Necrophages and necrophiles: a review of their antibacterial defenses and biotechnological potential

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ABSTRACT

With antibiotic resistance on the rise, there is an urgent need for new antibacterial drugs and products to treat or prevent infection. Many such products in current use, for example human and veterinary antibiotics and antimicrobial food preservatives, were discovered and developed from nature. Natural selection acts on all living organisms and the presence of bacterial competitors or pathogens in an environment can favor the evolution of antibacterial adaptations. In this review, we ask if vultures, blow flies and other carrion users might be a good starting point for antibacterial discovery based on the selection pressure they are under from bacterial disease. Dietary details are catalogued for over 600 of these species, bacterial pathogens associated with the diets are described, and an overview of the antibacterial defenses contributing to disease protection is given. Biotechnological applications for these defenses are then discussed, together with challenges facing developers and possible solutions. Examples include use of (a) the antimicrobial peptide (AMP) gene *sarcotoxin IA* to improve crop resistance to bacterial disease, (b) peptide antibiotics such as serrawettin W2 as antibacterial drug leads, (c) lectins for targeted drug delivery, (d) bioconversion-generated chitin as an antibacterial biomaterial, (e) bacteriocins as antibacterial food preservatives and (f) mutualistic microbiota bacteria as alternatives to antibiotics in animal feed. We show that carrion users encounter a diverse range of bacterial pathogens through their diets and interactions, have evolved many antibacterial defenses, and are a promising source of genes, molecules and microbes for medical, agricultural and food industry product development.

Keywords: scavenger; necrophagous; necrophilous; immunity; symbiosis; biotechnology; drug discovery; biocides; biomaterials; probiotics

Introduction

Antibiotic resistance is a serious global problem, contributing to an estimated 5 million deaths per year [1] and eroding our ability to perform medical interventions such as surgery and cancer chemotherapy safely [2]. To meet this challenge, efforts are being made to discover new antibacterial and antivirulence drugs capable of replacing those antibiotics that are no longer working [3]. Attempts are also being made to identify new antibiotic potentiators, drugs that suppress bacterial resistance and restore or enhance antibiotic activity [4]. Work is underway to reduce antibiotic consumption too as this is a major driver of resistance and a means to decelerate the emergence of new resistant strains of bacteria. In human health and healthcare, this may be achievable through the development of new or improved vaccines [5], colonization-resistant medical implants [6], food sanitizers [7] and other antibacterial products [8]. In agriculture, innovative methods of infection prevention are likewise being explored, including the use of probiotics in livestock and poultry production [9,10] and the development of disease-resistant crops [11].

Bioprospecting has been an important source of many pharmaceutical and agricultural products including medically useful antibiotics such as streptomycin and chlortetracycline [12], the antibiotic potentiator clavulanic acid [13], and the veterinary antibiotics novobiocin and avilamycin [14]. The antibacterial food preservatives nisin and sorbate [15] and versatile cephalosporin-class antibiotics [16] were also discovered and developed from nature. Antibacterial bioprospecting can be performed by randomly screening organisms for activity, but a more rational approach is to select niches or species based on ecological, historical or other information [12]. For example, Waksman and Schatz screened soil bacteria based on observations of microbial antagonism within soil and discovered streptomycin [17]. Also, Brotzu screened local marine fungi after observing that *Salmonella*-contaminated sewage was not infecting swimmers and discovered the cephalosporin C-producer *Acremonium chrysogenum* [18]. In addition, Lederle Laboratories screened soil streptomycetes based on Waksman and Schatz's prior success with these bacteria and discovered chlortetracycline [19].

Most antibacterial bioprospecting studies to date have focused on microbes and plants, but animals such as the Eurasian griffon vulture (*Gyps fulvus*) [20], Atlantic hagfish (*Myxine glutinosa*) [21] and common green bottle fly (*Lucilia sericata*) [22] are also attracting interest. These animals feed on decomposing animal carcasses populated with large numbers of bacteria, and selection pressure from pathogens in this diet could have favored the evolution of enhanced host defenses [20-22]. In this review, we catalogue some of the different animal species feeding on animal carcasses, and species in a closely related group immediately above them in the food chain. We present information on the bacteria and toxins these animals are exposed to, and the traits proposed to protect them. Because vertebrate pathogens are sometimes nonpathogenic in invertebrates (e.g. *Clostridium botulinum* [23]) and *vice versa* (e.g. *Bacillus thuringiensis* [24]), this information is presented separately. Vertebrate and invertebrate defenses are also described separately, since vertebrates have a more complex immune system. Applications for these defenses are then discussed from a medical, agricultural and food perspective, and the review concludes with suggestions for future research.

Necrophagy and necrophily: definitions and related terms

'Necrophagy' is defined as the act of eating 'carrion', the decaying flesh or tissue of dead animals. The term 'scavenging' is used to describe this feeding behavior too, but is less precise, encompassing also the consumption of dead plant material [25]. Necrophagous animals differ in their level of dependence on and adaptation to carrion feeding. Animals are categorized as 'obligate necrophages' if they use carrion as their sole or main food source and rely on carrion for survival or reproduction (Fig. 1a). Animals consuming carrion opportunistically and retaining the traits needed to kill prey or use other food sources are considered 'facultative necrophages' (Fig. 1b) [26]. Lastly, not all of the animals visiting carrion are necrophagous. Some are seeking live carrion inhabitants (e.g. insect larvae or pupae) to eat or to parasitize. These animals are categorized as 'necrophilous' (Fig. 1c) and sub-categorized as 'predators' and 'parasitoids' respectively [27].

Necrophagy and necrophily among vertebrates

Examples of vertebrate necrophages and necrophiles

Among terrestrial vertebrates, vultures are the only obligate necrophages (Suppl Table 1). Vultures are highly specialized, their large size enabling them to consume large, infrequent meals, their gliding flight helping them conserve energy, and an excellent olfactory sense helping them locate carrion [29]. Among marine vertebrates, some Myxinidae (hagfish) species rely heavily on carrion and may also be obligate necrophages. Like vultures, hagfish can survive extended periods without eating, are highly mobile, and can detect carrion from long distances [30].

Although few vertebrate species are obligate necrophages, there are an enormous number of facultative necrophages. Almost all carnivorous vertebrates use carrion as a food source [e.g. *Aquila rapax* (tawny eagles)], as do some omnivores [e.g. *Vulpes vulpes* (red foxes)] and even some largely herbivorous animals [e.g. *Neotoma floridana* (Eastern woodrats)] (Suppl Table 1). Quantities of carrion consumed vary greatly amongst facultative necrophages. For example, *Sus scrofa* (wild boars) consume carrion as ~15% of their diet [31], *Coryphaenoides armatus* (abyssal grenadiers) as ~69% of their diet [32], and *Hyaena brunnea* (brown hyenas) as up to 90% of their diet [29].

Necrophily is less commonly reported for vertebrates than invertebrates but does occur. For example, *Cyanopica cyanus* (azure-winged magpies), *Pica pica* (Eurasian magpies) and red fox puppies feed on insects at the carcass, and abyssal grenadiers feed on amphipods (Suppl Table 1).

Bacteria and toxins encountered by vertebrate necrophages and necrophiles

Whilst a necrophagous diet has certain advantages (e.g. high protein and energy content; does not need to be chased or subdued like live prey), there are also important risks including exposure to bacterial pathogens and toxins. One source of these pathogens and toxins is the carcass itself if the animal has died of infection (Suppl Table 2). Wildlife can die from many bacterial diseases (e.g. *Bacillus anthracis* toxico-infection of ungulates; *Francisella tularensis* infection of rabbits and rodents; *Listeria monocytogenes* and *Pasteurella multocida* infections of deer; *Yersinia pestis* infection of rodents). Bacterial diseases also kill livestock (e.g. *Klebsiella pneumoniae* infection of cattle, sheep and pigs) and other animals (e.g. *F. tularensis* and *Y. pestis* infections of cats). Post-mortem microbiological culture shows bacteria can remain viable in these carcasses (Suppl Table 2).

A second source of bacteria and toxins is other necrophagous and necrophilous animals visiting the carcass. These animals can harbor many pathogens (e.g. muscid flies carry *Aeromonas hydrophila*, *B. anthracis, Campylobacter coli*, *Campylobacter jejuni* and *Salmonella enterica* [33-35]; blow flies, flesh flies and dermestid beetles carry *Clostridium botulinum* [23,36]; carrion crows, rooks and red foxes carry *Mycobacterium avium* subsp. *paratuberculosis* [37]; wild boar carry *Mycobacterium bovis* [38]; carrion crows and rooks carry *P. multocida* [39]). Considerable inter- and intra-species contact is possible between these necrophages and necrophiles, especially if a carcass is large, there is a mass mortality event, or the animals feed communally (Suppl Table 3). Any such contact will provide opportunities for disease transmission [29].

Additional sources of pathogens and toxins necrophages are exposed to are the dead animal's microbiota and environmental species growing in or on the carcass (e.g. *C. botulinum* [40], *Clostridium novyi* [41], *Clostridium perfringens* [42], *Mycoplasma hyorhinis* [43], *Proteus mirabilis*, *Proteus vulgaris* [44,45], *S. enterica*, *Streptococcus suis* [43]). Lastly, many of the risks described above for necrophages also apply to necrophiles. This includes direct risks from their diet because the live carrion inhabitants that necrophiles prey upon (e.g. fly larvae) can accumulate bacterial pathogens and toxins from the carcass (e.g. *B. anthracis* [37], *C. botulinum* [36] and botulinum toxin [23]).

Traits reducing risk of disease in vertebrate necrophages and necrophiles

Traits proposed to protect vertebrate carrion users from bacteria can be divided into four categories: (a) anatomies less sensitive to bacterial toxins, (b) risk reduction behaviors, (c) innate immunity and (d) adaptive immunity. Innate immune defenses currently hold most promise from an antibacterial biotechnology perspective, but information will be presented on all four categories as it could be useful in prioritizing or deprioritizing animals for further study.

Most anatomical adapatations protecting animals from disease serve a barrier function (i.e. they stop bacteria and toxins entering the body or stop them reaching sterile body sites) and will be discussed below as part of the innate immune system. In vultures however, there is evidence of anatomical adaptation beyond their outer body surface and mucous membranes. A study comparing vultures and roosters shows the former are $1\text{-}2\times10^4$ times as resistant to intracardially administered botulinum toxin, with subsequent work on isolated biventer cervicis neuromuscular preparations suggesting vultures' presynaptic nerve endings are less toxin-sensitive [46].

Numerous risk reduction behaviors have been documented too. These include reaching carcasses quickly (e.g. Atlantic hagfish find carrion within minutes or hours [47]), avoiding older carcasses (e.g. turkey vultures eat 1-day-old carrion in preference to 4-day-old carrion [48]), avoiding carrion consumption in summer when decomposition is more rapid (e.g. gray wolves [49]), preferring predator-killed animals (e.g. common ravens [50]), feeding on bones rather than meat (e.g. bearded vultures [51]), avoiding carnivore carcasses (e.g. stone martens [52]), and sunning their plumage after feeding (e.g. black vultures [53]). Not all carrion users practice these precautions (Suppl Table 3).

The innate immune system comprises, as its first line of defense, different types of barrier. Examples of dermatological barriers include bald heads in vultures and slime production in hagfish. Bald heads, in addition to facilitating thermoregulation [54], decrease the accumulation of putrefying material during feeding [55]. Also, analysis of Atlantic hagfish slime shows it has elevated lysozyme activity compared to other epidermal fish secretions [56]. Moving onto gastrointestinal barriers, some necrophages hold food in their stomachs for an extended period (e.g. ~4-12 hours for wolves and dogs versus ~0.5-2 hours in primates) [57]. Inter-study comparisons of animal stomach acidity are challenging because of the many variables affecting measurements [58], but very low pH values have been documented in necrophages such as the white-backed vulture (pH 1.2) [59]. Strong stomach acidity in vultures may be due to adaptations in *ATP4B* and other genes of the gastric acid secretion pathway [60]. Some necrophages also have shorter intestinal tracts, so subsequent transit and excretion of the food bolus and any surviving bacteria is more rapid (e.g. 5-8 hours in dogs versus ≥12-60 hours in primates) [57]. Barriers present at both dermatological and gastrointestinal locations include mucus, antimicrobial peptides (AMPs), antimicrobial proteins and microbiota organisms. Positive selection and rapid evolution have been detected in mucin synthesis and mucus secretion genes in vultures and hyenas [60], novel AMPs and antimicrobial proteins (e.g. myxinidin, CRISP protein) have been identified in the Atlantic hagfish and Patagonia green racer snake [61,62], and antibiotic- and bacteriocin-producing microbiota bacteria have been detected in several vulture species [20,63].

In addition to barriers, innate immunity has numerous regulatory, humoral and cellular components, and there is evidence of adaptation in these too. In vultures, convergent changes have been detected in the genes encoding STING, a protein that controls type I interferon and proinflammatory cytokine transcription [60]. Humoral modifications include positive selection of the gene for opsonin alpha2-HS glycoprotein in vultures [64], and cellular changes include novel toll like receptor genes in vultures [64] and novel lysosomal AMPs in Komodo dragons [65].

Some carrion users have modifications in their adaptive immune systems too. In vultures, changes have been detected in genes important for B-cell development (*PIK3AP1*) [64], Tfh-cell and B-cell differentiation (*BCL6*) [66], IgA and IgM production (*JCHAIN*), and IgA and IgM transport to the GI tract surface *(PIGR*) [60]. Also, whilst *C. botulinum* toxins typically kill animals at concentrations lower than those needed to generate humoral immunity, anti-botulinum antibodies have been detected in turkey vultures, American crows and coyotes [67]. Comparatively little information is available on cell-based adaptive immunity in necrophages, but positive selection and rapid evolution have been detected in vulture genes affecting T-cell homeostasis [60].

Necrophagy and necrophily among invertebrates

Examples of invertebrate necrophages and necrophiles

Necrophagous invertebrates outnumber necrophagous vertebrates considerably, with species numbers in some locations reaching over 500 [68]. Many adult invertebrates use carrion not just as a food source for themselves but also their offspring, laying eggs or larvae in the carcass (e.g. blow flies, flesh flies) or its vicinity (e.g. silphine beetles, nicrophorine beetles) [69].

Obligately necrophagous terrestrial invertebrates include the piophilid flies *Centrophlebomyia furcata* and *Thyreophora cynophila*, nicrophorine beetles such as *Nicrophorus concolor*, and the vulture bees *Trigona crassipes* and *T. necrophaga* (Suppl Table 4). These species have specialist traits enabling them to quickly locate carrion (e.g. *Nicrophorus* spp. have sensitive antennal chemosensors [70]), chase away competitors (e.g. *T. necrophaga* [71]), or reduce the need for competition by niche partitioning (e.g. *Nicrophorus* spp. [72]). Marine invertebrates proposed to be obligately necrophagous include the malacostracans *Anonyx sarsi*, *Charcotia obesa*, *Paralicella caperesca* and *Tryphosa nana* (Suppl Table 4). Specialist traits consistent with obligate necrophagy include the ability to rapidly find carrion (e.g. *T. nana* [73]), gorge themselves (e.g. *P. caperesca* has expandable intestines [74]) and survive on infrequent meals (e.g. *C. obesa* can survive 18 months without meals [75]).

Many hundreds of invertebrates are facultatively necrophagous, some examples listed in Suppl Table 4. The most dominant orders terrestrially are flies (especially blow flies and flesh flies) and beetles (especially dermestid, hister, rove and silphine beetles). Traits enabling these organisms to outcompete other species include a keen sense of smell (e.g. flesh flies [76]), high fecundity (e.g. blow flies [77]) and the ability to repel competitors (e.g. *Necrodes surinamensis* [78]). Information on the relative dominance of facultatively necrophagous marine invertebrates is limited, but species detected in large numbers regionally include the malacostracans *Cirolana harfordi*, *Coenobita perlatus*, *Hirondellea gigas* and *Tmetonyx cicada*, the nematode *Pontonema vulgare*, and the nemertean *Parborlasia corrugatus* [79].

Invertebrate necrophiles may be predaceous or parasitic (Suppl Table 4). Predators feed on live carrion inhabitants (e.g. *Carcinops pumilio* eats fly eggs [69]) and parasitoids use carrion inhabitants as hosts (e.g. *Nasonia vitripennis* lays its eggs in blow fly pupae [80]).

Bacteria and toxins encountered by invertebrate necrophages and necrophiles

Invertebrate necrophages and necrophiles are exposed to many pathogens during feeding and reproduction. These include bacteria in the carcass (e.g. *Bacillus cereus* in wildlife and livestock [43,81]; *Bacillus circulans*, *Bacillus thuringiensis, Brevibacillus laterosporus* and *Lysinibacillus sphaericus* in cattle [82]; *B. thuringiensis* in insects [24,83]; *Clostridioides difficile* and *Paraclostridium bifermentans* in human remains [41]; *Clostridium perfringens* in wildlife, humans and livestock [42,43,81]; *Listeria monocytogenes* and *Pseudomonas chlororaphis* in livestock [44,81]; *S. enterica* in wildlife and livestock [43,81]; *Serratia marcescens* in boars and mice [43,45]; *Staphylococcus aureus* in livestock [84]; *Vibrio parahaemolyticus* in marine life [85]). Other carrion visitors can also be a source of bacterial pathogens (e.g. *B. cereus*, *L. sphaericus* and *Paenibacillus alvei* from *Musca domestica* [34]; *S. enterica* from *Carcinops pumilio*, *Hydrotaea aenescens* and *M. domestica* [34,86,87]; *S. aureus* and *Staphylococcus sciuri* from *M. domestica* [34]). These bacteria cause disease in invertebrates through direct colonization (e.g. *L. monocytogenes*) and toxin production (e.g. *B. thuringiensis* and *L. sphaericus*) [83,88].

Traits reducing risk of disease in invertebrate necrophages and necrophiles

Traits proposed to protect invertebrate carrion users from bacteria can be divided into four categories: (a) risk reduction behaviors, (b) innate immunity, (c) social immunity and (d) detoxification systems. Risk reduction behaviors observed include reaching carcasses quickly (e.g. blow flies and flesh flies find dead animals within minutes [76]), avoiding older carcasses (e.g. *Menippe mercenaria* eats fresh carrion 2.5 times more frequently than microbe-laden carrion [89]), feeding on carrion mainly in winter (e.g. *T. cynophila* [90]), and grooming their external surfaces (e.g. *Phormia regina* [91]).

Moving onto innate immunity, an important explanation for the general resistance of arthropods to bacterial disease is their exoskeletal cuticle. This barrier is constructed from the antibacterial polymer chitin, it is physically difficult for bacteria to penetrate [92], and is further reinfored in some necrophages (e.g. *Solenopsis invicta*) by the application of antibacterial secretions [93]. The digestive tract of many insects, including necrophagous *Calliphora* and *Dermestes* spp., is also partly protected by the cuticle [94,95] and a second chitin barrier called a peritrophic membrane or matrix [96,97]. Other digestive tract barriers include acidic conditions [e.g. *Camponotus floridanus* (pH 2) [98]], AMPs and lysozymes (e.g. *M. domestica* [99,100]), and mutualistic microbiota bacteria (e.g. antibiotic-producing *Myroides odoratimimus* in *Sarcophaga* sp. [101]). *Hermetia illucens* and *M. domestica* encode especially large numbers of lysozymes, 36 and 34, respectively (versus ~10 in other fly species) [102].

For bacteria that breach the above barriers and reach the hemocoel (circulatory system), there are additional innate defenses. Lining the hemocoel is a multi-functional tissue known as the fat body [103] that secretes molecules important for humoral immunity (e.g. AMPs [104,105], lysozymes and other antibacterial proteins [106]). Circulating fatty acids may provide protection too [107]. Also present in the hemocoel are immune cells called hemocytes. Some hemocytes (e.g. crystal cells, oenocytoids) contribute to humoral immunity by triggering phenoloxidase activation and melanization, a process where bacteria are bombarded with reactive oxygen species and sealed within melanin [108,109]. Other hemocytes (e.g. granulocytes, plasmatocytes) are phagocytic [109,110]. Pattern recognition receptors (PRPs) are responsible for detecting bacterial pathogens and activating the above effectors and, in some necrophages, expansion in the genes encoding these receptors has been detected (e.g. Nimrod PRPs in *M. domestica* [111]).

Social immunity resembles the above defenses in that it encompasses both behavioral and physiological traits but differs in that the individual expressing the trait is not the sole or main beneficiary. Several such traits become apparent during reproduction and brood care, with some mating necrophages avoiding old carrion (e.g. *N. vespilloides* [112]), rolling away or burying carrion (e.g. *Canthon cyanellus*, *Nicrophorus* spp. [113]), eviscerating carcasses (e.g. *N. vespilloides* [114]), dessicating carcasses (e.g. *S. invicta* [115]), smearing carcasses with antibacterial and toxin-degrading exudates (e.g. *N. vespilloides* [106,116]), and feeding antibacterial exudates to larvae (e.g. solenopsins in *S. invicta* [117]). The secretion of antibacterial factors onto carrion by larval broods (e.g. *Calliphora vicina* and *N. vespilloides*) is also a form of social immunity [118,119].

In addition to the above behavioral and immunological defenses, genome sequencing has detected expansions in the genes encoding detoxification enzymes in some necrophages (e.g. cytochrome P450 enzymes in *H. illucens* [102] and *M. domestica* [111]). These enzymes may help protect necrophages from bacterial toxins encountered in their diet.

Biotechnological potential of necrophage and necrophile defenses

Antimicrobial peptides (≤50 amino acids or ≤5.5 kDa)

Carrion users are a rich source of AMPs including cathelicidins, cecropins, defensins, diptericins, histone-derived AMPs, knottin-like peptides, proline-rich peptides and sarconesins (Suppl Table 5). Whole-genome and transcriptome sequencing of *H. illucens*, the black soldier fly, has shown it encodes 44-47 AMPs (excl. attacins), one of the largest AMP repertoires identified in any insect to date [102,120]. AMPs called bacteriocins are also produced by the microbiotas of some necrophages [20]. Several studies have purified the above AMPs and determined their minimum inhibitory concentrations (MICs; Table 1a). Also, some studies have identified AMPs that are not just inhibitory but bactericidal (e.g. *H. illucens* DLP2 [121], myxinidin [61]) and active, not just against planktonic bacteria, but bacterial biofilms (e.g.

C. vicina AMPs [104]). Very little toxicity data is available for these AMPs, but the half maximal cytotoxic concentration (CC_{50}) determined for DLP2 against mouse macrophages is >128 μg mL^{-1} [121] (giving a preliminary selectivity index value of >32). Sarconesin shows good selectivity in *in vitro* studies too [122].

Applications proposed for the above peptides include antibacterial [22,123] and anti-biofilm drugs [104]. Minimum requirements for this development pathway are under constant review, but MIC values must typically be <10 μg mL^{-1} and selectivity index values >10 if the end goal is a drug that can be used systemically [12]. Improvements in antibacterial potency are sometimes possible through medicinal chemistry optimization, as demonstrated with the Atlantic hagfish- and Komodo dragon-inspired synthetic peptides HF-18 [21] and DRGN-1 [124]. In addition to direct-acting antibacterial and anti-biofilm drugs, the development of AMPs as antibiotic potentiators is an option. Many AMPs reduce the structural integrity of the bacterial cell envelope, enabling intracellular-acting antibiotics to reach their targets more easily [125]. For AMPs unsuited to systemic use, possible applications include topical medications to treat skin infections [126] or, for AMPs with dual antibacterial and immunostimulatory activity, gels [124] or hydrogels [127] for dressing wounds. AMPs active against foodborne pathogens could be useful as food preservatives [20].

Factors hampering AMP development for the above applications are their instability to proteases, low bioavailability, hemolytic activity [125] and cost of synthesis [126], but these may be resolvable. For example, the stability of linear AMPs can be improved by structural modifications (e.g. stapling) [128,129]. Also, for localized infections, novel delivery systems such as inhalable microparticles can be used to bypass the GI tract and bloodstream [130]. Options for systemic administration are being developed too [131]. Cost of AMP synthesis may be reducible by using short derivatives of the parent peptide [126] or developing more efficient heterologous expression systems [132]. Lastly, many of the above problems could be resolved by using AMPs as templates for the rational design of peptidomimetic drugs or compounds [131].

Small-molecule antibacterials (<900 Da)

Small-molecule antibacterials produced by necrophages, necrophiles and their microbiotas include alkaloids (e.g. solenopsins A to C [142]), 1-lysophosphatidylethanolamine [146], peptide antibiotics (e.g. nicrophorusamide A [145], serrawettin W2 [144]), phenolic acids (e.g. *p*-hydroxybenzoic acid, *p*-hydroxyphenylacetic acid [147]) and proline diketopiperazine [147]. MIC data, where available, is presented in Table 1b. One possible application for such compounds is antibacterial drug leads [144,145]. Because they are small in size and contain few amino acids, bioavailability and proteolytic stability are less likely to be problematic with these compounds than AMPs. Another option for these molecules is their development as antibacterial biocides for use in medicine, dentistry or the food industry [148]. Some *p*-hydroxybenzoic acid derivatives already have a long history of use as preservatives [149], and the solenopsins (from *S. invicta*) display a useful combination of bactericidal [143] and anti-biofilm activity [148].

Lysozymes and other antibacterial proteins (>50 amino acids or >5.5 kDa)

Four types of lysozyme are recognized within the animal kingdom, c- (chicken), g- (goose), i- (invertebrate) and ch- (chalaropsis) types, with multiple variations of each sometimes present in a single species (e.g. nine c-type and four i-type lysozymes in *N. vespilloides* [106]). These proteins bind and hydrolyze exposed peptidoglycan, and are therefore active against Gram-positive bacteria [150]. Some c-, g- and i-type lysozymes also have a second, non-enzymatic mechanism of action, attributed to cationic, hydrophilic and lipophilic domains, which broadens their spectrum of activity to include Gram-negative bacteria [151]. Other antibacterial proteins detected in carrion users include attacins, cathepsin D-like proteins, coleoptericins, crustins, cysteine-rich secretory proteins (CRISPs) and hexamerins (Suppl Table 6). Very little quantitative data is available on the activity and toxicity of these proteins, but patagonin-CRISP (from the Patagonia green racer) has an MIC of 7.5 to 15 µg mL^{-1} against Gram-negative bacteria and a CC_{50} of >120 µg mL^{-1} against Vero cells [62] (giving a selectivity index value of >8).

Lysozymes are already used in industry as food preservatives [151] and for recovery of intracellular products in biopharmaceutical production [152]. New applications proposed for these antibacterial proteins and others include antibacterial therapies [62,153], antibiotic delivery systems [154], biomaterial constituents [154,155] and alternatives to antibiotics in livestock feed [156]. Lysozymes could be useful as antibacterial therapies or biomaterial constituents because, in addition to killing growing bacteria, they are active against dormant, multidrug-resistant and biofilm bacteria, and have a low propensity to generate resistance [153,154]. Lysozymes could also be useful in antibiotic delivery systems because they stabilize antibiotic-loaded liposomes, bind to bacteria, and increase the activity of the antibiotic being delivered [154]. Lysozymes hold promise as livestock feed additives too, since they increase feed efficiency and growth, and reduce intestinal counts of bacterial pathogens [156].

Obstacles limiting development of the above proteins for new applications are their inactivation by low pH, proteolytic enzymes and organic solvents [157,158]. Also, because proteins are larger in size and have more complex structures than AMPs, they are more likely to generate hypersensitivity reactions [159] and are more challenging and costly to manufacture [130,159]. Not all proteins have these limitations though [154] and, for those that do, there may be workarounds. For example, stability problems could be overcome by structural modifications [158], and the risk of hypersensitivity could be reduced by using short antibacterial peptides derived from the parent lysozyme [154,159] or protein [135]. Production difficulties could be overcome by using shorter peptides too [135,154,159] or by developing more cost-efficient heterologous expression systems [130].

Lectins

In addition to the proteins above, a small number of lectins have been identified in carrion users (e.g. *Chrysomya megacephala* [160], *Dermestes frischii* [161], *M. domestica* [162], *Sarcophaga bullata* [163]). Lectins are carbohydrate-binding proteins and glycoproteins that serve as pattern recognition receptors within the innate immune system [164]. Lectins bind selectively to different carbohydrate-containing molecules on bacteria (e.g. lipopolysaccharide, lipoteichoic acid) and immune system cells, triggering AMP upregulation, phagocytosis and other responses [165,166]. In binding to bacterial cells, lectins may also exert direct effects of their own, including cell wall growth inhibition and damage [164,165].

Possible applications for lectins include drugs, drug delivery systems and vaccine adjuvants. Lectins are being investigated as antibacterial drugs because their interaction with bacterial cell wall carbohydrates can damage bacteria and block bacterial attachment to host tissue (Fig. 2a) [165]. Lectins are also being investigated for use in drug delivery as their high affinity for bacterial surface molecules could facilitate the targeting of treatments to infected tissue (Fig. 2b) [164]. Lastly, lectins could be developed as immunomodulatory drugs or vaccine adjuvants since they enhance macrophage activity, cytokine secretion [167] and B-cell production [168].

Lectins share many of the same limitations as antibacterial peptides and proteins, including inactivation by low pH and proteolytic enzymes, and poor bioavailability [164]. Lectin-induced hemagglutination is an additional concern [165]. Possible solutions to these problems include the use of non-oral, non-intravenous routes of administration and the rational design of small-molecule drugs that mimic the carbohydrate recognition domains of lectins [164].

Chitin

Because *H. illucens* larvae are capable of feeding, not just on carrion but a wide range of other decomposing organic matter, it has been suggested this species could be used in the bioconversion of food and agricultural waste to chitin (Fig. 3) [169]. Chitin is a major component of the fly larvae's exoskeleton and can be converted into chitosan, a similarly bioactive but more chemically versatile derivative, by alkaline deacetylation [170].

Chitin and chitosan are already used in wound dressings [170], and chitosan is used in farming to protect crops from infection [171]. Additional applications proposed for chitin and chitosan include drug delivery systems (e.g. capsules) [172], burn dressings, absorbable sutures [170], medical implants (e.g. tissue engineering scaffolds) [172], antimicrobial fabrics [173], food packaging [174] and food sanitizers [175]. Chitin and chitosan are well-suited to these applications because, in addition to being antibacterial [176], they are antifungal [177], hemostatic [178], promote wound healing, have good biocompatibility, are biodegradable [170], and can be formulated into absorbent [172], oxygen-permeable [170], flexible [172], strong [179] and/or highly durable [172] materials according to need.

Currently, chitin and chitosan production from *H. illucens* larvae is not commercially feasible [169], but this may change as bioconversion is optimized through targeted breeding programs [180] and new extraction and processing methods are explored and developed [173,181,182].

Lauric acid

In addition to chitin and chitosan production, *H. illucens* could be a useful new source of lauric acid [183], a medium-chain fatty acid with antibacterial activity [184]. Lauric acid is found in high concentrations in *H. illucens* larvae, representing 44-61% of their total fatty acid profile [185]. Lauric acid is already used in soaps [186] and has been proposed as a possible anti-acne treatment and alternative to antibiotics in animal feed [183,187]. This is based, in part, on its activity against *Cutibacterium acnes* [184] and gastrointestinal pathogens [188,189] but also its excellent safety profile [183,184] and complementary activities such as antivirulence activity [183,190], AMP and immunoglobulin upregulation [191,192], anti-inflammatory activity [188,192] and animal growth promotion [192]. Obstacles hampering the development of lauric acid for the above applications are its low water solubility [184] and susceptibility to gastro-intestinal lipases [188]. Processing costs are problematic too [183]. Solutions being investigated include solubilization using liposomes [184], protection from lipases by encapsulation [191,193], and the development of novel enzyme-based processing methods [194].

Microbiota bacteria and yeasts

Several mutualistic microbiota bacteria and yeasts have been detected in carrion users including *Bacillus subtilis* (in black rats [195]), *Hylemonella gracilis*, *Lactobacillus sakei* and *Yarrowia lipolytica* (in black vultures and turkey vultures [63]), *Enterococcus faecium* and other lactic acid bacteria (in Eurasian griffons [20]), *Morganella*, *Myroides* and *Yarrowia* (in *N. vespilloides* [106,196]), *Myroides odoratimimus* (in *Sarcophaga* sp. [101]), and *Serratia myotis* (in emerald rockcods [197]). The antibacterial activity of these microbes has been attributed to AMPs (e.g. enterocins [20]), indole derivatives (e.g. violacein [63]), fatty acids (e.g. stearic acid [106]), siderophores (e.g. serranticin [197]) and surfactants (e.g. surfactin [63]), with some microbes encoding multiple active compounds [20,106].

Necrophage-sourced mutualistic microbes have been proposed for development as probiotics or 'direct-fed microbial products' in animal nutrition [20,197], these representing an attractive alternative to in-feed antibiotics in livestock, poultry, shrimp and fish farming [198-200]. In addition to preventing infection, prospective probiotics should be nonpathogenic (or extremely rarely pathogenic) in animals and humans [198,201], and incapable of transmitting antibiotic resistance genes [198,200]. Other important attributes include the ability to grow rapidly on inexpensive media [201], maintain viability during storage [202], survive gastric transit, attach to enterocytes or mucus [199,200] and, in the case of probiotics intended for marine aquaculture, grow at high salt concentrations [202]. If a probiotic candidate confers, not just disease protection, but positively affects weight gain or another animal performance measure, this will strengthen the economic argument for its development [203,204].

Current challenges facing animal probiotic developers are the elucidation of microbe mechanism(s) of action and assessment of microbe safety [203,205]. Information on the safety of necrophage-sourced mutualistic microbes is particularly limited because, with the exception of *B. subtilis* and *E. faecium* [201], none of the isolated species have been used previously as animal probiotics. Inconsistent results in clinical trials [203] and differences in regulation between countries [201] are other challenges. The above problems are likely to improve as technological advances allow microbiota ecology to be monitored more accurately [206,207], risk assessment guidance is developed and refined [208], and knowledge of the variables affecting probiotic efficacy grows [198,201].

Disease-resistance genes

In addition to the traits above, the genes encoding bacterial disease resistance in carrion users could be useful. Transgenic research has already been performed with *sarcotoxin IA*, a *Sarcophaga peregrina* gene encoding an AMP. This gene, when introduced into food and cash crops, increases their resistance to citrus canker, greening disease, bacterial soft rot and wildfire disease (caused by *Xanthomonas citri*, '*Candidatus* Liberibacter asiaticus', *Erwinia carotovora* and *Pseudomonas syringae*) [209-212]. The gene also confers protection from fungal phytopathogens [212], and can be introduced into orange, tomato and tobacco plants without apparent negative effects on growth or development [209,213,214].

A current hindrance to transgenic crop development is jurisdictional variation in regulation, which complicates market access and disincentivizes investment [215]. This situation may change as more data on transgenic crop safety and environmental impact becomes available [216], and issues such as food poverty [217] and global population growth [218] receive greater attention. In addition to this general obstacle, there may be challenges specific to an introduced gene or gene product. For example, the AMP sarcotoxin IA is susceptible to proteases present in some plant intercellular fluids [211,213]. Possible solutions to this problem include linking *sarcotoxin IA* with a gene encoding a more stable protein [213] or using a high-expression promoter to increase sarcotoxin IA synthesis [211,212].

Concluding remarks

Many antibacterial drugs and products in current use were developed from nature, including some, such as streptomycin, which were discovered via ecology-inspired bioprospecting. Past bioprospecting projects have focused largely on soil- and marine-dwelling microbes and plants, but interest is growing in carrion ecology and carrion users. In this review, we have catalogued over 660 such species, including 625 necrophages (≥46 obligately necrophagous) and 44 necrophiles (Suppl Tables 1 and 4). Information collected on the types of carrion consumed and the bacterial species detected in, on and around carrion shows necrophages and necrophiles are exposed to a diverse range of pathogens. The selection pressure to evolve, acquire and retain antibacterial defenses is likely to be stronger in these animals, therefore, than other trophic groups. Necrophage and necrophile defenses studied so far include toxin-resistant anatomies, risk reduction behaviors and enhancements in innate immunity, social immunity, adaptive immunity and detoxification systems. In some cases, the genes, molecules and microbes responsible for these defenses have been identified, and we have described their possible applications in drug treatments, medical devices and food production.

The present paper has a number of strengths and limitations. It is, to our knowledge, the first review to look at the bacterial pathogens to which carrion users are exposed, the first review of antibacterial defenses in invertebrate necrophages and necrophiles (for earlier work on vertebrates, see [219]), and the first review of biotechnological applications for necrophage- and necrophile-derived genes, molecules and microbes. To provide readers with as full a picture as possible, we consulted over 500 sources, including original articles, review articles and conference proceedings identified from PubMed, ScienceDirect, Google Scholar and hand searches. Set against these strengths, we acknowledge the following limitations. Firstly, because of the extremely large number of articles documenting necrophagy and necrophily, it has not been possible to comprehensively catalogue all of the animal species in these trophic groups. It has not even been possible to catalogue all of the probable obligate necrophages as some invertebrate genera, for example *Nicrophorus*, contain over 60 species [220]. Also, new species of marine necrophage, for example hagfish, have been discovered as recently as 2021 [221] and their diets are not yet fully characterized. Secondly, we did not assess the strength of evidence that the proposed antibacterial defenses confer *in situ* protection from infection or intoxication. Such assessments, whilst important, can be very contentious. In the case of streptomycin and other soil-derived antibiotics, scientific consensus regarding their ecological role remains elusive many decades after their successful clinical development [222].

Regarding future research, we have several suggestions. Given the large number of known necrophages and necrophiles, it would be useful to develop evidence-based criteria for prioritizing species for antibacterial studies [e.g. reliance on carrion as a food source (Suppl Tables 1 and 4); engaging in risky feeding behaviors (Suppl Table 3)]. Also, given the importance of necrophagous and necrophilous invertebrates in forensic studies, and the necessity for regional research within this discipline [69], there should be opportunities for ecologists and biotechnologists to pool resources with forensic scientists. Forensic science has already yielded an abundance of basic information on which invertebrates are necrophagous or necrophilous, and greater interdisciplinary cooperation would allow complementary information to be generated on their antibacterial defenses and biotechnological potential. For researchers who successfully isolate AMPs or other antibacterial molecules, we would encourage fully quantitative testing using internationally recognized technical standards to accurately determine MICs and selectivity index values [12]. Also, for researchers developing mutualistic microbiota organisms as animal probiotics, the European Food Safety Authority and US Food and Drug Administration websites [223,224] and associated publications [208,225] are useful sources of technical information. Lastly, suitable precautions should be taken during all carrion studies to reduce the risk of zoonosis and harm to threatened wildlife. Several necrophages, such as *Gyps indicus* (Indian vulture) and *Nicrophorus americanus* (American burying beetle), are already critically endangered [226].

Acknowledgements

The authors thank Professors James L. Alexander, M. Eric Benbow, Stefaan De Smet, Alexander V. Grishin, Michel J. Kaiser, Chaiyos Kunanusont, Rafael Mateo, Maria F.B. Morais-Braga, María S. Avaca, Kosta Y. Mumcuoglu, Dhammika Nanayakkara, Neil W. Ross, Abdel F.Z. Salem, Felix L. Santana and Janarthanan Sundaram for suggesting and/or sourcing some of the journal articles and book chapters used.

They also thank Prof. Esteban Soto for fielding questions on his team's *Edwardsiella ictaluri* research, Prof. Alma M. Novotny for information on innate immunity in vultures, and the two anonymous peer-reviewers for their constructive feedback and help improving the manuscript.

Disclosure statement

The authors report there are no competing interests to declare.

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Table 1 Examples of (a) antimicrobial peptides and (b) small-molecule antibacterials isolated from necrophages, necrophiles and their microbiotas, together with information on their minimum inhibitory concentrations (MICs) and how these MICs were determined.

Compound	**Source**	**MIC assay**	**Cell density (CFU mL^{-1})**	**MIC (µg mL^{-1})**		**Reference(s)**
				Gram-positive	**Gram-negative**	
(a) AMPs						
DLP2	*Hermetia illucens*	BMID	5×10^4	0.03 to 4.0	NA	[121]*
C-15867	*Hermetia illucens*	NS	5×10^5	0.16 to 0.28	0.16	[133]
Sapecin	*Sarcophaga peregrina*	AD	NS	1.2 to 39.0	20.0 to >78.0	[134]
Peptide 9	*Sarcophaga peregrina*	AD	NS	1.6 to 24.9	1.5 to 24.9	[135]
Sarconesin	*Sarconesia magellanica*†	BMID	5×10^4	1.8 to 6.9	3.5 to 6.9	[122,136]*
Lucifensin	*Lucilia sericata*	BMID	5×10^5	2.0 to >100	NA	[137]
Stomoxyn	*Lucilia sericata*	BMID	5×10^5	NA	2.0 to >100	[22]*
Cecropin 4	*Musca domestica*	BMID	5×10^5	4.3 to >100	2.2 to 8.7	[138]
Peptide 0593	*Periplaneta americana*	BMID	2×10^4	16.0	4.0	[139]*
Sarcotoxin IA	*Sarcophaga peregrina*	ABA	1×10^5	NT	4.2	[140,141]
(b) Small-molecule antibacterials‡						
Solenopsin B	*Solenopsis invicta*	BMID	5×10^5	0.5 to ≥32.0	>5.0	[142,143]*
Serrawettin W2	*Serratia marcescens* (from *Nicrophorus vespilloides*)	BMID	5×10^5	4.0	NA	[144]
Nicrophorus-amide A	*Microbacterium* sp. (from *Nicrophorus concolor*)	BMID	5×10^5	8.0 to 16.0	16.0 to >100	[145]

Notes: MIC, minimum inhibitory concentration; ABA, Alamar Blue assay; AD, agar dilution assay; BMID, broth microdilution assay; NS, not stated; NA, not active (MIC >100µg mL^{-1}); NT, not tested; *, authors identified more than one active compound; †, *Sarconesiopsis magellanica* is a synonym of *Sarconesia magellanica*; ‡, solenopsin B is an alkaloid, serrawettin W2 is a cyclic pentadepsipeptide, and nicrophorusamide A is a chlorinated cyclic hexapeptide

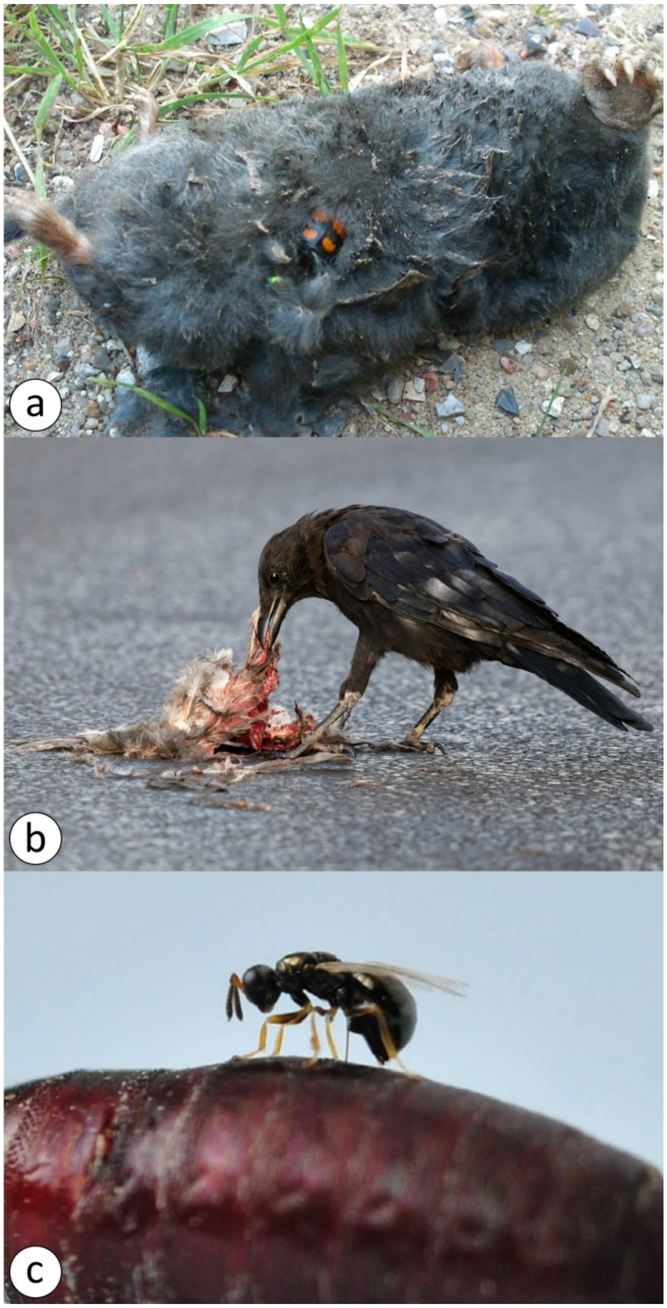

Figure 1 Examples of different carrion users: (a) *Nicrophorus vespillo* (common burying beetle), an obligate necrophage feeding on mole carrion, (b) *Corvus corone* (carrion crow), a facultative necrophage feeding on roadkilled pigeon and (c) *Nasonia vitripennis*, a necrophile parasitizing a *Calliphora vomitoria* (blue bottle fly) pupa. Photograph (a) by RhinoMind and photograph (b) by Marie-Lan Taÿ Pamart (both used under Creative Commons CC BY-SA 4.0 license). Photograph (c) by Koppik et al. [28] (used under Creative Commons CC BY 4.0 license).

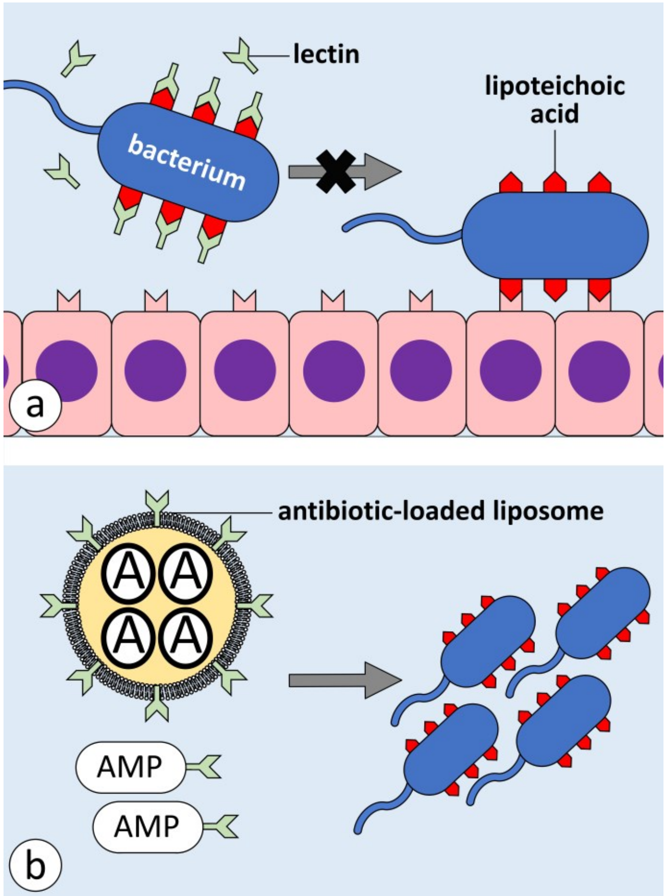

Figure 2 Lectins could be useful as (a) antivirulence drugs because they bind to carbohydrate-containing molecules such as lipoteichoic acid, preventing bacterial cells from attaching to host tissue. Lectins could also be useful in (b) drug delivery systems targeting bacterial infection if incorporated into the membranes of antibiotic-loaded liposomes or fused with AMPs. Image (a) adapted from Fonseca et al. [165] by permission of Elsevier, and image (b) adapted from Carneiro et al. [164] by permission of Wiley.

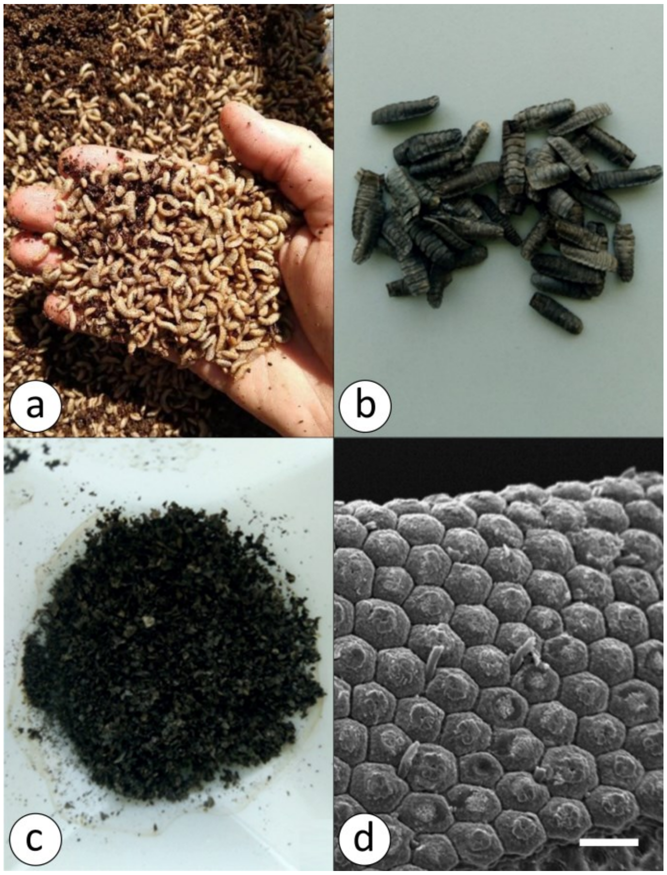

Figure 3 *Hermetia illucens* could be useful in chitin production: (a) *H. illucens* larvae feeding on agricultural waste, (b) exuviae obtained from waste-fed larvae, (c) oven-dried and ground exuviae and (d) a scanning electron micrograph of chitin obtained from exuviae powder after demineralization and fat and protein removal (bar = 50 µm). Photograph (a) by Fowles and Nansen [180] (used under Creative Commons CC BY 4.0 license) and photographs (b), (c) and (d) by Bhavsar et al. [173] (used under Creative Commons CC BY-NC-ND 4.0 license).

Supplementary online material

Supplementary Table 1 Examples of vertebrate necrophages, information on whether they are obligately or facultatively necrophagous, and other dietary details such as types of carrion they feed upon.

Supplementary Table 2 Examples of bacteria causing fatal infections and toxico-infections of wildlife, livestock and other animals, and which are transmissible by contact with or ingestion of contaminated carcasses.

Supplementary Table 3 Necrophages and necrophiles engaging in behaviors that might increase their risk or their offspring's risk of infection.

Supplementary Table 4 Examples of invertebrate necrophages and necrophiles, information on whether this feeding behavior is obligate or facultative (where available), and other dietary details such as type of carrion they feed upon or visit in search of eggs, larvae or pupae.

Supplementary Table 5 Examples of antimicrobial peptides (AMPs; ≤50 amino acid- or ≤5.5 kDa-sized molecules) detected in necrophages and necrophiles.

Supplementary Table 6 Examples of antibacterial proteins (>50 amino acid- or >5.5 kDa-sized molecules) detected in necrophages and necrophiles.

Supplementary Table 1 from the Critical Reviews in Biotechnology journal article 'Necrophages and necrophiles: a review of their antibacterial defenses and biotechnological potential'

To cite this article:

Cushnie TPT, Luang-In V, Sexton DW, Necrophages and necrophiles: a review of their antibacterial defenses and biotechnological potential. Critical Reviews in Biotechnology, 2024 (Published online ahead of print). DOI: 10.1080/07388551.2024.2389175

To link to this article:

https://doi.org/10.1080/07388551.2024.2389175

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Supplementary Table 1 Examples of vertebrate necrophages, information on whether they are obligately or facultatively necrophagous, and other dietary details such as types of carrion they feed upon.

Scientific name	Common name(s)	Association with carrion	Carrion consumed	Reference(s)
Amphibians				
Alytes obstetricans (Laurenti, 1768)	Midwife toad	Facultative necrophage (tadpoles are necrophagous)	Wildlife (adult frog, earthworm)	[1]
Anaxyrus americanus (Holbrook, 1836) = *Bufo americanus* Holbrook, 1836	American toad	Facultative necrophage (tadpoles are necrophagous)	Wildlife (conspecific tadpole)	[2]
Anaxyrus cognatus (Say, 1822) = *Bufo cognatus* Say, 1822	Great plains toad	Facultative necrophage (tadpoles are necrophagous); this species also feeds on plants & algae	Wildlife (insect remains)	[3]
Ceratophrys stolzmanni Steindachner, 1882	Pacific horned frog; Escuerzo	Facultative necrophage (necrophagy has been observed in an adult frog, but this behavior is thought to be rare [4])	Wildlife (tree frog)	[4]
Duttaphrynus himalayanus (Günther, 1864)	Günther's high altitude toad	Facultative necrophage (tadpoles are necrophagous)	Wildlife (conspecific adult)	[5]
Engystomops pustulosus (Cope, 1864)	Túngara frog	Facultative necrophage (tadpoles are necrophagous)	Wildlife (conspecific tadpole)	[6]
Hoplobatrachus tigerinus (Daudin, 1802)	Indian bullfrog; Indo-Pakistan tiger frog	Facultative necrophage (tadpoles are necrophagous)	Wildlife (centipede)	[7]
Nanorana vicina (Stoliczka, 1872)	Murree frog	Facultative necrophage (tadpoles are necrophagous)	Wildlife (adult toad)	[5]
Osteopilus septentrionalis (Duméril & Bibron, 1841)	Cuban tree frog	Facultative necrophage (tadpoles are necrophagous); this species also feeds on algae, & adults hunt live prey (invertebrates & small vertebrates)	Wildlife (grasshopper, beetle)	[8]
Pelophylax perezi (López-Seoane, 1885)	Perez's frog	Facultative necrophage (tadpoles are necrophagous)	Wildlife (mouse)	[9]

Polypedates megacephalus Hallowell, 1861	Hong Kong whipping frog; Spot-legged tree frog	Facultative necrophage (tadpoles are necrophagous)	Wildlife (adult frog)	[10]
Rhinella crucifer (Wied-Neuwied, 1821)	Striped toad	Facultative necrophage (tadpoles are necrophagous)	Wildlife (adult frog)	[11]
Birds				
Accipiter fasciatus (Vigors & Horsfield, 1827)	Australian goshawk; Brown goshawk	Facultative necrophage	Wildlife (pademelon)	[12]
Accipiter gentilis (Linnaeus, 1758)	Northern goshawk	Facultative necrophage	Wildlife (wild sheep)	[13-16]
Accipiter novaehollandiae (Gmelin, 1788)	Gray goshawk	Facultative necrophage	Carrion raided from crocodile caches	[17]
Aegypius monachus (Linnaeus, 1766)	Cinereous vulture; Eurasian black vulture	Obligate necrophage	Wildlife (wolf, jackal, red fox, bear, wild boar, badger, deer, antelope, wild sheep, wild goat, hare); hunting discards (wild boar & red deer gut piles); livestock (cow, water buffalo, horse, donkey, sheep, goat); companion animals (dog)	[18-21]
Aquila adalberti C.L. Brehm, 1861	Spanish imperial eagle	Facultative necrophage	Hunting discards (wild boar & red deer gut piles)	[18, 19]
Aquila audax (Latham, 1802)	Wedge-tailed eagle	Facultative necrophage	Wildlife (kangaroo, pademelon); carrion raided from crocodile caches	[12, 14, 17, 22]
Aquila chrysaetos (Linnaeus, 1758)	Golden eagle	Facultative necrophage	Wildlife (red fox); hunting discards (wild boar, red deer & elk gut piles); livestock (pig)	[13-16, 18, 19, 23-26]
Aquila nipalensis Hodgson, 1833	Steppe eagle	Facultative necrophage	Livestock (cow, goat)	[20, 27]
Aquila rapax (Temminck, 1828)	Tawny eagle	Facultative necrophage	Livestock (cow, horse, goat)	[27, 28]
Asio otus (Linnaeus, 1758)	Long-eared owl	Facultative necrophage	Wildlife (marten, porcupine)	[29]

Bubo virginianus (J.F. Gmelin, 1788)	Great horned owl	Facultative necrophage	Wildlife (rabbit)	[26, 30]
Buteo buteo (Linnaeus, 1758)	Common buzzard	Facultative necrophage	Wildlife (wild boar, bison, red deer, roe deer); poultry (chicken); roadkill	[14-16, 31-33]
Buteo jamaicensis (Gmelin, 1788)	Red-tailed hawk	Facultative necrophage	Wildlife (rat, rabbit); livestock (pig); poultry (chicken); roadkill	[26, 34-36]
Buteo lineatus (Gmelin, 1788)	Red-shouldered hawk	Facultative necrophage	Wildlife (rat, rabbit); livestock (pig)	[26, 35]
Calidris alba (Pallas, 1764)	Sanderling	Facultative necrophage	Marine life (jellyfish)	[37]
Caracara plancus (J.F. Miller, 1777)	Southern caracara	Facultative necrophage	Marine life (mojarra); livestock	[14, 38]
Cathartes aura (Linnaeus, 1758)	Turkey vulture	Obligate necrophage	Wildlife (wild boar, brown rat, cotton rat, wood rat, raccoon, mole, squirrel, rabbit, groundhog, birds, amphibians, reptiles, invertebrates); marine life (seal, burrfish); hunting discards (deer); livestock (pig, cow); livestock viscera (cow, sheep); poultry (chicken); roadkill	[14, 26, 34-36, 39-48]
Cathartes burrovianus Cassin, 1845	Lesser yellow-headed vulture; Savannah vulture	Obligate necrophage	Wildlife; freshwater fish (catfish)	[38, 41, 49]
Cathartes melambrotus Wetmore, 1964	Greater yellow-headed vulture; Forest vulture	Obligate necrophage	Wildlife (tree rat, porcupine)	[14, 41, 50]
Chionis minor Hartlaub, 1841	Black-faced sheathbill	Facultative necrophage	Marine life (penguin)	[37]
Chroicocephalus novaehollandiae (Stephens, 1826)	Silver gull	Facultative necrophage	Marine life (fish); fishing industry bycatch (mostly fish)	[14, 37]
Circus approximans Peale, 1848	Pacific marsh harrier; Swamp harrier	Facultative necrophage	Wildlife (pademelon)	[12]
Coragyps atratus (Bechstein, 1793)	Black vulture; Mexican vulture	Obligate necrophage	Wildlife (wild boar, rat, mouse, vole, squirrel, groundhog, rabbit); freshwater fish (Nile tilapia); marine	[14, 24, 26, 34, 35, 38, 41-43, 45,

			life (sea lion); hunting discards (deer); livestock & livestock viscera (pig, cow, sheep, goat)	47, 48]
Corvus bennetti North, 1901	Little crow	Facultative necrophage	Wildlife (kangaroo)	[14]
Corvus brachyrhynchos C.L. Brehm, 1822	American crow	Facultative necrophage	Wildlife (rat, rabbit); poultry (chicken); roadkill	[34-36]
Corvus corax Linnaeus, 1758	Common raven	Facultative necrophage	Wildlife (wild boar, birds, bison, deer); marine life (gray seal); hunting discards (wild boar, red deer & elk gut piles); livestock (cow, sheep, goat); poultry (chicken)	[13-16, 19, 20, 25, 31, 44, 51-53]
Corvus corone Linnaeus, 1758	Carrion crow	Facultative necrophage	Wildlife (wild boar, deer); livestock (sheep); poultry (chicken); roadkill	[13, 15, 33, 51, 54, 55]
Corvus coronoides Vigors & Horsfield, 1827	Australian raven	Facultative necrophage	Wildlife (kangaroo)	[14]
Corvus frugilegus Linnaeus, 1758	Rook	Facultative necrophage (necrophilous too, feeding on carrion inhabitants)	Birds, fish & mammals	[56, 57]
Corvus macrorhynchos Wagler, 1827	Large-billed crow	Facultative necrophage	Wildlife (deer)	[58]
Corvus orru Bonaparte, 1850	Torresian crow	Facultative necrophage	Marine life (fish)	[14]
Corvus tasmanicus Mathews, 1912	Forest raven	Facultative necrophage	Wildlife (pademelon)	[12, 59]
Cracticus torquatus (Latham, 1802)	Gray butcherbird	Facultative necrophage	Wildlife (pademelon)	[12]
Cyanocitta cristata (Linnaeus, 1758)	Blue jay	Facultative necrophage	Wildlife (mouse)	[30]
Cyanopica cyanus (Pallas, 1776)	Azure-winged magpie	Facultative necrophage (necrophilous too, feeding on carrion inhabitants)	Wildlife (wild boar, deer); hunting discards (wild boar & red deer gut piles); livestock (sheep)	[19, 51]
Diomedea exulans Linnaeus, 1758	Wandering albatross	Facultative necrophage	Marine life (sea birds); fishery discards	[60, 61]

Falco berigora Vigors & Horsfield, 1827	Brown falcon	Facultative necrophage	Wildlife (pademelon)	[12]
Fulmarus glacialis (Linnaeus, 1761)	Northern fulmar	Facultative necrophage	Fishery discards (fish offal)	[37]
Garrulus glandarius (Linnaeus, 1758)	Eurasian jay	Facultative necrophage	Wildlife (wild boar, bison, deer, wild sheep); livestock (sheep)	[13, 15, 16, 51]
Geococcyx californianus (Lesson, 1829)	Greater roadrunner	Facultative necrophage	Wildlife (birds)	[14]
Geranoaetus melanoleucus (Vieillot, 1819)	Black-chested buzzard eagle	Facultative necrophage	Livestock	[14]
Gymnogyps californianus (Shaw, 1797)	California condor	Obligate necrophage	Hunting discards; livestock (cattle)	[41, 62]
Gypaetus barbatus (Linnaeus, 1758)	Bearded vulture	Obligate necrophage (adults feed on bone marrow from carcasses; meat may be fed to young nestlings)	Wildlife (wolf, jackal, red fox, bear, polecat, weasel, wild boar, badger, raccoon, squirrel, hedgehog, mouse, herbivorous ungulates, birds, tortoise, porcupine); livestock (cow, horse, donkey, sheep, goat); poultry (chicken); companion animals (dog)	[14, 18, 20, 21, 63]
Gypohierax angolensis (Gmelin, 1788)	Palm-nut vulture	Facultative necrophage; this species also eats palm nuts & hunts small prey	Marine life (sardine)	[14, 27, 41, 64]
Gyps africanus Salvadori, 1865	White-backed vulture; Whiteback griffon vulture	Obligate necrophage	Wildlife (elephant); other large mammals (usually ungulates)	[27, 41, 65, 66]
Gyps bengalensis (Gmelin, 1788)	White-rumped vulture	Obligate necrophage	Livestock (cattle, water buffalo) & slaughterhouse offal	[41, 65, 67]
Gyps coprotheres (J.R. Forster, 1798)	Cape vulture; Kolbe's vulture	Obligate necrophage	Large mammals (usually ungulates)	[41, 65]
Gyps fulvus (Hablizl, 1783)	Griffon vulture; Eurasian griffon	Obligate necrophage	Wildlife (wolf, jackal, red fox, bear, wild boar, badger, deer, antelope, wild sheep, wild goat, hare); hunting	[13, 18, 19, 21, 23, 68, 69]

			discards (wild boar & red deer gut piles); livestock (cow, water buffalo, horse, donkey, sheep, goat); companion animals (dog, cat)	
Gyps himalayensis Hume, 1869	Himalayan vulture; Himalayan griffon	Obligate necrophage	Human remains (sky burial); livestock (yak, goat); poultry (chicken)	[20, 41, 70]
Gyps indicus (Scopoli, 1786)	Indian vulture	Obligate necrophage	Livestock (cattle, water buffalo) & slaughterhouse offal	[41, 65, 67]
Gyps rueppelli (A.E. Brehm, 1852)	Rüppell's vulture	Obligate necrophage	Large mammals (usually ungulates)	[14, 27, 41, 65]
Gyps tenuirostris G.R. Gray, 1844	Slender-billed vulture	Obligate necrophage	Livestock (cattle, water buffalo) & slaughterhouse offal	[41, 65, 67]
Haliaeetus albicilla (Linnaeus, 1758)	White-tailed eagle	Facultative necrophage	Wildlife (wild boar, bison, red deer, roe deer)	[14-16, 31]
Haliaeetus leucocephalus (Linnaeus, 1766)	Bald eagle	Facultative necrophage	Wildlife (white-tailed deer); aquatic life (waterfowl, salmon); hunting discards (elk gut piles); livestock (pig)	[14, 25, 26, 71, 72]
Haliaeetus leucogaster (Gmelin, 1788)	White-bellied sea eagle	Facultative necrophage	Marine life (fish)	[14]
Haliastur indus (Boddaert, 1783)	Brahminy kite	Facultative necrophage	Marine life (fish)	[14, 65]
Haliastur sphenurus (Vieillot, 1818)	Whistling kite	Facultative necrophage	Marine life (fish); carrion raided from crocodile caches	[14, 17]
Larus argentatus Pontoppidan, 1763	European herring gull	Facultative necrophage	Marine life (gray seal, seagull chick); fishery discards (whiting, haddock, cod, langoustine); poultry (chicken)	[36, 53, 55, 73-75]
Larus dominicanus Lichtenstein, 1823	Kelp gull	Facultative necrophage	Marine life (sea lion, penguin)	[14, 37]
Larus fuscus Linnaeus, 1758	Lesser black-backed gull	Facultative necrophage	Fishery discards (whiting, sole); poultry (chicken)	[55, 76]
Larus glaucescens J.F. Naumann, 1840	Glaucous-winged gull	Facultative necrophage	Aquatic life (salmon)	[14]
Larus glaucoides B. Meyer, 1822	Iceland gull	Facultative necrophage	Wildlife (reindeer)	[77]

Larus marinus Linnaeus, 1758	Great black-backed gull	Facultative necrophage	Marine life (gray seal, seagull chick)	[14, 53, 75]
Larus michahellis J.F. Naumann, 1840	Yellow-legged gull	Facultative necrophage	Marine life (fish)	[78]
Larus occidentalis Audubon, 1839	Western gull	Facultative necrophage (but feeds on carrion frequently, this sometimes accounting for >90% of its diet [37])	Poultry (chicken)	[37]
Leptoptilos crumeniferus (Lesson, 1831)	Marabou stork	Facultative necrophage	Carrion stolen from griffon vultures	[27, 79]
Leptoptilos dubius (Gmelin, 1789)	Greater adjutant	Facultative necrophage	Livestock (cow); companion animals (dog)	[80]
Macronectes giganteus (Gmelin, 1789)	Southern giant petrel	Facultative necrophage	Marine life (seal, penguin)	[14, 37]
Macronectes halli Mathews, 1912	Northern giant petrel	Facultative necrophage	Marine life (seal, penguin)	[14, 37]
Milvago chimachima (Vieillot, 1816)	Yellow-headed caracara	Facultative necrophage	Freshwater fish (redbreast tilapia)	[38]
Milvago chimango (Vieillot, 1816)	Chimango caracara	Facultative necrophage	Livestock	[14]
Milvus migrans (Boddaert, 1783)	Black kite	Facultative necrophage	Wildlife (deer); carrion raided from crocodile caches; roadkill	[18, 33, 58]
Milvus milvus (Linnaeus, 1758)	Red kite	Facultative necrophage	Wildlife (wild boar, roe deer); poultry (chicken, goose)	[18, 31, 32, 81]
Morus bassanus (Linnaeus, 1758)	Gannet	Facultative necrophage	Fishery discards (whiting, common dab)	[74]
Necrosyrtes monachus (Temminck, 1823)	Hooded vulture	Obligate necrophage	Livestock (cow, goat)	[27, 41]
Neophron percnopterus (Linnaeus, 1758)	Egyptian vulture	Facultative necrophage; this species also feeds on live turtles & invertebrates, livestock excrement & human refuse	Wildlife (wolf, jackal, snake, red fox, stone marten, badger, raccoon, squirrel, mouse, birds, toad, hare, tortoise); livestock (cattle, water buffalo, donkey, sheep, goat); companion animals (dog, cat)	[18, 21, 82]

Nisaetus nipalensis Hodgson, 1836	Mountain hawk-eagle	Facultative necrophage	Wildlife (deer)	[58]
Pagophila eburnea (Phipps, 1774)	Ivory gull	Facultative necrophage	Marine life (seal)	[14, 83]
Parus major Linnaeus, 1758	Great tit	Facultative necrophage	Wildlife (wild boar, bison, red deer); hunting discards (ungulate entrails)	[15, 16]
Pica pica (Linnaeus, 1758)	Eurasian magpie	Facultative necrophage (necrophilous too, feeding on carrion inhabitants)	Wildlife (wild boar, deer); hunting discards (wild boar, red deer & elk gut piles); livestock (sheep); poultry (chicken); roadkill	[15, 16, 19, 25, 32, 33, 51, 55]
Rissa tridactyla (Linnaeus, 1758)	Black-legged kittiwake	Facultative necrophage	Fishery discards (whiting, langoustine)	[74]
Sarcogyps calvus (Scopoli, 1786)	Red-headed vulture	Obligate necrophage	Wildlife (ungulates); livestock	[41, 84]
Sarcoramphus papa (Linnaeus, 1758)	King vulture	Obligate necrophage	Marine life (green turtle)	[41, 85]
Stercorarius antarcticus (Lesson, 1831)	Brown skua	Facultative necrophage	Marine life (carcasses abandoned by killer whales)	[14]
Strepera fuliginosa (Gould, 1837)	Black currawong	Facultative necrophage	Wildlife (marsupials)	[59]
Strepera graculina (Shaw, 1790)	Pied currawong	Facultative necrophage	Wildlife (kangaroo)	[22]
Strix uralensis Pallas, 1771	Ural owl	Facultative necrophage	Wildlife (deer)	[86]
Strix varia Barton, 1799	Barred owl	Facultative necrophage	Livestock (pig)	[26]
Terathopius ecaudatus (Daudin, 1800)	Bateleur	Facultative necrophage	Wildlife (elephant)	[66]
Thalassarche melanophris (Temminck, 1828)	Black-browed albatross	Facultative necrophage	Marine life (carcasses abandoned by killer whales)	[14]
Thalasseus bergii (Lichtenstein, 1823)	Greater crested tern	Facultative necrophage	Fishing industry bycatch (mostly fish)	[37]

Torgos tracheliotus (J.R. Forster, 1796)	Lappet-faced vulture	Obligate necrophage	Wildlife (elephant); livestock (cow, goat)	[27, 41, 66, 79]
Trigonoceps occipitalis (Burchell, 1824)	White-headed vulture	Obligate necrophage	Wildlife (hare)	[27, 41, 79]
Vultur gryphus Linnaeus, 1758	Andean condor	Obligate necrophage	Wildlife (vicuña, guanaco, hare); marine life (marine mammals & large seabirds); livestock (sheep, goat)	[14, 38, 41, 87, 88]
Fish				
Amblyraja radiata (Donovan, 1808)	Maiden ray	Facultative necrophage	Marine life (herring)	[89]
Anarhichas denticulatus Krøyer, 1845	Northern wolffish	Facultative necrophage	Marine life (squid)	[14, 90]
Anoplopoma fimbria (Pallas, 1814)	Sablefish	Facultative necrophage	Marine life (food falls)	[91]
Arothron hispidus (Linnaeus, 1758)	Broadbarred toadfish	Facultative necrophage	Marine life (starfish)	[37]
Boreogadus saida (Lepechin, 1774)	Arctic cod	Facultative necrophage	Marine life (herring)	[89]
Brosme brosme (Ascanius, 1772)	Brismak	Facultative necrophage	Marine life (herring)	[89]
Carcharodon carcharias (Linnaeus, 1758)	Great white shark	Facultative necrophage	Marine life (whale)	[14, 92]
Centroscymnus coelolepis Barbosa du Bocage & de Brito Capello, 1864	Portuguese dogfish	Facultative necrophage	Marine life (whale)	[91]
Chaetodipterus faber (Broussonet, 1782)	Atlantic spadefish; Angelfish	Facultative necrophage	Marine life (menhaden)	[93]
Coryphaenoides acrolepis (Bean, 1884)	Pacific grenadier	Facultative necrophage	Marine life (food falls)	[94, 95]

Coryphaenoides (Nematonurus) armatus (Hector, 1875)	Abyssal grenadier	Facultative necrophage (but feeds on carrion frequently - carrion accounted for ~69% of the diet in a study by Drazen et al. [96]); this species is a necrophile too, feeding on necrophagous amphipods at carrion	Marine life (hake, mackerel, squid)	[14, 96]
Coryphaenoides yaquinae Iwamoto & Stein, 1974	Rough abyssal grenadier	Facultative necrophage	Marine life (squid)	[96]
Eptatretus deani (Evermann & Goldsborough, 1907)	Black hagfish	Necrophage (possibly obligate)	Marine life (whale)	[14, 45, 91]
Eptatretus stoutii (Lockington, 1878)	Pacific hagfish	Necrophage (possibly obligate)	Marine life (hake); livestock (pig)	[45, 97-99]
Gadus morhua Linnaeus, 1758	Atlantic cod	Facultative necrophage	Marine life (herring)	[14, 89]
Galeocerdo cuvier (Péron & Lesueur, 1822)	Tiger shark	Facultative necrophage	Marine life (whale)	[14, 100]
Hippoglossoides platessoides (Fabricius, 1780)	American plaice	Facultative necrophage	Marine life (herring)	[89]
Holacanthus passer Valenciennes, 1846	King angelfish	Facultative necrophage	Marine life (starfish)	[37]
Melanogrammus aeglefinus (Linnaeus, 1758)	Haddock	Facultative necrophage	Marine life (mackerel)	[14, 101]
Myxine circifrons Garman, 1899	Whiteface hagfish	Necrophage (possibly obligate)	Marine life (whale)	[14, 45, 91]
Myxine glutinosa Linnaeus, 1758	Atlantic hagfish	Necrophage (possibly obligate)	Marine life (jellyfish, mackerel); fishery discards (whiting, langoustine)	[45, 73, 102]
Neogobius melanostomus (Pallas, 1814)	Round goby	Facultative necrophage	Marine life (fish)	[103]

Neomyxine biniplicata (Richardson & Jowett, 1951)	Slender hagfish	Facultative necrophage; it is thought this species may also hunt live prey (invertebrates)	Marine life (pilchard)	[104, 105]
Neomyxine caesiovitta Zintzen, Roberts, Shepherd, Stewart, Struthers, Anderson, McVeagh, Noren & Fernholm, 2015	Blueband hagfish	Facultative necrophage; this species also hunts live prey (red bandfish)	Marine life (pilchard)	[105, 106]
Nezumia stelgidolepis (Gilbert, 1890)	California grenadier	Facultative necrophage	Marine life (whale)	[91]
Prionace glauca (Linnaeus, 1758)	Blue shark	Facultative necrophage	Marine life (whale)	[14]
Somniosus pacificus Bigelow & Schroeder, 1944	Greenland shark; Pacific sleeper shark	Facultative necrophage	Marine life (whale)	[14, 91]
Stegastes acapulcoensis (Fowler, 1944)	Acapulco damselfish	Facultative necrophage	Marine life (starfish)	[37]
Sufflamen verres (Gilbert & Starks, 1904)	Orangeside triggerfish	Facultative necrophage	Marine life (starfish)	[37]
Thalassoma lucasanum (Gill, 1862)	Cortez rainbow wrasse	Facultative necrophage	Marine life (starfish)	[37]
Trematomus bernacchii Boulenger, 1902	Emerald rockcod; Emerald notothen	Facultative necrophage	Marine life (mackerel pike)	[107]
Trematomus loennbergii Regan, 1913	Deepwater notothen; Scaly rockcod	Facultative necrophage	Marine life (mackerel pike)	[107]

Mammals				
Ammospermophilus leucurus (Merriam, 1889)	White-tailed antelope squirrel	Facultative necrophage	Livestock (cow)	[44]
Canis aureus Linnaeus, 1758	Asiatic jackal; Golden jackal	Facultative necrophage	Wildlife (deer); livestock	[14, 86, 108]
Canis dingo Blumenbach, 1780	Dingo	Facultative necrophage	Wildlife (kangaroo)	[22]
Canis latrans Say, 1823	Brush wolf; Coyote	Facultative necrophage	Wildlife (wild boar, rat, birds, elk, rabbit); livestock (pig, cow); poultry (chicken)	[14, 26, 34, 36, 39, 44, 45, 109, 110]
Canis lupus Linnaeus, 1758	Gray wolf	Facultative necrophage (necrophagy may increase when natural prey such as moose is limited)	Wildlife (wild boar, bison, red deer, roe deer); hunting discards (skinned wolf carcasses); companion animals (dog)	[14-16, 31, 52, 108, 111, 112]
Canis lupus subsp. *familiaris* Linnaeus, 1758 = *Canis familiaris* Linnaeus, 1758	Domestic dog	Facultative necrophage	Wildlife (pademelon, deer); hunting discards (wild boar & red deer gut piles); poultry (chicken)	[12, 15, 19, 39, 49, 55]
	Feral dog	Facultative necrophage	Marine life (sea lion); livestock (goat); poultry (chicken)	[14, 20]
Canis mesomelas Schreber, 1775	Black-backed jackal	Facultative necrophage & necrophile (this species eats insects at carrion, perhaps inadvertently)	Wildlife; livestock (cow, goat)	[27, 113, 114]
Crocuta crocuta (Erxleben, 1777)	Spotted hyena	Facultative necrophage (but feeds on carrion frequently [43])	Livestock (cow, goat)	[14, 27, 43, 108]
Dasypus novemcinctus Linnaeus, 1758	Common long-nosed armadillo; Nine-banded armadillo	Necrophile (feeds on adult flies at carrion)	Wildlife (wild boar)	[115]
Dasyurus maculatus (Kerr, 1792)	Spotted-tailed quoll	Facultative necrophage	Wildlife (kangaroo, pademelon)	[12, 22, 59]
Dasyurus viverrinus (Shaw, 1800)	Eastern quoll	Facultative necrophage	Wildlife (pademelon)	[12]
Didelphis marsupialis Linnaeus, 1758	Common opossum	Facultative necrophage	Poultry (chicken)	[46]
Didelphis virginiana Kerr, 1792	Virginia opossum	Facultative necrophage	Wildlife (wild boar, mouse, rat, rabbit); livestock (pig)	[14, 26, 30, 34, 35, 48,

				116]
Erinaceus europaeus Linnaeus, 1758	European hedgehog	Facultative necrophage	Poultry (chicken)	[32]
Felis catus Linnaeus, 1758	Domestic cat	Facultative necrophage	Wildlife (wild boar, mouse, roe deer); marine life (fish); poultry (chicken)	[14, 30-32, 36, 39, 55]
	Feral cat	Facultative necrophage	Wildlife (kangaroo, pademelon)	[12, 22, 59]
Felis silvestris Schreber, 1777	Wildcat	Facultative necrophage	Wildlife (wild boar, roe deer, red deer)	[86, 117]
Galerella pulverulenta (Wagner, 1839)	Cape gray mongoose	Facultative necrophage	Livestock (pig)	[118, 119]
Genetta genetta (Linnaeus, 1758)	Common genet	Facultative necrophage	Livestock (cow, goat)	[27]
Glaucomys volans (Linnaeus, 1758)	Southern flying squirrel	Facultative necrophage	Wildlife (mouse, rat)	[26, 35]
Gulo gulo (Linnaeus, 1758)	Wolverine	Facultative necrophage (necrophagy may increase when natural prey such as rodents or hares is limited)	Wildlife (rodent, moose, reindeer)	[14, 120]
Halichoerus grypus (Fabricius, 1791)	Atlantic gray seal	Facultative necrophage	Fishery discards (whiting, langoustine)	[74]
Herpestes ichneumon (Linnaeus, 1758)	Egyptian mongoose	Facultative necrophage	Livestock (cow, goat)	[27]
Herpestes javanicus (É.Geoffroy Saint-Hilaire, 1818)	Indian mongoose	Facultative necrophage	Wildlife (toad)	[45]
*Homo sapiens** Linnaeus, 1758	Human	Facultative necrophage (modern-day hunter-gatherers such as the Hadza people of Tanzania have been reported to obtain 15-25% of the carcasses they eat by scavenging [121, 122])	Wildlife (warthog, elephant, giraffe, impala, wildebeest, zebra)	[121-123]
Hyaena brunnea Thunberg, 1820	Brown hyena	Facultative necrophage (but feeds on carrion frequently, this accounting for up to 90% of its diet [14])	Marine life (seal)	[14]
Hyaena hyaena (Linnaeus, 1758)	Striped hyena	Facultative necrophage	Livestock (cow, goat)	[27]

Lutra lutra (Linnaeus, 1758)	European otter	Facultative necrophage	Livestock (sheep); poultry (chicken, goose)	[14, 124]
Lycalopex culpaeus (Molina, 1782)	Andean fox; Culpeo	Facultative necrophage	Carcasses abandoned by pumas	[14]
Lycalopex gymnocercus (G. Fischer, 1814)	Pampas fox	Facultative necrophage	Carcasses abandoned by pumas	[14]
Lynx rufus (Schreber, 1777)	Bay lynx; Bobcat	Facultative necrophage	Wildlife (rabbit); livestock (pig)	[24, 26]
Martes foina (Erxleben, 1777)	Stone marten	Facultative necrophage	Wildlife (deer); poultry (chicken)	[13, 14, 32]
Martes martes (Linnaeus, 1758)	Pine marten	Facultative necrophage	Wildlife (wild boar, bison, red deer, roe deer); livestock (cow, sheep); poultry (chicken)	[15, 16, 31, 32, 125]
Martes melampus (Wagner, 1840)	Japanese marten	Facultative necrophage	Wildlife (mouse, deer)	[54, 58]
Meles meles (Linnaeus, 1758)	European badger	Facultative necrophage	Livestock (sheep)	[16]
Mephitis mephitis (Schreber, 1776)	Striped skunk	Facultative necrophage	Wildlife (mouse, rabbit)	[26, 30, 35]
Mustela frenata Lichtenstein, 1831	Long-tailed weasel	Facultative necrophage	Wildlife (mouse)	[30]
Mustela nivalis Linnaeus, 1766	Least weasel	Facultative necrophage	Wildlife (ungulates)	[14-16]
Mustela putorius subsp. *furo* Linnaeus, 1758	Ferret	Facultative necrophage	Wildlife (wild boar)	[126]
Myodes glareolus (Schreber, 1780)	Bank vole	Facultative necrophage	Poultry (chicken)	[32]
Neotoma floridana (Ord, 1818)	Eastern woodrat; Florida woodrat	Facultative necrophage (when seasonal herbaceous material is limited)	Wildlife (birds, salamanders, snakes)	[127]
Nyctereutes procyonoides (Gray, 1834)	Raccoon dog	Facultative necrophage	Wildlife (raccoon dog, red fox, wild boar, mouse, bison, red deer, roe deer); hunting discards (moose)	[14-16, 31, 54, 128-130]
Orcinus orca (Linnaeus, 1758)	Killer whale	Facultative necrophage	Marine life (whale)	[14]

Paguma larvata (C.E.H. Smith, 1827)	Masked palm civet	Facultative necrophage	Wildlife (mouse, deer)	[58, 128]
Panthera leo (Linnaeus, 1758)	Lion	Facultative necrophage	Livestock (cow, goat)	[14, 27, 108]
Panthera pardus (Linnaeus, 1758)	Leopard	Facultative necrophage	Livestock (cow, goat)	[27, 108]
Peromyscus gossypinus (Le Conte, 1853)	Cotton deermouse	Facultative necrophage	Wildlife (mouse)	[35]
Peromyscus leucopus (Rafinesque, 1818)	White-footed mouse	Facultative necrophage	Wildlife (mouse)	[30]
Procyon lotor (Linnaeus, 1758)	Raccoon	Facultative necrophage	Wildlife (mouse, rat, rabbit); livestock (pig); poultry (chicken)	[14, 24, 26, 30, 34-36, 39, 43, 116]
Puma concolor (Linnaeus, 1771)	Cougar	Facultative necrophage	Livestock	[14]
Rattus norvegicus (Berkenhout, 1769)	Brown rat	Facultative necrophage	Poultry (chicken)	[32]
Rattus rattus (Linnaeus, 1758)	Black rat	Facultative necrophage	Wildlife (pademelon)	[12, 59]
Sarcophilus harrisii (Boitard, 1841)	Tasmanian devil	Facultative necrophage	Wildlife (possum, wallaby, kangaroo, wombat, pademelon)	[12, 59, 131]
Sciurus niger Linnaeus, 1758	Fox squirrel	Facultative necrophage	Wildlife (mouse)	[30]
Sus scrofa Linnaeus, 1758	Wild boar; Feral pig	Facultative necrophage (but feeds on carrion frequently - carrion accounted for ~15% of the diet in a study by Thomson & Challies [132])	Wildlife (stone marten, wild boar[†], possum, mouse, rat, bison, kangaroo, red deer, roe deer, rabbit); hunting discards (wild boar & red deer gut piles); poultry (chicken)	[13-16, 19, 22, 26, 31, 32, 34, 35, 43, 54, 126, 128, 132]
Taxidea taxus (Schreber, 1777)	American badger	Facultative necrophage	Wildlife (rabbit); livestock (cow)	[44, 133, 134]
Trichosurus vulpecula (Kerr, 1792)	Brushtail possum	Facultative necrophage	Wildlife (wild boar, kangaroo, pademelon, deer)	[12, 22, 126]
Tursiops truncatus (Montagu, 1821)	Common bottlenose dolphin	Facultative necrophage	Fishing industry bycatch (mostly fish)	[37]

Urocyon cinereoargenteus (Schreber, 1775)	Gray fox	Facultative necrophage	Wildlife (rat, rabbit)	[26, 35, 43, 45]
Ursus americanus Pallas, 1780	American black bear	Facultative necrophage	Aquatic life (salmon)	[14, 25]
Ursus arctos Linnaeus, 1758	Brown bear	Facultative necrophage	Wildlife (deer); aquatic life (salmon)	[14, 25, 86, 108, 109]
Ursus maritimus Phipps, 1774	Polar bear	Facultative necrophage	Marine life (whale, seal)	[14]
Ursus thibetanus G. Cuvier, 1823	Asian black bear	Facultative necrophage	Wildlife (deer)	[58]
Vulpes corsac (Linnaeus, 1768)	Corsac fox	Facultative necrophage	Livestock (goat); poultry (chicken)	[20]
Vulpes lagopus (Linnaeus, 1758) = *Alopex lagopus* (Linnaeus, 1758)	Arctic fox	Facultative necrophage	Wildlife (lemming); marine life (seal, cetaceans)	[14, 37, 43]
Vulpes macrotis Merriam, 1888	Kit fox	Facultative necrophage	Wildlife (birds); livestock (cow)	[14, 44]
Vulpes vulpes (Linnaeus, 1758)	Red fox	Facultative necrophage (but feeds on carrion frequently - carrion accounted for ~12% of the diet in a study by Remonti et al. [135])	Wildlife (wild boar, mouse, bison, chamois, kangaroo, lemming, red deer, roe deer, wild sheep); marine life (gray seal, fish); hunting discards (wild boar & red deer gut piles); livestock (goat); poultry (chicken); companion animals (dog, cat)	[13-16, 19, 20, 22, 31, 32, 43, 54, 55, 128, 135]
Zaedyus pichiy (Desmarest, 1804)	Pichi; Dwarf armadillo	Facultative necrophage	Livestock	[14]
Reptiles				
Agkistrodon contortrix (Linnaeus, 1766)	Copperhead	Facultative necrophage	Wildlife (rat)	[35]
Alligator mississippiensis (Daudin, 1801)	American alligator	Facultative necrophage	Wildlife (rabbit)	[34]

Anolis carolinensis Voigt, 1832	Green anole	Necrophile (feeds on adult flies at carrion)	Wildlife (wild boar)	[115]
Boiga irregularis (Bechstein, 1802)	Brown tree snake	Facultative necrophage	Wildlife (mouse)	[136-138]
Coluber constrictor Linnaeus, 1758	Eastern racer; Southern black racer	Facultative necrophage	Wildlife (mouse, rat)	[26, 35]
Crocodylus moreletii (Duméril & Bibron, 1851)	Belize crocodile; Morelet's crocodile	Facultative necrophage	Wildlife (tapir); livestock (cow)	[139]
Crocodylus porosus Schneider, 1801	Estuarine crocodile	Facultative necrophage	Marine life (whale)	[100]
Crotalus horridus Linnaeus, 1758	Timber rattlesnake; Canebrake rattlesnake	Facultative necrophage	Wildlife (mouse)	[35]
Elaphe climacophora (Boie, 1826)	Japanese rat snake	Facultative necrophage	Wildlife (mouse)	[128]
Erythrolamprus miliaris (Linnaeus, 1758)	Military ground snake	Facultative necrophage	Wildlife (tree frog)	[140]
Pantherophis obsoletus (Say, 1823)	Black rat snake	Facultative necrophage	Wildlife (rat)	[35]
Philodryas patagoniensis (Girard, 1858)	Patagonia green racer	Facultative necrophage	Wildlife (red ovenbird)	[141]
Terrapene carolina (Linnaeus, 1758)	Common box turtle	Facultative necrophage	Wildlife (mouse, rat)	[35]
Varanus indicus (Daudin, 1802)	Indian monitor	Facultative necrophage	Aquatic life (fish)	[142]
Varanus komodoensis Ouwens, 1912	Komodo dragon	Facultative necrophage (but feeds on carrion frequently [14])	Marine life (fish); human remains (retrieved from shallow graves)	[14, 143-145]
Varanus panoptes Storr, 1980	Yellow-spotted monitor	Facultative necrophage	Carrion raided from crocodile caches	[17]

Varanus rosenbergi Mertens, 1957 = *Varanus gouldii* subsp. *rosenbergi* Mertens, 1957	Heath monitor	Facultative necrophage	Wildlife (marsupials)	[146]
Varanus varius (Shaw, 1790)	Lace monitor	Facultative necrophage (but feeds on carrion frequently [14])	Marine life (fish)	[14]

*, Anatomically and physiologically, primates are considered poorly adapted for necrophagy [147], but human communities practicing it prioritize reaching carcasses quickly [122] and cook or sun-dry what they find [121]; †, *Sus scrofa* usually avoids feeding on dead conspecifics [13, 15, 16, 26, 126], but stomach content analysis suggests it does occur [132]; =, synonym

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Supplementary Table 2 from the Critical Reviews in Biotechnology journal article 'Necrophages and necrophiles: a review of their antibacterial defenses and biotechnological potential'

To cite this article:

Cushnie TPT, Luang-In V, Sexton DW, Necrophages and necrophiles: a review of their antibacterial defenses and biotechnological potential. Critical Reviews in Biotechnology, 2024 (Published online ahead of print). DOI: 10.1080/07388551.2024.2389175

To link to this article:

https://doi.org/10.1080/07388551.2024.2389175

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Supplementary Table 2 Examples of bacteria causing fatal infections and toxico-infections of wildlife, livestock and other animals, and which are transmissible by contact with or ingestion of contaminated carcasses.

Susceptible animals		**Bacterial pathogens**											**Reference(s)**
Scientific name	**Common name(s)**	***Aeromonas hydrophila*** †	***Bacillus anthracis*** †	***Clostridium botulinum*** †	***Edwardsiella ictaluri*** †	***Francisella tularensis*** †	***Klebsiella pneumoniae*** †	***Listeria monocytogenes*** †	***Mycobacterium bovis*** †	***Mycobacterium marinum*** †	***Pasteurella multocida*** †	***Yersinia pestis*** †	
Wildlife (terrestrial)													
Alectoris rufa (Linnaeus, 1758)	Red-legged partridge							○					[1]
Alouatta palliata (Gray, 1849)	Howler monkey						●						[2]
Anaxyrus cognatus (Say, 1822) = *Bufo cognatus* Say, 1822	Great Plains toad									●			[3]
Anaxyrus woodhousii (Girard, 1854) = *Bufo woodhousii* Girard, 1854	Woodhouse's toad									●			[3]
Antidorcas marsupialis (Zimmermann, 1780)	Springbok		●										[4]
Bison bison (Linnaeus, 1758) = *Bison bison* subsp. *athabascae* Rhoads, 1898	American bison		●						●		●		[5-7]
Bison bonasus (Linnaeus, 1758)	European bison								●				[8]
Centrocercus urophasianus (Bonaparte, 1827)	Greater sage grouse					●							[9]
Cervus elaphus Linnaeus, 1758	Red deer		●	○				○			●		[10-13]
Cervus nippon Temminck, 1838	Sika deer										●		[14]

Connochaetes taurinus (Burchell, 1823)	Blue wildebeest		●								○		[4, 15]
Cynomys gunnisoni (Baird, 1855)	Gunnison's prairie dog										●	●	[16, 17]
Cynomys ludovicianus (Ord, 1815)	Black-tailed prairie dog					●						●	[18-20]
Dama dama (Linnaeus, 1758)	Common fallow deer		●	○				●	○		●		[11, 14, 21-25]
Diceros bicornis (Linnaeus, 1758)	African black rhinoceros		●										[4]
Elaphe taeniura (Cope, 1861)	Beauty rat snake									○			[26]
Equus hartmannae Matschie, 1898	Hartmann's mountain zebra		●										[4]
Equus quagga subsp. *burchellii* (Gray, 1824) = *Equus burchelli* (Gray, 1824)	Burchell's zebra		●								○		[4, 15]
Erinaceus europaeus Linnaeus, 1758	Western European hedgehog							●	●				[27, 28]
Giraffa camelopardalis (Linnaeus, 1758)	Giraffe		●						●				[4, 29]
Lagurus lagurus (Pallas, 1773)	Steppe lemming					●							[30]
Lemmus lemmus (Linnaeus, 1758)	Norway lemming					●							[31]
Leontopithecus chrysomelas (Kuhl, 1820)	Golden-headed lion tamarin						○						[32]
Lepus spp. Linnaeus, 1758	Hares					●	●				●		[33-39]
Litoria ewingii (Duméril & Bibron, 1841)	Southern brown tree frog						●						[40]
Loxodonta africana (Blumenbach, 1797)	African bush elephant		●										[4]
Lynx canadensis Kerr, 1792	Canada lynx											●	[41]
Lynx pardinus (Temminck, 1827)	Iberian lynx								●				[42]
Marmota spp. Blumenbach, 1779	Marmots										●	●	[43-45]
Meles meles (Linnaeus, 1758)	Eurasian badger								●				[46, 47]
Meriones spp. Illiger, 1811	Jirds											●	[48, 49]
Microtus spp. Schrank, 1798	Meadow voles					●		●					[20, 50]
Moschus spp. Linnaeus, 1758	Musk deer						●				○		[51, 52]

Mus musculus Linnaeus, 1758	House mouse					●							[30, 53]
Mustela spp. Linnaeus, 1758	Ermines		○	○								○	[54-57]
Nanger granti (Brooke, 1872)	Grant's gazelle		●										[58]
Neotoma spp. Say & Ord, 1825	Packrats					●					●	●	[17, 59, 60]
Odocoileus virginianus (Zimmermann, 1780)	White-tailed deer		○								○		[21, 61, 62]
Oryctolagus cuniculus (Linnaeus, 1758)	European rabbit	○				●		○			○		[36, 63-65]
Oryx spp. Blainville, 1816	Oryxes		●	○				○					[4, 66, 67]
Pan troglodytes (Blumenbach, 1775)	Chimpanzee		●					○					[68, 69]
Panthera pardus (Linnaeus, 1758)	Amur leopard								○				[70]
Pantherophis vulpinus (Baird & Girard, 1853) = *Elaphe vulpina* subsp. *vulpina*	Eastern fox snake									○			[71]
Papio spp. Erxleben, 1777	Baboons			○					●				[70, 72, 73]
Paramesotriton hongkongensis (Myers & Leviton, 1962)	Hong Kong warty newt									○			[74]
Peromyscus maniculatus (Wagner, 1845)	Deer mouse					●					●		[17, 75]
Pituophis catenifer subsp. *sayi* (Schlegel, 1837) = *Pituophis melanoleucus* subsp. *sayi* (Schlegel, 1837)	Bullsnake									○			[71]
Pseudocheirus peregrinus (Boddaert, 1785)	Common ringtail possum					●		○					[76, 77]
Puma concolor (Linnaeus, 1771) = *Felis concolor* Linnaeus, 1771	Cougar		○					○				●	[78-80]
Rattus spp. Fischer, 1803	Rats										●	●	[17, 81, 82]
Rhinoceros unicornis Linnaeus, 1758	Greater one-horned rhinoceros						○		●				[83, 84]
Saiga tatarica (Linnaeus, 1766)	Steppe saiga										●		[85]
Sciurus niger Linnaeus, 1758	Fox squirrel					●					●	●	[17, 86, 87]
Serinus canaria (Linnaeus, 1758)	Atlantic canary						○				○		[88, 89]

Struthio camelus Linnaeus, 1758	Common ostrich		●	○					○		○		[4, 15, 90, 91]
Sus scrofa Linnaeus, 1758	Wild boar; Feral pig	○							●		●		[92-94]
Taurotragus oryx (Pallas, 1766)	Cape eland		●								○		[4, 15]
Tragelaphus strepsiceros (Pallas, 1766)	Greater kudu		●						●				[4, 73]
Trichosurus vulpecula (Kerr, 1792)	Common brush-tailed possum							●	●				[77, 95]
Uncia uncia (Schreber, 1775) = *Panthera uncia* (Schreber, 1775)	Snow leopard								○				[70]
Urocitellus mollis (Kennicott, 1863)	Piute ground squirrel											●	[96]
Urocitellus townsendii (Bachman, 1839) = *Spermophilus townsendii* Bachman, 1839	Townsend's ground squirrel											●	[97]
Ursus arctos Linnaeus, 1758	Brown bear								●				[98]
Zhangixalus arboreus (Okada & Kawano, 1924) = *Rhacophorus arboreus* (Okada & Kawano, 1924)	Forest green tree frog									○			[99]
Zhangixalus dennysi (Blanford, 1881) = *Rhacophorus dennysi* Blanford, 1881	Chinese gliding frog									○			[100]
Wildlife (aquatic)													
Actitis hypoleucos (Linnaeus, 1758)	Common sandpiper			●							●		[101]
Ameiurus nebulosus (Lesueur, 1819)	Brown bullhead				○								[102]
Anas acuta Linnaeus, 1758 = *Anas acuta* subsp. *acuta* Linnaeus, 1758	Northern pintail			●							●		[103, 104]
Anas americana Gmelin, 1789	American wigeon										●		[103, 105]
Anas clypeata Linnaeus, 1758	Northern shoveler			●							●		[103, 106-110]
Anas crecca Linnaeus, 1758	Green-winged teal			●							●		[101, 111]
Anas platyrhynchos Linnaeus, 1758	Mallard; Wild duck	●		●							●		[106, 111-115]

Anas strepera Linnaeus, 1758	Gadwall			●							●		[106, 107]
Aythya americana (Eyton, 1838)	Redhead			●							●		[105, 116]
Aythya nyroca (Guldenstadt, 1770)	Ferruginous duck			●									[106]
Branta canadensis (Linnaeus, 1758)	Canada goose										●		[105]
Bucephala clangula (Linnaeus, 1758)	Common goldeneye			●							●		[117, 118]
Caretta caretta (Linnaeus, 1758)	Loggerhead sea turtle							●					[119]
Charadrius alexandrinus Linnaeus, 1758	Kentish plover			●							●		[101, 107]
Charadrius dubius Scopoli, 1786	Little ringed plover			●							●		[101, 107]
Chen caerulescens (Linnaeus, 1758) = *Anser caerulescens* (Linnaeus, 1758)	Snow goose										●		[105]
Chen rossii (Cassin, 1861) = *Anser rossii* Cassin, 1861	Ross's goose										●		[105]
Ciconia ciconia (Linnaeus, 1758)	White stork			●									[120]
Clangula hyemalis (Linnaeus, 1758)	Long-tailed duck			●							●		[116, 118]
Elseya irwini Cann, 1997	Irwin's snapping turtle	●											[121]
Fulica americana Gmelin, 1789	American coot			●							●		[103, 108, 122]
Fulica atra Linnaeus, 1758	Eurasian coot			●							●		[106, 111, 123]
Gavia immer (Brunnich, 1764)	Common loon			●									[116]
Gavia stellata (Pontoppidan, 1763)	Red-throated diver			●									[116]
Himantopus himantopus (Linnaeus, 1758)	Black-winged stilt			●							●		[101, 107]
Ichthyaetus relictus (Lonnberg, 1931)	Relict gull										●		[101]
Larus argentatus Pontoppidan, 1763	European herring gull			●									[116]
Larus delawarensis Ord, 1815	Ring-billed gull			●							●		[116, 118]
Lithobates catesbeianus (Shaw, 1802) = *Rana catesbeiana* Shaw, 1802	American bull frog								○	○			[71, 124]

Lithobates sylvaticus (LeConte, 1825)	Wood frog	●											[125]
Melanitta fusca subsp. *deglandi* (Bonaparte, 1850) = *Melanitta deglandi* (Bonaparte, 1850)	White-winged scoter			●							●		[116, 118]
Ondatra zibethicus (Linnaeus, 1766)	Muskrat					●	●						[126, 127]
Oxyura spp. Bonaparte, 1828	Stiff-tailed ducks			●							●		[106, 110]
Phocarctos hookeri (Gray, 1844)	Auckland sea lion						●						[128]
Plecoglossus altivelis (Temminck & Schlegel, 1846)	Ayu				●					○			[129, 130]
Podiceps caspicus (Hablizl, 1783)	Eared grebe			●									[116]
Recurvirostra avosetta Linnaeus, 1758	Pied avocet			●							●		[101, 107, 131]
Rhodeus ocellatus (Kner, 1866) = *Rhodeus ocellatus* subsp. *kurumeus* Jordan & Thompson, 1914	Rose bitterling									○			[132]
Tadorna ferruginea (Pallas, 1764)	Ruddy shellduck			●							●		[101, 107]
Trachemys scripta (Thunberg & Schoepff, 1792) = *Pseudemys scripta* (Schoepff, 1792)	Pond slider	○											[133]
Trichechus inunguis (Natterer, 1883)	Amazon manatee									○			[134]
Tringa nebularia (Gunnerus, 1767)	Common greenshank			●							●		[101, 107]
Vanellus vanellus (Linnaeus, 1758)	Northern lapwing			●							●		[101, 131]
Zalophus californianus (Lesson, 1828)	California sea lion			○			●						[135, 136]
Livestock													
Bos taurus Linnaeus, 1758	Cattle		●	●			●	●	●		●		[10, 61, 137] [58, 138-144]
Bubalus bubalis (Linnaeus, 1758)	Water buffalo		●	●				●	●		●		[145-149]

Camelus sp. Linnaeus, 1758	Camel		●				●	●			●	●	[150-154]
Capra hircus Linnaeus, 1758 = *Capra aegagrus* Erxleben, 1777	Domestic goat		●	●				●	●		●		[10, 58, 61, 137, 155-159]
Equus caballus Linnaeus, 1758 = *Equus ferus* subsp. *caballus* Linnaeus, 1758	Domestic horse		●	●		●		●	●				[10, 61, 160-163]
Lama glama (Linnaeus, 1758)	Llama		●					●	●				[164-166]
Ovis aries Linnaeus, 1758	Domestic sheep		●	●		●	●	●	●		●		[10, 61, 137] [58, 156, 158, 167-173]
Sus scrofa Linnaeus, 1758	Domestic pig		●				●	●			●		[61, 174-176]
Poultry													
Anas platyrhynchos f. *domesticus*	Domestic duck			●			●				●		[177-179]
Gallus gallus f. *domesticus*	Domestic chicken			●			●	●			●		[177, 180, 181]
Meleagris gallopavo Linnaeus, 1758	Common turkey			●							●		[177, 182, 183]
Farmed fish & shrimp													
Clarias gariepinus (Burchell, 1822)	African catfish						●			●			[184, 185]
Cynoglossus semilaevis Günther, 1873	Tongue sole									●			[186]
Dicentrarchus labrax (Linnaeus, 1758)	European seabass	●			●					●			[187, 188]
Ictalurus punctatus (Rafinesque, 1818)	Channel catfish	●		●	●								[189-192]
Labeo rohita (Hamilton, 1822)	Rohu						●						[193]
Lateolabrax japonicus (Cuvier, 1828)	Asian seabass									●			[194]
Macrobrachium spp. Spence Bate, 1868	River prawns	●					●						[195, 196]

Morone saxatilis (Walbaum, 1792)	Striped bass									●			[197]
Ompok bimaculatus (Bloch, 1794)	Butter catfish						●						[198]
Oncorhynchus mykiss (Walbaum, 1792) = *Salmo gairdneri* Richardson, 1836	Rainbow trout	●		●	●								[199, 200]
Oreochromis niloticus (Linnaeus, 1758)	Nile tilapia	●			●		●			●			[201-204]
Pangasianodon hypophthalmus (Sauvage, 1878) = *Pangasius hypophthalmus* (Sauvage, 1878)	Striped catfish	●			●								[205, 206]
Pangasius pangasius (Hamilton, 1822)	Pangas catfish				●								[207]
Sander lucioperca (Linnaeus, 1758)	European pike-perch									●			[208]
Silurus meridionalis Chen, 1977	Chinese large-mouth catfish				●								[209]
Systomus sarana (Hamilton, 1822)	Olive barb						●						[198]
Tachysurus fulvidraco (Richardson, 1846) = *Pelteobagrus fulvidraco* (Richardson, 1846)	Banded catfish				●								[210, 211]
Companion animals													
Canis lupus subsp. *familiaris* Linnaeus, 1758	Domestic dog		●	●			●		●			●	[212-215] [216]
Chinchilla spp. Bennett, 1829	Chinchilla						●	●			●		[217-219]
Felis catus Linnaeus, 1758	Cat			●		●		●	●		●	●	[220-227]

Notes: Bacteria causing fatal cases of disease are marked with a solid (●) or open (○) circle. Fatalities occurring in captive wildlife are marked with an open circle in recognition that their level of exposure [70, 71] and susceptibility [102, 184] to bacterial pathogens may differ from free-living wildlife. All other fatalities are marked with a solid circle. †, bacterial cells or endospores are capable of remaining viable in or on carcasses (as evidenced by post-mortem microbiological culture [1, 2, 4, 8, 10, 12-15, 20-23, 25, 26, 29, 32, 34, 36-39, 41-45, 47, 51, 53, 55, 64-66, 69, 75-79, 82, 91-94, 96, 97, 99-101, 103, 105, 106, 110, 112, 117-119, 122, 124, 127, 128, 134, 135, 137, 138, 141, 146, 147, 149, 152, 154-156, 159-162, 165, 168-172, 174, 177, 179, 182, 183, 185, 212, 215, 217, 220, 222-224, 226, 227] and transmission of infection from carcasses [9, 17, 31, 39, 56, 126, 161, 167, 191]); =, synonym

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<u>Supplementary Table 3 from the Critical Reviews in Biotechnology journal article 'Necrophages and necrophiles: a review of their antibacterial defenses and biotechnological potential'</u>

To cite this article:

Cushnie TPT, Luang-In V, Sexton DW, Necrophages and necrophiles: a review of their antibacterial defenses and biotechnological potential. Critical Reviews in Biotechnology, 2024 (Published online ahead of print). DOI: 10.1080/07388551.2024.2389175

To link to this article:

https://doi.org/10.1080/07388551.2024.2389175

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Supplementary Table 3 Necrophages and necrophiles engaging in behaviors that might increase their risk or their offspring's risk of infection.

Observation	Example necrophage(s) or necrophile(s)	Reference(s)
Working in groups to locate carrion [a]	*Corvus corax* (common raven)	[1]
	Gyps spp. (griffon vultures)	[2]
Interacting aggressively with other necrophages over access to carrion [a]	*Anarhichas denticulatus* (northern wolffish)	[3]
	Corvus corax (common raven)	[4]
	Trigona necrophaga (vulture bee)	[5]
Absence of parental care (no rolling away of carrion for offspring as seen with *Canthon cyanellus*, & no burying of carrion as seen with *Nicrophorus* spp.) [a]	Silphinae (silphine beetles)	[6]
Feeding on rotten (24- to 48-hour-old) carrion more often than fresh (<24-hour-old) carrion [b]	*Boiga irregularis* (brown tree snake)	[7]
Laying eggs in ≥24-hour-old carrion ('second wave' colonization) [a, b]	*Chrysomya albiceps* (green bottle)	[8]
Feeding on carnivore carcasses [c]	*Aquila chrysaetos* (golden eagle)	[9]
	Corvus corax (common raven)	[9]
	Corvus corone (carrion crow)	[9]
	Gyps fulvus (Eurasian griffon)	[9]
	Nyctereutes procyonoides (raccoon dog)	[10]
	Sus scrofa (wild boar)	[9]
	Vulpes vulpes (red fox)	[9]
Feeding on conspecific carcasses [d]	*Nyctereutes procyonoides* (raccoon dog)	[10, 11]
Feeding on large (>15 kg) carcasses (e.g. cattle, deer) more often than small carcasses (e.g. armadillo, skunk) [a]	*Coragyps atratus* (black vulture)	[12]
Feeding at mass mortality events (e.g. salmon die-offs) [a]	*Ursus* spp. (bears)	[13]
Feeding communally at carrion [a]	*Varanus komodoensis* (Komodo dragon)	[14]
Aggregation on carrion (insect larvae) [a]	*Calliphora vomitoria* (blue bottle fly)	[15]
	Lucilia sericata (common green bottle fly)	[15]

	Necrodes littoralis (shore sexton beetle)	[16]
Feeding on carrion or laying eggs in carrion during the summer or warm season [b]	*Canis latrans* (coyote)	[17]
	Cathartes aura (turkey vulture)	[17]
	Chrysomya albiceps (green bottle)	[18]
	Coragyps atratus (black vulture)	[17]
	Necrobia rufipes (redlegged ham beetle)	[18]
	Nicrophorus spp. (nicrophorine beetles)	[19]
	Pica pica (Eurasian magpie)	[19]
	Procyon lotor (raccoon)	[17]
	Sus scrofa (wild boar)	[17]
	Vulpes vulpes (red fox)	[4]

a, increases contact with other carrion users & the number of opportunities for infection transmission; b, increases the number of bacteria a necrophage/necrophile is exposed to; c, increases contact with animal pathogens; d, increases contact with pathogens adapted to that individual genus or species of necrophage

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Supplementary Table 4 from the Critical Reviews in Biotechnology journal article 'Necrophages and necrophiles: a review of their antibacterial defenses and biotechnological potential'

To cite this article:

Cushnie TPT, Luang-In V, Sexton DW, Necrophages and necrophiles: a review of their antibacterial defenses and biotechnological potential. Critical Reviews in Biotechnology, 2024 (Published online ahead of print). DOI: 10.1080/07388551.2024.2389175

To link to this article:

https://doi.org/10.1080/07388551.2024.2389175

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Supplementary Table 4 Examples of invertebrate necrophages and necrophiles, information on whether this feeding behavior is obligate or facultative (where available), and other dietary details such as type of carrion they feed upon or visit in search of eggs, larvae or pupae.

Scientific name	Common name(s)	Association with carrion	Carrion consumed or visited	Reference(s)
Annelids				
Haemopis marmorata (Say, 1824)	None*	Necrophage	Freshwater fish (perch)	[1]
Nephelopsis obscura Verrill, 1872	None*	Facultative necrophage	Freshwater fish (smallmouth bass)	[1]
Osedax spp. Rouse, Goffredi & Vrijenhoek, 2004	Bone-eating marine worms; Zombie worms	Necrophages	Marine life (whale bones)	[2, 3]
Polycirrus arcticus Sars, 1865	None*	Necrophage	Marine life (herring)	[4]
Arthropods – arachnids				
Agelenopsis potteri (Blackwall, 1846)	None*	Necrophage & necrophile (feeds on other carrion inhabitants)	Marine life (seagull)	[5]
Heterophrynus longicornis (Butler, 1873)	None*	Facultative necrophage (necrophagy has been observed in an adult spider, but this may have been due to food scarcity in its cave habitat)	Wildlife (bat)	[6]
Loxosceles reclusa Gertsch & Mulaik, 1940	Brown recluse spider	Facultative necrophage (the feeding preference of this species is for carrion)	Wildlife (insects & insect larvae e.g. cricket, cockroach, moth larvae, mealworm larvae)	[7]
Paraphrynus robustus (Franganillo, 1931)	None*	Facultative necrophage (necrophagy has been observed with this species, but may have been due to food scarcity in its cave habitat)	Wildlife (bat)	[6]
Phrynus longipes (Pocock, 1894)	None*	Facultative necrophage (necrophagy has been observed with this species, but may have been due to food scarcity in its cave habitat)	Wildlife (bat)	[6]

Protoribates (*Triaungius*) *haughlandae* Walter & Latonas, 2013	None*	Facultative necrophage	Wildlife (small arthropods)	[8]
Rowlandius potiguar Santos, Ferreira & Buzatto, 2013	None*	Facultative necrophage	Wildlife (mosquito)	[9]
Arthropods – entognaths				
Entomobrya proxima Folsom, 1924	None*	Necrophage	Wildlife (insects)	[10]
Arthropods – hexanauplia				
Xanthocalanus gracilis Wolfenden, 1911	None*	Necrophage	Marine life (mackerel pike)	[11]
Arthropods – insects				
Agelaia spp. Lepeletier de Saint Fargeau, 1836	None*	Necrophages	Livestock (pig)	[12, 13]
Aglais io (Linnaeus, 1758)	Peacock butterfly	Facultative necrophage (adult butterflies suck on carcasses, possibly to ingest sodium)	Wildlife (wild boar, badger, red deer, roe deer, mouflon)	[14]
Aleochara (Xenochara) asiatica Kraatz, 1859	None*	Necrophile (this species is parasitoid; beetle larvae parasitize fly larvae)	Livestock viscera (pig liver)	[15]
Aleochara (Aleochara) lata Gravenhorst, 1802	None*	Necrophile (feeds on other carrion inhabitants)	Wildlife (bear, alligator, deer); marine life (seagull); livestock (pig)	[5, 16-20]
Aleochara (Aleochara) lustrica Say, 1832	None*	NS	Wildlife (bear, alligator); livestock (pig)	[16, 19]
Aleochara nigra Kraatz, 1859	None*	Necrophile (this species is parasitoid; beetle larvae parasitize fly larvae)	Livestock viscera (pig liver)	[15]
Alydus calcaratus (Linnaeus, 1758)	Hvepsetæge	Necrophage (adult bugs are necrophagous)	Wildlife (wild boar, badger, red deer, roe deer, mouflon)	[14]
Alysia manducator (Panzer, 1799)	Parasitoid wasp	Necrophile (this species is parasitoid; adult wasps lay their eggs in fly larvae)	Wildlife (red fox, rabbit); livestock (pig)	[21-25]
Ammophila spp. W. Kirby, 1798	Sand wasps	Necrophiles (in some species of this genus, the adult wasps are	Wildlife (wild boar, badger, red deer, roe deer, mouflon)	[14]

		necrophilous)		
Amobia oculata (Zetterstedt, 1844)	None*	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[18]
Anabrus simplex Haldeman, 1852	Mormon cricket	Facultative necrophage; this species feeds mostly on plants	Wildlife (adult conspecifics)	[26, 27]
Angiopolybia spp. Araujo, 1946	None*	Necrophages	Livestock (pig)	[12]
Anomala aulacoides Ohaus, 1915	None*	Necrophage	Livestock (pig)	[28]
Anoplotrupes stercorosus (Scriba, 1791)	Dor beetle	Facultative necrophage; this species also feeds on dung	Wildlife (wolf, rat); human remains; livestock (pig)	[29-31]
Anotylus insignitus (Gravenhorst, 1806)	None*	NS	Wildlife (alligator, bear, deer); livestock (pig)	[16, 32]
Anotylus sculpturatus (Gravenhorst, 1806)	None*	Necrophile (feeds on fly eggs & larvae at carrion)	Wildlife (roe deer, rabbit)	[29, 33]
Anthomyia pluvialis (Linnaeus, 1758)	None*	NS	Wildlife (rabbit)	[34, 35]
Apatura ilia (Denis & Schiffermüller, 1775)	Lesser purple emperor	Facultative necrophage (adult butterflies suck on carcasses, possibly to ingest sodium)	Wildlife (wild boar, badger, red deer, roe deer, mouflon)	[14]
Aphantopus hyperantus (Linnaeus, 1758)	Ringlet	Facultative necrophage (adult butterflies suck on carcasses, possibly to ingest sodium)	Wildlife (wild boar, badger, red deer, roe deer, mouflon)	[14]
Apis mellifera Linnaeus, 1758	European honey bee	Facultative necrophage (adult bees sometimes feed on fluids from decomposing carrion)	Marine life (squid); human remains; livestock (pig)	[13, 36-38]
Araschnia levana (Linnaeus, 1758)	Map	Facultative necrophage (adult butterflies suck on carcasses, possibly to ingest sodium)	Wildlife (wild boar, badger, red deer, roe deer, mouflon)	[14]
Argoravinia rufiventris (Wiedemann, 1830)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rat); livestock (pig); livestock viscera (cow)	[39-42]
Ataenius aequalis Harold, 1880	None*	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[43]
Ataenius picinus Harold, 1867	None*	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[43]

Ataenius platensis (Blanchard, 1846)	None*	Necrophage	Wildlife (alligator, deer); livestock (pig)	[16, 44]
Ateuchus histeroides Weber, 1801	None*	Facultative necrophage; this species also feeds on dung	Wildlife (alligator, insects)	[16, 45]
Ateuchus (Ateuchus) vividus Germar, 1824	None*	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[43]
Atherigona orientalis Schiner, 1868	Pepper fruit fly	Facultative necrophage (fly larvae are necrophagous)	Wildlife (rat, rabbit); marine life (goatfish); livestock (pig); poultry (chicken)	[13, 40, 46-51]
Atheta iheringi Bernhauer, 1908	None*	Thought to be necrophagous &/or necrophilous	Wildlife (rabbit); livestock (pig)	[43]
Atholus duodecimstriatus (Schrank, 1781)	None*	NS	Livestock (pig); marine life (squid)	[17, 20, 52]
Belonuchus rufipennis (Fabricius, 1801)	None*	Thought to be necrophagous &/or necrophilous	Wildlife (bear, alligator, deer); marine life (squid); livestock (pig)	[16]
Bembix olivata Dahlbom, 1845	None*	Necrophile (feeds on other carrion inhabitants)	Wildlife (antelope)	[53]
Bembix rostrata (Linnaeus, 1758)	None*	Necrophile (adult wasps are necrophilous)	Wildlife (wild boar, badger, red deer, roe deer, mouflon)	[14]
Blaesoxipha (Gigantotheca) stallengi (Lahille, 1907)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rat); livestock viscera (cow)	[39-42, 54]
Blatta orientalis Linnaeus, 1758	Oriental cockroach	NS	Wildlife (bear, coyote, alligator)	[16, 55]
Bombus terrestris (Linnaeus, 1758)	Buff tailed bumblebee	Facultative necrophage (some *Bombus* spp. suck on carcasses, possibly to ingest salt, water & minerals)	Wildlife (wild goat); marine life (squid)	[14, 38, 56]
Calliphora croceipalpis Jaennicke, 1867	None*	Necrophage (fly larvae are necrophagous)	Livestock viscera (sheep liver)	[57, 58]
Calliphora (Aldrichina) grahami Aldrich, 1930	Common blowfly	Necrophage (fly larvae are necrophagous)	Livestock (pig)	[59, 60]
Calliphora hilli Patton, 1925	None*	Necrophage	Wildlife (possum)	[57, 61]
Calliphora stygia (Fabricius, 1781)	Brown blow fly	Necrophage (fly larvae are necrophagous)	Wildlife (possum)	[57, 61, 62]

Calliphora terraenovae Macquart, 1851	None*	Necrophage (fly larvae & adults are both necrophagous)	Aquatic life (salmon)	[63]
Calliphora vicina Robineau-Desvoidy, 1830 = *Calliphora erythrocephala* (Meigen, 1826) 1758	European blue bottle fly	Necrophage (fly larvae & adults are both necrophagous)	Wildlife (coyote, wolf, bear, alligator, fox, rat, mouse, badger, deer, rabbit); marine life (gray seal, seagull, squid); human remains; livestock (pig); livestock viscera (cow liver, goat)	[5, 16, 18, 21, 31, 34, 36, 37, 51, 52, 64-80]
Calliphora vomitoria Linnaeus, 1758	Blue bottle fly	Necrophage (fly larvae are necrophagous)	Wildlife (red fox, wolf, rabbit, rat); marine life (squid); human remains; livestock (pig)	[17, 18, 21, 31, 34, 36, 37, 52, 64, 66, 70, 74, 75, 78, 81]
Calliptamus italicus (Linnaeus, 1758)	Italian locust	Necrophage (adults are necrophagous, possibly to ingest minerals)	Wildlife (roe deer)	[14]
Camponotus aethiops (Latreille, 1798)	None*	Necrophile (adult ants feed on fly larvae)	Livestock (pig)	[82]
Camponotus americanus Mayr, 1862	None*	NS	Wildlife (alligator, bear, deer); livestock (pig)	[16, 32]
Camponotus floridanus (Buckley, 1866)	Florida carpenter ant	Facultative necrophage; this species also feeds on honey & nectar	Livestock viscera (cow liver); poultry (chicken)	[83-85]
Camponotus pennsylvanicus (De Geer, 1773)	Black carpenter ant	Necrophile (adult ants are necrophilous, feeding on larvae at carrion)	Wildlife (bear, alligator, deer); livestock (pig)	[16]
Camponotus sericeus (Fabricius, 1798)	Giant carpenter ant	NS	Wildlife (rabbit); livestock (pig)	[86, 87]
Camponotus sylvaticus (Olivier, 1792)	None*	NS	Livestock (pig)	[36, 88]
Canthidium (Neocanthidium) manni Arrow, 1913	None*	Thought to be necrophagous &/or necrophilous	Wildlife (small vertebrates); livestock (pig)	[43, 89]
Canthon (Francmonrosia) carbonarius Harold, 1868	None*	NS	Livestock (pig) & livestock viscera (cow spleen)	[43, 90]
Canthon (Canthon) cyanellus LeConte, 1859	None*	Necrophage	Wildlife (mouse, lizard, frog); aquatic life (fish)	[91-93]

Canthon (Canthon) ornatus Redtenbacher, 1868	None*	Necrophage	Livestock (pig)	[44]
Canthon (Francmonrosia) rutilans Castelnau, 1840	None*	Thought to be necrophagous &/or necrophilous	Wildlife (rat)	[43]
Canthon (Canthon) virens (Mannerheim, 1828)	None*	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[43]
Carabus auronitens Fabricius, 1792	None*	Necrophile (feeds on other carrion inhabitants)	Wildlife (rat, roe deer)	[33, 75]
Carabus nemoralis O.F. Müller, 1764	Bronze carabid	Necrophile (feeds on other carrion inhabitants)	Wildlife (roe deer); livestock (pig)	[33, 94]
Carabus problematicus Herbst, 1786	None*	Necrophile (feeds on other carrion inhabitants)	Wildlife (roe deer)	[33]
Carcinops pumilio (Erichson, 1834)	Poultryhouse pill beetle	Necrophile (beetle larvae & adult beetles are necrophilous, feeding on fly eggs at carrion)	Wildlife (alligator, bear, deer); livestock (pig)	[19, 29, 32]
Catops simplex Say, 1825	Small scavenger beetle	Necrophage	Wildlife (alligator, deer, rabbit, snail); livestock (pig)	[16, 95, 96]
Celastrina argiolus (Linnaeus, 1758)	Holly blue	Facultative necrophage (adult butterflies suck on carcasses, possibly to ingest sodium)	Wildlife (wild boar, badger, red deer, roe deer, mouflon)	[14]
Centrophlebomyia furcata (Fabricius, 1794)	European bone-skipper	Obligate necrophage (fly larvae are necrophagous, feeding on bone marrow)	Wildlife (red deer, mouflon); livestock (pig, mule, sheep)	[65]
Ceratophaga vastella (Zeller, 1852)	Horn moth	Necrophage (moth larvae are necrophagous)	Wildlife (antelope horns & hooves)	[53, 97]
Chaetodus (Chaetodus) exaratus Arrow, 1909	None*	Thought to be necrophagous &/or necrophilous	Wildlife (rabbit)	[43]
Chalconotus convexus Boheman, 1857	None*	Facultative necrophage; this species also feeds on dung	Wildlife (antelope)	[53]
Chloroprocta idioidea (Robineau-Desvoidy, 1830)	None*	Necrophage	Wildlife (rat); marine life (sardine); livestock (pig); livestock & poultry viscera (pig, cow, chicken); fishing discards (fish heads)	[13, 39, 40, 49, 98-100]
Chrysomya albiceps (Wiedemann, 1819)	Green bottle	Necrophage & necrophile† (fly larvae are necrophagous & also	Wildlife (wolf, rat, antelope, rabbit); marine life (sardine, goatfish, squid);	[31, 36, 39, 40, 46, 49,

		necrophilous, feeding on allospecific & conspecific fly larvae)	human remains; livestock (pig, sheep); poultry (chicken); livestock, poultry & fish viscera (pig, cow, chicken, fish)	52, 53, 57, 64, 66, 67, 69, 97-99, 101-105]
Chrysomya chani Kurahashi, 1979	None*	Necrophage	Wildlife (rabbit); livestock viscera (pig)	[106-108]
Chrysomya chloropyga (Wiedemann, 1818)	None*	Necrophage	Wildlife (antelope); livestock (pig, sheep); livestock viscera (cow liver)	[53, 67, 86, 97, 103, 104]
Chrysomya incisuralis (Macquart, 1851)	None*	Necrophage (fly larvae are necrophagous)	Human remains; livestock (pig)	[109, 110]
Chrysomya marginalis Wiedemann, 1830	Regal blowfly	Necrophage (fly larvae are necrophagous)	Wildlife (antelope, rabbit); livestock (sheep)	[53, 57, 101, 104]
Chrysomya megacephala (Fabricius, 1794)	Oriental latrine fly	Facultative necrophage (fly larvae & adult flies are necrophagous); this species also feeds on living tissue	Wildlife (coyote, alligator, otter, rat, rabbit); marine life (sardine, goatfish); human remains; livestock (pig); poultry (chicken); livestock, poultry & fish viscera (pig, cow, chicken, fish)	[29, 37, 39, 40, 46, 48, 51, 55, 57, 59, 66-68, 98, 99, 103, 106, 111-117]
Chrysomya nigripes Aubertin, 1932	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rabbit); human remains; livestock (pig); poultry (chicken)	[48, 107, 109, 117]
Chrysomya pinguis (Walker, 1858)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rabbit); human remains; livestock (pig); livestock viscera (pig)	[59, 106-108, 114, 118]
Chrysomya putoria (Wiedemann, 1830)	Tropical African latrine blow fly	Facultative necrophage & necrophile† (fly larvae are necrophagous &, if food is scarce or other larvae are injured, they will feed on other fly larvae); this species also feeds on excrement & occasionally living tissue	Wildlife (rat, antelope); marine life (sardine, goatfish); livestock (pig, sheep); livestock, poultry & fish viscera (pig, cow, chicken, fish)	[39, 40, 46, 49, 53, 57, 97-99, 104, 119]
Chrysomya rufifacies (Macquart, 1844) = *Achoetandrus rufifacies* (Macquart, 1843)	Hairy maggot blow fly	Necrophage & necrophile† (fly larvae are necrophagous & also necrophilous, feeding on other fly larvae; adult flies are necrophilous,	Wildlife (coyote, opossum, bear, bobcat, otter, alligator, raccoon, deer, rabbit); human remains; livestock (pig); livestock viscera	[16, 48, 51, 55, 59, 97, 106, 109, 113, 114,

		feeding on other carrion inhabitants)	(pig); poultry (chicken)	116, 117, 120, 121]
Chrysomya thanomthini Kurahashi & Tumrasvin, 1977	None*	NS	Wildlife (rabbit); livestock viscera (pig)	[106, 108]
Chrysomya villeneuvi Patton, 1922 = *Achoetandrus villeneuvi* (Patton, 1922)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rabbit); human remains; livestock viscera (pig)	[106-108, 118]
Cicindela sexguttata Fabricius, 1775	Six-spotted green tiger beetle	NS	Wildlife (bear, deer); livestock (pig)	[16, 94]
Cnemotrupes semiopacus (Jekel, 1865)	Blackburn's earth boring beetle	NS	Wildlife (bear, deer, alligator); livestock (pig)	[16, 29]
Cnemotrupes splendidus (Fabricius, 1775)	Splendid earth boring beetle	NS	Wildlife (bear, alligator, deer); livestock (pig)	[16, 29]
Cochliomyia macellaria (Fabricius, 1775)	Secondary screwworm	Facultative necrophage (fly larvae & adults are both necrophagous); this species also feeds on living tissue	Wildlife (opossum, bear, alligator, rat, deer); marine life (seagull); human remains; livestock (pig); livestock, poultry & fish viscera (pig, cow, chicken, fish)	[5, 16, 18, 29, 39, 40, 49, 55, 57, 68, 70, 98, 99, 103, 113, 122, 123]
Coelopa frigida (Fabricius, 1805)	Kelp fly	Necrophage (adult flies are necrophagous)	Marine life (seagull)	[5]
Coenonympha pamphilus (Linnaeus, 1758)	Small heath	Facultative necrophage (adult butterflies suck on carcasses, possibly to ingest sodium)	Wildlife (wild boar, badger, red deer, roe deer, mouflon)	[14]
Conicera tibialis Schmitz, 1925	Coffin fly	Necrophage (fly larvae are necrophagous)	Human remains	[37, 97]
Conocephalus (Anisoptera) fuscus (Fabricius, 1793)	Long-winged conehead	Possible necrophage (adult crickets are thought to be necrophagous)	Wildlife (wild boar, deer)	[14]
Coproica spp. Rondani, 1861	None*	Facultative necrophages; these species also feed on dung	Wildlife (bear, alligator, deer, antelope); livestock (pig)	[16, 53, 123]
Coprophanaeus (Megaphanaeus) ensifer (Germar, 1821)	None*	Necrophage (adult beetles are necrophagous)	Human remains; livestock (pig)	[29, 43, 124]

Coprophanaeus (Megaphanaeus) lancifer (Linnaeus, 1767)	Pikenträger	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[43]
Coprophanaeus (Metallophanaeus) pertyi (Olsoufieff, 1924)	None*	Necrophage	Livestock viscera (cow spleen)	[90]
Coprophanaeus (Metallophanaeus) saphirinus (Sturm, 1826)	None*	Thought to be necrophagous &/or necrophilous	Wildlife (rat)	[43]
Cosmina limbipennis (Macquart, 1848)	None*	NS	Livestock viscera (pig, cow)	[106, 125]
Crematogaster liengmei Forel, 1894	None*	Necrophage & necrophile† (adult ants are necrophagous & also necrophilous, feeding on fly eggs, larvae & adults)	Livestock (pig)	[126]
Crematogaster scutellaris (Olivier, 1792)	Fourmi du liège	Necrophage & necrophile† (adult ants are necrophagous & also necrophilous, feeding on fly eggs)	Livestock (pig)	[82]
Creophilus maxillosus (Linnaeus, 1758)	Hairy rove beetle	Facultative necrophage & necrophile† (beetle larvae & adult beetles are necrophagous & also necrophilous, feeding on fly larvae & conspecific larvae); this species also feeds on live ants, termites, earthworms & injured conspecific adults	Wildlife (coyote, fox, wolf, bear, alligator, lizard, badger, rat, porcupine, deer, rabbit); marine life (seagull, squid); human remains; livestock (pig)	[5, 16-18, 21, 29, 31, 33, 34, 36, 37, 52, 55, 64, 72, 94, 103, 114, 127]
Crumomyia pedestris (Meigen, 1830)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (snail)	[128]
Cynomya cadaverina Robineau-Desvoidy, 1830	Shiny blue bottle fly	Necrophage	Wildlife (alligator); livestock (pig)	[16, 70, 74]
Cynomya mortuorum (Linnaeus, 1761)	Bluebottle blow fly	Necrophage (fly larvae are necrophagous)	Wildlife (wolf); human remains; livestock (pig); livestock viscera (cow)	[29, 31, 74, 129]
Cyrtoneurina maculipennis (Macquart, 1844)	None*	NS	Wildlife (rat); marine life (goatfish)	[46, 130]

Decticus verrucivorus (Linnaeus, 1758)	Wart-biter	Necrophage (adult crickets are necrophagous)	Wildlife (wild boar, deer)	[14]
Delia platura (Meigen, 1826)	Bean seed fly	Necrophile (feeds on other carrion inhabitants)	Livestock (pig)	[17]
Deltochilum (Euhyboma) brasiliense (Castelnau, 1840)	None*	NS	Human remains	[29, 131]
Deltochilum (Parahyboma) furcatum (Castelnau, 1840)	None*	Facultative necrophage; this species also feeds on dung	NS	[91, 132]
Deltochilum (Hybomidium) gibbosum (Fabricius, 1775)	Humpback dung beetle; Tumblebug	Facultative necrophage (beetle larvae are necrophagous); this species also feeds on excrement & decaying vegetation	Wildlife (bear, deer); livestock (pig); poultry (chicken)	[16, 37]
Deltochilum verruciferum Felsche, 1911	None*	Facultative necrophage (adult beetles are necrophagous); the feeding preference of this species is for carrion & excrement	Livestock (pig); livestock viscera (cow spleen)	[43, 90]
Dendroxena sexcarinata Motschulsky, 1861	None*	Necrophage (beetle larvae & adult beetles are necrophagous)	Livestock (cow); poultry (chicken)	[133]
Dermestes (Dermestes) ater DeGeer, 1774	Black larder beetle; Incinerator beetle	Facultative necrophage (beetle larvae are necrophagous); this species also feeds on mushrooms & cheese	Wildlife (coyote); human remains; livestock (pig)	[29, 37, 55, 73, 97, 103]
Dermestes caninus Germar, 1824	None*	Facultative necrophage (beetle larvae & adult beetles are necrophagous)	Wildlife (bear, alligator, deer); marine life (seagull); human remains; livestock (pig)	[5, 16, 37]
Dermestes frischii Kugelman, 1792	None*	Necrophage (beetle larvae are necrophagous)	Wildlife (red fox, wolf, rabbit); marine life (squid); human remains; livestock (pig)	[17, 20, 21, 29, 31, 36, 52, 96, 97, 105, 134, 135]
Dermestes haemorrhoidalis Küster, 1852	Husklanner	Necrophage (beetle larvae are necrophagous)	Human remains; livestock (cow)	[97, 134, 136]
Dermestes maculatus DeGeer, 1774	Hide beetle	Facultative necrophage (beetle larvae & adult beetles are necrophagous); adult beetles are also necrophilous,	Wildlife (rat, mouse, antelope, rabbit); human remains; livestock (pig, sheep)	[20, 43, 51, 53, 68, 73, 86, 97, 101-

		feeding on fly larvae at carrion		105, 114, 116, 134, 137-140]
Dermestes peruvianus Laporte de Castelnau, 1840	Peruvian larder beetle	Necrophage	Wildlife (rabbit); livestock (pig)	[34, 43, 97]
Dermestes tessellatocollis Motschulsky, 1860	None*	Necrophage (beetle larvae & adult beetles are necrophagous)	Human remains; livestock (pig)	[134, 138, 141]
Dermestes (Dermestinus) undulatus Brahms, 1790	None*	Necrophage (beetle larvae are necrophagous)	Wildlife (red fox, badger); marine life (squid); livestock (pig)	[20, 21, 36, 52, 64, 72]
Dexosarcophaga carvalhoi (Lopes, 1980)	None*	NS	Livestock (pig); livestock viscera (cow)	[13, 39, 42, 142]
Dibelonetes hybridus (Erichson, 1840)	None*	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[43]
Dichotomius (Selenocopris) geminatus (Arrow, 1913)	None*	Thought to be necrophagous &/or necrophilous	Wildlife (small vertebrates); livestock (pig); livestock viscera (cow spleen)	[43, 89, 90]
Dichotomius (Selenocopris) louzadai Nunes, Carvalho & Vaz-de-Mello, 2016	None*	Necrophage	Aquatic life (fish); livestock (cow)	[91, 143]
Dichotomius nisus (Olivier, 1789)	None*	Thought to be necrophagous &/or necrophilous; this relationship is facultative because the species also feeds on dung	Livestock (pig); livestock viscera (cow spleen)	[13, 43, 90]
Dinoponera quadriceps Kempf, 1971	None*	Facultative necrophage; this species also feeds on live prey, seeds & fruit	Wildlife (insects, arachnids)	[144]
Diplonevra funebris (Meigen, 1830)	None*	Necrophage	Livestock (pig)	[28, 145]
Diplonevra peregrina Wiedemann, 1830	Hump-backed fly	Necrophage	Livestock (pig)	[28, 145]
Dissochaetus amazonicus Gnaspini, 1999	None*	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[43]
Dissochaetus murrayi Reitter, 1884	None*	Necrophage	Wildlife (rat, rabbit)	[43, 130]
Dohrniphora spp. Dahl, 1898	Scuttle flies	Facultative necrophages	Wildlife (bear, deer, snail)	[16, 146]

Dorylus spp. Fabricius, 1793	Driver ants; Safari ants	Necrophages & necrophiles (feed on fly larvae at carrion)	Wildlife (antelope)	[53, 97]
Emus hirtus (Linnaeus, 1758)	Hairy rove-beetle	Necrophile (adult beetles are necrophilous, feeding on fly larvae at carrion)	Wildlife (hedgehog, red deer, roe deer)	[147]
Ephydra (Ephydra) riparia Fallén, 1813	None*	Necrophage (adult flies are necrophagous)	Marine life (seagull)	[5]
Eulissus chalybaeus Mannerheim, 1830	None*	Thought to be necrophagous &/or necrophilous	Wildlife (rat); livestock (pig)	[13, 43]
Eurysternus parallelus Castelnau, 1840	None*	Thought to be necrophagous &/or necrophilous	Human remains; livestock (pig)	[29, 43]
Euspilotus assimilis (Paykull, 1811)	None*	Necrophile (feeds on other carrion inhabitants)	Wildlife (bear, alligator, deer); livestock (pig)	[16, 18, 94]
Euspilotus azurescens (Marseul, 1855)	None*	Thought to be necrophagous &/or necrophilous	Wildlife (bear, alligator, deer, rabbit); livestock (pig)	[16, 43, 148]
Euspilotus lacordairei (Marseul, 1855)	None*	Necrophile	Livestock (pig)	[44]
Euspilotus modestus (Erichson, 1834)	None*	Thought to be necrophagous &/or necrophilous	Wildlife (rabbit); livestock (pig)	[101, 148]
Euspilotus ornatus (Blanchard, 1843)	None*	Necrophile	Livestock (pig)	[44]
Euspilotus patagonicus (Blanchard, 1843)	None*	Necrophile	Livestock (pig)	[44]
Euspilotus pavidus (Erichson, 1834)	None*	Necrophile	Livestock (pig)	[44]
Euxesta spp. Loew, 1868	Picture-winged flies	NS	Wildlife (bear, alligator); marine life (sardine); livestock & poultry viscera (cow, chicken)	[16, 149]
Fannia canicularis (Linnaeus, 1758)	Little house fly	Facultative necrophage (fly larvae & adults are both necrophagous); this species also feeds on excrement & living tissue	Wildlife (coyote, bear, alligator, deer, rabbit); marine life (seagull); human remains; livestock (pig); poultry & poultry viscera (chicken)	[5, 16, 29, 37, 49, 55, 69, 74, 108, 148, 150]
Fannia pusio (Wiedemann, 1830)	Chicken dung fly	Necrophage (fly larvae are necrophagous)	Wildlife (rat); marine life (goatfish); livestock (pig)	[13, 40, 41, 46]
Fannia scalaris De Geer, 1776	Latrine fly	Necrophage (fly larvae are necrophagous)	Wildlife (coyote, bear, alligator, deer); marine life (goatfish);	[16, 46, 49, 55, 151]

			livestock (pig)	
Fannia trimaculata (Stein, 1898)	None*	Facultative necrophage (fly larvae are necrophagous); this species also feeds on dung	Wildlife (rat); marine life (goatfish)	[46]
Fannia yenhedi Albuquerque, 1957	None*	NS	Wildlife (rat); marine life (goatfish); livestock (pig)	[13, 40, 46, 49]
Formica spp. Linnaeus, 1758	Wood ants	Facultative necrophages & necrophiles† (adult ants are both necrophagous & necrophilous); some species also feed on fungi	Wildlife (wild boar, badger, red deer, roe deer, mouflon, fruit fly, allospecific & conspecific adult ants); livestock (pig)	[14, 36, 152, 153]
Galerita (Galerita) melanarthra Chaudoir, 1869	None*	Necrophile (feeds on other carrion inhabitants)	Livestock (pig)	[154]
Geotrupes stercorarius (Linnaeus, 1758)	None*	Facultative necrophage; this species also feeds on dung	Wildlife (wolf, roe deer)	[29, 31, 33]
Gymnophora spp. Macquart, 1835	Scuttle flies	Necrophages	Wildlife (alligator, deer, slug)	[16, 155]
Helicobia aurescens (Townsend, 1927)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rodent); livestock (pig); livestock viscera (cow); companion animals (dog)	[13, 39, 42, 142, 156, 157]
Helicobia borgmeieri Lopes, 1939	None*	NS	Livestock (pig); livestock viscera (cow)	[13, 39, 42, 142]
Helicobia morionella (Aldrich, 1930)	None*	NS	Livestock (pig); livestock viscera (cow)	[13, 39, 42, 142]
Helicobia pilifera Lopes, 1939	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rat); livestock viscera (cow)	[39, 41, 42]
Helicobia pilipleura Lopes, 1939	None*	NS	Livestock (pig); livestock viscera (cow)	[39, 42, 158]
Helicobia rapax (Walker, 1849)	None*	Thought to be necrophagous &/or necrophilous; this relationship is facultative because the species also parasitizes land snails	Livestock (pig); livestock viscera (cow)	[13, 18, 39, 42, 142]
Hemilucilia segmentaria Fabricius, 1805	None*	Necrophage (fly larvae are necrophagous)	Marine life (sardine); livestock (pig, cow); livestock, poultry & fish viscera (pig, cow, chicken, fish)	[13, 39, 98, 99, 137, 159, 160]

Hemilucilia semidiaphana (Rondani, 1850)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rat); marine life (sardine, goatfish); livestock (pig); livestock & poultry viscera (pig, cow, chicken); fishing discards (fish heads)	[39, 46, 98-100, 130, 160]
Hemilucilia souzalopesi Mello, 1972	None*	Necrophage	Livestock (pig)	[98]
Hemipyrellia fernandica (Macquart, 1855)	None*	Necrophage (fly larvae are necrophagous)	Livestock (cow); companion animals (guinea pig)	[97, 161]
Hemipyrellia ligurriens (Wiedemann, 1830)	None*	Facultative necrophage (fly larvae are necrophagous); this species also feeds on excrement	Wildlife (rabbit); human remains; livestock viscera (pig, cow); poultry (chicken)	[48, 106-108, 112, 162-164]
Hemipyrellia pulchra (Wiedemann, 1830)	None*	Necrophage	Livestock viscera (pig, cow); poultry (chicken)	[48, 106, 164, 165]
Hemipyrellia tagaliana (Bigot, 1877)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rabbit)	[107, 108, 121]
Hermetia illucens (Linnaeus, 1758)	Black soldier fly	Facultative necrophage (fly larvae are necrophagous); this species also feeds on decaying vegetation & excrement	Wildlife (bear, otter, deer); human remains; livestock (pig)	[16, 37, 49, 55, 97, 114, 160, 166]
Heterosilpha ramosa (Say, 1823)	Garden carrion beetle	Necrophage & necrophile† (beetle larvae & adult beetles are necrophagous & also necrophilous, feeding on fly larvae at carrion)	Human remains	[37]
Hipparchia semele (Linnaeus, 1758)	Grayling	Facultative necrophage (adult butterflies suck on carcasses, possibly to ingest sodium); this species mostly feeds on plants	Wildlife (wild boar, badger, red deer, roe deer, mouflon)	[14, 167]
Hister abbreviatus Fabricius, 1775	None*	Necrophage & necrophile† (beetle larvae & adult beetles are necrophagous & also necrophilous, feeding on eggs & larvae at carrion)	Wildlife (bear, alligator, deer); livestock (pig)	[16, 18, 37]
Hister coenosus Erichson, 1834	None*	Necrophage & necrophile† (beetle larvae & adult beetles are necrophagous & also necrophilous, feeding on eggs & larvae at carrion)	Wildlife (bear); livestock (pig)	[16, 18, 37]

Hister depurator Say, 1825	None*	Necrophage & necrophile† (beetle larvae & adult beetles are necrophagous & also necrophilous, feeding on eggs & larvae at carrion)	Wildlife (bear, alligator, deer); livestock (pig)	[16, 37]
Hister grandicollis Illiger, 1807	None*	Necrophage & necrophile† (beetle larvae & adult beetles are necrophagous & also necrophilous, feeding on eggs & larvae at carrion)	Livestock (pig)	[36, 37]
Hister quadrinotatus Scriba, 1790	None*	Necrophage & necrophile† (beetle larvae & adult beetles are necrophagous & also necrophilous, feeding on eggs & larvae at carrion)	Livestock (pig)	[20, 37]
Hister unicolor Linnaeus, 1758	None*	Facultative necrophage & necrophile† (beetle larvae & adult beetles are necrophagous & also necrophilous, feeding on eggs & larvae at carrion); this species also feeds on dung	Wildlife (rat, rabbit)	[34, 37, 75]
Hydrotaea aenescens (Wiedemann, 1830)	Dump fly	Necrophage & necrophile† (fly larvae are necrophagous & also necrophilous, feeding on other fly larvae)	Wildlife (rat); marine life (goatfish); human remains; livestock (pig)	[13, 40, 41, 46, 49, 73, 74, 97, 123, 148]
Hydrotaea chalcogaster (Wiedemann, 1824)	None*	Facultative necrophage & necrophile† (fly larvae are necrophagous & also necrophilous, feeding on other fly larvae); this species feeds on dung & decaying vegetation too	Wildlife (rat, rabbit); marine life (goatfish); livestock (pig); poultry (chicken)	[40, 46, 48, 49, 51, 97, 107, 121]
Hydrotaea dentipes (Fabricius, 1805)	None*	Facultative necrophage & necrophile† (fly larvae are necrophagous & also necrophilous, feeding on other fly larvae); this species feeds on dung too	Wildlife (wolf, bear, alligator, deer, rabbit); marine life (squid); livestock (pig)	[16, 31, 34, 52, 74, 97, 168]
Hydrotaea hennigi Pont, 1985	None*	Necrophage & necrophile† (fly larvae are necrophagous & also necrophilous, feeding on other fly	Wildlife (rabbit); poultry (chicken)	[48, 97, 121]

		larvae)		
Hydrotaea ignava (Harris, 1780)	None*	Facultative necrophage & necrophile† (fly larvae are necrophagous & also necrophilous, feeding on other fly larvae); this species feeds on excrement too	Wildlife (bear, alligator, rat, deer); marine life (squid); human remains; livestock (pig)	[16, 18, 37, 47, 52, 64, 74, 97, 168, 169]
Hydrotaea meridionalis Portschinsky, 1882	None*	Necrophage & necrophile† (fly larvae are necrophagous & also necrophilous, feeding on other fly larvae)	Livestock (pig)	[36, 97]
Hydrotaea similis Meade, 1887	None*	Necrophage (fly larvae are necrophagous)	Wildlife (wolf, rat)	[31, 75]
Hydrotaea spinigera (Stein, 1910)	None*	Necrophage (fly larvae are necrophagous)	Human remains; livestock (pig)	[59, 117]
Hypocaccus rugifrons (Paykull, 1798)	None*	Necrophile (feeds on other carrion inhabitants)	Wildlife (roe deer)	[33]
Hypopygiopsis fumipennis (Walker, 1856)	None*	Necrophage	Wildlife (rabbit)	[107, 108]
Hypopygiopsis infumata (Bigot 1877)	None*	NS	Livestock viscera (pig, cow)	[106, 164]
Hypopygiopsis tumrasvini Kurahashi, 1977	None*	NS	Livestock viscera (pig, cow)	[106, 164]
Hypopygiopsis violacea (Macquart, 1835)	None*	Necrophage	Wildlife (rabbit)	[107, 108]
Idiella divisa (Walker, 1861)	None*	NS	Livestock viscera (pig, cow)	[106, 125]
Idiella euidielloides Senior-White, 1922	None*	NS	Livestock viscera (pig, cow)	[106, 125]
Isomyia viridaurea (Wiedemann, 1819)	None*	NS	Livestock viscera (pig, cow)	[106, 125]
Labarrus pseudolividus (Balthasar, 1941)	None*	Necrophage	Livestock (pig)	[43, 44]
Lagria villosa (Fabricius, 1781)	None*	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[13, 43]
Lebia (Lebia) viridis Say, 1823	Flower Lebia beetle	Necrophage & necrophile (feeds on other carrion inhabitants)	Marine life (seagull)	[5]

Leptocera caenosa (Rondani, 1880)	None*	NS	Wildlife (alligator, deer); livestock (pig); poultry viscera (chicken)	[16, 170]
Limenitis arthemis Drury, 1773	Red-spotted admiral	NS	Livestock (pig)	[16, 171]
Limosina calcarifera Roháček, 1975	None*	Necrophage (fly larvae are necrophagous)	Wildlife (moth)	[128]
Limosina palmata (Richards, 1927)	None*	Facultative necrophage (fly larvae are necrophagous); this species also feeds on wheat grains	Wildlife (slug); livestock viscera (cow)	[128]
Limosina parapusio Dahl, 1909	None*	Facultative necrophage (fly larvae are necrophagous); this species also feeds on fungi	Wildlife (invertebrates)	[128]
Lotophila atra Meigen, 1830	None*	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[18]
Lucilia ampullacea Villeneuve, 1922	Streakless greenbottle	Necrophage (fly larvae are necrophagous)	Wildlife (wolf, mouse, rabbit); human remains; livestock viscera (pig, cow)	[31, 79, 80, 116, 172, 173]
Lucilia caeruleiviridis Macquart, 1855	Green bottle fly	Necrophage (fly larvae are necrophagous)	Wildlife (coyote, opossum, bear, bobcat, otter, alligator, raccoon, deer); livestock (pig)	[16, 18, 37, 55, 57, 70, 113, 122]
Lucilia caesar Linnaeus, 1758	Common greenbottle	Facultative necrophage (fly larvae are necrophagous); this species also feeds on living tissue	Wildlife (wolf, rat, mouse); marine life (squid); livestock (pig); poultry (chicken)	[29, 31, 36, 52, 64, 69, 74, 75, 80-82]
Lucilia cluvia (Walker, 1849)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (alligator); livestock (pig); livestock viscera (cow liver)	[67, 103, 113]
Lucilia cuprina (Wiedemann, 1830) = *Phaenicia pallescens* Shannon, 1924	Australian sheep blow fly	Facultative necrophage (fly larvae are necrophagous); this species also feeds on living tissue (especially in sheep) & decaying fruit	Wildlife (antelope, rabbit); human remains; livestock (pig, sheep); livestock viscera (pig, cow)	[13, 37, 53, 57, 66, 67, 87, 104, 106, 114, 117, 164, 174]
Lucilia eximia (Wiedemann, 1819)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rat); marine life (sardine); livestock (pig); livestock, poultry & fish viscera (pig, cow, chicken, fish)	[13, 16, 39, 47, 49, 67, 98, 99, 130]
Lucilia illustris Meigen, 1826	Green bottle fly	Necrophage (fly larvae & adults are both necrophagous)	Wildlife (wolf, badger, rabbit), marine life (seagull); livestock (pig)	[5, 18, 31, 51, 57, 68,

				72, 116]
Lucilia papuensis Macquart, 1844	None*	Necrophage	Livestock viscera (pig, cow)	[106, 164, 165]
Lucilia porphyrina (Walker, 1856)	None*	Necrophage (fly larvae are necrophagous)	Human remains; livestock viscera (pig, cow)	[106, 112, 118, 164]
Lucilia sericata (Meigen, 1826)	Common green bottle fly	Facultative necrophage (fly larvae & adult flies are necrophagous); this species also feeds on living tissue (especially in sheep)	Wildlife (wolf, bear, alligator, badger, mouse, deer, antelope, rabbit); marine life (gray seal, squid); human remains; livestock (pig, cow); livestock viscera (cow liver); poultry (chicken); companion animals (guinea pig)	[16, 18, 29, 31, 34, 36, 51-53, 57, 59, 66, 67, 69, 71, 72, 78-80, 82, 96, 114, 115, 161, 175]
Lucilia silvarum (Meigen, 1826)	Common toad fly	Necrophage	Wildlife (rabbit)	[34]
Lucilia sinensis Aubertin, 1933	None*	NS	Livestock viscera (pig, cow)	[106, 164]
Macronychia aurata (Coquillett, 1902)	None*	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[18]
Malacophagomyia filamenta (Dodge, 1964)	None*	NS	Livestock (pig); livestock viscera (cow)	[13, 39, 42, 176]
Margarinotus marginatus (Erichson, 1834)	None*	NS	Livestock (pig)	[36, 74]
Margarinotus (Ptomister) striola (C.R. Sahlberg, 1819)	None*	Necrophile (feeds on other carrion inhabitants)	Wildlife (rat, roe deer)	[33, 75]
Megaselia rufipes (Meigen, 1804)	Coffin fly	Facultative necrophage (fly larvae are necrophagous); this species also feeds on dung, decaying vegetation & fungi	Wildlife (insects); human remains; livestock (cow)	[29, 177]
Megaselia scalaris Loew, 1866	Humpbacked fly; Scuttle fly	Facultative necrophage (fly larvae are necrophagous); this species also feeds on vegetation & excrement	Wildlife (raccoon, rabbit); human remains; livestock (pig)	[13, 17, 37, 49, 50, 55, 103, 105, 117, 123, 137, 148,

				160, 178]
Melanolestes picipes (Herrich-Schaeffer, 1848)	Black corsair; Black May beetle-eater	Necrophile (feeds on other carrion inhabitants)	Wildlife (bear, alligator); livestock (pig)	[16, 179]
Melanoplus sanguinipes (Fabricius, 1798)	Migratory grasshopper	Facultative necrophage	Wildlife (conspecific & allospecific grasshoppers)	[180]
Meroplius minutus (Wiedemann, 1830)	None*	NS	Wildlife (alligator, deer); livestock (pig); slaughterhouse discards	[16, 181]
Mesembrinella batesi Aldrich, 1922	None*	Necrophage	Livestock viscera (cow); fishing discards (fish heads)	[98, 100]
Mesembrinella bellardiana Aldrich, 1922	None*	Necrophage	Marine life (goatfish); livestock (pig); livestock, poultry & fish viscera (cow, chicken, fish)	[46, 98, 160]
Mesembrinella benoisti (Séguy, 1925)	None*	Necrophage	Livestock, poultry & fish viscera (pig, cow, chicken, fish)	[98]
Mesembrinella bicolor Fabricius, 1893	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rat); marine life (sardine, goatfish); livestock & poultry viscera (cow, chicken)	[46, 98, 99]
Mesembrinella quadrilineata (Fabricius, 1805)	None*	Necrophage	Livestock viscera (cow)	[98]
Mesembrinella randa (Walker, 1849)	None*	Necrophage	Livestock, poultry & fish viscera (cow, chicken, fish)	[98]
Metopina sagittata Liu	None*	Necrophage	Livestock (pig)	[28]
Minilimosina parvula (Stenhammar, 1855)	None*	Facultative necrophage (fly larvae are necrophagous); this species also feeds on fungi	Wildlife (slug, moth); livestock viscera (cow)	[128]
Monomorium spp. Mayr, 1855	Pharaoh ants	NS	Wildlife (bear, deer); livestock (pig)	[16, 182]
Monotoma picipes Herbst, 1793	Root-eating beetle	Necrophage & necrophile (feeds on other carrion inhabitants)	Marine life (seagull)	[5]
Musca autumnalis De Geer, 1776	Facefly	Facultative necrophage (fly larvae are necrophagous); this species also feeds on excrement	Human remains; livestock (pig)	[29, 148, 168]
Musca domestica Linnaeus, 1758	Housefly	Facultative necrophage (fly larvae are necrophagous); this species also feeds on excrement & living tissue	Wildlife (coyote, otter, bobcat, rat, raccoon, antelope, rabbit); marine life (squid); human remains;	[18, 29, 34, 36, 40, 41, 46-50, 52,

			livestock (pig); poultry (chicken); livestock viscera (cow)	53, 55, 66, 69, 73, 86, 97, 101, 103, 105, 111, 114, 116, 148]
Musca pattoni Austen, 1910	None*	NS	Wildlife (rabbit); poultry (chicken)	[48, 51]
Musca sorbens Wiedemann, 1830	Bazaar fly	Facultative necrophage (fly larvae are necrophagous); this species also feeds on excrement	Wildlife (antelope, rabbit); poultry (chicken)	[48, 50, 53, 87]
Musca ventrosa Wiedemann, 1830	None*	NS	Wildlife (rabbit); livestock (pig); poultry (chicken)	[48, 51, 114]
Muscina levida (Harris, 1780)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (badger); marine life (squid); livestock (pig); livestock viscera (goat)	[36, 52, 72, 77, 168]
Muscina pascuorum (Meigen, 1826)	None*	NS	Livestock (pig)	[64, 168, 169]
Muscina prolapsa (Harris, 1780)	None*	Necrophage (fly larvae are necrophagous)	Marine life (squid); livestock (pig)	[36, 52, 168, 169]
Muscina stabulans (Fallén, 1817)	False stable fly	Facultative necrophage (fly larvae are necrophagous); this species also feeds on excrement	Wildlife (rabbit); marine life (squid); livestock (pig); poultry (chicken)	[36, 50, 52, 69, 97, 103, 123, 168]
Nasonia vitripennis (Walker, 1836)	None*	Necrophile (this species is parasitoid; adult wasps lay their eggs in fly pupae)	Wildlife (antelope); human remains; livestock (pig)	[16, 24, 53, 97]
Necrobia ruficollis (Fabricius, 1775)	Red-shouldered ham beetle	Thought to be necrophagous &/or necrophilous	Wildlife (bear, alligator, deer); livestock (pig)	[16, 18, 20, 43, 103, 114, 138, 148]
Necrobia rufipes (De Geer, 1775)	Redlegged ham beetle	Facultative necrophage & necrophile† (adult beetles are necrophagous & also necrophilous, feeding on eggs & larvae at carrion); this species feeds on figs & palm nut kernels too	Wildlife (coyote, wolf, bear, deer, antelope, rabbit); human remains; livestock (pig, sheep)	[16, 18, 20, 31, 37, 53, 55, 65, 68, 73, 97, 101, 103, 104, 109, 114, 116, 138,

				148, 183]
Necrobia violacea (Linnaeus, 1758)	Blacklegged ham beetle; Clerid beetle	Necrophile (feeds on other carrion inhabitants)	Wildlife (red fox, wolf, rat, roe deer); livestock (pig)	[18, 21, 31, 33, 65, 75]
Necrodes littoralis (Linnaeus, 1758)	Shore sexton beetle	Necrophage & necrophile (feeds on fly larvae at carrion)	Wildlife (wolf, roe deer); marine life (squid); livestock (pig)	[20, 31, 33, 52, 133, 138, 184]
Necrodes nigricornis Harold, 1875	None*	Necrophage	Livestock (pig)	[133, 138]
Necrodes surinamensis (Fabricius, 1775)	Red-lined carrion beetle; Suriname carrion beetle	Necrophage & necrophile† (beetle larvae & adult beetles are necrophagous & also necrophilous, feeding on fly larvae at carrion)	Wildlife (bear, alligator, rat, porcupine, deer, insects); human remains; livestock (pig); poultry (chicken)	[16, 18, 37, 127, 133, 185-188]
Necrophila americana (Linnaeus, 1758)	American carrion beetle	Necrophage & necrophile† (beetle larvae & adult beetles are necrophagous & also necrophilous, feeding on fly & beetle larvae at carrion)	Wildlife (alligator); human remains; livestock (pig); poultry (chicken)	[16, 18, 37, 94, 133, 185, 186]
Necrophila (Calosilpha) brunnicollis (Kraatz, 1877)	Carrion beetle	Necrophage & necrophile (feeds on fly larvae)	Marine life (mackerel)	[133, 189, 190]
Nehemitropia lividipennis (Mannerheim, 1830)	None*	Facultative necrophage; this species also feeds on decaying vegetation	Wildlife (rat)	[75]
Nemopoda nitidula Fallén, 1820	None*	Necrophage (fly larvae are necrophagous)	Livestock (pig)	[169]
Nicrophorus (Nicrophorus) americanus A.G. Olivier, 1790	American burying beetle	Obligate necrophage (beetle larvae & adult beetles are necrophagous)	Wildlife (rat, small birds)	[186, 187, 191]
Nicrophorus (Nicrophorus) antennatus (Reitter, 1884)	None*	Obligate necrophage (beetle larvae & adult beetles are necrophagous)	Wildlife (small birds & mammals)	[184, 191]
Nicrophorus (Nicrophorus) carolinus (Linnaeus, 1771)	None*	Necrophage	Wildlife (rat); poultry (chicken)	[83, 187]
Nicrophorus (Nicrophorus) concolor (Kraatz, 1877)	None*	Obligate necrophage (beetle larvae & adult beetles are necrophagous)	Wildlife (rat, mouse)	[191-193]
Nicrophorus (Nicrophorus) defodiens (Mannerheim, 1846)	None*	Obligate necrophage (beetle larvae & adult beetles are necrophagous)	Wildlife (small birds & mammals); livestock viscera (cow); poultry (chicken)	[83, 185, 191]

Nicrophorus (Nicrophorus) germanicus (Linnaeus, 1758)	None*	Obligate necrophage (beetle larvae & adult beetles are necrophagous)	Wildlife (small birds & mammals); livestock (pig)	[20, 184, 191]
Nicrophorus (Nicrophorus) hebes (Kirby, 1837)	None*	Necrophage	Poultry (chicken)	[185]
Nicrophorus (Nicrophorus) humator (Gleditsch, 1767)	Black sexton beetle	Obligate necrophage (beetle larvae & adult beetles are necrophagous); adult beetles are sometimes necrophilous too, feeding on other carrion inhabitants	Wildlife (rat, mouse, vole, roe deer); marine life (gray seal, squid); human remains; livestock (pig)	[20, 29, 33, 52, 66, 71, 75, 82, 191]
Nicrophorus (Nicrophorus) interruptus (Stephens, 1830) = *Nicrophorus fossor* Erichson, 1837	None*	Obligate necrophage (beetle larvae & adult beetles are necrophagous)	Wildlife (wolf, rat, small birds); marine life (squid)	[31, 52, 75, 184, 191]
Nicrophorus (Nicrophorus) investigator (Zetterstedt, 1824)	None*	Obligate necrophage (beetle larvae & adult beetles are necrophagous); adult beetles are sometimes necrophilous too, feeding on other carrion inhabitants	Wildlife (rat, mouse, rabbit, roe deer)	[33, 37, 75, 96, 191, 194]
Nicrophorus (Nicrophorus) maculifrons (Kraatz, 1877)	None*	Obligate necrophage	Aquatic life (fish)	[192, 195]
Nicrophorus (Nicrophorus) marginatus (Fabricius, 1801)	Margined burying beetle; Margined sexton beetle	Necrophage & necrophile† (beetle larvae & adult beetles are necrophagous & also necrophilous, feeding on fly larvae)	Wildlife (rat, rabbit); livestock (pig)	[18, 19, 37, 96, 186, 187]
Nicrophorus (Nicrophorus) nepalensis (Hope, 1831)	Asian burying beetle	Obligate necrophage (beetle larvae & adult beetles are necrophagous)	Wildlife (rat); poultry (chicken)	[196]
Nicrophorus (Nicrophorus) nigricornis (Faldermann, 1835)	None*	Obligate necrophage (beetle larvae & adult beetles are necrophagous)	Wildlife (small birds & mammals)	[184, 191]
Nicrophorus (Nicrophorus) obscurus (Kirby, 1837)	None*	Necrophage	Wildlife (rat)	[187]
Nicrophorus (Nicrophorus) orbicollis (Say, 1825)	Roundneck sexton beetle	Obligate necrophage (beetle larvae & adult beetles are necrophagous; adult beetles are also necrophilous, feeding	Wildlife (rat, mouse, robin); livestock (pig); livestock viscera (cow); poultry (chicken)	[18, 19, 37, 83, 94, 185-187, 191,

		on fly larvae)		197]
Nicrophorus (Nicrophorus) pustulatus (Herschel, 1807)	Pustulated carrion beetle	Facultative necrophage (beetle larvae & adult beetles are necrophagous, but both also feed on snake eggs)	Wildlife (mouse, rat, fish, small birds); livestock (pig); poultry (chicken)	[94, 185, 187, 191]
Nicrophorus (Nicrophorus) quadripunctatus (Kraatz, 1877)	None*	Obligate necrophage (beetle larvae & adult beetles are necrophagous)	Wildlife (mouse)	[191, 192, 198]
Nicrophorus (Nicrophorus) sayi (Laporte de Castelnau, 1840)	Say's burying beetle	Obligate necrophage (beetle larvae & adult beetles are necrophagous)	Wildlife (small birds & mammals); livestock (pig); livestock viscera (cow); poultry (chicken)	[83, 94, 185, 191]
Nicrophorus (Nicrophorus) sepulchralis (Heer, 1841)	None*	Obligate necrophage (beetle larvae & adult beetles are necrophagous)	Wildlife (small birds & mammals)	[184, 191]
Nicrophorus (Nicrophorus) sepultor (T. Charpentier, 1825)	None*	Obligate necrophage (beetle larvae & adult beetles are necrophagous)	Wildlife (small birds & mammals)	[184, 191]
Nicrophorus (Nicrophorus) tomentosus (Weber, 1801)	Gold-necked carrion beetle	Obligate necrophage (beetle larvae & adult beetles are necrophagous; adult beetles are also necrophilous, feeding on fly larvae)	Wildlife (snake, mouse, rat, robin); marine life (seagull); livestock (pig); livestock viscera (cow); poultry (chicken)	[5, 18, 19, 37, 83, 94, 186, 187, 191, 197]
Nicrophorus (Nicrophorus) vespillo (Linnaeus, 1758)	Common burying beetle	Obligate necrophage (beetle larvae & adult beetles are necrophagous); adult beetles are sometimes necrophilous too, feeding on other carrion inhabitants	Wildlife (rat, marten, mole, roe deer); marine life (squid); livestock (pig)	[33, 52, 75, 191, 199]
Nicrophorus (Nicrophorus) vespilloides Herbst, 1783	Common sexton beetle	Obligate necrophage (beetle larvae & adult beetles are necrophagous); adult beetles are sometimes necrophilous too, feeding on other carrion inhabitants	Wildlife (wolf, rat, mouse, roe deer); livestock (pig)	[19, 31, 33, 75, 191, 200, 201]
Nicrophorus (Nicrophorus) vestigator (Herschel, 1807)	None*	Obligate necrophage (beetle larvae & adult beetles are necrophagous)	Wildlife (small birds & mammals); marine life (squid); livestock (pig)	[20, 52, 184, 191]
Nitidula bipunctata (Linnaeus, 1758)	Two-spotted carrion beetle	Necrophage	Wildlife (rat); livestock (pig)	[36, 75, 202]
Nitidula flavomaculata Rossi, 1790	None*	NS	Wildlife (red fox), marine life (squid); human remains	[21, 52, 65, 203]

Nymphalis antiopa (Linnaeus, 1758)	Camberwell beauty; Mourning cloak	Facultative necrophage (adult butterflies suck on carcasses, possibly to ingest sodium)	Wildlife (wild boar, badger, red deer, roe deer, mouflon)	[14]
Nysius wekiuicola Ashlock & Gagne, 1983	None*	Necrophage	Wildlife (insects)	[204]
Ochlodes sylvanus (Esper, 1777)	Large skipper	Facultative necrophage (adult butterflies suck on carcasses, possibly to ingest sodium)	Wildlife (wild boar, badger, red deer, roe deer, mouflon)	[14]
Oecophylla spp. Smith, 1860	Weaver ants	Necrophiles (feed on fly eggs, fly larvae & adult flies)	Wildlife (monkey, toad); livestock (pig)	[205-208]
Oiceoptoma inaequale (Fabricius, 1781)	Ridged carrion beetle	Necrophage & necrophile (beetle larvae are necrophagous, & adult beetles are necrophilous, feeding on fly larvae)	Wildlife (bear, alligator, deer); human remains; livestock (pig); poultry (chicken)	[16, 37, 185, 186]
Oiceoptoma noveboracense (J.R. Forster, 1771)	Margined carrion beetle	Necrophage & necrophile (feeds on fly larvae at carrion)	Livestock (pig); poultry (chicken)	[94, 185, 186, 209]
Oiceoptoma rugulosum (Portevin, 1903)	None*	Necrophile (beetle larvae & adult beetles feed on fly larvae at carrion)	Wildlife (bear, deer); human remains; livestock (pig)	[16, 37]
Oiceoptoma thoracicum (Linnaeus, 1758)	Red-breasted carrion beetle	Necrophage & necrophile (feeds on other carrion inhabitants)	Wildlife (wolf, rat, roe deer); livestock (pig)	[31, 33, 75, 133, 184]
Omalium rivulare (Paykull, 1789)	Ocillate rove beetle	Thought to be necrophagous &/or necrophilous	Wildlife (wolf, rat, rabbit); livestock (pig)	[25, 31, 75, 202, 210, 211]
Omalodes (Omalodes) bifoveolatus Marseul, 1853	None*	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[43]
Omalodes (Omalodes) foveola Erichson, 1834	None*	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[43]
Omalodes (Omalodes) lucidus Erichson, 1834	None*	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[43]
Omalodes (Omalodes) planifrons Marseul, 1853	None*	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[43]
Omorgus (Afromorgus) drumonti (Pittino, 2011)	None*	Necrophage & necrophile (feeds on other carrion inhabitants)	Wildlife (antelope)	[53]

Omorgus (Afromorgus) mutabilis (Haaf, 1954) = *Trox mutabilis* Haaf, 1954	None*	Necrophage & necrophile (feeds on other carrion inhabitants)	Wildlife (antelope)	[53]
Omorgus radula (Erichson, 1843) = *Trox radula* Erichson, 1843	None*	Necrophage & necrophile (feeds on other carrion inhabitants)	Wildlife (antelope)	[53]
Omorgus (Afromorgus) rusticus (Fåhraeus, 1857) = *Trox rusticus* Fåhraeus, 1857	None*	Necrophage & necrophile (feeds on other carrion inhabitants)	Wildlife (antelope)	[53]
Omorgus squalidus (Olivier, 1789) = *Trox squalidus* Olivier, 1789	None*	Necrophage & necrophile (feeds on other carrion inhabitants)	Wildlife (antelope)	[53]
Omorgus suberosus (Fabricius, 1775) = *Trox suberosus* Fabricius, 1775 = *Trox tuberosus* Laporte de Castelnau, 1840	Hide beetle	Facultative necrophage & necrophile (feeds on other carrion inhabitants)	Wildlife (bear, alligator, antelope); marine life (sea turtle eggs); livestock (pig)	[13, 16, 43, 53, 148, 154, 212]
Omosita colon (Linnaeus, 1758)	Sap-feeding beetle	Facultative necrophage (beetle larvae are necrophagous); this species also feeds on grains & herbs	Wildlife (bear, alligator, rat, deer); human remains; livestock (pig)	[16, 37, 75, 94, 138, 213]
Ontherus (Ontherus) appendiculatus (Mannerheim, 1828)	None*	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[43]
Ontholestes cingulatus (Gravenhorst, 1802)	Gold-and-brown rove beetle	Necrophile (feeds on other carrion inhabitants)	Livestock (pig)	[18, 94]
Onthophagus hecate (Panzer, 1794)	Scooped scarab	Thought to be necrophagous &/or necrophilous; this species also feeds on dung	Wildlife (bear, rat, deer); livestock (pig)	[16, 94, 214, 215]

Onthophagus (Furconthophagus) lamelliger Gerstaecker, 1871	None*	Necrophage	Wildlife (antelope)	[53]
Onthophagus vinctus Erichson, 1843	None*	Necrophage	Wildlife (antelope)	[53]
Opalimosina liliputana (Rondani, 1880)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (moth)	[128]
Operclipygus subterraneus Caterino & Tishechkin, 2013	None*	Thought to be necrophagous &/or necrophilous	Wildlife (rabbit)	[43]
Ophyra capensis (Wiedemann, 1818)	None*	Facultative necrophage (fly larvae are necrophagous) & necrophile (feeds on other carrion inhabitants); this species also feeds on dung	Wildlife (antelope, rabbit); marine life (squid); human remains; livestock viscera (pig)	[50-53, 135]
Oscarinus rusicola (Melsheimer, 1845)	None*	NS	Wildlife (rat, deer)	[16, 214]
Oxelytrum discicolle (Brullé, 1836)	None*	Necrophage (beetle larvae are necrophagous)	Wildlife (opossum, three toed sloth, rat); human remains; livestock (pig); poultry (chicken)	[43, 130, 154, 216]
Oxelytrum erythrurum (É. Blanchard, 1842)	None*	Thought to be necrophagous &/or necrophilous	Wildlife (rabbit); livestock (pig); poultry (chicken)	[43]
Oxypoda (Mycetodrepa) alternans (Gravenhorst, 1802)	None*	Facultative necrophage; this species also feeds on decaying vegetation	Wildlife (rat)	[75]
Oxysarcodexia admixta (Lopes, 1933)	None*	NS	Livestock (pig); livestock viscera (cow); companion animals (dog)	[13, 39, 42, 142, 157, 217]
Oxysarcodexia amorosa (Schiner, 1868)	None*	NS	Wildlife (snake, rat); marine life (sardine); livestock (pig); livestock & poultry viscera (cow, chicken); companion animals (dog)	[39, 42, 47, 49, 99, 157, 218]

Oxysarcodexia aura (Hall, 1937)	None*	NS	Livestock (pig); livestock viscera (cow)	[13, 39, 142]
Oxysarcodexia avuncula (Lopes, 1933)	None*	Necrophage (fly larvae are necrophagous)	Livestock (pig); livestock viscera (cow); companion animals (dog)	[13, 39, 42, 49, 142, 157, 217]
Oxysarcodexia bakeri (Aldrich, 1916)	None*	NS	Wildlife (rat); livestock viscera (cow)	[39, 42, 47]
Oxysarcodexia culmiforceps Dodge, 1966	None*	NS	Marine life (sardine); livestock (pig); poultry viscera (chicken)	[13, 99, 217]
Oxysarcodexia diana (Lopes, 1933)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rat); livestock (pig); livestock viscera (cow); companion animals (dog)	[13, 47, 142, 157]
Oxysarcodexia fringidea (Curran & Walley, 1934)	None*	NS	Wildlife (rat); marine life (goatfish); livestock viscera (cow)	[39, 42, 46]
Oxysarcodexia intona (Curran & Walley, 1934)	None*	NS	Wildlife (rat); marine life (sardine, goatfish); livestock & poultry viscera (cow, chicken)	[39, 42, 46, 47, 99]
Oxysarcodexia modesta Lopes Det. R. Tibana, 1946	None*	Necrophage	Livestock viscera (cow)	[39, 42, 219]
Oxysarcodexia thornax (Walker, 1849)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rat); marine life (sardine); livestock (pig); livestock & poultry viscera (cow, chicken); companion animals (dog)	[13, 39, 40, 42, 49, 99, 142, 148, 157, 217]
Oxysarcodexia timida (Aldrich, 1916)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rat); marine life (sardine, goatfish); livestock & poultry viscera (cow, chicken)	[39, 42, 46, 99]
Oxysarcodexia xanthosoma (Aldrich, 1916)	None*	NS	Wildlife (rat); livestock (pig); livestock viscera (cow)	[46, 157, 217]
Oxytelus convergens J.L. LeConte, 1877	None*	Rove beetles (Staphylinidae) are typically necrophilous rather than necrophagous, feeding on fly eggs & larvae at carrion	Wildlife (bear, alligator, deer); livestock (pig)	[16, 29]
Oxytelus pensylvanicus Erichson, 1840	None*	Rove beetles (Staphylinidae) are typically necrophilous rather than necrophagous, feeding on fly eggs & larvae at carrion	Wildlife (deer)	[16, 29]

Oxytelus sculptus Gravenhorst, 1806	None*	Rove beetles (Staphylinidae) are typically necrophilous rather than necrophagous, feeding on fly eggs & larvae at carrion	Wildlife (bear, alligator, deer); livestock (pig)	[16, 29]
Paralucilia fulvinota (Bigot, 1877)	None*	Necrophage (fly larvae are necrophagous)	Human remains; livestock (cow)	[220-222]
Paralucilia paraensis (Mello, 1969)	None*	Necrophage	Livestock, poultry & fish viscera (pig, cow, chicken, fish)	[39, 98]
Peckia (Euboettcheria) anguilla (Curran & Walley, 1934)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rat); marine life (sardine); livestock (pig, cow); livestock & poultry viscera (cow, chicken)	[13, 39, 42, 99, 142, 157, 223]
Peckia (Peckia) chrysostoma (Wiedemann, 1830)	None*	Facultative necrophage (fly larvae are necrophagous)	Wildlife (rat); marine life (sardine, goatfish); livestock (pig); livestock & poultry viscera (cow, chicken)	[13, 42, 46, 49, 99, 137, 142, 157, 217]
Peckia (Euboettcheria) collusor (Curran & Walley, 1934)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rat); marine life (sardine, goatfish); livestock (pig, cow); livestock & poultry viscera (cow, chicken); companion animals (dog)	[13, 39, 42, 46, 99, 142, 157, 223]
Peckia (Squamatodes) ingens (Walker, 1849)	None*	Necrophage	Livestock (pig); livestock viscera (cow); companion animals (dog)	[13, 39, 42, 142, 217]
Peckia (Pattonella) intermutans (Walker, 1861)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rat); marine life (goatfish); livestock (pig); livestock viscera (cow)	[13, 42, 46, 137, 142, 157]
Peckia (Sarcodexia) lambens (Wiedemann, 1830)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rat); marine life (sardine, goatfish); livestock (pig); livestock viscera (cow); poultry viscera (chicken); companion animals (dog)	[39, 42, 46, 47, 49, 99, 142, 157]
Peckia (Pattonella) pallidipilosa (Curran & Walley, 1934)	None*	Necrophage (fly larvae are necrophagous)	Livestock (pig); livestock viscera (cow)	[39, 42, 224]
Peckia (Peckia) pexata (Wulp, 1895)	None*	NS	Livestock (pig); livestock viscera (cow)	[13, 39, 42, 49, 142, 157]
Peckia (Euboettcheria) subducta (Lopes, 1935)	None*	NS	Livestock viscera (cow); fishing discards (fish heads)	[39, 42, 100]

Peckia (Squamatodes) trivittata (Curran, 1927)	None*	Necrophage (fly larvae are necrophagous)	Livestock (pig); livestock viscera (cow)	[13, 39, 42, 142, 225]
Peckiamyia abnormalis (Hall, 1937)	None*	NS	Livestock viscera (cow)	[39, 42]
Periplaneta americana (Linnaeus, 1758)	American cockroach	Facultative necrophage	Wildlife (coyote, deer, insects); human remains	[32, 55, 73, 226]
Phaeochrous madagascariensis (Westwood, 1845)	None*	Necrophage	Wildlife (antelope)	[53]
Pheidole crassinoda Emery, 1895	None*	Necrophage	Wildlife (antelope)	[53]
Pheidole liengmei Forel, 1894	None*	Necrophage	Wildlife (antelope)	[53]
Pheidole megacephala (Fabricius, 1793)	Big-headed ant; Coastal brown ant	Necrophile (adult ants are necrophilous, feeding on fly eggs & larvae at carrion)	Wildlife (rabbit)	[97, 101]
Pheidole pallidula (Nylander, 1849)	None*	NS	Livestock (pig)	[36, 88]
Phelister sanguinipennis Marseul, 1853	None*	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[43]
Philonthus flavolimbatus Erichson, 1840	None*	Necrophile	Livestock (pig)	[13, 44]
Philonthus longicornis Stephens, 1832	None*	Necrophile (feeds on other carrion inhabitants)	Wildlife (rabbit); human remains	[29, 51]
Philonthus politus (Linnaeus, 1758)	None*	Necrophile (feeds on other carrion inhabitants)	Wildlife (rat, roe deer); marine life (seagull, squid); livestock (pig)	[5, 20, 33, 52, 75]
Philonthus succicola C.G. Thomson, 1860	None*	Necrophile (feeds on other carrion inhabitants)	Wildlife (rat, roe deer)	[33, 75]
Philonthus tenuicornis Mulsant & Rey, 1853	None*	Necrophile (feeds on other carrion inhabitants)	Wildlife (roe deer)	[33]
Philonthus umbrinus (Gravenhorst, 1802)	None*	Necrophile (feeds on other carrion inhabitants)	Wildlife (bear, alligator, deer); livestock (pig)	[16, 29]
Phormia regina (Meigen, 1826)	Black blow fly	Necrophage (fly larvae & adults are both necrophagous)	Wildlife (coyote, wolf, opossum, bear, bobcat, otter, alligator, raccoon, rabbit, deer); marine life (seagull); livestock (pig); livestock	[5, 16, 18, 31, 55, 57, 64, 70, 74, 96, 113, 115,

			viscera (cow liver)	116, 122, 227]
Phumosia testacea (Senior-White, 1923)	None*	NS	Livestock (pig); livestock viscera (pig)	[106, 208]
Physiphora alceae (Preyssler, 1791)	None*	Necrophage (fly larvae are necrophagous)	Human remains	[105]
Piophila bipunctata Fallén, 1823	None*	Necrophage	Livestock (pig)	[16, 160]
Piophila casei (Linnaeus, 1758)	Cheese skipper	Facultative necrophage (fly larvae are necrophagous); this species also feeds on other high protein substrates such as cheese	Wildlife (bear, otter, deer, antelope); human remains; livestock (pig)	[16, 17, 49, 53, 55, 70, 73, 97, 109, 123, 148, 160, 228]
Piophila latipes Meigen, 1838	None*	Necrophage	Wildlife (deer); marine life (seagull); livestock (pig); companion animals (cat)	[5, 228, 229]
Piophila megastigmata McAlpine, 1978	None*	Necrophage (fly larvae are necrophagous)	Wildlife (antelope); human remains; livestock (pig)	[97, 169, 228]
Piophila nigriceps Meigen, 1826	None*	Necrophage (fly larvae are necrophagous)	Wildlife (bear, alligator, deer); human remains; livestock (pig)	[16, 18, 29, 74, 169, 228]
Plagiolepis grassei Le Masne, 1956	None*	NS	Livestock (pig)	[36, 88]
Platydracus fossator (Gravenhorst, 1802)	Spotted rove beetle	NS	Wildlife (bear); human remains	[32, 37]
Platydracus maculosus (Gravenhorst, 1802)	Rove beetle	Necrophile (feeds on fly larvae at carrion)	Wildlife (bear, alligator, deer); livestock (pig)	[16, 18, 37]
Platydracus ochropygus (Nordmann, 1837)	None*	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[13, 43]
Platystoma mandschurica Enderlein, 1937	None *	Necrophage	Livestock (pig)	[28]
Poecilus (Poecilus) lucublandus (Say, 1823)	Woodland ground beetle	Necrophage & necrophile (feeds on other carrion inhabitants)	Marine life (seagull)	[5]
Polygonia interrogationis Fabricius, 1798	Question mark	Facultative necrophage (adult butterflies are necrophagous, but also feed on nectar, sweat & dung; larvae	Wildlife (bear); livestock (pig)	[16, 230]

		are herbivorous)		
Polygonia c-album (Linnaeus, 1758)	Comma	Facultative necrophage (adult butterflies suck on carcasses, possibly to ingest sodium)	Wildlife (wild boar, badger, red deer, roe deer, mouflon)	[14]
Polynoncus gemmingeri (Harold, 1872)	None*	Necrophage	Livestock (pig)	[44]
Polyommatus icarus (Rottemburg, 1775)	Common blue	Facultative necrophage (adult butterflies suck on carcasses, possibly to ingest sodium)	Wildlife (wild boar, badger, red deer, roe deer, mouflon)	[14]
Prenolepis spp. Mayr, 1861	None*	Necrophages & necrophiles (feed on fly eggs & larvae at carrion)	Wildlife (fly); livestock (pig)	[68, 231]
Prionochaeta opaca (Say, 1825)	None*	Facultative necrophage; this species also feeds on dung & decaying vegetation	Wildlife (bear, alligator, bat); aquatic life (fish); livestock (pig); companion animals (dog)	[16, 232]
Prochyliza nigrimanus (Meigen, 1826)	None*	Facultative necrophage (fly larvae are necrophagous); this species also feeds on decaying fruit & vegetables	Livestock (pig, sheep)	[228, 233]
Prochyliza xanthostoma Walker, 1849	Waltzing fly	Facultative necrophage	Wildlife (bear, alligator, deer, moose); livestock (pig, cow)	[16, 18, 234]
Proteinus crenulatus Pandellé, 1867	None*	Facultative necrophage; this species also feeds on decaying vegetation	Wildlife (rat)	[75]
Protophormia terraenovae (Robineau-Desvoidy, 1830) = *Phormia terraenovae* Robineau-Desvoidy, 1830	Northern blow fly; Blue bottle fly	Facultative necrophage (fly larvae are necrophagous); this species also feeds on living tissue	Wildlife (wolf, badger, rabbit); human remains; livestock (pig)	[29, 31, 57, 66, 70, 72, 96]
Pseudagolius bicolor (Say, 1823)	None*	Thought to be necrophagous &/or necrophilous; this species also feeds on dung	Wildlife (bear, alligator, rat, deer); livestock (pig)	[16, 214, 235]
Pseudocanthon perplexus (LeConte, 1847)	Four-toothed dung beetle	Thought to be necrophagous &/or necrophilous; this species also feeds on dung	Wildlife (alligator, rat, deer); livestock (pig)	[16, 214, 236]
Pterostichus niger (Schaller, 1783)	None*	Necrophile (feeds on other carrion inhabitants)	Wildlife (rat, roe deer)	[33, 75]
Ptomascopus plagiatus (Ménétriés, 1854)	None*	Necrophage	Livestock (pig)	[28]

Puliciphora borinquenensis Wheeler, 1906	Hump-backed fly	Necrophage	Wildlife (rabbit); livestock (pig)	[28, 237]
Puliciphora rufipes Silva Figueroa, 1916	None*	Necrophage (fly larvae are necrophagous)	Human remains	[135]
Rainieria antennaepes (Say, 1823)	None*	NS	Wildlife (deer); livestock (pig)	[16, 19]
Ravinia belforti (Prado & Fonseca, 1932)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rat); marine life (sardine); human remains; livestock (pig); livestock & poultry viscera (cow, chicken); companion animals (dog)	[13, 39, 40, 42, 47, 49, 99, 142, 157, 217, 219]
Ravinia effrenata (Walker, 1861)	None*	Necrophage	Livestock (pig); livestock viscera (cow)	[13, 39, 42, 142]
Retrocitomyia spp. Lopes, 1982	None*	NS	Livestock viscera (cow)	[39, 42]
Rugilus spp. Leach, 1819	None*	NS	Wildlife (bear, alligator, deer); livestock (pig)	[16, 210]
Saprinus acuminatus (Fabricius, 1798)	None*	NS	Marine life (squid); livestock (pig)	[36, 52]
Saprinus aeneus (Fabricius, 1775)	None*	Necrophage	Wildlife (rabbit)	[34]
Saprinus caerulescens (Hoffmann, 1803)	None*	NS	Wildlife (rabbit); marine life (squid); livestock (pig)	[17, 20, 36, 52]
Saprinus detersus (Illiger, 1807)	None*	NS	Wildlife (red fox); marine life (squid); livestock (pig)	[21, 36, 52]
Saprinus furvus Erichson, 1834	None*	NS	Wildlife (red fox); livestock (pig)	[21, 36]
Saprinus lugens Erichson, 1834	None*	NS	Livestock (pig)	[19, 36]
Saprinus melas Küster, 1849	None*	NS	Marine life (squid); livestock (pig)	[36, 52]
Saprinus politus (Brahm, 1790)	None*	NS	Marine life (squid); livestock (pig)	[36, 52]
Saprinus semistriatus (Scriba, 1790)	None*	Necrophage & necrophile (feeds on other carrion inhabitants)	Wildlife (wolf, rat, rabbit, roe deer); livestock (pig)	[20, 31, 34, 35, 75]

Saprinus subnitescens Bickhardt, 1909	None*	NS	Marine life (squid); livestock (pig)	[17, 20, 36, 52]
Saprinus tenuistrius Marseul, 1855	None*	NS	Marine life (squid); livestock (pig)	[20, 36, 52]
Sarcofahrtiopsis cuneata (Townsend, 1935)	None*	NS	Livestock viscera (cow)	[39, 42]
Sarconesia chlorogaster Wiedemann, 1830	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rat); livestock (pig); livestock viscera (cow liver)	[67, 103, 123, 130]
Sarconesia magellanica (Le Guillou, 1842) = *Sarconesiopsis magellanica* Le Guillou, 1842	None*	Necrophage (fly larvae are necrophagous)	Human remains; livestock (pig)	[238-241]
Sarcophaga aegyptica Salem, 1935	None*	Necrophage	Poultry (chicken)	[69, 97, 242]
Sarcophaga africa (Wiedemann, 1824) = *Sarcophaga haemorrhoidalis* (Fallén, 1817)	None*	Facultative necrophage	Wildlife (rat, antelope, rabbit); marine life (squid); livestock (pig); poultry (chicken)	[17, 37, 52, 53, 57, 69, 97, 101, 243]
Sarcophaga argyrostoma (Robineau-Desvoidy, 1830)	None*	Facultative necrophage (fly larvae are necrophagous); this species also feeds on living tissue	Marine life (squid); human remains; livestock (pig); poultry (chicken)	[52, 69, 97, 105, 244-246]
Sarcophaga bullata Parker, 1916	Gray flesh fly	Necrophage (fly larvae & adults are both necrophagous)	Marine life (seagull); livestock (pig)	[5, 18, 57]
Sarcophaga (Robineauella) caerulescens Zetterstedt, 1838	None*	Necrophage (fly larvae are necrophagous)	Wildlife (wolf, mouse); human remains; livestock (pig); livestock viscera (cow)	[31, 80, 172, 202, 246]
Sarcophaga (Liopygia) crassipalpis Macquart, 1839	None*	Facultative necrophage; this species also feeds on living tissue	Wildlife (rat)	[57, 243, 244]
Sarcophaga crispula Lopes, 1938	None*	NS	Livestock (pig); livestock viscera (cow)	[13, 39, 42]
Sarcophaga dux Thomson, 1869	None*	Necrophage (fly larvae are necrophagous)	Human remains; poultry (chicken)	[48, 105]

Sarcophaga exuberans Pandellé, 1896	None*	Necrophage (fly larvae are necrophagous)	Livestock (pig, cow); companion animals (guinea pig)	[86, 161]
Sarcophaga (Parasarcophaga) hirtipes Wiedemann, 1830	None*	Necrophage (fly larvae are necrophagous)	Wildlife (antelope, rabbit); poultry (chicken)	[48, 51, 53]
Sarcophaga (Helicophagella) melanura Meigen, 1826	None*	Necrophage (fly larvae are necrophagous)	Livestock (pig); poultry (chicken)	[17, 69, 245]
Sarcophaga nodosa Engel, 1925	None*	Necrophage	Wildlife (antelope)	[53]
Sarcophaga peregrina (Robineau-Desvoidy, 1830)	None*	Facultative necrophage (fly larvae are necrophagous); this species also feeds on excrement	Wildlife (rabbit); human remains; poultry (chicken)	[48, 203, 247]
Sarcophaga polistensis Hall, 1933	None*	Necrophage	Livestock (pig); livestock viscera (cow)	[39, 42, 142]
Sarcophaga (Pandelleisca) similis Meade, 1876	None*	Necrophage (fly larvae are necrophagous)	Wildlife (wolf); human remains	[31, 246]
Sarcophaga (Sarcophaga) subvicina Baranov = *Sarcophaga subvicina* Rohdendorf, 1937	None*	NS	Livestock (pig); livestock viscera (pig, cow)	[52, 172, 173, 202, 248]
Sarcophaga (Liosarcophaga) tibialis Macquart, 1851	None*	Necrophage (fly larvae are necrophagous)	Poultry viscera (chicken)	[57, 249]
Sargus spp. Fabricius, 1798	Soldier flies	Necrophages (fly larvae are necrophagous)	Wildlife (deer); human remains	[16, 250]
Scapomegas auritus Marseul, 1855	None*	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[43]
Scaptomyza spp. Hardy, 1850	Vinegar flies	NS	Wildlife (bear, alligator, deer); livestock (pig); livestock viscera (pig)	[16, 173]
Sepsis (Sepsis) punctum (Fabricius, 1794)	None*	Necrophage (adult flies are necrophagous)	Marine life (seagull)	[5]
Silpha (Silpha) carinata Herbst, 1783	None*	Facultative necrophage & necrophile (feeds on other carrion inhabitants); this species also feeds on mushrooms	Wildlife (slug, snail)	[184]

Silpha (Silpha) obscura Linnaeus, 1758	None*	Necrophage & necrophile (feeds on other carrion inhabitants)	Livestock (pig)	[184, 202]
Silpha (Silpha) tristis Illiger, 1798	None*	Necrophage & necrophile (feeds on other carrion inhabitants)	Marine life (squid)	[52, 184]
Solenopsis geminata (Fabricius, 1804)	Fire ant	Necrophile (adult ants are necrophilous, feeding on fly larvae)	Wildlife (toad); livestock viscera (pig liver); companion animals (cat)	[251-254]
Solenopsis invicta Buren, 1972	Red imported fire ant	Facultative necrophage (adult ants are necrophagous); this species also feeds on insects, plants, fungi & bacteria	Wildlife (coyote, opossum, bear, bobcat, alligator, raccoon, deer, insects); marine life (tuna); human remains; livestock (pig); livestock viscera (cow liver); poultry (chicken)	[16, 37, 55, 83-85, 255, 256]
Solenopsis invicta X *richteri*	Hybrid imported fire ant	Necrophage (adult ants are necrophagous)	Livestock (pig)	[257]
Spelobia nana (Rondani, 1880)	None*	Necrophage (adult ants are necrophagous)	Wildlife (earthworm, slug, snail)	[128]
Spirobolomyia flavipalpis (Aldrich, 1916)	None*	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[18]
Stelidota geminata (Say, 1825)	Strawberry sap beetle	Necrophage (adult flies are necrophagous)	Wildlife (rabbit); marine life (seagull)	[5, 43]
Stelidota octomaculata (Say, 1825)	None*	Thought to be necrophagous &/or necrophilous	Wildlife (rabbit)	[43]
Stenobothrus nigromaculatus (Herrich-Schäffer, 1840)	None*	Necrophage & necrophile† (adult grasshoppers are necrophagous & also necrophilous, feeding on fly eggs at carrion)	Wildlife (wild boar)	[14]
Stomorhina discolor (Fabricius, 1794)	None*	NS	Livestock viscera (pig, cow); poultry (chicken)	[48, 106, 125]
Stomorhina siamensis Kurahashi & Tumrasvin, 1992	None*	NS	Livestock viscera (pig, cow); poultry (chicken)	[48, 106, 125]
Synthesiomyia nudiseta (Wulp, 1883)	None*	Facultative necrophage & necrophile† (fly larvae are necrophagous & also necrophilous, feeding on other fly larvae at carrion); this species feeds on	Wildlife (rat, raccoon); marine life (goatfish); human remains; livestock (pig)	[13, 37, 40, 41, 46, 47, 49, 55, 97, 117, 123, 135, 258]

		excrement too		
Tabanus sudeticus Zeller, 1842	Dark giant horsefly	Facultative necrophage (adult flies are necrophagous)	Wildlife (European bison, red deer)	[14]
Tachinus (Tachinus) rufipes (Linnaeus, 1758)	None*	Facultative necrophage; this species also feeds on decaying vegetation	Wildlife (rat)	[75]
Telomerina flavipes Meigen, 1830	None*	Necrophage (fly larvae are necrophagous)	Wildlife (moth); livestock viscera (cow)	[128]
Telomerina levifrons (Spuler, 1925)	None*	Necrophage (fly larvae are necrophagous)	Livestock viscera (cow)	[128]
Tetramorium caespitum (Linnaeus, 1758)	Pavement ant	Necrophage & necrophile (feeds on other carrion inhabitants)	Marine life (seagull)	[5]
Tettigonia viridissima (Linnaeus, 1758)	Great green bush-cricket	Facultative necrophage (adult crickets are necrophagous)	Wildlife (wild boar, deer)	[14]
Thanatophilus dispar (Herbst, 1793)	None*	Necrophage & necrophile	Aquatic life (fish)	[184, 259]
Thanatophilus lapponicus (Herbst, 1793)	Lapland carrion beetle; Northern carrion beetle	Necrophage & necrophile† (beetle larvae & adult beetles are both necrophagous & necrophilous, feeding on insect larvae at carrion)	Wildlife (rabbit); human remains	[37, 96, 186]
Thanatophilus micans (Fabricius, 1794)	None*	Necrophage (beetle larvae are necrophagous) & necrophile (feeds on other carrion inhabitants)	Marine life (hake); human remains; livestock (sheep)	[97, 104, 260]
Thanatophilus ruficornis (Küster, 1851)	None*	Necrophage	Wildlife (red fox); marine life (squid); livestock (pig)	[21, 36, 52, 65]
Thanatophilus rugosus (Linnaeus, 1758)	None*	Necrophage & necrophile (feeds on other carrion inhabitants)	Wildlife (red fox, wolf, rat, badger, roe deer, rabbit); marine life (squid); livestock (pig)	[20, 21, 31, 33, 34, 36, 52, 65, 72, 75, 133, 184]
Thanatophilus sinuatus (Fabricius, 1775)	None*	Necrophage & necrophile (feeds on other carrion inhabitants)	Wildlife (wolf, rat, roe deer); marine life (squid); livestock (pig)	[31, 33, 52, 75, 133, 184]
Thyreophora cynophila (Panzer, 1794)	European bone-skipper	Obligate necrophage (fly larvae are necrophagous, feeding on bone marrow)	Wildlife (red deer); livestock (pig, cow, horse, mule, sheep, goat)	[14, 65, 261]

Titanogrypa (Ayripel) cryptopyga Lopes, 1956	None*	NS	Livestock viscera (cow)	[39, 42]
Titanogrypa (Sarconeiva) larvicida (Lopes, 1935)	None*	Necrophage (fly larvae are necrophagous)	Wildlife (rat); livestock (pig); livestock viscera (cow)	[13, 40-42, 142]
Tricharaea (Sarcophagula) canuta (Wulp, 1896)	None*	NS	Wildlife (rat); livestock viscera (cow)	[39, 42, 47]
Tricharaea (Sarcophagula) occidua Fabricius, 1794	None*	NS	Wildlife (rat); marine life (sardine); livestock (pig); livestock viscera (cow); poultry viscera (chicken)	[13, 39, 40, 42, 47, 49, 99, 142, 148, 217]
Trichillum externepunctatum Preudhomme de Borre, 1880	None*	Thought to be necrophagous &/or necrophilous	Livestock (pig)	[13, 43]
Trigona corvina Cockerell, 1913	Zagañas	Facultative necrophage	Poultry (chicken)	[262-264]
Trigona crassipes (Fabricius, 1793)	None*	Obligate necrophage	Wildlife (worm); aquatic life (fish); livestock (pig)	[12, 262]
Trigona ferricauda Cockerell, 1917	None*	Facultative necrophage	Poultry (chicken)	[264]
Trigona fulviventris Guérin-Méneville, 1844	Culo-de-vaca	Facultative necrophage	Wildlife (lizard); poultry (chicken)	[251, 262, 264]
Trigona hypogea Silvestri, 1902	None*	Facultative necrophage; this species also feeds on wasp larvae & pupae in abandoned wasps' nests	Wildlife (monkey, snake, lizard, toad, bird, frog, fish, worm, large insects); livestock (pig); poultry; livestock viscera (pig)	[12, 262, 265-267]
Trigona necrophaga Camargo & Roubik, 1991	None*	Obligate necrophage	Wildlife (snake, bird, fish, toad, frog, lizard); livestock (pig); poultry (chicken)	[262, 264]
Trigona recursa Smith, 1863	None*	Facultative necrophage	Wildlife (otter)	[262]
Trigona silvestriana (Vachal, 1908)	None*	Facultative necrophage	Poultry (chicken)	[264]
Trigona truculenta Almeida, 1985	None*	Facultative necrophage	Livestock (pig)	[262, 268]

Trox (Granulitrox) hispanicus Harold, 1872	None*	Necrophage (feeds on hide, fur & feathers)	Wildlife (red fox)	[21, 29]
Trox hispidus (Pontoppidan, 1763)	Måsknotbagge	Necrophage (feeds on hide, fur & feathers)	Wildlife (rabbit)	[29, 34]
Vanessa atalanta (Linnaeus, 1758)	Red admiral	Facultative necrophage (adult butterflies suck on carcasses, possibly to ingest sodium)	Wildlife (wild boar, badger, red deer, roe deer, mouflon)	[14]
Vanessa cardui (Linnaeus, 1758)	Painted lady	Facultative necrophage (adult butterflies suck on carcasses, possibly to ingest sodium)	Wildlife (wild boar, badger, red deer, roe deer, mouflon)	[14]
Vespa crabro Linnaeus 1758	European hornet	Thought to be necrophilous	Wildlife (wild boar, rabbit)	[14, 101]
Vespula germanica (Fabricius, 1793)	European wasp; German yellowjacket	Facultative necrophage & necrophile† (adults are both necrophagous & necrophilous, but feed mostly on bee carrions)	Wildlife (wild boar, rat, honey-bee)	[14, 243, 269]
Vespula maculifrons (Buysson, 1905)	Eastern yellowjacket	Necrophage	Wildlife (coyote, bear, bobcat, alligator, rat); livestock (pig)	[16, 55, 270]
Vespula squamosa (Drury, 1770)	Southern yellowjacket	Necrophile (adult wasps are necrophilous, feeding on flies at carrion)	Human remains	[37]
Vespula vulgaris (Linnaeus, 1758)	Common wasp; Common yellowjacket	Facultative necrophage	Wildlife (red fox); livestock (pig)	[21, 78, 271]
Villegasia almeidai (Lopes, 1938)	None*	Necrophage (fly larvae are necrophagous)	Livestock (pig); livestock viscera (cow)	[39, 42, 151]
Wohlfahrtia nuba (Wiedemann, 1830)	None*	Facultative necrophage (fly larvae are necrophagous); this species also feeds on living tissue	Wildlife (rabbit); human remains; poultry (chicken)	[69, 97, 105, 272]
Xenosepsis fukuharai Iwasa, 1984 = *Meroplius fukuharai* (Iwasa, 1984)	None*	Necrophage (fly larvae are necrophagous)	Livestock (pig)	[64, 273]

Arthropods – malacostracans				
Abyssorchomene abyssorum (Stebbing, 1888)	None*	Facultative necrophage	Marine life (mackerel, jack mackerel)	[274-276]
Anonyx lilljeborgi Boeck, 1871	Kagitsunoa-gesokoebi	Necrophage	Marine life (herring)	[4, 277]
Anonyx makarovi Gurjanova, 1962	Makarofutsunoa-gesokoebi	Necrophage	Marine life (herring)	[4, 277]
Anonyx nugax (Phipps, 1774)	Tadanotsunoa-gesokoebi	Necrophage	Marine life (herring)	[4, 277]
Anonyx sarsi Steele & Brunel, 1968	None*	Necrophage (possibly an obligate necrophage); this species preys on dislodged or injured animals, but is highly adapted to necrophagy	Marine life (pollock)	[277-279]
Bathynomus giganteus A. Milne-Edwards, 1879	Giant isopod	Facultative necrophage	Marine life (fish, squid)	[278, 280]
Callinectes similis A.B. Williams, 1966	Lesser blue crab	Facultative necrophage	Marine life (menhaden)	[281]
Cancer productus Randall, 1840	Pacific rock crab; Red rock crab	Facultative necrophage	Livestock (pig)	[282]
Carcinus maenas (Linnaeus, 1758)	European green crab	Facultative necrophage & necrophile (feeds on other carrion inhabitants)	Marine life (seagull); fishery discards (whiting, langoustine)	[5, 283]
Centromedon productus (Goës, 1866)	None*	Necrophage	Marine life (herring)	[4]
Charcotia obesa Chevreux, 1906	None*	Necrophage (possibly an obligate necrophage)	Marine life (mackerel pike, notothenioid fish)	[11, 284]
Cheirimedon femoratus (Pfeffer, 1888)	None*	Facultative necrophage; this species also feeds on microalgae	Marine life (notothenioid fish)	[284]
Cirolana cranchii Leach, 1818	None*	Necrophage	Marine life (pilchard)	[285]
Cirolana harfordi (Lockington, 1877)	None*	Facultative necrophage	Marine life (fish)	[278]
Clibanarius vittatus (Bosc, 1801)	Thinstripe hermit	Necrophage	Marine life (menhaden)	[281]
Coenobita clypeatus (J.C. Fabricius, 1787)	Caribbean hermit crab; Land hermit	Facultative necrophage	Livestock (donkey)	[278]

Coenobita perlatus H. Milne-Edwards, 1837	Strawberry hermit crab	Facultative necrophage; this species also feeds on fruit, twigs & excrement	Marine life (noddy tern, reef fish); poultry (chicken)	[278, 286]
Cyclocaris franki Horton & Thurston, 2014	None*	Necrophage	Marine life (tuna)	[287, 288]
Cyclocaris guilelmi Chevreux, 1899	None*	Necrophage	NS	[287]
Cyclocaris lowryi Horton & Thurston, 2014	None*	Necrophage	NS	[287]
Cyclocaris tahitensis Stebbing, 1888	None*	Necrophage	Marine life (jack mackerel)	[276, 287]
Eurycope sarsi Beddard, 1885	None*	Necrophage	Marine life (mackerel pike)	[11]
Eurythenes atacamensis Weston & Espinosa-Leal, 2021	None*	Necrophage	Marine life (mackerel)	[289]
Eurythenes gryllus (Lichtenstein, 1822)	Oookisokoebi	Facultative necrophage	Marine life (mackerel pike, mackerel, jack mackerel, squid, jellyfish)	[11, 275, 276, 278, 290]
Eurythenes plasticus Weston, 2020	None*	Necrophage	Marine life (mackerel)	[291]
Eusirus laticarpus Chevreux, 1906	None*	Necrophage	Marine life (mackerel pike)	[11]
Gammarus crinicornis Stock, 1966	None*	Necrophage	Marine life (pilchard)	[285]
Glyptonotus antarcticus Eights, 1852	Giant Antarctic isopod	Necrophage; this species feeds largely on carrion	Marine life	[278]
Gnathia spp. Leach, 1814	None*	Necrophages	Marine life (mackerel pike); fishery discards	[11, 292]
Hippa marmorata (Hombron & Jacquinot, 1846)	Pacific mole crab	Facultative necrophage	Marine life (hydrozoans)	[278]
Hippomedon kergueleni (Miers, 1875)	None*	Necrophage	Marine life (notothenioid fish)	[284]
Hippomedon major (K.H. Barnard, 1932)	None*	Necrophage	Marine life (mackerel pike)	[11]

Hirondellea gigas (Birstein & Vinogradov, 1955)	Kaikouoosokoebi	Facultative necrophage	Marine life (fish)	[278, 293]
Hyas araneus (Linnaeus, 1758)	Atlantic lyre crab	Necrophage	Marine life (herring)	[4]
Menippe mercenaria (Say, 1818)	Florida stone crab	Facultative necrophage	Marine life (menhaden)	[281]
Metacarcinus magister (Dana, 1852)	Californian crab; Dungeness crab	Facultative necrophage	Livestock (pig)	[282]
Munida tenuimana Sars, 1872	Narrow-legged squat lobster	Necrophage	Marine life (jellyfish, mackerel)	[294]
Natatolana borealis (Lilljeborg, 1851)	None*	Necrophage; this species feeds largely on carrion	Marine life (fish, crustaceans)	[278]
Natatolana meridionalis Hodgson, 1910	None*	Necrophage	Marine life (mackerel pike)	[11]
Nebalia bipes (Fabricius, 1780)	None*	Facultative necrophage	Marine life (crab)	[295]
Orchomenella (Orchomenopsis) obtusa (G.O. Sars, 1891)	None*	Necrophage	Marine life (jellyfish, mackerel)	[294]
Orchomenella rotundifrons K.H. Barnard, 1932	None*	Necrophage	Marine life (notothenioid fish)	[284]
Pagurus bernhardus (Linnaeus, 1758)	Hermit crab	Necrophage	Marine life (fish); fishery discards (whiting, langoustine)	[296, 297]
Pagurus prideaux Leach, 1815	Prideaux's hermit crab	Necrophage	Marine life (fish)	[296]
Pagurus pubescens Krøyer, 1838	Downy hermit crab	Necrophage	Marine life (herring)	[4]
Pandalus platyceros Brandt, 1851	Spot shrimp	Necrophage	Livestock (pig)	[282]
Paralicella caperesca Shulenberger & Barnard, 1976	Sogiochisakazukisokoebi	Obligate necrophage	Marine life (mackerel, jack mackerel)	[274-276, 298]
Paralicella similis Birstein & Vinogradov, 1960	None*	Necrophage	Marine life (mackerel pike)	[11]

Parandania boecki (Stebbing, 1888)	None*	Necrophage	Marine life (mackerel pike)	[11]
Parandania gigantea (Stebbing, 1883)	None*	Necrophage	Marine life (mackerel pike)	[11]
Podoprionides incerta Walker, 1906	None*	Necrophage	Marine life (mackerel pike)	[11]
Portunus armatus (A. Milne-Edwards, 1861)	Blue swimmer crab	Necrophage	Marine life (crustaceans, fish)	[278]
Procambarus clarkii (Girard, 1852)	Red swamp crayfish	Facultative necrophage; this species also feeds on periphyton & macrophytes	Freshwater fish (largemouth bass)	[299]
Pseudorchomene coatsi (Chilton, 1912)	None*	Necrophage	Marine life (mackerel pike)	[11]
Saduria megalura (G.O. Sars, 1879)	None*	Necrophage	Marine life (squid)	[290]
Scopelocheirus crenatus Spence Bate, 1857	None*	Necrophage	Marine life (herring)	[4]
Scopelocheirus hopei (Costa, 1851)	Kutsumigakisokoebi	Necrophage; this species feeds largely on carrion	Marine life (crustaceans, mollusks, fish)	[278, 295]
Siriella clausii G.O. Sars, 1877	None*	Necrophage	Marine life (pilchard)	[285]
Socarnes bidenticulatus (Spence Bate, 1858)	None*	Necrophage	Marine life (herring)	[4]
Socarnes erythrophthalmus Robertson, 1892	None*	Necrophage	Marine life (pilchard)	[285]
Tmetonyx cicada (Fabricius, 1780)	None*	Facultative necrophage	Marine life (fish)	[278]
Tmetonyx similis (G.O. Sars, 1891)	None*	Necrophage	Marine life (crustaceans, mollusks, fish)	[295]
Trizopagurus magnificus (Bouvier, 1898)	None*	Facultative necrophage	Marine life (starfish)	[278]
Tryphosa nana (Krøyer, 1846)	None*	Necrophage (possibly an obligate necrophage)	Marine life (fish, crab)	[278, 284, 295]
Uristes murrayi (Walker, 1903)	None*	Necrophage	Marine life (mackerel pike)	[11]

Arthropods – ostracods				
Doloria (Doloria) levis Skogsberg, 1920	None*	Necrophage	Marine life (mackerel pike)	[11]
Skogsbergiella sp. Kornicker, 1975	None*	Necrophage	Marine life (mackerel pike)	[11]
Vargula antarctica (Müller, 1908)	None*	Necrophage	Marine life (mackerel pike)	[11]
Arthropods – pycnogonids				
Colossendeis spp. Jarzynsky, 1870	Sea spiders	Facultative necrophages; these species also feed on live prey	Marine life (tunicates)	[300, 301]
Cnidarians				
Actinoscyphia aurelia (Stephenson, 1918)	Venus flytrap sea anemone	Necrophage	Marine life (tunicates)	[300]
Actinostola sp. Verrill, 1883	None*	Necrophage	Marine life (tunicates)	[300]
Echinoderms				
Asterias rubens Linnaeus, 1758	Common sea star	Necrophage	Marine life (gray seal, pilchard); fishery discards (whiting, langoustine)	[71, 285, 297]
Cidaris sp. Leske, 1778	Pencil sea urchin	Necrophage	Marine life (tunicates)	[300]
Diadema sp. Gray, 1825	None*	Necrophage	Marine life (tunicates)	[300]
Luidia ciliaris (Philippi, 1837)	Seven-armed starfish	Facultative necrophage	Marine life (starfish, mollusks)	[278]
Marthasterias glacialis (Linnaeus, 1758)	Spiny starfish	Facultative necrophage; this species also hunts live prey	Marine life (pilchard)	[285]
Ophiocomina nigra (Abildgaard, 1789)	Black brittle star	Facultative necrophage	Marine life (fish)	[278]
Ophiocten sericeum (Forbes, 1852)	None*	Necrophage	Marine life (herring)	[4]
Ophiophthalmus normani (Lyman, 1879)	None*	Necrophage	Marine life (food falls)	[302]

Ophiopleura borealis Danielssen & Koren, 1877	None*	Necrophage	Marine life (herring)	[4]
Ophiothrix fragilis (Abildgaard, 1789)	Common brittle star	Facultative necrophage	Marine life (fish)	[278]
Ophiura albida Forbes, 1839	Serpent's table brittle star	Facultative necrophage	Marine life (herring)	[4, 278]
Ophiura ophiura (Linnaeus, 1758)	Serpent star	Facultative necrophage	Marine life (fish)	[278]
Ophiura sarsii Lütken, 1855	Notched brittle star	Necrophage	Marine life (herring)	[4]
Orthasterias koehleri (deLoriol, 1897)	Long-rayed star	Necrophage	Livestock (pig)	[282]
Patiria miniata (Brandt, 1835)	Bat star	Facultative necrophage	Marine life (wide range of carrion)	[278]
Phormosoma sp. Thomson, 1872	None*	Necrophage	Marine life (tunicates)	[300]
Pycnopodia helianthoides (Brandt, 1835)	Sunflower star	Necrophage	Livestock (pig)	[282]
Urasterias lincki (Müller & Troschel, 1842)	None*	Necrophage	Marine life (herring)	[4]
Mollusks				
Adipicola pelagica (Forbes, 1854)	None*	Necrophage	Marine life (whale)	[302]
Buccinastrum deforme (P.P. King, 1832) = *Buccinanops globulosus* (Kiener, 1834)	None*	Necrophage	Marine life (crabs, mollusks, fish)	[303, 304] [305]
Buccinum undatum Linnaeus, 1758	Waved whelk	Necrophage	Marine life (carcasses abandoned by starfish, herring); fishery discards (whiting, langoustine)	[4, 295, 297]
Bullia spp. Gray, 1833	Whelks	Facultative necrophages; these species also feed on algae & live prey	Marine life (hydrozoans, tunicates)	[278]
Dicathais orbita (Gmelin, 1791)	White rock shell	Facultative necrophage	Marine life (reef invertebrates)	[278]

Nassarius pauperatus (Lamarck, 1822)	Impoverished dog whelk	Facultative necrophage	Marine life (cockles)	[278]
Octopus vulgaris Cuvier, 1797	Common Atlantic octopus	Facultative necrophage; this species also hunts live prey	Marine life (pilchard)	[285]
Oliva sayana Ravenel, 1834	Lettered olive	Facultative necrophage	Marine life (fish)	[278]
Rubyspira spp. S.B. Johnson, Warén, R.W. Lee, Kano, Kaim, Davis, E.E. Strong & Vrijenhoek, 2010	None*	Necrophages	Marine life (whale bones)	[2, 306]
Tritia reticulata (Linnaeus, 1758)	Netted dog whelk	Facultative necrophage	Marine life (cockles, pilchard)	[278, 285]
Tritia varicosa (W. Turton, 1825)	Small dog whelk	Necrophage	Marine life (pilchard)	[285]
Nematodes				
Pontonema vulgare (Bastian, 1865) Filipjev, 1916	None*	Facultative necrophage	Marine life (fish, jellyfish, starfish)	[278]
Nemerteans (also known as ribbon worms)				
Parborlasia corrugatus (McIntosh, 1876)	None*	Facultative necrophage	Marine life (starfish)	[278]
Sipunculans (also known as peanut worms)				
Phascolosoma (Phascolosoma) saprophagicum Gibbs, 1987	None*	Necrophage	Marine life (whale-bone oil)	[302]

*, no common name is listed in the Global Biodiversity Information Facility (https://www.gbif.org/), Integrated Taxonomic Information System (https://www.itis.gov/), Catalogue of Life (http://www.catalogueoflife.org/) or Atlas of Living Australia (https://collections.ala.org.au/); †, in the carrion ecology and forensic entomology literature, the term 'omnivore' is sometimes given to organisms eating both carrion and the live invertebrates within carrion; =, synonym; NS, not stated in reference(s)

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<u>Supplementary Table 5 from the Critical Reviews in Biotechnology journal article 'Necrophages and necrophiles: a review of their antibacterial defenses and biotechnological potential'</u>

To cite this article:

Cushnie TPT, Luang-In V, Sexton DW, Necrophages and necrophiles: a review of their antibacterial defenses and biotechnological potential. Critical Reviews in Biotechnology, 2024 (Published online ahead of print). DOI: 10.1080/07388551.2024.2389175

To link to this article:

https://doi.org/10.1080/07388551.2024.2389175

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Supplementary Table 5 Examples of antimicrobial peptides (AMPs; ≤50 amino acid- or ≤5.5 kDa-sized molecules) detected in necrophages and necrophiles.

Necrophage or necrophile	**AMP families**											**Reference(s)**
	Bombolitin-like peptides	**Cathelicidins**	**Cecropins**	**Defensins**	**Diptericins**	**Histone-derived AMPs**	**Knottin-like peptides**	**Piscidins**	**Proline-rich peptides**	**Sarconesins**	**Serprocidin-derived AMPs**	
Alligator mississippiensis (American alligator)		●		●								[1-3]
Bombus terrestris (buff tailed bumblebee)				●					●			[4, 5]
Calliphora vicina (European blue bottle fly)			●	●	●				●			[6-8]
Calliphora vomitoria (blue bottle fly)			●									[8]
Cathartes aura (turkey vulture)				●								[9]
Chrysomya pinguis			●	●								[8]
Crocodylus porosus (estuarine crocodile)				●								[3]
Hermetia illucens (black soldier fly)			●	●	●		●					[10-16]
Lucilia ampullacea (streakless greenbottle)			●	●								[8]
Lucilia caesar (common greenbottle)			●	●								[8]
Lucilia eximia			●									[17]
Lucilia illustris (green bottle fly)			●	●								[8]
Lucilia porphyrina			●	●								[8]
Lucilia sericata (common green bottle fly)			●	●					●			[8, 18-21]
Musca domestica (housefly)			●	●	●							[22-25]
Myxine glutinosa (Atlantic hagfish)								●				[26]
Nicrophorus vespilloides (common sexton beetle)			●	●								[27-29]
Periplaneta americana (American cockroach)	●			●								[30-32]
Protophormia terraenovae[†] (northern blow fly)				●	●							[33, 34]

Sarconesia magellanica‡										●		[35-37]
Sarcophaga peregrina			●	●							●	[8, 38-41]
Varanus komodoensis (Komodo dragon)		●		●		●						[42, 43]

●, AMP(s) detected; †, *Phormia terranovae* is a synonym of *Protophormia terraenovae*; ‡, *Sarconesiopsis magellanica* is a synonym of *Sarconesia magellanica*

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<u>Supplementary Table 6 from the Critical Reviews in Biotechnology journal article 'Necrophages and necrophiles: a review of their antibacterial defenses and biotechnological potential'</u>

To cite this article:

Cushnie TPT, Luang-In V, Sexton DW, Necrophages and necrophiles: a review of their antibacterial defenses and biotechnological potential. Critical Reviews in Biotechnology, 2024 (Published online ahead of print). DOI: 10.1080/07388551.2024.2389175

To link to this article:

https://doi.org/10.1080/07388551.2024.2389175

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Supplementary Table 6 Examples of antibacterial proteins (>50 amino acid- or >5.5 kDa-sized molecules) detected in necrophages and necrophiles.

Necrophage or necrophile	Antibacterial protein families											Reference(s)
	Attacins	**Cathepsin D-like proteins**	**Cecropins†**	**Coleoptericins**	**Crustins**	**Cysteine-rich secretory proteins**	**Glycine-rich peptides**	**Hexamerins**	**KTX toxin-like peptides**	**PBSIP family peptides**	**Reeler domain-containing proteins**	
Bombus terrestris (buff tailed bumblebee)							●					[1, 2]
Camponotus pennsylvanicus (black carpenter ant)		●										[3]
Carcinus maenas (European green crab)					●							[4]
Hermetia illucens (black soldier fly)	●		●									[5-8]
Lucilia illustris (green bottle fly)	●											[9]
Musca domestica (housefly)	●							●				[10, 11]
Nicrophorus vespilloides (common sexton beetle)	●			●					●	●		[12-14]
Periplaneta americana (American cockroach)	●											[15]
Philodryas patagoniensis (Patagonia green racer snake)						●						[16]
Procambarus clarkii (red swamp crayfish)					●						●	[17-19]
Sarcophaga peregrina			●									[20-22]

●, antibacterial protein(s) detected; †, stomoxynZH [5] and sarcotoxins IIA, IIB, IIC and III [20-22] are quite large (6.1 kDa, 24 kDa, 24 kDa, 24 kDa and 7 kDa, respectively), so are included here instead of Supplementary Table 5

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