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Manual of Procedures for Wildlife Disease Risk Analysis

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WORLD ORGANISATION FOR ANIMAL HEALTH
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1. Bushmeat hunters returning to their village on the boundary of Odzala National Park, Republic of Congo, with a variety of duiker species harvested from the forest. Photo courtesy: Michael Kock
2. Oriental white-rumped vultures, Gyps bengalensis, feeding on a domestic water buffalo, Bubalus bubalis, in India. This species is now critically endangered as a result of ingesting the veterinary drug diclofenac used to treat buffalo and cattle for lameness and other conditions but highly toxic to vultures. Photo courtesy: Munir Virani – The Peregrine Fund
3. A Tasmanian devil, *Sarcophilus harrisii* with the cancerous growths typical of Devil Facial Tumour Disease which has decimated populations of this top predator on the Australian island state of Tasmania. Photo courtesy: Sarah Doornbusch
4. Zebra and domestic animals share a grazing area near a local village in the buffer zone of Limpopo National Park, Mozambique. Photo courtesy: Michael Kock

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Disease risk analysis (DRA) process steps

Steps in the disease risk analysis (DRA) process

Risk communication (applies throughout all DRA steps)

Purpose: Engage with relevant experts and stakeholders in a way that will maximise the quality of analysis and the probability that the recommendations arising will be implemented.

Questions: 'Who has an interest, who has knowledge or expertise to contribute, and who can influence the implementation of recommendations arising from the DRA?'

1 Problem description

Purpose: Outline the background and context of the problem, identify the goal, scope and focus of the DRA, formulate the DRA question(s), state assumptions and limitations and specify the acceptable level of risk.

Questions: 'What is the specific question for this DRA? What kind of *risk analysis* is needed?'

2 Hazard identification

Purpose: Identify all possible health *hazards* of concern and categorise into 'infectious' and 'non-infectious' *hazards*. Establish criteria for ranking the importance of each *hazard* within the bounds of the defined problem. Exclude *hazards* with zero or negligible probability of release or exposure, and construct a scenario tree for the remaining, higher priority, *hazards* of concern, which must be more fully assessed (Step 3).

Questions: 'What can cause *disease* in the population of concern?', 'How can this happen?' and 'What is the potential range of consequences?'

3 Risk assessment

Purpose: To assess for each *hazard* of concern:

a) the likelihood of release (introduction) into the area of concern;

b) the likelihood that the species of interest will be exposed to the *hazard* once released;

c) the consequences of exposure. On this basis the *hazards* can be prioritised in descending order of importance.

Questions: 'What is the likelihood and what are the consequences of an identified hazard occurring within an identified pathway or event?'

4 Risk management

Purpose: Review potential risk reduction or management options and evaluate their likely outcomes. On this basis decisions and recommendations can be made to mitigate the risks associated with the identified *hazards*.

Questions: 'What can be done to decrease the likelihood of a hazardous event?' and 'What can be done to reduce the implications once a hazardous event has happened?'

5 Implementation and review

Purpose: To formulate an action and contingency plan and establish a process and timeline for monitoring, evaluation and review of *risk management* actions. The review may result in a clearer understanding of the problem and enable refinement of the DRA. (See 'Adaptive management' on p. 45.)

Questions: 'How will the selected *risk management* options be implemented?' and, once implemented, 'Are the *risk management* actions having the desired effect?' and, if not, 'How can they be improved?'

How to use this *Manual*

Users of this *Manual* will vary considerably in their level of knowledge and experience of *risk analysis* and the resources available to them. As such, the subject matter has been organised to enable users to work through it in a logical sequence or, for more experienced users, to rapidly find and turn to their specific items of interest.

Front and back

Two quick references have been incorporated into the layout:

– The process diagram inside the cover of this *Manual* is positioned for ease of reference to the stages of the DRA process, regardless of which part of the *Manual* is being used. Next to this is a succinct description of the purpose of each step and the questions they are designed to answer. The main steps in the DRA process are colour coded throughout the book.

– The glossary is located at the back of the book for quick reference. In addition, all terms used in the glossary are italicised in the text.

Overall design

Following a brief history of *disease risk analysis* (p. 15), this *Manual* is divided into five major sections:

1. **Key concepts for wildlife *disease risk analysis*** (pp. 17–20):

An outline of fundamental concepts that should be considered when analysing wildlife disease risks.

2. **Planning and conducting a wildlife *disease risk analysis*** (pp. 21–49):

A detailed description of each step in the DRA process with examples taken from published and unpublished sources. This section also includes guidelines for successful interdisciplinary collaboration, technical, social and political considerations and some of the associated challenges.

3. **Tools for wildlife *disease risk analysis*** (pp. 51–92):

Each of the DRA process step descriptions in the previous chapter is accompanied by a box listing the tools that may be useful in completing that step. This chapter provides detailed information on a representative array of the tools available to assist practitioners in working through a DRA. The tools included range from relatively simple drawing tools that help illustrate the disease system of interest and the main influences on it, to more complex, probability-based disease and population modelling programmes that can help with more detailed quantitative analyses. For ease of access, tools are categorised according to the step(s) in the DRA process to which they apply, and also according to their utility in situations in which resources, data or access to specialists, may be constrained.

4. **Appendices** (pp. 93–136):

The appendices include additional information, examples and references relevant to the topics covered in this *Manual*.

Appendix 1 provides a guide to further sources of information of value to *wildlife disease risk analysis*. Appendices 2, 3 and 4 provide information on disease surveillance, screening for pathogens and Monte Carlo modelling. These are large topics which are dealt with comprehensively in other texts. The purpose of the brief introductions included here is to help the broader audience of wildlife managers, policy makers and field biologists, who may be less familiar with these topics, to access a basic understanding and vocabulary in these areas.

Also included are guidelines for planning a DRA workshop (Appendix 5) and a DRA evaluation (Appendix 6). Three wildlife DRA case summaries that illustrate the application of the process to a range of scenarios are contained in Appendix 7, while Appendix 8 provides an example of a more comprehensive DRA utilising some of the tools featured in this *Manual*.

5. **References and Glossary**

A reference section on pages 137–143 is followed by a glossary of the technical terms used in this *Manual*. As the meaning of some of these words or phrases can vary between different disciplines (e.g. veterinary science vs ecology), it is advisable to check the meaning attributed to them by the authors of this publication. As noted above, to assist this, each of the terms featured in the glossary is italicised in the text.

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Dedication

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Key concepts for wildlife disease risk analysis

D. Travis, S.C. MacDiarmid, K. Warren, C. Holyoake, R. Kock, R.M. Jakob-Hoff, I. Langstaff & L. Skerratt

People with a range of backgrounds and perspectives may apply *disease risk analysis* (DRA) to a broad spectrum of situations. To be successful, this *Manual* must communicate its contents effectively and consistently to all of these groups. In pursuit of this goal, we begin by describing a number of key concepts. Gaining an understanding of these is an important precursor to understanding the science and practice of DRA.

Risk

Risk is usually defined as the chance of encountering some form of harm, loss or damage. For this reason it has two components:

1. the likelihood[1], or probability, of something happening and, if it does happen,
2. the consequences of the deleterious activity.

Because of the element of chance, we can never predict exactly what will happen but, through an appropriate process, we can estimate the probability of any particular outcome occurring (Brückner *et al.* 2010).

Risk analysis

'*Risk analysis* is a formal procedure for estimating the likelihood and consequences of adverse effects occurring in a specific population, taking into consideration exposure to potential *hazards* and the nature of their effects' (Thrusfield 2007). It is a tool to enable decision makers to insert science into policy.

Disease

At the most basic level, disease is defined as any impairment of the normal structural or physiological state of an organism. The manifestation of disease is often complex and may include responses to environmental factors such as food availability, exposure to toxins, climate change, infectious agents, inherent or congenital defects, or a combination of these factors (Wobeser 1997).

Three important epidemiological concepts of disease to keep in mind are:

1. Disease never occurs randomly.
2. All diseases are multifactorial.
3. Disease is always a result of an interaction among three main factors: pathogenic agent, host and environment (Fig. 2).

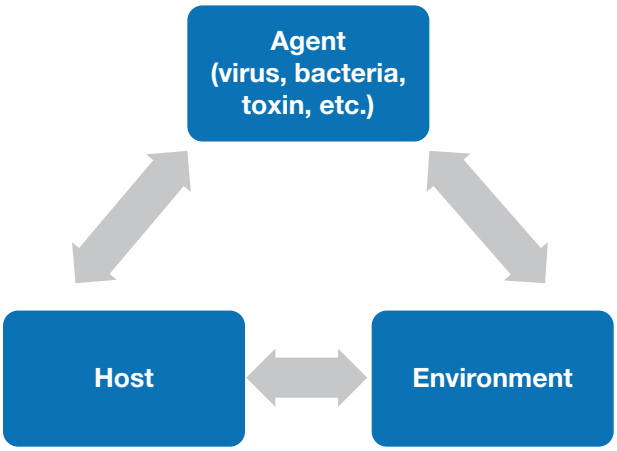

Fig. 2
Interaction among pathogenic agent, host and environment

Infectious microbes are a normal part of the *ecosystem* and thus disease plays an important role in maintaining the genetic health of populations and in regulating population numbers (Smith *et al.* 2009). However, in a highly disturbed environment, where significant and relatively permanent changes from earlier ecological states have occurred, disease may threaten the survival of an entire population.

Disease causes and impacts

Given that infectious microbes ('agents') occur normally in the environment, severe environmental events (natural or human induced) that alter the balance among agent, host and environment may result in the introduction, spread or manifestation of disease in a specific population. Some examples are given below.

1 The terms 'likelihood' and 'probability' may be used interchangeably. There is a tendency to use the term 'probability' when referring to quantified risk, and 'likelihood' when risk has been assessed qualitatively. However, both terms are correct

1. Human–wildlife interactions

Human–*wildlife* interactions can occur through hunting or harvesting, construction of roads, habitat modification, ecotourism, animal movement including global trade of animals and animal parts, pollution (e.g. organic contaminants, heavy metals, toxins, pharmaceutical drugs, sewage, oil spills, etc.). See Box 3 for an example.

Box 3:
How human pregnancy testing may have contributed to global amphibian decline

In 1934 urine from pregnant women, injected into African clawed frogs, *Xenopus laevis*, was found to stimulate ovulation and became the basis of a human pregnancy test.

Subsequently large numbers of this frog species were shipped to diagnostic and research laboratories worldwide.

African clawed frogs have since been found to be carriers of the amphibian chytrid fungus, *Batrachochytrium dendrobatidis* but usually remain disease free.

Mass extinction of amphibians in multiple geographic regions has subsequently been associated with the spread of the disease chytridiomycosis caused by this fungus.

The accidental or deliberate release of infected *Xenopus* frogs is one mechanism proposed for the dissemination of this pathogen. One retrospective study demonstrated that the fungus was introduced to Mallorca through the release of captive-bred Mallorcan midwife toads, *Alytes muletensis*, which had been in contact with chytrid-infected Cape platanna, *Xenopus gilli*, an endangered frog native to Western Cape, South Africa.

References: Weldon et al. *2004; Skerratt 2007; Walker* et al. *2008*

2. Livestock–wildlife interactions

Interactions between *wildlife* and domestic livestock (cattle, sheep, pigs, etc.) can occur, for example, through direct or indirect contact, erection of fences, use of pesticides or use of veterinary drugs (Box 4).

Box 4:
How pain relief for cattle increased the risk to people from rabies

Diclofenac (a non-steroidal anti-inflammatory drug) was used to provide pain relief for cattle in India, Pakistan and Nepal where these animals are allowed to die naturally, in accordance with Hindu beliefs.

Vultures scavenged the carcases of cattle left to decay in the open.

Diclofenac residues in the tissues of treated dead cattle have been found to be highly toxic to vultures, resulting in up to 99% mortality in some species.

The decline in vultures has favoured an increase in packs of rabies-carrying feral dogs scavenging cattle remains.

The number of cases of rabies in people due to dog bites has since increased.

References: Oaks et al. *2004; Sharp 2006; Markandya* et al. *2008; see also Appendix 7 (p. 119) of this* Manual

3. Wildlife management

Wildlife management actions may include animal movements, reintroductions, veterinary treatments, *vaccination*, fencing (e.g. creation of a *wildlife* reserve). For instance, see Box 5.

Box 5:
The spread of crayfish plague by fisheries management

Healthy North American signal crayfish, *Pacifastacus leniusculus*, are carriers of a fungus, *Aphanomyces astaci*.

These apparently healthy crayfish were translocated and released into European crayfisheries in the 1970s.

European white-clawed crayfish, *Austopotamobius pallipes*, had no immunity to the fungal organism which, in these previously unexposed animals, caused 'crayfish plague', leading to mass mortality.

In Britain since 1970 native crayfish populations from 88.6% of sites have either been eliminated, or are directly threatened, by crayfish plague infection, or habitat invasion by signal crayfish or pollution.

References: Holdich and Reeve 1991; Alderman 1996; Daszak et al. *2000*

4. Climatic events

Climatic events that may be associated with *wildlife* disease emergence include climate change, El Niño and La Niña events, fire, flooding and drought (Box 6).

Box 6:
Examples of disease spread associated with climatic events

1. Impacts of climate change on sheep parasites in Northern Ireland

'The results of this [10 year study] … revealed shifts in seasonal abundance and appearance times of parasites during the calendar year, which are likely due to the effects of climate, specifically: an increased abundance of trichostrongylosis/ teladorsagiosis and strongyloidosis in the south and west of the Province.'

Reference: McMahon et al. *2012*

2. Mosquito-borne malaria and El Niño

Ecuador, Peru and Bolivia suffered serious malaria *epidemics* after heavy rainfall in the 1983 El Niño. The *epidemic* in Ecuador was exacerbated by displacement of populations due to the flooding.

Reference: World Health Organization 2000

3. Plant diseases favoured by drought

'Drought reduces the breakdown of plant residues. This means that inoculum of some [*pathogens*] does not decrease as expected and will carry over for more than one growing season. The expected benefits of crop rotation may not occur.

Bacterial numbers decline in dry soil. Some bacteria are important antagonists of soil borne fungal diseases. These diseases can be more severe after drought'.

Reference: Murray et al. *2006*

The consequences of pathogen introduction or spread at the individual level may be obvious (e.g. overt *clinical signs* of ill health or death), or may be more subtle such as a reduction in immune function, impaired reproduction, subtle behavioural changes that may render individuals more prone to predation or accident, or decreased growth rate (Wobeser 2006).

As illustrated in Figure 3, diseases that affect many individuals may result in adverse effects on the population. These effects may be driven by multiple factors such as changes in birth rates, death rates, immigration and emigration. The population effect exerted by disease may, in turn, result in *ecosystem*–scale consequences through changes in community composition (competitors, predators, prey), productivity and stability (Tompkins *et al.* 2011).

The examples described in Boxes 3 to 6, illustrate that sometimes the less visible and longer term effects of disease on individuals or populations can have a profound impact. Consequently these potential impacts need to be considered in a *wildlife* DRA.

Objectivity

It is often said that *risk analysis* is an 'objective' process. The reality is that in disease risk analyses there are often so few data available that the analyst begins, unconsciously, to substitute value judgments for facts. Indeed, in assessing the consequences of disease introduction a degree of subjectivity is almost unavoidable. Risk analyses are seldom truly *objective* and for this reason *transparency* in declaring all assumptions made is essential (MacDiarmid 2001).

Proportionality

Actions taken to prevent or minimise disease risks to *wildlife* populations or biodiversity conservation must be in proportion to the likely consequences of disease entry. For instance, a *risk analysis* may conclude that there is a significant likelihood that an introduction of animals into a new area would introduce a particular disease agent. However, if there are other, unmanaged movements of animals, people or their chattels into the same area, the application of risk mitigation measures to the planned introduction may not be warranted.

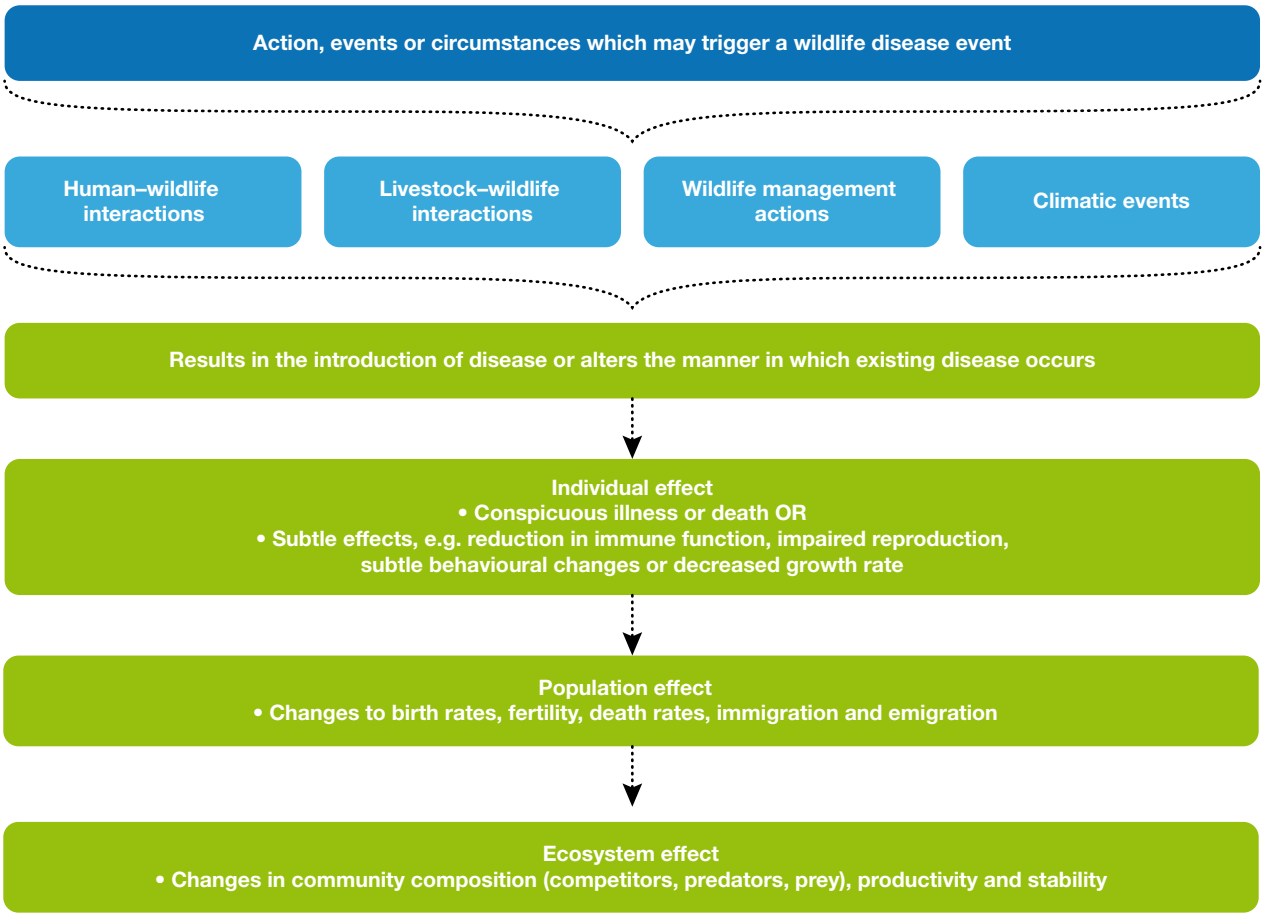

Fig. 3
Possible drivers of disease introduction and associated consequences

Worthington and MacDiarmid (2011) pointed out that it is important to consider this issue of proportionality in an analysis of the disease risks posed by the importation of non-human primates into zoos. As an example they considered a situation in which there is some likelihood of an imported primate carrying a *pathogen* that is equally likely to be carried by a human. It would not be justified to impose stringent measures on the importation of a few primates when there are no meaningful preventive measures that could be applied to the hundreds of thousands of humans who enter the country each year. In this situation, the imposition of risk mitigation measures to the primate importation would do nothing to significantly reduce the biosecurity risk to the importing country. (However, the manager of the zoo might well impose measures to reduce risks to other animals in the zoo.)

Acceptable risk

The *risk communication* process is essential in helping decision makers to deal with one of the most difficult problems encountered during the *risk analysis* process, namely determining what constitutes an 'acceptable risk' (MacDiarmid and Pharo 2003).

Zero risk is seldom, if ever, attainable and some degree of risk is unavoidable. For this reason, deciding whether or not a particular risk is acceptable is generally a societal or political decision because the benefits of a particular activity for one stakeholder group may have adverse consequences for another (MacDiarmid and Pharo 2003; Thrusfield 2007).

For example, when considering the disease risks to an unspoiled *ecosystem* posed by the construction of a road, risks considered acceptable by a government agency tasked with economic development may be quite unacceptable to the government agency tasked with *wildlife* conservation.

Similarly, the disease risks posed by relocation of wild animals into a conservation reserve may be acceptable to those ecologists concerned with maintenance of a genetically diverse population of endangered animals but be considered unacceptable to neighbouring farmers or ranchers concerned with the health of their livestock.

An example of an acceptable disease risk may be the translocation of kiwi harbouring a low number of coccidian intestinal parasites providing that other, specified, health indicators (e.g. body condition, behaviour, haematology parameters, etc.) are within the range considered healthy for the species.

The 'precautionary principle'

In situations in which there is significant scientific *uncertainty* regarding a risk and its consequences, such as a cause-and-effect relationship not being fully established, the 'precautionary principle' may be invoked. This principle holds that the implementation of preventive measures can be justified even in the absence of such a risk. This precautionary approach has a useful protective effect as the initial response to a new potential threat and may be an appropriate reaction to complex problems such as loss of biodiversity, where more formal *risk analysis* may not be adequate (Thrusfield 2007).

Assumptions

A *risk assessment* may sometimes be criticised because some of its inputs are based on assumptions. However, all decision making is based on assumptions, and *uncertainty* and subjectivity do not mean that valid conclusions cannot be drawn. Although many of the inputs of a *risk assessment* are surrounded by *uncertainty*, one may be able to have confidence that the 'true risk' is unlikely to exceed the estimate resulting from a careful and conservative analysis (MacDiarmid 2001).