In the wake of the pandemic

A survey of companion animal owners' knowledge of One Health

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Independent Project • 30 credits
Swedish University of Agricultural Sciences, SLU
Faculty of Veterinary Medicine and Animal Science
Veterinary Medicine Programme

Uppsala 2023

In the wake of the pandemic – A survey of companion animal owners' knowledge of One Health

I pandemins spår – en undersökning om smådjursägares kunskaper om One Health

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Credits:	30 credits
Level:	Second cycle, A2E
Course title:	Independent Project in Veterinary Medicine
Course code:	EX1003
Programme/education:	Veterinary Medicine Programme
Course coordinating dept:	Department of Clinical Sciences
Place of publication:	Uppsala
Year of publication:	2023

Keywords:	one health, zoonoses, antimicrobial resistance, companion animals, pets, online survey

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Abstract

One Health is a concept that recognises the link between human, animal, and environmental health, and that to achieve optimal health an interdisciplinary approach is needed to tackle the major threats to global health. Two important areas within One Health are antibiotic resistance and zoonoses. The aim of this study was to investigate pet owners' knowledge about One Health for further use when designing guidelines and knowledge-raising measures. For this study, a survey was designed and distributed to pet owners who were visiting the participating clinics in Sweden to investigate their knowledge of zoonoses and antibiotic resistance. The results of this study show that many pet owners have relatively good knowledge of antibiotic treatment and its risks, and to some extent that antibiotic-resistant bacteria can spread between animals and humans. However, they have less knowledge of zoonotic infections such as rabies and echinococcosis. The majority of pet owners know how rabies is spread and know that it is important to quickly seek medical attention if you are bitten by an unknown dog abroad, but at the same time the majority do not know that seemingly healthy animals can carry the infection or that Sweden is free from rabies. These results can be useful for veterinarians in their daily interactions with pet owners during consultation.

Keywords: one health, zoonoses, antimicrobial resistance, companion animals, pets, online survey

Sammanfattning

One Health är ett koncept som bygger på att människans, djurens och naturens hälsa hänger ihop. Interdisciplinärt samarbete krävs för att tackla de stora hoten mot den globala hälsan. Två viktiga områden inom One Health är antibiotikaresistens och zoonoser. Syftet med denna studie var att undersöka djurägares kunskap om One Health för vidare användning vid utformning av riktlinjer och kunskapshöjande åtgärder. Resultaten i denna studie visar att många djurägare har relativt god kunskap om antibiotikabehandling och dess risker, och till viss grad också om att antibiotikaresistenta bakterier kan spridas mellan djur och människor. Däremot har de mindre kännedom om zoonotiska infektioner såsom rabies och rävens dvärgbandmask. Majoriteten av djurägarna känner till hur rabies sprids och känner till att det är viktigt att snabbt söka vård om man blir biten av en okänd hund utomlands, men samtidigt känner majoriteten inte till att till synes friska djur kan bära på smittan eller att Sverige är fritt från rabies. Väldigt få kände till begreppet One Health. Resultaten kan vara användbara för veterinärer i deras dagliga interaktion med djurägare som kommer för konsultation.

Nyckelord: one health, zoonoser, antimikrobiell resistens, sällskapsdjur, husdjur, online-undersökning

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Abbreviations

AMR	Antimicrobial resistance
CDC	Centers for Disease Control and Prevention
ECDC	European Center for Disease Control
FAO	Food and Agricultural Organization
MERS	Middle Eastern Respiratory Syndrome
OHHLEP	One Health High-Level Expert Panel
OIE	Office International des Epizooties, now WOAH
SARS	Severe Acute Respiratory Syndrome
UNEP	United Nations Environmental Program
WHO	World Health Organisation
WOAH	World Organization for Animal Health, former OIE
HIV	Human Immunodeficiency Virus
AIDS	Acquired Immunodeficiency Syndrome
STRAMA	Swedish strategic programme against antibiotic resistance

1. Introduction

The One Health approach recognizes the interconnectedness of human, animal, and environmental health and the importance of a collaborative, interdisciplinary approach to addressing health threats (OHHLEP *et al.* 2022). In the 21st century, various health threats have emerged, including zoonotic and (re)emerging infectious diseases, antimicrobial resistance, climate change, and environmental sustainability. The COVID-19 pandemic, caused by a zoonotic virus, has highlighted the need for a comprehensive strategy and transdisciplinary collaboration across all aspects of health for people, animals and the environment (Bronzwaer *et al.* 2022). The pandemic, caused by the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), has once again highlighted the interdependence between humans, animals, and the environment. This situation highlights the importance of adopting a One Health approach, which recognizes the interconnectedness of these systems. While the concept of One Health has been discussed for years, there is now a growing interest in putting this approach into practice (OHHLEP *et al.* 2022). However, it is not only in the area of infectious diseases a One Health approach can be applied. It also emphasizes the potential for physicians and veterinarians to learn from each other through a comparative approach to disease and health.

The importance of incorporating a One Health approach as a part of medical and veterinary education is well recognized. It is established in the veterinary field and incorporated in veterinary education, with the medical field being a few steps behind (Mackenzie & Jeggo 2019).

This study focuses on what small animal owners know about One Health, and how it can be used in the dialogue with their veterinarian.

2. Literature review

2.1 One Health

2.1.1 History

The term One Health was first used in 2003-2004 and is associated with the emergence of severe acute respiratory disease (SARS) followed by the spread of highly pathogenic avian influenza, and with the One World, One Health symposium organised by the Wildlife Conservation Society and hosted by Rockefeller University in September 2004 in New York (Cook *et al.* 2004). The symposium focused on the current and potential movements of diseases among humans, domestic animals, and wildlife populations. Using case studies on Ebola, avian influenza, and chronic wasting disease, a list of 12 recommendations was developed known as the "Manhattan Principles", establishing a more holistic approach for responding to threats to life on Earth through disease prevention, surveillance, and control. The symposium recognised the link between animal and human health and highlighted the need to include wildlife health as an important part of global disease prevention (Cook *et al.* 2004; Atlas 2012; Mackenzie *et al.* 2014; Mackenzie & Jeggo 2019).

The One Health concept has been associated with the physician Rudolf Virchow, who acknowledged the relationship between animal and human medicine. He is known to have coined the term zoonosis to describe pathogens transmitted between animals and humans as a result of his studies in livestock parasites. Physician Sir William Osler studied under Virchow and established the field of veterinary pathology in North America. He is often credited to have coined the term "One Medicine", but the term was first introduced by Dr Calvin Schwabe in his book Veterinary Medicine and Human Health. (Schwabe 1984; Conrad *et al.* 2009; Kaplan & Scott 2011; Mackenzie *et al.* 2014)

"One medicine" later became "One world, one health" and eventually One Health (Mackenzie & Jeggo 2019).

> "This terminology change occurred during the first decade of the 21st century. "One Health" is the evolution of the earlier used term "One Medicine," which historically implied the crossing over between veterinarians and physicians. One Health recognizes that humans do not exist in isolation, but are a part of a larger whole, a living ecosystem, and that activities of each member affect the others. Thus, One Health considers health as a whole: that of humans, animals, and the environment they exist on." (Kaplan & Scott 2011)

2.1.2 Definition

The One Health concept has been associated with many different interpretations and definitions (Mackenzie & Jeggo 2019). The most commonly used definition was *"*One Health is a collaborative, multisectoral, and trans-disciplinary approach - working at local, regional, national, and global levels - to achieve optimal health (and well-being) outcomes recognising the interconnections between people, animals, plants and their shared environment.*"* This definition was shared by Centre for Disease Control and One Health Commission (Mackenzie & Jeggo 2019; One Health Commission n.d.)

The One Health High-Level Expert Panel (OHHLEP) was founded by the Food and Agricultural Organization (FAO), the World Organization for Animal Health (OIE), the United Nations Environmental Program (UNEP) and the World Health Organization (WHO) in 2021 as a result of a proposal made by the French and German Foreign Affairs ministers at the 2020 Peace Forum in Paris. "The creation of OHHLEP represents a recognition at the highest level of the urgency and complexities surrounding One Health and the intent to take this concept into policies and concrete actions". They developed a new definition:

> "One Health is an integrated, unifying approach that aims to sustainably balance and optimise the health of people, animals, and ecosystems. It recognizes the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent. The approach mobilizes multiple sectors, disciplines, and communities at varying levels of society to work together to foster well-being and tackle threats to health and ecosystems, while addressing the collective need for healthy food, water, energy, and air, taking action on climate change and contributing to sustainable development."

An integral part of the definition is implementation, which is emphasised by the four Cs: Communication, Coordination, Collaboration, and Capacity building. The aim of the new definition developed by OHHLEP was to reach a consensus around a definition as a solid foundation of the concept and that included all aspects of One Health (OHHLEP *et al.* 2022).

2.2 Zoonosis

2.2.1 Definition

Zoonosis is any infection or disease that can be transmitted naturally between animals and humans or vice versa. Zoonotic pathogens can be bacterial, viral, parasitic, mycotic, or unconventional (prions) and can spread to humans through

direct contact or indirectly through food, water, environment or vectors (Chomel 2014; WHO 2020; ECDC n.d.).

It is estimated that about 60% of human infections are zoonotic and that 75% of emerging diseases are zoonotic (Taylor *et al.* 2001). In addition, about 80% of animal pathogens are "multi-host", meaning they infect various animal species, occasionally infecting humans (United Nations Environment Programme and International Livestock Research Institute 2020).

2.2.2 Routes of transmission

The transmission of infectious agents between animals and humans can take place through:

- Direct contact with infected animals or humans' body fluids, such as urine, blood, faeces etc. It includes petting animals, bites, and scratches.
- Indirect contact with objects and environment contaminated with these infectious agents. Including pet habitats, fish tanks, barns, plants, soil etc.
- Vectors: such as ticks, mosquitos, or fleas.
- Food: Through the consumption of contaminated food, such as undercooked meat or eggs, unpasteurised milk, raw fruits and vegetables.
- Water: Drinking or coming in contact with contaminated water.

(CDC 2021; National Veterinary Institute [SVA] n.d.d)

2.2.3 Classification

Zoonotic infectious diseases can be classified according to their etiological agent: bacterial, viral, parasitic, mycotic, and unconventional (prions). They can also be classified based on the zoonosis maintenance cycle, which categorizes them into four groups (Chomel 2014):

- Orthozoonoses are diseases transmitted directly through direct contact or mechanical vectors; an example is rabies.
- Cyclozoonoses require more than one vertebrate species for development; echinococcosis is an example of this.

- Pherozoonoses, also known as metazoonoses, require invertebrate vectors such as ticks and mosquitos for their transmission. An example is Lyme disease which is transmitted by ticks.

- Saprozoonoses require a vertebrate host and an environmental reservoir such as food, plants, and soil. An example is listeriosis.

2.2.4 Zoonoses of importance in cats and dogs

The number of zoonotic infections that can be transmitted from companion animals to humans is low (do Vale *et al.* 2021). Nevertheless, there is potential for the transmission of infectious pathogens from pets to humans. Zoonotic pathogens included in the project survey are described below.

Rabies

Rabies is caused by a virus of the lyssavirus genus. It affects all mammals. It is a severe disease; once an infected individual develops symptoms, it is almost always fatal. Circa 99% of rabies cases in humans are transmitted by dogs (Fooks *et al.* 2017; WHO 2021). The disease is distributed worldwide. However, several countries are free of rabies, among them are Sweden and other countries in Western Europe such as Germany, Denmark and The Netherlands. (CDC 2022b; WHO n.d.d).

It is estimated that rabies causes about 60 000 human deaths annually, but this number is most likely underestimated. Circa 95% of deaths occur in Africa and Asia, although rabies is present in all continents. It is considered to be an important threat to public health. (MacLachlan & Dubovi 2017; WHO 2021)

Rabies virus is transmitted mainly through direct contact with saliva from infected animals, through broken skin, mucous membranes in the eyes, mouth or nose. The majority of cases are caused by dog bites. Other transmission routes, although rare, include aerosol routes and organ transplantations. (Fooks *et al.* 2017; WHO 2021)

In 2015 the World Health Organisation (WHO), World Organisation for Animal Health (WOAH, formerly known as OIE), Food and Agricultural Organization of the United Nations (FAO), and the Global Alliance for Rabies Control set a goal to eliminate rabies by 2030 (WHO 2018).

Sweden has been free from rabies since 1886. In the past 50 years, two people have been hospitalised in Sweden due to rabies and succumbed to it. In 1974 a man fell ill after a visit to India, and in 2000 a woman fell ill after a visit to Thailand. Both

are suspected of having been infected by rabid dogs. Because Sweden is free from classical rabies, the risk of acquiring the disease from Swedish animals is negligible. However, there has been an increasing problem with illegal importation of pets, primarily dogs, from countries where rabies is endemic which poses a risk to the rabies-free status of Sweden. (Höjer *et al.* 2001; National Veterinary Institute [SVA] 2021; Folkhälsomyndigheten n.d.c).

Echinococcosis

Echinococcus are cestode parasites that currently consist of eight recognised species. All species in the genus are suspected to be zoonotic, but *E. granulosus sensu lato* and *E. multilocularis* are of significant public health concern, causing cystic echinococcosis (CE) and alveolar echinococcosis (AE), respectively, in humans (Woolsey & Miller 2021).

Echinococcosis is mainly transmitted faecal-orally. Humans can acquire it through consumption of contaminated food and water or contact with the environment which has been contaminated with *Echinococcus* eggs. Dog ownership is considered a risk factor for both, since *E. multilocularis* and *E. granulosus* s.l., parasite eggs can stick to the dog's coat and unintentionally infect humans through direct contact (EFSA BIOHAZ Panel [EFSA Panel on Biological Hazards] *et al.* 2018; Woolsey & Miller 2021).

E. multilocularis was first detected in Sweden in a fox in 2010 in Västra Götaland county as part of an active monitoring program which was initiated in response to findings of *E. multilocularis* in foxes in Denmark. During that time, *E. multilocularis* was also detected in two other counties: Södermanland and Dalarna (National Veterinary Institute [SVA] 2021). A new monitoring program has been initiated to obtain current information about the prevalence and spread of *E. multilocularis* in Sweden which was initiated in 2021 and is expected to continue until 2024 (National Veterinary Institute [SVA] 2023).

On the other hand, *E. granulosus sensu latu* used to be relatively common in northern Scandinavia, particularly among reindeers, but it has not been detected in reindeers since the late 1990s (National Veterinary Institute [SVA] 2021).

Human infection with echinococcosis has been a notifiable disease since 2004 in Sweden. Echinococcosis in humans is a rare but potentially fatal disease.

Cystic echinococcosis, caused by *E. granulosus*, is typically found in people originating from countries where the parasite is endemic. Infection is often asymptomatic until hydatid cysts, containing larval parasites, grow large enough to cause discomfort, pain, nausea, and vomiting (CDC 2019a). As the cysts develop

slowly, it can take many years before symptoms appear. These are usually caused by the pressure that the cyst exerts on surrounding tissues, for example gallstone-like symptoms if the cyst is located in the liver (Folkhälsomyndigheten 2019a). The cysts are typically well-defined, but there is a risk of spontaneous rupture that lead to anaphylactic reactions, and in some cases even death, due to the release of cystic fluid (CDC 2019a; Folkhälsomyndigheten 2019a). In Sweden, around 15-30 human cases are reported annually (Folkhälsomyndigheten 2019b; a; National Veterinary Institute [SVA] 2021).

Echinococcus multilocularis causes alveolar echinococcosis in humans. It manifests as tumour-like growths in the liver, which can spread to other organs such as the brain and lungs. In humans, the larval stage of *E. multilocularis* does not develop into fully formed cysts but forms vesicles that invade and destroy surrounding tissues, leading to discomfort or pain, weight loss, and a general feeling of illness (malaise) (CDC 2019a). In 2012, the first cases of alveolar echinococcosis were diagnosed in Sweden, but these two people were considered to have been infected abroad. Between 2013 and 2015, no human cases were reported; since 2016, up to four cases have been reported annually (National Veterinary Institute [SVA] 2021).

Leptospirosis

Leptospira is a spirochaetal bacterium that occurs worldwide. It affects all mammals, with rodents being the first recognised carriers of leptospirosis. The brown rat is among the most important sources of human infection. (Haake & Levett 2015; WHO n.d.c)

Humans become infected through direct contact with urine from infected animals or through contact with contaminated soil or water. The bacteria enter the body through wounds and mucous membranes such as the eyes, mouth and nose. Symptoms in humans and dogs vary from asymptomatic to severe infection and death. Severe infection is characterised by multiple organ dysfunction, including liver, kidneys, lungs and brain (Geisen *et al.* 2007; Haake & Levett 2015; Griebsch *et al.* 2022; WHO n.d.c).

Like humans, dogs become infected through direct contact with urine or indirectly through contact with contaminated environments like soil and water. The transmission can occur through intact mucus membranes, abrasions, or ingestion of infected tissue. Venereal and placental transmission have been described (Geisen *et al.* 2007; Griebsch *et al.* 2022).

Leptospirosis is a relatively uncommon disease in Europe. The majority of human cases occur during the summer. In the latest surveillance report, from 2020, 565

confirmed cases of leptospirosis were reported to the European Centre for Disease Prevention and Control (ECDC), of which France, Germany, the Netherlands and Portugal accounted for the majority (66%) of cases (ECDC 2022a).

Leptospirosis mainly occurs in tropical and subtropical regions and is relatively rare in Sweden. The majority of the reported human cases in Sweden are infected abroad (Levett 2001; Haake & Levett 2015; Folkhälsomyndigheten n.d.b). Analyses of serum samples from Swedish dogs sent to the National Veterinary Institute has shown that antibodies to leptospiral bacteria are present in the Swedish dog population. Clinical cases in dogs have also been confirmed by laboratory analysis (paired titre samples, and/or PCR analyses). The true seroprevalence in Swedish dogs is unknown, as is the exact number of clinical cases (Windahl, U., National Veterinary Institute, pers. com., 2022-12-08). In 2019 seven human cases were reported, two of which were reported to have been infected in Sweden (Folkhälsomyndigheten n.d.a).

Salmonellosis

Salmonella is a bacterium of the Enterobacteriaceae family. It is transmitted by faecal-oral route. Humans are infected by contaminated food, contact with infected animals and people, and contaminated environment. It is among the most important bacterial zoonoses and was the second most reported foodborne infection in humans in the EU in 2021. (European Food Safety Authority & European Centre for Disease Prevention and Control 2021; National Veterinary Institute [SVA] 2021; Moxley 2022)

In Sweden, circa 2000-3000 cases of human salmonellosis are reported annually to the Public Health Agency of Sweden. The majority (3/4) are infected abroad. The most common cause of salmonella outbreaks nationally is contaminated, imported, food. (National Veterinary Institute [SVA] 2021; Folkhälsomyndigheten n.d.d)

Salmonella infection in pets may cause symptoms such as diarrhoea, vomiting and fever, but is often asymptomatic. Infected dogs can shed salmonella in their faeces for six weeks or more after exposure (Sanchez *et al.* 2002). There are various salmonella sources in dogs, including coprophagia, consumption of infected rodents and contaminated foods.

Sources of salmonella in cats depend on whether they are indoor or outdoor cats, as indoor cats' likely exposure is contaminated food, while outdoor cats often have been exposed to birds. (Finley *et al.* 2006; Jacob & Lorber 2015). Salmonellosis in passerines (songbirds/ garden birds) is often highly seasonal and appears during late winter and early spring and is linked to garden bird feeders. The birds often gather in large flocks near bird feeders. Salmonella-infected birds become easy prey for

domestic cats. The birds also contaminate the area around feeders with faecal material. Infected birds may transmit the infection to humans through handling or indirectly from exposure to cats (Tizard 2004; Giovannini *et al.* 2013). This has also been observed in Sweden (Söderlund *et al.* 2019).

Leishmaniasis

Leishmaniasis is caused by an intracellular parasite. It is a zoonotic vector-borne disease which is transmitted between mammalian hosts by sandflies. Different species of *Leishmania* cause different clinical presentations. Visceral leishmaniasis is the most serious form of leishmaniasis in humans. If left untreated, it is often fatal. The disease is characterised by fever and emaciation. The liver and spleen can become enlarged, and the patient can develop anaemia. Cutaneous leishmaniasis is not lethal but causes ulcers that usually heal over 3-18 months (Burza *et al.* 2018). Visceral leishmaniasis is endemic in more than 60 countries. However, in 2015 more than 90% of cases were reported from Brazil, Ethiopia, India, Kenya, Somalia, South Sudan, and Sudan. Previously the majority of cases were reported from India, Nepal and Bangladesh, which have seen a steady decline as a result of elimination efforts. In the case of cutaneous leishmaniasis, 90% of cases occur in Afghanistan, Pakistan, Syria, Saudi Arabia, Algeria, Iran, Brazil, and Peru (Burza *et al.* 2018).

Domestic dogs is the primary reservoir of *Leishmania infantum*, although other mammalian reservoirs exist. Surveys from southwestern Europe showed that approximately 10% of dogs carried *L. infantum* antibodies, ranging from 0% to 18%. Meanwhile, other studies utilizing PCR tests showed that up to 80% of dogs in endemic regions are infected. A cohort study conducted in Italy showed that infected dogs developed symptomatic disease over a 2-year period (Burza *et al.* 2018).

Clinical manifestation of canine leishmaniasis include weight loss, weakness, skin lesions, epistaxis, polyuria and polydipsia (Meléndez-Lazo *et al.* 2018; Baneth & Solano-Gallego 2022). Ocular or periocular lesions such as uveitis and kerato-conjunctivitis are common (Baneth & Solano-Gallego 2022). Skin lesions are also prevalent in dogs with leishmaniasis, with the most common being exfoliative dermatitis. This condition can be localized or generalized over different parts of the body such as the face, ears, tail, and limbs (Baneth & Solano-Gallego 2022).

Leishmaniasis is endemic in areas of Europe where the vector is present. This includes countries such as France, Greece, Italy, Portugal and Spain. Sandflies have not been reported in Scandinavia. Movements of humans and dogs are important factors of emergence in non-endemic countries (ECDC 2022b).

Leishmaniasis is not endemic in Sweden, but in recent years it has been diagnosed in several dogs in Sweden imported from southern European countries such as Spain, Greece, Portugal and France (National Veterinary Institute [SVA] n.d.b).

2.3 Antibiotic resistance

2.3.1 Definition

"Antimicrobial resistance (AMR) occurs when bacteria, viruses, fungi and parasites no longer respond to antimicrobial agents. As a result of drug resistance, antibiotics and other antimicrobial agents become ineffective and infections become difficult or impossible to treat, increasing the risk of disease spread, severe illness and death" (FAO *et al*. 2022). Antibiotic resistance occurs when bacteria no longer responds to antibiotics (WHO n.d.a). Antimicrobial resistance and antibiotic resistance are often used interchangeably.

2.3.2 A global health challenge

Antibiotic resistance is a rapidly growing global challenge that threatens our ability to successfully treat infections rendering them potentially fatal (McEwen & Collignon 2018; Eriksen *et al.* 2021). It is estimated that 10 million people are expected to die annually by 2050 due to antibiotic resistance if action is not taken, with a cumulative cost to the global economy of 100 trillion USD. According to these calculations, the death toll will be one person every three seconds (O'Neill 2016). This led the UN General Assembly in 2016 to conclude that antimicrobial resistance is one of the biggest global threats to human health (Eriksen *et al.* 2021). The threat is most acute for antibiotics, but antiviral, antifungal and antiparasitic agents are also threatened. Antibiotic use and overuse are essential drivers of resistance, and others include the spread of resistant bacteria and their genes through poor infection control, environmental contamination, and geographic movement of infected people and animals (McEwen & Collignon 2018).

The benefits of antibiotics are many. They have helped to extend the expected life span and played a vital role in significantly advancing the medical field. The use of antibiotics have successfully helped to treat and prevent infections in people receiving chemotherapy, suffering from chronic diseases or having complex surgeries (Ventola 2015).

2.3.3 Situation in Sweden

In 1986 Sweden banned the use of antibiotics as growth promotion in livestock, becoming the first country in the world to legislate the use of antibiotics. In 1995 the Swedish strategic programme against antibiotic resistance (Strama) was created as a result of an increase in penicillin-resistant pneumococci among children (Mölstad *et al.* 2017). These are two of several important events, which put Sweden at the forefront of the fight against antibiotic resistance (Folkhälsomyndigheten 2014; Mölstad *et al.* 2017; Wierup *et al.* 2021).

The Public Health Agency of Sweden and the National Veterinary Institute publish Swedres-Svarm annually, a report on antibiotic sales and resistance in human and veterinary medicine in Sweden. In the latest report from 2021 the total sales of antibiotics for humans decreased by 2.9% from the previous year, which is part of a continuous downward trend. Since the peak of antibiotic prescription in 1992, sales of antibiotics in outpatient care have decreased by 59%. The largest decrease is seen among children aged 0-4 years (Swedres - Svarm 2021). In the year 2021 the national target of 250 prescriptions per 1000 inhabitants set by Strama was reached, with in total 230 prescriptions per 1000 inhabitants (Swedres - Svarm 2021; Strama n.d.b).

A decrease is also seen in veterinary medicine measured in population corrected unit (PCU), where the overall sales decreased with 70% from the beginning of the 1980s to 2021. This decrease is due to the ban of antibiotics for growth promotion and a gradual decrease in antibiotic sales and group medication (Swedres - Svarm 2021).

From a global standpoint, Sweden has a very favourable resistance situation. The overall use of antibiotics is also exceptionally low, both in terms of quantity and quality. Since the mid-1990s, there has been a decline in the total use of antibiotics, which coincides with the inception and early years of Strama's activity (Folkhälsomyndigheten 2014). Sweden is actively involved in international efforts to address antibiotic resistance through partnerships with other countries, the EU, and the WHO. By participating, Sweden stays updated and prepared for new resistance variants, and learns from preventive measures in other countries. The export of Swedish expertise in this field is viewed as a way of shaping the evolution of antibiotic resistance on a global scale (Folkhälsomyndigheten 2014).

2.3.4 Resistance mechanisms

Bacteria acquire resistance in many ways. Resistance can be transferred among different species of bacteria through horizontal gene transfer. Genes can also be

received from plasmids, transposons, naked DNA or bacteriophages. Resistance can also occur spontaneously through mutation or natural selection (Levy & Marshall 2004; Ventola 2015).

Long-term use of antibiotics selects for bacteria that are resistant to more than one group of antibiotics. This was observed after prolonged use for urinary tract infections and acne. This was also observed in animals, where multidrug-resistant strains developed as a result of antibiotic use for growth promotion (Levy & Marshall 2004).

In many countries, antibiotics are unregulated and available without a prescription, resulting in cheap and easily accessible antibiotics which promote overuse. Another factor that promotes antibiotic resistance is inappropriate prescription. Sub-therapeutic antibiotic concentrations can promote antibiotic resistance through genetic changes, such as alteration in gene expression, horizontal gene transfer (HGT) and mutagenesis (Ventola 2015).

Antibiotics are still used in livestock for growth promotion in both the developed and the developing world. Antibiotics are administered to healthy animals in low doses for prolonged periods, favouring selection for resistant bacteria (Ventola 2015; Collignon & McEwen 2019). It is estimated that up to 90% of the antibiotics consumed by livestock is excreted into the environment and contaminates surface runoff, groundwater, and fertilisers. It also affects humans as antibiotic-resistant bacteria can be transmitted through meat products (Ventola 2015).

A challenge to combating resistance is the availability of new antibiotics. The development of new antibiotics has halted due to economic obstacles. As antibiotics are used for short periods of time and are often curative, they are not as profitable as medications used to treat chronic conditions such as diabetes, asthma, and psychiatric disorders, hence the lack of investment in the antimicrobial field (Ventola 2015).

2.3.5 Methicillin-resistant *Staphylococcus aureus*

Staphylococcus aureus is a gram-positive bacterium belonging to the family *Staphylococcaceae. S. aureus* was among the first described pathogens and is one of the leading causes of human hospital and community-acquired infections (Weese 2010; Lakhundi & Zhang 2018).

Methicillin-resistant *S. aureus* (MRSA) was identified in 1960, shortly after the antibiotic methicillin was developed. MRSA are resistant to a group of antibiotics known as beta-lactams. Infections with methicillin-resistant *S. aureus* are associated with higher mortality rates, extended hospital stays, and higher

healthcare costs than methicillin-susceptible strains in humans (Lakhundi & Zhang 2018).

MRSA also occurs in animals, including livestock and companion animals (Weese & van Duijkeren 2010; Pomba *et al.* 2017). Studies have found that MRSA strains detected in pets are identical to those found in humans in close contact with these animals. Specifically, the MRSA strains in pets are predominantly human strains, suggesting that MRSA transmission can occur between humans and animals, with humans likely serving as the primary source of MRSA in pets (Weese & van Duijkeren 2010).

In dogs, cats and horses, MRSA has been isolated from skin and soft tissue infections (Socialstyrelsen 2011; Pomba *et al.* 2017). In Sweden, the first case of MRSA in animals was detected in dogs in 2006, and in 2008 MRSA became a notifiable disease in pets. In humans, it has been notifiable since 2000, in accordance with the Communicable Disease Act (Socialstyrelsen 2011). The occurrence of MRSA in Sweden is still low, limiting the spread from humans to animals or animals to humans (National Veterinary Institute [SVA] 2021).

2.4 Pet owner surveys

A handful of studies that investigate pet owners' knowledge of zoonotic infections or antimicrobial resistance have been included in this review, all with different approaches and focus areas. The studies conducted in various countries highlight the limited awareness of zoonotic infections and preventative measures among pet owners.

Stull *et al.* (2012) created two paper surveys, for pet and non-pet owners, and distributed them in two general practice physician offices in Ontario, Canada. The aim was to investigate the general public's knowledge and attitudes related to pet ownership and animal contact, and to determine if households with people with high risk of disease differed in knowledge and attitudes from the rest of the population. They found that the general publics' knowledge of zoonotic diseases is limited, with no difference between households with and without people with increased risk of infection. In their study they highlighted that animal contact did not only occur in households with pets, and that many individuals come into contact with pets outside of the household such as petting zoos and animal parks.

An online survey was conducted across five European countries to evaluate reported infection and transmission risks of dogs and cats and assess if the

deworming practices reported by pet owners complied with recommended deworming practices (McNamara *et al.* 2018).

Similar studies were conducted in Qatar (Alho *et al.* 2018) and Portugal (Pereira *et al.* 2016), which focused on pet owners knowledge of zoonotic parasites and deworming practices.

Another study was conducted in Portugal to investigate pet owners' knowledge of zoonotic diseases and pet-related practices, such as sleeping in the same bed as their pets, and highlighted the importance of combating zoonoses through education (do Vale *et al.* 2021). A similar study was conducted in the UK (Sum & Mateus 2022).

Hopman *et al.* (2018), Smith *et al.* (2018) and Scarborough *et al.* (2021) investigated AMR and pet owner knowledge about their perception of AMR. Smith (*et al.* 2018) and Hopman (*et al.* 2018) conducted interviews with both vets and pet owners to better understand their perceptions of antimicrobial stewardship. Similarly, Scarborough *et al.* (2021) conducted online surveys to investigate pet owners' opinions, expectations and preferences with respect to veterinary consul-§tations and antimicrobial use, and to assess their knowledge about antimicrobial use and the risks associated with it.

Another study conducted in the US investigated if pet owners' sociodemographic background affects their perception of zoonotic disease transmission, specifically Covid-19 as well as their view on veterinarians and physicians as sources for zoonoses information (Powell *et al.* 2022).

Two Msc thesis studies were conducted in Sweden. Hirvonen (2011) investigated how often pet owners travelled with their dogs abroad and their knowledge of zoonotic diseases they may encounter while travelling outside Sweden. Wallin (2003) studied which zoonotic infections physicians and veterinarians considered important to inform immunocompromised people about, and investigated how this information was conveyed to patients and pet owners.

Immunocompromised people, which include children, pregnant women, elderly and those with immunocompromising conditions are at higher risk of infection. In the study conducted by Stull *et al.* (2012) participants were given a list of 11 infectious pathogens and asked to identify which of those had zoonotic potential. The results showed that there was no difference in knowledge of zoonotic diseases between housholds with or without high-risk individuals (immunocompromised or by age). There was however a small difference between pet and non-pet owning households, in which pet owning households more often correctly classified infectious agents as zoonotic.

Overall, these studies collectively emphasize the importance for increased education and awareness among pet owners regarding zoonotic diseases, transmission pathways, and preventive measures. The studies recognized veterinarians as trusted sources of information and highlighted the importance of collaboration between physicians and veterinarians in managing zoonoses and promoting a One Health approach.

2.5 Survey designs/ data collection method

There are various different ways to collect data, and new formats are created as technology develops. These different survey designs have their strengths and weaknesses, which will be further elaborated on in the discussion. They vary regarding distribution method, how confidential they are, how much feedback they allow and what control over data collection they allow (Couper *et al.* 2011; SCB 2016). The different survey designs can be used on their own or combined in what is called a mixed mode. They can be combined in many different ways, for example, an online survey can be followed by a telephone interview (SCB 2016).

Interviews can be conducted over the phone or in person. In-person interviews usually occur in a neutral space. During the interview, the interviewer asks the respondents questions and the responses are recorded/logged. Interviews enable complex questions as the interviewer has the ability to clarify questions and adjust the course of the interview based on the answers they receive (SCB 2016).

There are two types of surveys, online and paper surveys. Paper surveys can be distributed through mail or in-person to potential participants. Respondents fill out the paper survey and send it back via mail or in person, depending on the distribution method. This is in comparison to an online survey, where responses are collected in an online database (SCB 2016).

3. Materials and method

3.1 Literature review

A literature search was conducted through this course, using several databases such as the National Library of Medicines´ PubMed and Web of Science for the terms “One Health”, “One Medicine”, “pets”, “companion animals”, ”antimicrobial resistance”, “antibiotic resistance”, “MRSA”, and “zoonoses”. Articles were selected based on their title and abstract. Articles were also found through searches for renowned authors in the fields of AMR and zoonotic diseases. Review articles have been used as sources to convey background information. Additional articles were found using the bibliographies of selected articles and similar articles list.

3.2 Survey

The study is based on a two-part online survey (Appendix 1 and 2) conducted on Netigate (https://www.netigate.net), directed to cat and dog owners. Individual clinics and educational/medical boards of companies, Anicura and Evidensia, were contacted and offered to participate in the study. Veterinary clinics to participate, were selected conveniently. The aim was to collaborate with at least ten clinics across Sweden to assess the knowledge of the average Swedish pet owner on One Health related topics.

The plan was to further cooperate with clinicians to enhance the questionnaires' quality and include questions from which results could be used in everyday practice. This was, however, more difficult than expected; only two veterinarians were available to participate. To collect further insight into the quality of the questionnaires, veterinarians from the National Veterinary Institute were contacted to review the two questionnaires. Modifications were made to the questionnaire based on the feedback received. The questions were written in Swedish and consisted of open-ended and closed questions. Part one of the survey was distributed through information leaflets in the waiting area of 14 veterinary clinics across Sweden. In contrast, part two was sent to respondents’ email addresses 3-4 weeks after completing the first part of the survey.

Respondents had to be at least 18 years old and consent to having their personal information collected and analysed according to GDPR to participate. Information on owners' age, gender, and education level was collected, together with their email addresses, in order to be able to distribute part two of the survey.

The first part of the survey (see Appendix 1) was available between 24 October and 27 November 2022 and attracted 127 respondents. To get a better understanding of pet owners' knowledge of zoonosis, they were asked if they knew the term zoonosis and if they could correctly identify zoonoses from a list of pathogens. Rabies was highlighted, as information is readily available and has recently received much media attention, and questions regarding antibiotic stewardship were also included.

Due to the low response rate in the first part of the survey, invitation cards with a QR code (Appendix 3) were created. These invitation cards were designed and cut manually and hand-delivered to two clinics within travelling distance.

The second part of the survey was available between 7 November and 4 December, 27 days in total (see Appendix 2). This survey was sent out to participants who expressed their interest in participating in the second part of the survey, 80 respondents in total. The structure of this part of the survey was different from the first. Questions were followed by a series of infographics about antibiotic resistance, rabies, and echinococcosis. A number of questions were later repeated after the infographics to check if these infographics impacted pet owners' knowledge. The questionnaire was concluded with an open question where respondents could leave feedback about the surveys.

Respondents received an invitation via email with a short introductory text describing the layout of the second part of the survey and a link to it, together with contact information. These emails were followed by 2 follow-up reminder emails to all the respondents who had not completed the survey. The reminders were sent out late evenings on weekdays and midday on weekends to attract as many of the respondents as possible to complete the survey.

Because of the risk of e-mail servers being blacklisted or flagged as spam, a neutral email address provided by Netigate was used to increase the chance of emails reaching respondents. The Netigate-provided email address survey@netigate.se was used to send the second part of the survey to interested respondents, which is a no-reply address, which is why contact information was added in the introductory text.

4. Results

4.1 Survey part 1

4.1.1 Background information

A total of 127 people chose to participate in the survey. However, 21 respondents were excluded as they did not complete the survey, resulting in a total of 106 respondents. Because of suspected technical errors, a handful of questions were not answered by all respondents. A visit was made to one of the clinics to observe whether pet owners interacted with the leaflets or not. Most pet owners seemed to glance past them while looking for a seat. Possible reasons for why pet owners might not have been inclined to participate in the survey include that pet owners might be nervous when visiting the veterinarian due to being worried about their pets.

Half of the respondents had owned a pet for more than 10 years (53/106; 50%) (Figure 1). The respondents were evenly distributed across different age groups (Figure 2). The majority of respondents were female (82/105; 78%) (Figure 3) and had completed university education (67/106; 63%) (Figure 4).

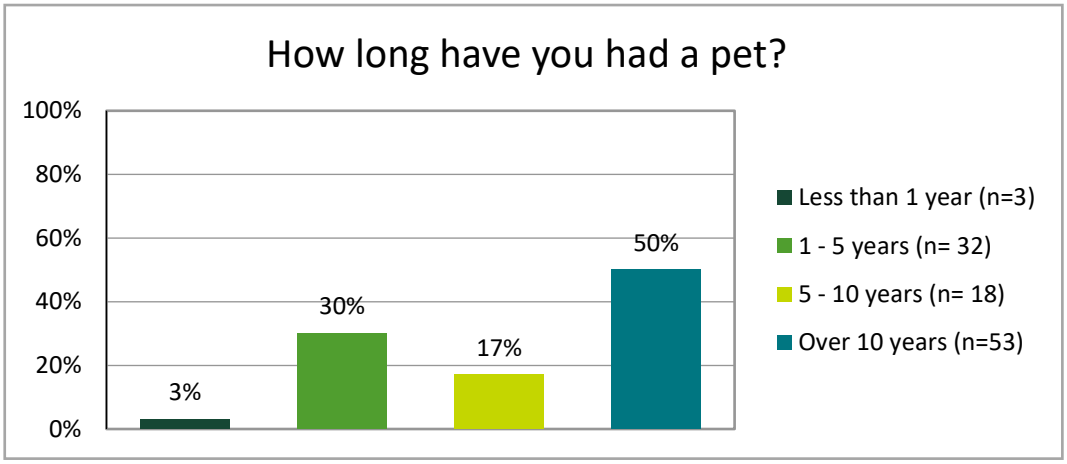

Figure 1. How many years pet owners in Sweden that participated in this study have owned a dog or cat. Total number of respondents: 106

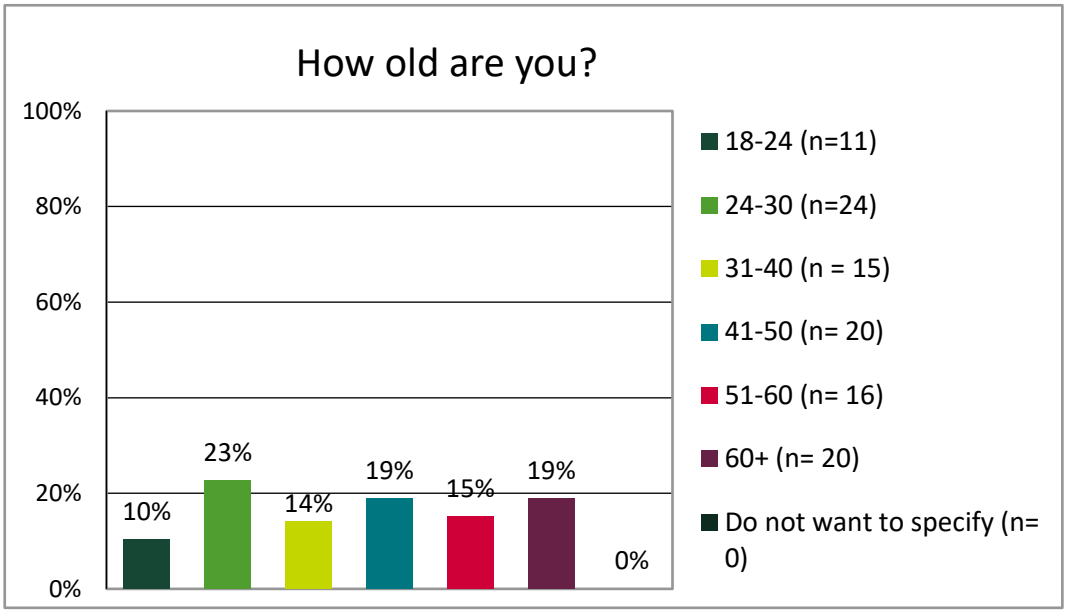

Figure 2. Age distribution among respondents. Total number of respondents: 106

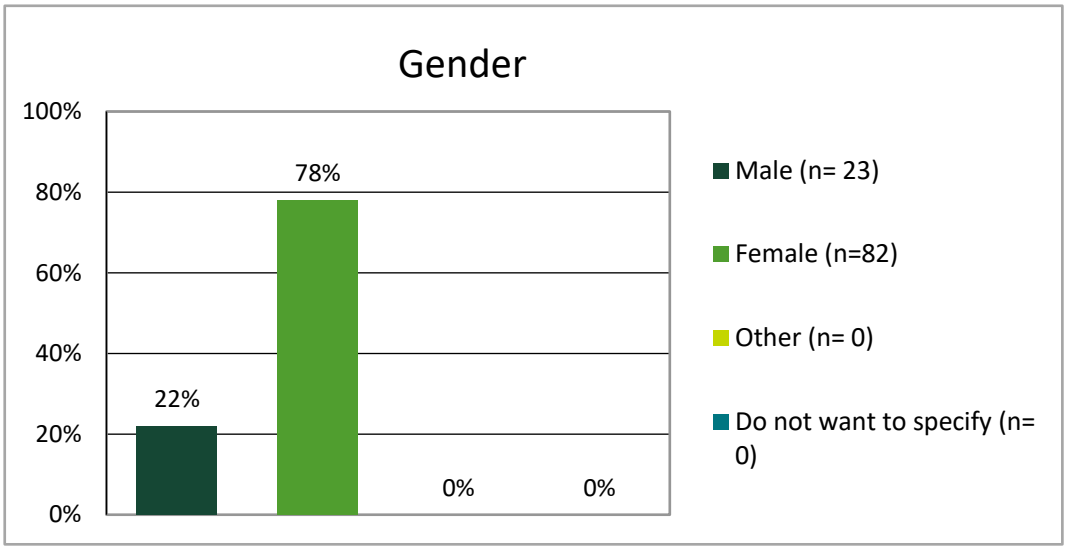

Figure 3. Respondents' gender. Total number of respondents: 105

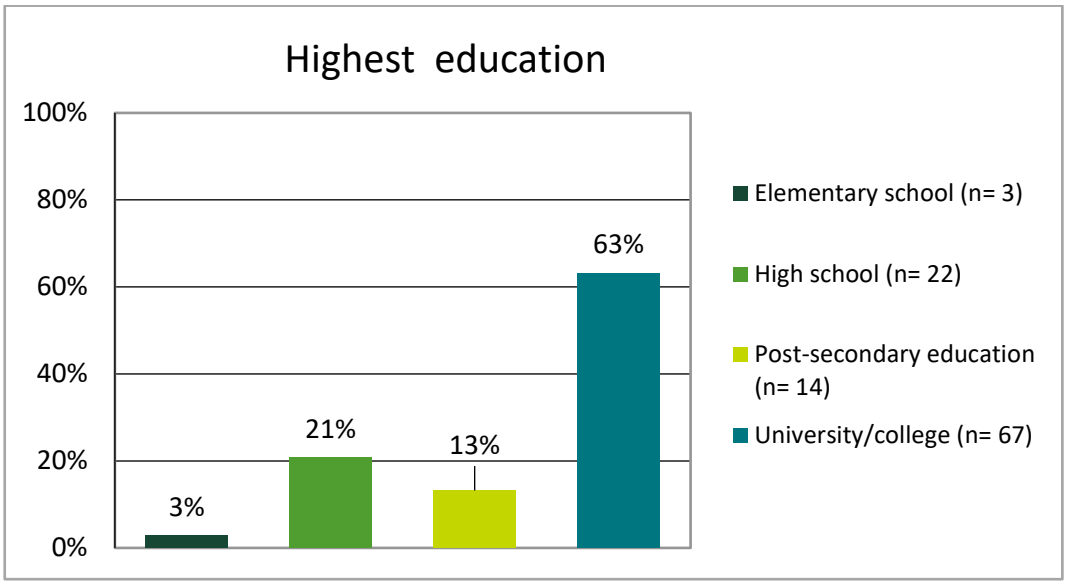

Figure 4. Respondents highest level of education. Total number of respondents: 106

When the respondents were asked what sources of information they used if they had questions about their pets and diseases that can afflict their pets, the majority (103/106; 97%) would consult their veterinarian (Figure 5). The second most common source of information was the internet (62/106; 58%), followed by friends and family with pets (40/106; 37%) and pet breeders (24/106; 23%). Less common sources of information were: The Swedish Board of Agriculture (10/106; 9%), the National Veterinary Institute (SVA) (8/106; 8%) and social media (5/106; 5%). Four respondents (4/106; 4%) reported other sources of information such as: FirstVet, animal shelter, animal hospital switchboard, and "Father-in-law is a veterinarian". The majority (99/106; 93%) of respondents were not familiar with the One Health concept (Figure 6).

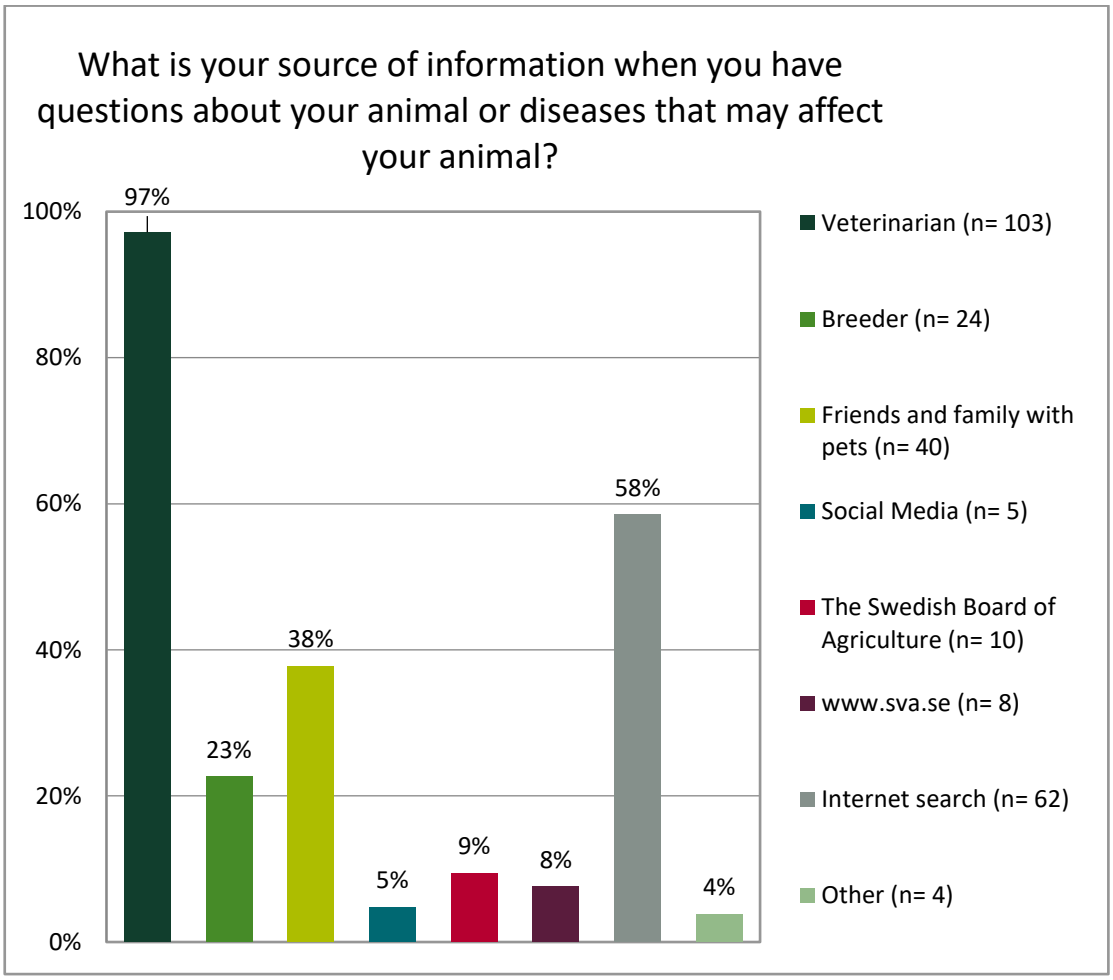

Figure 5. Common sources of information about companion animals and diseases that can afflict their pets. Total number of respondents: 106

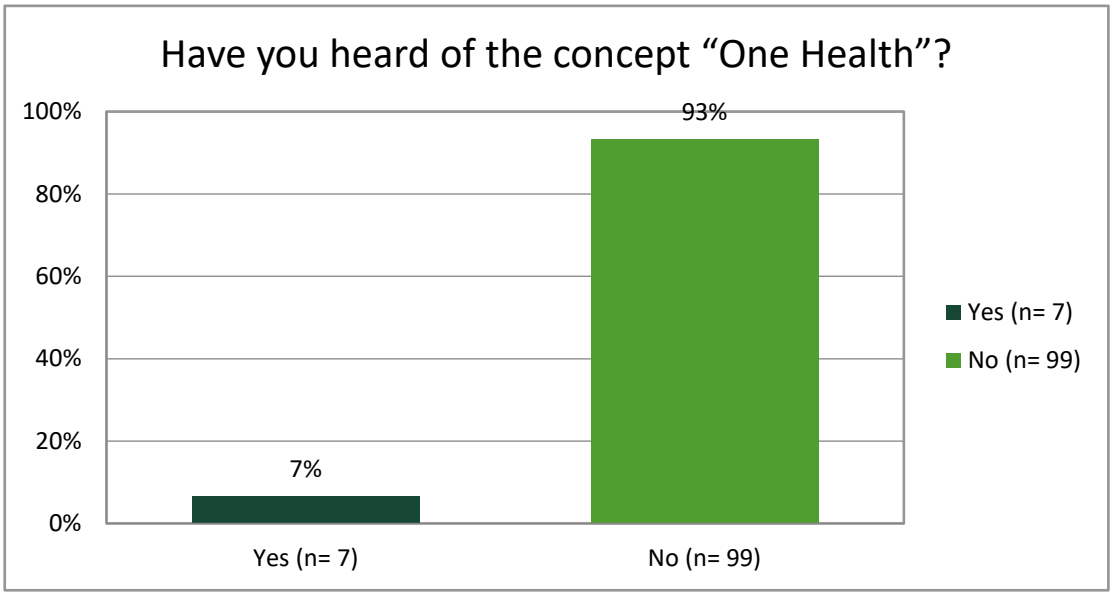

Figure 6. Awareness of One Health concept among pet owners in Sweden. Total number of respondents: 106

4.1.2 Zoonotic disease knowledge

Thirty (29%) respondents recognized the term zoonosis (Figure 7). When asked to identify the correct definition of the term from a list, 39 (37%) respondents answered correctly (Figure 8).

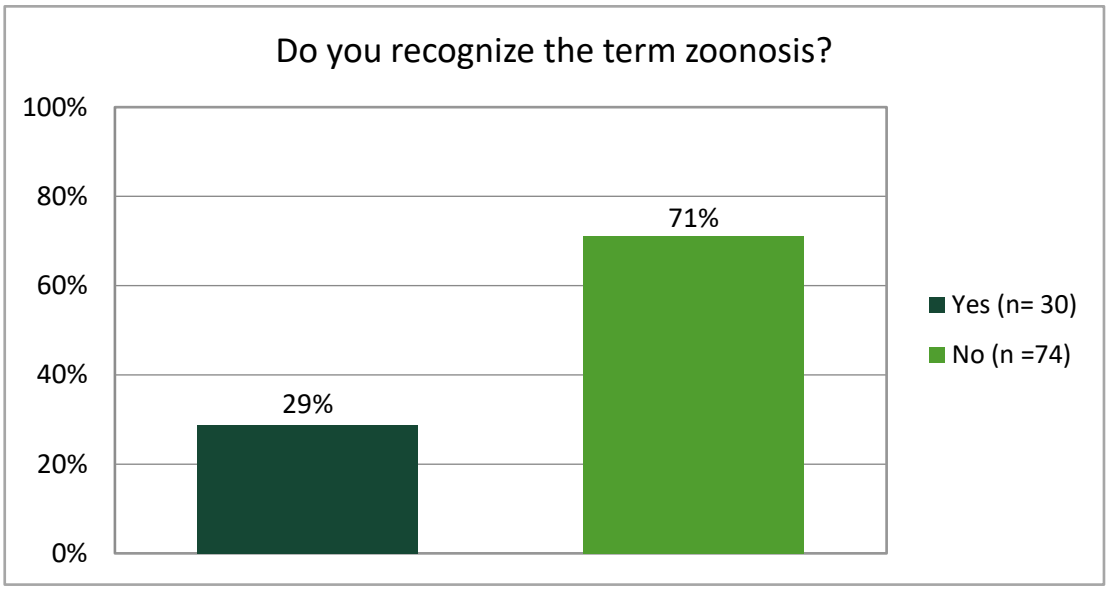

Figure 7. Awareness of the term zoonosis among pet owners. Total number of respondents: 104

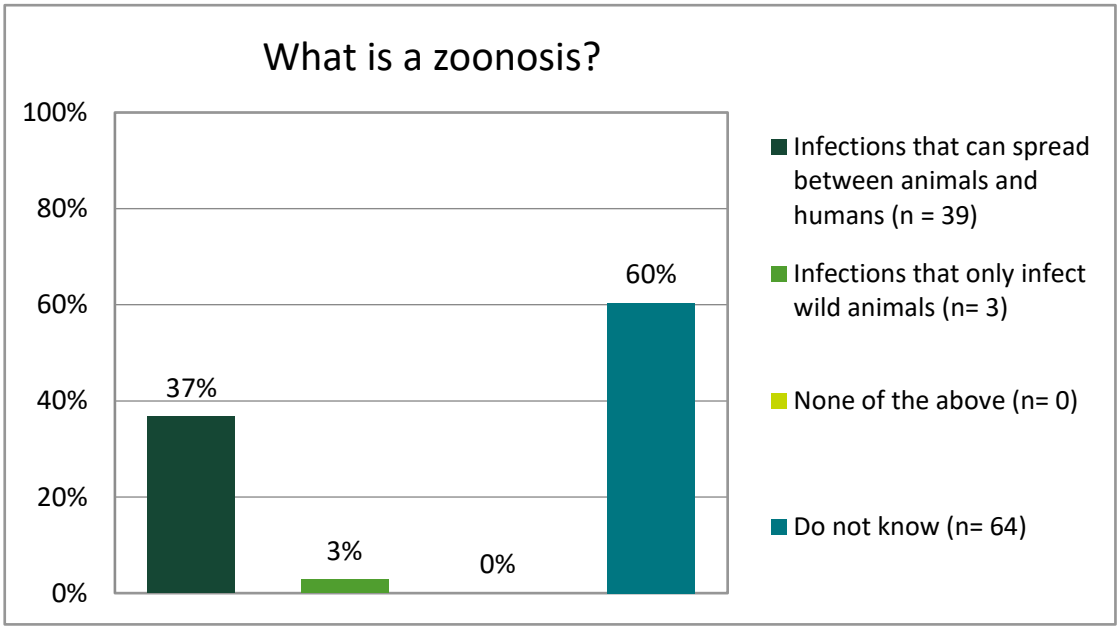

Figure 8. Knowledge of the definition of the term zoonosis among pet owners. Total number of respondents: 106

When respondents were asked to identify zoonotic infections from a list of infectious agents (see Appendix 1), the results were as follows: The majority correctly identified rabies as a zoonotic infection (97/105; 92%), as well as *Salmonella* (57/105; 54%). Ringworm was identified by 47% (49/105), *Echinococcus* by 28% (19/105) and MRSA by 21% (22/105) as zoonotic, (figure 9). Some of the respondents incorrectly classified sarcoptic mange (30/105; 29%) as a zoonotic infection, as well as feline distemper (5/105; 5%) and *Pneumonyssoides caninum,* (1/105; 1%), (Figure 9).

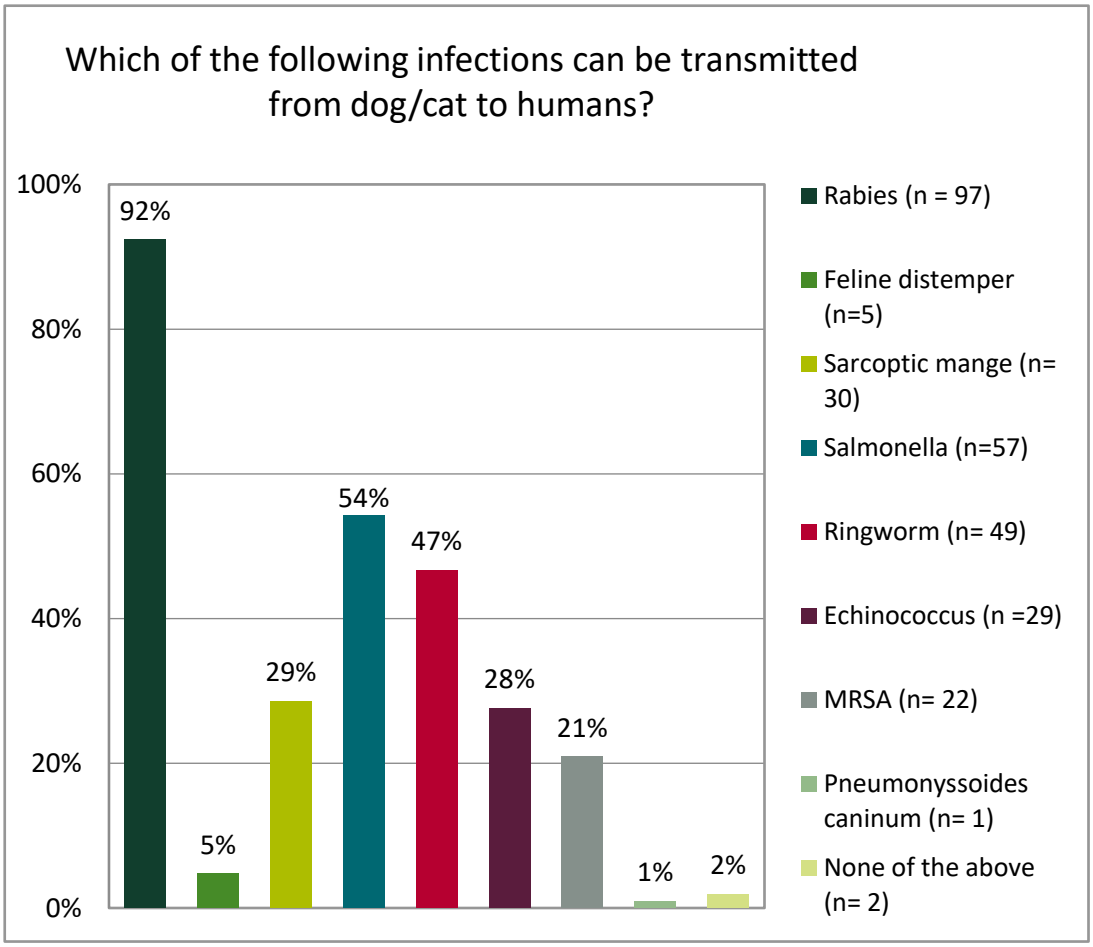

Figure 9. Pet owners' knowledge of zoonotic pathogens. Pet owners were asked to identify which of infectious pathogens are zoonotic. Total number of respondents: 105

When provided with 5 statements about rabies, pet owners were asked to identify which statements are true. Out of 102 respondents, 37 (36%) knew that rabies was a 100% fatal disease if an infected person developed symptoms, and 40 (39%) that dog bites caused the majority of rabies cases. However, only 47 (46%) knew that Sweden is free from rabies. The majority of respondents (90/102; 88%) knew that it is important to quickly seek medical attention if one is bitten by an unknown dog

while travelling abroad, and (89/102; 87%) that rabies is transmitted through contact with saliva from infected animals, whether it is through bites, licks or contact with mucous membranes such as the nose, mouth and eyes (Figure 10).

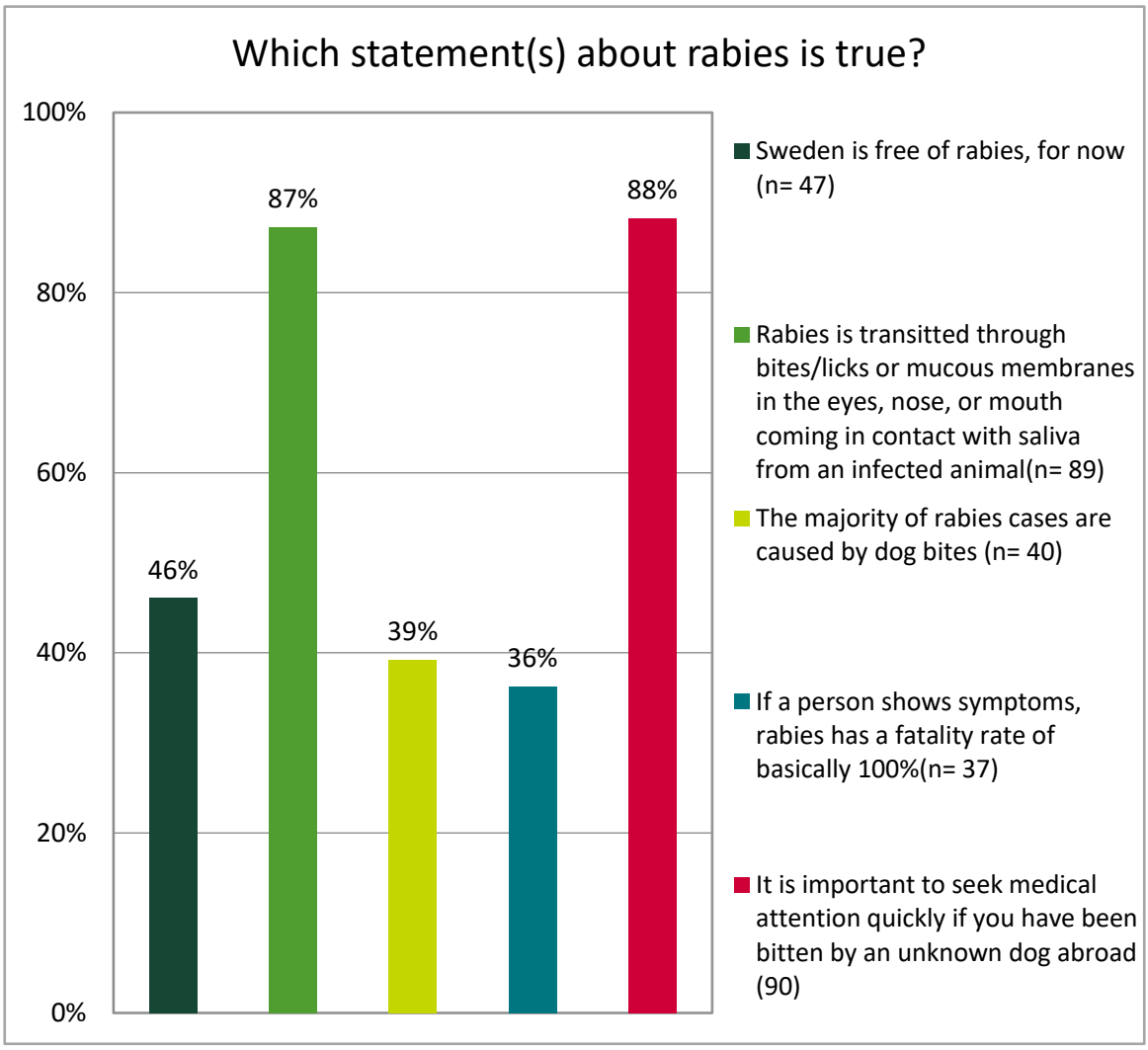

Figure 10. Pet owners' knowledge about rabies. Pet owners were asked which statements about rabies are true. Total number of respondents: 102

Pet owners were asked if their pet had been afflicted with a zoonotic infection, five pet owners (5/106; 5%) answered affirmatively. The diseases reported by the pet owners were salmonellosis (2), sarcoptic mange (1), leptospirosis (1) and yeast infection (1). Eleven pet owners (11/106; 10%) did not know whether their pets had been infected with a zoonotic disease or not. The majority of pet owners (85%; 90/106) reported that their pet had not been infected with a zoonotic infection (Figure 11). Respondents were not asked whether they contracted the same infection that affected their pet.

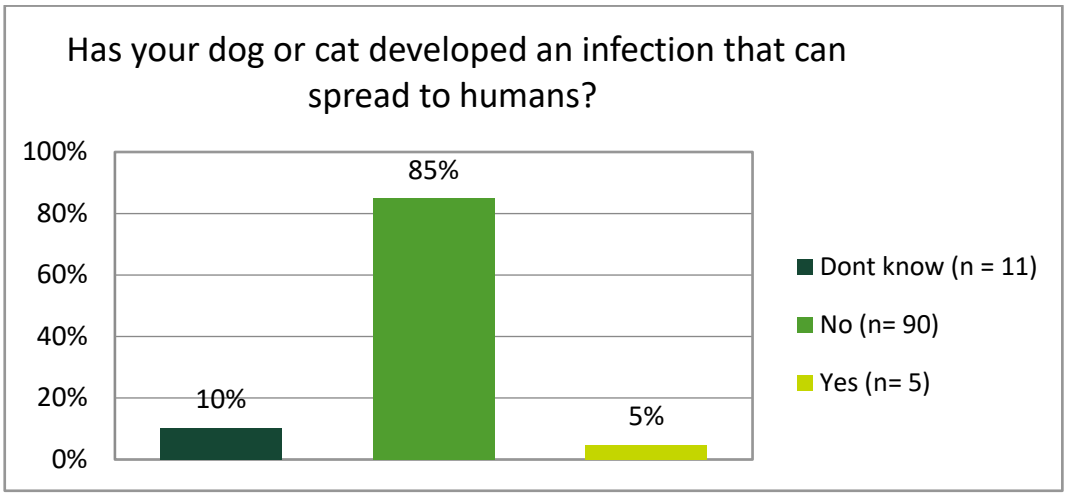

Figure 11. Number of respondents whose pets' been infected with an infection that can spread between humans and animals. Total number of respondents: 106

4.1.3 Pets and travel

Out of 106 respondents, 22 (21%) had travelled abroad with their pets (Figure 12). When provided with four statements about travelling with pets within Europe, over 90% were aware that their pets' rabies vaccination status should be valid, and that they should have a valid EU pet passport before travelling abroad (Figure 13). Circa 56% of respondents knew that the pet should be at least 3 months old to cross the Swedish border, and that when travelling into Sweden with their pets that they should notify customs (Figure 13).

The majority of pet owners (99%; 101/102) reported that there was an increased risk of exposure to rabies while travelling abroad. More than half of the respondents (54%; 55/102) reported that there is an increased risk of exposure to *Echinococcus*, followed by heartworm (37%; 38/101) and *Leishmania* (27%; 28/101).

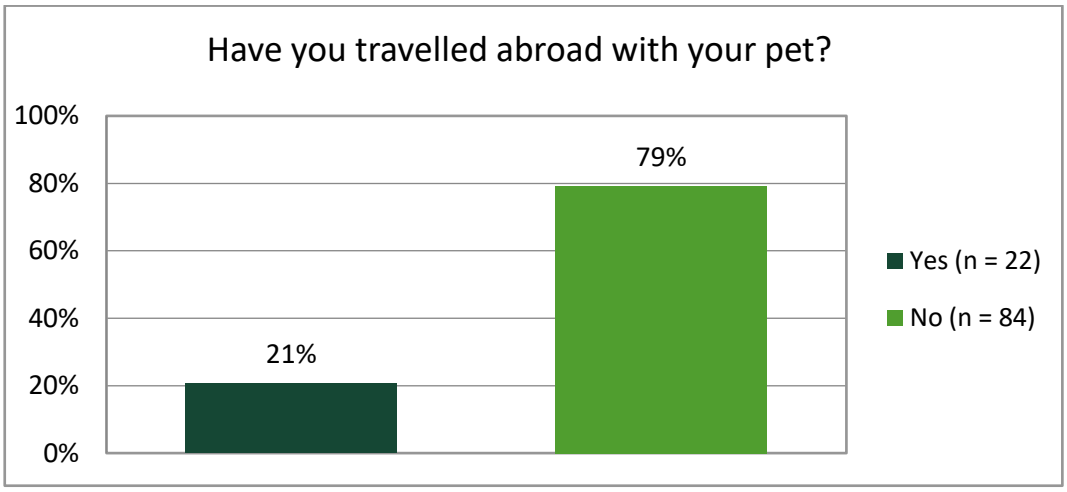

Figure 12. Distribution of pet owners that have travelled with their pets. Total number of respondents: 106

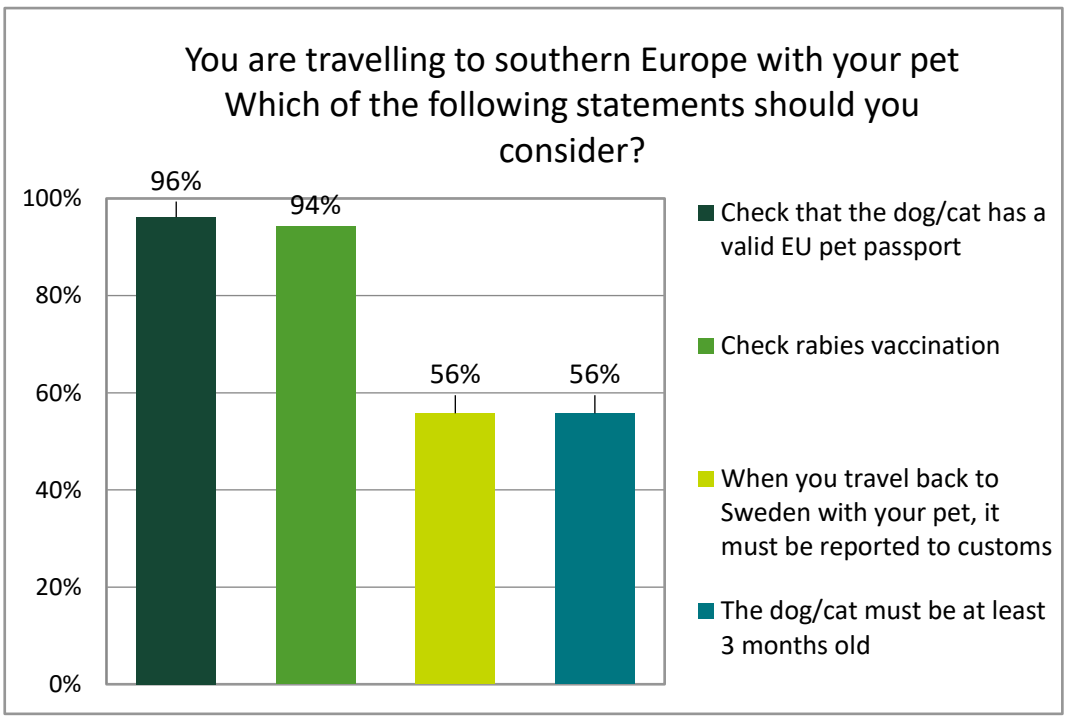

Figure 13. Distribution among respondents about travelling abroad. Total number of respondents: 104

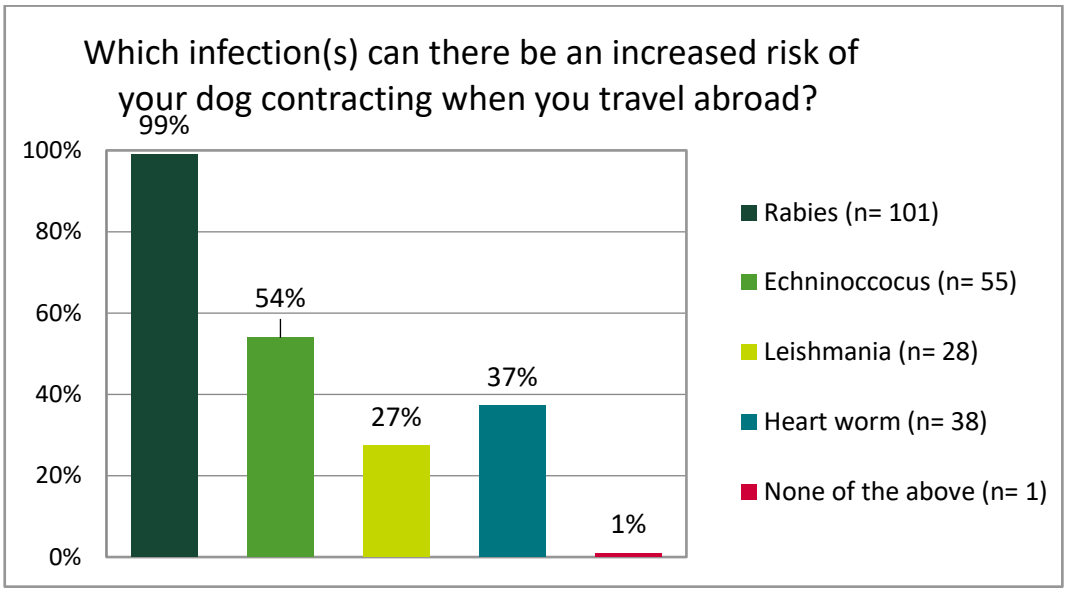

Figure 14. Infections that there is an increased risk of pets contracting while travelling abroad. Total number of respondents: 102

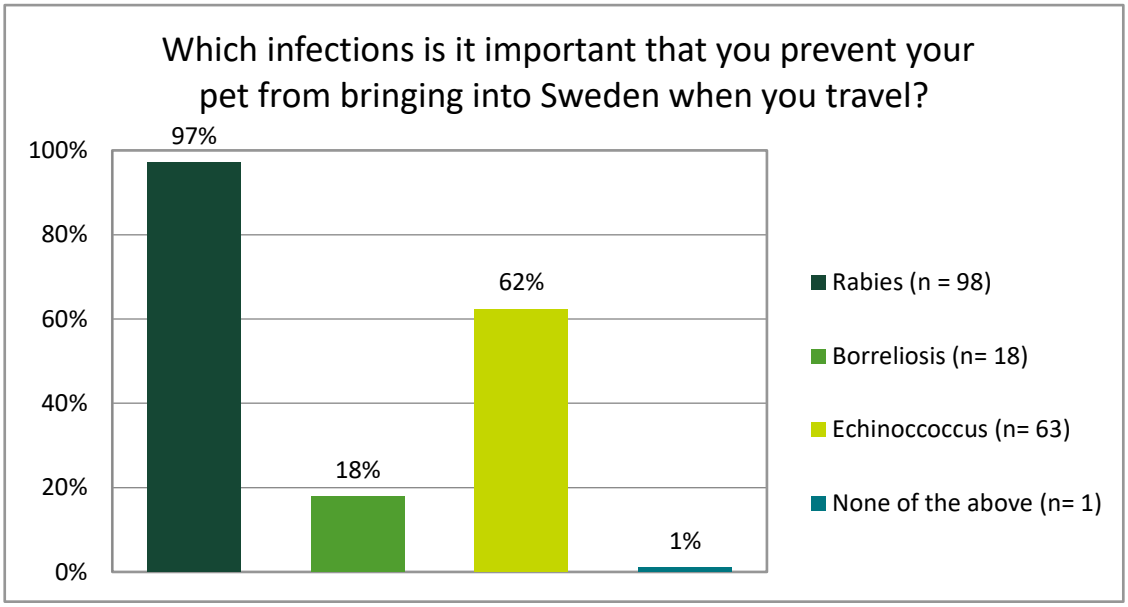

Figure 15. Infections that are important to prevent from bringing into Sweden. Total number of respondents: 101

4.1.4 Antibiotic treatment

When asked if pet owners wished that their veterinarians had prescribed their pet antibiotics during a visit to a veterinary clinic, 17% (17/105) answered affirmatively. Two (2%) of the respondents have hinted that they wanted an antibiotic prescription, and five (5%) respondents had specifically requested it (Figure 16).

One respondent (1%) reported that they were disappointed, surprised or frustrated when their pet did not receive antibiotics, while the rest responded that they were not (Figure 17). Most respondents felt that they were sufficiently involved in deciding whether their pet should receive antibiotics (Table 1).

The majority of respondents, 94% (99/105), prefer that their pets do not receive antibiotics if it can be avoided. Some respondents (18% (19/95)) simultaneously reported that viral and bacterial infections should be treated with antibiotics. The majority of respondents, 92% (84/91), were aware that antibiotics have a negative effect on the gut microbiota. Most of the respondents, 82% (77/94), disagreed that their pets should always receive antibiotics while treating a wound (Table 1).

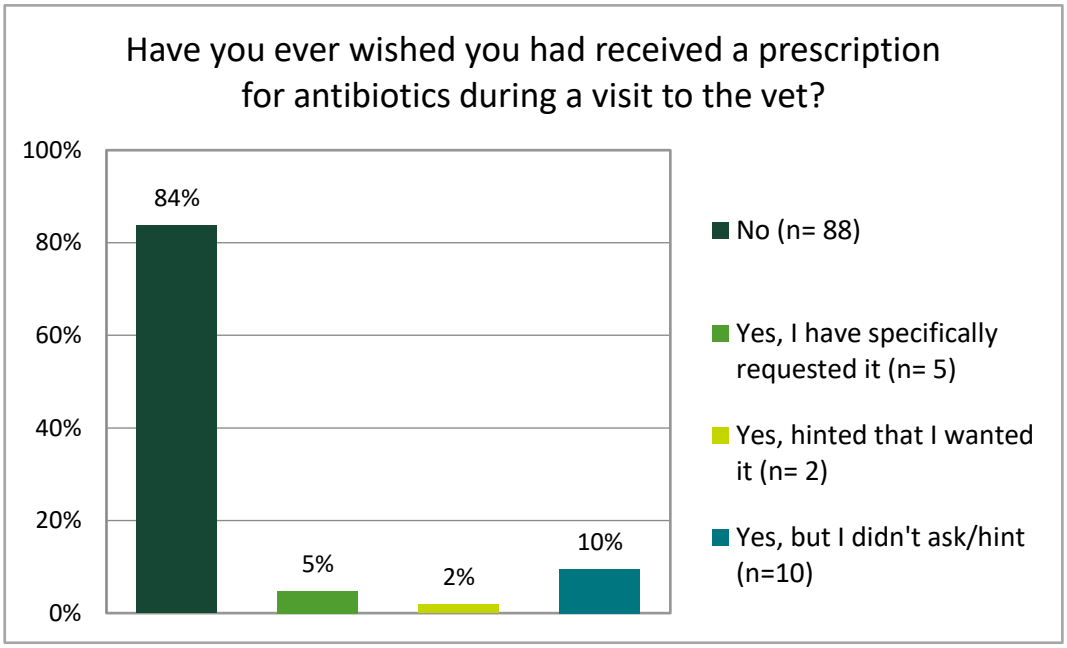

Figure 16. Distribution of pet owners who have wished for an antibiotic prescription during a visit to the veterinarian. Total number of respondents: 105

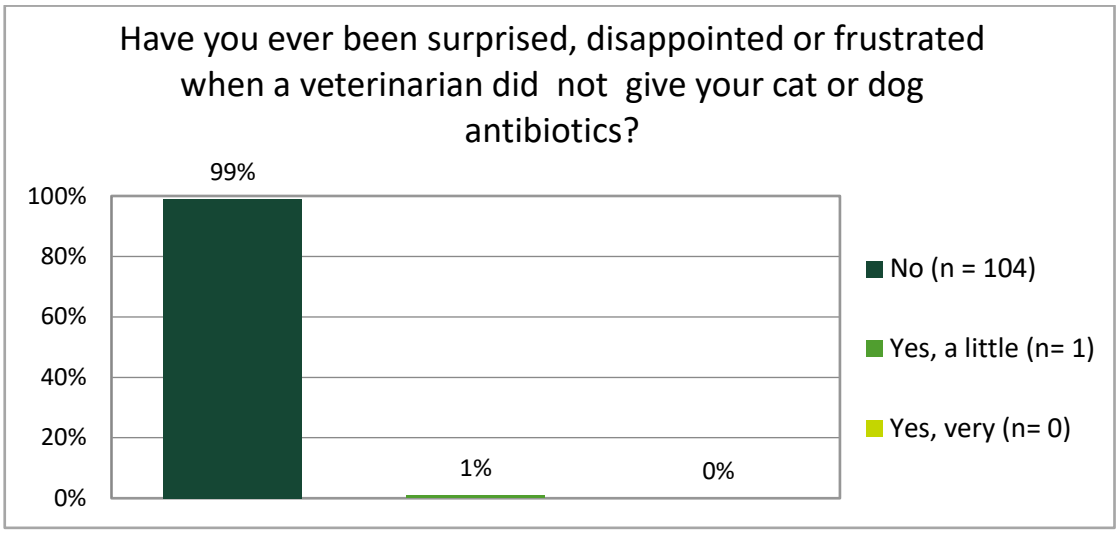

Figure 17. Distribution of pet owners who have been surprised or upset that they did not receive an antibiotic prescription for their pet. Total number of respondents: 105

Table 1. Pet owners' knowledge on antibiotic treatment and its effects

Statement	**Strongly agree**	**Somewhat agree**	**Somewhat disagree**	**Strongly disagree**	**Total**
I would prefer if my pet did not receive antibiotics, if it can be avoided	87	12	0	6	105
All infections, whether viral or bacterial, should be treated with antibiotics	5	14	18	58	95
Antibiotics has negative effect on the gut microbiota	56	28	6	1	91
Treating pets with antibiotics can increase the risk of resistance	65	25	4	1	95
You should always get a prescription for antibiotics when treating a wound on your dog or cat	9	8	28	49	94
Most of the time, I feel sufficiently involved in the decision of whether my pet should be treated with antibiotics or not	40	39	11	3	93

4.2 Survey part two

Of the 80 respondents who showed interest in participating in the second survey, only 50 respondents started the survey, of which 44 completed it. However, the number of respondents varied from 40 to 44 per question. Reasons for not answering all questions were reported to be that they did not understand the technical terms or that they skipped questions as they couldn´t find a relevant alternative to indicate.

4.2.1 Echinococcus

Respondents were given five statements about *Echinococcus* and were asked to identify the correct statements, before being shown infographics regarding *Echinococcus.* This question is new for part two of the questionnaire. The majority of respondents correctly identified 4/5 statements (figure 18). Only 41% (18/44) reported that the statement that dogs infected with *Echinococcus granulosus* are asymptomatic as being correct. For the remainder of the statements, more than 60% agreed that they were true (figure 19). Over 80% (37/44) of respondents agreed with the statements that dogs can be dewormed from *Echinococcus*, and 89% (39/44) that they can spread *Echinococcus* eggs in nature. More than half of the respondents (64%; 28/44) were aware that humans can become infected with *Echinococcus multilocularis* through the consumption of contaminated berries, and 75% (33/44) that infected people can develop the disease (Figure 18).

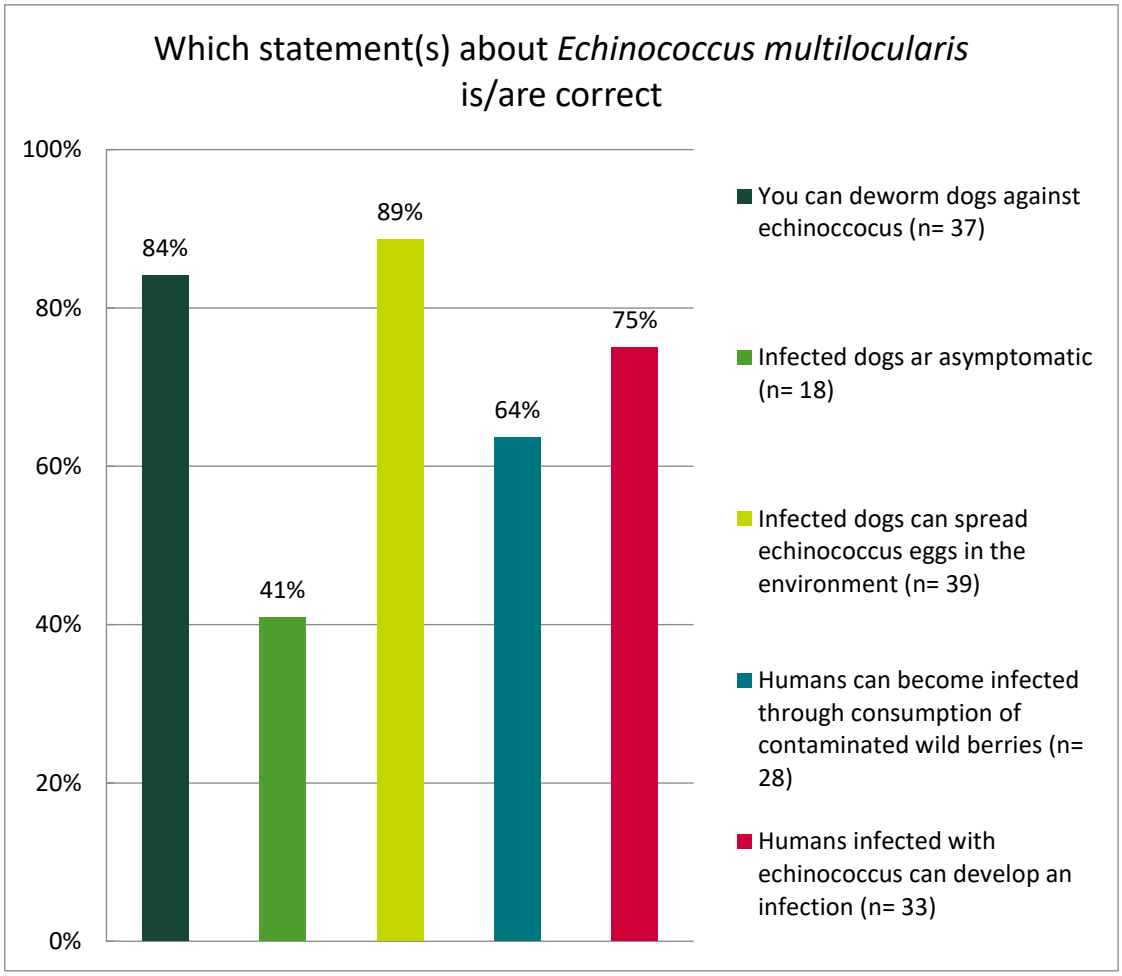

Figure 18. Knowledge of Echinococcus multilocularis among pet owners in Sweden. Total number of respondents: 44

4.2.2 Zoonotic infections and antibiotic resistance

Most respondents had not discussed zoonotic infectious disease with their physician (39/44; 89%) or veterinarian (32/44; 73%) during a consultation (Table 2).

The majority of respondents were comfortable with their level of knowledge, most of whom felt most comfortable with their knowledge of antibiotic resistance (84%; 36/43), followed by their knowledge of how to protect their pets from infectious diseases (77%; 33/43), and how infectious diseases spread (65%; 28/43) (Table 3).

Table 2. Distribution of pet owners who have discussed zoonotic infections with their physician or veterinarian

Statement	**Strongly agree**	**Somewhat agree**	**Somewhat disagree**	**Strongly disagree**	**Total**
In connection with a veterinary visit, I have discussed infections that can spread between animals and humans	5	7	3	29	44
In connection with a doctor's visit, I have discussed infections that can spread between animals and humans	2	3	7	32	44

Table 3. Pet owners' self-assessment of their knowledge

Statement	**Strongly agree**	**Somewhat agree**	**Somewhat disagree**	**Strongly disagree**	**Total**
I think I have enough knowledge about how infections spread.	9	19	11	4	43
I think I have enough knowledge about how to protect my dog/cat from infectious diseases.	9	24	8	2	43
I think I have enough knowledge about antibiotic resistance.	14	22	3	4	43

Respondents were given two scenarios to assess their knowledge of pet healthcare. The first scenario is a cat with a scratch wound. All respondents strongly agreed (100%; 43/43) with the statement that when a cat with a bite wound develops symptoms such as fever and loss of appetite, and the wound becomes inflamed, it indicates that the wound have become infected. All of the respondents (100%; 43/43) agreed with the statement that bite wounds can heal with cleaning. Most respondents (93%; 40/43) agreed that when an abscess develops it often needs drainage, and that they often heal well without antibiotic treatment (84%; 36/43) (Table 4).

The second scenario addressed the topic of dental care. Most (98%; 42/43) respondents know that a tooth root abscess can occur as a result of a dental fracture, and that a dental fracture requires veterinary examination (96%; 42/44). Most respondents know that brushing their pets' teeth is important to maintain dental hygiene to prevent inflammation and infections in the oral cavity (93%; 41/44) (table 5).

Table 4. Respondents' knowledge regarding cat bite wounds

Statement	**Strongly agree**	**Somewhat agree**	**Somewhat disagree**	**Strongly disagree**	**Total**
Wounds can often heal well by themselves if the wound is cleaned.	21	22	0	0	43
If an abscess develops, drainage is often needed	23	17	3	0	43
Abscesses often heal well without antibiotics.	11	25	6	1	43
If the cat develops symptoms such as fever, loss of appetite, the wound becomes swollen, red and smells bad, it can indicate that the wound has become infected	43	0	0	0	43

Table 5. Respondents' knowledge of oral health

Statement	**Strongly agree**	**Somewhat agree**	**Somewhat disagree**	**Strongly disagree**	**Total**
If my dog/cat has fractured a tooth, the vet needs to examine the tooth	36	6	2	0	44
Tooth root abscesses can occur as a complication of tooth fracture	30	12	1	0	43
Toothbrushing is important to prevent inflammation and infection in the oral cavity	30	11	3	0	44

Respondents were asked questions regarding antibiotic stewardship and rabies before and after viewing infographics and videos created by WHO (WHO n.d.b, n.d.e), CDC (CDC 2022a), Svenskt Kött (Swedish Meat) (Svenskt kött n.d.), Strama (Strama u.å.a) and Review on Antimicrobial Resistance (AMR Review n.d.) to investigate if respondents would change their answer after receiving informative material.

When asked if they can contribute to reducing antibiotic resistance by following their physicians' antibiotic prescription, all respondents agreed (100%; 43/43). Similar attitudes were seen regarding responses about the question "antibiotic resistance is a growing problem worldwide" in which all respondents agreed with the statement (100%; 43/43). Regarding the statements about mortality as a result of antibiotic resistant infections and the zoonotic potential of antibiotic resistance, 95% (39/41) and 88% (36/41), respectively, agreed that the statements are correct. A shift in response is noted after respondents are shown infographics relevant to the question, with an increase in the prevalence of respondents strongly agreeing with the given statements (Table 6).

Table 6. Pet owners' knowledge and attitude regarding antibiotic stewardship before receiving informative material

Statement	**Strongly agree**	**Somewhat agree**	**Somewhat disagree**	**Strongly disagree**	**Total**
Antibiotic resistance is a growing problem worldwide	40	3	0	0	43
Certain types of antibiotic resistance can be transmitted between animals and humans	22	14	3	2	41
Many people die globally as a result of antibiotic-resistant infections	24	15	2	0	41
I can contribute to reducing antibiotic resistance by following the physician prescription when prescribing antibiotics	40	3	0	0	43

Table 7. Pet owners' knowledge and attitudes regarding antibiotic resistance after receiving informative material

Statement	**Strongly agree**	**Somewhat agree**	**Somewhat disagree**	**Strongly disagree**	**Total**
Antibiotic resistance is a growing problem worldwide	39	1	0	0	40
Certain types of antibiotic resistance can be transmitted between animals and humans	33	6	1	0	40
Many people die globally as a result of antibiotic-resistant infections	36	4	0	0	40

In regard to rabies, the majority of respondents agreed with all of the statements. Almost all respondents correctly identified that the statements "rabies occurs in large parts of Africa and Asia" (98%; 42/43) and "rabies is a deadly disease" (98%; 43/44) were true. The majority of respondents accurately identified that the statements that seemingly healthy animals can spread the infection (93%; 40/43), and that the disease can be prevented through vaccination (91%; 40/44) were correct (Table 8). Even in this case a small shift in response, with more people strongly agreeing with the statements is seen (Table 9).

Table 8. Pet owners' knowledge and attitudes regarding rabies before receiving informative material

Statement	**Strongly agree**	**Somewhat agree**	**Somewhat disagree**	**Strongly disagree**	**Total**
Rabies occurs in large parts of Africa and Asia	25	17	1	0	43
Rabies is a deadly disease	38	5	1	0	44
Rabies can be prevented by vaccination	33	7	2	2	44
Seemingly healthy animals can infect animals and humans with rabies	25	15	2	1	43

Table 9. Pet owners' knowledge and attitudes regarding rabies after receiving informative material

Statement	**Strongly agree**	**Somewhat agree**	**Somewhat disagree**	**Strongly disagree**	**Total**
Rabies occurs in large parts of Africa and Asia	39	1	2	0	42
Rabies is a deadly disease	40	1	1	0	42
Rabies can be prevented by vaccination	37	2	1	2	42

5. Discussion

This study was conducted in Sweden to investigate pet owners' knowledge on One Health. The results show that pet owners have gaps in their knowledge in One Health, antibiotic resistance and zoonotic diseases.

5.1 Knowledge of zoonotic diseases

When asked if pet owners recognized the term zoonosis, most responded that they did not. However, when asked to identify the correct definition from a list, 8 (11%) of the respondents who said they did not know the term correctly identified the definition of zoonosis. This could be due to how the question was asked, since it led respondents to think they were asked if they knew the definition of zoonoses rather than what was the purpose of the question, which was to investigate if the respondents had previously heard of the term. A third alternative should have been provided for owners who were unsure if they recognized the term or the definition.

To investigate pet owners' knowledge of zoonotic diseases, they were presented with a list of 8 pathogens and asked to identify which of the pathogens on the list could be transmitted between humans and their pets. Most respondents correctly identified the zoonotic agents from the list. In this study a higher percentage of respondents correctly identified rabies as zoonotic (92%) compared to a similar survey conducted as a part of a master thesis in Uppsala, Sweden in 2010 in which 57% correctly identified it as zoonotic (Hirvonen 2011).

In total 30 respondents (29%) incorrectly identified sarcoptic mange as a zoonotic agent. It is not a zoonotic infection as sarcoptic mange cannot survive on humans as a host. They may, however, cause short-term reactions in humans which is called pseudoscabies which might explain why some respondents thought it was zoonotic. (National Veterinary Institute [SVA] n.d.c). Another reason for this confusion could be the human host-specific sarcoptes mite, *Sarcoptes scabei* var. *hominis*, which is not the same species of sarcoptes that primarily infects dogs and other animals (CDC 2019b; Folkhälsomyndigheten n.d.e).

Respondents were relatively uninformed about rabies, which was unexpected as it is serious disease which has recently received a lot of media attention. Less than half of the respondents (46%; 47/102) thought that Sweden is free from rabies. This might partly be due to news reports in 2016 when positive antibody results were detected in bats in southern Sweden. The news reported that Sweden had lost its

status as a rabies-free country due to the positive findings of rabies in bats (SVT 2016a; b). This information was later rectified when the Public Health Agency of Sweden announced that Sweden did not lose its rabies-free status per the OIE (today known as WOAH) (Lund 2016).

The news reporting regarding the rabies status of Sweden was due to the finding of antibodies in bats to the European bat lyssavirus (EBLV). Between 2008 and 2013, active surveillance was performed to study the prevalence of EBLV in Sweden, with positive findings of EBLV antibodies in bats in southern Sweden, specifically in the counties Skåne and Småland, indicating exposure to lyssavirus in bats. None of the bats examined was found to be positive for rabies virus through saliva sampling (Hammarin *et al.* 2016).

It is important to differentiate between classical rabies and bat lyssavirus. The bat lyssavirus is adapted to bats but can in rare cases cause disease and even death in other species, including humans, with symptoms similar to those seen in classic rabies. Healthy bats do not attack humans, and neither do bats that have antibodies against rabies or are infected with rabies, according to available experience from all over Europe (Hammarin *et al.* 2016; National Veterinary Institute [SVA] n.d.a).

Respondents were also asked if they had ever had a discussion regarding zoonotic infections with a physician or a veterinarian, most respondents reported that they had not. However, they were more likely to have discussed zoonotic infections with a veterinarian compared to a physician. Previous studies have reported similar results (Stull *et al.* 2012; do Vale *et al.* 2021; Powell *et al.* 2022). Veterinarians are more likely to have discussed zoonotic infections with people due to their professional expertise in animals and one health, as well as having direct contact with pet owners. This increases veterinarians´ likelihood of discussing zoonotic infections with people compared to physicians. Studies have shown that people who had heard of the phrase "zoonotic disease" and understood its meaning were more likely to ask their veterinarian about zoonotic diseases (Powell *et al.* 2022). In a Swedish MSc thesis, 77% of the in total 30 immunocompromised individuals that participated in the study had received information about the risk of disease transmission from pets from their physician (Wallin 2003). The results of the study also show that there was a difference among participating veterinarians and physicians regarding which zoonotic infections immunocompromised individuals should receive information about. The majority of immunosuppressed people received only verbal information about the risks of infection from animals. Information leaflets about zoonotic infections can be distributed to immuno-suppressed people, their relatives and pet owners with animals infected by zoonotic agents. With the added bonus that they can be saved and the information can be

used during discussions with their veterinarian during future consultations (Wallin 2003).

5.2 Owners' attitudes to antibiotic treatment

Respondents were asked general questions about antibiotic resistance and stewardship and specific questions about antibiotic use for pets. This survey showed that most pet owners agreed that preventing infections is key to reducing antibiotic resistance. Most respondents are also aware of the importance of following their physicians' antibiotic prescriptions, and that antibiotics are not always necessary when treating a wound. Most respondents reported that they were more comfortable with their knowledge of antibiotic resistance than about infectious diseases that can affect their pets.

Most respondents were aware of the negative effects of antibiotics, such as the development of resistance and negative effect on the gut microbiota, and that antibiotics should be avoided if they are not necessary, which shows that they have good knowledge about antibiotic use and stewardship. This was also seen in the Eurobarometer regarding antibiotic resistance, in which Swedish participants had the second-highest score among the participating countries (European Commission. Directorate General for Health and Food Safety 2022).

Respondents were given two different scenarios to better understand their knowledge and attitudes regarding antibiotic stewardship. The questions were written in a way where pet owners were asked to agree with statements instead of identifying whether the statements were true or false in an attempt to increase response rates and to get a better sense of how confident they were with their answers. The majority of respondents reported that they were comfortable with their level of knowledge regarding antibiotic resistance, which can explain why they were more confident about their answers about antibiotics. Respondents were well aware that antibiotic resistance is a growing, global problem. But they were not as certain about the fact that some types of resistant bacteria can be transmitted between humans and pets and that many people die annually as a result of resistant infections.

5.3 Study limitations

In retrospect, both surveys should have been designed according to the template in the second. This would have enabled the second questionnaire to be shortened or even combined into the first questionnaire. A survey based on a single questionnaire

might have resulted in a higher response rate. The survey could also have been distributed through invitation cards (see Appendix 3), which was shown to result in a higher response rate compared to other strategies used. This was unfortunately not possible for this study, as there were no economic means to mass produce and distribute the cards to the participating clinics.

6. Conclusion

The survey showed important knowledge gaps among pet owners in the areas of One Health, zoonotic diseases and antimicrobial resistance. The fact that very few pet owners knew about the concept One Health and that the majority were not aware of what a zoonosis is, points to the importance of veterinarians in the dialogue with pet owners to explain the interrelationships between health in animals and humans. This is more important than ever, in the wake of the pandemic.

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Populärvetenskaplig sammanfattning

One Health är ett koncept som bygger på att människans, djurens och miljöns hälsa är sammankopplade. Det är ett koncept vars strategi syftar till att nå en hållbar balans och att förbättra hälsan hos människor, djur och ekosystem genom samarbete mellan olika sektorer och discipliner att främja välbefinnande och ta itu med hot mot hälsa och ekosystem. Grundidén som konceptet bygger på är inte ny, utan associeras i litteraturen till 1900-talet och bland annat den tyske läkaren Robert Virchow vars studier ledde honom till att mynta begreppet zoonos och Dr. Calvin Schwabe som introducerade termen ”One Medicine” som idag är känt som One Health.

Termen One Health började användes först i början på 2000-talet i samband med SARS (severe acute respiratory disease) utbrottet och ”One World, One Health” konferensen som hölls på Rockerfelleruniversitetet i New York. Under konferensen utvecklade man en lista med 12 rekommendationer som kallas ”the Manhattan principles” vilket satte grunden till ett mer holistiskt tillvägagångssätt att jobba med att förebygga sjukdomar, men även övervakning och kontroll av sjukdomar för att förbättra hälsan på jorden.

One Health är ett väldigt brett koncept och har genom tiderna haft många olika definitioner och det är inte förrän One Health High Level Expert Panel bildades år 2020 som en definition utvecklades med målet att nå en enighet kring definitionen för att bilda en grund som konceptet bygger på. Två viktiga aspekter inom One Health är zoonoser och antibiotikaresistens, vilka är huvudfokus-områden i detta projekt. Men One Health hanterar inte bara dessa två områden utan kan appliceras på allt från förebyggande hälsosjukvård och hälsofrämjande arbete till att jobba proaktivt för att förebygga hälsokriser.

Zoonoser är infektioner som smittar mellan djur och människor. De kan vara orsakade av bakterier, virus eller parasiter och kan smitta människor genom direkt kontakt med andra infekterade individer eller indirekt genom mat, vatten, miljön eller vektorer såsom myggor. Exempel på zoonotiska infektioner som kan spridas mellan människor och hund och katt är: rabies, leptospiros, echinokockos, salmonella och MRSA (meticillinresistent *Staphyloccocus aureus*) mm.

När antibiotika överanvänds eller används olämpligt kan bakterier utveckla resistens mot läkemedlen. Detta innebär att antibiotika inte längre är effektiva för att behandla infektioner orsakade av dessa bakterier, vilket gör det svårare att behandla och förhindra spridning av sjukdomar. Antibiotikaresistens är en viktig fråga eftersom den utgör ett stort hot mot folkhälsan, som hotar vår förmåga att framgångsrikt behandla infektioner vilket gör dem potentiellt dödliga. Man har länge studerat antibiotika och resistensutvecklingen, och man har i en studie uppskattat att 10 miljoner människor förväntas dö årligen år 2050 på grund av antibiotikaresistens om inga åtgärder vidtas, vilket motsvarar en person var tredje sekund. Detta faktum har lett till nationella och internationella kampanjer för att bromsa utvecklingen av resistens.

Syftet med den här redovisade studien var att undersöka vad djurägare i Sverige vet om One Health-konceptet med fokus på ämnena zoonotiska infektioner och antibiotikaresistens. För att undersöka frågan togs två separata enkäter fram med hjälp av online-verktyget Netigate. Den första delen av undersökningen delades ut via QR koder på informationsblad som fanns att tillgå i väntrummet på de kliniker som valt att delta, och genom inbjudningskort som delades ut till djurägare i receptionen. Del två av enkäten skickades ut till djurägare som hade anmält sitt intresse av att ta del av den. Den första enkäten bestod av 19 flervalsfrågor, och i del två av undersökningen fick man ta del av informationsmaterial från bland annat WHO och CDC och därefter svara på frågor om zoonoser och antibiotikaresistens.

Resultatet visade att deltagarna hade relativt god kunskap om antibiotikaanvändning och dess negativa effekter, men många kände inte till att antibiotikaresistenta bakterier kan smitta mellan djur och människor. Detta ses även i EU:s barometer från 2022 om antibiotika, där svenska deltagare hade näst högst poäng, strax bakom Finland som hade högst poäng. Deltagarna hade dock inte lika goda kunskaper om zoonotiska infektioner, vilket inte är unikt för denna studie utan kan även ses i internationella studier.

Överlag belyser resultaten vikten av kunskap inom dessa områden, då kunskap är en förutsättning för att förebygga sjukdomar. Resultaten kan även användas på djurkliniker i samband med konsultationen till djurägare. Denna studie kan i kombination med övrig befintlig forskning utgöra en värdefull grund för framtida studier inom One Health.

Acknowledgements

I would like to thank my supervisors Karin Artursson and Ulrika Windahl for their patience, guidance, and resourcefulness during the course of this project. I would also like to thank the wonderful staff at Västerorts animal hospital for their insightful feedback on the surveys and distribution methods. Thank you to the veterinarians at the National Veterinary Institute for their wise feedback. I would also like to thank all the veterinary clinics that participated in the study, and a special thank you to Marlene Areskoug at Evidensia who helped me recruit clinics. Most importantly, I would like to thank all the pet owners who made this study possible by responding to the survey.

Last, but not least, a special thank you to my family who have supported me and assisted me throughout this project.

Appendix 1

1. How long have you had a pet?
    i. Less than 1 year
    ii. 1 - 5 years
    iii. 5 - 10 years
    iv. Over 10 years

2. How old are you?
    i. 18-24
    ii. 24-30
    iii. 31-40
    iv. 41-50
    v. 51-60
    vi. 60+
    vii. Don’t want to specify

3. What is your gender
    i. Male
    ii. Female
    iii. Other
    iv. Don’t want to specify

4. Highest completed level of education?
    i. Elementary school
    ii. High school
    iii. Post-secondary education
    iv. University/college

5. Where do you turn if you have questions about your animal or diseases that may affect your animal? (You can choose several answers)
    i. Veterinary
    ii. Breeder
    iii. Friends and family with pets
    iv. Social Media
    v. The Swedish Agency for Agriculture
    vi. www.sva.se
    vii. Internet search
    viii. Another, namely

6. Have you heard of the concept of “One Health”?
    i. Yes
    ii. No

7. Do you recognize the term ‘zoonosis’?
    i. Yes
    ii. No

8. What is a zoonosis?
    i. Infections that can spread between animals and humans
    ii. Infections that only infect wild animals
    iii. None of the above

9. Which of the following infections can be transmitted between dog/cat and humans? (You can choose several answers)
    i. Rabies
    ii. Feline distemper
    iii. Sarcoptes mange
    iv. Salmonella
    v. Ringworm

vi. Echinococcus
vii. MRSA
viii. Pneumoyssoides caninum
ix. None of the above

10. Has your dog/cat become ill with an infection that can spread to humans?
    i. Yes, which one?
    ii. No
    iii. Don't know

11. Have you ever travelled abroad with your dog/cat?
    i. Yes
    ii. No

12. You are going to travel with your dog/cat to southern Europe. Which of the following statements should you consider?
    i. Check that the dog/cat has a valid EU pet passport
    ii. Check rabies vaccination status
    iii. When you travel back to Sweden with your pet, it must be reported to customs
    iv. The dog/cat must be at least 3 months old

13. What/Which infection(s) can there be an increased risk of your dog getting when you travel abroad?
    i. Rabies
    ii. Echinococcus
    iii. Leishmania
    iv. Heartworm
    v. None of the above

14. What/Which infection(s) is it important that you prevent your dog/cat from bringing into Sweden when you travel?
    i. Rabies
    ii. Lyme disease
    iii. Echinococcus
    iv. None of the above

15. What/Which statement(s) about rabies is true?
    i. If a person shows symptoms, rabies has a fatality rate of basically 100%
    ii. The majority of rabies cases are caused by dog bites
    iii. Sweden is so far free of rabies
    iv. It is important to seek medical attention quickly if you have been bitten by an unknown dog abroad
    v. Rabies is transmitted by being bitten/licked, or by the infected animal's saliva coming into contact with your mucous membranes, e.g. eyes, nose or mouth

16. Have you ever wished you had received a prescription for antibiotics during a visit to the vet?
    i. No
    ii. Yes, specifically requested it
    iii. Yes, hinted that I wanted it
    iv. Yes, but I didn't ask/hint that I wanted it

17. During a visit, have you been surprised/disappointed or frustrated that you did not receive a prescription for antibiotics?
    i. No
    ii. Yes, a little
    iii. Yes, very

18. How do veterinarians best reach you with information about preventive animal health care? (You can choose several answers)
    i. Conversation with a veterinarian
    ii. At the clinic
    iii. Via social media
    iv. Via information sheets in the waiting room
    v. Other, namely

Appendix 2

1. Preventing infections reduces the risk of antibiotic resistance
    i. Strongly agree
    ii. Somewhat agree
    iii. Somewhat disagree
    iv. Strongly disagree
    v. My dog/cat has not needed antibiotics

2. I am satisfied with my vet's reasoning as to why my dog/cat does not receive antibiotics in connection with a visit
    i. Agree to a great extent
    ii. Partially agree
    iii. Partially disagree
    iv. Totally disagree
    v. My dog/cat has not needed antibiotics

3. I assume my dog/cat doesn't need antibiotics unless we get it prescribed
    i. Strongly agree
    ii. Somewhat agree
    iii. Somewhat disagree
    iv. Strongly disagree
    v. My dog/cat has not needed antibiotics

4. I can contribute to reduced antibiotic resistance
    i. Agree to a great extent
    ii. Partially agree
    iii. Partially disagree
    iv. Totally disagree

5. I assume my dog/cat doesn't need antibiotics unless we get a prescription for it
    i. Strongly agree
    ii. Somewhat agree
    iii. Somewhat disagree
    iv. Strongly disagree

6. I can contribute to reducing antibiotic resistance by following the doctor's prescription when prescribing antibiotics
    i. Strongly agree
    ii. Somewhat agree
    iii. Somewhat disagree
    iv. Strongly disagree

7. Antibiotic resistance is a growing problem in healthcare
    i. Strongly agree
    ii. Somewhat agree
    iii. Somewhat disagree
    iv. Strongly disagree

8. Some types of antibiotic resistance can be transferred between animals and humans
    i. Strongly agree
    ii. Somewhat agree
    iii. Somewhat disagree
    iv. Strongly disagree

9. Many people die globally as a result of antibiotic-resistant infections
    i. Strongly agree
    ii. Somewhat agree
    iii. Somewhat disagree
    iv. Strongly disagree

10. Rabies occurs in large parts of Africa and Asia
    i. Strongly agree
    ii. Somewhat agree
    iii. Somewhat disagree
    iv. Strongly disagree

11. Seemingly healthy animals can infect animals and humans with rabies
    i. Strongly agree
    ii. Somewhat agree
    iii. Somewhat disagree
    iv. Strongly disagree

12. Rabies is a deadly disease
    i. Strongly agree
    ii. Somewhat agree
    iii. Somewhat disagree
    iv. Strongly disagree

13. Rabies can be prevented through vaccination
    i. Strongly agree
    ii. Somewhat agree
    iii. Somewhat disagree
    iv. Strongly disagree

14. In connection with a veterinary visit, I have discussed infections that can spread between animals and humans
    i. Strongly agree
    ii. Somewhat agree
    iii. Somewhat disagree
    iv. Strongly disagree

15. In connection with a doctor's visit, I have discussed infections that can spread between animals and humans
    i. Strongly agree
    ii. Somewhat agree
    iii. Somewhat disagree
    iv. Strongly disagree

16. I think I have enough knowledge about how infections spread
    i. Strongly agree
    ii. Somewhat agree
    iii. Somewhat disagree
    iv. Strongly disagree

17. I think I have enough knowledge about how to protect my dog/cat from infectious diseases
    i. Strongly agree
    ii. Somewhat agree
    iii. Somewhat disagree
    iv. Strongly disagree

18. I think I have enough knowledge about antibiotic resistance
    i. Strongly agree
    ii. Somewhat agree
    iii. Somewhat disagree
    iv. Strongly disagree

19. I don't feel the need to look up more information regarding:
    i. Infections affecting dogs/cats
    ii. Antibiotic resistance
    iii. Infections that are transmitted between dogs/cats and humans

20. Which statement(s) about Echinococcosis are true?
    i. You can deworm dogs against Echinococcus
    ii. Infected dogs are asymptomatic
    iii. Infected dogs can spread echinococcus eggs in the environment
    iv. Humans can become infected through consumption of contaminated wild berries
    v. Humans infected with Echinococcus can develop an infection

21. Bite injury in cat
    i. Wounds can often heal well by themselves if the wound is cleaned
    ii. If an abscess develops, drainage is often needed
    iii. Abscesses often heal well without antibiotics
    iv. If the cat gets symptoms such as fever, loss of appetite, the wound becomes swollen, red and smells bad, it may mean that the wound has become infected

22. Dental care
    i. If my dog/cat has fractured a tooth, a veterinarian needs to examine the tooth
    ii. Tooth root abscess can occur as a complication of tooth fracture
    iii. Brushing is important to prevent inflammation and infection in the oral cavity
    iv. Where do you think you can find good information about infections that infect animals

23. If you have any comments/opinions about the survey, please write them down here

Appendix 3

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Hej!
Vill du delta i en undersökning, syftet är att skapa informationsunderlag om djursjukdomar och antibiotika till djurägare. Enkäten tar max 10 minuter att besvara
Jag är tacksam om ni skannar QR-koden och besvarar den digitala enkäten!

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