Animal Health and Animal Welfare European Commission).

Schertler, A., Rabitsch, W., Moser, D., Wessely, J., and Essl, F. (2020). The potential current distribution of the coypu (Myocastor coypus) in Europe and climate change induced shifts in the near future. *NeoBiota* 58, 129–160. doi: 10.3897/neobiota.58.33118

Sengupta, M. E., Pagh, S., Stensgaard, A. S., Chriel, M., and Petersen, H. H. (2021). Prevalence of Toxoplasma gondii and Cryptosporidium in Feral and Farmed American Mink (Neovison vison) in Denmark. *Acta Parasitol.* 66 (4), 1285–1291. doi: 10.1007/s11686-021-00409-0

Shamaev, N. D., Shuralev, E. A., Petrov, S. V., Kazaryan, G. G., Aleksandrova, N. M., Valeeva, A. R., et al. (2020). Seroprevalence and B1 gene genotyping of Toxoplasma gondii in farmed European mink in the Republic of Tatarstan, Russia. *Parasitol. Int.* 76, 102067. doi: 10.1016/j.parint.2020.102067

Shriner, S. A., Ellis, J. W., Root, J. J., Roug, A., Stopak, S. R., Wiscomb, G. W., et al. (2021). SARS-coV-2 exposure in escaped mink, utah, USA. *Emerg. Infect. Dis.* 27 (3), 988–990. doi: 10.3201/eid2703.204444

Sidik, S. M. (2023). Bird flu outbreak in mink sparks concern about spread in people. *Nature* 614 (7946), 17. doi: 10.1038/d41586-023-00201-2

Sidorovich, V. E., Polozov, A. G., and Zalewski, A. (2010). Food niche variation of European and American mink during the American mink invasion in north-eastern Belarus. *Biol. Invas.* 12, 2207–2217. doi: 10.1007/s10530-009-9631-0

Silvenius, F., Koskinen, N., Kurppa, S., Rekilä, T., Sepponen, J., and Hyvärinen, H. (2012). "Life cycle assessment of mink and fox pelts produced in Finland," in *Proceedings of the X th International Scientific Congress in fur animal production: Scientifur volume 36 (3/4)* (The Netherlands: Wageningen Academic Publishers), 106–111. doi: 10.3920/978-90-8686-760-8

Sinclair, M., and Phillips, C. J. (2017). The cross-cultural importance of animal protection and other world social issues. *J. Agric. Environ. Ethics* 30, 439–455. doi: 10.1007/s10806-017-9676-5

Siviö, K., Heikkilä, R., Niemi, S., and Hiltunen, E. (2018). Properties of local produced animal-fat based biodiesel and its blend with fossil fuel. *Agronomy Research* 16 (Special Issue 1). doi: 10.15159/ar.18.083

Skyrienė, G., and Paulauskas, A. (2012). Distribution of invasive muskrats (Ondatra zibethicus) and impact on ecosystem. *Ekologija* 58 (3), 357–367.

Śmielewska-Łoś, E., Pacoń, J., Jańczak, M., and Płoneczka, K. (2003). Prevalence of antibodies to Toxoplasma gondii and Neospora caninum in wildlife and farmed foxes (Vulpes vulpes). *Electronic J. Polish Agric. Universities* 6 (2).

Smura, T., Aaltonen, K., Virtanen, J., Moisander-Jylhaü, A.-M., Nordgren, H., Peura, J., et al. (2016). "Fecal microbiota of healthy and diarrheic farmed arctic foxes (Vulpes lagopus) and American mink (Neovison vison) – a case-control study," in *Proceedings of the XI th International Scientific Congress in fur animal production: Scientifur volume 40 (3/4)* (Helsinki, Finland: International Fur Animal Scientific Association), 17–22.

Sobey, K. G., Jamieson, S. E., Walpole, A. A., Rosatte, R. C., Donovan, D., Fehlner-Gardiner, C., et al. (2019). ONRAB® oral rabies vaccine is shed from, but does not persist in, captive mammals. *Vaccine* 37 (31), 4310–4317. doi: 10.1016/j.vaccine.2019.06.046

Souillard, R., Grosjean, D., Le Gratiet, T., Poezevara, T., Rouxel, S., Balaine, L., et al. (2021). Asymptomatic carriage of C. botulinum type D/C in broiler flocks as the source of contamination of a massive botulism outbreak on a dairy cattle farm. *Front. Microbiol.* 12. doi: 10.3389/fmicb.2021.679377

Stefansson, R. A., von Schmalensee, M., and Skorupski, J. (2016). A tale of conquest and crisis: invasion history and status of the American mink (Neovison vison) in Iceland. *Acta Biol.* 23, 87–100. doi: 10.18276/ab.2016.23-08

Suarez, D. L. (2017). "Influenza A virus," in *Animal influenza, 2nd ed* Ed. D. E. Swayne (New Jersey, United States: John Wiley & Sons, Inc), 3–30.

Sun, C. (2013). *A federal ban on fur farming across the United States: long overdue legislation* (Jersey, USA: Seton Hall University Student Scholarship), 313.

Sun, H., Li, F., Liu, Q., Du, J., Liu, L., Sun, H., et al. (2021). Mink is a highly susceptible host species to circulating human and avian influenza viruses. *Emerg. Microbes Infect.* 10 (1), 472–480. doi: 10.1080/22221751.2021.1899058

Taylor, D. (2009). "*A water quality survey of ten lakes in the Carleton river watershed area Yarmouth county, Nova Scotia"* (Nova Scotia, USA: Water & Wastewater Branch Nova Scotia Environment).

Taylor, D. (2010). "*A water quality survey of ten lakes in the Carleton river watershed area Yarmouth and Digby counties, Nova Scotia*," (Nova Scotia, USA: Water & Wastewater Branch Nova Scotia Environment).

Tedeschi, L., Biancolini, D., Capinha, C., Rondinini, C., and Essl, F. (2022). Introduction, spread, and impacts of invasive alien mammal species in Europe. *Mammal Rev.* 52 (2), 252–266. doi: 10.1111/mam.12277

The Fur-Bearers (2022) *3/4 of Canadians support a ban on fur farming.* Available at: https://thefurbearers.com/blog/3-4-of-canadians-support-a-ban-on-fur-farming/ (Accessed 15 March 2023).

The Fur-Bearers (2023) *Marking the end of mink farming in British Columbia.* Available at: https://thefurbearers.com/blog/marking-the-end-of-mink-farming-in-british-columbia/ (Accessed 23 March 2023).

Thubron, S. (2017). *Bridging the gap between science and animal ethics. The morality of industrial animal farming with regards to animal welfare* (Tromsø, Norway: The Arctic University of Norway).

Toland, E., Bando, M., Hamers, M., Cadenas, V., Laidlaw, R., Martínez-Silvestre, A., et al. (2020). Turning negatives into positives for pet trading and keeping: A review of positive lists. *Animals* 10 (12), 2371. doi: 10.3390/ani10122371

Toland, E., Warwick, C., and Arena, P. (2012). The exotic pet trade: pet hate. *Biologist* 59 (3), 14–18.

Tsiamis, K., Palialexis, A., Connor, D., Antoniadis, S., Bartilotti, C., Bartolo, A., et al. (2021). *Marine Strategy Framework Directive-Descriptor 2, Non-Indigenous Species, Delivering solid recommendations for setting threshold values for non-indigenous species pressure on European seas* (Palma, Spain: Centro Oceanográfico de Baleares).

Turner, P. V. (2022)Bacterial diseases of mink. In: (MSD Veterinary Manual). Available at: https://www.msdvetmanual.com/exotic-and-laboratory-animals/mink/bacterial-diseases-of-mink (Accessed 4 March 2023).

Tyhtilä, J. (2016) *Biohiilestä ja turpeesta haetaan apua turkistarhauksen ympäristöhaittoihin.* Available at: https://yle.fi/a/3-8623749 (Accessed 22 March 2023).

Uitti, J. (2020). "Fur farming and the fur industry," in *Kanerva's Occupational Dermatology*. Ed. S. M. John (Cham, Switzerland, Springer) 1991–1995. doi: 10.1007/978-3-319-68617-2_155

Uspensky, A., Bukina, L., Odoevskaya, I., Movsesyan, S., and Voronin, M. (2019). The epidemiology of trichinellosis in the Arctic territories of a Far Eastern District of the Russian Federation. *J. Helminthol* 93 (1), 42–49. doi: 10.1017/s0022149x18000020

Vaitkunas, K. E. (2000). *Furor over furs* (Massachusetts, USA: Degree of Bachelor of Science, Worcester Polytechnic Institute).

Valdovska, A., and Pilmane, M. (2011). Histopathologic and immunohistochemical lesions in liver of mink infected with Aleutian disease virus. *Pol. J. Vet. Sci.* 14 (1), 69–76. doi: 10.2478/v10181-011-0010-2

Valnisty, A. A., Homel, K. V., Kheidorova, E. E., Shpak, A. V., and Nikiforov, M. E. (2020). Molecular genetic polymorphism of american mink populations (Neovison vison) in model fur farms and on the adjacent territories in Belarus. *Доклады Национальной академии наук Беларуси* 64 (6), 685–693. doi: 10.29235/1561-8323-2020-64-6-685-693

Van Bruggen, C., Groenestein, C., de Haan, B., Hoogeveen, M., Huijsmans, J., Sluis, S., et al. (2012). *"Ammonia emissions from animal manure and inorganic fertilisers in 2009: calculated with the Dutch National Emissions Model for Ammonia (NEMA)"* (Wageningen, The Netherlands: Wettelijke Onderzoekstaken Natuur & Milieu).

Van Heyst, A., A, S., and Jamieson, R. (2022). Application of phosphorus loading models to understand drivers of eutrophication in a complex rural lake-watershed system. *J. Environ. Manage* 302 (Pt A), 114010. doi: 10.1016/j.jenvman.2021.114010

Velando, A., Morán, P., Romero, R., Fernández, J., and Piorno, V. (2017). Invasion and eradication of the American mink in the Atlantic Islands National Park (NW Spain): a retrospective analysis. *Biol. Invas.* 19, 1227–1241. doi: 10.1007/s10530-016-1326-8

Virtanen, J. (2022). "Epidemiology and pathogenicity of Aleutian mink disease virus," (Finland: Doctoral Programme in Clinical Veterinary Medicine, University of Helsinki).

Warwick, C. (2020). Zoonoplasticity as an intuitive risk protocol for companion-animal-linked zoonoses. *Rev. Scientifique Technique (Internat. Office Epizootics)* 39 (3), 817–830. doi: 10.20506/rst.39.3.3180

Warwick, C. (2022). "Our knowledge of animal welfare principles constantly needs refreshing," in *Veterinary practice*. Available at: https://www.veterinary-practice.com/article/animal-welfare-principles (Accessed 10 April 2023).

Warwick, C., Arena, P., Steedman, C., and Jessop, M. (2012). A review of captive exotic animal-linked zoonoses. *J. Environ. Health Res.* 12 (1), 9–24.

Warwick, C., and Steedman, C. (2021). Wildlife-pet markets in a one-health context. *Int. J. One Health* 7 (1), 42–64. doi: 10.14202/IJOH.2021.42-64

We Animals Media (2022) *The decline of fur farming in Canada*. Available at: https://weanimalsmedia.org/2022/06/20/the-decline-of-fur-farming-in-Canada/ (Accessed 15 March 2023).

Weiskopf, S. R., Rubenstein, M. A., Crozier, L. G., Gaichas, S., Griffis, R., Halofsky, J. E., et al. (2020). Climate change effects on biodiversity, ecosystems, ecosystem services, and natural resource management in the United States. *Sci. Tot. Environ.* 733, 137782. doi: 10.1016/j.scitotenv.2020.137782

WelFur (2015). "Welfare assessment protocol for foxes," in *Welfur consortium, brussels, Belgium* (Brussels, Belgium: Welfur Consortium).

Wlazlo, Ł., Ossowski, M., Kasela, M., Bis-Wencel, H., Żebracka, A., Chmielowiec-Korzeniowska, A., et al. (2022). Relaxer feed additive as a natural tranquilizer for farmed mink (Neovison vison) in stress situations. *Med. Weter* 78 (9), 442–449. doi: 10.21521/mw.6668

Zalewski, A., Piertney, S. B., Zalewska, H., and Lambin, X. (2009). Landscape barriers reduce gene flow in an invasive carnivore: geographical and local genetic structure of American mink in Scotland. *Mol. Ecol.* 18 (8), 1601–1615. doi: 10.1111/j.1365-294X.2009.04131.x

Zhang, X., Ba, H., Jia, B., Yue, Z., Qiu, J., and Yang, F. (2016). "Detection of raccoon dog and fox amdoparvovirus infection and viral genetic characteristics," in *Proceedings of the XI th International Scientific Congress in fur animal production: Scientifur volume 40 (3/4)* (Helsinki, Finland: International Fur Animal Scientific Association), 99–106.

Zhang, L., Hua, Y., and Wei, S. (2021). High genetic diversity of an invasive alien species: comparison between fur-farmed and feral american mink (Neovison vison) in China. *Animals* 11 (2), 472. doi: 10.3390/ani11020472

Zhao, W., Zhang, W., Yang, Z., Liu, A., Zhang, L., Yang, F., et al. (2015). Genotyping of Enterocytozoon bieneusi in Farmed Blue Foxes (Alopex lagopus) and Raccoon Dogs

(Nyctereutes procyonoides) in China. *PloS One* 10 (11), e0142611. doi: 10.1371/journal.pone.0142611

Zheng, B., Xu, H., Huang, C., Yu, X., Guo, L., Han, H., et al. (2019). Occurrence and genomic characterization of two MCR-1-producing escherichia coli isolates from the same mink farmer. *mSphere* 4 (6). doi: 10.1128/mSphere.00602-19

Zschille, J., Stier, N., Roth, M., and Mayer, R. (2014). Feeding habits of invasive American mink (Neovison vison) in northern Germany—potential implications for fishery and waterfowl. *Acta theriol.* 59, 25–34. doi: 10.1007/s13364-012-0126-5

Zsolt, M., Beilicci, E., Beilicci, R., Carabet, A., and Stefanescu, C. (2016). Mathmatical modeling of eutrophication processes in Gozna and Secu reservoires. *Int. Multidiscip. Sci. GeoConf.: SGEM* 2, 553–559.

Zuberogoitia, I., González-Oreja, J. A., Zabala, J., and Rodríguez-Refojos, C. (2010). Assessing the control/eradication of an invasive species, the American mink, based on field data; how much would it cost? *Biodiversity Conserv.* 19, 1455–1469. doi: 10.1007/s10531-010-9776-2

Zubir, M. A., Bong, C. P., Ishak, S. A., Ho, W. S., and Hashim, H. (2022). The trends and projections of greenhouse gas emission by the livestock sector in Malaysia. *Clean Technol. Environ. Policy* 24, 363–377. doi: 10.1007/s10098-021-02156-2