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Artículo

A preliminary list of beetles (Insecta: Coleoptera) of forensic importance from Peru

Lista preliminar de coleópteros (Insecta: Coleoptera) de importancia forense del Perú

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ABSTRACT

A preliminary list of beetles of forensic importance from Peru is presented, based on bibliographic revision. As a result, eight families, 31 genera, and 94 species are reported. According to their frequency in studies reviewed or number of species of forensic importance in each of them, families and genera that deserve special attention in Peru are Cleridae (*Necrobia* Olivier), Dermestidae (*Dermestes* Linnaeus), Histeridae (*Hister* Linnaeus, *Euspilotus* Lewis, *Saprinus* Erichson, *Xerosaprinus* Wenzel), Silphidae (*Oxelytrum* Gistel), Staphylinidae (*Creophilus* Leach, *Philonthus* Curtis) and Trogidae (*Omorgus* Erichson, *Polynoncus* Burmeister). These findings are discussed taking into account the available evidence from the Neotropical region.

Keywords: carcasses, Coleoptera, necrocolous species, Neotropical, South America.

RESUMEN

Se presenta una lista preliminar de coleópteros de importancia forense del Perú, basada en revisión bibliográfica. Como resultado, se reportan ocho familias, 31 géneros y 94 especies. Según su frecuencia en los estudios revisados o la cantidad de especies de importancia forense en cada uno de ellos, familias y géneros que merecen especial atención en Perú son Cleridae (*Necrobia* Olivier), Dermestidae (*Dermestes* Linnaeus), Histeridae (*Hister* Linnaeus, *Euspilotus* Lewis, *Saprinus* Erichson, *Xerosaprinus* Wenzel), Silphidae (*Oxelytrum* Gistel), Staphylinidae (*Creophilus* Leach, *Philonthus* Curtis) and Trogidae (*Omorgus* Erichson, *Polynoncus* Burmeister). Estos hallazgos son discutidos tomando en cuenta la evidencia disponible de la región Neotropical.

Palabras clave: cadáveres, Coleoptera, especies necrócolas, Neotrópico, Sudamérica.

Forensic entomology is a discipline of growing interest, as suggested by a review of studies on this subject published between 1984 and 2013 in a worldwide sample of scientific journals (Rodriguez-Olivares *et al.* 2015). Two other interesting trends revealed by this review were that pig is the most widely used biological model in cadaveric succession studies and, Coleoptera and Diptera are the most valuable forensic arthropod orders at family, genus and species level, due to its clear association with different stages of cadaveric succession.

The heterotrophic succession of animal remains is an ecological process necessary for the recycling of organic matter in the soil, in which various necrophagous, necrophilous and omnivorous species of Coleoptera arrive and inhabit carcasses during different stages of cadaveric decomposition (Nadeau *et al.* 2015, Zanetti *et al.* 2015a). In forensic entomology context, useful biological attributes of Coleoptera are long duration of its immature stages, which allows better estimates of the minimum postmortem interval (PMI min) and tough structures of larvae, pupae and exuviae, from which toxicological samples can be obtained (Midgley *et al.* 2010). According to studies carried out in Nearctic (Midgley *et al.* 2010, Nadeau *et al.* 2015), Neotropical (Almeida and Mise 2009, Almeida *et al.* 2015), Oriental (Bala and Singh 2015) and Palearctic (Özdemir and Sert 2009, Sawaby *et al.* 2016) regions, Coleoptera of forensic importance belong to following families: Anthicidae, Carabidae, Cleridae, Dermestidae, Geotrupidae, Histeridae, Hybosoridae, Hydrophilidae, Lathridiidae, Leiodidae, Monotomidae, Nitidulidae, Ptinidae, Scarabaeidae, Silphidae, Staphylinidae, Tenebrionidae and Trogidae.

In Peru, forensic entomology has also received increasing attention in recent years. Thus, there are a number of studies on cadaveric succession available in scientific journals or as dissertation works. Most of them were carried out in localities to the west of the Peruvian Andes including Callao (Iannacone 2003), La Libertad (Sarmiento-Yengle and Padilla-Sagástegui 2015), Lambayeque (Ginés-Carrillo *et al.* 2015, Medina-Achín *et al.* 2018), Lima (Peceros-Peláez 2011, Grados 2014, Murrugarra-Bringas 2016) and Piura (Andrade-Herrera *et al.* 2018). In comparison, the number of studies is rather scarce in the eastern Amazon (Pizango-Pérez *et al.* 2019) or practically absent for localities in inter-Andean valleys and high Andean plateaus.

The present work provides a preliminary list of beetles of forensic importance from Peru, based on an extensive bibliographic review, including studies on entomological cadaveric succession, reviews of forensic relevant species, checklists for Peruvian fauna and others works with valuable data for necrocolous beetle species. This list is expected to be a useful source of information for future field surveys and cadaver succession studies in Peru.

MATERIAL AND METHODS

The list of genera and species was prepared from a bibliographic review of works dealing with Neotropical necrocolous beetles, following five stages:

First, 35 recent studies (1997-2019) describing the cadaveric succession of insects in different localities of South American countries, were used to elaborate the basic list of beetle species. These studies were selected by a combination of three criteria, availability in electronic databases, recent publication date and representation of different environmental conditions found in South America. Studies carried out in Argentina (7), Bolivia (1), Brazil (9), Colombia (4), Ecuador (1), Peru (9), Uruguay (2) and Venezuela (2) were included, which are detailed in appendix 1.

Second, data from the basic list of species were grouped into genera, to find the most frequent genera of necrocolous beetles. Thus, only species of genera with frequency above mean (0.09) in a range of 0.03-0.80 were used in the following stages. For each genus, frequency = [number of genus records] / [total number of studies].

Third, eight reviews on beetles of forensic importance were used to check and expand South American species in most frequent genera selected in second stage. The included studies cover beetle fauna of Argentina (Oliva 2001, Aballay *et al.* 2013, 2014), Brazil (Vasconcelos and Araujo 2012, Almeida *et al.* 2015, Celli *et al.* 2015), Ecuador (Salazar y Donoso 2015) and Latin America (Almeida and Mise 2009).

Fourth, seven recent checklists were used to check the species recorded for most frequent genera in Peru. The included studies are about Cleridae (Burke and Chaboo 2015), Dermestidae (Háva and Chaboo 2015), Histeridae (Mazur 2011, Arriagada 2015, Tishechkin and Dégallier 2015), Nitidulidae (Cline *et al.* 2015), Scarabaeoidea (Ratcliffe *et al.* 2015), Silphidae (Giraldo-Mendoza 2016) and Staphylinidae (Newton 2015).

Fifth, 10 recent works with biology remarks or collecting data for most frequent genera were used for to add species overlooked by studies cited in first and third stages. The included studies are about *Deltochilum* Eschscholtz (González *et al.* 2009), *Eurysternus* Dalman (Génier 2009), *Euspilotus* Lewis (Dégallier *et al.* 2012, Arriagada 2015), *Phelister* Marseul (Caterino and Tishechkin 2019, 2020), Scarabaeinae (Ratcliffe 2013, Cajaiba *et al.* 2017), Trogidae (Scholtz 1990) and *Xanthopygus* Kraatz (Navarrete-Heredia 2004).

The species obtained with the procedure described above were classified into three categories:

Known species, species recorded in the nine entomological cadaveric succession studies carried out in Peruvian localities included in first stage. Also, their forensic importance is supported by cadaveric succession studies and reviews carried out in other South American countries included in first and third stages.

Expected species, species not recorded yet in cadaveric succession trials carried out in Peruvian territory. Their forensic importance is supported by cadaveric succession studies and reviews carried out in other South American countries included in first and third stages.

Potential species, species not recorded yet in cadaveric succession trials carried out in South American countries. They are likely forensic valuables based on collecting data indicating its association with vertebrate carcasses or catch with carrion-baited traps as noted by the studies of fifth stage.

In addition to the information at the species level, for each genus were calculated: a simple ratio of forensic important species = [forensic important species] / [species recorded in Peru] and an index of forensic importance = [(0.5) (known species) + (0.3) (expected species) + (0.2) (potential species)] / [species recorded in Peru]. Both equations were elaborated intuitively and proposed here, as quantitative expressions to highlight forensic importance of selected genera.

Taxonomic determination carried out in Peruvian cadaveric succession studies could not be checked for the most part. Two clear exceptions were the studies carried out by Grados (2014) and Murrugarra-Bringas (2016), whose specimens are housed in Museo de Entomología Klaus Raven Büller – Universidad Nacional Agraria La Molina, Lima, Peru (MEKRB). Also, some species of Histeridae could be identified from the photos presented by Ginés-Carrillo *et al.* (2015) and Medina-Achín *et al.* (2018). Based on currently knowledge of Peruvian Histeridae fauna, the record of *Saprinus aeneus* (Fabricius) (Iannacone 2003), species that present known distribution to England, Europe, Russia, Syria, Turkey, Iran and, Kazakhstan (Mazur 2011), was attributed to an indeterminate species of the genus *Euspilotus*.

RESULTS AND DISCUSSION

The present list of beetles of forensic importance includes eight families, 31 genera, and 94 species. The most frequent genera in the 35 studies of cadaveric succession were *Dermestes* Linnaeus (0.80), *Necrobia* Olivier (0.71) and *Euspilotus* (0.63) recorded in more than half of studies and *Hister* Linnaeus (0.46), *Philonthus* Curtis (0.43) and *Oxelytrum* Gistel (0.40) recorded in more than a third of studies. The genera *Aleochara* Gravenhorst, *Eurysternus*, *Hister*, *Phelister*, *Philonthus*, *Polynoncus* and *Stelidota* Erichson were recorded in Peruvian cadaveric succession studies, but only as undetermined species. For the genera *Atheta* Thomson, *Anotylus* Thomson and *Canthidium* Erichson, it was not possible to assign forensic valuable species for the Peruvian fauna.

The species included in each category were 14 known, 53 expected and 27 potential. The genera with the highest ratio and index of forensic importance species were: *Creophilus* Leach, *Dermestes*, *Euspilotus*, *Necrobia*, *Omorgus* Erichson, *Oxelytrum*, *Polynoncus*, *Saprinus* Erichson and *Xerosaprinus* Wenzel. Data for each of 31 genera are presented in appendix 2.

In the list, species are arranged according to forensic importance categories established in material and methods section, known, expected or potential.

Known species

Species recorded in entomological cadaveric succession studies carried out in Peru and other South American countries. Detailed Peruvian records and South American country records are provided.

Cleridae Latreille, 1802
Korynetinae Laporte, 1836
Necrobia Olivier, 1795
Necrobia ruficollis (Fabricius, 1775)

PERU: Lima, Lima, Pantanos de Villa, pig carcasses (Murrugarra-Bringas 2016). ARGENTINA (Oliva 2001, Centeno *et al.* 2002, Aballay *et al.* 2017), BRAZIL (Mise *et al.* 2007, Souza *et al.* 2008), URUGUAY (Remedios-De León *et al.* 2017, Castro *et al.* 2019).

Necrobia rufipes (DeGeer, 1775)

PERU: Callao, Ventanilla, pig carcasses (Iannacone 2003); La Libertad, Trujillo, rabbit carcasses (Sarmiento-Yengle and Padilla-Sagástegui 2015); Lambayeque, Lambayeque, UNPRG, pig carcasses (Ginés-Carrillo *et al.* 2015, Medina-Achín *et al.* 2018); Lima, Huarochirí, pig carcasses (Peceros-Peláez 2011), Lima, El Agustino, pig carcasses (Grados 2014), Pantanos de Villa, pig carcasses (Murrugarra-Bringas 2016); Piura, Piura, Castilla, guinea pig carcasses (Andrade-Herrera *et al.* 2018). ARGENTINA (Oliva 2001, Centeno *et al.* 2002, Aballay *et al.* 2008, Aballay *et al.* 2012, Trigo and Centeno 2014, Armani *et al.* 2015, Aballay *et al.* 2017, Armani *et al.* 2017), BRAZIL (Souza and Linhares 1997, Mise *et al.* 2007, Souza *et al.* 2008, Silva and Santos 2012, Santos *et al.* 2014), COLOMBIA (Wolff *et al.* 2001), ECUADOR (Aguirre-Carrera 2014), URUGUAY (Remedios-De León *et al.* 2017, Castro *et al.* 2019), VENEZUELA (Magaña *et al.* 2006).

Dermestidae Latreille, 1804
Dermestinae Latreille, 1804
Dermestes Linnaeus, 1758
Dermestes ater DeGeer, 1774

PERU: Lima, Huarochirí, pig carcasses (Peceros-Peláez 2011); Piura, Piura, Castilla, guinea pig carcasses (Andrade-Herrera *et al.* 2018). ARGENTINA (Centeno *et al.* 2002, Aballay *et al.* 2008, Aballay *et al.* 2012), VENEZUELA (Liria-Salazar 2006, Magaña *et al.* 2006).

Dermestes frischii Kugelann, 1792

PERU: Lambayeque, Lambayeque, UNPRG, pig carcasses (Ginés-Carrillo et al. 2015); La Libertad, Trujillo, rabbit carcasses (Sarmiento-Yengle and Padilla-Sagástegui 2015); Lima, Huarochirí, pig carcasses (Peceros-Peláez 2011), Lima, El Agustino, pig carcasses (Grados 2014), Pantanos de Villa, pig carcasses (Murrugarra-Bringas 2016); Piura, Piura, Castilla, guinea pig carcasses (Andrade-Herrera *et al.* 2018). VENEZUELA (Magaña *et al.* 2006).

Dermestes maculatus DeGeer, 1774

PERU: Callao, Ventanilla, pig carcasses (Iannacone 2003); Lambayeque, Lambayeque, UNPRG, pig carcasses (Ginés-Carrillo *et al.* 2015, Medina-Achín *et al.* 2018); Lima, Huarochirí, pig carcasses (Peceros-Peláez 2011), Lima, Pantanos de Villa, pig carcasses (Murrugarra-Bringas 2016); Loreto, Maynas, pig carcasses (Pizango-Pérez *et al.* 2019); Piura, Piura, Castilla, guinea pig carcasses (Andrade-Herrera *et al.* 2018). ARGENTINA (Oliva 2001, Centeno *et al.* 2002, Aballay *et al.* 2008, Aballay *et al.* 2012, Trigo and Centeno 2014, Armani *et al.* 2015, Aballay *et al.* 2017, Armani *et al.* 2017), BRAZIL (Souza and Linhares 1997, Mise *et al.* 2007, Souza *et al.* 2008, Santos *et al.* 2014, Costa-Silva *et al.* 2017), ECUADOR (Aguirre-Carrera 2014), URUGUAY (Remedios-De León *et al.* 2017, Castro *et al.* 2019).

Histeridae Gyllenhal, 1808
Saprininae Blanchard, 1845
Euspilotus Lewis, 1907
Euspilotus ater Arriagada, 2015

PERU: Lima, Lima, El Agustino, pig carcasses (Grados 2014).

Euspilotus (*Euspilotus*) *decoratus* (Erichson, 1834)

PERU: Lambayeque, Lambayeque, UNPRG, pig carcasses (Ginés-Carrillo *et al.* 2015, Medina-Achín *et al.* 2018); Lima, Lima, El Agustino, pig carcasses (Grados 2014), Pantanos de Villa, pig carcasses (Murrugarra-Bringas 2016).

Saprinus Erichson, 1834
Saprinus caerulescens (Hoffmann, 1803)

PERU: Lambayeque, Lambayeque, UNPRG, pig carcasses (Ginés-Carrillo *et al.* 2015, Medina-Achín *et al.* 2018); Lima, Lima, El Agustino, pig carcasses (Grados 2014), Pantanos de Villa, pig carcasses (Murrugarra-Bringas 2016); Piura, Piura, Castilla, guinea pig carcasses (Andrade-Herrera *et al.* 2018).

Xerosaprinus Wenzel, 1962
Xerosaprinus (*Xerosaprinus*) *chiliensis* (Marseul, 1855)

PERU: Lima, Lima, El Agustino, pig carcasses (Grados 2014), Pantanos de Villa, pig carcasses (Murrugarra-Bringas 2016).

Scarabaeidae Latreille, 1802
Scarabaeinae Latreille, 1802
Canthon Hoffmannsegg, 1817
Canthon balteatus Boheman, 1858

PERU: Piura, Piura, Castilla, guinea pig carcasses (Andrade-Herrera *et al.* 2018).

Canthon fuscipes Erichson, 1847

PERU: Piura, Piura, Castilla, guinea pig carcasses (Andrade-Herrera *et al.* 2018).

Canthon subhyalinus Harold, 1867

PERU: Loreto, Maynas, pig carcasses (Pizango-Pérez *et al.* 2019).

Silphidae Latreille, 1807
Silphinae Latreille, 1807
Oxelytrum Gistel, 1848
Oxelytrum cayennense (Sturm, 1826)

PERU: Loreto, Maynas, pig carcasses (Pizango-Pérez *et al.* 2019). BRAZIL (Mise *et al.* 2010), COLOMBIA (Ramos-Pastrana *et al.* 2018), ECUADOR (Aguirre-Carrera 2014).

Trogidae MacLeay, 1819
Omorgus Erichson, 1847
Omorgus suberosus (Fabricius, 1775)

PERU: Piura, Piura, Castilla, guinea pig carcasses (Andrade-Herrera *et al.* 2018). ARGENTINA (Aballay *et al.* 2008, Aballay *et al.* 2012, Aballay *et al.* 2017), BRAZIL (Santos *et al.* 2014, Costa-Silva *et al.* 2017), URUGUAY (Castro *et al.* 2019), VENEZUELA (Magaña *et al.* 2006).

Expected species

Species recorded in cadaveric succession studies and reviews carried out in South American countries, but not yet in Peru. South American country records are provided.

Dermestidae Latreille, 1804
Dermestinae Latreille, 1804
Dermestes carnivorus Fabricius, 1775

ECUADOR (Aguirre-Carrera 2014).

Dermestes haemorrhoidalis Küster, 1852

BRAZIL (Santos *et al.* 2014).

Dermestes peruvianus Laporte, 1840

ARGENTINA (Oliva 2001), BRAZIL (Souza and Linhares 1997).

Histeridae Gyllenhal, 1808
Histerinae Gyllenhal, 1808
Hister Linnaeus, 1758
Hister cavifrons Marseul, 1854

BRAZIL (Celli *et al.* 2015, Costa-Silva *et al.* 2017).

Omalodes Dejean, 1834
Omalodes bifoveolatus Marseul, 1853

BRAZIL (Mise *et al.* 2010, Vasconcelos and Araujo 2012, Celli *et al.* 2015,).

Omalodes foveola Erichson, 1834

BRAZIL (Mise *et al.* 2010, Santos *et al.* 2014, Celli *et al.* 2015, Costa-Silva *et al.* 2017).

Omalodes lucidus Erichson, 1834

BRAZIL (Mise *et al.* 2010, Celli *et al.* 2015). Note: Peruvian records refer to *Omalodes lucidus peruvianus* Marseul, 1861

Phelister Marseul, 1853
Phelister rufinotus Marseul, 1861

ARGENTINA (Aballay *et al.* 2013), URUGUAY (Remedios-De León *et al.* 2017).

Saprininae Blanchard, 1845
Euspilotus Lewis, 1907
Euspilotus (*Euspilotus*) *lepidus* (Erichson, 1847)

ARGENTINA (Aballay *et al.* 2013, Aballay *et al.* 2017).

Euspilotus (*Hesperosaprinus*) *azureus* Sahlberg, 1823

ARGENTINA (Aballay *et al.* 2013), BRAZIL (Souza and Linhares1997, Mise *et al.* 2007, Souza *et al.* 2008, Mise *et al.* 2010, Silva and Santos 2012, Santos *et al.* 2014, Celli *et al.* 2015, Costa-Silva *et al.* 2017), ECUADOR (Aguirre-Carrera 2014), URUGUAY (Remedios-De León *et al.* 2017, Castro *et al.* 2019).

Euspilotus (*Hesperosaprinus*) *modestus* (Erichson, 1834)

ARGENTINA (Aballay *et al.* 2008, Aballay *et al.* 2012, Aballay *et al.* 2013, Armani *et al.* 2015, Aballay *et al.* 2017, Armani *et al.* 2017), URUGUAY (Remedios-De León *et al.* 2017, Castro *et al.* 2019).

Euspilotus (*Hesperosaprinus*) *pavidus* (Erichson, 1834)

ARGENTINA (Aballay *et al.* 2008, Aballay *et al.* 2012, Aballay *et al.* 2013, Aballay *et al.* 2017).

Xerosaprinus Wenzel, 1962
Xerosaprinus (*Xerosaprinus*) *diptychus* (Marseul, 1855)

ARGENTINA (Aballay *et al.* 2008, Aballay *et al.* 2012, Aballay *et al.* 2013, Aballay *et al.* 2017), BRAZIL (Santos *et al.* 2014).

Nitidulidae Latreille, 1802
Carpophilinae Erichson, 1842
Carpophilus Stephens, 1830
Carpophilus hemipterus Linnaeus, 1758

ARGENTINA (Oliva 2001).

Nitidulinae Latreille, 1802
Stelidota Erichson, 1843
Stelidota geminata (Say, 1825)
BRAZIL (Santos *et al.* 2014).

Scarabaeidae Latreille, 1802
Aphodiinae Leach, 1815
Ataenius Harold 1867
Ataenius picinus Harold, 1868
BRAZIL (Mise *et al.* 2007, Costa-Silva *et al.* 2017).

Scarabaeinae Latreille, 1802
Canthon Hoffmannsegg, 1817
Canthon conformis Harold, 1868
BRAZIL (Almeida and Mise 2009, Costa-Silva *et al.* 2017).

Canthon lituratus (Germar, 1813)
BRAZIL (Almeida and Mise 2009, Almeida *et al.* 2015).

Canthon mutabilis Lucas, 1857
BRAZIL (Almeida and Mise 2009, Almeida *et al.* 2015).

Canthon muticus Harold, 1867
BRAZIL (Almeida and Mise 2009, Almeida *et al.* 2015).

Canthon septemmaculatus (Latreille, 1807)
BRAZIL (Almeida and Mise 2009, Almeida *et al.* 2015).

Canthon smaragdulus (Fabricius, 1781)
BRAZIL (Almeida and Mise 2009, Almeida *et al.* 2015).

Canthon triangularis Drury, 1870
BRAZIL (Almeida and Mise 2009, Mise *et al.* 2010).

Canthon unicolor Blanchard, 1843
BRAZIL (Almeida *et al.* 2015).

Coprophanaeus Olsoufieff, 1924
Coprophanaeus (*Megaphanaeus*) *lancifer* (Linnaeus, 1767)
BRAZIL (Mise *et al.* 2010).

Deltochilum Eschscholtz, 1822
Deltochilum (*Calhyboma*) *carinatum* Westwood, 1837
BRAZIL (Almeida and Mise 2009, Almeida *et al.* 2015).

Deltochilum (*Calhyboma*) *robustus* Molano and Gonzalez, 2009
ECUADOR (Aguirre-Carrera 2014).

Deltochilum (*Deltohyboma*) *peruanum* Paulian, 1939
BRAZIL (Mise et al. 2010).

Deltochilum (*Telhyboma*) *orbiculare* Lansberge, 1874
BRAZIL (Almeida and Mise 2009, Almeida *et al.* 2015).

Dichotomius Hope, 1838
Dichotomius (*Cephagonus*) *fissus* (Harold, 1867)
BRAZIL (Almeida *et al.* 2015).

Dichotomius (*Dichotomius*) *semiaeneus* (Germar, 1824)
BRAZIL (Almeida *et al.* 2015).

Eurysternus Dalman, 1824
Eurysternus caribaeus (Herbst, 1789)
BRAZIL (Costa-Silva *et al.* 2017).

Eurysternus foedus Guérin-Méneville, 1830
BRAZIL (Almeida and Mise 2009, Almeida *et al.* 2015).

Eurysternus hypocrita Balthasar, 1939
BRAZIL (Mise *et al.* 2010).

Ontherus Erichson, 1847
Ontherus (*Ontherus*) *sulcator* (Fabricius, 1775)
BRAZIL (Costa-Silva *et al.* 2017), URUGUAY (Castro *et al.* 2019).

Onthophagus Latreille, 1807
Onthophagus bidentatus Drapiez, 1819
BRAZIL (Almeida and Mise 2009, Almeida *et al.* 2015).

Silphidae Latreille, 1807
Silphinae Latreille, 1807
Oxelytrum Gistel, 1848
Oxelytrum anticola (Guérin-Méneville, 1855)
ECUADOR (Aguirre-Carrera 2014).

Oxelytrum discicolle (Brullé, 1840)
BRAZIL (Mise *et al.* 2007, Souza *et al.* 2008, Costa-Silva *et al.* 2017), COLOMBIA (Ospina-Maldonado 2006, Grisales *et al.* 2010), ECUADOR (Aguirre-Carrera 2014), URUGUAY (Remedios-De León *et al.* 2017).

Staphylinidae Latreille, 1802
Aleocharinae Fleming, 1821
Aleochara Gravenhorst, 1802
Aleochara (*Coprochara*) *notula* Erichson, 1839
BRAZIL (Almeida *et al.* 2015).

Aleochara (*Coprochara*) *signaticollis* Fairmaire & Germain, 1862
ARGENTINA (Aballay *et al.* 2014).

Aleochara (*Xenochara*) *puberula* Klug, 1832
ARGENTINA (Aballay *et al.* 2014).

Aleochara (*Xenochara*) *taeniata* Erichson, 1839
BRAZIL (Almeida *et al.* 2015).

Staphylininae Latreille, 1802
Belonuchus Nordmann, 1837
Belonuchus rufipennis (Fabricius, 1801)
ARGENTINA (Aballay *et al.* 2014).

Creophilus Leach, 1819
Creophilus maxillosus (Linnaeus, 1758)
ARGENTINA (Centeno *et al.* 2002, Aballay *et al.* 2008, Aballay *et al.* 2012, Armani *et al.* 2015, Armani *et al.* 2017), BOLIVIA (Castillo *et al.* 2017), URUGUAY (Remedios-De León *et al.* 2017).

Creophilus variegatus Mannerheim, 1830
ARGENTINA (Aballay *et al.* 2014), BRAZIL (Costa-Silva *et al.* 2017).

Eulissus Mannerheim, 1830
Eulissus chalybaeus Mannerheim, 1830
ARGENTINA (Aballay *et al.* 2014), BRAZIL (Souza and Linhares 1997, Mise *et al.* 2007, Moretti *et al.* 2008, Costa-Silva *et al.* 2017), ECUADOR (Aguirre-Carrera 2014).

Philonthus Curtis, 1829
Philonthus feralis Erichson, 1840
BRAZIL (Almeida *et al.* 2015).

Philonthus figulus Erichson, 1840
BRAZIL (Santos *et al.* 2014).

Philonthus flavolimbatus Erichson, 1840
BRAZIL (Almeida *et al.* 2015).

Philonthus longicornis Stephens, 1832
ARGENTINA (Aballay *et al.* 2008, Aballay *et al.* 2012).

Platydracus Thomson, 1858
Platydracus chrysotrichopterus (Scheerpeltz, 1933)
ARGENTINA (Aballay *et al.* 2014).

Platydracus ochropygus (Nordmann, 1837)
BRAZIL (Mise *et al.* 2010, Costa-Silva *et al.* 2017).

Platydracus scabrosus (Curtis, 1839)
ARGENTINA (Aballay *et al.* 2014).

Potential species

Species not recorded yet in cadaveric succession trials carried out in South American countries. Their forensic importance is based on collecting data indicating its association with vertebrate carcasses or catch with carrion-baited traps.

Histeridae Gyllenhal, 1808
Histerinae Gyllenhal, 1808
Phelister Marseul, 1853
Phelister blairi Hinton, 1935
Phelister sphaericus Caterino & Tishechkin, 2020
Phelister uncinatus Caterino & Tishechkin, 2020

Saprininae Blanchard, 1845
Euspilotus Lewis, 1907
Euspilotus (*Hesperosaprinus*) *amazonicus* (Desbordes, 1923)
Euspilotus (*Hesperosaprinus*) *arrogans* (Marseul, 1855)
Euspilotus (*Hesperosaprinus*) *excavata* Arriagada, 2012
Euspilotus (*Hesperosaprinus*) *flaviclava* (Marseul, 1870)

Scarabaeidae Latreille, 1802
Scarabaeinae Latreille, 1802
Coprophanaeus Olsoufieff, 1924
Coprophanaeus (*Coprophanaeus*) *parvulus* (Olsoufieff, 1924)
Coprophanaeus (*Coprophanaeus*) *telamon* (Erichson, 1847)

Deltochilum Eschscholtz, 1822
Deltochilum (*Calhyboma*) *hypponum* Buquet, 1844
Deltochilum (*Calhyboma*) *mexicanum* Burmeister, 1848
Deltochilum (*Hybomidium*) *amazonicum* Bates, 1887

Dichotomius Hope, 1838
Dichotomius (*Dichotomius*) *worontzowi* (Pereira, 1942)
Dichotomius (*Luederwaldtinia*) *lucasi* (Harold, 1869)

Eurysternus Dalman, 1824
Eurysternus cayennensis Laporte, 1840
Eurysternus hamaticollis Balthasar, 1939
Eurysternus plebejus Harold, 1880
Eurysternus wittmerorum Martínez, 1988

Onthophagus Latreille, 1807
Onthophagus clypeatus Blanchard, 1846

Staphylinidae Latreille, 1802
Staphylininae Latreille, 1802
Xanthopygus Kraatz, 1857
Xanthopygus xanthopygus (Nordmann, 1837)

Trogidae MacLeay, 1819
Omorgus Erichson, 1847
Omorgus persuberosus (Vaurie, 1962)

Polynoncus Burmeister, 1876
Polynoncus aricensis (Gutiérrez, 1950)
Polynoncus brevicollis (Eschscholtz, 1822)
Polynoncus gordoni (Steiner, 1981)
Polynoncus peruanus (Erichson, 1847)
Polynoncus pilularius (Germar, 1824)
Polynoncus sallei (Harold, 1872)

According to frequency in studies reviewed and forensic importance ratios presented here, *Dermestes* and *Necrobia* genera are the most relevant beetles of forensic importance in Peru and elsewhere. Recently, it has been shown that the species of these genera leave significant traces on carcasses, marks on epithelial and connective tissues caused by feeding activity of *Necrobia rufipes* (DeGeer, 1775) (Zanetti *et al.* 2015b), and bone depressions caused by feeding and pupation of *Dermestes maculatus* DeGeer, 1774 (Zanetti *et al.* 2018). The identification of these species is relatively simple, with valid keys for wide geographic areas, since the species of these genera are cosmopolitan and, in many cases, also pests of stored products (Midgley *et al.* 2010).

Forensic importance ratios for Histeridae genera attained their highest values for *Euspilotus*, *Saprinus* and *Xerosaprinus*, all of them belonging to Saprininae subfamily. Species of *Euspilotus* and *Xerosaprinus* have been frequently associated with vertebrate carcasses in arid and tropical ecosystems of South America (Dégallier *et al.* 2012, Aballay *et al.* 2013, Arriagada 2015, Celli *et al.* 2015). *Saprinus caerulescens* (Hoffmann, 1803) is an introduced and established species in Peru (Arriagada 2015), well known for its necrophilous habits in countries of the Palearctic region (Özdemir and Sert 2009, Sawaby *et al.* 2016). In comparison, forensic value of species in the Histerinae subfamily appears rather lesser. The patterns observed here for Peruvian fauna of necrophilous histerids reflect the global patterns observed in studies published from 1811 to 2014 for this group (Correa *et al.* 2020). In this review, subfamilies recorded with the highest frequency were Saprininae (62%) and Histerinae (30%), and among the genera with highest percentage of necrophilous species were *Euspilotus* (29%), *Saprinus* (36%) and *Xerosaprinus* (21%). Although there are genera and species widely distributed in South America, available keys for Argentina (Aballay *et al.* 2013) and Brazil (Celli *et al.* 2015) should be applied with caution to avoid misidentifications.

Within Staphylinidae, forensic importance ratios were highest for *Creophilus* genus, of which *C. maxillosus* (Linnaeus, 1758) is a cosmopolitan species with well-established necrophilous habits (Navarrete-Heredia *et al.* 2002, Asenjo and Clarke 2007). Other Staphylininae genera did not attain high values in calculated ratios, but they have species with Pan American distributions and have been clearly associated with animal carcasses or collected with carrion-baited traps, this is the case of *Belonuchus rufipennis* (Fabricius, 1801), *Eulissus chalybeus* Mannerheim, 1830 and *Xanthopygus xanthopygus* (Nordmann, 1837) (Navarrete-Heredia *et al.* 2002, Navarrete-Heredia 2004). In comparison, there is considerable uncertainty about the forensic value of species in other genera of Staphylininae, and for Aleocharinae and Oxytelinae subfamilies. Although there are genera and species widely distributed in America, available keys for Argentina (Aballay *et al.* 2014) and Mexico (Navarrete-Heredia *et al.* 2002) should be applied with caution to avoid misidentifications.

In Silphidae and Trogidae families, all species are clearly associated with carrion, being necrophilous and necrophagous respectively. The forensic importance for genus *Oxelytrum* was noted early by Oliva (2001) and the same is suggested by ratios presented here. This statement has been corroborated by cadaveric succession trials and findings on human corpses for *O. discicolle* (Brullé, 1840) and *O. cayennense* (Sturm, 1826), whose larvae and adult have potential use as a postmortem interval indicator because have been recorded on carcasses from early days onward (Ururahy-Rodrigues *et al.* 2010, Kotzko *et al.* 2015). In the case of *O. anticola* (Guérin-Méneville, 1855), it was included in a checklist of forensic valuable species from Ecuador (Salazar y Donoso 2015) and should be forensically important in Peruvian Andean environments where other silphids are scarce or absent (Giraldo-Mendoza 2016). Within Trogidae, *Omorgus* and *Polynoncus* reached high values for forensic importance ratios that were proposed. *Omorgus suberosus* (Fabricius, 1775) has the greatest forensic potential due to its wide distribution from Canada to southern Argentina, and its probable tolerance to anthropogenic environments (Scholtz 1990, Correa *et al.* 2013). While other trogid species with a more restricted distribution, endemic or inhabiting native vegetation require further studies.

In Nitidulidae and Scarabaeidae (Aphodiinae, Scarabaeinae) families, most species are associated to decaying fruits and dung respectively. Consequently, more rigorous studies are required to establish preference or specialization for carrion. For Scarabaeinae, studies incorporating simultaneous collecting with different baits (carrion, dung, rotting fruits) and establishing their food preferences (relative abundance per bait) are required, like those performed by Ratcliffe (2013) and Cajaiba *et al.* (2017). The forensic importance of *Ataenius picinus* Harold, 1868 has been suggested from cadaveric succession trials in which its abundance was higher during decomposition phase and positively related to duration for each stage (Ries *et al.* 2016). Similarly, *Coprophanaeus lancifer* (Linnaeus, 1767) has been suggested as a biotaphonomic important species, with the ability to dismember and to change position of a man-size pig carcass (Ururahy-Rodrigues *et al.* 2008).

Several species, genera and even families of necrocolous beetles that occur in Peru would have been omitted from present list, since only the most frequent ones were included and due to the lack of studies about carrion-associated insects in Peruvian localities. The families relevant to the Neotropics, but absent from the list are Carabidae, Leiodidae, Geotrupidae, Hybosoridae, Hydrophilidae, Monotomidae and Tenebrionidae (Almeida and Mise 2009, Almeida *et al.* 2015). Regarding Carabidae and Tenebrionidae, most are epigeic species effectively sampled with pitfall traps (Zanetti *et al.* 2016) and in some ecosystems they could be important components of the necrocolous fauna. For instance, carabids collected with pitfall traps surrounding pig carcasses in an agroecosystem of Buenos Aires province (Scampini *et al.* 2002) and tenebrionids collected with carrion-baited traps and on vertebrate carcasses in arid and semiarid areas of Buenos Aires, Catamarca, Mendoza and San Juan provinces (Aballay *et al.* 2016).

Putting the future of forensic entomology in Peru in perspective, a first point is to break the bias that until now has had the geographic location of cadaveric succession studies (Appendix 1). More studies of this type need to be carried out in inter-Andean valleys, high Andean plateaus and eastern Amazon. A second point is using combinations of sampling methods rather than a single method in cadaveric succession studies. Manual collecting is the most widely method employed, but use of Malaise traps, pitfall traps, Shannon traps, substrate extraction, and underneath trays are advisable for to collect more taxa (Zanetti *et al.* 2016, Santos *et al.* 2019, Appendix 1). A third point is to carry out surveys of necrocolous beetles covering wider geographic areas, examining vertebrate carcasses found in open air and using carrion-baited traps as has been successfully applied in other countries, such as Argentina (Aballay *et al.* 2013, 2014, 2016) and Mexico (Navarrete-Heredia *et al.* 2002, Rodriguez-Olivares *et al.* 2015).

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Appendix 1. Summary of studies about entomological cadaveric succession in South America.

	locality	substrates	collecting methods	references
1	Campinas city, Sao Paulo, Brazil	pig carcasses	Shannon traps (named conical), underneath tray	Souza and Linhares (1997)
2	Medellín city, Antioquia, Colombia	pig carcasses	manual collecting	Wolff *et al.* (2001)
3	20 km SE from Buenos Aires city, Argentina	pig carcasses	manual collecting, pitfall traps	Centeno *et al.* (2002)
4	Ventanilla, Callao, Perú	pig carcasses	manual collecting	Iannacone (2003)
5	Carabobo University, Carabobo, Venezuela	rat carcasses	underneath tray, substrate extraction	Liria-Salazar (2006)
6	Maracay city, Aragua, Venezuela	rabbit and rat carcasses	manual collecting	Magaña *et al.* (2006)
7	Villeta, Cundinamarca, Colombia	pig carcasses	manual collecting	Ospina-Maldonado (2006)
8	Curitiba, Paraná, Brazil	pig carcasses	underneath tray, Shannon trap, pitfall trap	Mise *et al.* (2007)
9	San Juan Province, Argentina	pig carcasses, open air vertebrate carcasses	manual collecting, Malaise trap	Aballay *et al.* (2008)
10	Campinas city, Sao Paulo, Brazil	mice and rat carcasses	manual collecting, substrate extraction	Moretti *et al.* (2008)
11	Rio Grande do Sul, Brazil	rabbit carcasses	manual collecting	Souza *et al.* (2008)
12	Pereira city, Risaralda, Colombia	pig carcasses	manual collecting	Grisales *et al.* (2010)
13	Adolpho Ducke Forest Reserve, Brazil	pig carcasses	manual collecting, pitfall traps	Mise *et al.* (2010)
14	Huarochirí, Lima, Perú	pig carcasses	manual collecting, underneath tray	Peceros-Peláez (2011)
15	SJNU campus, San Juan, Argentina	pig carcasses	manual collecting, Malaise trap, pitfall traps	Aballay *et al.* (2012)
16	Ribeirão do Pinhal, Paraná, Brazil	rabbit carcasses	underneath tray, Shannon trap, pitfall traps	Silva and Santos (2012)
17	Pichincha province, Ecuador	guinea pig carcasses	manual collecting, McPhail trap, pitfall traps	Aguirre-Carrera (2014)
18	Mata Viva reserve, Paraná, Brazil	rabbit carcasses	substrate extraction, pitfall traps	Correa *et al.* (2014)
19	El Agustino, Lima, Perú	pig carcasses	manual collecting	Grados (2014)
20	Fazenda Almas reserve, Paraíba, Brazil	pig carcasses	underneath tray, Shannon trap, pitfall traps	Santos *et al.* (2014)
21	Tandil, Buenos Aires, Argentina	pig carcasses	manual collecting	Trigo and Centeno (2014)
22	Puerto Madryn, Chubut, Argentina	pig carcasses	manual collecting, pitfall traps	Armani *et al.* (2015)
23	UNPRG botanic garden, Lambayeque, Perú	pig carcasses	manual collecting	Ginés-Carrillo *et al.* (2015)
24	Experimental field UNT, La Libertad, Perú	rabbit carcasses	manual collecting	Sarmiento-Yengle and Padilla-Sagástegui (2015)
25	Pantanos de Villa, Lima, Perú	pig carcasses	manual collecting	Murrugarra-Bringas (2016)
26	Telteca reserve, Mendoza, Argentina	cow and horse carcasses	substrate extraction	Aballay *et al.* (2017)
27	Trelew city, Chubut, Argentina	pig carcasses	manual collecting, pitfall traps	Armani *et al.* (2017)
28	Pucarani, La Paz, Bolivia	pig carcasses	manual collecting	Castillo *et al.* (2017)
29	Santa Maria, Rio Grande do Sul, Brazil	rat carcasses	manual collecting, pitfall traps	Costa-Silva *et al.* (2017)

30	Pando city, Canelones, Uruguay	pig carcasses	manual collecting, Malaise trap, pitfall traps	Remedios-De León *et al.* (2017)
31	Caserío Miraflores, Castilla, Piura, Perú	guinea pig carcasses	manual collecting	Andrade-Herrera *et al.* (2018)
32	UNPRG botanic garden, Lambayeque, Perú	pig carcasses	manual collecting	Medina-Achín *et al.* (2018)
33	Florencia, Caquetá, Colombia	pig carcasses	manual collecting, pitfall traps	Ramos-Pastrana *et al.* (2018)
34	Paysandú city, Paysandú, Uruguay	pig carcasses	manual collecting, Malaise trap, pitfall traps	Castro *et al.* (2019)
35	San Juan Bautista, Maynas, Loreto, Perú	pig carcasses	manual collecting	Pizango-Pérez *et al.* (2019)

Appendix 2. Summary of species, frequency, ratio and index for each genus. Numbers already mentioned in results and discussion section is highlighted in bold.

Family/genus	species				frequency 35 studies	ratio	index
	known	expected	potential	In Peru			
Cleridae							
Necrobia	2	0	0	2	**0.71**	**1.00**	**0.50**
Dermestidae							
Dermestes	3	3	0	6	**0.80**	**1.00**	**0.40**
Histeridae							
Hister	0	1	0	6	**0.46**	0.17	0.05
Omalodes	0	3	0	9	0.11	0.33	0.10
Phelister	0	1	3	39	0.20	0.10	0.02
Euspilotus	2	4	4	14	**0.63**	**0.71**	**0.21**
Saprinus	1	0	0	1	0.23	**1.00**	**0.50**
Xerosaprinus	1	1	0	2	0.17	**1.00**	**0.40**
Nitidulidae							
Carpophilus	0	1	0	6	0.14	0.17	0.05
Stelidota	0	1	0	3	0.11	0.33	0.10
Scarabaeidae							
Ataenius	0	1	0	30	0.17	0.03	0.01
Canthidium	0	0	0	23	0.14	---	---
Canthon	3	8	0	38	0.20	0.29	0.10
Coprophanaeus	0	1	2	9	0.17	0.33	0.08
Deltochilum	0	4	3	21	0.14	0.33	0.09
Dichotomius	0	2	2	33	0.17	0.12	0.03
Eurysternus	0	3	4	19	0.14	0.37	0.09
Ontherus	0	1	0	18	0.14	0.06	0.02
Onthophagus	0	1	1	17	0.20	0.12	0.03
Silphidae							
Oxelytrum	1	2	0	3	**0.40**	**1.00**	**0.37**
Staphylinidae							
Aleochara	0	4	0	19	0.29	0.21	0.06
Atheta	0	0	0	12	0.11	---	---
Anotylus	0	0	0	3	0.11	---	---

Belonuchus	0	1	0	21	0.11	0.05	0.01
Creophilus	0	2	0	2	0.23	**1.00**	**0.30**
Eulissus	0	1	0	3	0.14	0.33	0.10
Philonthus	0	4	0	21	**0.43**	0.19	0.06
Platydracus	0	3	0	18	0.14	0.17	0.05
Xanthopygus	0	0	1	8	0.17	0.13	0.03
Trogidae							
Omorgus	1	0	1	2	0.29	**1.00**	**0.35**
Polynoncus	0	0	6	6	0.14	**1.00**	**0.20**