Red fox (*Vulpes vulpes*) as a synurbic species and its role in the spread of the Echinococcus multilocularis tapeworm

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Summary:

Urbanization of the environment contributes to the degradation of many natural habitats of many plants and animals, which causes reduction of biodiversity. There are however certain species, adapting easily to both suburban and urban conditions. Red fox (*Vulpes vulpes*) is a good example, since it is increasingly noted not only in the natural habitats, such as fields or forests, but also in the direct vicinity of human residencies like farms, suburban areas or even large agglomerations. Fox is becoming a permanent feature of urban fauna, enriching the biodiversity. It is also a relevant epidemiological threat, constituting a zoonotic reservoir for many parasites which are important from veterinary, as well as from medical point of view, including tapeworm *Echinococcus multilocularis* which causes alveolar echinococcosis.

Key words: red fox, rabies, scabies, alveolar echinococcosis, hunting, parasites, *Echinococcus multilocularis*

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Introduction

The progressing urbanization process causes the displacement of numerous plant and animal species from their current habitats, thus contributing to the reduction of biodiversity (Vitousek et al., 1997; Hunter, 2007). However, some animals are capable of overcoming the fear of humans and learn how to use new ecological niches resulting from human activity. The process of species emerging in urban areas is referred to as synurbization (Andrzejewski et al., 1978). Due to the synurbization, animals acquire new skills to live and utilize new sources of food and to reproduce in the vicinity of humans (Champan & Jones, 2012; Luniak 2008). The species observable in cities include, inter alia, rodents: the striped field mouse *Apodemus agrarius* (Babińska-Werka et al., 1979), the red squirrel (*Sciurus vulgaris*), (Verbelyen et al., 2003); birds, including the peregrine falcon (*Falco peregrinus*; Rejt, 2001), and larger mammals, e.g. the badger (*Meles meles*), (Harris, 1984). The red fox (*Vulpes vulpes*) is also coping well in urban areas, thus enriching the urban fauna. However, the red fox is a zoonotic reservoir of parasites which can pose danger to human and animal health.

Biology and prevalence

The red fox is a predator belonging to the canids family. Mature specimens reach an approximate weight of 5–6 kg (Fig. 1). Females are smaller than males. The red fox breeds once a year, during winter months. On

Fig. 1. Adult foxes

Source: http://dinoanimals.pl/zwierzeta/lis-vulpes-vulpes-rudy-spryciarz/attachment/lis-dinoanimals-pl-5/

average, 3–5 pups are born which become self-sufficient after 3 months. The female cares for the young and the male helps feed the offspring by bringing the food near the burrow (http://animaldiversity.org/accounts/Vulpes_vulpes/#reproduction). It is the most common practice for foxes to dig burrows in a sandy ground (Scheldon, 1950) or to inhabit or even share the burrows dug by other animals, mainly the badger.

The fox is the world's most widespread predator (www.iucnredlist.org). It is present in Europe, North America, Asia, and it was also brought to Australia. It prefers field and forest habitats, mid-forest woodlots, and forest edges. The red fox is an omnivorous animal that mainly hunts for small-size rodents (Jędrzejewski & Jędrzejewska, 1992; Dell'Arte et al., 2007). The research on fox's food base conducted in north-eastern Poland shows that voles are the main source of food for these predators. In addition, it has been stated that male and young foxes have a wider food base than females. The percentage of rodents in the diet increases in autumn and winter seasons (Kidawa & Kowalczyk, 2011). The fox is an undesirable neighbor of poultry breeders. It can penetrate into farmlands, farms, and chicken coops where it has access to easy prey, ultimately leading to economic losses (Panek & Breziński, 2002; Jankowiak et al., 2008; Baker et al., IFAW.org.).

Fox population limiting factors

The main factor that limits the fox population is rabies; however, the associated threat was effectively eliminated through vaccines spread on a massive scale across the forest areas. Since 1978, as many as 24 European countries have been included in the program aimed to eradicate rabies. In 2007, the territory where fox vaccination campaigns were carried out, amounted to 21,077,370 km^2 (Freuling et al., 2013). According to the World Organization for Animal Health (OIE), countries where no single case of rabies have been detected, are considered virus–free. In Europe, such countries include, inter alia, the Netherlands (Clinguet et al., 2004), Austria (Muller et al., 2012), and Switzerland (Zannoni et al., 2000). In Poland, several dozen cases of rabies are reported on an annual basis (97 in 2015 with 70.1% relating to the red fox). Each case of rabies originated from the following 5 voivodships: Warmińsko-Mazurskie, Zachodnioporskie, Lubelskie, Małopolskie, and Podkarpackie (Flis, 2017). The specimen fallen due to rabies are found in the vicinity of human habitats (http://www.nowiny24.pl/wiadomosci/krosno/art/6137625,uwaga-wscieklizna-w-krosnie,id,t.html).

Fig. 2. Fox infected with scabies.

Source: http://www.nfws.org.uk/mange/mange_gallery.html

Another factor that impacts the size of fox population is scabies. Scabies is classified in the group of infectious diseases caused by small-size mites (*Sarcoptes scabiei*). It is a widespread parasite that attacks 104 species of domestic and wild animals across Europe, North and South Americas, Australia, Asia, and Africa (Bornestein et al., 2001). It may be the cause lying behind human scabies (Madhusudhan Bandi & Saikumar, 2013; Currie et al., 2004; Walton et al., 1999).

These small parasites are present in the host's skin tissue into which they burrow while feeding on the living tissue, tissue fluids, and epidermis (Arlian & Vyszenski-Moher, 1988, https://www.cdc.gov/dpdx/scabies/index.html).

The course of this disease depends on the condition and immune system of the animal. The most commonly observed symptoms include extensive allergic reactions, shedding, weight loss, and apathy (Little et al., 1995), (Fig. 2.). An extensive infection may lead to the death of the animal (Newman et al., 2002).

Scabies was the main cause of death in the population of foxes (particularly amongst the young specimens) monitored within the Bristol area between 1996–2007. In addition, it was demonstrated that females infected with this particular parasite had smaller litters and the puppies were in a much worse condition as compared to non-infected specimens (Sousbury et al., 2007). Death rate amongst the fox population prior to the emergence of scabies was approx. 10% per annum. After reporting the first infected fox in autumn of 1994, the death rate increased to 55% in the autumn season. Among the reported causes, scabies was the cause of 91% of fox deaths between the period of autumn 1994 and winter 1995. In addition, it was observed that the Bristol areas inhabited by fox family groupings had increased from 29.5±12.1 ha in 1990 to 209.6±127.5 ha in the winter season of 1995 (Baker et al., 2004). It was proved that, in the winter, foxes infected with scabies are less scared of people and are more frequently keen on selecting easily accessible sources of food (such as garbage) as compared to healthy specimens. The process of approaching human habitats and feeding the infected specimens may result in spreading scabies amongst humans and domestic animals (Cricondo-Sanchez, 2017).

In addition, the size of the fox population is also significantly impacted by hunters' activities. The red fox is a game animal and the hunting season in Poland lasts from June 1 to March 31. In areas where the pheasant, capercaillie or hare are reintroduced, the fox hunting season can last all year. Nevertheless, the Polish population of foxes remains high. Between 1980 and 2006, there was a continuous increase in the number of foxes in central Poland (Goszczyński et al., 2008). Despite the hunting activities, high concentrations of the species were observed in surveys conducted between 1998/1999 and 2006/2007 in the eastern and central regions of the country. Interestingly, the largest number of foxes in the smallest survey area were recorded in the Bialskie district, while the smallest number in the largest survey area was reported in the Siedlce district (Bombik et al., 2014). In western Poland, over the 5-fold higher density of this predator was recorded between 1997 and 2000 as compared to 1970 (Panek & Breziński, 2002). According to the Polish Hunting Association, the fox population in Poland was estimated at 200,000 in the 2011/2012 hunting season (www.pzlow.pl, Fig. 3). In 2013, the population was estimated at 208,200. By the spring of 2015, it had slightly decreased and was estimated at 191,000 specimens. To summarize, over a 4-fold increase in the population of this predator has been observed as compared to the years preceding the application of the rabies vaccines (Panek & Budny, 2015).

The red fox in urban areas

This particular predator accustoms itself perfectly to urban areas (Soulsbury et al., 2010; Lombardi et al., 2017) (Fig. 4). Fox concentrations in urban areas may reach quite high values (Harris & Baker, 2001; Gosselink et al., 2003). In Estonia, the presence of foxes was reported in 33 of 47 large cities. The existence of fox burrows was reported even in downtown areas. Foxes are capable of entering households, thus posing a direct threat to humans and domestic animals. Several cases of dogs and cats attacked by foxes have been reported (Plumer et al., 2014). In Switzerland, fox burrows with offspring were reported in 20 large cities (Gloor et al., 2001).

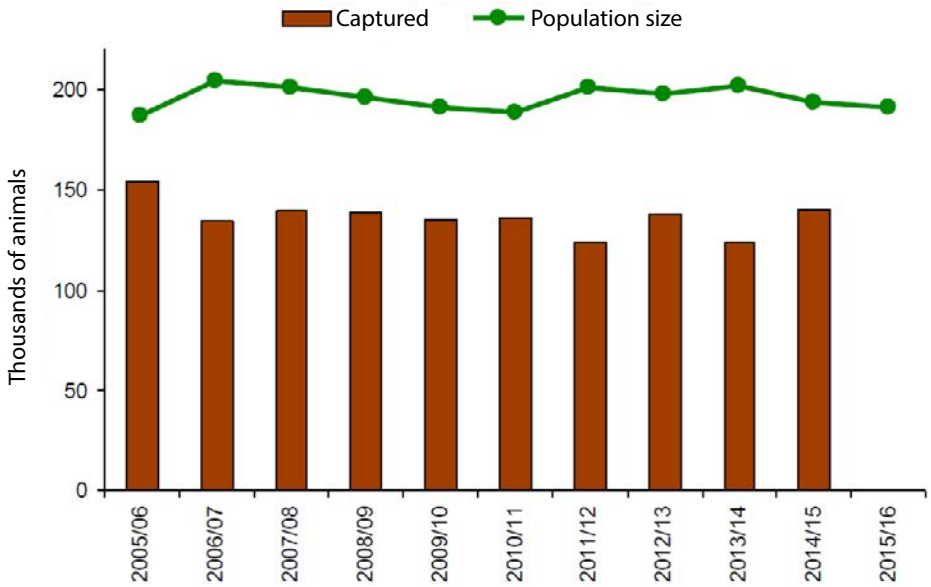

Fig. 3. Fox population in Poland

Source: www.pzlow.pl

Fig. 4. The red fox in city streets

Source: http://www.athensvoice.gr/kosmos/alepoy-neo-katoikidio-toy-londinoy

Specimens dwelling in urban areas are often spotted around dumpsters or in backyards (https://www.youtube.com/watch?v=IHeVJQPoy_w). As much as 80% of the content of the urban area fox digestive systems may comprise food of anthropological origin (Contesse et al., 2004). Animals inhabiting urban areas must cope with intensive road traffic which poses a direct life threat. Foxes can adapt their migrations to the type of crossed roads by selecting a small–traffic route and by crossing these routes at nighttime when traffic is at its lowest. Most frequently, the roads are crossed by males and the young while searching for a new territory (Baker et al., 2007). Adaptive skills, ability to use new sources of food and wide food base enable intensive expansion of the red fox to new areas, including downtowns (Bateman & Fleming, 2012).

Cyclophyllid tapeworm (*Echinococcus multilocularis*) and multilocular echinococcosis

The red fox is a host for a number of dangerous parasites. By accessing urban areas, it increases the risk of exposure to the worms that pose danger from the medical and veterinary perspective. The cyclophyllid tapeworm (*Echinoccocus multilocularis*) poses the highest risk for humans. A mature tapeworm, measuring approximately 2–5 mm in length (Fig. 5), dwells in the fox's and less frequently in the dog's and cat's intestines. The infection may be very intensive and may exceed as many as 10 000 tapeworms per specimen (Hoffer et al., 2000). Rodents are intermediate hosts of the tapeworm (https://www.cdc.gov/parasites/echinococcosis/biology.html). Currently, the *E. multilocularis* is assumed to be a global problem (Davidson et al., 2012). Tapeworms are common in numerous European countries, including Germany (Tackman et al., 1998), Slovakia (Dubinsky et al., 1999), Denmark (Saed at el., 2006), and Sweden (Osterman et al., 2011). It also extends to Asia (Giraduoux et al., 2013) and North America (Jenkins et al., 2012). It is widely spread amongst the foxes inhabiting the urban areas of Japan (Tsukada et al., 2000). In Poland, the cyclophyllid tapeworm has also been reported (Karamon et al., 2014) with the largest range of infections registered in the foxes caught mainly in the Warmińsko-Mazurskie, Podkarpackie, and Mazowieckie Voivodships (Karamon et al., 2015), (Fig. 6.). The factors providing the favorable conditions for the spread of the parasite include, first and foremost, the quantity and synanthropization of the fox (remaining in the immediate vicinity of humans). In environments contaminated with fox excrements and tapeworm eggs, infected rodents may emerge that will fall prey to domestic cats and dogs. Ultimately, these specimens will become the end hosts of the tapeworm and excrete eggs that are invasive to humans (Deplazes et al., 1999; Knapp et al., 2016). It has been proved that, in urban conditions, this parasite may close its life cycle on the basis of synanthropic species of rodents, i.e. the intermediate hosts. *E. multilocularis* cysts (larvae) have been reported in the European water vole (*Arvicola terrstis*) caught in Zurich (Hofer et al., 2000). Numerous studies confirming the presence of the *E. multilocularis* in foxes inhabiting the urban areas of many European countries, (Fisher et al., 2005; Robarded et al., 2008), show the widespread presence of this particular parasite posing potential risks for humans. Humans are threatened by contact with fox excrements and excrement–contaminated soil, e.g. in suburban gardens, parks, or forests.

The parasite causes an illness referred to as multilocular echinococcosis. The first case of the disease was described by Buhl in 1852 (Hosemann et al., 1928). Humans contract this disease by swallowing tapeworm eggs, thus becoming accidental hosts (Fig. 7). While in a human body, the larva hatches from the egg and, as it is not surrounded by any connective tissue, it quite easily spreads with blood and lymph to other organs (Czapliński & Kurnatowski, 1999). The studies conducted in Germany on a group of 120 patients with confirmed echinococcosis show that persons at risk of exposure to *E. multilocularis* include inhabitants of rural areas, dog and cat owners, persons who either consume

Fig. 5. *Echinococcus multilocularis* – adult form

Source: http://research.vet.upenn.edu/Default.aspx?TabId=7812

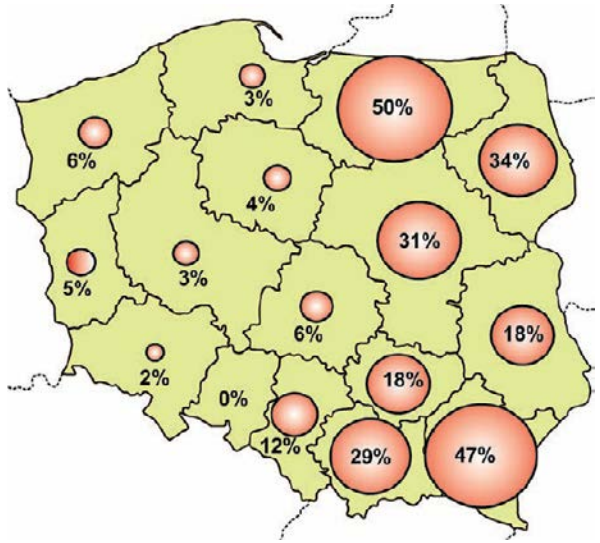

Fig. 6. Foxes infected with *E. multilocularis* between 2009–2013 in Poland

Source: Karamon J, Kochanowski M, Dąbrowska J, Różycki M, Bilska-Zając E, Sroka J, Cencek T (2015). *Echinococcus multilocularis* w Polsce – sytuacja epizootyczna u lisów wskaźnikiem ryzyka zarażenia ludzi. Życie Weterynaryjne 90(9)

unwashed fruits, vegetables, and grass or collect wood in forests, and persons with occupations related to forest areas (Kern et al., 2004). Traces of tapeworm DNA were discovered on fruits, vegetables and mushrooms originating from the Warmińsko-Mazurskie Voivodship, i.e. the area of Poland assumed to be endemic for the cyclophyllid tapeworm. The parasite's genetic material has been discovered with the use of molecular biology methods featuring sensitivity rates of above 100 eggs per tested sample. This proves the high significance of the food contaminated with eggs as a direct source of risk to humans. This is why it is important to educate communities living in areas endemic for *E. multilocularis* on means of prevention and threats resulting from failure to adhere to hygiene rules while preparing meals of fruits and vegetables that may contain tapeworm eggs (Lass et al., 2015). It is worth noting that the eggs of this particular tapeworm show extreme resistance to environmental factors. At 4 °C, they preserve the ability to remain immune to any type of intrusion for 478 days and for 240 days at -18 °C. It is not until the temperature reaches -83 °C / -196 °C that the eggs are killed within 48 / 20 hours respectively. The eggs are also immune to numerous chemical agents (Veit et al., 2009). The echinococcosis development process is similar to the development of cancer, with which the echinococcosis is often confused, and may last from 10 to 15 years. In case of non-treatment or improper treatment due to misdiagnosis, it may lead to death. Unfortunately, despite the quick diagnosis and properly selected therapy, the patient will ultimately lose his battle with the disease (Davis et al., 1986). It often happens that the symptoms are non-specific and depend on the location of the cyst in the body. Cysts are typically located in the liver, less commonly in the brain, heart or lungs. The non-specific symptoms include, inter alia, weight loss, upper and lower abdominal pain, hepatitis, apathy, ascites, swollen

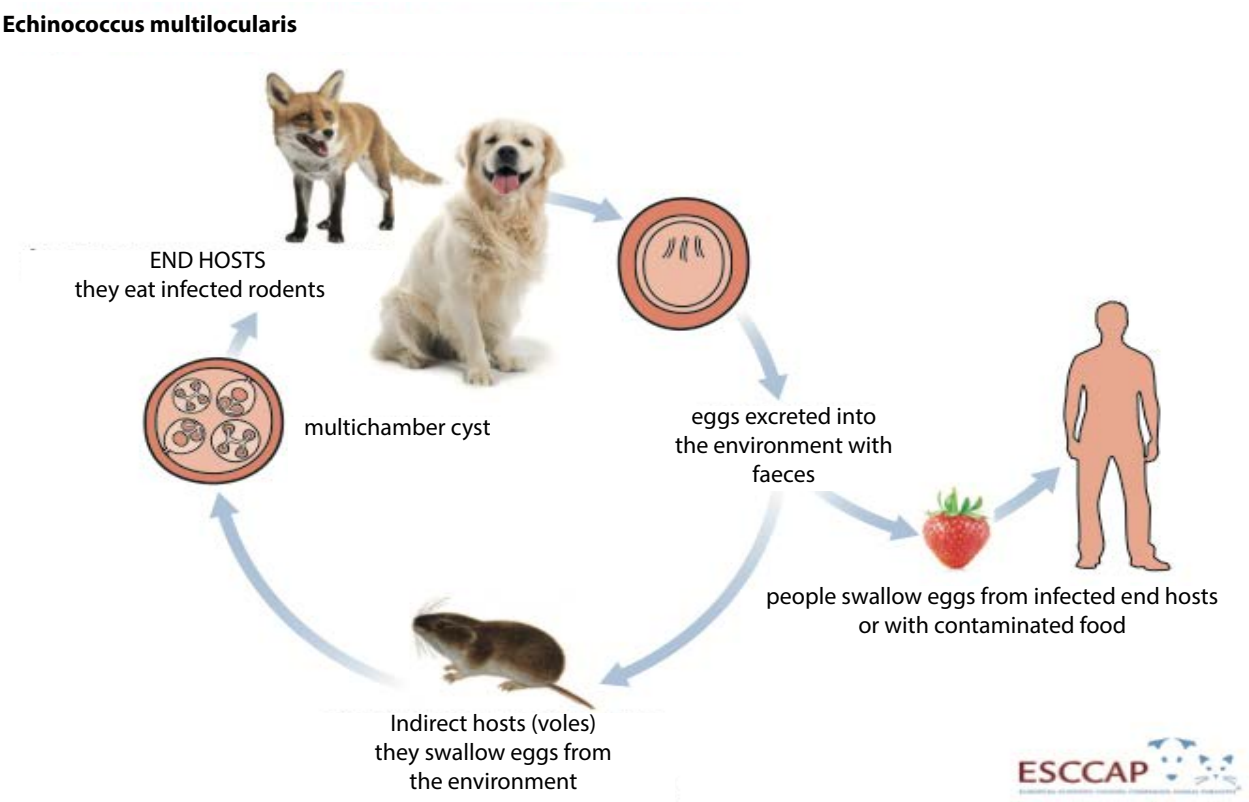

Fig. 7. The life cycle of *E. multilocularis*

Source: http://esccap.pl/wpcontent/uploads/2017/08/Cykl_rozwojowy_bablowiec_wielojamowy_Echinococcus_multilocularis.png

shanks, tachycardia (Pawłowski et al., 2001; Parfieniuk et al., 2009). The most effective method of removing the tapeworm is the surgical removal of cysts and long-term drug treatment based primarily on anti-parasitic medicine such as Albendazole and Mebendazole (Brunetti et al., 2010). The cases of multilocular echinococcosis are reported mainly in France (Pirraux et al., 2011), Germany (Romig et al., 1999), Lithuania (Sarkunas et al., 2010), and Switzerland (Schweiger et al., 2007). The first descriptions of multilocular echinococcosis patients in Poland come from 1951 and 1958 (Sowiakowski, 1955; Głuszcz & Kalczak, 1960). Between the years of 1990–2011, an increased number of multilocular echinococcosis cases was reported. The majority (57.3%) of the cases were reported in the Warmińsko-Mazurskie Voivodship believed to be an endemic region for *E. multilocularis*. Research conducted for over 20 years has included 121 cases of echinococcosis registered by the

Chief Sanitary Inspectorate. It included the ELISA and Western Blot tests that enabled the discovery of specific antibodies to the parasite in the patient's serum. In several cases, molecular biology methods (polymerase chain reaction; PCR) were also applied to discover the parasite's genetic material (Nahorski et al., 2013).

Summary

The red fox is a predator well–accustomed to dwell in all types of environments from forests to big city downtowns. Despite several significant factors that limit its quantities, an increase in this predator's population has been observed across a number of countries. This particular species enrich the urban fauna by becoming its permanent element. However, the presence of the fox in the vicinity of humans brings along a threat from the parasites for which the predator serves as the host. The most dangerous is the cyclophyllid tapeworm (*E. multilocularis*) causing multilocular echinococcosis – a deadly disease for humans. Monitoring the fox population and continuing the research on *E. multilocularis* may help take actions to prevent the infection process.

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