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Commentary

Surveillance, monitoring and surveys of wildlife diseases: a public health and conservation approach

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Abstract

During the past decades the interest in surveillance and monitoring of wildlife diseases has grown internationally. The main reasons could be the following: a) increased size of many wildlife populations that host pathogens affecting humans; b) the increased economic relevance of some wildlife disease; c) the role played by infections/diseases in the conservation of some wild endangered species. According to the above-described epidemiological situations there is an international need to develop appropriate strategies for the early detection, monitoring and surveys of infectious diseases in wildlife. The paper reviews the epidemiological assumptions on which disease surveillance, monitoring and surveys are, or should be, based. The main conclusions are: 1) wildlife disease surveillance and monitoring are long lasting activities that should be implemented when legal bases are available; 2) a wildlife disease introduced in a free area is more likely to be detected early using passive rather than active surveillance; 3) the definition of the "suspect case" largely affects the sensitivity of the whole passive surveillance; thus the suspected case definition should be modulated according to the level of risk; 4) in both active surveillance and monitoring, sampling plays an important role. The sensitivity of any active surveillance/monitoring system is highly dependent from the sampling unit that we define as: "*the host target subpopulation, whose size can maintain the pathogen during a defined inter-sampling interval*". Such definition merges the ecological, epidemiological and mathematical approaches aimed in controlling or eradicating infections in both livestock and wildlife; 5) When dealing with the conservation-disease interface, a standardized risk assessment procedure including risk mitigation has to become the rule.

Introduction

During the past decades, a widespread interest in wildlife diseases including surveillance and monitoring has internationally grown. The World Organization for Animal Health (OIE) includes wildlife diseases in its international reporting system for animal health (World Animal Health Information Database - WHAIS; http://www.oie.int/animal-health-in-the-world/the-world-animal-health-information-system/the-oie-data-system/).

The possible reasons for such interest can be summarized as follow:

1. Wildlife is the epidemiological reservoir for several emerging, re-emerging or not yet discovered diseases of humans (Woolhouse, 2002; Woolhouse and Gowtage-Sequeria, 2005; Jones et al., 2008).
2. The presence of certain communicable diseases in wildlife, will results also in trade restrictions for susceptible domestic species resulting in a high economic impact (Artois et al., 2001). For example, according to the EU rules (2002/60/EC) the presence of African Swine Fever (ASF) in the sole wild boar population of an area, prevents live pigs or pork trade from the wild boar infected areas into the whole European Union for a minimum of fifteen months (SANCO/7138/2013).
3. Wildlife species are involved (often playing an unknown epidemiological role) in many domestic animals infectious diseases such as Tuberculosis (TB) and Brucellosis. In such circumstances, even in the absence of an international ban, the eradication process in domestic animals usually last longer than expected increasing both the cost of eradication and the conflicts between farmers and wildlife. The unclear epidemiological role played by the wildlife species highly interferes with any control/eradication process (Godfroid et al., 2013).
4. Diseases are a potential threat for endangered species even if the real risk are rarely assessed and mitigated (McCallum and Dobson, 1995; Cleaveland et al., 2002; De Castro and Bolker, 2005; Smith et al., 2006, 2009).

The issues linked to 1), 2) and 3) fall under *the usual duties* of the National Veterinary Services, whereas the possible activities linked to animal disease and conservation lie in a shadowed, neglected area bordering both animal health and conservation and are rarely properly addressed.

In such a context several of the Animal Health Authorities (namely the National Veterinary Services) of the countries belonging to the OIE and/or WTO (EU countries included), demand for a convincing and sustainable methodology to include wildlife in the routine preventive veterinary surveillance activities.

The aim of this paper is to offer a practical and standardized framework for surveillance, monitoring and surveys of infectious diseases in wildlife. The paper is structured as follows: a) present the epidemiological assumptions on which the paper is based; b) outline wildlife diseases surveillance, monitoring and surveys including procedures for the development of optimized strategies; c) highlight a field example derived from specific case-studies, d) summarize the most relevant and practical steps.

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Epidemiological assumptions and definitions

Most of the technical definitions are of common use and reported in Margolis et al. (1982), Thursfield (2007) and Hoinville (2013) while few of them are here reported for easy reading and because of their importance in the paper framework:

1. *Surveillance*: the on-going systematic collection, analysis and interpretation of animal health data and the dissemination of information to those who need to know in order to take action. Surveillance is long-term action that lasts until the health risk is present. Surveillance is a part of a wide system in which actions to mitigate the risk are always included.
   a) *Passive (reactive) surveillance*: activities addressed in obtaining information on disease agent in sick or dead animals retrieved by stakeholders during their usual activities. The efficacy (and the efficiency) of surveillance increases when a clear definition of "suspect case" is available and shared with the stakeholders. The individual animal, the one falling in the suspect case definition, is the real target of passive surveillance.
   b) *Active surveillance (proactive)*: activities addressed in actively searching the disease in animals through sampling. Search can be performed in the whole population or in a selected part of it (i.e. the most at risk due to geographical location). Disease can be detected using several approaches such as clinical investigation/examination, laboratory testing etc.
2. *Monitoring*: monitoring may share common features with surveillance programs with the main difference being that monitoring activities do not require a pre-specified action to be taken although significant changes are likely to lead action.
   In general, monitoring is addressed in measuring epidemiological parameters related to a defined disease. The parameter to be measured might be prevalence, incidence, basic reproductive number R_0 etc. The value of the parameter to be monitored is known or, at least, is estimated from available studies, educated guesses etc. Monitoring is always based on an active approach (searching diseased animals, sampling and testing).
3. *Surveys* are specific activities addressed in identifying or understanding a specific problem (for instance a preliminary survey carried out to have an estimate of prevalence before implementing a surveillance system for a specific disease). Surveys are usually limited in both space and time hence they are just a component of the whole surveillance system (e.g. a survey aimed to highlight the epidemiological role played by wildlife in a disease of domestic animals).
4. *Surveillance sensitivity and specificity*: the concepts of sensitivity and specificity express the probability of the system to identify as positive an infected population (real warning) and as negative a disease free population (real disease freedom) (Christensen and Gardner, 2000). The suspect case definition plays a pivotal role in modifying the sensitivity and specificity of a passive surveillance system. A broad suspect case definition (e.g. all the retrieved dead animals) will increase the number of warnings (false alarms increase) but will prevent the non-detection of true positive animals. In contrast a narrow suspect case definition will reduce the number of warnings but will increase the probability of having undetected positive individuals (false disease freedom). In active surveillance, demographic and epidemiological parameters of both the host population and the infection, are the main drivers of the sensitivity of the system.
5. *Suspect Case*: individuals are enrolled in the surveillance program according to their likelihood of being infected. The suspect case definition indicates which animals have to be included in the surveillance system. The criteria to define an animal as a suspect case depend on information on the animal itself, such as presence of clinical symptoms, abnormal behaviour, site of corpse finding etc. In disease free areas, where an infection is very unlikely to be introduced (low risk), the definition of suspect case might be narrow and based on the most severe signs of the disease of interest. Conversely, in areas where the introduction of the infections is more likely (high risk area: a free area bordering infected countries), the inclusion criteria will be broader. For example, the surveillance of rabies can identify foxes as suspect cases according to two different risk levels: in areas where the virus is unlikely to be introduced the suspect case can be defined as the animal with neurological related symptoms. Alternatively, in a free area bordering infected areas, any foxes found dead, including road kills, must be considered as a suspect case. In Italy, recently, the Emilia Romagna region adopted two different suspect case definitions in order to fit the appropriate risk level for each one of the infections included in the official wildlife disease surveillance plan (VV. AA., 2012).
6. *Critical Community Size (CCS)*: Bailey (1975) defined the CCS as the population size able to maintain the parasite for an undefined period of time. The CCS has been then defined as the host community composed by either susceptible, immune or infectious individuals in which the probability to observe the spontaneous fade out of the agent is 50% (Nasell, 2005; Keeling and Grenfell, 1997). Practically, the CCS represents the population in which the infection persists and from which it should be eradicated (compare Ashford 1997; Haydon et al. 2002). CCS differs from the parasite invasion threshold density that is the density of susceptible individuals needed by the infection to initially spread in the population (Lloyd-Smith et al., 2005). In the present paper the definition of the CCS represents the starting point for the identification of the sampling unit for active surveillance and monitoring.

Surveillance, monitoring, surveys in the framework of animal and veterinary public health

Wildlife diseases for which a surveillance system has to be implemented

Surveillance or monitoring of infection in wildlife is of little meaning if no actions are foreseen when the infection is detected. The definition of surveillance indirectly addresses the diseases for which it could be implemented: a positive finding has to be followed by defined actions for which a legal base has to be available. Wildlife disease studies, limited in time and space, should never be considered as surveillance systems (or surrogates) especially when the detection of the infection is not followed by any actions.

Surveillance for the early detection of an infection in a free area

Countries that are free from the main internationally communicable diseases (see OIE), need to detect any new introduction of these infections also in wildlife. The detection should be as early as possible in order to prevent secondary cases and thus limit disease spread. Early detection of wildlife diseases is a modern, economical necessity and it must be achieved by applying appropriate strategies and techniques with the lowest cost-benefit ratio (Vallat, 2008).

Any early detection strategy has to be built considering the epidemiological and demographic parameters of both the pathogen and the host populations. The choice to develop a passive or active surveillance system will be based on such parameters. Usually, since almost all the internationally recognized diseases cause evident clinical symptoms, passive surveillance is the first detection choice. Wild animals showing clinical signs are difficult to be observed; as a consequence dead individuals are the main targets of wildlife passive surveillance. There is a clear positive correlation between the case fatality rate of an infection and the probability that the passive surveillance has to detect it early (Bacon, 1981). Available resources (human and financial) should be addressed in the retrieval of dead/sick animals. The decision of which – and therefore how many – animals to test will depend on the definition of suspect case and will be made according to the epidemiological status of the area (see point 5 above). The number of the suspect case tested and the natural mortality of the target species can be compared in order to evaluate the efficiency of the passive surveillance intensity (Bacon, 1981). The passive surveillance intensity is insufficient if no or few suspect cases have been identified and tested compared with expected natural mortality. Ad hoc simulations would help in checking the sustainability and reliability of the early detection system including the cost-benefit ratio evaluation (Willeberg et al., 2011; Townsend et al., 2013). However the simulation approach is not yet of common use in wildlife disease surveillance planning.

Surveillance in the framework of outbreak management

The outbreak management of almost all the international communicable diseases in domestic animals is outlined by legislation, as for example African Swine Fever in domestic pigs (2002/60/EC). Stamping out, zoning, active surveillance, tracing and disinfection are the main measures to be applied; these measures are of limited applicability in wildlife diseases control/eradication. In case of ASF in wild boar the infected and surveillance areas are replaced by a unique infected area (SANCO/7138/2013). As a general rule, for wildlife diseases, the size of the area to be considered "infected" should correspond to the uninterrupted geographical distribution range of the epidemiological reservoir species, considering both natural and artificial barriers that can limit individual homogeneous mixing between two or more adjacent areas (i.e. metapopulation approach). It is worth to mention that wildlife infections are more likely to spread because of the continuous geographical distribution of the susceptible host species in favourable habitats (Rossi et al., 2005) rather than through large movements of some infectious individual. Wildlife infected areas (when foreseen by the legislation) should be adequately designed, also considering the restrictions prescribed for many human activities (i.e. hunting ban, domestic animal movement restrictions etc.). In these areas, active surveillance or monitoring has to be implemented. Since both active surveillance and monitoring are based on sampling, a clear definition of the sampling unit should be provided. At present there are no general criteria to define the sampling unit size (or its surface) in wildlife disease surveillance.

Here we proposed to identify the sampling unit as: "**the host target subpopulation, which size can maintain (under the density dependent and homogeneous mixing assumptions) the infectious agent during a defined inter-sampling interval**". For example, since Classical Swine Fever (CSF) in wild boar is monitored mainly through testing hunted animals, the sampling unit corresponds to the wild boar population size (or the area) that could maintain the virus between two consecutive hunting seasons, approximately 1000 animals living in 200-400 km^2 (2002/106/EC). When the surface of a wildlife-infected area is very large, it should be divided in several sampling units and for each one of them sampling intensity should be estimated independently from the others. Unluckily, the sampling unit estimate is based on several epidemiological and host demographic data that have to be collected using ad hoc surveys. Once the sampling unit has been correctly identified a coherent sample size could be easily calculated considering both the expected prevalence and the desired confidence level.

Evaluate the efficacy of interventions: monitoring

Usually the variation of prevalence, and rarely incidence or R_0, is used to evaluate the efficacy of interventions. The efficacy of any intervention should be accurately checked. The reduced disease prevalence (or $R_0 < 1$) following the eradication measures or the increased herd immunity resulting from a vaccination program are common aims of monitoring. Again, we propose the above definition of the sampling unit in order to calculate the correct sample size. A further stratification of the sample (by age, gender etc.) will depend on the epidemiological parameters to be estimated and the host population risk factors.

Ad hoc surveys

In the framework of surveillance, surveys are important for an early estimation of the prevalence of the infection/disease (the percentage of infected/diseased animals in a population) or when the epidemiological reservoir of the infection is not completely identified (Haydon et al., 2002). Surveys are also needed to highlight the main transmission and maintenance mechanisms of relatively unknown wildlife diseases, especially when detected in a novel host species or circulating in a multiple host – susceptible-species system (e.g. West Nile virus). The complete knowledge of these mechanisms is still lacking for many wildlife diseases, among them African Swine Fever (ASF) in wild boars (EFSA, 2010, 2014) and Brucellosis in deer (Godfroid et al., 2013) thereby limiting the efficacy of the respective surveillance systems. Hence, the main goal of a survey should provide information on the effectiveness of the surveillance system.

Wildlife diseases and species conservation

Despite a number of scientific papers that highlight the negative effect of diseases on population dynamics (De Castro and Bolker, 2005; Lafferty et al., 2006; Smith et al., 2009) diseases are rarely directly included in the international or national legislation concerning biodiversity conservation. Sometimes, the protection level of a rare host species is even reduced to facilitate disease control/eradication (92/43/EEC). The usual management of domestic animal diseases should be modified when wildlife is involved and even more when a disease impact on animal conservation is likely to be observed.

Rare species live at low density, have small population size and live in limited geographical areas. Except few diseases transmitted through frequency dependent processes (Hamede et al., 2012), the size of the host population is often below the threshold of endemic persistence of any infection and only limited invasion of the parasite in the host population will be possible (invasion threshold vs. persistence threshold see Lloyd-Smith et al. 2005).

In multi-host systems other, sympatric, species may maintain the infection, as is the case for rabies and distemper in domestic dogs. The domestic dog is the reservoir from which the infections could lethally invade the endangered local wild dog population of Africa (Gascoyne et al., 1993; Alexander and Appel, 1994). In such situations, where the infection spill-over has low transmission rates, the real impact of distemper on the population dynamic of the rare species is hard to quantify although vaguely perceived (low recruiting rate, fertility rate etc.). Two main strategies might be developed: a) the specific investigation approach; b) the risk assessment approach.

The investigation approach is addressed to specifically investigate the role played by an infection in interfering on the population dynamic of a rare species; its success depends on the capacity to obtain samples, to retrieve carcasses and determine the cause of death, matching data with the host population dynamic parameters. Finally, action is taken to control the identified infection.

The risk assessment approach might be more easily finalised to provide management options. Risk assessment will be performed integrating different information sources from literature analyses, expert opinions and available data regarding possible and locally present threats, species susceptibility, host population size, geographical distribution, applied management system etc. and having as a final outcome a risk ranking. The risk assessment approach is largely accepted in both animal welfare and health and thus widely utilized at both national and international level (EFSA, OIE) while it is of recent introduction in animal conservation (Jakob-Hoff et al., 2014). However the inclusion of a health risks assessment together with the appropriate risk mitigation strategies should play a relevant role in any wild species conservation action plan.

Wildlife surveillance and monitoring: working examples

Early detection strategy: passive vs. active surveillance of a highly lethal disease

Rabies in fox has a case fatality rate of about 0.07 day^{-1} (100% of infected animals die in 14 days = 1/14), while the natural fox mortality (free rabies areas) is estimated to be 30% of the annual population (0.3/365) and then with a rate of 0.00082 day^{-1}. High depopulation rates were achieved during rabies control in Germany during the 70ies when about 40% of the whole fox population was shot during one year

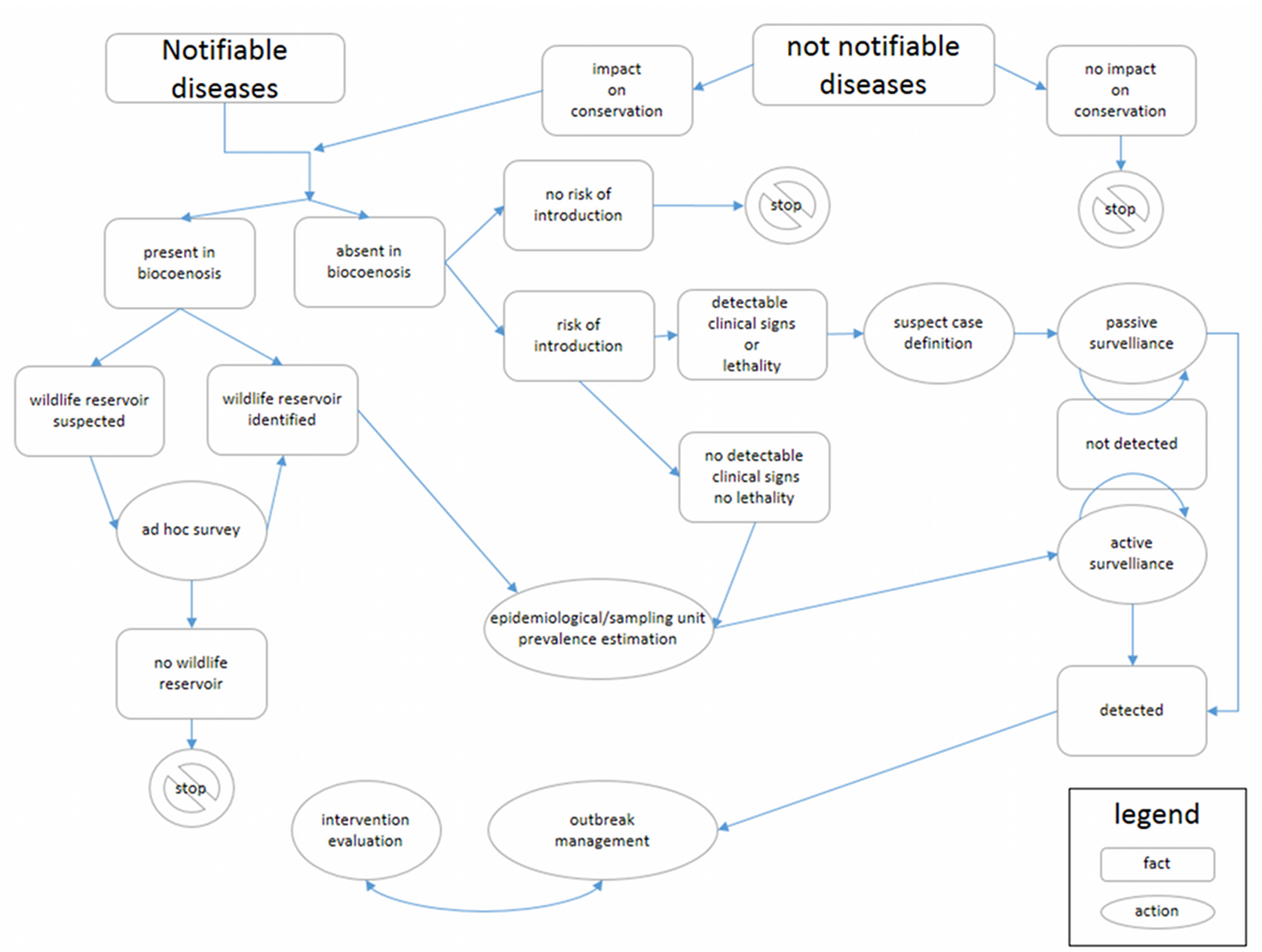

Figure 1 – Proposed decisional flow chart for surveillance of wildlife disease implementation.

period reaching a hunting rate of (0.4/365) = 0.001 day^{-1}. Such a high depopulation rate was considered compensative of the natural mortality rate (Wandeler et al., 1974).

The ratio between case fatality and depopulation rates (0.07/0.001) is 70, this means that when rabies will be introduced in the population, an infected fox is 70 times more likely to die because of the virus rather than being shot for sampling. Moreover, considering the prevalence of rabies, usually at about 1%, the probability to shot a still healthy-infected fox is even lower (hunting rate×prevalence). It means that, while a hunter is unhooking his rifle, the fox he should have killed to detect rabies virus, has been already killed by the virus itself. The speed at which the virus spreads among and kills its hosts is higher than the speed of any depopulation/sampling methods. This is also the reason why rabies has never been eradicated through mass depopulation. The system applies to all high lethal infections, as African Swine Fever, genotype II, in wild boars or H5N1 High Pathogenic Influenza Strain, Asian lineage in wild birds (Hesterberg et al., 2009).

Increasing the sensitivity of an early detection system using serological investigation: a trivial and predictable false warning

In the framework of an early detection strategy, active surveillance based on serological testing might be suggested, especially for low lethal diseases. Serological tests are aimed at detecting antibodies against the infection to be detected. Antibodies last longer than the infection; the system is thus set to detect past contacts rather than directly the infection agent. The sensitivity of the whole surveillance system will be increased. However serological tests are mainly designed for domestic animals and their sensitivity and specificity performances are poorly known when applied to wild species.

For example, if a test with a specificity of 95% is used to detect antibodies against Foot and Mouth Disease (FMD) in a disease-free country, the average test results after testing 100 healthy animal will be the following: $100\times0.95 = 95$ negative samples and 5 false positive samples. Due to the test performance limits, the FMD detection system finds some positives even if the disease is not present. Official samples tested in official laboratory result in official warnings. Positive findings, even if epidemiologically not coherent, have to be managed and a number of confirmatory tests have to be applied in order to further exclude the infection. The described example is a real one: antibodies against FMD were detected in a FMD free area in roe deer using serology.

It must be underlined that a disease free country/area with a functioning veterinary service is free from a specific disease not because samples of wildlife population have been tested negative but because all the at risk animals did not show any specific clinical sign and all the possible suspected cases are promptly investigated ruling out the presence of the infection.

The unique case of macroparasites: how to deal with abundance and aggregate distributions

Microparasites presence, such as viruses and bacteria, might be simply described by prevalence. Prevalence cannot describe macroparasites (as intestinal helminths or ticks) adequately and a better quantification of the number of parasite individual in the hosts (abundance) is needed. Abundance describes the macroparasite epidemiological meaning and

Table 1 – Most relevant and practical steps in disease surveillance and monitoring in wildlife.

Aim	Activity	Assumptions	Efficacy	Notes
Early detection	Passive surveillance	The infection has not yet introduced; high case fatality is expected	High if stakeholders collaborate; higher in large or hunted species	N/A
Early detection	Active surveillance	The infection has not yet introduced; low/null case fatality is expected	Low, high sampling intensity and continuous activities are necessary	Active serological surveillance might be used to confirm negative results obtained by passive surveillance
Understanding disease epidemiology evolution	Monitoring	Knowledge of: size of the whole at risk population(s), sampling unit, expected prevalence	High if correct methodology is applied	Sampling intensity should be calculated in order to highlight changes of prevalence over time
Assessing intervention effectiveness (i.e. vaccination)	Monitoring	Knowledge of: size of the at risk population (i.e. vaccinated), sampling unit, expected prevalence	High if correct methodology is applied	Sampling intensity should be calculated in order to highlight biologically sounding differences possibly determined by the intervention

allows the evaluation of the efficacy of any interventions. In addition, the distribution of the parasites in host population has to be considered. In a sample of 89 Italian wolves, the mean abundance of *Echinococcus granulosus* was 574.4 parasites/host (Guberti et al., 1993). The 95% confidence interval was 470-680 parasites/host, indicating that the mean number of parasites/host in the population lies at 95% probability in this range (and not that 95% of the wolves host 470-680 individual parasites). Assuming a correct mean of 600 parasites, the mean might be obtained indifferently if a) all the examined wolves host exactly 600 parasites; b) half of the wolves host 0 parasites and half 1200 parasites; c) in the unlikely hypothesis that all but one of the wolves are negatives with a single wolf hosting all the parasite population. Typically, for macroparasites, a small number of hosts arbour the largest fraction of parasites (Shaw et al., 1998). This so-called aggregated distribution of parasites has four main consequences:

1. in a host population, it is likely to observe several negative individuals even when a parasite species is abundant;
2. it is possible to have large differences in parasite abundance even with negligible differences in parasite prevalence (Anderson, 1986), making essential to estimate parasite abundance;
3. the variance of the number of macroparasites is usually much larger than the mean, which implies large standard errors and consequently large confidence intervals;
4. classical statistical methods require a very large sample size to calculate confidence intervals for macroparasite abundance.

A computer simulation demonstrates that a minimum of 50-100 individuals are needed to correctly estimate the confidence intervals given the observed mean and standard deviation of *E. granulosus* in the Italian wolf population.

Another aspect to consider for most of macroparasite species is their intimate ecological relationship with host populations. There is an increasing tendency to individuate parasites as an important part of the host ecosystem and in the evolution processes. This is certainly true for both macro and micro-parasites, whose communities usually show reduced richness in threatened host populations (Altizer et al., 2007), but this is particularly evident for helminths since very few of them (for example *Trichinella* spp. and *Echinococcus* spp.) are of public health concern whereas they are proven to play a major role in the regulation and stability of the ecological webs (White and Grenfell, 1997; Tompkins et al., 2011).

Brown bear conservation in Central Italy and the threat of Aujeszky's disease in sympatric wild boars

Aujeszky's disease is a threat for the survival of the brown bears (Bourne et al., 2010). Since most of the wild boar populations are a reservoir of the virus, the final goal of a conservation approach in veterinary medicine would be to estimate the risk of infection to spread into brown bears. A further mitigation strategy, if needed, should be a part of the entire procedure of the assessment. Ad hoc age stratified sampling (survey) should be addressed in estimating two main epidemiological parameters: the percentage of viremic wild boars and the percentage of wild boars harbouring silently the virus in some nervous ganglions. The two parameters, linked with the wild boar and brown bear population sizes and the feeding habits of the brown bear, will result in a rough estimation of the risk that a brown bear will be lethally infected through a contact with a viremic wild boar or scavenging on a (still infectious) carcass. When necessary, active wild boar management could be aimed at reducing the risk of brown bear mortality. Such an approach could lead to specific actions (including ad hoc surveys, risk mitigation etc.) avoiding debates on the relevance of theoretical threats whose real risk for the endangered species lacks any quantification.

Discussion

A simple step-by-step procedure aimed at selecting appropriate surveillance/monitoring strategies could be developed according to the above considerations, highlighted in Tab. 1; a flow chart is show in Fig. 1. In general, wildlife diseases surveillance should be based on passive surveillance and direct test. Passive surveillance only can guarantee (once it has been appropriately planned and implemented) the continuity necessary to ensure the detection of a pathogen as soon as it is introduced. Active surveillance, even when appropriately planned (right sample size, laboratory tests, sampled organs) cannot be performed continuously. Active surveillance cannot guarantee the detection of any pathogens the day after the completion of sampling and samples cannot be taken every day of the year to detect the first introduction of any infection. Moreover when lethal diseases, or diseases that cause evident clinical signs, are involved, it is likely that the rate at which a disease kills or clinical signs appear is higher (faster) than any sampling methods. Easy recognizable diseases (because of clinical signs or case fatality) can be early detected using an appropriate strategy in the framework of the passive surveillance. Active surveillance might play an important role in supporting the passive one whenever the efficacy of passive surveillance is revealed insufficient due to a limited number of tested samples. Active surveillance plays a pivotal role during outbreak management. Active surveillance, monitoring and surveys need all precise sample size estimations based on expected prevalence, population size and confidence level. However while the mere sample size calculation can be easily performed using tables or software, the identification of the sampling unit size in wildlife remain a technical challenge. The domestic animal approach (based on herd/farms, administrative unit) revealed its unfitness when applied to wildlife diseases. At present – to our best knowledge – any definition of sampling units for any wildlife disease is not available. Since most of the wildlife diseases results from a balance of local extinction and colonization (i.e. epidemic waves for Classical Swine Fever in wild boars or rabies in foxes) the size of the metapopulation that can maintain an infection for a defined period is of paramount importance for the evolution and persistence of the infection (Grenfell and Harwood, 1997). Here, we apply the following wildlife sampling unit definition: **the host target subpopulation, whose size can maintain (under the density dependent and homogeneous mixing assumptions) the infectious agent during a defined inter-sampling interval**.

Conclusions

Surveillance, monitoring and surveys are different parts of the same menu.

Legal bases and appropriate strategies tailored to the specific epidemiological situation are the pillars of any successful activity. The technical approach cannot be trivial; it must comply with both practice and theory, having a clear, achievable and sustainable aim. In the modern world all the aspects of the Veterinary Science are linked together and must meet the highest standard level. Wildlife diseases management, because of the strict links with public health, animal production and biodiversity conservation, is among the most difficult tasks showing worst counter effects when not appropriately performed. Finally the relationship between conservation and diseases deserves specific attention. A standardized risk assessment procedure has to highlight which infection/disease poses an effective risk for the survival of rare, endangered species while methodologies for appropriate mitigation strategies have still to be developed. The final aim is to turn general principles into effective actions able to minimize the risk posed by the diseases in the conservation of rare species living in complex ecosystems.

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