National competence center for wildlife diseases in Switzerland: Mandate, development and current strategies

M.-P. Ryser-Degiorgis, H. Segner

Centre for Fish and Wildlife Health, Vetsuisse-Faculty, University of Bern

DOI 10.17236/sat00019

Received: 10.03.2015
Accepted: 17.03.2015

Abstract

The need for wildlife health surveillance has become increasingly recognized. However, comprehensive programs which cover a wide spectrum of species, pathogens and geographic areas are still lacking in most European countries and practical examples of systems in place remain scarce. This article provides an overview of the organization of wildlife health surveillance in Switzerland, with a focus on the development, current strategies and the activities of the national program carried out by the Centre for Fish and Wildlife Health (FIWI), University of Bern. This documentation may stimulate on-going discussions on the design and development of national wildlife health surveillance programs in other countries. Investigations into wildlife health in Switzerland date back to the 1950s. The FIWI acts as a national competence center for wildlife diseases on mandate of the Swiss federal authorities. The mandate includes four main activities: disease diagnostics, research, consulting and teaching. In line with this, the FIWI has made continuous efforts to strengthen a national network of field partners and implemented strategies to facilitate long-term and metastudies.

Keywords: diagnostics, health, research, surveillance, wild animals

Nationales Kompetenzzentrum für Wildtierkrankheiten in der Schweiz: Auftrag, Entwicklung und gegenwärtige Strategien

Der Bedarf nach Überwachung der Wildtiergesundheit wird zunehmend anerkannt. Allerdings fehlen in den meisten europäischen Ländern nach wie vor umfassende Programme, die ein breites Spektrum von Tierarten, Krankheitserregern und geographischen Gebieten abdecken, und praktische Beispiele laufender Programme bleiben selten. Dieser Artikel gibt einen Überblick der Organisation der Wildtiergesundheitsüberwachung in der Schweiz mit Fokus auf der Entwicklung, den gegenwärtigen Strategien und den Aktivitäten des nationalen Programms, das vom Zentrum für Fisch- und Wildtiermedizin (FIWI) an der Universität Bern durchgeführt wird. Diese Dokumentation soll laufende Diskussionen über die Gestaltung und den Ausbau nationaler Gesundheitsüberwachungsprogramme für Wildtiere in anderen Ländern stimulieren. Untersuchungen von Wildtierkrankheit in der Schweiz gehen auf die 1950er Jahre zurück. Das FIWI wirkt als nationales Kompetenzzentrum für Wildtierkrankheiten gemäss Auftrag der Bundesbehörde. Der Auftrag beinhaltet vier Hauptaktivitäten: Diagnostik, Forschung, Beratung und Lehre. Demnach hat sich das FIWI kontinuierlich bemüht, sein landesweites Netzwerk von Feldpartnern auszubauen, und es hat Strategien implementiert, die langfristige und Metastudien ermöglichen.

Schlüsselwörter: Diagnostik, Forschung, Gesundheit, Überwachung, Wildtiere

Introduction

The threat of diseases to wildlife conservation and biodiversity, the increasing risk of pathogen transmission between wild and domestic animals, as well as the emergence of zoonoses of wildlife origin are of growing concern worldwide. The need for wildlife health surveillance has therefore become increasingly recognized during the past decade (Daszak et al., 2000; Harvell et al., 2002; Chomel et al., 2007; Gortázar et al., 2007; Hoberg et al., 2008). The World Health Organization (WHO), Food and Agriculture Organization of the

National competence center for wildlife diseases in Switzerland: Mandate, development and current strategies

M.-P. Ryser-Degiorgis, H. Segner

United Nations (FAO), the international organization of animal health (OIE) and the European Food Safety Authority (EFSA) have all recognized the need to conduct health surveillance in wildlife. As an example, the OIE recommends to give the same importance and thoroughness to the surveillance and control of diseases in wildlife as applied to farm animals.

Surveillance is the on-going recording of diseases in animal populations with the aim of disease management. In short, surveillance means "information for action". Surveillance data are needed for early detection of disease outbreaks and emerging diseases, for priority setting and decision-making, for timely and adequate response to new disease events, to document a disease free status and to understand the factors driving disease dynamics. General or scanning (formerly: passive) surveillance is defined as the recording of cases (dead or diseased) as they occur and are submitted for investigation. In the case of wildlife, it aims at identifying disease events in which wild animals are the victims. It is typically performed by pathological investigation of animal carcasses followed by further laboratory analyses. It differs from targeted (active) surveillance, which implies pro-active sampling of live or dead animals to detect a specific pathogen or disease independently of the health status of the animals. Traditionally, targeted surveillance of wildlife has relied on a cross-sectional study design and aimed at the identification of risk factors associated with disease, pathogen or antibody prevalence (Ryser-Degiorgis, 2013a). The objective, concepts and methodology of investigations into wildlife health are similar to those of domestic animal health surveillance. But given the zoological, behavioral and ecological characteristics of wildlife populations, there are also some substantial differences that need to be taken into account when planning for, implementing and interpreting data from investigations into wildlife health (Ryser-Degiorgis, 2013a). Major challenges include the access to investigation materials, the limited reliability of diagnostic tests developed for domestic animals when applied on wildlife species, differences in the pattern of diseases between domestic and wild species, the lack of population data, the limited knowledge on physiology and immunology of wild animal species, and the role of multiple factors in the observed disease patterns, including the life history of the host and the landscape structure.

Comprehensive surveillance programs which cover a wider spectrum of wildlife species, pathogens and geographic areas, are still lacking in most European countries and practical examples of systems in place remain scarce. In fact, Switzerland is one of the few European countries with both a long history of wildlife health surveillance and an existing comprehensive general surveillance program for wildlife health (Kuiken et al., 2011). This article provides an overview of the organization of wildlife health surveillance in Switzerland. In particular, it describes the development, current strategies and nature of the activities of the national program carried out by the Centre for Fish and Wildlife Health (FIWI) in Bern. The output of this program is described elsewhere (Ryser-Degiorgis, 2013b). Here, the aim is to document how wildlife health surveillance is currently performed by the FIWI and to stimulate on-going discussions on the design and development of surveillance programs in other countries willing to setting up a national wildlife health surveillance program.

Institutions involved in wildlife health investigations in Switzerland

There is no single national organization in charge of all investigations of wildlife health and ecology in Switzerland. Instead various groups with competence in different wildlife topics are mandated on either short- or long-term basis by the Federal Food Safety and Veterinary Office (FSVO) and Federal Office for the Environment (FOEN). The disadvantage of this construct is that no central database exists to document health and ecological status of wildlife in Switzerland. Targeted investigations are performed by several reference laboratories such as the Institute of Virology and Immunology, which includes the Swiss Rabies Center and is in charge of diagnosing highly contagious notifiable infectious diseases. General surveillance of wildlife health is carried out by the Institute Galli-Valerio in Lausanne, two institutes at the University of Zurich, and the FIWI at the University of Bern.

The Institute Galli-Valerio (IGV) has played a major role in general wildlife health surveillance since the 1950s (e.g. Bouvier et al., 1958; Burgisser, 1983). However, in the past decade budget restrictions have progressively led to a reduction of the wildlife caseload handled by the IGV. It still carries out routine wildlife investigations on cantonal mandate, draining cases from the French-speaking region of Switzerland, but wildlife health surveillance has progressively become a side activity (15-21 wild mammals and birds per year in 2009-2011). At the University of Zurich, the Department of Poultry Diseases of the Institute of Veterinary Bacteriology performs necropsies on wild birds (29-48 cases per year in 2009-2011); this laboratory is also the national reference center for important avian diseases (such as avian influenza and Newcastle disease) and lagomorph diseases (myxomatosis and rabbit hemorrhagic disease). In addition, a small number of wildlife necropsy cases are performed at the Institute for Veterinary Pathology (17 cases in 2011). The FIWI works on a national man-

date of the FOEN and FSVO and receives the majority of submitted cases (226-322 cases per year in 2009-2011). The FIWI includes a group entirely dedicated to wildlife health and whose tasks include scanning surveillance, targeted investigations, research programs as well as training and education in wildlife health.

History and general mandate of the FIWI

In 1956, the Division for Poultry, Game and Fish Diseases was founded within the Institute of Veterinary Bacteriology at the University of Bern. The federal authorities provided financial support from 1962 onwards (Schatzmann et al., 2004). In 1986, the Division was moved to the Institute of Veterinary Pathology (ITPA) of the University of Bern. In 1997 the Division for Poultry Diseases was moved to the University of Zurich, while wildlife and fish competences remained at Bern. In January 1998, the Division for Game and Fish Diseases and the zoo animal team of the ITPA were merged to found the FIWI, with Professor Willy Meier as a head. At the end of 2009, activities related to zoo animals and exotic pets were re-integrated into the domestic animal section of the ITPA. This reflected the fact that fish and wildlife investigations were increasingly oriented towards a population medicine approach, in contrast to the predominating individual animal focus of the zoo animal diagnostics. In January 2014, the FIWI (including its two groups: Fish and Wildlife) became an independent entity within the Department of Infectious Diseases and Pathobiology of the Vetsuisse Faculty Bern.

The Swiss Ordinance on Hunting and Protection of Free-living Mammals and Birds (no. 922.01) stipulates that the FOEN shall support practice-oriented research in wildlife biology and ornithology, in particular investigations into species conservation, deterioration of habitats, damage due to wildlife and diseases of wildlife (Article 11.2). This legal basis led to the mandate of the FOEN to the former Division for Game Diseases for the surveillance of wildlife health and research on wildlife diseases in Switzerland. Thus, the general mandate of the FIWI Wildlife Group (FIWild) was originally given by the FOEN based on this ordinance, while the activities of the FIWI Fish Group were mostly supported by the FSVO. Starting in 2005, the tasks of both groups were redefined in a common cooperation contract and associated performance agreement with the FOEN and FSVO, this agreement being revised every year.

The mandate of the FIWI is to act as a national competence center for diseases of free-living and captive fish and wildlife (the latter being understood as wild animals other than fish and invertebrate aquatic organisms). This includes four main activities: (1) accredited diagnostics of diseases; (2) internationally competitive and recognized research on infectious and non-infectious diseases. This encompasses research on the pathogenesis, pathology and epidemiology of fish and wildlife diseases, the role of ecological and anthropogenic disease-inducing factors, the importance of fish and wildlife as pathogen source for domestic animals and humans, and research related to fish and wildlife welfare; (3) consulting for governmental agencies, non-governmental organizations and private persons; and (4) academic training of under- and postgraduate students and early stage researchers, as well as the continuing education of practitioners, public authorities and other stakeholders (Fig.1).

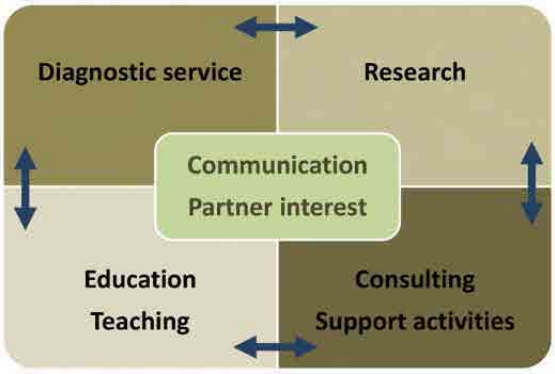

Figure 1: FIWild tasks and synergistic effects. The main tasks of the FIWild are all interconnected, resulting in synergystic effects based on a «give and take» principle. Good communication (including pro-active information, feedbacks, personal contacts and the use of an appropriate language), diagnostics and consulting of high quality as well as teaching and education will positively influence the interest of field partners in wildlife health, which in turn will determine how they will contribute to general surveillance and research activities. Knowledge from diagnostics and research are important to provide good education and consulting. Observations from general surveillance contribute to determine needs for research, and research data improve competences for diagnostics.

Specific tasks and current strategies of the Wildlife Group (FIWild)

The basic mandate of the FIWild (diagnostics, research, consulting and teaching) has remained the same for at least two decades. In practice, however, the specific tasks have progressively grown to cover a larger spectrum of activities. In particular, there has been an increasing demand for support of wildlife captures in the fields, contributions to hunters' education in wild meat hygiene, and targeted investigations of important livestock pathogens in wild populations. A large part of the activities of the FIWild is concerned with mammals. This

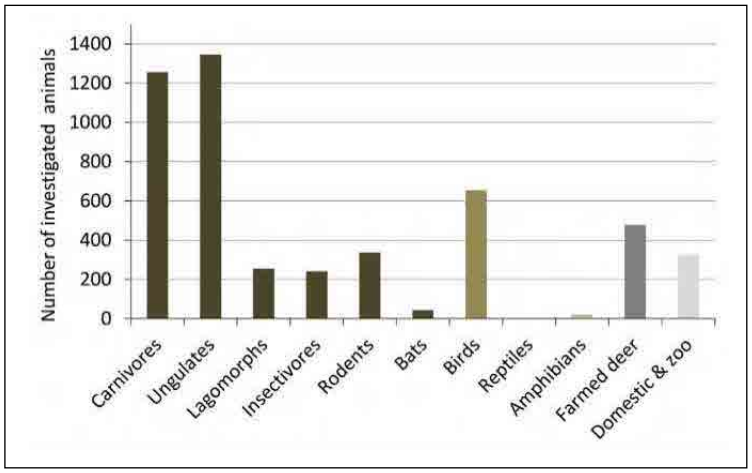

Figure 2: Number of cases submitted for postmortem investigation to the FIWild in the past 21 years. Unless otherwise specified, numbers refers to free-ranging indigenous wildlife. Cases are classified according to taxonomic groups. Investigated domestic and zoo animals were submitted for diagnostic of predation or in the framework of analyses related to wildlife damages.

largely reflects human interests: hunting activities, conservation efforts in the past decades and damages of human property have mostly been related to mammal species. Furthermore, due to their genetic relatedness, wild mammal species represent the greatest risk for pathogen transmission to/from livestock and domestic pets. Last but not least, mammals have been shown to represent the major source of zoonotic infections (Ostfeld and Holt, 2004; Wolfe et al., 2007). Birds closely follow mammals in the number of investigated animals and in their importance in hunting activities, damage to human property and the risk they represent for domestic animal and human health. Other taxa have rarely been investigated at the FIWild so far (Fig. 2).

Diagnostic service

The routine diagnostic service of the FIWild encompasses: (1) scanning surveillance of the health of free-ranging wildlife in Switzerland, and to a growing extent in the Principality of Liechtenstein; (2) pathology examinations of farmed deer; and (3) forensic investigations, in particular in relation to predation and poaching. In the framework of scanning surveillance, the FIWild is an important component of the early warning system of the FSVO (Hadorn et al., 2014).

Investigated material consists of animal carcasses or organs submitted mainly by game wardens and hunters, but also by the police, veterinarians, field biologists, private persons and other organizations. Postmortem analyses include at minimum a gross necropsy following accredited standard protocols. The approach is usually question-oriented. Histological, parasitological and bacteriological analyses are regularly performed, while virological, toxicological, genetic and radiological investigations are less common. The final diagnostic report includes an interpretation for non-veterinarians. It is sent to the submitter and the relevant cantonal offices. All FIWild necropsy cases are recorded in a database that enables long-term observations and retrospective analyses.

The number of investigated cases has nearly doubled in the past 20 years. From 1994-1999, an average of 156 cases were investigated per year (range: 105-188 cases) while an average of 282 cases were submitted in the past five years (range: 222-323). Requests for forensic investigations occur regularly, particularly in the context of poaching and suspected predation by wild carnivores and domestic dogs. Carcasses of protected species such as lynx (*Lynx lynx*) and wolves (*Canis lupus*) are systematically reported and investigated in-depth, independently of the cause of death. The Swiss management plans for the Eurasian lynx, grey wolf and brown bear (*Ursus arctos*) (BAFU, 2009, 2010; BUWAL, 2004) stipulate that any carcass of these species must immediately be submitted to the FIWI for postmortem investigation. Systematic collection of dead beavers (*Castor fiber*) has also been periodically performed (Wimmershoff et al., 2012), and the submission of wildcats (*Felis sylvestris*) is strongly encouraged (CSCF, 2012). All submitted mid-size to large mammals belonging to a protected species are necropsied according to a standard protocol, including body measurements, pictures for individual identification, x-rays, systematic histological examination of main organs and collection of samples to be archived. To promote collaboration among biologists, taxidermists and veterinarians, postmortem investigations often consist in a compromise between analysis and body preservation: valuable body parts are preserved for exhibitions and scientific research (Thüler, 2002).

The discovery of disease events with epidemic character in the frame of routine diagnostic activities (scanning surveillance) requires in-depth clarification. If the disease is truly emerging, investigations are necessary to determine its origin and current distribution (Fig. 3). As an example, the first cases of babesiosis in chamois were diagnosed in 2005 and the potential impact of this apparently new disease on the local chamois population was of concern (Hoby et al., 2007). The FIWild initiated research activities to better describe the pathogen and assess the source of infection as well as the distribution of the pathogen in animal populations (Schmid et al., 2008; Hoby et al., 2009; Michel et al., 2014). Similarly, an outbreak of canine distemper in wild carnivores and of salmonellosis in passerine birds were followed by pathological, epidemiological and molecular investigations (Origgi et al., 2012; Giovannini et al., 2013). If disease etiology cannot be determined, syndro-

mic approaches are applied to study risk factors such as sex, age, geographical location and seasonality of diseases, and to formulate hypotheses regarding potential disease causes (Euzenat, 2004). Syndromic approaches are also used for early detection and monitoring of diseases with typical macroscopic signs, such as the first cases of sarcoptic mange in wild boar in Switzerland (Haas et al., 2015). Finally, diagnostic data are used for retrospective studies to provide an overview on disease occurrence in selected species, identify spatio-temporal trends and potential needs for targeted investigations (Schmidt-Posthaus et al., 2002; Euzenat, 2004; Wimmershoff et al., 2012).

Research

FIWild research is devoted to three categories of diseases: (1) those affecting wildlife, with a potential impact on populations; (2) those affecting domestic animals, where wildlife may play a role as a pathogen reservoir; (3) zoonoses. Examples of the first category are the research projects on infectious keratoconjunctivitis in wild Caprinae (Giacometti et al., 2002; Ryser-Degiorgis et al., 2009; Mavrot et al., 2012a, 2012b), on causes of mortality in brown hares (*Lepus europaeus*) (Büttner, 1996; Frölich et al., 2001; Haerer et al., 2001), investigations on sarcoptic mange in red foxes (Dürr et al., 2010; Nimmervoll et al., 2013) and on the potential role of infectious diseases in the observed population decrease of Alpine ibex (Marreros et al., 2010, 2011, 2012).

The importance of wildlife for diseases affecting livestock and humans has increasingly come into the focus of the FIWild research over the past decade. A first project in this field, mandated by the FSVO, was related to the bovine spongiform encephalopathy crisis (Meslin et al., 2000). The question was whether meat from farmed game might be a risk to consumers as there was a parallel emergence of a prion disease (chronic wasting disease) in deer of Northern America. Switzerland became one of the first European countries to investigate game species for this disease (Sieber et al., 2008, 2010). Research on wildlife was also required in the context of the eradication program of bovine virus diarrhea and of the bluetongue vaccination campaign, since wildlife populations may have acted as pathogen reservoirs (Casaubon et al., 2012, 2013). Another example is the discussion on the role of wild boar in diseases of domestic livestock. In its function as national competence laboratory for wild boar diseases, the FIWild has investigated a range of pathogens potentially occurring in wild boar, such as brucellosis (Köppel et al., 2007; Abril et al., 2011; Wu et al., 2011, 2012), bovine tuberculosis (Schöning et al., 2013), enzootic pneumonia (Batista Linhares et al., 2015) and Aujeszky's disease (Meier et al., 2014), and documented wild boar distribution and interactions with domestic swine (Wu et al., 2012).

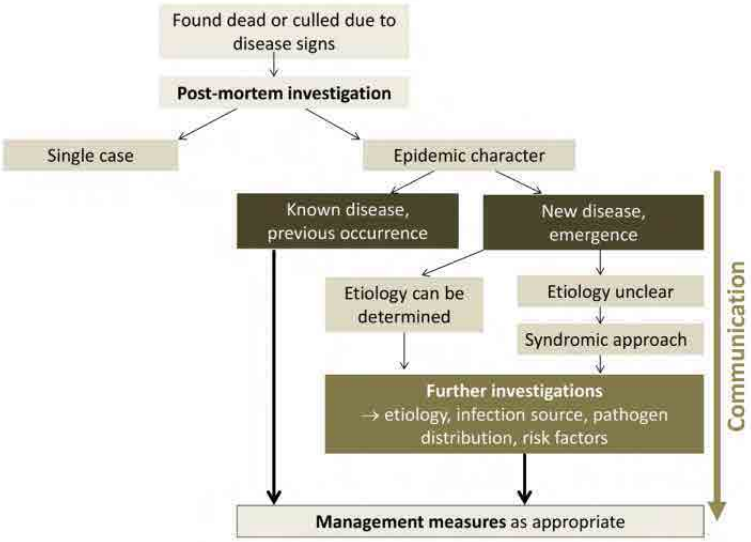

Figure 3: Scanning disease surveillance in wildlife and early warning strategies. Pathological investigations represent the first of several steps after reporting of cases from the field has occurred.

Because wildlife does not live within national borders and no less than five countries surround Switzerland, international collaboration has been promoted to evaluate the risk of trans-boundary pathogen movement by wild animals. For example, the FIWild has participated in international projects on bovine tuberculosis in Alpine wildlife (Fink et al., 2015) and on harmonization efforts in the monitoring of wildlife population health and abundance in Europe (www.aphaea.eu). In recent years, a European wildlife health surveillance network has been setup, aimed at the rapid exchange of information among countries (early warning) and at facilitating access to expert knowledge (Kuiken et al., 2011). The FIWild is among the institutions contributing to this network development and actively participating in it by sharing information on relevant diagnostic cases. Such international communication channels are essential for reseach on and management of wildlife diseases.

FIWild research on zoonoses includes contributions to projects of other laboratories, such as studies on trichinellosis (Frey et al., 2009), Hepatitis E Virus infections (Burri et al., 2014) and tularemia (Origgi et al., 2014), as well as the regular diagnostic and research activities on diseases with zoonotic risk such as brucellosis (Wu et al., 2011), bovine tuberculosis (Schöning et al., 2013), leptospirosis (Giovannini et al., 2012), salmonellosis (Giovannini et al., 2013) and babesiosis (Michel et al., 2014).

Research on diseases in wildlife populations in Switzerland depends on the close collaboration with cantonal hunting offices (sometimes with the additional support of cantonal veterinary offices), game wardens, hunters

and biologists. The existence of a system employing professional game wardens, as established in many Swiss cantons, generally facilitates specimen collection, in particular where hunted game has to be systematically submitted to official controls. Occasionally, non-invasive sample collection is also carried out (Marreros et al., 2012). Sampling is performed by FIWild staff in the field, or shipped by field partners to the FIWild laboratory. Sampling strategies take into consideration population size, expected prevalences and requirements for statistical analyses. Efforts are made towards sample stratification but due to practical limitations, convenience sampling dominates. Overall, the establishment of a reliable, long-term relationship between researchers and field partners, including the bidirectional information flow between them, as well as the integration of tools and knowledge from diverse disciplines are a key for the success of research projects on wildlife health. In addition to sample collection, information is regularly obtained by questionnaire. Participatory approaches (or citizen science) can be very valuable, particularly in the case of rare events which are difficult to observe. This method has proven especially helpful for the collection of data on interspecific interactions (Ryser-Degiorgis et al., 2002a, 2009; Casaubon et al., 2012; Wu et al., 2012) and the documentation of the pattern of disease spread (Ryser-Degiorgis and Capt, 2003).

Data collection and management are standardized as much as possible in order to allow comparisons among projects. Metadata (sex, age, date of death and geographical coordinates, etc.) are systematically recorded. Importantly, epidemiological and sampling units have been defined based on biological and geographical criteria, which can be used in the context of different projects and are designed to facilitate comparisons (Ryser-Degiorgis et al., 2009; Marreros et al., 2011; Casaubon et al., 2012; Mavrot et al., 2012b). Classification of land (and associated animal populations) into relatively homogenous strata provides a valuable spatial framework for comparison and analysis of ecological and environmental data across large heterogeneous areas (Metzger et al., 2013). Species-specific age classes have been defined with consideration of both morphological criteria and intraspecific social interactions of potential epidemiological importance (Ryser-Degiorgis et al., 2009; Tryland et al., 2011; Wu et al., 2011; Mavrot et al., 2012b). Calendar seasons are systematically defined in the same way, but species-specific biological seasons, given the temporal variations in intraspecific interactions with potential consequences for disease dynamics, have also been proposed (Tryland et al., 2011; Mavrot et al., 2012b). In addition to geographical origin and age, other risk factors for infection are regularly included, such as species, sex, season and topography. The heterogeneous landscape of Switzerland in terms of altitudinal variations, the existence of natural and anthropogenic barriers and climatic differences, make the consideration of the potential influence of these factors in disease occurrence essential.

Overall, research at the FIWild includes outbreak investigations, the study of the etiology and pathogenesis of disease, risk factor identification, targeted investigations including the acquisition of baseline data and retrospective analysis of scanning surveillance data. Baseline data are essential to understanding the importance of detected macro- or microorganisms with unclear pathogenic potential, and for detecting trends in disease dynamics (Fig. 4). In order to understand patterns of disease spread, triangulation strategies (Fig. 5) have proven invaluable. For example, questionnaire surveys

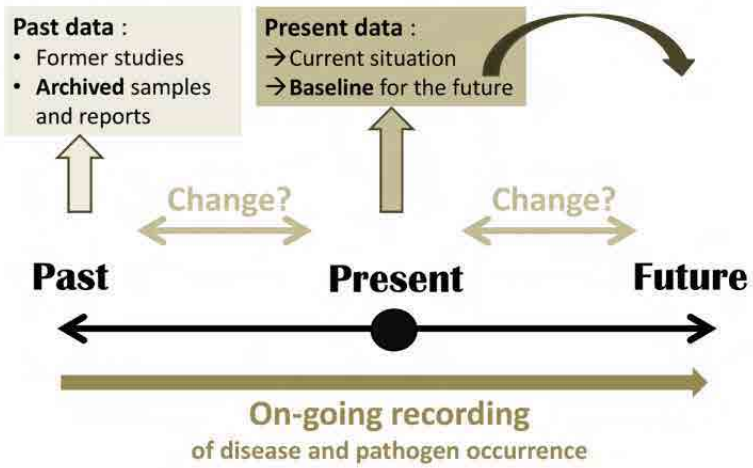

Figure 4: Concept of disease surveillance and tools necessary to assess changes over time. Surveillance implies continuous data collection and material storage, data analysis and communication, with the goal to assess changes over time and to take action as appropriate.

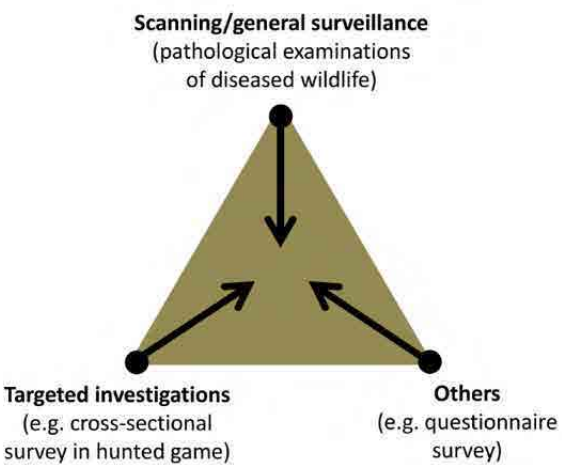

Figure 5: Concept of triangulation approaches. When none of the existing methods is able to deliver fully reliable or representative data, several methods may be applied in parallel. Convergence of the results obtained by these different methods suggests that these results are valid.

can be validated by direct field observations, camera trapping, personal interviews or laboratory analyses.

Education and training in wildlife health

Teaching activities of the FIWild include lectures and courses on wildlife diseases, predation diagnosis, wildlife immobilization (i.e. physical and/or chemical restraint of wild animals) and wildlife research for undergraduate and graduate students in veterinary medicine and biology. Also externship students are regularly coached for diagnostic and research training. Additionally, the FIWild has engaged in the setting up of the residency program in wildlife population health of the European College of Zoological Medicine (ECZM, www.eczm.eu). Besides academic education, the FIWild contributes to continuous education programs for hunters and game wardens as well as practicing veterinarians. Since 2006, the topic of wild meat hygiene has gained in importance and the FIWild has contributed to courses and a book publication on this topic (Volery, 2006). Lectures and courses take place mostly at a national level. Nevertheless, in recent years the wildlife health surveillance system carried out by the FIWild has attracted growing attention at an international level, resulting in increasing invitations for participation in working groups, committees and for presentations at international conferences.

Consulting and support activities

The FIWild acts as a consultant to hunting and veterinary authorities, game wardens and hunters, biologists, veterinarians and the general public. In addition, the FIWild provides support for wildlife conservation projects. This includes training in wildlife anesthesia, immobilization and capture, as well as sample collection (Breitenmoser-Würsten and Obexer-Ruff, 2003; Minnig, 2010), postmortem investigations (Ryser-Degiorgis et al., 2002b; Schmidt-Posthaus et al., 2002; Ryser-Degiorgis and Robert, 2006; Wimmershoff et al., 2012), clinical examinations, literature reviews (Ryser-Degiorgis, 2009a) and risk assessment for translocations (Ryser-Degiorgis et al., 2002c, 2006; Ryser-Degiorgis, 2009b). Furthermore, field support is provided, within the limits of the available resources, for wildlife captures (anesthesia). In the past years, live veterinary examinations were conducted on a number of species, including Eurasian lynx, Alpine ibex, wildcat and red deer. The FIWild is also mandated by the FOEN for the veterinary care of lynx orphans, which are then integrated into zoo collections or reintroduced to the wild.

Data and sample archive

Reports of necropsies performed on wildlife at the University of Bern are available back to 1958, and formalin-fixed tissues have been stored since the 1970s, i.e. data and samples of several thousand animals are available for retrospective investigations. Furthermore, in the past decade a frozen sample archive has been set up, including blood and organ samples from protected species as well as tissues and body fluids from research projects, which are stored in sufficient amounts to allow later investigations unrelated to the initial project. This procedure has already shown a number of advantages: (1) It keeps the costs and efforts required by field partners to a minimum, as several investigations are possible from a single sampling campaign. For example, blood samples collected for investigations on bovine virus diarrhea and bluetongue in Swiss wild ruminants (Casaubon et al., 2012, 2013) were also used for another project on babesiosis (Michel et al., 2014). (2) If access to samples is very limited (e.g. non-hunted, secretive species), the continuous collection of specimens or anecdotal data will, at some point, represent an interesting sample size. For instance, usually less than 10-15 Eurasian lynx are submitted to necropsy per year and opportunities to sample captured animals are few. However, thanks to archival samples, a meaningful sample size was available for a project on hemoplasma infections in wild felids (Willi et al., 2007). (3) Analyses of historical samples can contribute to the understanding of apparent pathogen emergence. After the accidental discovery of *Cytauxzoon* sp. in a Swiss lynx, the testing of archived blood samples revealed that this parasite has been widespread in the lynx population as far back as samples have been collected (Ryser-Degiorgis et al., 2010). (4) Archived samples allow additional investigations on well-documented animals and facilitate independent research programs in other laboratories. For example, samples from wild boar were provided for a study on Hepatitis E virus at the IGV (Burri et al., 2014).

Concluding comments

A wildlife health surveillance program needs to include several components to be efficient and comprehensive: scanning and targeted surveillance approaches, outbreak investigations, archiving of biological samples, field and laboratory studies, predictive modeling, and risk assessment (Hoberg et al., 2008; Mariner et al., 2011; Ryser-Degiorgis, 2013a). For an overview at the national level, centralization of the available information is important. Stratification, systematic collection of metadata and methodological harmonization efforts are all required for risk factor identification, which in turn is essential to the understanding of emerging infectious diseases (Patz et al., 2004; Beerli et al., 2015). Last but not least, a wildlife health surveillance program can greatly benefit from participatory approaches. In fact, the effectiveness of wildlife surveillance depends in the first place on appropriate communication with field partners (Ryser-Degiorgis, 2013a). This requires the use of an

appropriate language, which is a two-fold requirement: First, in a multi-lingual country like Switzerland, oral and written communication has to occur in the local language. Second, feedback must be accessible to non-veterinarians, i.e. technical terms should be avoided or simply explained, and interpretations should not go into complex considerations but refer to reality in the field.

The FIWild has been mandated by the FOEN and FSVO as the national competence center for wildlife health in Switzerland. In line with this, the FIWild has developed its activities towards a comprehensive national program encompassing nearly all of the previously mentioned surveillance components. To this end, the FIWild has made continuous efforts to enlarge and strengthen a national network of field partners contributing to the collection of material and information. In parallel, it has benefited from synergies between scanning surveillance, research and teaching, as well as among research projects (Fig. 1) and from multidisciplinary collaboration. Strategies to facilitate long-term and meta-studies include the standardization of methods for sample and metadata collection, laboratory analysis and data management; the collection of baseline data; and the archiving of data and samples. Importantly, data collection is not limited to disease records, but genetic and molecular analyses of wildlife populations and their pathogens have been promoted, and epidemiological investigations including risk factor analyses have been repeatedly performed. Here, ecological parameters and species-specific life histories have been integrated into epidemiological concepts because meaningful definitions of epidemiological or sampling units, age classes and biological seasons are required for sound data interpretation.

Switzerland's limited surface area provides a number of advantages for the implementation of an efficient national wildlife health surveillance program. Short distances facilitate the establishment of personal contacts and material shipment, and the dense road network renders most areas accessible for field investigations. Furthermore, the existence of a professional game warden system is essential for the surveillance program. At the same time, developing and maintaining the network among all involved partners is challenging given the heterogeneity of Switzerland in terms of language, culture, politics, hunting regimes and wildlife habitats. Improvement of the current surveillance program of the FIWild could be achieved by increasing the intensity of surveillance through further development of the existing national network, aiming at an increase of the diagnostic case load and the inclusion of a larger number of taxa; by performing more systematic sample collection for archive purposes; by developing in-house capacity for microbiological and molecular-biological diagnostics; by completing field studies with experiments; by using more sophisticated statistical tools in data analysis; and by investing more time in the redaction of popular articles in multiple languages. Efforts in this direction are currently impaired by the limitations of financial resources and infrastructure, however, the development of the group and increasing governmental support over the past decade demonstrates that the general trend is positive.

Acknowledgements

Many thanks go to the FOEN and FSVO for the attribution or the long-term mandates and their financial support. We also acknowledge numerous institutions and colleagues in Switzerland and abroad for the fruitful collaboration in the framework of diagnostic, research and teaching activities. In particular we would like to mention the Institute of Veterinary Bacteriology and the Institute of Parasitology of the University of Bern and the Clinical Veterinary Laboratory of the University of Zurich for their continuing support. The development of the FIWild would have not been possible without the very strong engagement and excellent work of the many scientific collaborators, students and technicians who have been part of the team over the years; while it is not possible to name all of them, we would like to mention at least the current FIWild team: Francesco Origgi, Julia Wimmershoff, Mirjam Pewsner, Roman Meier, Nelson Marreros, Ezgi Akdesir, Rebecca Hari and Alexandra Brügger. Last but not least, we sincerely thank all cantonal hunting offices, game wardens, hunters, biologists, veterinarians and private persons who make our work possible by submitting investigation material and valuable information from the fields. Patrick Boujon, Richard Hoop and Monika Hilbe provided the numbers of free-ranging wild animals investigated at the Institute Galli-Valerio, the Department for Poultry Diseases and the Institute for Veterinary Pathology of the University of Zurich, respectively. Marc Artois and Peter Neumann critically read the manuscript. Maja Stodte improved the English language.

Centre national de compétence pour les maladies de la faune en Suisse: mandat, développement et stratégies actuelles

La nécessité d'un système de surveillance pour la santé de la faune sauvage est de plus en plus reconnue. Cependant, la plupart des pays européens ne disposent toujours pas d'un programme complet couvrant un large spectre d'espèces animales, de pathogènes et de régions géographiques, et les exemples de systèmes en place restent rares. Cet article fournit une vue d'ensemble de l'organisation de la surveillance de la santé de la faune sauvage en Suisse, en portant toutefois une attention particulière au développement, aux stratégies et aux activités actuelles du programme national mené par le Centre pour la Médecine des Poissons et des Animaux sauvages (FIWI) à l'Université de Berne. Cette documentation pourrait stimuler les discussions sur la conception et le développement de programmes nationaux de surveillance de la santé de la faune dans d'autres pays. Les investigations sur la santé de la faune en Suisse remontent aux années 1950. Le FIWI agit comme centre national de compétence pour les maladies de la faune sur mandat des autorités fédérales suisses. Le mandat comprend quatre activités principales: le diagnostic des maladies, la recherche, l'expertise-conseil et l'enseignement. Conformément à cela, le FIWI a fourni des efforts continus pour renforcer un réseau national de partenaires sur le terrain et mis en place des stratégies pour faciliter des études à long terme et des méta-analyses.

Centro di competenza nazionale per le malattie degli animali selvatici, sviluppo e strategie attuali

La sorveglianza della salute degli animali selvatici è sempre piu' riconosciuta come una necessità. Tuttavia, programmi di ampio respiro che si occupino di un vasto spettro di specie, patogeni e aree geografiche sono ancora poco diffusi in Europa e gli esempi pratici sono scarsi. Questo articolo presenta un'overview dell'organizzazione della sorveglianza della salute degli animali selvatici in Svizzera con particolare attenzione allo sviluppo, alle strategie attuali e alle attività del programma nazionale svolte dal Centro per la Salute della Fauna Ittica e Selvatica (FIWI) dell'Università di Berna. Questa documentazione potrebbe stimolare i dibattiti attuali sulla progettazione e sullo sviluppo di programmi di sorveglianza della salute degli animali selvatici in altri paesi. Le indagini riguardanti la salute degli animali selvatici in Svizzera risalgono agli anni '50. Il FIWI rappresenta il centro di competenza nazionale per le malattie degli animali selvatici su mandato delle autorità federali Svizzere. Il mandato riguarda quattro attività principali: diagnosi delle malattie, ricerca, consulenza ed insegnamento. In linea con tutto questo, il FIWI si sforza costantemente di rafforzare il network nazionale dei collaboratori sul campo e di implementare le strategie per facilitare gli studi successivi a lungo termine e i metastudi.

National competence center for wildlife diseases in Switzerland: Mandate, development and current strategies

M.-P. Ryser-Degiorgis, H. Segner

References

Abril C., Thomann A., Brodard I., Wu N., Ryser-Degiorgis M.-P., Frey J., Overesch G.: A novel isolation method of *Brucella* species and molecular tracking of *Brucella suis* biovar 2 in domestic and wild animals. Vet. Microbiol. 2011, 150: 405–410.

BAFU: Konzept Bär - Managementplan für den Braunbären in der Schweiz. 2009, http://www.bafu.admin.ch/tiere/09262/09285/index.html?lang=de

BAFU: Konzept Wolf – Managementplan für den Wolf in der Schweiz. 2010, http://www.kora.ch/pdf/divers/Wolfkonzept_01-05-2010_d.pdf

Batista Linhares M., Belloy L., Origgi F. C., Lechner I., Segner H., Ryser-Degiorgis M.-P.: Investigating the role of free-ranging wild boar (*Sus scrofa*) in the re-emergence of enzootic pneumonia in domestic pig herds: a pathological, prevalence and risk-factor study. PLoS ONE 2015, 10: e0119060.

Beerli O., Blatter S., Boadella M., Schöning J., Schmitt S., Ryser-Degiorgis M.-P.: Towards harmonised procedures in wildlife epidemiological investigations: a serosurvey of infection with *Mycobacterium bovis* and closely related agents in wild boar (*Sus scrofa*) in Switzerland. Vet. J. 2015, 2013: 131–133.

Bouvier G., Bürgisser H., Schneider P. A.: Les maladies des ruminants sauvages de la Suisse. Service vétérinaire cantonal et Institut Galli-Valerio, Lausanne, Switzerland, 1958.

Breitenmoser-Würsten C., Obexer-Ruff G.: Population and conservation genetics of two re-introduced lynx (*Lynx lynx*) populations in Switzerland – a molecular evaluation 30 years after translocation. In: Proceedings of the 2nd Conference on the Status and Conservation of the Alpine Lynx Population, Amden, Switzerland, 2003, 28–31.

Burgisser H.: Compte-rendu sur les maladies des animaux sauvages de 1975 à 1982. Schweiz. Arch. Tierheilk. 1983, 125: 519–527.

Burri C., Vial F., Ryser-Degiorgis M.-P., Schwermer H., Darling K., Reist M., Wu N., Beerli O., Schöning J., Cavassini M., Waldvogel A.: Seroprevalence of hepatitis E in pigs and wild boars in Switzerland. Zoonoses Public Hlth 2014, 61: 537–544.

Büttner, S.: Gesundheitszustand von Feldhasen (*Lepus europaeus*) in der Schweiz. Dissertation, Universität Bern, 1996.

National competence center for wildlife diseases in Switzerland: Mandate, development and current strategies

M.-P. Ryser-Degiorgis, H. Segner

BUWAL: Konzept Luchs Schweiz. 2004, http://www.sib.admin.ch/uploads/media/konzept-luchs_2004_de-1.pdf

Casaubon J., Vogt H.-R., Stalder H., Hug C., Ryser-Degiorgis M.-P.: Bovine viral diarrhea virus in free-ranging wild ruminants in Switzerland: low prevalence of infection despite regular interactions with domestic livestock. BMC Vet. Res. 2012, 8: 204.

Casaubon J., Chaignat V., Vogt H.-R., Michel A. O., Thür B., Ryser-Degiorgis M.-P.: Survey of bluetongue virus infection in free-ranging wild ruminants in Switzerland. BMC Vet. Res. 2013, 9: 166.

Chomel B. B., Belotto A., Meslin F.-X.: Wildlife, exotic pets, and emerging zoonoses. Emerg. Infect. Dis. 2007, 13: 6–11.

CSCF: Wald- oder Wildkatzen in der Schweiz! Accessed 2012, http://www.baselland.ch/fileadmin/baselland/files/docs/vsd/vjf/jagd/Wildkatzenflyer.pdf

Daszak P., Cunningham A. A., Hyatt A. D.: Emerging infectious diseases of wildlife – threats to biodiversity and human health. Science 2000, 287: 443–449.

Dürr S., Nimmervoll H., Hoby S., Robert N., Soglia D., Rossi L., Sager H., Hüssy D., Meli M. L., Berny P., Ryser-Degiorgis M.-P.: Assessment of factors influencing the occurrence and pathological picture of sarcoptic mange in red foxes (*Vulpes vulpes*). In: Proceedings of the 9th EWDA Conference, Vlieland, The Netherlands, 2010, 94.

Euzenat K.: Causes de mortalité et de morbidité du chevreuil en Suisse: étude rétrospective (1992-2002). Veterinary thesis, Ecole Nationale Vétérinaire de Nantes, France, 2004.

Fink M., Schleicher C., Gonano M., Prodinger W. M., Pacciarini M., Glawischnig W., Ryser-Degiorgis M.-P., Walzer C., Stalder G. L., Lombardo D., Schobeserg H., Winter P., Büttner M.: Red deer as maintenance host for bovine tuberculosis, Alpine Region. Emerg. Infect. Dis. 2015, 21: 464–467.

Frey C. F., Schuppers M. E., Müller N., Ryser-Degiorgis M.-P., Gottstein, B.: Assessment of the prevalence of *Trichinella* spp. in red foxes and Eurasian lynxes from Switzerland. Vet. Parasitol. 2009, 159, 295–299.

Frölich K., Haerer G., Bacciarini L., Janovsky M., Rudolph M., Giacometti M.: European brown hare syndrome in free-ranging European brown and mountain hares from Switzerland. J. Wildl. Dis. 2001, 37: 803–807.

Giacometti M., Janovsky M., Belloy L., Frey J.: Infectious keratoconjunctivitis of ibex, chamois and other Caprinae. Rev. Off. Int. Epizoot. 2002, 21: 335–345.

Giovannini S., Pewsner M., Hüssy D., Hächler H., Degiorgis M.-P., von Hirschheydt J., Origgi F. C.: Epidemic of salmonellosis in passerine birds in Switzerland with spillover to domestic cats. Vet. Pathol. 2013, 50: 597–606.

Giovannini S., Ryser-Degiorgis M.-P., Tagliabue S., Pewsner M., Origgi F. C.: Leptospirosis in European beavers (*Castor fiber*) from Switzerland. In: Proceedings of the Joint EWDA/WDA Conference, Lyon, France, 2012, 300.

Gortázar C., Ferroglio E., Höfle U., Frölich K., Vicente J.: Diseases shared between wildlife and livestock: a European perspective. Eur. J. Wildl. Res. 2007, 53: 241–256.

Haas C., Origgi F. C., Akdesir E., Batista Linhares M., Giovannini S., Mavrot F., Casaubon J., Ryser-Degiorgis M.-P.: First detection of sarcoptic mange in free-ranging wild boar (*Sus scrofa*) in Switzerland. Schweiz. Arch. Tierheilk. 2015, 157: in press.

Haerer G., Nicolet J., Bacciarini L., Gottstein B., Giacometti M.: Causes of death, zoonoses, and reproduction in the European brown hare in Switzerland. Schweiz. Arch. Tierheilk. 2001, 143: 193–201.

Harvell C. D., Mitchell C. E., Ward J. R., Altizer S., Dobson A. P., Ostfeld R. S., Samuel M. D.: Climate warming and disease risks for terrestrial and marine biota. Science 2002, 296, 2158–2162.

Hoberg E. P., Polley L., Jenkins E. J., Kutz S. J.: Pathogens of domestic and free-ranging ungulates: global climate change in temperate to boreal latitudes across North America. Rev. Off. Int. Epizoot. 2008, 27: 511–528.

Hoby S., Robert N., Mathis A., Schmid N., Meli M. L., Hofmann-Lehmann R., Lutz H., Deplazes P., Ryser-Degiorgis M.-P.: Babesiosis in free-ranging chamois (*Rupicapra r. rupicapra*) from Switzerland. Vet. Parasitol. 2007, 148: 341–345.

Hoby S., Mathis A., Doherr M. G., Robert N., Ryser-Degiorgis M.-P.: Babesia capreoli infections in Alpine chamois (*Rupicapra r. Rupicapra*), roe deer (*Capreolus c. Capreolus*) and red deer (*Cervus elaphus*) from Switzerland. J. Wildl. Dis. 2009, 45: 748–753.

Köppel C., Knopf L., Ryser M.-P., Miserez R., Thür B., Stärk K. D.: Serosurveillance for selected infectious disease agents in wild boars (*Sus scrofa*) and outdoor pigs in Switzerland. Eur. J. Wildl. Res. 2007, 53: 212–220.

Kuiken T., Ryser-Degiorgis M.-P., Gavier-Widén D., Gortázar C.: Establishing a European network for wildlife health surveillance. Rev. Off. Int. Epizoot. 2011, 30: 755–761.

Mariner J. C., Hendrickx S., Pfeiffer D. U., Costard S., Knopf L., Okuthe S., Chibeu D., Parmley J., Musenero M., Pisang C., Zingeser J., Jones B. A., Ali S. N., Bett B., McLaws M., Unger F., Araba A., Mehta P., Jost C. C.: Integration of participatory approaches into surveillance systems. Rev. Off. Int. Epizoot. 2011, 30: 653–659.

Marreros N., Friess M., Origgi F. C., Robert N., Engels M., Hüssy D., Vilei E. M., Frey C. F., Ryser-Degiorgis M.-P.: Caprine lymphotropic herpesvirus infection associated with broncho-interstitial pneumonia in Alpine ibex. In: Proceedings of the 9th EWDA Conference, Vlieland The Netherlands, 2010, 38.

Marreros N., Hüssy D., Albini S., Frey C. F., Abril C., Vogt H.-R., Holzwarth N., Wirz-Dittus S., Friess M., Engels M., Borel N., Willisch C., Signer C., Hoelzle L., Ryser-Degiorgis M.-P.: Epizootiologic investigations of selected abortive agents in free-ranging Alpine ibex (Capra ibex ibex) in Switzerland. J. Wildl. Dis. 2011, 47: 530–543.

Marreros N., Frey C. F., Willisch C. S., Signer C., Ryser-Degiorgis M.-P.: Coprological analyses on apparently healthy Alpine ibex (*Capra ibex ibex*) from two Swiss colonies. Vet. Parasitol. 2012, 186: 382–389.

Mavrot F., Zimmermann F., Vilei E. M., Ryser-Degiorgis M.-P.: Is the development of infectious keratoconjunctivitis in Alpine ibex and Alpine chamois influenced by topographic features? Eur. J. Wildl. Res. 2012a, 58: 869–874.

Mavrot F., Vilei E. M., Marreros N., Signer C., Frey J., Ryser-Degiorgis M.-P.: Occurrence, quantification, and genotyping of *Mycoplasma conjunctivae* in wild Caprinae with and without infectious keratoconjunctivitis. J. Wildl. Dis. 2012b, 48: 619–631.

Meier R. C., Ruiz-Fons F., Ryser-Degiorgis M.-P.: Serosurvey of Aujeszky's disease virus in the Swiss wild boar population. In: Proceedings of the 11th EWDA Conference, Edinburgh, Scotland, 2014, Poster Abstract No. 109.

Meslin F. X., Stöhr K., Heymann D.: Public health implications of emerging zoonoses. Rev. Off. Int. Epizoot. 2000, 19: 310–317.

Metzger M. J., Brus D. J., Bunce R. G. H., Carey P. D., Gonçalves J., Honrado J. P., Jongman R. H. G., Trabucco A., Zomer R.: Environmental stratifications as the basis for na-

tional, European and global ecological monitoring. Ecological Indicators. 2013, 33: 26–35.

Michel A., Mathis A., Ryser-Degiorgis M.-P.: Babesia spp. in European wild ruminant species: parasite diversity and risk factors for infection. Vet. Res. 2014, 45: 65.

Minnig S.: Genetische Analyse nichtinvasiv gewonnener Proben von *Castor fiber*: Castoreum und Kot. Bachelorarbeit, Universität Fribourg, 2010.

Nimmervoll H., Hoby S., Robert N., Lommano E., Welle M., Ryser-Degiorgis M.-P.: Pathology of sarcoptic mange in red foxes (*Vulpes vulpes*): macroscopic and histologic characterization of three disease stages. J. Wildl. Dis. 2013, 49: 91–102.

Origgi F. C., Plattet P., Sattler U., Robert N., Casaubon J., Mavrot F., Pewsner M., Wu N., Giovannini S., Oevermann A., Stoffel M. H., Gaschen V., Segner H., Ryser-Degiorgis M.-P.: Emergence of canine distemper virus strains with modified molecular signature and enhanced neuronal tropism leading to high mortality in wild carnivores. Vet. Pathol. 2012, 49: 913–929.

Origgi F. C., Frey J., Pilo P.: Characterisation of a new group of *Francisella tularensis* subsp. holarctica in Switzerland with altered antimicrobial susceptibilities, 1996 to 2013. Euro Surveill. 2014, 19 pii: 20858.

Ostfeld R. S., Holt R. D.: Are predators good for your health? Evaluating evidence for top-down regulation of zoonotic disease reservoirs. Front. Ecol. Environ. 2014, 2: 13–20.

Patz J. A., Daszak P., Tabor G. M., Aguirre A. A., Pearl M., Epstein J., Wolfe N. D., Kilpatrick A. M., Foufopoulos J., Molyneux D., Bradley D. J.: Unhealthy landscapes: Policy recommendations on land use change and infectious disease emergence. Environ. Health Perspect. 2004, 112: 1092–1098.

Ryser-Degiorgis M.-P.: Causes of mortality and diseases of Eurasian lynx (*Lynx lynx*). In: Iberian lynx ex-situ conservation: an interdisciplinary approach. Eds. A. Vargas, C. Breitenmoser-Würsten, U. Breitenmoser, Fundación Biodiversidad, Madrid, Spain, 2009a, 274–289.

Ryser-Degiorgis M.-P.: Planning of veterinary supervision for translocation programmes of wild felids. In: Iberian lynx ex-situ conservation: an interdisciplinary approach. Eds. A. Vargas, C. Breitenmoser-Würsten, U. Breitenmoser, Fundación Biodiversidad, Madrid, Spain, 2009b, 488–497.

Ryser-Degiorgis, M.-P.: Wildlife health investigations: needs, challenges and recommendations. BMC Vet. Res. 2013a, 9: 223.

Ryser-Degiorgis, M.-P.: Output of surveillance and research activities carried out at the FIWild – an overview. In: Wildlife population health in Switzerland: Novel approaches and applications, Habilitation thesis, University of Bern, Switzerland, 2013b, 103–111.

Ryser-Degiorgis M.-P., Capt S.: Occurrence of sarcoptic mange in free-ranging wildlife in Switzerland. Mamm. Biol. 2003, 68: 57–58.

Ryser-Degiorgis M.-P., Robert N.: Causes of mortality and diseases in free-ranging Eurasian lynx from Switzerland – An update. In: Proceedings of the "Iberian Lynx Ex-Situ Conservation" Seminar Series, Module I, Veterinary Aspects, Sevilla, Spain, 2006, 31–35.

Ryser-Degiorgis M.-P., Ingold P., Tenhu H., Tébar A. M., Ryser A., Giacometti M.: Encounters between Alpine ibex, Alpine chamois and domestic sheep in the Swiss Alps. Hystrix 2002a, 13: 1–11.

Ryser-Degiorgis M.-P., Ryser A., Bacciarini L. N., Angst C., Gottstein B., Janovsky M., Breitenmoser U.: Notoedric and sarcoptic mange in free-ranging lynx from Switzerland. J. Wildl. Dis. 2002b, 38: 228–232.

Ryser-Degiorgis M.-P., Lutz H., Bauer K., Sager H., Ryser A., Zimmermann F., Breitenmoser-Würsten C., Breitenmoser U.: Veterinary supervision of lynx translocation within the Swiss Alps. In: Proceedings of the Joint EWDA Conference and 4th EAZWV Scientific Meeting, Heidelberg, Germany, 2002c, 147–153.

Ryser-Degiorgis M.-P., Ryser A., Lutz, H. Sager H., Zimmermann F., Breitenmoser U.: Translocations of Eurasian lynx within Swiss Alps: veterinary supervision. In: Proceedings of the course "Conservatión y Medicina de Felinos Salvajes", Barcelona, Spain, 2006, 83-86.

Ryser-Degiorgis M.-P., Bischof D. F., Marreros N., Willisch C., Signer C., Filli F., Brosi G., Frey J., Vilei E. M.: Detection of *Mycoplasma conjunctivae* in the eyes of healthy, free-ranging Alpine ibex: possible involvement of Alpine ibex as carriers for the main causing agent of infectious keratoconjunctivitis in wild Caprinae. Vet. Microbiol. 2009, 134: 368–374.

Ryser-Degiorgis M.-P., Meli M. L., Zimmermann F., Lutz H.: First evidence of *Cytauxzoon* sp. infection in Eurasian lynx. In: Proceedings of the 9th EWDA Conference, Vlieland, The Netherlands, 2010, 35.

Schatzmann U., Hörning B., Nicolet J., Sackmann W.: Denkschrift – Veterinärmedizinische Fakultät Bern 1900–2002. Hans Huber, Bern, Switzerland, 2004.

Schmid N., Deplazes P., Hoby S., Ryser-Degiorgis M.-P., Edelhofer R., Mathis, A.: Babesia divergens-like organisms from free-ranging chamois (*Rupicapra r. rupicapra*) and roe deer (*Capreolus c. capreolus*) are distinct from B. *divergens* of cattle origin – an epidemiological and molecular genetic investigation. Vet. Parasitol. 2008, 154: 14–20.

Schmidt-Posthaus H., Breitenmoser-Würsten C., Posthaus H., Bacciarini L., Breitenmoser, U.: Causes of mortality in reintroduced Eurasian lynx in Switzerland. J. Wildl. Dis. 2002, 38: 84–92.

Schöning J. M., Cerny N., Prohaska S., Wittenbrink M. M., Smith N. H., Bloemberg G., Pewsner M., Schiller I., Origgi F. C., Ryser-Degiorgis M.-P.: Surveillance of bovine tuberculosis and risk estimation of a future reservoir formation in wildlife in Switzerland and Liechtenstein. PLoS ONE 2013, 8: e54253.

Sieber V., Ryser-Degiorgis M.-P., Botteron C.: A study of neurological diseases in farmed deer in Switzerland, with emphasis on chronic wasting disease. Eur. J. Wildl. Res. 2008, 54: 189–192.

Sieber V., Robert N., Schybli M., Sager H., Miserez R., Engels M., Ryser-Degiorgis M.-P.: Causes of mortality and diseases in farmed deer in Switzerland. Vet. Med. Int. 2010, 2010: pii: 684924.

Thüler K.: Spatial and temporal distribution of coat patterns of Eurasian lynx (*Lynx lynx*) in two re-introduced populations in Switzerland. KORA-Bericht, 2002, http://www.kora.ch/pdf/reports/rep13_e.pdf

Tryland M., Okeke M. I., af Segerståd C. H., Mörner T., Traavik T., Ryser-Degiorgis M.-P.: Orthopoxvirus DNA in Eurasian lynx, Sweden. Emerg. Infect. Dis. 2011, 17: 626–632.

Willi B., Filoni C., Catão-Dias J. L., Cattori V., Meli M. L., Vargas A., Martínez F., Roelke, M. E., Ryser-Degiorgis M.-P., Leutenegger C. M., Lutz H., Hofmann-Lehmann R.: Worldwide occurrence of feline hemoplasma infections in wild felid species. J. Clin. Microbiol. 2007, 45: 1159–1166.

Wimmershoff J., Robert N., Mavrot F., Hoby S., Boujon P., Frey C. F., Weber M., Café Marçal V., Hüssy D., Mattsson R., Pilo P., Nimmervoll H., Marerros N., Pospischil A., Angst C.,

Ryser-Degiorgis M.-P.: Causes of mortality and diseases in the reintroduced European beaver population in Switzerland from 1989 to 2009. In: Proceedings of the Joint EWDA/WDA Conference, Lyon, France, 2012, 37.

Wolfe, N. D., Dunavan, C. P., Diamond J.: Origins of major human infectious diseases. Nature 2007, 447: 279–283.

Wu N., Abril C., Hinić V., Brodard I., Thür B., Fattebert J., Hüssy D., Ryser-Degiorgis M.-P.: Free-ranging wild boar: a disease threat to domestic pigs in Switzerland? J. Wildl. Dis. 2011, 47: 868–879.

Wu N., Abril C., Thomann A., Grosclaude E., Doherr M. G., Boujon P., Ryser-Degiorgis, M.-P.: Risk factors for contacts between wild boar and outdoor pigs in Switzerland and investigations on potential *Brucella suis* spill-over. BMC Vet. Res. 2012, 8: 116.

Corresponding author

PD Dr. med. vet. Marie-Pierre Ryser-Degiorgis, Dipl. ECZM (WPH)
Centre for Fish and Wildlife Health (FIWI)
Dept. Infectious Diseases and Pathobiology
Vetsuisse Faculty, University of Bern
Postfach 8466, Länggass-Str. 122
CH-3001 Bern, Switzerland
Tel. +41 31 631 24 43; Fax +41 31 631 24 43
E-Mail: marie-pierre.ryser@vetsuisse.unibe.ch