Wildlife, environment and (re)-emerging zoonoses, with special reference to sylvatic tick-borne zoonoses in North-western Italy

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Summary. Over the last century, changes in land-use, modification of agriculture-livestock production systems, disruption of wildlife habitats, increase of human activities, higher frequency of international and intercontinental travels, wider circulation of animals and animal products have contributed to alter the distribution, presence and density of hosts and vectors. As a result, the number of emerging and reemerging diseases, including zoonoses, have greatly increased. Some infectious pathogens, originated in wild animals and/or maintained in sylvatic environments, have become increasingly important worldwide for their impact on wildlife, human health, livestock and agricultural production systems. In this paper, a synthesis of the information available on selected zoonoses of wildlife origin is given, with special reference to sylvatic tick-borne zoonoses in North-western Italy.

Key words: wildlife, ecological research, veterinary public health, sylvatic tick-borne zoonoses, Italy.

Riassunto (Fauna selvatica, ambiente e zoonosi (ri-)emergenti, con particolare riferimento alle zoonosi silvestri trasmesse da zecche in Italia nord-occidentale). Nel corso dell'ultimo secolo, cambi d'uso del territorio e dei sistemi di produzione agro-zootecnici, sconvolgimenti degli habitat delle fauna selvatica, aumento delle attività umane, maggior frequenza di viaggi internazionali ed intercontinentali, più ampia circolazione di animali e prodotti di origine animale hanno contribuito ad alterare la distribuzione, presenza e densità di specie ospiti e dei vettori. Come conseguenza, il numero delle malattie emergenti e ri-emergenti, incluse le zoonosi, è fortemente aumentato. Alcuni agenti patogeni, che derivano da animali selvatici e/o che vengono mantenuti in ambiente silvestre, hanno assunto una sempre più grande importanza in ragione del loro impatto sulla fauna selvatica stessa, sulla salute umana, sulle specie zootecniche e sui sistemi di produzione agricola. Nel presente lavoro, viene fornita una sintesi delle informazioni disponibili su alcune delle zoonosi legate alla fauna e all'ambiente silvestre, con particolare riferimento alle zoonosi silvestri trasmesse da zecche in Italia nord-occidentale.

Parole chiave: fauna selvatica, ricerca ecologica, sanità pubblica veterinaria, zoonosi silvestri da zecche, Italia.

INTRODUCTION

The number and diversity of wildlife species all over the world is enormous. This abundance and variety of wild animals is distributed throughout different habitats and ecological niches. Such diversity of species and ecosystems may also support a large and diverse number of pathogens [1, 2]. Over the last century, global environmental changes have determined a bimodal evolution of wildlife: a great biodiversity loss with an increasing number of endangered/threatened species was observed, while some few opportunistic taxa augmented their distribution range and density [1, 2]. Increase of human activities, changes in land-use, modification of agriculture-livestock production systems, disruption of wildlife habitats, higher frequency of international and intercontinental travels, wider circulation of animals (pets, exotic animals) and products of animal origin – in association with environmental

and climatic changes – have contributed to alter the distribution, presence and density of hosts (wild and domestic) and vectors [1, 3]. As a result, there has been an increase or recrudescence of "old zoonoses" along-side with the emergence of "new ones". It is worth recalling that approximately 75% of the diseases, including zoonoses, which emerged during the last few decades are of wildlife origin [1, 4].

Recent and comprehensive review papers on the role of wildlife in (re-)emerging zoonoses and on the ecological sources of zoonotic diseases have been prepared, respectively, by Bengis *et al.* [1] and Slingenbergh *et al.* [3]. Detailed description of zoonoses and communicable diseases common to man and animals can be found in the reference books by Hugh-Jones *et al.* [5], and Acha & Syfres [6]. For the scope of this paper, a synthesis of the information available on selected zoonoses of wildlife origin has been attempt-

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ed. Information provided is based on the bibliographic sources mentioned above [1, 4-6], integrated with additional data obtained from websites of relevant international organizations, institutions and associations: World Organization for Animal Health (OIE) www.oie. int; Food and Agriculture Organization - Emergency Prevention System for Transboundary Animal and Plant Test Diseases (FAO/EMPRES) www.fao.org; World Health Organization (WHO) www.who.int; Pan American Health Organization (PAHO) www.paho. int; Centers for Disease Control and Prevention (CDC) www.cdc.gov; European Wildlife Disease Association (EWDA) www.ewda.org.

A brief description of some field experiences in ecological research on sylvatic tick-borne zoonoses in North-western Italy is also given, as an example of the importance of multi-disciplinary collaboration for research, prevention and control of tick-borne zoonoses.

ROLE OF WILDLIFE IN (RE-)EMERGING ZOONOSES

Bengis *et al.* [1] have listed some twenty (re-)emerging zoonoses in which wildlife and/or the sylvatic environment play an important role.

A brief description of selected zoonoses, including some from the above list, is given hereunder.

Hantaviruses. These agents cause haemorrhagic fever, with renal (HFRS) and pulmonary syndromes (HPS) in humans. Mortalities due to these syndromes varies greatly (up to 10% in case of HPRS, and 45% for HPS). HPS and HPRS are reported to occur in Europe, Asia and Americas. Human infection is by respiratory route from the excreta of wild rodents, which are asymptomatically infected and represent the natural maintenance hosts of these pathogens. These viruses are excellent examples of zoonoses agents that periodically spill over into human populations, with devastating effects.

Nipah virus. During the last decade, in different locations of the Eastern hemisphere, some paramyxoviruses (previously unknown) have caused outbreaks of "new" and fatal diseases in humans and animals. In 1998-99, a contagious neurological and respiratory disease in pigs, and simultaneous outbreaks of encephalitis in workers of the affected farms and local slaughter-houses were reported in various location of Malaysia. Mortality rate in piglets was as high as 40%, and more than 260 cases of viral encephalitis were reported in humans, with 38% fatality rate. Fruit bats (Pteropus spp.) are the natural host and reservoir of this "new" virus, called Nipah virus. The virus emerged as a result of changing ecological features (bush fires and rocketing rates of deforestation in Southeast Asia, severe droughts, etc.), associated which expansion of agricultural areas and pig industry; fruit bats were then forced to move from their previous natural forest habitats to the nearest agricultural areas (a mosaic of villages, vegetable and fruit gardens, and pig farms). As a result, the "new" virus was transmitted to pigs, and then to humans. During 2001-2004, Nipah virus infection was also confirmed in Bangladesh, but in this case patients might have been infected directly through the consumption of fruit contaminated by bats.

West Nile virus (WNV). This flavivirus - maintained in a wide range of wild bird species and in Culicidae mosquitos – is known to periodically occur in Europe, Africa and Western Asia. WNV generally causes an influenza-like illness and encephalitis in some mammalian hosts, including horses and humans. During the period 1999-2003, WNV was involved in an unprecedented number of meningo-encephalitis outbreaks in North America, causing more than 500 human deaths; also horses were affected. WNV has spread from the east coast of the USA to the west, affecting the whole country. High morbidity and mortality rate was observed in many autochthonous bird species, especially in corvids. WNV is now established in North America and may pose a risk for Central, South America and the Caribbean, due to Southwards movements of migratory birds.

Severe acute respiratory syndrome (SARS) and zoonotic avian flu (Influenza A). In Southeast Asia, during 2002-2003, a novel coronavirus emerged as the cause of a severe respiratory syndrome in humans. First cases of infections and disease syndromes have been associated with palm civets, a small carnivore quite common in the region. The expanding trade of these wild or pseudo-domesticated carnivores (for food or other by-products) was claimed to have triggered the epidemics. In traditional local markets throughout Asia, intensive and prolonged contacts amongst livestock, poultry, wild animals and humans occur routinely; these places are thus ideal "melting pots" for pathogens transmission and cross-over between species, not only for SARS, but also for avian flu (AI). Serious epidemics and pandemics caused by AI virus have occurred many times in humans, birds, horses, pigs and marine mammals. AI strains isolated from wild birds do not usually cause much harm in their natural hosts, but it may occur that - due to genetic mutation or recombination - these viruses become well adapted to poultry, pigs and humans, turning highly pathogenic to these new target hosts. Since 1997, H5N1 AI strains have been causing high poultry mortalities in Southeast Asia, with human deaths directly associated to poultry-human contacts. In July 2005, H5N1 has expanded in a North-westerly direction, and both Russia and Kazakhstan reported outbreaks in poultry and in wild birds. There is a potential risk that H5N1 might be carried along migration routes of wild water birds to densely populated areas in the South Asian subcontinent, and subsequently, along intermingling migratory flyways, to Africa and Europe¹.

¹Only a few months after the present paper was written, new outbreaks of Avian Influenza (H5N1 strains) have been reported in both domestic and wild birds from Middle East, Europe and Africa. Since the start of the poultry epidemic in Asia, cats and other felidae have been also occasionally found to be infected with H5N1. More recently, H5N1 virus was detected in a domestic cat found dead on the northern island of Ruegen (Germany). Since mid-February 2006, over 100 birds have died on this island and tests confirmed H5N1 infection.

Monkeypox virus. Tree squirrels and other rodents of the African tropical forests are known reservoirs of this poxvirus. Human cases of monkeypox virus infection have been sporadically reported in West and Central Africa, especially in hunters or in people handling the reservoir species. In most recent years, after smallpox vaccination was globally discontinued, many people from African countries ravaged by civil war - involved in poaching and subsistence hunting, became infected with high fatality rates. In 2003, monkeypox made headlines in North America when exotic pet owners contracted the disease from prairie dogs, accidentally infected by imported African rodents. This monkeypox outbreak in humans and prairie dogs is one of the visible results of international pet trade, increased number of people owning exotic animals and captive wildlife.

Rabies and related Lyssavirus infections. Lyssaviruses include classical rabies and other rabies-related viruses, comprising 7 genotypes and different strains. Rabies still causes some 50 000-100 000 human deaths annually, mainly in developing countries. Although more than 1700 cases of rabies in wildlife have been reported in Europe (in 2004), wildlife associated rabies in humans has become rare, and most rabies cases in humans are linked to dogs (domestic or stray ones). Different strains of Lyssavirus genotype 1 - the classical rabies virus with worldwide distribution - have adapted in different but specific wild carnivore hosts, as well as in vampire bats. Bats (insectivorous and fruit bats) represent the most frequent maintenance hosts for most genotypes and many strains of rabies viruses in Africa, Europe, Asia and Australia.

Rift valley fever (RVF). This mosquito-borne viral disease of ruminants and man is characterized by abortions, haemorrhages, hepatitis, and encephalitis. RVF outbreaks and epidemics tend to occur at cyclical intervals, mainly associated with climatic conditions favouring mosquito vectors. During the long inter-epidemic periods, RVF virus is mainly maintained in Aedes mosquitoes (characterised by transovarial transmission and egg hatching latency), but it believed that wild vertebrate hosts (rodents, antelopes, wild bovids) could play a role of in the epidemiology of RVF. Changing climate and environmental conditions, in association with a varying pattern of livestock trade, have made it possible for RVF virus to extend its former geographical range outside Africa (in the Arabian peninsula). These recent events have raised a serious concern for a potential risk of RVF expanding its range to most of the Mediterranean Basin.

Tuberculosis and brucellosis. These "old" and well-known bacterial diseases are good examples of infections which can spread between domestic and wild animals (and viceversa), and thence to humans. The increased incidence of these diseases could be attributable to modification in breeding systems, ecological and land-use changes, increased interactions of livestock with wildlife. In European countries, *Mycobacterium bovis* is reported in badgers, wild boars and cervids. In North America, bovine tuberculosis occurs in bison and deer populations. In New Zeland, M. bovis is maintained in possums and ferrets, while in Australia it has been signalled in wild water buffalo. In Africa, it is being reported in many wild ungulates species (mainly Cape buffalos) and in carnivores (mainly lions). As regards brucellosis, Brucella abortus and B. melitensis are the most commonly transmitted species between wild and domestic ungulates (bison and deer, in USA). B. suis is another Brucella species occurring in wild animals: biotype 1 occurs in wild boars and feral pigs; biotype 2 affects brown hares and wild boars (also domestic pigs), and is commonly reported in France; biotype 4 continues to be found in reindeer and caribous in North America. Most recently, some species not yet completely characterised - called "marine Brucella" - have been reported in seals and whales.

Other recent (re-)emerging zoonotic infections originating from wildlife reservoirs, although not related exclusively to wild animals and/or to sylvatic environment, are plague, leptospirosis, Crimean-Congo Haemorrhagic fever, anthrax, tularemia, trichinellosis and alveolar echinococcosis.

Sylvatic tick-borne zoonoses, with special reference to Lyme borreliosis, will be specifically dealt with in the following paragraph.

SYLVATIC TICK-BORNE ZOONOSES: FIELD EXPERIENCES IN ECOLOGICAL RESEARCH ON LYME BORRELIOSIS IN NORTH-WESTERN ITALY

In Italy, like other industrialised European countries, the incidence of sylvatic tick-borne zoonoses has increased over the last decades. Land use changes - abandonment of areas that were once dedicated to traditional agriculture, and their colonisation by woodlands, in conjunction with the rapid increase of wildlife population - created favourable conditions for Ixodid ticks, particularly Ixodes ricinus [7]. This tick is the western European vector of Borrelia burgdorferi s.l., agent of Lyme borreliosis (LB), the most frequent vector-borne zoonosis in the Northern hemisphere. Recent increase of recreational activities in wildlife/woodland areas greatly augmented the incidence of tick bites in man, hence the risk of infection by tick-borne pathogens [7]. In Italy, LB is endemic in many areas of the country, and within the vector geographic range, intensity of B. burgdorferi s.l. transmission is highly heterogeneous. The reported prevalence of infection in host seeking ticks varies greatly, and consequently the risk of infection for man and for susceptible animal hosts [7, 8].

As the different stages of *I. ricinus* feed on different wild animals species – characterised by different level of competence as reservoirs for *B. burgdorferi* s.l. – the intensity of LB transmission is conditioned by the role played by micro-mammals and birds (competent reservoirs), and by wild ungulates – mainly deer (non-competent reservoirs) as host for ticks. For the above reasons, ecological research plays an important role in the evaluation of LB transmission risk, and a multidisciplinary approach is needed to get an insight of the ecological

dynamics of sylvatic tick-borne zoonoses. Therefore, a collaborative effort by veterinarians, physicians, epidemiologists, eco-pathologists, microbiologists, parasitologists, wildlife managers, etc. is extremely important in order to assess the real risk of exposure, both at small and large geographical scale [7, 8].

As an example of this kind of interdisciplinary approach, an overview of the research activities carried out by a multidisciplinary team (co-ordinated by the Department of Animal Production, Epidemiology and Ecology or DPAEE, University of Turin) is hereafter given. The four study areas are located in Liguria (Borzonasca-Chiavari, Genoa province), Piedmont (Squaneto, and Villarvernia, Alessandria Province) and Tuscany (Montefalcone, Lucca province). These study areas are markedly different as regards land use, and wildlife population and human density: the one in Liguria is characterised by a high human density, with no wild ungulates, except wild boars [9]; Squaneto study area is characterised by scarce human settings, with a high density of roe deer [10], while the other one in Piedmont (Villarvernia) has virtually no wild ungulates, and human population is low [11]; the latter (in North Tuscany) is quite distinct from the other study areas for being a fenced forest reserve, with quite low density of wild ungulates, and restricted access of the general public to the area [12].

In order to assess the acarological risk of exposure to agents of sylvatic tick-borne zoonoses, a research protocol including the following was designed for each of these study areas:

- collecting host-seeking ticks;
- studying the intensity of infestation by ixodid ticks in wild hosts (wild rodents, roe deer, birds, lizards);
- collecting data on the incidence of ticks infesting humans;
- collecting biological samples (blood, skin biopsies, lizards'tails);
- performing laboratory analysis to identify pathogens in vector ticks and biological samples.

The first Italian case of LB was reported in 1984 from the study area in Liguria, where LB annual incidence has been estimated at 17 cases/100 000 inhabitants [13]. In Chiavari-Borzonasca ticks were present throughout the year, with significant nymphs and adult peaks, respectively in spring and autumn. About 18.2% of the ticks submitted to PCR (31/170) were positive for *B. burgdorferi* s.l. [9]. Prevalence of infection in ticks was significantly lower than in other LB endemic areas in North-eastern Italy (Friuli-Venezia Giulia region; over 50% infection prevalence in nymphs).

In Squaneto study area, *I. ricinus* ticks were also found all year round, even in coldest months. Host-seeking ticks were more abundant than in Liguria. High intensity of *I. ricinus* infestation was reported in roe deer (over 1,000 immature ticks on metacarpi of hunted deer). Ticks infesting humans have been often reported from the area. However, prevalence of infection in ticks was negligible: *B. burgdorferi* s.s. was identified by DNA sequence analysis from only one out of 3 adults and 132 *I. ricinus* nymphs which were tested by PCR [10]. In Villarvernia, birds (n. = 1206) belonging to 59 species were live captured by using mistnets. *I. ricinus* larvae were collected from 59 birds belonging to 9 species, and nymphs were recovered on 79 birds belonging to 10 species. Blackbirds had significantly higher levels of infestation by ticks than other passerine species. *B. burgdorferi* s.l. was identified by PCR in 58.3% of larvae [11]. Larvae that were collected from other passerine species gave negative PCR results. Sixteen of 21 PCR-positive samples belonged to *B. garinii* (76.2%), and 5 (23.8%) were *B. valaisiana*. Results of this study suggest that blackbirds play an important role as hosts for immature *I. ricinus*, and as reservoir of *B. garinii* in North-western Italy [11].

In Montefalcone forest reserve, ticks were collected on the ground by dragging, and on vertebrate hosts (mice, common wall lizards, passerine birds). Ticks (identified as I. ricinus and Rhipicephalus spp.), ear biopsies from mice, blood from birds, tails and blood from lizards were submitted to PCR for the detection of tick-borne pathogens [12]. B. burgdorferi s.l. was found in 22.1% of host seeking *I. ricinus* (n. = 167), in 8% of host seeking Rhipicephalus spp. (84% of the strains were characterized as B. lusitaniae); rickettsiae of Spotted Fever Group were found in 36.7% of examined host seeking I. ricinus (n. = 117), and in 50% of host seeking Rhipicephalus spp. (n. = 12). An interesting finding was that B. lusitaniae was detected in 16 out of 70 ticks (22.9%) collected from lizards, and in two out of 14 (14.3%) lizard tails, and in two out of eight (25.0%) lizard blood samples [12]. These results suggest that lizards might play a major role as reservoirs for B. lusitaniae in the study area.

Results from these inter-disciplinary researches showed – in all study areas – the presence of abundant *I. ricinus* populations which are active throughout the year. Moreover, acarological risk, prevalence of infection by *B. burgdorferi* s.l. in vector ticks, and number of reported LB human cases differed markedly in the four locations. These findings are consistent with the known mosaic-like pattern of LB distribution, and confirm an highly heterogeneous intensity of *B. burgdorferi* s.l. transmission [7, 9].

Ecological researches can generate useful set of data and information that could be used to quantify the relationship between tick abundance and seasonal dynamics, host availability and infection prevalence in tick populations with pathogenic agents, and develop epidemiological models of tick-borne diseases, driven by landscape and climate changes, as well as socio-economical changes. Such a set of methods and skills (predictive models, early warning and monitoring tools) can be used by decision makers for risk assessment, decision support for intervention and public health policies.

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References

- 1. Bengis RG, Leighton FA, Fischer JR, Artois M, Mörner T, Tate CM. The role of wildlife in emerging and re-emerging zoonoses. *Rev Sci Tech Off Int Epiz* 2004;23(2):497-511.
- Lanfranchi P, Ferroglio E, Poglayen G, Guberti V. Wildlife veterinarian, conservation and public health. *Vet Res Comm* 2003;27(Suppl.1):567-74.
- Slingenbergh J, Gilbert M, de Balogh K, Wint W. Ecological sources of zoonotic diseases. *Rev Sci Tech Off Int Epiz* 2004;23:467-84.
- Brown C. Emerging zoonoses and pathogens of public health significance – an overview. *Rev Sci Tech Off Int Epiz* 2004;23:435-42.
- Hugh-Jones M, Hubbert WT, Hagstad HV. Zoonoses-recognition, control, and prevention. Ames: Iowa State University Press; 1995.
- Acha PN, Szyfres B. Zoonoses and communicable diseases common to man and animals. 3rd ed. (3 Voll). Washington DC: PAHO Publ.; 2001, 2003.
- Meneguz PG, De Meneghi D, Mannelli A, Peyrot R. Importance of ecological research to study the risk of tick-borne zoonoses: field experience in Southern Piedmont, Italy. *SISvet Annual meeting selected abstracts* 1999; Anno I (Vol.I): 113-4.
- Mantovani A, Battelli G, Caprioli A, Cosivi O, De Meneghi D, Pasquali P, Poglayen G, Seimenis A. Multidisciplinary approach to veterinary public health delivery system at community level. In: FAO Animal Production & Health Proceedings

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no. 2. Proceedings Expert Consultation on Community-Based Veterinary Public Health Systems. Rome, 27-28 October 2003. Rome: FAO Publ.; 2004. p. 79-110.

- Mannelli A, Boggiatto G, Grego E, Cinco M, Murgia R, Stefanelli S, De Meneghi D, Rosati S. Acarological risk of exposure to agents of tick-borne zoonoses in the first recognised Italian focus of *Lyme borreliosis*. *Epidemiol Infect* 2003;131:1139-47.
- De Meneghi D, Peyrot R, Mannelli A, Meneguz PG, Boggiato G, Tomassone L. Ecology of *Ixodes ricinus (Acarina: Ixodidae)*, and identification of *Borrelia burgdorferi* s.s. in ticks from South-western Piedmont (Italy). *Parassitologia* 2002;44(Suppl.1):54.
- Mannelli A, Nebbia P, Tramuta C, Grego E, Tomassone L, Ainardi R, Venturini L, De Meneghi D, Meneguz PG. Borrelia burgdorferi sensu lato infection in larval Ixodes ricinus (Acari: Ixodidae) feeding on Blackbirds in Northwestern Italy. J Med Entomol 2005;42:168-75.
- 12. Tomassone L, Bertolotti L, Tramuta C, Nebbia P, Amore G, Ambrogi C, Ragagli C, Mannelli A. Bacterial tick-borne pathogens in ticks and vertebrate hosts in Tuscany (Italy). In: *Proceedings of 5th International Conference on Ticks and Tick-Borne Pathogens*, Neuchatel (CH), 29 August- 2 September 2005. Neuchatel, University of Neuchatel Publ.: 2005. p. 220-2.
- Cimmino MA, Fumarola D, Sambri V, Accardo S. The epdemiology of Lyme borelliosis in Italy. *Microbiologica* 1992;15:419-24.