Cestodes of the genera *Diplopylidium* and *Joyeuxiella* (Eucestoda: Dipylidiidae) – a review of historical data, species inventory and geographical distribution

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**Abstract.** Italian parasitologists (P. Marchi of Florence, Corrado Parona of Sardinia, Vincenco Diamare of Naples, Prospero Sonsino of Pisa) of the second half of the 19th century deserved respect in the exploration on the life cycle of dipylidiid cestodes by finding and describing larval stages of these tapeworms in reptiles. They also gave the description of the strobilar stages of cestodes (*Joyeuxiella echinorhynchoides*, *J. pasqualei* and *Diplopylidium acanthotetra*) detected in carnivores. At the beginning of the 20th century, scientists from Spain (Carlos R. Lopez Neyra of Granada in cooperation with Jose M. Munoz Medina) and France (Charles Joyeux) proved experimentally the affiliation of larval stages from reptiles to the adult cestodes in cats. Further cestodes of the genus *Diplopylidium* and *Joyeuxiella* were described from African mammals and carnivores from India and the southern parts of the former Soviet Union. Witenberg (1932), Matevosjan (1963) and Jones (1983) reviewed the genera and reduced the number of valid species. *D. acanthotetra*, *D. genettae*, *D. nölleri*, *D. polyacantha*, *D. zschokkei*, *D. monoophorum*, *J. pasqualei*, *J. echinorhynchoides* and *J. fuhrmanni* were considered valid species. Of these, *D. genettae*, *D. monoophorum*, *D. zschokkei* were not found again in recent times and the position of *J. rossicum* remains dubious. Other cestodes of these genera were insufficiently described or synonyms to already known species. Historical and recent findings showed that *Diplopylidium* and *Joyeuxiella* species occur in countries of southern Europe and Northern Africa surrounding the Mediterranean Sea, in the Middle East, in Central and South Asia, East and South Africa. They are no reports of the indigenous cases of these cestodes in America, Australia and northern East Asia. The life cycle of these cestodes is not fully disclosed. Larval stages of both genera were found in 60 reptile species. Single findings of *Joyeuxiella* cysticercoids were also made in amphibians, rodents and insectivores.

**Keywords:** *Joyeuxiella*; *Diplopylidium*; Dipylidiidae; Carnivores; Reptiles.

Cestode din genurile *Diplopylidium* și *Joyeuxiella* (Eucestoda: Dipylidiidae) – o evaluare a datelor istorice, a inventarului speciilor și a distribuției geografice

Cuvinte cheie: Joyeuxiella; Diplopylidium; Dipylidiidae; Carnivore; Reptile.

Introduction

Dipylidium Leuckart, 1863, Diplopylidium Beddard, 1913 and Joyeuxiella Fuhrmann, 1935 of the family Dipylidiidae Railliet, 1896 are tapeworm genera species of which parasitize the small intestines of carnivores.

Despite the wide distribution of species of the other two genera, Diplopylidium and Joyeuxiella, in subtropical and tropical countries, their full life cycle of that includes reptiles remained nebulous until recent times. A large number of different species names occurred in the literature, but most of them insufficiently described, were synonyms to known species, or were never found again after the original description. Also, the independent description of the larva stages in reptiles and their strobilar stage in carnivores caused some confusion. In addition, generic names had changed over time from Taenia to Dipylidium, a genus that was later split into Dipylidium, Diplopylidium and Joyeuxia. Since the name joyeuxia was already preoccupied Fuhrmann (1935) suggested the genus Joyeuxiella.

The aim of this paper is to review the discovery history of Diplopylidium and Joyeuxiella species and their geographical distribution.
Review of the discovery history

The Italian parasitologist Marchi (1872) detected armed cysticercoids attached to the intestinal wall of a gecko (*Ascalabotes mauritanicus*). The scolex of the parasite was armed with 70 hooks arranged in four circles. The size of the hooks ranged from 6 to 18 µm.

An inoculation trial by Marchi (1879) with cysticercoids found in the same host caused some confusion. The author fed the alleged tapeworm larvae found in the viscera of a wall gecko to a cat, a vulture and an owl and detected six days later small worms only in the intestine of the owl. It is assumed that Marchi dealt with a mixed infection of cestode larvae and cystacanths of an acanthocephalan species and that the "small cestodes" recorded in the gut of the owl were in reality juvenile acanthocephalans.

Rizzo (1902) reported *Cysticercus ascalabotidis* apart from wall geckos also from garden lizards (*Lacerta agilis*) from Sicily without giving further morphological details. It is assumed that this was the same larval stage Marchi dealt with (Lopez-Neyra, 1927b).

- **Diplopylidium acanthotetra** (Parona, 1886)

Parona (1886) discovered *Cysticercus acanthotetra*, a so far unknown cestode larval stage attached to the intestinal wall of a juvenile green whipsnake (*Coluber viridiflavus*) in Sardinia. The rostellum of this larval stage was armed with approximately 80 to 90 hooks arranged in four circles. The size of the hooks measured 69, 59, 33 and 18 µm. By comparing scolex structures, Diamare (1894b) concluded that this cysticercoid might be the larval stage of *Diplopylidium trinchesi*, a small cestode of the cat of 25 mm in length that Diamare (1892) had described previously.

Lopez-Neyra and Munoz Medina (1919) detected the larval stage of *D. trinchesii* at pleura and mesenterium of wall lizards collected in Granada/Spain and compared it to *C. acanthotetra* of Parona. Parrot and Joyeux (1920) proved experimentally by infection of cats with cysticercoids from wall geckos that *C. acanthotetra* is the larval stage of *D. trinchesii*.

Lühe (1898) described *Diplopylidium triseriale* from a genet in Tunisia. According to the author, this species was morphologically very close to *D. trinchesi* and both species were later synonymized with *Diplopylidium acanthotetra* by Witenberg (1932).

Lopez-Neyra and Munoz Medina (1921) recorded a further new species from cats in Granada (Spain). The length of *Diplopylidium quinquecoronatum* was 65 mm and its scolex was furnished with five rows of rostellar hooks. According to Witenberg (1932), it was identical with *D. acanthotetra*. *D. acanthotetra* was also found in a dog in Turkmenistan (Gnezdilov and Cebotarevic (1934). The figure of the anterior end of the cestode however, showed an unusual long neck.

- **Joyeuxiella echinorrhynchoides** (Sonsino, 1889)

In a short note, Sonsino (1889b) reported the finding of *Taenia echinorrhynchoides* in a fennec fox (*Vulpes cerda*) from Egypt. The new cestode with two lateral genital openings and a length of 7 cm seemed to be related to *Taenia caninum* and was subsequently transferred into the genus *Dipylidium*. The striking difference were 16 rows of 5-18 µm long hooks, on the long cylindrical rostellum. Since Sonsino did not

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1 Prior to Marchi, already Rudolphi (1819) referring to communications with Bremer mentioned cestode larval stages in the body cavity of the European green and the European wall lizards. These stages possessed an unarmed scolex, were called dithyridii and are known today as tetrahyridii, the larval stage of the cestode genera Mesocotyloides.

2 Today *Tarentola mauritanica* (common wall gecko) - a geckonid species that is widely distributed in the western Mediterranean region.

3 Today: *Hierophis viridiflavus*.

4 The original description by Diamare (1882) did not mention the size of the rostellar hooks, arranged in 4 circles. It only said that the hooks are three times bigger than those of *D. caninum* and contrary to those of *D. caninum* they were divided into root, guard and blade. A table given in a later paper (Diamare, 1894b) gave hook lengths for *D. trinchesi* of 36, 30, 22 and 12 µm.
mention gravid segments it can be concluded that the strobila was prepatent. Due to the morphological conformance Diamare (1894a) was convinced that a *Cysticercoides rostratus* of Mingazzini (1893) could have been the larval stage of *Dipylidium echinorhynchoides*. The adult cestode was also found in a fox in Tunesia (Lühe 1898) and later in a jackel in Mauritania (Joyeux and Baer, 1930).

- **Joyeuxiella pasqualei** (Diamare, 1893)

*Dipylidium pasqualei*, a larger cestode measuring 20 – 30 cm in length, was described from a cat from Egypt by Diamare (1893). Apart from bigger measurements of strobila and scolex it differed also in the shape of the rostellum from a similar cestode that Sonsino (1889) found in the fennec fox.

Among numerous cestodes in the gut of a cat from Hungary5 there were specimens similar to *D. pasqualei* that v. Ratz (1897) named *Dipylidium chyceri*. Lopez-Neyra and Munoz Medina (1919) described the subsequent larval stage in wall geckos in Granada in Spain. By experimental inoculation of these cysts in a kitten, the authors could close the life cycle of this tapeworm. Also, Parrot and Joyeux (1920) were able to produce the adult cestode in a cat after a feeding experiment with cysticercoids obtained from wall geckos.

Skrjabin (1923) described *Dipylidium rossicum* from a dog (out of 89 dissected) in the Rostov Region in Southern Russia based on a single specimen. Scolex structures and morphology of hermaphrodite segments matched with those of *D. pasqualei* but gravid segments contained several eggs. It is noteworthy that the dog was also infected with a large number of *D. caninum*. According to Skrjabin (1923) *D. rossicum* was also found in one out of 210 dissected cats from the same region.

After being transferred into the new genus *Joyeuxia*, Witenberg (1932) synonymized *J. chyceri* and *D. rossicum* with *J. pasqualei* making the former ones junior synonyms.

- **Diplopylidium monoophorum** (Lühe, 1898)

While studying cestodes of a zibet cat, most probably a common genet (*Genetta genetta*)6 shot in the outskirts of Tunis, Lühe (1898) described a cestode with a maximum length of 10 mm. *Diplopylidium monoophorum* had scolex structures comparable to *D. triseriale* with larger hooks measuring only 30 µm. The most striking difference however, were ovaries consisting only of a single rounded, compact lobe while ovaries of all other species of the genus were bilobed. Also, the testes posterior to ovaries in the slim mature segments were arranged in two longitudinal rows. In gravid segments, genital openings were moved forward without egg capsules between the cirrus sacs. The description of *D. monoophorum* was completed by Lopez-Neyra (1927a) and Witenberg (1932).

- **Diplopylidium zschockei** (Hungerbühler, 1910)

*Diplopylidium zschockei* was described by Hungerbühler (1910) from a yellow mongoose (*Cynictis penicillata*) trapped in the Kalahari of South Africa. According to the description, this species was close to *D. triseriale* of Lühe (1898) but differed by a larger strobila size of 120 mm, a conspicuously long unsegmented neck and smaller dimensions of hooks (45, 30, 17 µm). Joyeux (1921) found cysticercoids with scolex structures matching with those of *D. zschockei* in a horned viper (*Cerastes cornutus*) in Northern Africa.

- **Diplopylidium genettae** Beddard, 1913

Beddard (1913) gave a description of two tapeworms from a common genet from London Zoological Garden. He named one species *Diplopylidium genettae* and created a new genus, *Diplopylidium*. *D. genettae* consisting of 28 proglottids was 6 mm long and its rostellum was armed with two circles of hooks.

The main characters of the newly established genus *Diplopylidium* were:

5 The origin of the cat was not mentioned. At that time, Hungary was part of the Austria-Hungarian Empire that included also territories at the Mediterranean like Slovenia, Croatia, Bosnia-Herzegovina and Montenegro.

6 The author mentioned only the German name: Zibethkatze.
a retractile muscular rostellum armed with two circles of hooks;
- a double set of reproductive organs in each proglottid;
- vagina in front of cirrus sac;
- large and muscular cirrus sac, cirrus coiled, slender and unarmed;
- numerous testes filling available spaces in the proglottid;
- ovaries in front of vitelline glands, vagina narrow with a receptaculum seminis;
- uterus with numerous cavities each containing a single egg only.

*Joyeuxiella fuhrmanni* (Baer, 1924)

Baer (1924) listed a number of helminths collected by Arnold Theiler in South Africa and given to Otto Fuhrmann. Amongst them, was a 30 mm long cestode from a serval cat (*Leptailurus serval* Schreber, 1776) with 14 to 16 rows of rose thorn shaped rostellar hooks. Striking features of this new species, *Dipylidium fuhrmanni*, were the concentration of testes in the mature segments posterior to vasa deferens, the situation of genital pores in the anterior part of the segments, the presence of thin and very long cirra and single eggs in egg capsules that are confined mediially to the longitudinal excretory vessels and are concentrated in the posterior part of the gravid segments. The author suspected that *Dipylidium* sp. of Kofend (1921) collected from a serval in Sudan also belong to this species. However, in that description the cirrus was described as cylindrical and egg capsules were seen also externally to the longitudinal excretory vessels.

Ortlepp (1933) recorded *J. furmanni* also in a domestic cat in South Africa and Hudson (1934) and Mettric & Beverley-Burton (1961) described the species from serval cats in Kenya and Southern Rhodesia (today: Zimbabwe), respectively.

Little attention was paid to a paper by Setti (1895) who described *Dipylidium gervaisi* from a genet (*Genetta tigrina*) from Eritrea. This small sized tapeworm species named after the French natural scientist Paul Gervais had a cylindrically based, conical rostellum, armed with 8-12 rows of thorn like hooks in an average size of 10 µm. The strikingly long cirra and the coiled vasa deferens occupying the anterior part of mature segments suggest that this species could have been identical with *J. fuhrmanni*.

Only Witenberg (1932) cited Setti (1895) and Kofend (1921) and listed *D. gervaisi* and *Dipylidium* sp. as synonyms for *J. pasqualei*.

- **Diplopylidium nølleri** (Skrjabin, 1924)

During the 5th Russian helminthological expedition to Russian Turkestan, Skrjabin (1924) described *Progynopylidium nølleri* from a cat from Perowsk. The 40 to 50 mm long dipylidiid strobila stroke due to the dark brown pigmentation of the gravid segments. The scolex was armed with three to four rows of rostellar hooks in a total number of up to 100. In premature segments, female reproductive organs occur first before testes can be seen. The vagina enters the genital pore in front or ventral to the cirrus pouch.

Skrjabin (1924) pointed out that Perowsk was the northernmost place for *P. nølleri*. In more southern latitudes it was found in higher prevalence comparable to those of *D. caninum*. Lopez-Neyra (1928) described *Progynopylidium monoophoroides* – a very similar cestode with reddish brown terminal segments in dogs from Granada, Almeria and Cordoba in southern Spain. *P. monoophoroides* differed only by a slightly larger number of testes from *P. nølleri* and is now treated as a junior synonym.

- **Diplopylidium polyacantha** Velikanov, 1982

Sharpilo (1976b) mentioned a larval stage of a *Diplopylidium* species with seven to ten rows of rostellar hooks in six lizard and two snake species in Azerbaidzhan and southern Kazakhstan. In a feeding experiment of a juvenile fox, a dog and a cat with Caspian gecko (*Tenuidactylus caspius*), Velikanov (1982) could produce the strobilar stage of *Diplopylidium polyacantha*, a cestode of 20 to 40 mm in length. The relative large scolex of 400 to 500 µm was armed with nine rows of hooks of which the

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7 Beddard studied histological sections of the cestode and in one section he saw 2 circles of hooks. Most probably he missed further circles because they were situated at a different level.

8 Perowsk is today Qysyl'dora in southern Kazakhstan.
largest measured 65 – 71 µm. These hooks were striking due to a long and thin blade. Velikanov (1989) mentioned eight lizard and four snake species from Turkmenistan in which the larval stage of D. polyacantha was found. While the percentage of infected lizards was small, snake species showed prevalence between 36.7 in Spalerosophis diadema and 41.9% in Psammophis lineolatus.

Description of further species

Popov (1935) found cysticercoids in the peritoneum of Caspian geckos (Tenuidactylus caspius) caught in Karabach/Azerbaijan. Cysticercoids contained in cysts of a size of 800 µm had a rostellum with four rows of hooks (42, 19, 12, 7 µm). A feeding experiment with two cats revealed six weeks after inoculation findings of three cestodes in the small intestine of one cat. The size of the cestodes varied between 4 and 5 cm and scolex structures matched with those of the cysticercoids. The helminth was named Diplopylidium skrjabini. The adult cestode was nearly identical with D. noelleri and differed mainly in a shorter length of rostellar hooks of the 2nd row. The species has never been reported again.

A number of Diplopylidium and Joyeuxiella species were reported from India. Amongst them was J. pasqualei in domestic cats and in a wild cat in Dehli by Gill (1972) and Das et al. (2011), respectively. In addition, Agrawal and Pande (1980) found cysticercoids in a yellow bellied gecko (Hemidactylus viridiflavus) and were able to raise the strobilar stage of J. pasqualei in an experimentally infected cat.

Capoor and Srivastava (1976) found a large number of J. vulpusi in a fox in Allahabad. The description of J. vulpusi however, matched with the redescription of J. echinorhynchoides by Jones (1983) who compared material collected from carnivores from South Africa, Palestine, Iran, Kuwait and Iraq. Deshmukh (1990) described J. domestica from a cat. The descriptions of other species from India were parsimonious with missing important details like total size and the description of the gravid segments. D. udgirensis from a cat by Shinde et al. (1994), D. iayashreeae from dog by Patil and Shinde (1997), D. aurangabadensis from a cat by Shinde and Pawar (2001), D. shindei from a dog by Chavan et al. (2003), D. parvatae from a cat by Shinde et al. (2004), D. shindei9 from an Asian palm civet (Paradoxurus hermaphroditus) by Patil et al. (2007) and D. murtizarpurensis from a cat by Sawakar (2014) were wrongly allocated to the genus Diplopylidium. In fact, they must belong to the genus Joyeuxiella since drawings of the mature segments showed the position of the vagina posterior to the cirrus sac and only the size of the rostellar hooks of D. aurangabadensis, D. shindei (by Chavan et al., 2003) and D. murtizarpurensis resemble those of Diplopylidium. Only D. chandensis from jungle cat (Felis chaus) described by Suryawanshi et al. (2010) matched with features of the genus Diplopylidium. All “new” species from India have never been mentioned in the literature again.

Taxonomy and species inventory

The name Dipylidium was created by Leuckart (1863) for cestodes with two marginalized genital openings in which male and female genital ducts lead. The rostellarium of these cestodes is armed with multiple rows of small hooks which have a disc shaped root. Gravid segments contain eggs glued together as larger conglomerates. Despite the new name, the author called the tapeworm that occurs frequently in dogs and cats Taenia cucumerina, with synonyms T. elliptica and T. canina. For the first time, Diamare (1892) used Dipylidium as genus name and gave a definition. Contrary to Leuckard, Diamare defined egg capsules in gravid segments to contain one or several eggs.

In a monograph on the old genus Dipylidium, Diamare (1894b) recognized D. caninum, D. trinchesi, D. pasqualei and D. echinorhynchoides as valid species. He considered D. genettae10 (Gervais, 1847) and D. monticellii (Diamare, 1893) as insufficiently described but probably also belonging to the genus Dipylidium and also listed all the 12 synonyms of D. caninum.

9 Patil et al. 2007 did not cite the paper the paper of Chavan et al. (2003) and thus, did not know that the species name D. shindei was already preoccupied.

10 In the very superficial original description by Gervais (1847) the cestode was named Halysis genettae. Diesing (1850) mentioned it as Taenia genettae.
Railliet (1896) suggested some modifications in the nomenclature of parasites within the family Taeniidae\textsuperscript{11}. In this connection, he suggested to rename the subfamily Cystoidotaenae and proposed the name Dipylidiinae\textsuperscript{12} for small cestodes with two or multiple circles of rostellar hooks. These cestodes have cysticeroid type larval stages. The definition of this subfamily was later on emended, became more defined and was upgraded to family level (Matevosjan, 1953; Jones, 1983; Mariaux et al., 2017).

At the end of the 1920\textsuperscript{th} of last century the genus Dipylidium contained about 30 species of which only 18 names were more or less well known. Lopez-Neyra (1927a) discussed the various morphological types within this genus and proposed a division into three distinct genera:

- **Dipylidium**: rostellar hooks rose thorn shaped, male genital opening in front of vagina, multiple eggs in one capsule, genital openings posterior to middle of the segment. Type species: *D. caninum*.

- **Joyeuxia**: rostellar hooks rose thorn shaped, male genital opening in front of vagina, single eggs in one capsule, genital openings in the middle of the segment. Type species: *J. chyceri* (= *J. pasqualei*).

- **Diplopylidium**: part of rostellar hooks of taenioid type, male genital opening posterior to vagina, genital openings in the first half of the segment, one egg per egg capsule. Type species: *D. genettae*.

Since the type species of *Diplopylidium, D. genettae*, was only poorly described Lopez-Neyra (1928) suggested to rename this genus in *Progyonopylidium* with a properly described by Skrjabin (1924) type species *P. nölleri*.

Witenberg (1932) adopted the system suggested by Lopez-Neyra (1927a, 1928) but disagreed regarding the genus name *Progyonopylidium*. In his revision of the inventory of the family Dipilyidiinae he considered *D. caninum* as the only exactly described valid species of the genus *Dipylidium*. The adult cestode infects canids, hyenas, cats, civet cats and occasionally man. Fleas and biting lice are intermediate hosts.

The author mentioned also *D. buencaminoi* Tubangui, 1925 from a dog on the Philippines, but this species differs only by its smaller total size and unusually smaller eggs.

With regards to the genus *Joyeuxia* he left only two species, *J. pasqualei* and *J. echinorhynchoides*. Both differ in the number of rows of rostellar hooks 14-18 vs. 23-25\textsuperscript{13} and the distribution of eggs in the gravid segments. Due to the very much contracted holotype specimen of *J. fuhrmanni* Witenberg doubted that this species is substantially different from *J. pasqualei*, especially because the scolex structures were similar. Witenberg also synonymized *Dipylidium rossicum* that Skrjabin (1923) described from a dog from the Don Region of Russia with *J. pasqualei*.

Within the genus *Diplopylidium* Witenberg (1932) recognized *D. acanthotetra*, *D. nölleri*, *D. zschokkei* and *D. monoophorum* as valid species. *D. genettae* as the type species of the genus was only poorly described. Only the position of the vagina anteriorly to the cirrus and the taenioid shape of the rostellar hooks defined its systematic position. *D. arvicola* and *D. columbae* found as strobilar stages in unusual hosts (rodent and pigeon) were considered as insufficiently described.

In a short note, Fuhrmann (1935) informed that the genus name *Joyeuxia* was already preempted by a sponge and for this reason he proposed the name *Joyeuxiella*.

Matevosjan (1963) added *D. skrjabini* to the genus *Diplopylidium*. Based on a redecription of *J. rossicum* by Gamcemlidze (1939) he also restored the status of this species. Despite morphological similarities of *J. rossicum* and *J. pasqualei*, both are listed as valid species together with *J. echinorhynchoides* in Fauna Europea (2019).

\textsuperscript{11} Today: Taeniidae.

\textsuperscript{12} In many sources Stiles (1896) is named as author for Dipilyidiinae. However, the paper by Railliet (1896) on Dipilyidiinae was published in March 1896 while that by Stiles appeared four months later.

\textsuperscript{13} The number of rostellar hooks reported by earlier scientist were counted in a wrong way resulting in lower numbers.
Jones (1983) revised the genus *Joyeuxiella* and recognized *J. pasqualei* and *J. echinorhynchoides*, and after studying material from Onderstepoort Veterinary Institute, also *J. fuhrmanni* as valid species.

**Geographical distribution**

Early findings of larval stages and adult cestodes were made in countries surrounding the Mediterranean. *Dipolypсидium acanthotetra* (synonyms: *Dipolypсидium trinchesi*, *D. quinquecoronatum*, *D. triseriale*) was reported from Italy, Spain, Algeria, Tunisia and Palestine. *Dipolypсидium nölleri* (synonym: *D. monoophoroides*) was discovered in Kazakhstan and later detected also in Spain, Egypt and Palestine. The larval stage, *Cysticercus rostratus*, of *Joyeuxiella echinorhynchoides* was found for the first time in Italy, while its strobilar stage was described from a fennec fox from Egypt. It was later also detected in Tunisia, Mauritania, Niger and Palestine.

*Joyeuxiella pasqualei* (synonyms: *Dipolypсидium chyceri*, *Dipolypсидium rossicum*, *Joyeuxxia aegyptica*, *Joyeuxxia pasqualeiformis*) occurred in Spain, Algeria, Egypt and was found also in Hungary, Russia, India, southern China, Malaysia, Tanzania and South Africa.

According to historical sources, some species, like *Joyeuxxia fuhrmanni*. *Dipolypсидium zschokkei* and *D. monoophoroid* were known only from Africa. The type species of the genus *Dipolypсидium*, *D. genetettae*, is poorly described. It was found in a genet of the London Zoological Garden. The origin of the host was Africa without specification of the country.

The occurrence of strobilar *Dipolypсидium* and *Joyeuxxia* stages in the former Soviet Union in the 1950th and 1970th is well documented by Kozlov (1977). According to the author, *D. acanthotetra* and *D. nölleri* were found in Turkmenistan in domestic cats and in Azerbaijan, Uzbekistan, Turkmenistan and Kazakhstan, respectively in in domestic and wild cats (*Felis margarita*, *F. chaus*), dogs, wolves and foxes. *J. echinorhynchoides* was diagnosed in foxes in Georgia, Uzbekistan and Tajikistan and *J. pasqualei* was diagnosed in Georgia, Uzbekistan, Kazakhstan and southern Russia. Kozlov (1977) listed also *J. rossicum* with findings made in domestic and wild cats, wolves and red foxes in Moldova, Ukraine, Uzbekistan, Kazakhstan and Lower Volga region and west Siberia of Russia. Sharpilo (1976b) listed findings of larval stages of *D. acanthotetra* and *D. nölleri* in reptiles in Turkmenistan and Uzbekistan and those of *J. echinorhynchoides* in Azerbaijan, Turkmenistan and Uzbekistan.

Table 1 and Table 2 summarizes recent findings of *J. pasqualei* and *J. echinorhynchoides* and *D. nölleri* and *D. acanthotetra* findings in carnivores around the world. A further species, *J. fuhrmanni*, was mentioned in the past 30 years only in three reports. Baker et al. (1989) detected the parasite in 38 (=2.5%) out of 1,502 cats in Transvaal/South Africa. Outside of Africa, *J. fuhrmanni* was found in Dubai in 30 (=12.5) out of 240 cats (Schuster et al., 2009). In a controlled test with naturally tapeworm infected cats carried out in Dubai 11 out of 13 animals were positive for *J. fuhrmanni* (Schuster et al., 2016). It is notable that other species (*J. rossicum*, *D. skrjabini*, *D. monoophorum* and *D. gervaisi* *D. zschokkei*) were not reported in the past 30 years.

Cestodes of both genera were not always identified to species level like in the case of El Shehabi (1999) in dogs and foxes and Al-Qaoud et al. (2003) in dogs in Jordan; Zare-Bidaki et al. (2010) in foxes and Parsa et al. (2014) in dogs in Iran and El-Dakhly et al. (2017) in cats in Egypt. The reason for this is a difficult differentiation between the species, particularly between *J. pasqualei* and *J. fuhrmanni* in the case of fresh infections or, when dealing with faecal samples only. In addition to Tab.1, there was a case report of an intestinal pleating in a cat associated with *J. pasqualei* infection in Greece (Papazoglou et al. 2006). In Corsica a *J. echinorhynchoides* infection was detected in a road killed fox (Jordi et al., 2005). In the Lefkosia, Lemesos, Larnaka, Pafos and Ammochostos districts of Cyprus, 7% out of 185 examined cats were diagnosed with *Joyeuxiella* and *Dipolypсидium* infections without further differentiation (Diakou et al., 2017).

Very few findings these cestodes were reported from central Europe. In a parasitological study on parasites of dogs and cats in Austria, two out of 505 dissected cats were positive for *J.
Supperer and Hinaidy (1986). Schuster and Montag (2000) reported a case of *J. pasqualei* in a cat in Berlin. Out of 8,438 dog faecal samples examined in southern Germany, only 0.1% contained *Joyeuxiella/Diplopylidium* segments and none of the 3167 cat faeces were positive for these cestodes (Barutzki & Schaper, 2003).

Table 1. Recent findings of *J. pasqualei* and *J. echinorhynchoides* in carnivores

<table>
<thead>
<tr>
<th>Country</th>
<th>Region</th>
<th>Host</th>
<th>Number examined</th>
<th><em>J. pasqualei</em></th>
<th><em>J. echinorhynch</em></th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spain</td>
<td>mid Ebro valley</td>
<td>cat</td>
<td>58</td>
<td>29.3</td>
<td></td>
<td>Calvete et al. (1998)</td>
</tr>
<tr>
<td></td>
<td>All over</td>
<td>red fox</td>
<td>399</td>
<td>2.8</td>
<td>6.0</td>
<td>Segovia Arias et al. (2004)</td>
</tr>
<tr>
<td></td>
<td>Sierra Morena</td>
<td>cat</td>
<td>19</td>
<td>21.0</td>
<td></td>
<td>Millan &amp; Casanova (2007)</td>
</tr>
<tr>
<td></td>
<td>Mallorca</td>
<td>cat</td>
<td>58</td>
<td>76.0</td>
<td></td>
<td>Millan &amp; Casanova (2009)</td>
</tr>
<tr>
<td></td>
<td>Valencia</td>
<td>red fox</td>
<td>286</td>
<td></td>
<td>27.6</td>
<td>Sanchis Monsonis (2015)</td>
</tr>
<tr>
<td></td>
<td>Murcia</td>
<td>red fox</td>
<td>55</td>
<td></td>
<td>34.6</td>
<td>Martinez Carracao et al. (2007)</td>
</tr>
<tr>
<td>Portugal</td>
<td>Lisbon</td>
<td>cat</td>
<td>162</td>
<td>16.4</td>
<td></td>
<td>Waab et al. (2014)</td>
</tr>
<tr>
<td></td>
<td>all over</td>
<td>cat</td>
<td>1150</td>
<td>1.2</td>
<td></td>
<td>Symeonidou et al. (2018)</td>
</tr>
<tr>
<td></td>
<td>Tessaloniki</td>
<td>cat</td>
<td>118</td>
<td>10.2</td>
<td></td>
<td>Gianelli et al. (2017)</td>
</tr>
<tr>
<td>Greece</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>all over</td>
<td>cat</td>
<td>18</td>
<td>11.1</td>
<td></td>
<td>Knaus et al. (2011)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.3</td>
<td>Aydenizoz (1997)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50.0</td>
<td>Yaman et al. (2006)</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>2.7</td>
<td>Öter et al. (2011)</td>
</tr>
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<td>cat</td>
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<td>11.1</td>
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<td></td>
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<tr>
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<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Turkey</td>
<td>Hatay</td>
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<td>60</td>
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<td></td>
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<tr>
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<td>n.i.</td>
<td>red fox</td>
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<td>Alagali et al. (2011)</td>
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<tr>
<td>Kuwait</td>
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<td>61.2</td>
<td></td>
<td>Abdul-Salam &amp; Baker (1990)</td>
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<tr>
<td></td>
<td>Kuwait city</td>
<td>cat</td>
<td>240</td>
<td>38.3</td>
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<td>El Azazy et al. (2016)</td>
</tr>
<tr>
<td>Iraq</td>
<td>Babylon</td>
<td>cat</td>
<td>57</td>
<td>12.5-20</td>
<td></td>
<td>Al-Rammahi et al. (2014)</td>
</tr>
<tr>
<td></td>
<td>Baghdad</td>
<td>cat</td>
<td>254</td>
<td>58.3</td>
<td></td>
<td>Al-Rubaie et al. (2015)</td>
</tr>
<tr>
<td>UAE</td>
<td>Dubai</td>
<td>cat</td>
<td>240</td>
<td>67.1</td>
<td></td>
<td>Schuster et al. (2009)</td>
</tr>
<tr>
<td></td>
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<td>102</td>
<td>3.9</td>
<td></td>
<td>Dalimi et al. (1996)</td>
</tr>
<tr>
<td></td>
<td>Kashan</td>
<td>wolf</td>
<td>10</td>
<td>20.0</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>dog</td>
<td>70</td>
<td>11.4</td>
<td></td>
<td>Arbabi et al. (2004)</td>
</tr>
<tr>
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<td></td>
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<td>22</td>
<td>6.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td>jackal</td>
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<td>7.5</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Mashad</td>
<td>dog</td>
<td>100</td>
<td>1.0</td>
<td></td>
<td>Razmi et al. (2006)</td>
</tr>
<tr>
<td></td>
<td>Kordestan</td>
<td>fox</td>
<td>22</td>
<td>27.3</td>
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<td>Dalimi et al. (2006)</td>
</tr>
<tr>
<td></td>
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<td>jackal</td>
<td>10</td>
<td>3.0</td>
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</tr>
<tr>
<td></td>
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<td>cat</td>
<td>100</td>
<td>55</td>
<td></td>
<td>Changizi et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Zanjan</td>
<td>cat</td>
<td>100</td>
<td>55</td>
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<td>Esmailzadeh et al. (2009)</td>
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<tr>
<td></td>
<td>Kashan</td>
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<td>85.0</td>
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<td>Arbabi &amp; Hooshyyar (2009)</td>
</tr>
<tr>
<td></td>
<td>all over</td>
<td>fox</td>
<td>37</td>
<td>10.8</td>
<td></td>
<td>Meshgi et al. (2009)</td>
</tr>
<tr>
<td></td>
<td>Mashad</td>
<td>cat</td>
<td>52</td>
<td>17.6</td>
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<td>Borji et al. (2011)</td>
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<tr>
<td></td>
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</tr>
<tr>
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<td>Puducherry</td>
<td>cat</td>
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<td>Das et al. (2011)</td>
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<td>S. Africa</td>
<td>Gauteng</td>
<td>cat</td>
<td>1502</td>
<td>6.0</td>
<td></td>
<td>Minnaar &amp; Krecek (2001)</td>
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</tbody>
</table>
Table 2. Recent findings of *D. noelleri* and *D. acanthotetra* in carnivores

<table>
<thead>
<tr>
<th>Country</th>
<th>Region</th>
<th>Host</th>
<th>Number examined</th>
<th>Prevalence (%)</th>
<th>References</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><em>D. noelleri</em></td>
<td><em>D. acanthotetra</em></td>
</tr>
<tr>
<td>Spain</td>
<td>mid Ebro valley</td>
<td>cat</td>
<td>58</td>
<td>8.6</td>
<td>20.7</td>
</tr>
<tr>
<td></td>
<td>All over</td>
<td>red fox</td>
<td>399</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mallorca</td>
<td>cat</td>
<td>58</td>
<td>60.0</td>
<td></td>
</tr>
<tr>
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<td>3.7</td>
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</tr>
<tr>
<td>Tuenisia</td>
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<td>jackal</td>
<td>31</td>
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<td></td>
<td>Ariana</td>
<td>dog</td>
<td>271</td>
<td>27.7</td>
<td></td>
</tr>
<tr>
<td>Egypt</td>
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<td>cat</td>
<td>62</td>
<td>22.5</td>
<td>8.0</td>
</tr>
<tr>
<td>Saudi Arabia</td>
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<td>red fox</td>
<td>8</td>
<td>(4/8)</td>
<td></td>
</tr>
<tr>
<td>Kuwait</td>
<td>Kuwait-city</td>
<td>cat</td>
<td>103</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>cat</td>
<td>240</td>
<td>54.6</td>
<td>45.4</td>
</tr>
<tr>
<td>Iraq</td>
<td>Babylon (urban)</td>
<td>cat</td>
<td>32</td>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Babylon (rural)</td>
<td>cat</td>
<td>25</td>
<td>14.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Babylon</td>
<td>cat</td>
<td>254</td>
<td>50.8</td>
<td></td>
</tr>
<tr>
<td>Qatar</td>
<td>Doha</td>
<td>cat</td>
<td>658</td>
<td>47.1</td>
<td></td>
</tr>
<tr>
<td>UAE</td>
<td>Dubai</td>
<td>cat</td>
<td>240</td>
<td>37.1</td>
<td></td>
</tr>
<tr>
<td>Iran</td>
<td>Tehran</td>
<td>cat</td>
<td>102</td>
<td>37.25</td>
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</tr>
<tr>
<td></td>
<td>Kordestan</td>
<td>fox</td>
<td>22</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bandar e Anzali</td>
<td>cat</td>
<td>50</td>
<td>54.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Zanjan</td>
<td>cat</td>
<td>100</td>
<td>23.0</td>
<td>41.0</td>
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<td></td>
<td>Kashan</td>
<td>cat</td>
<td>113</td>
<td>64.6</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>red fox</td>
<td>37</td>
<td>8.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>jackal</td>
<td>79</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Uzbekistan</td>
<td>Samarkand</td>
<td>dog</td>
<td>28</td>
<td>7.1</td>
<td></td>
</tr>
</tbody>
</table>

The only known case of a *Joyeuxiella* infection in America was reported from a cat that had been imported from Saudi Arabia (Blagburn & Todd (1986)).

Studies of the life cycle

The involvement of reptiles in the life cycles of *Diplopylidium* and *Joyeuxiella* species is known for a long time. Early communications mentioned wall lizards and whipsnakes as intermediate hosts. The larval stages of dipylidiid cestodes were frequently found in lizards in Spain, Morocco, Algeria, Tunesia and Greece but also in snakes in southern Europe and northern Africa (Lopez-Neyra, 1927b). Working in Palestine on dipylidiid cestodes Witenberg (1932) added more reptile species as intermediate hosts. According to Joyeux (1920), 20% of the wall geckos in Algeria were infected with these cysticercoids.

For Spain, Lopez-Neyra (1927b) gave cysticercoid prevalences in wall geckos with different cysticercoids between 6 and 25%. These small lizards are a frequent prey of cats while snakes are less likely to be eaten by cats. In Turkmenistan, Velikanov (1989) examined more than 1000 reptiles belonging to 34 species and detected cysticercoids of *D. acanthotetra* in one, *D. nölleri* in 9, *D. polyacantha* in 12 and *J. echinorhynchoides* in 20 reptile hosts.

Snakes always showed higher prevalence compared to lizards. Table 3 listed 57 known reptile species that are involved in the life cycles of dipylidiid cestodes.
The description of the larval stages was based on microscopic examination of the whole cyst or examination of the isolated metacestode. Valkounova (1982) did histological examination of D. noelleri larval stages collected from an Egyptian cat snake (Telæscop tus obtusus) caught in a village next to Giza/Egypt by Rysavy (1973). The metacestode was surrounded by a host derived capsule consisting of muscles and connective fiber tissue. Gelatinous matter filled the space between parasite and capsule. Contrary to the larval stage of D. caninum for which Cervi (2002) proposed the name cryptocysticercus histological sections with D. noelleri larvae did not reveal any signs of scolex invagination and no attachment of the larva to the capsule could be observed. Little is known about the participation of other vertebrate classes in the life cycle of these cestodes. Bursey and Goldberg (2004) reported findings of Joyeuxiella sp. in Palau frogs (Cornufer pelewensis) and Mashaii (2005) detected D. acanthotetra cysticercoids in a green toad (Bufo viridis) in Iran. Schulz (1929) and Gamcemlidze (1939) found Joyeuxiella larval stages in the lesser white toothed shrew (Crocidura suaveolens) in Kazakhstan and Georgia, respectively. The authors were convinced dealing with J. rossicum. For this reason, further findings of Joyeuxiella cysticercoids in small mammals were all attributed to J. rossicum. Thus, Semenova (1968), Sharpilo (1976a) and Tarasovskaja (1994) reported J. rossicum in rodents in the lower Volga region of Russia, in Kiev (Ukraine) and in Kirgistan.
respectively. Behnke et al. (2004) found the larval stage of *J. rossicum* in a spiny mouse (*Acomys dimidiatus*) in Egypt.

The question how reptiles become infected with subsequent cysticercoids remained obscure. After unsuccessful inoculation experiments of wall geckos with cestode segments carried out by Joyeux (1923), the author suggested that a further host is necessary and this could be a coprophagous insect. According to López-Neyra (1927c) house flies might play a role at least as disseminators for dipyliuid eggs.

In short communication, Dadaev et al. (2005) reported findings of cysticercoids in darkling beetles of the genus *Adesmia* in Uzbekistan. The cysticercoids in a size of 280 – 380 µm were embedded in connective tissue capsules and were characterized by tree rows of rostellar hooks. The hooks in the first row measured 30-40 µm, others were considerably smaller. Isolated cysticercoids transferred in jelly capsules and were orally inoculated to four different lizards (*Eremias velor* Pallas, 1771, *Trachelus sanguinolentus* Cuvier, 1817, *Phrynocephalus helioscopus* Pallas, 1771, *Tenuidactylus fedtschenkoi* Strauch, 1887). All these reptiles were harbored cysticercoids when being dissected 64-97 d after inoculation. The authors were convinced to have dealt with *Diplopylidium noellleri*.

Acknowledgements

The author is grateful to Prof. Dr. V. Charchenko (Schmalhausen Institute of Zoology, Kiev/ Ukraine), to Prof. Dr. S. Rehbein (Boehringer-Ingelheim, Rohrdorf/ Germany) and to Dr. B. Neuhaus (Naturkundemuseum Berlin/ Germany) for their help in acquisition of some historical literature sources.

References


Beddard F.E. 1913. Contributions to the Anatomy and Systematic arrangement of the Cestoidea. 10. On

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14 The authors were uncertain about the species affiliation. They used the name *J. rossicum* since other *joyeuxiella* species that were known to occur in Egypt employ reptiles in their life cycle. Also they cited literature from Kirgistan where *J. rossicum* was found in rodents.


Lopez-Neyra C.R. 1928. Recherches sur le genre 


Melnikov N. 1869. Über Jugendzustände der Taenia cecumerina. [On juvenile stages of Taenia cecumerina] [in German]. Arch. für Naturgesch. 35:62-69.


Mingazzini P. 1893. Ricerche sul parassismo nelle cestode helminths of farm and wild animals]. In the University of Kansas and Natural History Museum of Kansas, Special Publication No 25. pp. 77-148.


Ortlepp R.J. 1933. Joyeuxia fuhrmanni Baer, 1924, hitherto unrecorded cestode parasite of the


Setti E. 1895. *Diplopylidium gervaisi* n.sp. e qualche considerazione sui limiti specifici nei cestodi *Diplopylidium gervaisi* n.sp. and some considerations on specificity of cestodes] [in Italian]. Thesis Volgograd University pp. 1-18.

Sharpilo L.D. 1976a. Rol’ gryzunov fauny Ukrainy v cirkulacii gel’mintov [Significance of rodents in...


