A synoptic overview of golden jackal parasites reveals high diversity of species
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Abstract
The golden jackal (Canis aureus) is a species under significant and fast geographic expansion. Various parasites are known from golden jackals across their geographic range, and certain groups can be spread during their expansion, increasing the risk of cross-infection with other carnivores or even humans. The current list of the golden jackal parasites includes 194 species and was compiled on the basis of an extensive literature search published from historical times until April 2017, and is shown herein in synoptic tables followed by critical comments of the various findings. This large variety of parasites is related to the extensive geographic range, territorial mobility and a very unselective diet. The vast majority of these parasites are shared with domestic dogs or cats. The zoonotic potential is the most important aspect of species reported in the golden jackal, some of them, such as Echinococcus spp., hookworms, Toxocara spp., or Trichinella spp., having a great public health impact. Our review brings overwhelming evidence on the importance of Canis aureus as a wild reservoir of human and animal parasites.

Keywords: Golden jackal, Canis aureus, Parasites

Background
The golden jackal, Canis aureus (Carnivora: Canidae) is a medium-sized canid species [1] also known as the common or Asiatic jackal [2], Eurasian golden jackal [3] or the reed wolf [4]. Traditionally, Canis aureus has been regarded as a polytypic species (Table 1), with 14 subspecies distributed across a vast geographical territory in Europe, Asia and Africa [5, 6]. Recently, phylogenetic studies have demonstrated that at least two of the African subspecies need a formal recognition as distinct species. Koepfli et al. [3] suggested that C. aureus anthus forms a distinct monophyletic lineage to C. aureus and should be recognized as a separate species. Similarly, the phylogenetic comparison of the Egyptian jackal (C. aureus lupaster) with other wolf-like canids showed a close relationship with the gray wolf species complex rather than with other subspecies of golden jackals [7]. Nevertheless, because most of the studies dealing with parasites of golden jackals do not mention the subspecies, for the purpose of this review we have considered the entire group, without excluding the two former subspecies.

The distribution of golden jackals is limited to the Old World [8]. Molecular evidence supports an African origin for all wolf-like canids including the golden jackal [8]. It is considered that the colonization of Europe by the golden jackal took place during the late Holocene and early Neolithic, through the Balkan Peninsula [9]. During the last century, the species has recorded at least two geographic expansion events. A notable expansion started in the 1950s, with a second one following during the 1980s. This is particularly evident in Europe. Stable reproductive populations have been recorded in about 20 European countries, while in other nine, vagrant specimens were observed [10]. The factors that facilitate the territorial expansion of golden jackals are unclear, but land use [11], climate change [12, 13], and the lack of intra-genus competition have been suggested [12–14].

Golden jackals have an opportunistic nutritional behaviour with an extremely varied diet [15]. They prey or scavenge on small mammals, birds and their eggs, amphibians, reptiles, even invertebrates, and they take carrion when available. Occasionally, jackals also feed on vegetables or fruits. Additionally, their relatively broad home range, varying from 1.1 to 20.0 km² [16, 17], increases the chance of contact with various parasites but also with other hosts.

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| Subspecies               | Common name                  | Range                                                                 | Synonyms                                                                 |
|-------------------------|------------------------------|----------------------------------------------------------------------|--------------------------------------------------------------------------|
| Canis a. aureus Linnaeus, 1758 | Common jackal               | Middle Asia; Afghanistan; Iran; Iraq; Arabian Peninsula; Baluchistan; northwestern India | C. balcanicus; C. caucasicus; C. dalmatinus; C. hadramarticus; C. hungaricus; C. kola; C. lanka; C. maroccanus; C. typicus; C. vulgaris |
| Canis a. algirensis Wagner, 1841 | Algerian wolf              | Algeria; Morocco; Tunisia                                            | C. barbarus; C. gray; C. tripolitanus; C. senegolensis                   |
| Canis a. anthus Cuvier, 1820 | Senegalese wolf; grey jackal; slender jackal | Senegal                                                            |                                                                          |
| Canis a. bea Heller, 1914 | Serengeti wolf; Serengeti jackal | Kenya; northern Tanzania                                            |                                                                          |
| Canis a. cneumanni Matschie, 1900 | Siamese jackal; South East Asian jackal | Thailand; Myanmar; East India                                        |                                                                          |
| Canis a. czechadensis Kretzoi, 1947 | Pannonian jackal           | Pannonian Basin                                                     | C. minor; C. balcanicus; C. hungaricus                                 |
| Canis a. indicus Hodgson, 1833 | Indian jackal; Himalayan jackal | Pakistan; India; Nepal; Bhutan; Burma                              |                                                                          |
| Canis a. lusater Hemprich & Ehrenberg, 1833 | African wolf; Egyptian wolf; Egyptian jackal | Egypt; Algeria; Mali; Ethiopian Highlands; Senegal                  | C. lupaster; C. lupus lupaster; C. soxer                                  |
| Canis a. moreoticus Geoffroy Saint-Hilaire, 1835 | European jackal; Caucasian jackal; Reed wolf | Southeastern Europe; Asia Minor; Caucasus                           | C. graecus                                                               |
| Canis a. nigra Wroughton, 1916 | Sri Lankan jackal           | Southern India; Sri Lanka                                           | C. lanka                                                                |
| Canis a. palaeotina Khalaf, 2008 |                                                                       | Palestine; Israel                                                   |                                                                          |
| Canis a. riparius Hemprich & Ehrenberg, 1832 | Somali wolf                | Somalia; Ethiopia; Eritrea                                           | C. hagenbecki; C. menges; C. somalicus                                 |
| Canis a. soudanicus Thomas, 1903 | Variegated wolf; Nubian wolf | Sudan; Somalia                                                     | C. doederleinii; C. nubianus; C. thooides; C. variegatus                |
All these biological and behavioural features create premises for their infection with a broad range of pathogens, including parasites. Golden jackals are known to host a large spectrum of viral, bacterial and parasitic pathogens [18–20]. The literature survey indicates that the studies published on golden jackal parasites are usually limited to a country or, more commonly to a region, and there is no synoptic overview on this potentially important topic. The aim of the present work was to review all the published data on the parasite fauna of golden jackals in a comprehensive and updated list. The goal is consistent with the demographic and territorial expansion tendency of this species and increased contact with domestic animals and humans.

**Literature survey methodology**

The list of the golden jackal parasites was compiled on the basis of an extensive literature search published from historical times until April 2017. Abstracts in conference proceedings and theses were also considered. The search queries were performed in the several databases: Pub Med [21], Science Direct [22], Web of Science [23], Helminthological Abstracts [24], Biological Abstracts [25], BioOne [26], Host-Parasite Database of the Natural History Museum (London) [27] and the web search engine Google Scholar [28]. Additionally, two Russian databases, namely the Russian Scientific Electronic Library [29] and the Scientific Library Earth Papers [30] were also used as sources of information.

The parasites are listed in tables, organized according to their taxonomic rank, and species within families are alphabetically listed. Taxonomy follows Adl et al. [31] for protists; Gibson et al. [32], Jones et al. [33], and Bray et al. [34] for trematodes; Kahlil et al. [35] and Nakao et al. [36] for cestodes; De Ley & Blaxter [37] for nematodes; Amin [38] for acanthocephalans; and the database “Catalogue of Life: 2016 Annual Checklist” by Roskov et al. [39] for arthropods. The names of the species were updated according to the current taxonomy, but synonyms used by different authors are also indicated. Each species is indexed together with the country of the report, the method of examination and reference. The records within a species are listed according to the alphabetical order of the country name. If two or more reports for the same country are registered, the ranking was made chronologically, according to the year publication. The prevalence, frequency and intensity of infection are also given, when available. The prevalence was provided or calculated only when the sample size was at least 10. In the case of experimental infection studies, the country has not been specified. Articles that report infections in captive jackals and doubtful records are mentioned and/or discussed accordingly.

**Protists**

Eight families with 21 species were reported in golden jackals in 23 countries. Additionally, several protists were identified only to the generic level or were doubtfully considered as parasites of golden jackals (Table 2) [40–85].

**Leishmania**

The sand fly-borne kinetoplastids of the genus *Leishmania* were reported in golden jackals from 13 countries (Table 2), showing a large geographical distribution in Asia, Africa and Europe. At least three species of *Leishmania* have been identified by molecular methods in naturally infected golden jackals (*L. donovani, L. infantum* and *L. tropica*). Additionally, golden jackals were experimentally shown to be receptive for the infection with *L. major* [85], but this species has never been found in naturally infected specimens. The multiple records of *Leishmania* spp. in golden jackals suggest a reservoir role for this carnivore, for both visceral and cutaneous leishmaniasis in humans, as well as for canine leishmaniasis. Infected jackals have been found also at the margin of the endemic area for canine leishmaniasis (i.e. Romania), where this finding has been temporally correlated with the re-emergence of the disease in domestic dogs [86]. Although there is no clear link between the emergence of leishmaniasis in dogs and the spreading of jackals, this is an issue to be further investigated, mainly as the jackal continues to spread into areas at the margin of canine leishmaniasis endemicity. This was previously demonstrated when infected dogs were newly introduced to non-endemic areas in Europe [87].

**Tick-borne protists (Babesiidae, Theileriidae and Hepatozoidae)**

Experimental evidence showed that golden jackals are receptive to the infection with *Babesia canis* [40] and *B. gibsoni* [43]. However, there are surprisingly few records of natural infections with piroplasms in golden jackals (Table 2) despite the large variety and number of studies on ticks (see below). In Europe, the only *Babesia* species molecularly confirmed in golden jackals is *B. canis*, recently reported in Romania [42]. The other report of *B. canis* in jackals is from Nigeria [41], but the species identification was based on blood smears and in captive animals. We consider this record doubtful, as the typical vector for *B. canis, Dermacentor reticulatus*, does not occur in Nigeria. Probably the species in this case belongs to the same complex group of large canine *Babesia* known in this area, *B. rossi* or *B. vogeli* [88]. *Babesia gibsoni*, which is widely distributed in Asia, has been reported only once in golden jackals, in India. Although *Babesia rossi* is common in domestic and wild carnivores in Africa [89], so far there are no records of this species in golden jackals. The scarcity of reports of *Babesia* spp. in this wild canid is probably related to the low number of studies and the lack of
Table 2  Protist parasites of the golden jackal, *Canis aureus*

| Family         | Species                        | Origin       | Prevalence (%) | Frequency | Method | Reference     |
|----------------|--------------------------------|--------------|----------------|-----------|--------|---------------|
| **Phylum Apicomplexa** |                                |              |                |           |        |               |
| Class Aconoidasida |                                |              |                |           |        |               |
| Babesididae     | *Babesia canis* (syn. *Piroplasma canis*) | na (as *P. canis*) | na            | na        | EI     | [40]          |
|                 |                                | Nigeriaa     | 1/6            | BS        |        | [41]          |
|                 |                                | Romania      | 9.2            | 5/54      | MI     | [42]          |
|                 | *Babesia gibsoni*              | na           | na             | na        | EI     | [43]          |
|                 |                                | India        | na             | na        | BS     | [44]          |
| Theilerididae   | “*Theileria anaeae*”           | Romania      | 3.7            | 2/54      | MI     | [42]          |
| Class Conoidasida |                                |              |                |           |        |               |
| Eimeriidae      | *Eimeria* sp. b                | Bulgaria     | 5.8            | 3/56      | CO     | [45]          |
|                 | *Eimeria aurei* b              | India        | na             | na        | CO     | [46]          |
|                 | *Isospora* sp.                 | Bulgaria     | 5.8            | 3/56      | CO     | [45]          |
|                 |                                | Indiaa       | case report    | CO        |        | [47]          |
|                 |                                | Iran         | 7.1            | 4/56      | CO     | [48]          |
|                 |                                | Serbia       | 6.6            | 4/60      | CO     | [49]          |
|                 | *Isospora duotoiti*            | former USSR  | na             | na        | CO     | [50]          |
|                 |                                | Turkmenistan | na             | na        | CO     | [51]          |
|                 | *Isospora kamilordiniensis*    | Kazakhstan   | na             | 2/9       | CO     | [52]          |
|                 | *Isospora neorivolta*         | Russia       | 9.3            | 14/150    | CO     | [53]          |
|                 | *Isospora ohiensis*           | Russia       | 5.3            | 8/150     | CO     | [53]          |
|                 | *Isospora theileni*           | Azerbaijan   | na             | na        | CO     | [54]          |
|                 |                                | Turkmenistan | na             | na        | CO     | [51]          |
| Hepatozoidae    | *Hepatozoon* sp.              | Algeria      | na             | 2/5       | MI     | [55]          |
|                 |                                | Mauritania   | 25.0           | 4/16      | MI     | [55]          |
|                 | *Hepatozoon canis*            | Austria      | case report    | MI        |        | [56]          |
|                 |                                | case report   |               | MI        |        | [42]          |
|                 |                                | Croatia      | 30.4           | 14/46     | MI     | [57]          |
|                 |                                | Czech Republic | na           | 1/1     | MI     | [42]          |
|                 |                                | Hungary      | 57.9           | 33/57     | MI     | [57]          |
|                 |                                | 60.0          | na             | MI        |        | [58]          |
|                 |                                | Israel       | 2.1            | 1/46      | BS     | [19]          |
|                 |                                | Montenegro   | na             | 2/2       | MI     | [57]          |
|                 |                                | Romania      | 72.2           | 39/54     | MI     | [42]          |
|                 |                                | Serbia       | 67.5           | 140/206   | MI     | [57]          |
| Sarcocystidae   | *Cystoisospora canis*          | Hungary      | 15.0           | 3/20      | CO     | [59]          |
|                 | *Neospora caninum*            | Israel       | 1.7            | 2/114     | IFAT   | [60]          |
|                 | *Sarcocystis* sp.             | Bulgaria     | 1.9            | 1/56      | CO     | [45]          |
|                 | *Sarcocystis cruzi* (syn. *S. bovicanis*) | Russia (as *S. bovicanis*) | 20.0    | 30/150  | CO     | [53]          |
|                 | *Sarcocystis tenella* (syn. *S. ovicanis*) | Russia (as *S. ovicanis*) | 34.0    | 51/150  | CO     | [53]          |
|                 | *Sarcocystis tropicalis* (syn. *Isospora tropicalis*) | India (as *I. tropicalis*) | case report | CO     |        | [61]          |
|                 |                                | India        | case report    | CO        |        | [62]          |
|                 | *Toxoplasma*-type oocysts      | Hungary      | 5.0            | 1/20      | CO     | [59]          |
|                 | *Toxoplasma gondii*           | Iran         | 33.3           | na        | LAST   | [63]          |
more sensitive/specific methods, as the typical vector ticks [D. reticulatus for B. canis, Rhipicephalus sanguineus (sensu lato) for B. vogeli and Haemaphysalis leachi for B. rossi] have been reported on various occasions on these hosts.

An interesting recent report indicates the presence of "Theileria annae" in golden jackals from Romania [42]. Currently, the taxonomic status of this species is debated and it is most commonly referred to as "Babesia microti-like". This group has been reported predominantly in red foxes, but also in several other wild carnivores in North America, Asia and Europe [89]. However, so far, the role of golden jackals in its ecology remains unknown.

The first report of Hepatozoon canis in golden jackals is relatively recent [19] and has been followed in the last years by several records, mainly in Europe and North Africa (Table 2). Surprisingly, despite the wide distribution

| Family               | Species                        | Origin        | Prevalence (%) | Frequency | Method       | Reference |
|----------------------|--------------------------------|---------------|----------------|-----------|--------------|-----------|
| *Flagellates*         |                                |               |                |           |              |           |
| Hexamitidae          | Giardia sp.                    | Iraq a        | 100            | 4/4       | CO           | [65]      |
|                      | Giardia duodenalis (syn. G. canis) | Croatia      | 12.5           | 1/8       | IF, MI       | [66]      |
|                      |                                | Iran          | 7.1            | 4/56      | CO           | [48]      |
|                      |                                | Russia (as G. canis) | 1.3 | 2/150      | CO           | [53]      |
| Trichomonadidae      | Pentatrichomonas hominis (syn. P. canis auri) | India (as P. canis auri) | case report | CO           | [67]      |
| Trypanosomatidae     | Leishmania sp.                 | Iran          | 2.5            | 4/161     | SIO          | [68]      |
|                      |                                | Serbia        | 12.5           | 6/48      | IFA          |           |
|                      |                                | Spain a       | 6.9            | 15/126    | MI           | [69]      |
| Leishmania donovani  | Bangladesh                     | 5 cases       | na             | MI        | [71]      |
|                      | Georgia                        | na            | 1/4            | SIO       | [72]      |
|                      | Kazakhstan                     | na            | na             | na        | [73]      |
|                      | Iran                           | 5.0           | 1/20           | SIO       | [74]      |
|                      | na                             | na            | na             | El        | [75]      |
| Leishmania infantum  | Algeria                        | case report   | IRI, MI        |           | [76]      |
|                      | Georgia                        | 2.5           | 1/39           | IA        | [77]      |
|                      | Iran                           | 10.0          | 1/10           | DAT, ELISA, IFAT | [78] |
|                      |                                | 11.6          | 7/60           | DAT       | [78]      |
|                      |                                | 1.6           | 1/60           | SIO       |           |
|                      | Iraq                           | 59.6          | 90/151         | SIO, Cult, IFAT, ELISA | [79] |
|                      | Israel                         | 7.6           | 4/53           | ELISA     | [80]      |
|                      |                                | 6.5           | 3/46           | ELISA     | [19]      |
|                      |                                | 1.3           | 1/77           | MI        | [81]      |
|                      | Kazakhstan                     | na            | na             | na        | [82]      |
|                      | Romania                        | 2.7           | 1/36           | MI        | [42]      |
|                      | Tajikistan                     | na            | na             | na        | [83]      |
|                      | Turkmenistan                   | 2 specimens   | na             | na        | [84]      |
| Leishmania major     |                                | na            | na             | El        | [85]      |
| Leishmania tropica   | Israel                         | 6.5           | 5/77           | na        | [81]      |

*Abbreviations: BS blood smear May-Grünwald-Giemsa stained, CO coprological examination, Cult cultures from the viscera, blood and other tissues, DAT direct agglutination test, EI experimental infection, ELISA enzyme-linked immunosorbent assay, H histopathology, IA immunochromatographic assay, IF immunofluorescence assay, IFAT indirect fluorescent antibody test, IRI indirect fluorescent immunoassay, LAST latex agglutination slide test, MI molecular identification, SIO smears from internal organs stained with standard Giemsa, na not applicable/unknown

*AAnimals kept in captivity

*Doubtful record

"Various opinions on the higher taxonomy of these groups are available, hence we keep the generic term "flagellates"
of *H. canis* in canids [90], this tick-borne apicomplexan has never been found in jackals from sub-Saharan Africa or Asia. Nevertheless, the large number of records and the presence of its main vector, *R. sanguineus* (s.l.) suggest a reservoir role of golden jackals for *H. canis* at least in Europe, Middle East and North Africa.

**Intestinal homoxenous coccidia (Eimeriidae)**
Various species of intestinal coccidia of the family Eimeriidae have been found in, or even described from jackals (Table 2). We consider all records of *Eimeria* as pseudoparasites, as previously suggested [91]. Three species of the genus *Isospora* have been described from golden jackals but currently their taxonomic status is listed as doubtful [91]: *Isospora distoii* is a misidentification with *Hammondia* spp. or *Neospora caninum*, while *I. theileri* and *I. kzilordiniensis* are probably invalid names (as they might be synonyms with other *Isospora* species from canids). Two other species, *I. neoriotola* and *I. ohioenisis*, which are known to infect several species of canids [91], were reported in golden jackals. Interestingly, all these *Isospora* reports in golden jackals are from countries in the former USSR, and this probably reflects a greater interest of researchers from this area for this group of parasites rather than the real geographical distribution. Few reports of unnamed *Isospora* sp. in golden jackals are known from Asia and the Balkans (Table 2).

**Heteroxenous coccidia (Sarcocystidae)**
Various records list golden jackals host to Sarcocystidae. Sporocysts of *Sarcocystis* (*S. cruzi, S. tenella* and *S. tropicalis*) and oocysts of *Cystoisospora canis* have been reported in the faeces of golden jackals in Europe, Russia and India, suggesting their role as definitive hosts (Table 2). Although antibodies against *Neospora caninum* have been detected in *C. aureus* in Israel [60], the role of golden jackals as definitive hosts for this parasite has never been demonstrated and needs to be investigated. So far, various canid species were demonstrated to shed oocysts of *N. caninum*: dogs (*Canis familiaris*) [92], coyotes (*C. latrans*) [93], dingoes (*C. lupus dingo*) [94], and gray wolves (*C. lupus*) [95]. Interestingly, Takacs et al. [59] reported “Toxoplasma-like” oocysts in the faeces of jackals but, unfortunately, no morphometric data were provided and there was no attempt to characterize them molecularly. We can only assume that these were small oocysts which, in our opinion, could represent any of the small canine coccidia *N. caninum, Besnoitia* spp. or *Hammondia* spp., none of them confirmed so far in golden jackals.

**Helminths**
The highest number of studies on the parasitic fauna of golden jackals are related to helminths. Our literature survey found at least 178 publications in 38 countries reporting helminths in golden jackals, with 119 species belonging to three phyla: Platyhelminthes, Nematoda and Acanthocephala [96–119].

**Trematodes**
The diversity of trematodes in golden jackals is relatively high (27 species from nine families) (Table 3). Most of the studies originate in the countries of the former USSR, Asia and North Africa, with few scattered records in Europe. There are no trematodes recorded in golden jackals in sub-Saharan Africa. This situation reflects probably the impact of the Russian helminthological school and the lack of studies in other regions rather than the influence of ecological factors or feeding behaviour of jackals. Among the various records of trematodes in golden jackals, two groups could be identified: the canid- or Carnivora-specific trematodes and other trematodes (specific rather to other mammal groups or birds).

The most commonly reported and widely distributed trematode in golden jackals is *Alaria alata*, found in Caucasus, Russia and Central Asia to Middle East and the Balkans (Table 3). We consider the report of *Alaria americana* in Iran doubtful, as the species is known otherwise only in canids from North America [120].

Jackals have been commonly reported as hosts for fish-borne trematodes typically associated with carnivores. Such examples include species of the genera *Ascoscolecotyle, Cryptocotyle, Heterophyes, Metagonimus* (Heterophyidae), *Echinococchus, Euparyphium* (Echinostomatidae), *Pseudamphistomum, Opisthorchis* (Opisthorchiidae) mainly in Asia and northern Africa. The fish-borne *Nanophyetus salmincola* was identified in India, but its geographical distribution is limited to the Pacific Northwest of the USA [121]; with high probability, the report might represent a misidentification with *N. schikhobalowi*, an Asian troglob-trematid [122]. The diversity of trematode species in golden jackals is completed by other groups which use various invertebrates (i.e. arthropods) (*Plagiorchis massino, Microphallus narii*) or non-fish small vertebrates (i.e. amphibians) (*Pharyngostomum cordatum*) as second intermediate hosts, reflecting the wide diet composition of this carnivore.

Interestingly, *Dicrocelium dendriticum*, a hepatic fluke typically associated with herbivores, has been found on several occasions in the bile ducts of golden jackals [97, 98] in Russia. As the infection source for this parasite is represented by ant second intermediate hosts, the infection of jackals is probably accidental.

Several of these trematodes reported in golden jackals have zoonotic potential. Human alariosis caused by *Alaria mesocercariae* manifests in various clinical signs which range from cutaneous symptoms to respiratory disorders, a diffuse unilateral neuroretinitis even to an anaphylactic shock with fatal outcome [123]. However,
Table 3 A comprehensive list of trematode parasites of the golden jackal, *Canis aureus*

| Family         | Species                          | Origin       | Prevalence (%) | Frequency | Intensity | Method     | Reference |
|----------------|----------------------------------|--------------|----------------|-----------|-----------|------------|-----------|
| Phylum Platyhelminthes |                                 |              |                |           |           |            |           |
| Class Trematoda |                                 |              |                |           |           |            |           |
| Dicrocoeliidae | *Dicrocoelium dendriticum* (syn. | Russia       | 5.0            | 1/20      | 5.00 ± 4.45 | necropsy   | [96]      |
|                | *D. lanceatum*)                  |              |                |           |           |            |           |
|                |                                   |              | 26.1           | na        | na        | necropsy   | [97]      |
|                |                                   |              |                | na        | na        | necropsy   | [98]      |
| Diplostomidae  | *Alaria alata*                    | Azerbaijan   | 22.4           | 20/89     | 2–30      | necropsy   | [99]      |
|                |                                   | Bulgaria     | 9.0            | na        | na        | necropsy   | [100]     |
|                |                                   | Croatia      | 1.9            | 1/56      | na        | necropsy   | [45]      |
|                |                                   | Chechnya     | 100            | 16/16     | 22–268    | necropsy   | [103]     |
|                |                                   | Croatia      | 0.9            | 4/447     | 19.00 ± 3.63 | necropsy   | [108]     |
|                |                                   | Uzbekistan   | 30.0           | 18/60     | na        | necropsy   | [49]      |
|                | *Alaria americana* (syn. *A. canis*)b | Iran         | 5.0            | 1/20      | 34        | necropsy   | [110]     |
|                |                                   | Azerbaijan   | 10.0           | 1/10      | na        | necropsy   | [111]     |
|                | Pharyngostomum cordatum* (syn.   | Azerbaijan   | 8.3            | 1/12      | 2         | necropsy   | [99]      |
|                | *P. fausti*)                      |              |                | na        | na        | necropsy   | [100]     |
|                |                                   | Russia       | 66             | 4/60      | na        | necropsy   | [106]     |
| Echinostomatidae | Echinocotmus corvis               | India        | na             | na        | na        | na         | [112]     |
|                | Echinocotmus schwarzii            | Iran         | na             | na        | na        | necropsy   | [105]     |
|                | Euparyphium sp.                   | Iran         | na             | na        | na        | necropsy   | [105]     |
|                | Euparyphium melis                 | Russia       | 16.6           | 10/60     | na        | necropsy   | [106]     |

*Note: a = frequency of infection, b = reference number*
| Family       | Species                                      | Origin     | Prevalence (%) | Frequency | Intensity | Method       | Reference |
|-------------|----------------------------------------------|------------|----------------|-----------|-----------|--------------|-----------|
| Heterophyidae | Ascocotyle italica (syn. Parascocotyle italica) | Russia     | 8.3            | 5/60      | na        | necropsy     | [106]     |
|             | Ascocotyle sinoecum (syn. Phagicola sinoecum) | Iran       | na             | na        | na        | necropsy     | [105]     |
|             | Cryptocotyle linguid³                           | Russia     | 2.7            | 4/150     | 3–18      | necropsy     | [53]      |
|             | Heterophyes sp.                                | Egypt      | na             | 3/5       | na        | necropsy     | [113]     |
|             | Heterophyes aequalis                           | Egypt      | na             | na        | na        | necropsy     | [113]     |
|             | Heterophyes dispar                             | Egypt      | na             | na        | na        | necropsy     | [113]     |
|             | Heterophyes heterophyes                        | Egypt      | 2 specimens    | na        | na        | necropsy     | [113]     |
|             | Metagonimus ciureanus (syn. Dexiogonimus ciureanus) | Georgia   | na             | na        | na        | necropsy     | [114]     |
|             | Metagonimus yokogawai                          | Iran       | 14.2           | 4/28      | na        | necropsy     | [115]     |
|             | Metagonimus yokogawai                          | Italy      | case report    | 6        |           | necropsy     | [116]     |
|             | Metagonimus yokogawai                          | Serbia     | 1.6            | 1/60      | na        | necropsy     | [49]      |
| Microphallidae | Microphallus narii (syn. Spelotrema narii)     | India      | na             | na        | na        | na           | [112]     |
| Opisthorchiidae | Metorchis xanthosomus¹                        | Russia     | 21.8           | na        | na        | necropsy     | [97]      |
|             | Opisthorchis sp.                               | Bangladesh | na             | 1/5       | na        | necropsy     | [118]     |
|             | Pseudamphistomum truncatum                     | Serbia     | 0.2            | 1/447     | 2        | necropsy     | [108]     |
|             |                                                |            |                | 3.3       | 2/60      | necropsy     | [49]      |
| Plagiorchidae | Plagiorchis sp.                               | Iran       | na             | na        | na        | necropsy     | [105]     |
|             | Plagiorchis elegans¹                            | Russia     | 3.3            | 2/60      | na        | necropsy     | [106]     |
|             | Plagiorchis massino                            | Uzbekistan | na             | na        | na        | na           | [109]     |
| Schistosomatidae | Schistosoma spindale¹                        | India      | case report    | na        |          | CO           | [119]     |
| Troglotrematidae | Nanophyetus salmincol¹                       | India      | case report    | na        |          | CO           | [47]      |

**Abbreviations:** na not applicable/unknown, CO coprological examination

¹Unknown site of infection

²Doubtful record
all human cases originate in North America (and are probably caused by *A. americanum*). The zoonotic potential of *A. alata* in Eurasia remains unknown. Adults *Heterophyes dispar* and *H. heterophyes* may produce diarrhoea, abdominal pain and discomfort in humans [124], while *Metagonimus yokogawai* is considered to be the most common intestinal trematode infection in the Far East, highly important due to the ability of their eggs to invade the blood stream thus causing serious complications [125]. Hence, golden jackals might have a significant role in the environmental contamination with such parasites and represent an indirect source for human contamination. Hepatic and biliary trematodes *D. dendriticum*, *Pseudamphistomum truncatulum* and *Opisthorchis felineus* are also able to infect humans, causing abdominal pain, weight loss, chronic relapsing watery diarrhea and hepatobiliary system damages [126, 127].

However, for many other trematode species, golden jackals, as other carnivores, are probably accidental hosts, or most likely, present a pseudoparasitism following ingestion of birds or rodents, as they typically infect other vertebrate groups. For instance, *Cryptocotyle lingua* is mainly a parasite of different gull species in Europe, North America and Japan [128]; *Plagiorchis elegans* is a parasite of raptors, waterfowl, passerines and several mammals as the wood mouse, rat, gerbil and hamster [129]; *Metorchis xanthosomus* is specific for birds in Anseriformes, Gaviiformes, Podicipediformes and Gruiformes [130]; and *Schistosoma spindale* has been described in ruminants and rodents in southeastern Asia [131].

**Cestodes**

Cestode infections in golden jackals have been recorded across all their distribution range, with a relatively high species diversity (Table 4) [132–152].

Among all the cestode species, *Aelurotaenia cameroni* is the only one known exclusively in the golden jackal. However, as the species was only recently described [132], its absence from other carnivores cannot be excluded until further studies. It is not surprising that all other identified tapeworm species are characteristic to carnivores, confirming the low specific affinity of the adult parasites [153]. As such species infect usually a wider range of canid or non-canid carnivores, this demonstrates a close environmental connection between multiple carnivore species and the use of the same trophic source.

The most commonly reported tapeworms in golden jackals are *Dipylidium caninum*, *Mesocestoides* spp., *Echinococcus granulosus* and *Taenia* spp., found across a wide geographical range (Europe, Asia and Africa). The cosmopolitan character of all these cestodes is attributed to the abundance and diversity of intermediate hosts and the lack of specificity for the definitive hosts [153]. Hence, the jackal, together with other carnivores, represents an important source of environmental contamination. Several of these species are known to be zoonotic, some with a minor impact (i.e. *D. caninum*), but other being a major public health threat (i.e. *E. granulosus*).

*Dipylidium caninum* occurs across the globe, human cases being reported in European and Asian countries after accidental ingestion of the infected cat and dog fleas with cysticercoid larvae [154]. Although the jackal is not a domestic species, hence not a direct source of infection to humans, it may transmit fleas to hunting, shepherd or stray dogs and participates together with other wild canids in the natural cycle of this cestode.

Several species of the genus *Mesocestoides* have been found in golden jackals in various regions. *Mesocestoides lineatus* is spread in Africa, Asia and Europe; it was rarely found in humans, with about 20 cases being described to date across the world [155]. Although the main definitive hosts are carnivores, humans can also act as accidental final hosts following ingestion of raw or undercooked meat of birds, amphibians, reptiles or small mammals [156]. The zoonotic potential of the other species of *Mesocestoides* is unknown.

The most well-represented family of tapeworms found in jackals is the *Taeniidae*. The high diversity of the *Taeniidae* in golden jackals reflects furthermore the wide range of mammalian prey species on which they feed. Golden jackals are hosts to both zoonotic species of *Echinococcus*. *Echinococcus granulosus* and *E. multilocularis* have been reported in this wild canid on multiple occasions and across a wide geographical range. The unilocular or cystic hydatidosis produced by larvae of *E. granulosus* (sensu lato) is a ubiquitous infection with high prevalence in various parts of the world [157]. Human multilocular or alveolar echinococcosis caused by *E. multilocularis* has recorded a significant increase in the incidence in northern Eurasia since 1990 [157, 158]. In several regions, high prevalences with both species were reported in golden jackals (Table 4). Reports of *Echinococcus* spp. in areas where this canid has recently spread or increased in abundance (i.e. central and eastern Europe) raise the important question on its role as a potentially new natural reservoir and infection source for humans and livestock.

Among species of genus *Taenia* and *Multiceps*, the most commonly reported species in golden jackals are *T. hydatigena*, *T. pisiformis*, *T. ovis* and *M. multiceps*. Other species (*T. polycantha*, *T. taeniaeformis*, *T. krabbei*, *T. krepkogorski*, *T. crassiceps* and *M. serialis*) have been also found but only occasionally, mainly within the limited geographical range of Caucasus and central Asia (Table 4). The zoonotic potential of these species is limited, and only few human cases have been reported so far: *T. taeniaeformis* [159–162], *T. crassiceps* [163], *T. hydatigena* [164], *T. ovis* [165, 166], *M. multiceps* and *M. serialis* [167]. *Taenia krabbei*, *T. krepkogorski* and *T. polycantha* are considered non-zoonotic.
| Family          | Species                        | Origin         | Prevalence (%) | Frequency | Intensity | Method        | Reference |
|-----------------|--------------------------------|----------------|----------------|-----------|-----------|---------------|-----------|
| Phylum Platyhelminthes                        |                                |                |                |           |           |               |           |
| Class Cestoda                                         |                                |                |                |           |           |               |           |
| Dilepididae                                            | Aelurotaenia cameroni          | India          | na             | na        | na        | na            | [132]     |
| Diphyllobothriidae                                    | Diphyllobothrium sp.           | India*         | na             | na        | na        | CO            | [133]     |
|                     | Diphyllobothrium latum         | Bangladesh      | 20.0           | 6/30       | na        | necropsy     | [134]     |
|                     | Spirometra sp.                 | India*          | na             | na        | na        | na            | [135]     |
|                     |                                | Iran            | 7.1            | 1/14       | 4         | necropsy     | [136]     |
|                     | Spirometra erinaceei          | Azerbaijan      | 25.0           | 19/76      | 1–19      | necropsy     | [99]      |
|                     | (syn. S. erinacei)             | Azerbaijan (as S. erinacei) | 3.5 | 4/114 | 2–21 | necropsy | [137] |
|                     | Spirometra houghtoni          | Iran            | na             | na        | na        | necropsy     | [105]     |
|                     | Spirometra mansoni (syn. Bothriocephalus mansoni) | Italy | case report | na | necropsy | [138] |
| Dipylidiidae                                            | Diplopylidium noelleri        | Iran            | 5.0            | na        | na        | necropsy     | [139]     |
|                     |                                | Tunisia         | 16.0           | 5/31       | 1–66      | necropsy     | [140]     |
|                     | Dipylidium caninum (syns Taenia elliptica, T. cucumerrina) | Azerbaijan | na | na | na | necropsy | [100] |
|                     |                                | Bangladesh      | 26.6           | 8/30       | na        | necropsy     | [134]     |
|                     |                                | Bulgaria        | 3.8            | na         | na        | necropsy     | [141]     |
|                     |                                | 63.6            | 7/11           | na        | necropsy     | [142]     |
|                     |                                | Chechnya        | 100            | 16/16      | 3–12      | necropsy     | [103]     |
|                     |                                | Hungary         | 5.0            | 1/20       | 4         | necropsy     | [59]      |
|                     |                                | India           | na             | na         | na        | na            | [143]     |
|                     |                                | India*          | 5.0            | 3/60       | na        | CO            | [144]     |
|                     |                                | Iran            | 7.1            | 1/14       | 4         | necropsy     | [136]     |
|                     |                                | Bangladesh      | 10.0           | 4/40       | na        | necropsy     | [145]     |
|                     |                                | Bulgaria        | 20.0           | 2/10       | na        | necropsy     | [111]     |
|                     |                                | Ungaria         | 10.1           | 8/79       | na        | necropsy     | [139]     |
|                     |                                | Chechnya        | 33.9           | 19/56      | na        | necropsy     | [48]      |
|                     |                                | Israel          | 46.6           | 7/15       | na        | necropsy     | [146]     |
|                     |                                | Israel          | 5.8            | 1/17       | na        | CO            | [19]      |
|                     |                                | Italy           | na             | na         | na        | necropsy     | [138]     |
|                     |                                | Kazakhstan      | 16.6           | 3/18       | 2–8       | necropsy     | [147]     |
|                     |                                | Russia          | 47.8           | na         | na        | necropsy     | [97]      |
|                     |                                | Russia          | 5.0            | 1/20       | 1.00 ± 0.25 | necropsy | [96] |
|                     |                                | 10.0           | 6/60          | na        | necropsy     | [106]     |
|                     |                                | na             | na            | na        | necropsy     | [107]     |
|                     |                                | 8.0            | 12/150        | 1–13      | necropsy     | [53]      |
|                     |                                | Serbia          | 1.6            | 7/447      | 4.8 ± 0.6  | necropsy     | [108]     |
|                     |                                | Tajikistan      | na             | na         | na        | necropsy     | [148]     |
|                     |                                | Tunisia         | na             | 1/5        | na        | necropsy     | [149]     |
|                     |                                | Turkey          | na             | na         | na        | necropsy     | [150]     |
|                     |                                | Uzbekistan     | na             | na         | na        | necropsy     | [151]     |
## Table 4 A comprehensive list of cestode parasites of the golden jackal, Canis aureus (Continued)

| Family               | Species                                         | Origin      | Prevalence (%) | Frequency | Intensity | Method  | Reference |
|----------------------|-------------------------------------------------|-------------|----------------|-----------|-----------|---------|-----------|
| na                   | Joyeuxiella echinorhynchoides                    | Azerbaijan  | 30.2           | 23/76     | 1–30      | necropsy | [99]      |
| na                   | na                                              | Iran        | 27.8           | 5/18      | na        | necropsy | [334]     |
| na                   | na                                              | Turkey      | 7.5            | 3/40      | na        | necropsy | [145]     |
| na                   | Joyeuxiella pasqualei                            | Iran        | 30.0           | 3/10      | na        | necropsy | [111]     |
| Mesocestoididae      | Mesocestoides sp. group A (oval to elongate cirrus-pouch and short cirrus) | Israel | 8.1            | 7/86      | na        | necropsy, ME | [335] |
| Mesocestoides sp. group B (broad-oval cirrus-pouch and long, more or less strongly coiled cirrus) | Israel | 15.2 | 13/85 | na | necropsy, ME | [335] |
| Mesocestoides sp.    | Greece                                          | na          | 3/5            | na        | necropsy  | [104]   |
| Tunisia              | na                                              | Iran        | 2/5            | na        | necropsy  | [149]   |
| Iran                 | na                                              | Bulgaria    | 1/1            | na        | necropsy  | [336]   |
| na                   | Mesocestoides corti                              | Azerbaijan  | 12.9           | 4/31      | 1–10      | necropsy | [140]     |
| na                   | Mesocestoides lineatus (syn. M. carnivoricolus)  | Azerbaijan  | 2.6            | 3/114     | 9–47      | necropsy | [137]     |
| na                   | na                                              | Bulgaria    | 27.0           | 37/98     | 2–63      | necropsy | [99]      |
| na                   | na                                              | Hungary     | 72.0           | 7/10      | na        | necropsy | [111]     |
| na                   | na                                              | India       | 20.0           | 8/11      | na        | necropsy | [142]     |
| Mesocestoides corti  | na                                              | India       | 15.0           | 4/20      | na        | necropsy | [59]      |
| na                   | India (as M. carnivoricolus)                     | na          | 15.0           | 3/20      | na        | necropsy | [110]     |
| na                   | Bulgaria                                        | na          | 70.0           | 7/10      | na        | necropsy | [111]     |
| na                   | Mesocestoides lineatus                          | Russia      | 26.1           | 5/0       | 1.00 ± 0.53 | necropsy | [97]      |
| na                   | na                                              | Serbia      | 5.0            | 1/20      | 1.00 ± 0.53 | necropsy | [96]      |
| na                   | Tadjikistan                                     | Russia      | 5.0            | 1/20      | 1.00 ± 0.53 | necropsy | [97]      |
| na                   | Tunisia                                         | Russia      | 74.0           | 23/31     | na        | necropsy | [140]     |
| na                   | Turkey                                          | Russia      | 74.0           | 23/31     | na        | necropsy | [140]     |
| na                   | Ukraine                                         | Russia      | 74.0           | 23/31     | na        | necropsy | [140]     |
| na                   | Uzbekistan                                      | Russia      | 74.0           | 23/31     | na        | necropsy | [140]     |
Table 4 A comprehensive list of cestode parasites of the golden jackal, *Canis aureus* (Continued)

| Family       | Species                       | Origin    | Prevalence (%) | Frequency | Intensity | Method    | Reference |
|--------------|-------------------------------|-----------|----------------|-----------|-----------|-----------|-----------|
|              | *Mesocestoides litteratus*    | Serbia    | 4.7            | 21/447    | 64.3 ± 15.1 | necropsy  | [108]     |
|              |                               | Tunisia   | 23.0           | 7/31      | 6–130     | necropsy  | [140]     |
|              | *Mesocestoides petrowi*       | Azerbaijan| na             | na        | na        | necropsy  | [100]     |
|              |                               | Russia    | na             | na        | na        | necropsy  | [342]     |
|              | *Mesocestoides zacharowae*    | Azerbaijan| case report    | na        | necropsy  |          | [343]     |
| Taeniidae    | *Echinococcus granulosus*     | Azerbaijan| 16.3           | 16/98     | 2–400     | necropsy  | [99]      |
|              |                               | Bangladesh| 20.0           | 6/30      | na        | necropsy  | [134]     |
|              |                               | Bulgaria  | 23.0           | na        | na        | necropsy  | [101]     |
|              |                               | na        | 3/3            | na        | PCR       |          | [344]     |
|              |                               | na        | 9.0            | 1/11      | na        | necropsy  | [142]     |
|              |                               | Ceylon    | case report    | 7         | necropsy  |          | [345]     |
|              |                               | Chad      | 1.2            | 1/82      | na        | necropsy  | [346]     |
|              |                               | Chechnya  | na             | na        | na        | necropsy  | [347]     |
|              |                               | Chechnya, Ingushetia | na   | 2/7      | 74–217   | necropsy  | [348]     |
|              |                               | Hungary   | 10.0           | 2/20      | na        | necropsy  | [59]      |
|              |                               | India     | na             | na        | na        | CO        | [349]     |
|              |                               | Iran      | 5.0            | 1/20      | 48        | necropsy  | [110]     |
|              |                               | na        | 16.0           | na        | na        | necropsy  | [350]     |
|              |                               | na        | 2.3            | 2/86      | na        | necropsy  | [351]     |
|              |                               | na        | 40.0           | 16/40     | na        | necropsy  | [145]     |
|              |                               | na        | 40.0           | 16/40     | na        | necropsy  | [352]     |
|              |                               | na        | 8.9            | 7/79      | na        | necropsy  | [139]     |
|              |                               | na        | 20.0           | 2/10      | na        | necropsy  | [353]     |
|              |                               | na        | 66.7           | 6/9       | na        | CO        | [353]     |
|              |                               | na        | 3.5            | 2/56      | na        | necropsy  | [48]      |
|              |                               | Italy     | case report    | 1         | necropsy  |          | [356]     |
|              |                               | Kazakhstan| 5.9            | na        | 3–29      | necropsy  | [147]     |
|              |                               | Kenya     | 27.2           | 6/22      | < 200     | necropsy  | [357]     |
|              |                               | Palestine | na             | na        | na        | na        | [358]     |
|              |                               | Pakistan | 9.0            | 9/100     | na        | necropsy  | [359]     |
|              |                               | Russia    | 12.5           | 2/16      | na        | necropsy  | [360]     |
|              |                               | Tajikistan| 30.7           | 4/13      | > 1,000   | necropsy  | [363]     |
|              |                               | Tunisia   | na             | 1/5       | 72        | necropsy  | [149]     |
|              |                               | na        | 2/2            | na        | PCR       |          | [364]     |
Table 4: A comprehensive list of cestode parasites of the golden jackal, *Canis aureus* (Continued)

| Family | Species                     | Origin            | Prevalence (%) | Frequency | Intensity | Method    | Reference |
|--------|-----------------------------|-------------------|----------------|-----------|-----------|-----------|-----------|
|        | *E. multilocularis* (syn. *Alveococcus multilocularis*) | Azerbaijan       | 3.7            | 2/54      | 3–5       | necropsy  | [99]      |
|        |                              | Hungary           | 9.0            | 1/11      | 412       | necropsy  | [365]     |
|        |                              | Ingushetia        | na             | 1/2       | na        | necropsy  | [338]     |
|        |                              | Iran              | 16.0           | 4/25      | na        | necropsy  | [366]     |
|        |                              | Russia (as *Alveococcus multilocularis*) | 18.7 | 3/16 | na | necropsy | [360] |
|        |                              | Serbia            | 14.3           | 4/28      | 4–57      | necropsy  | [367]     |
|        |                              | Tajikistan        | 7.7            | 1/13      | na        | necropsy  | [363]     |
|        |                              | Uzbekistan        | na             | 1/4       | na        | necropsy  | [368]     |
|        | *Multiceps multiceps* (syn. *Taenia multiceps*) | Azerbaijan | 8.9 | 8/89 | 2–11 | necropsy | [99] |
|        |                              | Bangladesh (as *T. multiceps*) | 10.0 | 3/30 | na | necropsy | [134] |
|        |                              | Bulgaria          | 9.0            | na        | na        | necropsy  | [101]     |
|        |                              | Chechnya          | 7.5            | 3/40      | na        | necropsy  | [145]     |
|        |                              | India             | na             | na        | na        | necropsy  | [369]     |
|        |                              | Kazakhstan        | 11.1           | 2/18      | 4–16      | necropsy  | [147]     |
|        |                              | Russia            | 39.1           | na        | na        | necropsy  | [97]      |
|        |                              | Serbia            | 1.6            | 7/447     | 3.00 ± 0.53 | necropsy | [108]     |
|        | *Taenia serialis*            | Kazakhstan        | 5.5            | 1/18      | 10        | necropsy  | [147]     |
|        |                              | Kenya             | na             | 2/2       | 42        | PCR       | [371]     |
|        |                              | Serbia            | 1.1            | 5/447     | 2.7 ± 0.2 | necropsy  | [108]     |
|        | *Taenia sp.*                 | Bulgaria          | 23.0           | na        | na        | necropsy  | [141]     |
|        |                              | Greece            | na             | 1/5       | na        | necropsy  | [104]     |
|        |                              | India             | na             | na        | na        | na        | [143]     |
|        |                              | India*            | 11.6           | 7/60      | na        | CO        | [144]     |
|        |                              | Iran*             | na             | 2/2       | 11 ± 2 epg | CO | [372] |
|        | *Taenia crassiceps*          | Azerbaijan        | na             | na        | na        | necropsy  | [100]     |
|        |                              | Hungary           | 40.0           | 8/20      | na        | necropsy  | [59]      |
|        | *Taenia hydatigena* (syn. *T. marginata*) | Azerbaijan | 15.3 | 14/91 | 1–18 | necropsy | [99] |
|        |                              | Bulgaria          | 55.0           | na        | na        | necropsy  | [101]     |
|        |                              | Chechnya          | na             | 27.2      | 3/11      | na        | [142]     |
|        |                              | Hungary           | 15.0           | 3/20      | na        | necropsy  | [59]      |
|        |                              | India             | na             | na        | na        | necropsy  | [369]     |
Table 4: A comprehensive list of cestode parasites of the golden jackal, *Canis aureus* (Continued)

| Family          | Species | Origin            | Prevalence (%) | Frequency | Intensity | Method      | Reference |
|-----------------|---------|-------------------|----------------|-----------|-----------|-------------|-----------|
|                 |         | Iran              | 7.1            | 1/14      | 2         | necropsy    | [136]     |
|                 |         | 40.0              | 16/40          | na        | necropsy  | [145]       |
|                 |         | 10.0              | 1/10           | na        | necropsy  | [111]       |
|                 |         | 7.6               | 6/79           | na        | necropsy  | [139]       |
|                 |         | 7.1               | 4/56           | na        | necropsy  | [48]        |
|                 |         | 5.6               | 1/18           | na        | necropsy  | [334]       |
|                 |         | Italy (as *T. marginata*) | na | na | na | necropsy | [138] |
|                 |         | Kazakhstan        | 22.0           | 4/18      | 2–8       | necropsy    | [147]     |
|                 |         | Russia            | 6.2            | 1/16      | na        | necropsy    | [360]     |
|                 |         | 36.8              | 14/38          | 1–3       | necropsy  | [374]       |
|                 |         | 34.8              | na             | na        | necropsy  | [97]        |
|                 |         | 5.6               | 1/20           | 3.00 ± 2.18 | necropsy | [96]        |
|                 |         | 1.6               | 1/60           | na        | necropsy  | [106]       |
|                 |         | Bulgaria case report | na | na | na | necropsy | [375] |
|                 |         | Iran              | 5.6            | 1/18      | na        | necropsy    | [334]     |
|                 |         | Russia            | 39.1           | na        | na        | necropsy    | [97]      |
|                 |         | Tajikistan        | na             | na        | na        | necropsy    | [148]     |
|                 |         | Uzbekistan        | na             | na        | na        | necropsy    | [152]     |
|                 | *Taenia krabbei* | Azerbaijan | 0.8            | 1/114     | 3         | necropsy    | [137]     |
|                 |         | na                | na             | na        | na        | necropsy    | [100]     |
|                 | *Taenia krepkogorski* (syn. *Hydatigera krepkogorski*) | Azerbaijan | na | na | na | necropsy | [100] |
|                 | *Taenia ovis* | Azerbaijan | 5.1            | 2/39      | 1–2       | necropsy    | [99]      |
|                 |         | na                | na             | na        | na        | necropsy    | [100]     |
|                 |         | Bulgaria          | case report    | na        | necropsy  | [375]       |
|                 | *Taenia pisiformis* (syn. *T. serrata*) | Azerbaijan | 15.7           | 14/89     | 1–6       | necropsy    | [99]      |
|                 |         | na                | na             | na        | na        | necropsy    | [100]     |
|                 |         | Bulgaria          | 18.0           | na        | na        | necropsy    | [101]     |
|                 |         | 54.5              | 6/11           | na        | necropsy  | [142]       |
|                 |         | Chechnya          | 100            | 16/16     | 3–18      | necropsy    | [103]     |
|                 |         | Greece            | na             | 1/5       | na        | necropsy    | [104]     |
|                 |         | Hungary           | 20.0           | 4/20      | na        | necropsy    | [59]      |
|                 |         | India (as *T. serrata*) | na | na | na | na | [377] |
|                 |         | na                | na             | na        | na        | necropsy    | [369]     |
|                 |         | Iran              | na             | na        | na        | necropsy    | [105]     |
|                 |         | Kazakhstan        | 5.5            | 1/18      | 3         | necropsy    | [147]     |
|                 |         | Russia            | 17.4           | na        | na        | necropsy    | [97]      |
|                 |         | 3.3               | 2/60           | na        | necropsy  | [106]       |
|                 |         | 16.7              | 25/150         | 1–3       | necropsy  | [53]        |
|                 |         | Serbia            | 1.8            | 8/447     | 10.1 ± 2.1 | necropsy | [108] |
|                 |         | Tajikistan        | na             | na        | na        | necropsy    | [148]     |
tapeworms [158, 168]. Considering the common findings of a wide range of Taeniidae in golden jackals, the high spatial mobility of these hosts and the high resistance of taeniid eggs in the environment [169], the role of jackals as natural reservoirs and infection source for humans and domestic animals should be considered potentially important.

Species of Spirometra (Diphyllobothriidae) identified in golden jackals from Europe and Asia (S. mansoni, S. houghtoni and S. erinaceieuropaei) cause sparganosis in intermediate hosts. Humans may acquire the infection after drinking water contaminated with infected copepods or by ingestion of uncooked meat, and occasionally may lead to blindness, paralysis, and death [170, 171]. Diphyllobothrium latum is also reported in humans due to consumption of raw or undercooked fish, in cold water areas from the Holarctic Eurasia, overlaid to those regions where the species is recorded in jackal [172]. However, due to the limited number of reports, the role of golden jackals in the natural cycle of these diphyllobothrid cestodes remains unknown.

Tape worm species with a limited geographic distribution are also reported in jackals. Diplopylidium noelleri and Joyeuxiella spp. are spread only in warm regions from Asia and Europe, probably due to the high abundance and diversity of reptiles, known as common intermediate hosts [173].

Acanthocephalans
Although the diet of golden jackals generally includes invertebrates, wild birds, reptiles and small mammals which are intermediate or paratenic hosts in the life-cycle of thorny-headed worms [174–176], compared to other groups of helminths, there are only few and geographically limited reports of acanthocephalans in golden jackals. The diversity of acanthocephalans identified in this canid includes at least six species (Table 5) [176–181].

Macracanthorhynchus catulinus has been reported on several occasions in jackals in former USSR and Bulgaria, while the congeneric species M. hirudinaceus was found only in Tunisia and Iran. It is unclear if the reports of M. hirudinaceus (a parasite typically found in pigs; [155]) represent cases of pseudoparasitism or misidentifications with M. catulinus (a parasite typically found in canids), as most papers referring to these findings do not provide details on the identification methods. There are few scattered records of other carnivore-specific acanthocephalan species in golden jackals (Oncicola canis, Pachysentis canicolor, Centrorhynchus itatisinis and Echinorhynchus pachyacanthus) in central Asia and Italy (Table 5).

Nematodes
Nematodes constitute the most well-represented group of parasites in golden jackals, with 41 species identified (28 species in Chromadorea and 13 species in Enoplea) (Table 6) [182–256].

Ascarids
Ascarids, primarily considered heteroxenous nematodes, have lost their intermediate hosts and have adapted to direct transmission or through paratenic hosts [257]. Four species are reported in golden jackals, with Toxocara canis and Toxascaris leonina being ubiquitous. Baylisascaris devoisi is a species typically found in mustelids inhabiting the northern hemisphere [258]. Its presence in golden jackals has been reported only once, in Azerbaijan [99]. This broad distribution and common presence of ascarids in this wild canid can be explained by the intervention of numerous paratenic hosts, possible preys for jackals, in the life-cycle of these nematode species (mostly rodents and invertebrates such as earthworms and insects) [259].

Strongyloides
The cosmopolitan and zoonotic Strongyloides stercoralis infects about 200 million people, more commonly in tropical and subtropical climates [260]. Despite the large number of records in domestic dogs from various countries, the species has been reported only once in golden jackals (Table 6). The lack of reports in other parts of the jackal’s range could be explained by a low receptivity of this host or by failures of finding the parasites during necropsy due to their small size. A moderate prevalence of 5.6% is also recorded in dogs from northeastern Iran [261].

Table 4 A comprehensive list of cestode parasites of the golden jackal, Canis aureus (Continued)

| Family    | Species                        | Origin                  | Prevalence (%) | Frequency | Intensity | Method     | Reference |
|-----------|--------------------------------|-------------------------|----------------|-----------|-----------|------------|-----------|
|           | Taenia polyacantha (syn.        | Tunisia                 | 3.2            | 1/31      | 1         | necropsy   | [140]     |
|           | Tetratirotaenia polyacantha)    | Azerbaijan (as          | na             | na        | na        | necropsy   | [100]     |
|           |                                | Turkey                  | na             | na        | na        | necropsy   | [340]     |
|           | Taenia taeniaformis (syn.       | Azerbaijan (as H.        | na             | na        | na        | necropsy   | [100]     |
|           | Hydatigera taeniaformis)        | taeniaformis)           | na             | na        | na        | necropsy   | [148]     |
|           |                                | Tajikistan              | na             | na        | na        | necropsy   | [100]     |
|           |                                | Uzbekistan              | na             | na        | na        | necropsy   | [152]     |

Abbreviations: CO coprological examination; ME microscopic/morphological examination; PCR polymerase chain reaction; epg eggs per gram faeces; na not applicable/not available

*Animals kept in captivity

represent cases of pseudoparasitism or misidentifications with M. catulinus (a parasite typically found in canids), as most papers referring to these findings do not provide details on the identification methods. There are few scattered records of other carnivore-specific acanthocephalan species in golden jackals (Oncicola canis, Pachysentis canicolor, Centrorhynchus itatisinis and Echinorhynchus pachyacanthus) in central Asia and Italy (Table 5).
which is higher than estimated prevalence in humans across the country that ranges between 0.1 and 0.3% [262]. Although carnivores can be a source of infection for humans via larvae that develop in the environment, the principal reservoirs of \textit{S. stercoralis} are humans. The role of domestic and wild carnivores in the epidemiology of strongyloidiasis remains to be clarified [155].

**Hookworms and other digestive tract strongylids**

Several hookworm (Ancylostomatidae) species have been reported in golden jackals, with \textit{Ancylostoma caninum} and \textit{Uncinaria stenocephala} commonly reported across the entire geographical range of these hosts. Additionally, \textit{A. guentini} was described from golden jackals in India, being so far the only known host for this parasite [191]. The remaining two records (\textit{Placoconus lotoris}, known otherwise only from new world procyonids, and \textit{Ancylostoma braziliense}, typically found in the Americas) we list as doubtful and as these are probably misidentifications of other hookworm species. The opportunistic behaviour of the golden jackals leads them to venture close to human habitats to feed [2]. The proximity with domestic dogs allows interspecific transmission of ancylostomid species, due to the high rate of soil and grass contamination [263]. In this regard, increased prevalence recorded in Russia, ranging between 5.0 and 52.2%, is correlated with similar values in dogs, between 2.06 and 62.3% [264]. \textit{Ancylostoma caninum} and \textit{U. stenocephala} possess a zoonotic potential causing dermal larva migrans in humans [260]. Although a direct relationship between the numerous reports in golden jackals and the presence of disease in humans cannot be established, this carnivore species probably contributes to the presence of Ancylostomatidae larvae in rural and peri-urban areas.

\textit{Molineus patens} is a hookworm commonly reported in a wide range of carnivores in the Palaearctic and Nearctic [265], including two records from jackals in Russia. However, its zoonotic role has not been documented.

| Family                  | Species (synonym)                      | Origin          | Prevalence (%) | Frequency | Intensity | Method     | Reference |
|-------------------------|----------------------------------------|-----------------|----------------|-----------|-----------|------------|-----------|
| Class Archiacanthocephala | \textit{Macracanthorhynchus sp.}        | Iran            | 10.0           | 1/10      | necropsy  | [111]      |
|                         | \textit{Macracanthorhynchus catulinus}  | Azerbaijan      | 0.8            | 1/114     | 24        | necropsy   | [137]     |
|                         |                                        |                 | 17.0           | 14/82     | 1–6       | necropsy   | [99]      |
|                         |                                        | Bulgarian       | na             | na        | na        | necropsy   | [100]     |
|                         |                                        | Kazakhstan      | 3.8            | na        | na        | necropsy   | [45]      |
|                         |                                        | Russian         | 5.5            | 1/18      | 3         | necropsy   | [147]     |
|                         |                                        | Russian         | 6.6            | 4/60      | na/a      | necropsy   | [106]     |
|                         |                                        | Russian         | 6.7            | 10/150    | 1–6       | necropsy   | [53]      |
|                         |                                        | Tajikistan      | na             | na        | na        | necropsy   | [148]     |
|                         |                                        | Turkmenistan    | na             | na        | na        | necropsy   | [177]     |
|                         | \textit{Macracanthorhynchus hirudinaceus}\(^a\) | Tunisia        | 3.2            | 1/31      | 6         | necropsy   | [149]     |
|                         |                                        | Iran            |                | na        | necropsy   | [178]      |
|                         |                                        | Iran            |                | 62.5      | 25/40     | necropsy   | [179]     |
|                         |                                        | Iran            |                | 30.0      | 3/10      | necropsy   | [111]     |
|                         |                                        | Iran            |                | 5.0       | 4/79      | necropsy   | [139]     |
|                         |                                        | Iran            |                | 3.5       | 2/56      | necropsy   | [48]      |
|                         | \textit{Oncicola sp.}                   | Iran            | na             | na        | na        | necropsy   | [178]     |
|                         | \textit{Oncicola canis}                 | Iran            |                | 12.6      | 10/79     | necropsy   | [139]     |
|                         | \textit{Pachysentis canicola}           | Iran            | case report    | na        | necropsy   | [180]      |
| Class Palaeacanthocephala | \textit{Centrorhynchus itatisinis}      | Azerbaijan      | 1.4            | 1/71      | na        | necropsy   | [181]     |
|                         | \textit{Echinorhynchus pachyacanthus}   | Italy           | na             | na        | na        | necropsy   | [138]     |

Abbreviation: na not applicable/not available/no answer

\(^a\)Doubtful record
| Family                | Species (synonym) | Origin   | Prevalence (%) | Frequency | Intensity | Method | Reference |
|-----------------------|-------------------|----------|----------------|-----------|-----------|--------|-----------|
| Phylum Nematoda        |                   |          |                |           |           |        |           |
| Class Chromadorea      |                   |          |                |           |           |        |           |
| Ancylostomatidae      | Ancylostoma sp.   | India    | na             | 3/3       | na        | CO     | [182]     |
|                       |                   | na       | 5/5            | na        | CO        | [183] |
|                       |                   | 31.6     | 19/60          | na        | CO        | [144] |
|                       |                   | case report | 700 epg | CO        | [184]     |
|                       |                   | case report | na    | CO        | [47]       |
|                       |                   | Iran     | 2/2            | 10.5 epg  | CO        | [372] |
| Ancylostoma/Uncinaria sp. |     | Bulgaria | 84.6            | na        | na        | necropsy | [141]     |
|                       |                   | India    | na             | na        | na        | CO      | [135]     |
|                       |                   | India    | na             | 3/6       | na        | CO      | [185]     |
|                       |                   | Iran     | na             | na        | na        | necropsy | [105]     |
|                       |                   | Serbia   | 33.3           | 20/60     | na        | necropsy | [49]      |
|                       |                   | Tunisia  | na             | 5/5       | na        | necropsy | [149]     |
| Ancylostoma braziliense | Ancylostoma caninum | India | na             | na        | na        | na      | [117]     |
|                       | Azerbaijan        | 17.3     | 17/98          | 1–20      | necropsy  | [99]    |
|                       | Bangladesh        | 46.6     | 14/30          | na        | necropsy  | [134]   |
|                       | Bulgaria          | 54.5     | 6/11           | na        | necropsy  | [142]   |
|                       |                   | 11.5     | na             | na        | necropsy  | [45]    |
|                       | Chechnya          | 50.0     | 8/16           | 3–18      | necropsy  | [103]   |
|                       | Egypt             | na       | na             | na        | necropsy  | [186]   |
|                       | Greece            | na       | 1/5            | na        | necropsy  | [104]   |
|                       | Hungary           | 40.0     | 8/20           | na        | necropsy  | [59]    |
|                       | India             | na       | na             | na        | na        | [187]   |
|                       |                   | na       | na             | na        | na        | [143]   |
|                       |                   | na       | na             | na        | [188]     |
|                       | India             | 100      | 12/12          | 100–400 epg | CO | [190]     |
|                       | Iran              | 100      | 20/20          | 27.1      | necropsy  | [110]   |
|                       |                   | 7.1      | 1/14           | 4         | necropsy  | [136]   |
|                       |                   | 2.5      | 2/79           | na        | necropsy  | [139]   |
|                       |                   | case report | na    | necropsy  | [155]     |
| Family | Species (synonym) | Origin | Prevalence (%) | Frequency | Intensity | Method | Reference |
|--------|-------------------|--------|----------------|-----------|-----------|--------|-----------|
|        |                   |        |                |           |           |        |           |
|        |                   |        |                | na        |          | necropsy | [48]      |
|        |                   | Israel | 3.5            | 2/56      | na        | necropsy | [146]     |
|        |                   | Russia | 76.0           | 13/17     | 50–800 epg| CO      | [19]      |
|        |                   | Russia | 52.2           | na        | na        | necropsy | [97]      |
|        |                   | Russia | 5.0            | 3/60      | na        | necropsy | [106]     |
|        |                   | Russia | na             | na        | na        | necropsy | [111]     |
|        |                   | Russia | 12.0           | 18/150    | 3–265    | necropsy | [53]      |
|        |                   | Serbia | 0.2            | 1/447     | 2         | necropsy | [108]     |
|        |                   | Tajikistan | na     | na    | na        | necropsy | [148]     |
|        |                   | Tunisia | 9.7        | 3/31    | 2–4      | necropsy | [140]     |
|        |                   | Uzbekistan | na    | na    | na        | necropsy | [151]     |
|        |                   | India | na             | na       | na        | necropsy | [191]     |
|        |                   | Russia | 16.6           | 2/12      | 4        | necropsy | [98]      |
|        | Ancylostoma guentini |        |                |           |           |         |           |
|        | Placoconus lotoris (syn. Uncinaria lotoris) |        |                |           |           |         |           |
|        | Uncinaria stenocephala |        |                |           |           |         |           |
|        | Afghanistan | na    | na             | na        | necropsy | [192] |
|        | Azerbaijan | 50.0  | 49/98          | 1–404     | necropsy | [99]  |
|        | Bulgaria | 64.0  | na             | na        | necropsy | [101] |
|        | Bulgaria | na    | na             | na        | necropsy | [237] |
|        | Bulgaria | 45.4  | 5/11           | na        | necropsy | [142] |
|        | Bulgaria | 84.6  | na             | na        | necropsy | [45]  |
|        | Chechnya | 50.0  | 8/16           | 4–23      | necropsy | [103] |
|        | Greece | na    | 4/5            | na        | necropsy | [104] |
|        | Hungary | 40.0  | 8/20           | na        | necropsy | [59]  |
|        | Iran | 85.0  | 17/20          | 11.1      | necropsy | [110] |
|        | Iran | 6.3   | 5/79           | na        | necropsy | [139] |
|        | Russia | 34.8  | na             | na        | necropsy | [97]  |
|        | Russia | na    | na             | na        | necropsy | [339] |
|        | Russia | 30.0  | 18/60          | na        | necropsy | [106] |
|        | Russia | na    | na             | na        | necropsy | [107] |
|        | Russia | 89.3  | 134/150        | 3–550     | necropsy | [53]  |
|        | Tajikistan | na    | na             | na        | necropsy | [148] |
|        | Tunisia | 68.0  | 21/31          | 1–54      | necropsy | [140] |
| Family | Species (synonym) | Origin | Prevalence (%) | Frequency | Intensity | Method | Reference |
|--------|------------------|--------|----------------|-----------|-----------|--------|-----------|
| Ascarididae | Baylisascaris devosi | Azerbaijan | 17.7 | 14/79 | 1–16 | necropsy | [99] |
| | Toxascaris sp. | Kazakhstan | 11.1 | 2/18 | 2–8 | necropsy | [147] |
| | Toxascaris leonina | Afghanistan | na | na | na | necropsy | [192] |
| | Armenia a | case report | na | na | CO | [195] |
| | Azerbaijan | 0.8 | 1/114 | 1 | necropsy | [137] |
| | | 31.8 | 29/91 | 1–19 | necropsy | [99] |
| | | na | na | na | necropsy | [100] |
| | Bulgaria | 36.0 | na | na | necropsy | [101] |
| | | 5.8 | na | na | necropsy | [141] |
| | Chechnya | 100 | 16/16 | 1–12 | necropsy | [103] |
| | Egypt | na | na | na | necropsy | [186] |
| | Hungary | 15.0 | 3/20 | na | necropsy | [59] |
| | Iran | 30.0 | 3/10 | na | necropsy | [111] |
| | Iran a | na | 2/2 | 166.5 epg | CO | [372] |
| | Kazakhstan | 11.1 | 2/18 | 2–11 | necropsy | [147] |
| | Russia | 43.5 | na | na | necropsy | [97] |
| | | 10.0 | 2/20 | 4.00 ± 3.14 | necropsy | [96] |
| | | 15.0 | 9/60 | na | necropsy | [106] |
| | | na | na | na | necropsy | [98] |
| | | na | na | na | necropsy | [107] |
| | | 4.7 | 7/150 | 2–23 | necropsy | [53] |
| | Tajikistan | na | na | na | necropsy | [148] |
| | Tunisia | 6.5 | 2/31 | 1–7 | necropsy | [140] |
| | Turkey | na | na | na | necropsy | [150] |
| | Uzbekistan | na | na | na | necropsy | [152] |
| | | na | na | na | necropsy | [152] |
| | Toxocara sp. | India a | 21.6 | 13/60 | na | CO | [144] |
| | | na | na | na | CO | [196] |
| | | na | 2/2 | 40–700 epg | CO | [197] |
| Family       | Species (synonym)       | Origin      | Prevalence (%) | Frequency | Intensity | Method | Reference |
|--------------|-------------------------|-------------|----------------|-----------|-----------|--------|-----------|
|              | *Toxocara canis* (syn. *Belascaris marginata*) | **Azerbaijan** | 32.6           | 32/98     | 1–21      | necropsy | [99]      |
|              |                         | **Bangladesh** | 40.0           | 12/30     | na        | necropsy | [134]     |
|              |                         | **Bulgaria**  | 54.5           | 6/11      | na        | necropsy | [142]     |
|              |                         | **Chechnya**  | 7.7            | na        | na        | necropsy | [45]      |
|              |                         | **Greece**    | na             | 2/5       | na        | necropsy | [104]     |
|              |                         | **Hungary**   | 20.0           | 4/20      | na        | necropsy | [59]      |
|              |                         | **India (as *B. marginata*)** | na | 2/5 | na | necropsy | [107]     |
|              |                         | **India**     | na             | na        | na        | necropsy | [187]     |
|              |                         | **Iran**      | 10.0           | 2/20      | na        | necropsy | [110]     |
|              |                         | **Russia**    | 60.9           | 2/2       | 25 ± 5 epg | CO | [372]     |
|              |                         | **Serbia**    | 23.3           | 35/150    | 1–22      | necropsy | [53]      |
|              |                         | **Tajikistan** | na | na | na | necropsy | [107]     |
|              |                         | **Turkey**    | na             | na        | na        | necropsy | [150]     |
|              |                         | **Uzbekistan** | na | na | na | necropsy | [151]     |
Table 6. Nematode parasites of the golden jackal, Canis aureus (Continued)

| Genus          | Species (synonym) | Origin   | Prevalence (%) | Frequency | Intensity | Method  | Reference |
|----------------|-------------------|----------|----------------|-----------|-----------|---------|-----------|
| Toxocara       | cati (syns. Ascaris mystax, T. mystax) | Italy    | na             | na        | na        | necropsy| [152]     |
|                |                   | Russia   | 26.1           | 1/20      | 2.0 ± 1.9 | necropsy| [138]     |
|                |                   | Uzbekistan | na         | 1/5       | na        | necropsy| [97]      |
|                |                   | Azerbaijan | 14.6       | 1/20      | na        | necropsy| [189]     |
|                |                   | Belarus   | na            | na        | na        | necropsy| [98]      |
|                |                   | Russia    | 5.0           | 1/20      | na        | necropsy| [100]     |
|                |                   | Caucasus  | na            | 1/5       | na        | necropsy| [189]     |
|                |                   | Hungary   | 100           | 16/16     | 10–23     | necropsy| [118]     |
| Crenosomatidae | Crenosoma vulpis | Russia    | na            | na        | na        | necropsy| [97]      |
|                |                   | Uzbekistan | na         | na        | na        | necropsy| [152]     |
|                |                   | Chechnya  | 100           | 6/60      | 6–297     | necropsy| [98]      |
|                |                   | Tajikistan | na         | 6/60      | 6–297     | necropsy| [147]     |
|                |                   | Tajikistan | na         | 6/60      | 6–297     | necropsy| [148]     |
|                |                   | Poland    | 12.0          | 18/150    | 10–23     | necropsy| [200]     |
|                |                   | Italy     | na            | na        | na        | necropsy| [201]     |
|                |                   | Russia    | 10.0          | 6/60      | na        | necropsy| [100]     |
|                |                   | Uzbekistan | na         | na        | na        | necropsy| [152]     |
|                |                   | Bulgaria  | 26.0          | 39/150    | 3–104     | necropsy| [104]     |
|                |                   | Georgia   | 26.0          | 39/150    | 3–104     | necropsy| [104]     |
|                |                   | Chechnya  | 9.6           | na        | na        | necropsy| [45]      |
|                |                   | Russia    | 8.9           | 5/56      | 2–16      | necropsy| [118]     |
|                |                   | Bulgaria  | 8.9           | 5/56      | 2–16      | necropsy| [202]     |
|                |                   | Azerbaijan | 9.6         | na        | na        | necropsy| [45]      |
| Family    | Species (synonym) | Origin       | Prevalence (%) | Frequency | Intensity | Method          | Reference |
|-----------|-------------------|--------------|----------------|-----------|-----------|-----------------|-----------|
| Nematode  |                   |              | 70.0           | 7/10      | na        | K               | [200]     |
|           |                   | Greece       | 37.5           | 122/325   | 1–19      | necropsy        | [203]     |
|           |                   | Hungary      | 7.4            | 2/27      | 1–10      | necropsy        | [205]     |
|           |                   | India*       | na             | na        | na        | necropsy        | [206]     |
|           |                   | Iran         | 28.5           | 4/14      | 13        | necropsy        | [136]     |
|           |                   |              | na             | na        | na        | necropsy        | [207]     |
|           |                   |              | 11.4           | 9/79      | na        | necropsy        | [139]     |
|           |                   |              | 1.7            | 1/56      | na        | necropsy        | [48]      |
|           |                   |              | 8.9            | 4/45      | 1–10      | necropsy, molecular | [208] |
|           |                   | Romania      | 18.52          | 10/54     | 1–7       | necropsy        | [209]     |
|           |                   | Russia       | 9.26           | 5/54      | na        | molecular      | [209]     |
|           |                   |              | 8.3            | 1/12      | 29        | necropsy        | [98]      |
|           |                   |              | 8.3            | 5/60      | na        | necropsy        | [106]     |
|           |                   |              | 20.0           | na        | na        | necropsy        | [339]     |
|           |                   |              | 22.7           | 34/150    | 2–23      | necropsy        | [53]      |
|           |                   | Serbia       | 7.3            | 32/437    | na        | necropsy        | [210]     |
|           |                   | Uzbekistan   | na             | na        | na        | necropsy        | [152]     |
|           |                   |              | Dirofilaria repens | na | na | necropsy | [186] |
|           |                   |              | Egypt          | na        | na        | necropsy        | [110]     |
|           |                   | Iran         | 10.0           | 2/20      | na        | necropsy        | [106]     |
|           |                   | Romania      | 1.8            | 1/54      | na        | molecular      | [209]     |
|           |                   | Russia       | 3.3            | 2/60      | na        | necropsy        | [106]     |
|           |                   | Uzbekistan   | na             | na        | na        | necropsy        | [152]     |
| Oxyuridae | Syphacia sp. a    | Kazakhstan   | 5.5            | 1/18      | 7         | necropsy        | [147]     |
| Physalopteridae | Physaloptera sp. | Iran          | na            | na        | na        | necropsy        | [105]     |
|           |                   | Kazakhstan   | 5.5            | 1/18      | 4         | necropsy        | [147]     |
|           |                   | Azerbaijan   | na             | na        | na        | necropsy        | [100]     |
|           |                   | Kazakhstan   | 11.1           | 2/18      | 1–3       | necropsy        | [147]     |
| Rictulariidae | Rictularia sp. | Egypt         | na            | na        | na        | necropsy        | [186]     |
|           |                   | Greece       | na             | 1/5       | na        | necropsy        | [104]     |
|           |                   | Azerbaijan   | 36.3           | 28/77     | 1–29      | necropsy        | [90]      |

References:
- [200], [203], [204], [205], [206], [207], [136], [208], [209], [98], [106], [339], [53], [210], [152], [186], [110], [209], [106], [152], [147], [105], [147], [100], [147], [90], [104], [90]
Table 6 Nematode parasites of the golden jackal, *Canis aureus* (Continued)

| Family          | Species (synonym)                  | Origin                   | Prevalence (%) | Frequency | Intensity | Method   | Reference |
|-----------------|------------------------------------|--------------------------|----------------|-----------|-----------|----------|-----------|
|                 |                                     |                          |                |           |           |          |           |
| **Bulgaria**    | 7.7                                 | na                       | na             |           | na        | necropsy | [45]      |
| **India (as *P. affinis*)** | na                                 | na                       | na             |           | na        | necropsy | [117]     |
| **Iran**        | 50.0 (as *P. affinis*)              | 5/10                     | na             |           | na        | necropsy | [111]     |
| **Kazakhstan**  | 11.1                                | 2/18                     | 1–3            |           |           | necropsy | [147]     |
| **Tunisia (as *P. affinis*)** | 6.5                                | 2/31                     | 1              |           |           | necropsy | [140]     |
| **Turkmenistan**| na                                  | na                       | na             |           | na        | necropsy | [177]     |
| **Uzbekistan**  | na                                  | na                       | na             |           | na        | necropsy | [151]     |
| **Rictularia cahiensis** | Egypt                             | na                       | na             |           | na        | necropsy | [186]     |
| **Iran**        | 10.0                                | 2/20                     | na             |           | na        | necropsy | [110]     |
| **Turkey**      | na                                  | na                       | na             |           | na        | necropsy | [340]     |
| **Uzbekistan**  | na                                  | na                       | na             |           | na        | necropsy | [151]     |
| **Spiroceridae**| Spirocerca arctica                 | Azerbaijan               | 16.6           | 2/12      | 5–14      | necropsy | [99]      |
| **India**       | na                                  | na                       | na             |           | na        | necropsy | [100]     |
| **India**       | na                                  | na                       | na             |           | na        | necropsy | [211]     |
| **Iran**        | 2.5                                 | 2/79                     | na             |           | na        | necropsy | [139]     |
| **Italy (as *F. sanguinolenta*)** | na                                | na                       | na             |           | na        | necropsy | [138]     |
| **Uzbekistan**  | na                                  | na                       | na             |           | na        | necropsy | [151]     |
| **Spirocerca sanguinolenta** | India                              | na                       | na             |           | na        | necropsy | [213]     |
| **Strongylidae**| Strongyloides sp.                  | India*                   | na             | na        | na        | CO       | [214]     |
| **Iran**        | na                                  | na                       | na             |           | na        | CO       | [372]     |
| **Strongyloides stercoralis** | na                                | 2/2                      | 5.5 ± 0.7 epg  | na        | necropsy | [105]     |
| **Subuluridae** | Oxyurina linkiti                      | Tunisia                  | 3.2            | 1/31      | 2         | necropsy | [140]     |
| **Thelaziidae** | Thelazia callipaeda                | Romania                  | 1.6            | 1/64      | 70        | necropsy | [215]     |
| **Class Enoplea**| Gherman and Mihalca                  | Parasites & Vectors      |                |           |           |          |           |
| Family       | Species (synonym) | Origin            | Prevalence (%) | Frequency | Intensity | Method    | Reference |
|--------------|-------------------|-------------------|----------------|-----------|-----------|-----------|-----------|
| Capillariidae| Capillaria sp.     | India             | na             | na        | na        | CO        | [214]     |
|              |                   | Russia            | 2.7            | 4/150     | 1–45      | necropsy  | [53]      |
|              | Eucoleus aerophilus (syn. Thominx aerophilus) | Azerbaijan (as T. aerophilus) | na | na | na | necropsy | [100] |
|              |                   | Hungary           | 5.0            | 1/20      | na        | necropsy  | [59]      |
|              | Eucoleus aerophilus (syn. Thominx aerophilus) | Russia | 8.3 | 5/60 | na | necropsy | [106] |
|              |                   |                  | 37.3           | 56/150    | 1–6       | necropsy  | [53]      |
|              | Capillaria boehmi  | Russia            | 30.0           | 45/150    | 1–11      | necropsy  | [53]      |
|              | Capillaria plica   | Azerbaijan        | 14.8           | 4/27      | 1–4       | necropsy  | [99]      |
|              |                   | Bulgaria          | 16.4           | na        | na        | necropsy  | [45]      |
|              |                   | Hungary           | 45.0           | 9/20      | na        | necropsy  | [59]      |
|              |                   | Russia            | 11.6           | 7/60      | na        | necropsy  | [106]     |
|              | Capillaria putorii | Azerbaijan        | na             | na        | na        | necropsy  | [100]     |
| Dioctophymatidae | Dioctophyme renale | Azerbaijan | 3.5 | 4/114 | 1 | necropsy | [137] |
|              |                   | Iran              | 35.0           | 7/20      | na        | necropsy  | [110, 216]|
|              |                   | Russia            | 3.3            | 2/60      | na        | necropsy  | [106]     |
|              |                   | Tajikistan        | na             | na        | na        | necropsy  | [148]     |
|              |                   | Uzbekistan        | na             | na        | na        | necropsy  | [151]     |
| Dioctophymatidae | Dioctophyme skrjabini | Russia | 17.4 | na | na | necropsy | [97] |
| Trichinellidae | Trichinella sp.    | Armenia           | 33.3           | 5/15      | na        | TRIC      | [217]     |
|              |                   | Azerbaijan        | 30.1           | na        | na        | TRIC      | [218]     |
|              |                   | Bulgaria          | 50.0           | na        | na        | TRIC      | [220]     |
|              |                   | Romania           | 53.7           | 29/54     | na        | TRIC      | [223]     |
|              |                   | Russia            | 14.3           | na        | na        | TRIC      | [224]     |
|              |                   | case report       | na             | na        | AD        | AD        | [225]     |
| Family | Species (synonym) | Origin                  | Prevalence (%) | Frequency | Intensity | Method | Reference |
|--------|-------------------|-------------------------|----------------|-----------|-----------|--------|-----------|
|        |                   |                         | 25.0           | 75/302    | na        | TRIC   | [226]     |
|        |                   |                         |                |           |           | AD     | [227]     |
|        | Tajikistan        |                         | na             | na        | na        | TRIC   | [228]     |
|        | Thailand          |                         | case report    | na        | TRIC      | [229]  |
|        |                   |                         | case report    | na        | TRIC      | [230]  |
|        | USSR (former)     | 36.5                    | na             | na        | TRIC      | [231]  |
|        | Yugoslavia (former)| 25.0                   | na             | na        | TRIC      | [232]  |
|        | Trichinella       |                         |                |           |           |        |           |
|        | britovi           |                         |                |           |           |        |           |
|        | Algeria           |                         | case report    | na        | PCR       | [233]  |
|        | Azerbaijan        |                         | case report    | na        | AD        | [234]  |
|        | Iran              | 11.1                    | 2/18           | na        | AD, PCR   | [235]  |
|        | Kazakhstan        | na                      | na             | na        | TRIC      | [236]  |
|        | Lithuania         | na                      | 3/4            | 0.9–1.4 lpg| AD, PCR   | [237]  |
|        | Romania           | case report             | 55 lpg         | AD, PCR   | [238]  |
|        | Serbia            | 4.7                     | 2/42           | na        | AD, PCR   | [239]  |
|        | 15.4              | 2/13                    | na             | AD, PCR   | [240]  |
|        | 27.8              | 25/90                   | 1.1–576 lpg    | AD, PCR   | [241]  |
|        | Turkmenistan      | case report             | na             | AD        | [234]  |
|        | Uzbekistan        | case report             | na             | AD        | [234]  |
|        | Trichinella       |                         |                |           |           |        |           |
|        | nativa            |                         |                |           |           |        |           |
|        | Kazakhstan        | 18.9                    | 4/18           | 7 lpg     | AD        | [147]  |
|        | Lithuania         | na                      | 1/4            | 0.9–1.4 lpg| AD, PCR   | [236]  |
|        | URSS (former)     | 61.5                    | na             | na        | TRIC      | [241]  |
|        | Trichinella       |                         |                |           |           |        |           |
|        | nelsoni           |                         |                |           |           |        |           |
|        | Iran              | na                      | 2/2            | na        | TRIC      | [242]  |
|        | Kazakhstan        | 16.2                    | 3/18           | 6 lpg     | na        | [147]  |
|        | Trichinella       |                         |                |           |           |        |           |
|        | pseudospiralis    |                         |                |           |           |        |           |
|        | Russia            | 2.7                     | 4/150          | na        | TRIC      | [243]  |
|        | Trichinella       |                         |                |           |           |        |           |
|        | spiralis          |                         |                |           |           |        |           |
|        | Afghanistan       | case report             | 214 lpg        | TRIC      | [244]  |
|        | Azerbaijan        | 20.4                    | 17/83          | 1–7 lpg   | TRIC      | [244]  |
|        |                    | 17.5                    | 16/91          | 1–44 lpg  | TRIC      | [99]   |
|        | Bulgaria          | na                      | na             | na        | TRIC      | [245]  |
|        |                    | 4.50                    | na             | na        | AD        | [45]   |
|        | Georgia           | 36.6                    | na             | na        | TRIC      | [246]  |
| Family                  | Species (synonym)       | Origin       | Prevalence (%) | Frequency | Intensity | Method   | Reference |
|------------------------|-------------------------|--------------|----------------|-----------|-----------|----------|-----------|
|                        |                         |              |                |           |           |          |           |
|                        |                         | Hungary      | 9.0            | 1/11      | na        | AD, PCR  | [365]     |
|                        |                         | Iran         | 60.3           | 38/63     | na        | TRIC     | [247]     |
|                        |                         |              | 55.5           | 10/18     | na        | TRIC     | [248]     |
|                        |                         | na           | 3/3            | na        | TRIC      | [249]    |
|                        |                         |              | 55.7           | 59/106    | na        | TRIC     | [250]     |
|                        |                         |              | 84.0           | na        | na        | TRIC     | [251]     |
|                        |                         | Kazakhstan   | 5.5            | 1/18      | 3 lpg     | TRIC     | [147]     |
|                        |                         | Russia       | 43.5           | na        | na        | TRIC     | [97]      |
|                        |                         |              | 21.6           | 13/60     | na        | TRIC     | [106]     |
|                        |                         |              | 55.3           | 83/150    | na        | TRIC, AD | [53]      |
|                        |                         | Senegal      | 33.0           | na        | na        | TRIC     | [252]     |
|                        |                         | Serbia       | na             | 3/3       | 1.9–21.4 lpg | AD, PCR | [253]     |
|                        |                         |              | 8.3            | 1/12      | 3 lpg     | AD, PCR  | [254]     |
|                        |                         |              | 7.9            | 3/38      | 3 lpg     | AD, PCR  | [255]     |
|                        |                         |              | 14.2           | 6/42      | na        | AD, PCR  | [238]     |
|                        |                         |              | 38.4           | 5/13      | na        | AD, PCR  | [239]     |
|                        |                         |              | 71.1           | 64/90     | 0.59–1528 lpg | AD, PCR | [240]     |
|                        |                         | Tunisia      | na             | 2/2       | na        | TRIC     | [256]     |
| Trichuroidea          | Trichuris sp.           |              |                |           |           |          |           |
|                        |                         | India*       | 15.0           | 9/60      | na        | CO       | [144]     |
|                        |                         | Azerbaijan   | 14.4           | 12/83     | 1–12      | necropsy | [99]      |
|                        |                         |              | na             | na        | na        | necropsy | [100]     |
|                        |                         |              | 11.2           | 11/98     | 1–11      | necropsy | [99]      |
|                        |                         |              | na             | na        | na        | necropsy | [100]     |
|                        |                         | Bangladesh   | 30.7           | na        | 1–156     | necropsy | [141]     |
|                        |                         | Bulgaria     | 36.3           | 4/11      | na        | necropsy | [142]     |
|                        |                         |              | 21.6           | 13/60     | na        | necropsy | [106]     |
|                        |                         |              | 35.3           | 53/150    | 1–70      | necropsy | [53]      |
|                        |                         | Russia (as   | 11.6           | 4/60      | na        | necropsy | [49]      |
|                        |                         | Trichocephalus vulpis) |              |           |           |          |           |
|                        |                         |              | 10.0           | 2/20      | na        | necropsy | [59]      |

Abbreviations: AD artificial digestion, CO coprological examination, EI experimental infection, epg eggs per gram faeces, lpg larvae per gram tissue, K Knott test, PCR polymerase chain reaction, TRIC trichinelloscopy, na not applicable/not available

*Animals kept in captivity

*Doubtful record
**Metastrongyloids**

Compared to foxes, little is known about the respiratory and cardiovascular strongylids of golden jackals. *Crenosoma vulpis* has been reported on several occasions in Asia and Europe, with variable prevalence (Table 6). There is a single report of *Crenosoma petrowi* in golden jackals, a parasite otherwise known mainly from mustelids in North America [266], one report from bears (also in North America) and another one from stone martens in Italy [267]. Surprisingly, there is only one record of *Angiostrongylus vasorum* in golden jackals, suggesting either a lack of habitat overlap or a low detection sensitivity during necropsy.

**Filaroids**

Zoonotic filaroids *Acanthocheilonema reconditum*, *Dirofilaria immitis* and *D. repens* have been all reported in golden jackals in various countries (Table 6). They have been found both as adults during necropsies but also as microfilariae demonstrating the reservoir role of jackals. *Dirofilaria* spp. are responsible in humans of conjunctivitis, focal pulmonary infarction with granuloma formation and subcutaneous and submucosal lesions in the lung and conjunctiva [268–270]. A recent review listed 1782 human *Dirofilaria* spp. infections, out of which 372 were pulmonary (in Australia, North and South America) and 1410 were subcutaneous/ocular cases (mostly in Europe and Asia) [271]. *Acanthocheilonema reconditum* is considered non-pathogenic for canids [155], but a single human case is well documented as being caused by this species and at least other two, by other *Acanthocheilonema* species [270, 272, 273]. The recorded prevalence of *D. immitis* has significantly varied in different areas between 7.3% in Serbia and 80.0% in Bangladesh, and seems to be consistent with the prevalence registered in dogs, generally between 40 and 70% in endemic areas [155]. The prevalence of *D. repens* in golden jackals ranged between 3.3 and 10.0%, resembling that recorded in dogs, generally varying from 5 to 20% [155].

The oriental eye-worm *Thelazia callipaeda* has been identified in golden jackals only in Romania [215], but this is probably due to lack of proper examinations of the eyes during the necropsy in other studies rather than a resistance of this host. Dogs originating in the Far East were initially considered the main host of the nematode [257]. Over the last 15 years, *T. callipaeda* has shown an increase in the distribution area mainly in Europe, with many new host records [274]. Human thelaziosis followed the same geographical spreading, with recent cases of infection diagnosed [274]. In this epidemiological picture, the golden jackal occurs as a new reservoir host.

**Capillariids**

Respiratory capillariids of carnivores (*C. aerophila*, *C. boehmi* and *C. putorii*) are considered primarily homoxenous, but the earthworms often act as facultative intermediate hosts [1, 275]. Along with the heteroxenous species *Capillaria plica* found in the urinary bladder, all species are cosmopolitan [257]. They have been found in golden jackals in Russia and other former Soviet Union countries. Only *C. plica* and *C. aerophila* are known to be zoonotic [276, 277], but their public health impact is minor. As the primary source of infection with *Capillaria* is the soil contaminated by infective eggs [155], the jackal can play an epidemiological role and secondary source of infection for domestic carnivores and humans.

**Trichinella**

Trichinellosis are an important group of meat-borne zoonotic parasites [278] for which the golden jackals represent an important reservoir. Five species, *T. britovi*, *T. nativa*, *T. nelsoni*, *T. pseudospiralis* and *T. spiralis*, were recorded in mountainous and lowland regions across the distribution range of the golden jackal in Europe and Asia. However, only three of these (*T. britovi*, *T. nativa* and *T. spiralis*) have been confirmed molecularly (Table 6). We consider all the records by artificial digestion or trichinelloscopy (see Table 6) where the species is named as hypothetic, as there is no reliable morphological means of differentiation between species, hence we recommend to consider these as *Trichinella* sp. Nevertheless, the zoonotic potential have been shown for most *Trichinella* species, hence, the golden jackal represents an important natural sylvatic reservoir for these nematodes [240].

**Other nematodes**

Various other groups of nematodes have been found in golden jackals (families *Spiroceridae*, *Dracunculidae*, *Gnathostomatidae*, *Physalopteridae*, *Rictulariidae*, *Subuluridae*), but the reports are occasional (Table 6). Other groups (*Kalicephalus*, *Syphacia* and *Gongylonema*) are with high probability pseudoparasites, originating in prey hosts.

*Spirocerca lupi* is a rare zoonotic nematode species also identified in golden jackals in Europe, central and southern Asia (Table 6). Although a single human infection has been reported [279], the jackal may represent a reservoir host that maintains the life-cycle of the parasite in a certain region. Two other species of the genus *Spirocerca* (*S. arctica* and *S. sanguinolenta*, both described from domestic dogs) have been also reported in jackals, but their taxonomic status and biology are unknown.

*Dracunculus medinensis* has been identified in the golden jackal from several central and southern Asian countries. Currently the disease in humans has been declared extinct in the vast majority of the countries, with only three (Chad, South Sudan and Ethiopia) reporting cases in 2016 [280]. Dogs are considered to be important reservoirs for human infection [155, 281, 282]. In 2016,
more than 1000 dogs in Chad, 14 dogs in Ethiopia, and 11 dogs in Mali were reported with guinea-worm [280]. In this context, understanding the role of wild canids (including golden jackals) remains a crucial aspect in the management of the ongoing eradication campaign.

Another zoonotic species identified in golden jackals from tropical Asian countries (India, Bangladesh, Myanmar) is Gnathostoma spinigerum. Gnathostomiasis, a major food-borne parasitic zoonosis and a significant public health problem, is considered an emerging imported disease in Europe and a common human infection in central and South America, and Asia [283]. Domestic and wild mammals are the final hosts and numerous intermediate and paratenic hosts are the source for the human infection. The golden jackals maintain the sylvatic focus of the parasites and interfere with the domestic cycle, at least in several Asian countries (Table 6).

Various other carnivore-specific spirurids have been found in golden jackals (Physaloptera sibirica, Rictularia affinis, R. cahirensis and Oxynema linstowi), but the role of this host species in their natural cycle remains unknown.

The cosmopolitan species Dioctophyme renale causes a severe kidney destruction in the carnivore definitive hosts. Although with limited zoonotic importance, so far around 20 human cases have been reported [284]. American minks seem to be the main reservoirs of the parasite [257], but an increased prevalence is also recorded in other wild and domestic carnivores. In golden jackals, D. renale has been reported in Asia, where the prevalence ranged between 3.3–35.0% (Table 6). Interestingly, this wild canid has shown a twice higher prevalence than stray dogs in the same geographical region [110], demonstrating the role of the jackal in the development of parasite’s cycle in nature.

Trichuris vulpis has been found on various occasions in golden jackals in Europe and Asia (Table 6). The high prevalence of T. vulpis infection in golden jackals (10.0–36.3%) is in line with the value recorded in dogs originating from the same areas: 25% in India [285], 20% in Bulgaria [286] and 8.95% in Russia [264]. Although the prevalence of T. vulpis in domestic and wild canids is generally high, only around 60 human cases have been recorded [155].

**Arthropods**

A great variety of Arthropods have been found in golden jackals (Table 7) [287–328].

**Ticks**

Due to the large geographical range, the diversity of ticks parasitizing golden jackals is high. Ticks from 37 species belonging to six genera have been recorded in jackals throughout Europe, Asia and Africa. Nevertheless, the number of studies on tick-borne pathogens is surprisingly low. The common tick species found in golden jackals in Europe, i.e. Dermacentor reticulatus, D. marginatus, Haemaphysalis concinna, I. punctata, Ixodes canisuga, I. hexagonus, I. ricinus and Rhipicephalus sanguineus (s.l.), show that they share these ticks with other wild canids, like foxes [329] or with domestic dogs [330]. The two most commonly reported ticks in golden jackals from Europe are D. reticulatus and I. ricinus. These ticks are known to be important vectors for Babesia canis and important tick-borne bacteria, Borrelia burgdorferi (s.l.) and Anaplasma phagocytophilum. However, the reports of these pathogens in C. aureus are scarce (a single report of Babesia canis from Romania [42]). In Asia, the most common ticks on jackals are several species of genus Haemaphysalis, with a high diversity of species reported: H. leachi, H. adleri, H. bispinosa, H. canestrinii, H. flava, H. indoerflava, H. intermedia, H. kutchensis and H. parva. However, studies on the pathogens they might transmit are absent. Several of these Haemaphysalis species are shared with domestic dogs or other wild carnivores, raising the question of the reservoir role of jackals for certain tick-borne pathogens. Except for Haemaphysalis ticks, another commonly reported tick on golden jackals from Asia is Rhipicephalus haemaphysaloides, a tick which prefers ungulates and is known as vector of several viral and protozoan diseases [331]. Studies in golden jackals from arid regions (northern Africa and Middle East) demonstrated the predominant presence of ticks from the genus Rhipicephalus: R. sanguineus (s.l.), R. turanicus and R. leporis. Surprisingly, there are no reports of ticks on golden jackals in sub-Saharan Africa.

**Mites**

Compared to foxes, jackals seem to be less affected by mange-causing mites (Table 7). So far, there is a single report of Sarcoptes scabiei in golden jackals, in Israel [287] and a single report of Otodectes cynotis, in Iran [295]. It is unclear if the scarcity of data regarding Sarcoptes is because of the low prevalence or because of the lack of studies and/or reports. Except sarcoptid mites, there are few records of Demodex in golden jackals, but its clinical significance is not known (Table 7).

**Fleas and lice**

The diversity of fleas reported in golden jackals is relatively high, with at least seven species reported (Table 7), with the most common being Pulex irritans, Ctenocephalides canis and C. felis. Most of the reports of fleas in golden jackals originate in Russia and other former USSR countries and western and southern Asia. Surprisingly, there are no reports of fleas in golden jackals in Europe. The reports of lice in golden jackals are scarce with only three species occasionally reported (Table 7).
| Family       | Species                                | Origin         | Prevalence (%) | Frequency    | Intensity | Reference |
|--------------|----------------------------------------|----------------|----------------|--------------|-----------|-----------|
| Class Arachnida |                                        |                |                |              |           |           |
| Demodecidae  | Demodex spp.                           | Israel         | na             | 1/1          | na        | [287]     |
|              | Demodex canis                          | Russia         | 3.3            | 5/150        | na        | [53]      |
|              | Demodex folliculorum                   | Bangladesh     | na             | na           | na        | [118]     |
| Ixodidae     | Amblyomma sp.                          | Nepal          | na             | na           | na        | [288]     |
|              | Amblyomma varanense (syn. Aponomma gervaisi lucasi) | India          | na             | na           | na        | [289]     |
|              | Amblyomma variegatum                   | Haute-Volta    | na             | na           | 7 N       | [290]     |
|              |                                        | Senegal        | na             | na           | 54 L      | [291]     |
|              | Dermacentor marginatus                 | Russia         | 15.3           | 23/150       | 1–26      | [53]      |
|              |                                        | Serbia         | 45.0           | 9/20         | na        | [292]     |
|              | Dermacentor reticulatus                | Austria        | na             | 1/1          | 17♂; 2♀   | [56]      |
|              |                                        | Hungary        | na             | 4/4          | 10 A      | [293]     |
|              |                                        | Italy          | na             | 1/1          | na        | [116]     |
|              |                                        | Romania        | 12.6           | 10/79        | 46♂; 25♀  | [294]     |
|              |                                        | Russia         | 62.0           | 93/150       | 1–26      | [53]      |
|              | Haemaphysalis sp.                      | Iran           | 1.7            | 1/56         | na        | [48, 295, 296] |
|              |                                        | Nepal          | na             | na           | na        | [288]     |
|              | Haemaphysalis adleri                   | Iraq           | na             | na           | na        | [297]     |
|              |                                        | Israel         | na             | 2/2          | 4♂; 1♀    | [298]     |
|              |                                        | na             | 3/3           | na           | [299]     |
|              | Haemaphysalis bispinosa                | India          | na             | na           | na        | [300]     |
|              |                                        | Nepal          | na             | na           | na        | [288]     |
|              | Haemaphysalis canestrinii              | India          | na             | 1/1          | 9♂; 3♀    | [301]     |
|              |                                        | na             | na           | na           | [300]     |
|              |                                        | Pakistan       | na             | 3/3          | 3♂; 1♀    | [301]     |
|              | Haemaphysalis concinna                 | Austria        | na             | 1/1          | 1 N       | [56]      |
|              |                                        | Hungary        | na             | 4/4          | 7 N; 4 L  | [293]     |
|              |                                        | Romania        | 1.2           | 1/79         | 1 N       | [294]     |
|              | Haemaphysalis flava                    | India          | na             | na           | A         | [289]     |
|              | Haemaphysalis indoflava                | India          | na             | na           | na        | [302]     |
|              | Haemaphysalis intermedia               | India          | na             | 2/2          | 8♂; 17♀; 28 N; 13 L | [303] |
|              |                                        | na             | na           | na           | [300]     |
|              | Haemaphysalis kutchensis               | India          | na             | na           | 10♂; 1♀   | [348]     |
|              | Haemaphysalis leachi (syns H. leachi leachi, H. leachi indica) | Egypt (as H. leachi leachi) | na             | na           | na        | [305]     |
|              |                                        | India          | na             | 1/1          | 9♂; 3♀    | [306]     |
|              |                                        | India (as H. leachi indica) | na         | na           | na        | [289]     |
|              |                                        | Nepal (as H. leachi indica) | na         | 2/2          | 7♂; 2♀; 4 N; 1 L | [307] |
|              |                                        | na             | 3/3           | 6 N         | [307]     |
|              | Haemaphysalis longicornis (syn. H. neumanni) | Ceylon         | na             | na           | na        | [308]     |
|              | Haemaphysalis paraleachi               | Sudan          | 100            | 10/10        | 42♂; 4♀   | [309]     |
Table 7  Arthropod parasites of the golden jackal, *Canis aureus* (Continued)

| Family          | Species                             | Origin                     | Prevalence (%) | Frequency | Intensity (A, ♂, ♀, N, L) |
|-----------------|-------------------------------------|----------------------------|----------------|-----------|---------------------------|
|                 |                                     |                            |                |           |                           |
| *Haemaphysalis parva* (syn. *H. otophila*) | India                      | na                         | na             | na        |                           |
|                 |                                     | Israel                     | na             | 3/3       | na                        |
|                 |                                     | Israel (as *H. otophila*)  | na             | 6/6       | 37                        |
| *Haemaphysalis punctata* | Romania                  | na                         | na             | 4/4       | na                        |
| *Hyalomma sp.*   | Romania                            | na                         | na             |        |                           |
|                 |                                     | Israel                      | na             | 3/3       | na                        |
|                 |                                     | Tajikistan                 | na             | na        | na                        |
| *Hyalomma aegyptium* | USSR (former)                  | na                         | na             | na        | na                        |
| *Hyalomma anatolicum* | Tajikistan                  | na                         | na             | na        | na                        |
| *Hyalomma asiaticum* | Tajikistan                  | na                         | na             | na        | na                        |
| *Hyalomma scupense* | Tajikistan                  | na                         | na             | na        | na                        |
| *Ixodes sp.*     | Iran                               | na                         | 1/1            | na        |                           |
|                 |                                     | Russia                      | na             | na        | na                        |
|                 |                                     | Tajikistan                 | na             | na        | na                        |
| *Ixodes acuminatus* (syn. *I. redikorzevi theodori*) | Israel                  | na                         | 6/6           | 1         |                           |
| *Ixodes canisuga* | Hungary                           | na                         | 4/4           | 3 A       |                           |
| *Ixodes hexagonus* | Romania                          | na                         | 8/79           | 2 ♂; 11 ♀; 24 ♂; 12 L | [294]    |
| *Ixodes ovatus*  | Nepal                              | na                         | 1/1           | 6 ♀        |                           |
| *Ixodes ricinus* | Hungary                           | na                         | 4/4           | 3 A       |                           |
|                 |                                     | Iran                        | 3.5           | 2/56      | na                        |
|                 |                                     | Italy                       | na             | 1/1       | na                        |
|                 |                                     | Romania                     | na             | 1/1       | na                        |
| *Rhipicephalus sp.* | Iran                     | na                         | 1/1           | 1 N       |                           |
|                 |                                     | Serbia                      | 55.0          | 11/20     | na                        |
| *Rhipicephalus annulatus* (syn. *Boophilus calcarius*) | Russia                | 1.3                        | 2/150         | 1–2       | [53]                      |
| *Rhipicephalus cuspidatus* | Haute-Volta                 | na                         | na             | na        | na                        |
| *Rhipicephalus haemaphysaloides* | India                       | na                         | na             | na        | na                        |
|                 |                                     | na                         | 1/1           | 4 ♀       |                           |
|                 |                                     | na                         | 2/2           | 1 ♀; 2 N  |                           |
| *Rhipicephalus leporis* | Iraq                         | na                         | na             | na        | na                        |
| *Rhipicephalus pumilio* | Tajikistan                 | na                         | na             | na        | na                        |
| *Rhipicephalus rossicus* | Tajikistan                 | na                         | na             | na        | na                        |
| *Rhipicephalus sanguineus* | Algeria                  | na                         | 2/2           | 15 ♀; 8 ♀ |                           |

Reference: [289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311].
Table 7 Arthropod parasites of the golden jackal, *Canis aureus* (Continued)

| Family          | Species                | Origin                | Prevalence (%) | Frequency | Intensity (A, ♂, ♀, N, L) | Reference |
|-----------------|------------------------|-----------------------|----------------|-----------|---------------------------|-----------|
|     |                        | India                 | na             | na        | na                        | [300]     |
|     |                        | Iran                  | na             | na        | na                        | [314]     |
|     |                        | Israel                | na             | 6/6       | na                        | [311]     |
|     |                        | Nepal                 | na             | na        | na                        | [288]     |
|     |                        | Nigeria*              | na             | 3/6       | na                        | [41]      |
|     |                        | Romania               | na             | 1/1       | na                        | [316]     |
|     |                        | Serbia                | 0.5            | 1/20      | na                        | [292]     |
|     |                        | Tajikistan            | na             | na        | na                        | [148]     |
|     |                        | Turkey                | na             | na        | na                        | [150]     |
|     |                        |                      | 1.2            | 1/79      | 1 ♂                       | [294]     |
|     |                        | Serbia                | 0.5            | 1/20      | na                        | [292]     |
|     |                        | Tajikistan            | na             | na        | na                        | [148]     |
|     |                        | Turkey                | na             | na        | na                        | [150]     |
|     | Rhipicephalus schulzei| Tajikistan            | na             | na        | na                        | [148]     |
|     | Rhipicephalus simus    | Kenya                 | na             | na        | na                        | [319]     |
|     | Rhipicephalus sulcatus | Haute-Volta           | na             | na        | 5 ♂                       | [290]     |
|     | Rhipicephalus turanicus| Iraq                  | na             | na        | na                        | [320]     |
|     |                        |                      | 100            | 14/14     | na                        | [297]     |
|     |                        | Tajikistan            | na             | na        | na                        | [148]     |
|     |                        | Uzbekistan            | na             | na        | na                        | [152]     |
|     | Psoroptidae            | Otodectes cynotis    | Iran           | 1.7       | 1/56                      | [48, 295, 296] |
|     | Sarcoptidae            | Sarcoptes scabiei     | Israel         | na        | 1/1                       | [287]     |
| Class Insecta   | Boopiidae              | Heterodoxus spiniger  | Africa (North, East); Asia (South); Europe (Southeast) | na | na | na | [321] |
|     | Ceratophyllidae        | Paraceras melis       | Russia         | 10.0      | 15/150                    | [53]      |
|     |                        |                      | 3.3            | 5/150     | na                        | [323]     |
|     | Coptopsyllidae         | Coptopsylla lamellifer dubinini | Uzbekistan | na | na | na | [152] |
|     | Hippoboscidae          | Hippobosca longipennis| Russia         | 2.7       | 4/150                     | [53]      |
|     | Linognathidae          | Linognathus setosus   | Afrotropical Region | na | na | na | [324] |
|     | Pediculidae            | Pediculus sp.         | Bangladesh     | na        | na                        | [118]     |
|     | Pulicidae              | Pulex irritans        | Afghanistan    | na        | 2 ♂; 1 ♀             | [325]     |
|     |                        | Iran                  | na             | na        | 3 ♂; 1 ♀             | [326]     |
|     |                        | Israel                | na             | 6/6       | 36                       | [311]     |
|     |                        | Russia                | 24.0           | 36/150    | 1–15                     | [53]      |
|     |                        |                      | 14.0           | 21/150    | na                       | [323]     |
|     |                        | Tajikistan            | na             | na        | na                        | [148]     |
|     |                        | Uzbekistan            | na             | na        | na                        | [152]     |
|     | Ctenocephalidae        | Ctenocephalides canis | Afghanistan    | na        | 10 ♂; 38 ♀          | [325]     |
|     |                        | Iran                  | na             | na        | 13 ♂; 25 ♀          | [326]     |
|     |                        | Israel                | na             | 4/6       | 27                       | [311]     |

Reference:

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Other arthropods

Although relatively common in most wild carnivores and domestic dogs (Mihalca, personal observation), there is only a single report of *Hippobosca longipennis* in golden jackals (Table 7). This species is an important vector for *Acanthocheilonema dracunculoides*, a filarioid widely distributed in canids across Africa [332]. However, this vector-borne nematode was never reported in golden jackals.

### Conclusions

This is the first comprehensive checklist summarizing the data on parasites of golden jackals. The large variety of parasites reported in golden jackals is caused by multiple factors, including their large geographical range, their extensive territorial mobility and wide food spectrum. Moreover, like in other carnivores, the predator behaviour of golden jackals is the cause of common records of pseudoparasites. Nevertheless, even in such cases, although these parasites do not infect jackals, they can be spread and can remain infective for their natural hosts. Considering that jackals share their habitats with domestic dogs and a wide variety of wild carnivores across their distribution range and the high similarity with canine parasites [333], the risk of interspecific transmission among canid species, and the continued spread of the species, is likely to be associated with future territorial expanding of different parasitic diseases. The vast majority of parasites recorded in golden jackals are shared with domestic dogs or even domestic cats. Other parasites of jackals can use a wide variety of other domestic species, including livestock, as intermediate hosts. Hence, jackals are an important source of infection for domestic animals and might be directly or indirectly responsible for economic losses. Probably the most important aspect regarding the parasites of golden jackal is the large number and common occurrence of zoonotic parasites. Among these, several are with high public health impact: *Leishmania*, *Echinococcus*, hookworms, *Toxocara*, and *Trichinella*. Our review brings overwhelming evidence on the importance of *Canis aureus* as wild reservoir of human parasites.

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CMG collected the information from databases, systematized information in tables and wrote the manuscript. ADM had the initial idea of this review and critically revised the manuscript for important intellectual content. Both authors read and approved the final manuscript.

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References
1. Viranta S, Atickem A, Werdelin L, Stenseth NC. Rediscovering a forgotten canid fauna of Europe (Canidae). Mamm Biol. 2005;70:227–31.
2. Koepfli KP, Pollinger J, Godinho R, Robinson J, Lea A, Hendricks S, Schweizer RM, et al. Genome-wide evidence reveals that African and Eurasian golden jackals are distinct species. Curr Biol. 2015;25(16):1758–65.
3. Khalaf-Sakerfalke VJ, Taher NABA. Population densities and habitat use of the golden jackal (Canis aureus) in farmlands across the Balkan peninsula. Eur J Wildl Res. 2014;60:256–62.
4. Nagy J. Régibb és újabb adatok a nádifarkasok és a sakálok el fordulásairól. Nimród Vadászlap. 1942;30(35):554–6.
5. Wozencraft WC. Order Carnivora. In: Wilson DE, Reeder DM, editors. The mammals of the world. 4th ed. Baltimore: John Hopkins University Press; 1983.
6. Kingdon J. East African mammals: an atlas of evolution in Africa, volume 3, Part A: Carnivores. Chicago: University of Chicago Press; 1977.
7. Rueness EK, Asmyhr MG, Sillero-Zubiri C, Macdonald DW, Bekele A, Atickem Ṡ, Riegert J. Population densities and habitat use of the golden jackal (Canis aureus lupaster) in a terrestrial carnivore: the case of the golden jackal (Canis aureus) in Israel. Vet J. 2011;162(1):66–72.
8. Shamir M, Yakobson B, Baneth G, King R, Dar-Verker S, Markovics A, Aroch I. Antibodies to selected canine pathogens and infestation with intestinal helminths in golden jackals (Canis aureus) in Israel. Vet J. 2011;162(1):66–72.
9. Agridue AA. Wild canids as sentinels of ecological health: a conservation medicine perspective. Parasit Vectors. 2009(Suppl. 1):S7.
10. National Center for Biotechnology Information. U.S. National Library of Medicine, Rockville Pike. 2003. https://www.ncbi.nlm.nih.gov/pubmed. Accessed 20 Sept 2016.
11. Science Direct. Amsterdam: Elsevier BV; 1997. http://www.sciencedirect.com/. Accessed 1 Aug 2016.
12. Web of Science. Institute for Scientific Information. New York: Thomson Reuters; 1964. http://apps.webofknowledge.com/. Accessed 1 Sept 2016.
13. Helminthological Abstracts. Wallingford: CAB; 1910. http://www.cabi.org/publishing-products/online-information-resources/helminthological-abstracts/. Accessed 27 July 2016.
14. Biological Abstracts. BIOSIS. New York: Thomson Reuters; 1926. http://www.ebscohost.com/academic/biological-abstracts. Accessed 15 August 2016.
15. BioOne, Washington, DC. 1999. http://www.bioone.org/. Accessed 15 Sept 2016.
16. Host-Parasite Database. London: Natural History Museum; 1922. http://www.nhm.ac.uk/research-curation/scientific-resources/taxonomy-systematics/host-parasites/database/. Accessed 15 July 2016.
17. Scholar G. Bibliographic database. Mountain View: Google; 2004. https://scholar.google.com/. Accessed 30 Sept 2016.
18. Scientific Electronic Library “Cyberleninka”. Moscow, 2012. http://cyberleninka.ru. Accessed 1 July 2016.
19. Scientific Library Earth Papers. http://earthpapers.net/. Accessed 30 June 2016.
20. Add SM, Simpson AG, Lane CE, Lukes J, Bass D, Bowser SS, Brown MW, et al. The revised classification of eukaryotes. J Eukaryot Microbiol. 2012;59(5):429–93.
21. Gibson DI, Jones A, Bray RA, editors. Keys to the Trematoda, vol. 1. Wallingford: CAB International; 2002.
22. Jones E, Bray RA, Gibson DI, editors. Keys to the Trematoda, vol. 2. Wallingford: CAB International; 2005.
23. Bray RA, Gibson DI, Jones A, editors. Keys to the Trematoda, vol. 3. Wallingford: CAB International; 2008.
24. Kahil LF, Jones A, Bray RA, editors. Keys to the cestode parasites of vertebrates. Wallingford: CAB International; 1994.
25. Nakao M, Lavikainen A, Iwaki T, Hauskämper V, Konyaev S, Oku Y, Okamoto M, Ito A. Molecular phylogeny of the genus Taenia (Cestoda: Taeniidae): proposals for the resurrection of Hydatigera Lamarck, 1816 and the creation of a new genus Versteria. Int J Parasitol. 2013;43(6):427–37.
26. De Ley P, Blaxter M. A new system for Nematoda: combining morphological characters with molecular trees, and translating clades into ranks and taxa. In: Cook R, Hunt DJ, editors. Nematology monographs and perspectives, vol. 2. Leiden: Brill; 2004. p. 633–53.
27. Amin OM. Classification of the Acanthocephala. Parasitol, 2013;60(4):273–305.
28. Roskov Y, Abucay L, Orrell T, Nicolson D, Flann C, Bailly N, Kirk P, Bourgoin T, et al. The revised classification of eukaryotes. J Eukaryot Microbiol. 2012;59(5):429–93.
29.什ervinka J, Banea OC, Krofel M, Forejtek P, Amico G, Duscher GG, Suchentrunk F, Forejtek P, Brown MW, et al. The revised classification of eukaryotes. J Eukaryot Microbiol. 2012;59(5):429–93.
30. DeWalt RE, Decock W, De Wever A. (editors) 2016. Species 2000 & ITIS Catalogue of Life, 28th July 2016. Digital resource at www.catalogueoflife.org/col. Species 2000: Naturals, Leiden, the Netherlands ISSN 2405-8858. Accessed 11 August 2016.
31. Rau MAN. Experimental infection of the jackal (Canis aureus) with Ploplasmia canis Prana & Gallivalerio, 1895. A preliminary note. Indian J Med Res. 1926;14:243–4.
32. Mbaya AW, Aliyu MM, Nwosu CO, Ibrahim UI. Captive wild animals as potential reservoirs of haemo- and ectoparasitic infection of man and domestic animals in the arid-region of northeastern Nigeria. Vet Afr. 2006;78:429–40.
33. Milková B, Hradilová K, D’Amico G, Duscher GG, Suchentrunk F, Forejtek P, Gherman CM, et al. Eurasian golden jackal as host of canine vector-borne parasites. Protist Vectors. 2017;10(1):183.
34. Maronpot RR, Guindy E. Preliminary study of Babesia gibsoni Patton in wild carnivores and domesticated dogs in Egypt. Am J Vet Res. 1970;31:797–9.
35. Patton WS. Preliminary report on a new piroplasm (“Piroplasma gibsoni” sp. nov) found in the blood of hounds of the madras hunt and subsequently
discovered in the blood of the jackal "Canis aureus". Bull Soc Pathol Exot 1910;3:271–81.
45. Kirkova Z, Raychev E, Georgieva D. Studies on feeding habits and parasitological status of red fox, golden jackal, wild cat and stone marten in Sredna Gora, Bulgaria. J Life Sci. 2011;15:264–70.
46. Bhata BB, Chauhan PPS, Agrawal RD, Ahluwalia SS. Eimeria aurei n. sp. from jackal. Indian J Parasitol. 1979;3:49–50.
47. Latchumikanth A, Virnalaj PG, Gomathinayagam A, Andykostano sp. and Isospora sp. in a captive jackal (Canis aureus). J Vet Parasitol. 2012;26(1):87–92.
48. Razmjoo M, Bahrami AM, Shamsollahi M. Seroprevalence of antibodies to Neospora caninum in domestic cats. Abstracts of First International Jackal Symposium; Oct 13, 2014, Veliko Tarnovo. 2014;3(1):133–41.
49. Duscher GG, Kübber-Heiss A, Richter B, Suchentrunk F. A golden jackal (Canis aureus L.) in ecosystems of the north-west Caucasus. Krasnodar: Kuban State Agrarian University, Dissertation for the Degree of Candidate of Biological Sciences; 2013. (In Russian).
50. Yakimoff WL, Matikaschwili IL, Rastegaieff EF. Zur Frage über die Coccidien der Schakale. Archiv für Parasitologie. 1933;80:177–8.
51. Glebezdin VS. On the fauna of coccidia wild mammals Southwest Turkmenistan. Izvestiya Akademii Nauk Turkmenskoi SSR Seriya Biologicheskikh Nauk. 1978;3:271–8. (In Russian).
52. Dzerzhinsky VA, Musabekov KS. Findings of coccidians of the genus Isospora (Coccidioda) in the Central Asian jackal. Parasitology. 1985;19(4):318–20. (In Russian).
53. Tulov AV. Parasitocenoses of jackal (Canis aureus L.) in ecosystems of the north-west Caucasus. Krasnodar: Kuban State Agrarian University, Dissertation for the Degree of Candidate of Biological Sciences; 2013. (In Russian).
54. Yakimoff WL, Lewkowitch EN. Isospora thelei n. sp., coccidie de Schakale. Arch Protistenk. 1932;75:33–7.
55. Maia JP, Alvares F, Boratyński M. A new species of coccidia (protozoa: Sporozoa) in the north-west Caucasus. Krasnodar: Kuban State Agrarian University, Dissertation for the Degree of Candidate of Biological Sciences; 2013. (In Russian).
56. Radhy AM, Khalaf JM, Faraj AA. Some gastro-intestinal protozoa of zoonotic importance observed in captive animals of al- Zawraa zoo in Baghdad. Int J Parasitol. 2006;36(1):215–8.
57. Mukherjea AK, Krassner SM. A new species of coccidia (protozoa: Sporozoa) of the genus Isospora. J Dept Sc Calcutta Univ. 1926;8:11.
58. Levine ND, Tadros W. Named species and hosts of Pentatrichomonas canis-auri. J Arthropod-Borne Dis. 2015;10(4):538.
59. Hamidi AN, Nadim A, Edrissian GH, Tahvildar-Bidruni G, Javadian E. Visceral leishmaniasis. BioMed Res Int. 2014;2014:728516.
60. Duszynski DW, Couch L, Upton SJ. Coccidia (Eimeriidae) of Canidae and canids and rodents from north Africa, with implications for transmission dynamics across taxonomic groups. J Wildl Dis. 2014;50(1):87–88.
61. Mohebali M, Arzamani K, Zarei Z, Akhoundi B, Hajarian H, Raegh S, Heidari Z, et al. Canine visceral leishmaniasis in wild canines (fox, jackal, and wolf) in northeastern Iran using parasitological, serological, and molecular methods. J Arthropod-Borne Dis. 2015;10(4):538–45.
62. Bessad A, Moutoua F, Zenati I, Vézien T, Polaček D, Chochlakis D, Tomanović B, Milić B, Minčić D, Carić M, Baneth G. First molecular evidence of Hepatozoon canis in golden jackals (Canis aureus) in Croatia. J Arthropod-Borne Dis. 2013;7(2):133–41.
63. Latychev NI, Kryukova AP, Povalishina TP. Essays on the regional parasitology of Middle Asia. I. Leishmaniasis in Tajikistan. Materials for the medical geography of Tadjik SSR. (Results of expeditions in 1945–1957). Moscow: Medizinsky i Biologichesky Issledovaniy, Moskva. 1972;49:52. (In Russian).
64. Talmi-Frank D, Kedem-Vanuunen N, King R, Bar-Gal GK, Edery N, Jaffe CL, Baneth G. Leishmania tropica infection in golden jackals and red foxes, Israel. Emerg Infect Dis. 2010;16(12):1973–5.
65. Istayev NJ, Kryukova AP, Povalishina TP. Essays on the regional parasitology of Middle Asia. I. Leishmaniasis in Tajikistan. Materials for the medical geography of Tadjik SSR. (Results of expeditions in 1945–1957). Moscow: Medizinsky i Biologichesky Issledovaniy, Moskva. 1972;49:52. (In Russian).
66. Duszynski DW, Couch L, Upton SJ. Coccidia (Eimeriidae) of Canidae and canids and rodents from north Africa, with implications for transmission dynamics across taxonomic groups. J Wildl Dis. 2014;50(1):87–88.
67. Radhy AM, Khalaf JM, Faraj AA. Some gastro-intestinal protozoa of zoonotic importance observed in captive animals of al- Zawraa zoo in Baghdad. Int J Parasitol. 2006;36(1):215–8.
68. Mukherjea AK, Krassner SM. A new species of coccidia (protozoa: Sporozoa) of the genus Isospora Schneider, 1881, from the jackal, Canis aureus Linnaeus. Proc Zool Soc Calcutta. 1965;35:40.
69. Levine ND, Tadros W. Named species and hosts of Sarcocystis (protozoa: Apicomplexa: Sarcocystidae). Syst Parasitol. 1980;2:41.
70. Radhy AM, Khalaf JM, Faraj AA. Some gastro-intestinal protozoa of zoonotic importance observed in captive animals of al- Zawraa zoo in Baghdad. Int J Sci Nat. 2013(4):567–70.
71. Beck R, Srong H, Lucinger S, Pozio E, Caccioli SM. A large survey of Croatian wild mammals for Gardia duodenalis reveals a low prevalence and limited zoonotic potential. Vector Borne Zoonotic Dis. 2011;11(8):1049–55.
72. Chatterjee GC, Roy H. Mitra AN. Notes on Pentatrichomonas canis-a sp. nov. found in cecal contents of an Indian jackal (Canis aureus), its cultivation in vitro and its method of multiplication. J Dept Sc Calcutta Univ. 1926;8(1).
73. Hamidi AN, Nadim A, Edrisian GH, Tavil-Didruni G, Javadian E. Visceral leishmaniasis of jackals and dogs in northern Iran. Trans R Soc trop Med Hyg. 1982;76(6):576–7.
147. Musabekov KS. [Diseases and parasites of jackal (Canis aureus L., 1758) from South Kazakhstan.] Proceedings of the NAS RK, ser. biological and medical. 2008;30:13–15. (In Russian).

148. Chemykhov V. [On the ecology and parasites of the jackal in Tadzhikistan.] Trudy Akademii Nauk Tadzhikskoi SSR Dushanbe. 1954;21:151. (In Russian).

149. Lahmar S, Boufana B, Lahmar S, Inoubli S, Guadoura M, Dhibi M, et al. Echinococcus in the wild carnivores and stray dogs of northern Tunisia: the results of a pilot survey. Anit Trop Med Parasitol. 2009;10(3):323–31. (In Russian).

150. Merdivenci A. Yabançıkların parazitolojik Araştırmalar. İzmir: Proceedings of The 6th National Congress of Biology; 1998. pp 81–101. (In Turkish).

151. Irgashev IK. [The helminth fauna of domestic and wild carnivores in the Samarkand region.] Uzbekskii Biologicheskii Zhurnal. 1956;5:39–45. (In Russian).

152. Tariannikov T. [Parasites of the jackal (Canis aureus aureus) from the region of middle Sary Daria.] Parazitologiya. 1983;17(6):478–480. (In Russian).

153. Baer JG. The origin of human tapeworms. J Parasitol. 1940;26(2):127–34.

154. Turner JA. Human dipylidiasis (dog tapeworm infection) in the United States. J Parasitol. 1962;26:173–83. (In German).

155. Acha PN, Szyfres B. Zoonoses and communicable diseases common to man and animals. Volume 3. Parasitoses. 3rd ed. Washington DC: PAHO (Pan American Health Organization) [PAHO]. Scientific and Technical Publication No. 580, 2003.

156. Dhaliwal BBS, Juyal PD. Parasitic zoonoses. New Delhi: Springer; 2013.

157. Deplazes P, Rinaldi L, Alvarez Rojas CA, Torgerson PR, Harandi MF, Romig T, et al. Global distribution of alveolar and cystic echinococcosis. Adv Parasitol. 2017;95:315–403.

158. Romig T, Bilger B, Makenstedt U. Current spread and epidemiology of Echinococcus multilocularis. Otsch Tierzahrt Wochenscr. 1999;106(8):352–7. (In Russian).

159. Baciagalupo J. Sobre una nueva especie de Taenia, Taenia infantis. Semana Med. 1922;26:236.

160. Morishita K, Sawada I. On tapeworms of the genus Multiceps in dogs. Acta Sci Nat Brno. 1972;6:1–5.

161. Spassky AA, Spasskaya LP, Reznik VN. On the biological polyclavoure of Hydatigera taeniformis and its occurrence in man. Med Parasitol Mosk. 1968;37(3):339–43. (In Russian).

162. Sterba J, Barus V. First record of Srobilocercus fasciolaris (Taeniidae-larvae) in man. Folia Parasitol. 1972;63:221–6.

163. Hoberg EP, Elbing R, Nader JA. Fatal cysticercosis by Taenia crassiceps (Cyclophyllidea: Taeniidae) in a presumed immunocompromised canine host. J Parasitol. 1999;85:174–8.

164. Slais J. Befunde von frühen Entwicklungsstadien des Cysticercus ovis in der Liber der Menschen. Zbl allg Path path Anat. 1965;108:316–21. (In Russian).

165. Sadykov VM. [Epizootiological and epidemiological significance of Cysticercus ovis.] In: Genchi C, Rinaldi L, Cringoli G, editors. Mappe Semana. 1971;344:1–9.

166. Beugnet E, Gevey J, Messouak A. The Cysticercus ovis cysticercosis: a non zoonotic muscular cysticercosis. Rev Med Vet. 1984;44(4):337–46.

167. Ing MB, Schantz PM, Turner JA. Human coenurosis in North America: case reports and review. Clin Infect Dis. 1998;27:519–23.

168. Nguyen MT, Gabriell S, Abath EN, Dormy P. A systematic review on the global occurrence of Taenia hydatigena in pigs and cattle. Vet Parasitol. 2016;226:97–103.

169. Heyman D, Cestodes. In: Baron S, editor. Medical Microbiology, 4th ed. Galveston, University of Texas Medical Branch at Galveston. 1996. Chapter 87.

170. Yoon KC, Seo MS, Park SW, Park YG. Eyelid sparganosis. Am J Ophthalmol. 2000;130(5):798–805.

171. Radović A, Kovačić D. Diet composition of the golden jackal (Canis aureus L.) on the Pelješac Peninsula, Dalmatia, Croatia. Period Biol. 2010;112(2):219–24.

172. Babaev Y. Data on the helminth fauna of wild mammals in the Karakumskii Canal zone. Ivetia Akademi Nauk Turkmenskoi SSR. Biol Nauk. 1976;648–74. (In Russian).

173. Zarifard MR. Study on helminth parasites of carnivores of East Azerbaijan Province of Iran with focus on Echinococcus multilocularis and its importance in public health. Tehran: University of Tehran, Doctor of Philosophy dissertation; 1994.

174. Arbabi M, Houshyar H, Mobedi E. Prevalence of Dirofilaria immitis and D. repens in dog and cat and human Infections. Zagreb: Rolando Editore; 2007. p. 204.
Panayotova-Pencheva MS, Mirchev RL, Trifonov AP. Dirofilaria immitis infection in carnivores from Bulgaria: 2012–2013 update. Bulg J Vet Med. 2016;19(2):153–62.

Djakou A, Migli D, Spiridakis G. Dirofilaria immitis (heartworm) in a golden jackal (Canis aureus) in Greece. In: Poulaakis N, Antoniou A, Karaneta E, Poonis N, Vazdoinyanissi K, editors. Book of abstracts, 13th International Congress on the Zoogeography and Ecology of Greece and Adjacent Regions, University of Crete. Irakleio Hellenic Zoological Society; 2015. p. 27.

Tolnai Z, Széll Z, Sproch Á, Szeredi L, Sȕtér T. Dirofilaria immitis: an emerging parasite in dogs, red foxes and golden jackals in Hungary. Vet Parasitol. 2014;203(3–4):339–42.

Rao AT, Acharjyo LN. Incidence of heartworm in captive wild carnivores. Indian J Parasitol. 1993;17:201–2.

Meshghi B, Eslami A, Helan JA. Epidemiological survey of blood filariae in rural and urban dogs of Tabriz. J Fac Vet Med Tehran Univ. 2002;57(4):59–63. (In Persian).

Heidari Z, Kia EB, Arzamani K, Mobedi I, Zarei Z, Kamranrashani M. Trichinellosis. Surrey: Reedbooks; 1981. p. 387–400.

Heidari Z, Kia EB, Arzamani K, Mobedi I, Zarei Z, Kamranrashani M. Proceedings of the 7th All-Russia Conf for trichinosis, and against trichinosis in the Republic of North Ossetia-Alania. Abstract of the Papers. 1987;21:34–40.

Odoevskaila IM, Kumsosova OP, Klinkov AV, Bocharova MM. Biological properties of the isolate of Trichinella spp. from a jackal in the North Caucasian Region. Med Parasitol (Moscow). 2009;43(3):326. (In Russian).

Kurashvili BE, Rodanoy AE, Mataaberdzhe GV, Gurchiani KR, Savateeva IA, Zhiznevskiy AI. First report of a human case of trichinellosis due to Trichinella britovi after jackal (Canis aureus) meat consumption in Afghanistan. Bull Soc Pathol Exot. 2006;99(2):94–5. (In French).

Meshghi B, Eslami A, Helan JA. Epidemiological survey of blood filariae in rural and urban dogs of Tabriz. J Fac Vet Med Tehran Univ. 2002;57(4):59–63. (In Persian).

Kurashvili BE, Rodanoy AE, Mataaberdzhe GV, Gurchiani KR, Savateeva IA, Zhiznevskiy AI. First report of a human case of trichinellosis due to Trichinella britovi after jackal (Canis aureus) meat consumption in Afghanistan. Bull Soc Pathol Exot. 2006;99(2):94–5. (In French).

Meshghi B, Eslami A, Helan JA. Epidemiological survey of blood filariae in rural and urban dogs of Tabriz. J Fac Vet Med Tehran Univ. 2002;57(4):59–63. (In Persian).

Kurashvili BE, Rodanoy AE, Mataaberdzhe GV, Gurchiani KR, Savateeva IA, Zhiznevskiy AI. First report of a human case of trichinellosis due to Trichinella britovi after jackal (Canis aureus) meat consumption in Afghanistan. Bull Soc Pathol Exot. 2006;99(2):94–5. (In French).

Meshghi B, Eslami A, Helan JA. Epidemiological survey of blood filariae in rural and urban dogs of Tabriz. J Fac Vet Med Tehran Univ. 2002;57(4):59–63. (In Persian).

Kurashvili BE, Rodanoy AE, Mataaberdzhe GV, Gurchiani KR, Savateeva IA, Zhiznevskiy AI. First report of a human case of trichinellosis due to Trichinella britovi after jackal (Canis aureus) meat consumption in Afghanistan. Bull Soc Pathol Exot. 2006;99(2):94–5. (In French).

Meshghi B, Eslami A, Helan JA. Epidemiological survey of blood filariae in rural and urban dogs of Tabriz. J Fac Vet Med Tehran Univ. 2002;57(4):59–63. (In Persian).

Kurashvili BE, Rodanoy AE, Mataaberdzhe GV, Gurchiani KR, Savateeva IA, Zhiznevskiy AI. First report of a human case of trichinellosis due to Trichinella britovi after jackal (Canis aureus) meat consumption in Afghanistan. Bull Soc Pathol Exot. 2006;99(2):94–5. (In French).

Meshghi B, Eslami A, Helan JA. Epidemiological survey of blood filariae in rural and urban dogs of Tabriz. J Fac Vet Med Tehran Univ. 2002;57(4):59–63. (In Persian).

Kurashvili BE, Rodanoy AE, Mataaberdzhe GV, Gurchiani KR, Savateeva IA, Zhiznevskiy AI. First report of a human case of trichinellosis due to Trichinella britovi after jackal (Canis aureus) meat consumption in Afghanistan. Bull Soc Pathol Exot. 2006;99(2):94–5. (In French).
306. Mitchell CJ, Hoogstraal H, Schaller GB, Spillet J. Ectoparasites from mammals in Kanha National Park, Madhya Pradesh, India, and their potential disease relationships. J Med Ent. 1966;3(2):113–24.

307. Hoogstraal H. Identity, distribution, and hosts of Haemaphysalis (Rhipistoma) indicus Warburton (resurrected) (Ixodoidea: Ixodidae), a carnivore parasite of the Indian subregion. J Parasitol. 1970;66(5):1013–22.

308. Galbi V. Notes de parasitologie et de technique parasitologique. Zbl Bakteriol. 1909;5:138–45.

309. El Kammah KM, Hoogstraal H, Carncis JL. Notes on African Haemaphysalis ticks: XI. H. (Rhipistoma) paralaechi (Ixodoidea: Ixodidae) distribution and hosts of adults. Int J Acarol. 1992;18(3):205–12.

310. Dias Traversos Santos JA. Contribuição para o conhecimento da fauna ixodológica da India portuguesa. An Ist Med Troop. 1954;11(2):361–430.

311. Theodor O, Costa M. A survey of the parasites of wild mammals and birds in Israel. Part one. Ectoparasites. The Israel Academy of Sciences and Humanities: Jerusalem; 1967.

312. Mihalca AD, Dumitrache MO, Magdad C, Gherman CM, Dompa C, Micnean V, et al. Synopsis of the hard ticks (Acari: Ixodidae) of Romania with update on host associations and geographical distribution. Exp Appl Acarol. 2012;15:183–206.

313. Abusalimov NS. [Cattle, pigs, wild deer and jackals as hosts of Bartonella spp.]. Pap Proc Roy Soc Tasmania. 1940:19.

314. Emerson KC, Price RD. A host-parasite list of the Mallophaga on mammals. Parasitol Res. 2011;108(5):51–64.

315. Hoogstraal H, Clifford CM, Saito Y, Keirans JE. The arthropod parasites of the Indian subregion. J Parasitol. 1970;66(5):1013–22.

316. Leulmi H, Aouadi A, Bitam I, Bessas A, Benakhla A, Raoult D, Parola P. The role of wildlife (carnivores, cloven-hoofed animals and predatory mammals of Ukraine. Cestodes Vestn Zool. 2011;45(9):1–8.

317. Nama HS. Comparative study of the cestodes Mesocestoides canis and M. lineatus. Biology. 1981;3(3):31–4.

318. Gasarov MI, Plieva AM. Helminth fauna of carnivores caught at the territory of the Republic of Ingushetia. Theor Pract Parasit Dis Anim. 2010;11:112–6. (In Russian).

319. Zverzhanovsky MI, Basova NY, Tulov AV. Parasitocenosis of jackals (Canis aureus L.) with participation of Dichelofilaria imitis (Leidy, 1856) in trophic-epizootological chains of premountain zone of the Krasnodar Territory. Theor Pract Parasit Dis Animals - Biology. 2011;12:212–5. (In Russian).

320. Mimioglou GM, Guralp N, Tolgat N, Syyn F. Ankara civarnda ticklerde (Vulpes vulpes) bulgulumuz helminht. Ankara Univ Vet Fak Derg. 1965;12:164–90.

321. Komyushin WV, Malyskho (Varodi) EI, Malega AM. The helminths of wild prey of wild prey animals of Ukraine. Cestodes Vestn Zool. 2011;45(9):1–8.

322. Sadykhov IA. A new cestode species - Mesocestoides petrowi nov. sp. – from the intestine of fox (Vulpes vulpes). Srb. Rev Geomint. 1971;351–3. (In Russian).

323. Chernkova AN, Kosupko GA. Cestodes of the genus Mesocestoides found in domestic and wild animals in USSR and some principles of their systematic. Trudy Vsesoyuznogo Instituta Geselmintolii im K Klarynova Teoreticheskie Problemy Veterinarnoi Geselmintologii. 1975;219–211. (In Russian).

324. Breyer I, Georgieva D, Kordova R. Echinococcus granulosus strain typing in Bulgaria: the G1 genotype is predominant in intermediate and definitive wild hosts. Parasit Res. 2004;93(2):127–30.

325. Dissanainke AS, Paramanathan DC. On the occurrence of Echinococcus granulosus (Batsch 1786) in a Ceylon jackal. Ceylon Vet J. 1860;8(3-4)82–7.

326. Troncy P, Graber M. L'échinococcose-hydatidose en Afrique centrale. III. - Teniasis des carnivores à Echinococcus granulosus (Batsch 1186 - Rudolph, 1801). Rev Elev Med Vet Pays Trop. 1969;22(1):75–84.

327. Yandarhanov HS. Species composition, ecological and biological characteristics and communication biocenotic trematodes and cestodes mining of the Chechen Republic. The South of Russia: ecology, development. 2010;9:94–9. (In Russian).

328. Belyaeva AM. The role of wildlife (carnivores, cloven-hoofed animals and rodents) in the epizootology of echinococcosis. Vet Pathol Moscow. 2006;21(7):117–9.

329. Rao AT, Acharjyo LN. Diagnosis and classification of common diseases of captive animals at Nandankanon zoo in Orissa (India). Indian J Anim Health. 1984;2(1):147–52.

330. Zarifard MR. A study on helminthic parasites of wild carnivorous of east Azerbaijan with emphasis on Echinococcus multilocularis. Tehran: Tehran University of Medical Sciences; PhD Thesis. 1993.

331. Dalim A, Motamedi G, Hosseini M, Mohammadian B, Malaki H, Gharibi Z, Gharifi FF. Echinococcosis/hydatidosis in western Iran. Vet Parasitol. 2002;105(2):161–71.

332. Arbab M, Hoozhyar H. Survey of echinococcosis and hydatidosis in Kashan region, central Iran. Iran J Publ Health. 2006;35(1):75–81.

333. Beromand M, Akhlaghi L, Fattahi Massom SH, Mobedi I, Oormazdi H, et al. Detection of Echinococcus multilocularis in carnivores in Razavi Khorasan province, Iran using mitochondrial DNA. PLoS Neg Trop Dis. 2011;5(1):e1379.

334. Mobedi I, Zarif-Dadaki M, Siasavi MR, Naddaf SR, Kia EB, Mohammadi M. Differential detection of Echinococcus spp. copro-PCR by nested-PCR in domestic and wild definitive hosts in Moghan plain, Iran. Iran J Parasitol. 2013;8(1):107–13.

335. Gholami S, Jahandar H, Abastabar M, Pagheh A, Mobedi I, Sharbatkhohi M. Echinococcus granulosus species in dogs and jackals from Caspian Sea region, northern Iran. Iran J Parasitol. 2016;11(2):186–94.

336. Panceri P. Due fatti relativi ai Cestodi. Rend dell’Acad Sci Ficici e Mat Napoli. 1866:32–4.
357. Macpherson CNL, Karstad L. The role of jackals in the transmission of *Echinococcus granulosus* in the Turkana District of Kenya. In: Karstad L, Nestel B, Graham M, editors. Wildlife disease research and economic development. Ottawa: International Development Research Centre; 1980. p. 53–6.

358. Witenberg G. Zur Kenntnis der Verbreitung von Echinokokkus und Trichinen in Palästina. Arch Schiffs- Tropenhyg. 1933;37:37–41.

359. Iqbal Z, Danso P, Hayat CS, Khan MN. Epidemiology of hydatid disease. *Echinococcosis* in dogs and jackals in Faisalabad (Pakistan). Indian Vet J. 1996;73(6):620–2.

360. Ulyanov SD. A study on the role of wolves and jackals in spreading larval cestodosis animals. *Tr. NIVI Kazakh Phil Academy of Agricultural Sciences*. 1957;9:402–4. (In Russian).

361. Elkanova ZZ. \[Epizootological and epidemiological characteristics of foci of echinococcosis in animals and humans in the ecosystem of the Kabardino-Balkarian Republic.\] Moscow: Thesis for the degree of candidate of biological sciences; 2010 (In Russian).

362. Bichieva MM, Atabieva JA, Levchenko NV, Bittirov AM, Shikhaliyev MA, Sarbasheva MM. Epizootological features of *Echinococcosis* in dogs and wild carnivores in the foothills of the North Caucasus. Vet Pathol. (Moscow). 2011;4(38):103–5. (In Russian).

363. Razikov S, Shodmonov IS, Adylov MH. The role of wild animals (carnivorous, artiodactyl and rodents) in epizootology of echinococcosis in Tadjikistan. *Russian Parasitol J*. 2010;4:59–63. (In Russian).

364. Boufana B, Lahmar S, Rebaï W, Safta ZB, Jebabli L, Ammar A, et al. Genetic variability and haplotypes of *Echinococcus* isolates from Tunisia. *T Roy Soc Trop Med H*. 2014;108(11):706–14.

365. Széll Z, Marucci G, Pozio E, Sréter T. *Echinococcus multilocularis* and *Trichinella spiralis* in golden jackals (*Canis aureus*) of Hungary. *Vet Parasitol*. 2013;197(1–2):393–6.

366. Zariffard MR, Massoud J. Study of *Echinococcus granulosus* and *Echinococcus multilocularis* infections in Canidae in Ardabile province of Iran. *Arch Inst RAZI*. 1998;48/49:47–52.

367. Lalošević D, Lalošević V, Simin V, Miljević M, Ćabrilović B, Bješić CO. Spreading of multilocular echinococcosis in southern Europe: the first record in foxes and jackals in Serbia, Vojvodina Province. *Eur J Wildl Res*. 2016;62(6):793–6.

368. Kairov IK. \[A study of multilocular hydatidosis in Karakalpakiya.\] *Sovremennoe sostoyanie prirodnykh resursov Karakalpakii*. 1977;177–189 (In Russian).

369. Acharjyo LN. Helminthiasis in captive wild carnivores and its control in India. *Zoo’s Print J*. 2004;19(7):1540–3.

370. Polishchuk VI, Dolgov VV. *Multiceps* infection in carnivores and coenuriasis in sheep in southern and central Tadzhikistan, USSR. *Trudy Nauchno-Issledovatel’skogoVeterinarnogo Instituta Tadzhikskoi SSR*. 1979;9:78–80. (In Russian).

371. Zhang L, Hu M, Jones A, Allsopp BA, Beveridge I, Schindler AR, Gasser RB. Characterization of *Taenia madoquae* and *Taenia regis* from carnivores in Kenya using genetic markers in nuclear and mitochondrial DNA, and their relationships with other selected taeniids. *Mol Cell Probes*. 2007;21(5–6):379–85.

372. Shemshadi B, Ranjbar-Bahadori S, Jahani S. Prevalence and intensity of intestinal helminths in carnivores and primates at Vakilabad zoo in Mashhad, Iran. *Comp Clin Pathol*. 2014;24(2):387–91.