

# Zoonoplasticity as an intuitive risk protocol for companion-animal-linked zoonoses

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## Summary

Zoonoses are diseases transmissible between non-human and human animals. Over 200 zoonoses are known, of which at least 60 are associated with (especially exotic) companion animals. Current risk-impact assessment approaches for zoonoses are largely cumbersome and, to be meaningful, may require extensive detailed information. A literature search and review were conducted for current risk assessment protocols for common zoonoses, with subsequent development of two novel rapid scoring methods for evaluating potential risk associated with companion-animal-linked zoonoses. Accordingly, a novel, two-tier methodological concept – ‘zoonoplasticity’ – was prepared using an intuitive risk approach. The first tier considers risk principles for companion animals and husbandry practices, and pre-weights animals by class or species. The second tier considers established pathogen- or disease-based questions and assigns a degree of risk. Thus, the zoonoplasticity concept enables pathogens or their resultant zoonoses to be scored and provides a clear points-based protocol offering guidance concerning potential threat, in particular where more quantifiable risk assessment is unavailable because of information deficits. The zoonoplasticity concept was tested with 15 animal species and 22 known zoonoses against European Centre for Disease Prevention and Control (ECDC) operational guidance as a comparative system. Risk categorisation was 100% consistent for 21 of the 22 specific zoonoses, while requiring minimal information input, and the overall comparison rate was 98.85%. Zoonoplasticity is not intended to provide an absolute measure of risk or to replace existing methodologies, rather it is an attempt to standardise a practical judgement protocol that accounts for various relevant issues, and to offer a potentially helpful indicator of concern. The zoonoplasticity concept will be relevant to remits for medical professionals, veterinary medical professionals, public health professionals, government administrators, biomedical researchers and others.

## Keywords

Companion animal – Intuitive risk – Risk assessment – Zoonoplasticity – Zoonoses.

## Introduction

Zoonoses are diseases transmissible between non-human and human animals, and relevant pathogens include parasites, bacteria, viruses, fungi and prions (1, 2, 3). Across human diseases, 61% are believed to be of potentially zoonotic origin (4) and 75% of global emerging human diseases have a wild animal link (5). Over 200 zoonoses are known (3, 6), of which at least 60 are associated with companion animals (3). It is estimated that in the United Kingdom 13 million households (45%) collectively keep 51 million

companion animals, which include 17 million domesticated dogs and cats, and 34 million semi-domesticated and exotic animals (using the lower published estimate of 30 million indoor aquaria and outdoor fishes) (7). Over 13,000 species across all animal classes (invertebrates, fishes, amphibians, reptiles, birds, mammals) are involved in companion animal trading and keeping (8), meaning that >99% of kept animals are exotic, or types other than dogs and cats.

Whilst humans and domesticated animals may have closer associations and more regular contact, exotic companion animal zoonoses are considered a disproportionate risk

due to these animals harbouring locally atypical pathogens (3, 9). In addition, familiarity of veterinarians with exotic zoonoses and with normal and abnormal animal health states across diverse species is highly limited, as is the availability of advice to the public (3, 10, 11). Accordingly, the zoonotic reservoir is large and diverse, with close proximity to regular human lifestyles (12) – leading to companion animal trading and keeping being described as a ‘Trojan horse’ because wild animals in particular are invited into households that are unaware of relevant risks (13, 14). Despite many targeted governmental and non-governmental attempts at public health education regarding companion-animal-linked zoonoses (3, 15), emergent diseases, for example reptile-related salmonellosis, are not abating (16). For some zoonoses much is known regarding pathogens and resultant diseases and therapies, as well as related epidemiology, prevalence and incidence, whereas for others little is known beyond occurrence, thus the importance of the threat remains under-ascertained (1, 15). For this report, zoonoses and risk issues are associated with animals kept as companion animals in the home or at any of the variety of hubs at which supply, storage and trading of animals occurs. In such situations, proximity and therefore direct or indirect contact with animals is common. Although this report focuses on exotic companion animals, some semi-domesticated and domesticated animals are also included, in particular for comparative purposes.

This investigation resulted in the development of a novel, two-tier methodological concept – ‘zoonoplasticity’ – which uses an intuitive risk approach for evaluating potential risk associated with companion-animal-linked zoonoses. The first tier considers risk principles for companion animals and husbandry practices, and pre-weights animals by class or species. The second tier considers established pathogen- or disease-based questions and assigns a degree of risk. Thus, the zoonoplasticity concept enables pathogens or their resultant zoonoses to be scored and provides a clear points-based protocol offering guidance on potential threats, in particular where more quantifiable risk assessment is unavailable because of information deficits. It is intended that the zoonoplasticity concept will be relevant to medical and public health professionals, government administrators, impact assessors, researchers and others.

## Terminology

In this report, the following terms have these particular meanings:

– ‘Zoonoplasticity’ = generalisation of pathogenic potential in a population accounting for diverse biological and management factors that can increase public health risk, including microbial pathogenicity, microbial reservoir,

disease prevalence, transmissibility and opportunities for transmission.

– ‘Intuitive risk’ = an approach associated with either situation- or evidence-specific decision-making that involves recognising cues or patterns (17). Intuitive risk utilises both subjective and objective information (18, 19, 20, 21).

– ‘Exotic companion animal’ = any animal produced or kept for pleasure or companionship that is non-native to a region or non-domesticated (8).

– ‘Low’, ‘Moderate’, ‘High’ and ‘Very High’ are indications of potential risk that broadly correspond to categorisations in general use. Each zoonoplasticity risk category is divided into points, for example Low (1–10), therefore this category effectively includes very low risk where scores are at or close to 1 and borderline moderate risk where scores are at or close to 10, and this principle continues across all categories.

– ‘Risk assessment’ = use of Figure 1 and Tables I to III to evaluate potential threat.

## Intuitive risk in epidemiology and public health

At its most essential, applying intuitive risk to zoonoses is commonly practised. For example, it may be correctly presumed that rabies (a rhabdovirus) manifests extremely high pathogenicity and mortality whilst having a minimal reservoir, and being rare in western global regions (22), whereas giardiasis (*Giardia* spp.) manifests low pathogenicity and mortality despite having common reservoirs and occurring in eastern and western global regions (23). Beyond such examples, prioritising risk elements can be highly speculative, and user-friendly systematisation is probably beneficial. Wisdom and experience offer helpful guidance in public health. However, individual experience can also bias decision-making (24), i.e. ‘negative medical salience’, although this complication may be reduced or avoided by reference to essential tabulated prompts (24), which the zoonoplasticity concept may augment.

Accordingly, intuitive risk-based assessment, whether resulting from unconscious experiential prompts or from external algorithms, is integral to medical and epidemiological decision-making. Zoonoplasticity potentially offers an alternative provisional assessment criterion to protracted analytical deliberative evaluations.

## Current zoonoses assessment methods

Several general zoonotic risk assessment methods are available to prioritise risk, for example multidisciplinary evidence- and expert-based assessment and opinion (25), questionnaire-based evaluation of public perception (26), study of local community and human practices (27) and evaluation of global disease hotspots and human occupation of regional habitats (28). These and other approaches inform and refine the evaluation of zoonoses in various contexts, although their application to exotic companion animal trading and keeping is limited, in particular because this sector has certain uniquely combined and cumulatively relevant characteristics including complex animal sources and routes, animals of uncertain origin and health status, rapid global movement of animals, largely unregulated and widely criticised husbandry and hygiene practices, negligible quarantine procedures and a high frequency of exposure in the home (3, 12).

## Methods

### Literature search and review

A literature search and review were conducted by the author for current common zoonoses risk assessment protocols using online resources, Google Scholar, Embase and PubMed, since the year 2000, using the following key terms: 'zoono', + 'disease', + 'animal', + 'human', + 'risk assessment', + 'evaluation'. Sixty-seven publications were identified to which inclusion–exclusion criteria were applied in respect of sufficient relevance on the basis of: a) appearing in a peer-reviewed source; b) relevance to multiple rather than specific zoonoses; and c) containing risk assessment discussion or protocols. Twelve publications met all inclusion criteria. Of the 12 selected publications, five included protocol-based zoonoses assessment methodologies and thus were considered of further particular relevance. The 12 selected publications and their essential messages were:

- Brown (5) provides an assessment of risk factors associated with emerging zoonoses
- Karesh *et al.* (4) provide an assessment of risk factors associated with emerging zoonoses
- Chomel *et al.* (1) provide an assessment of risk factors associated with emerging zoonoses
- the European Centre for Disease Prevention and Control (ECDC) (25) provides a risk assessment protocol for zoonoses
- Ng & Sargeant (26) provide a method for prioritisation of zoonotic diseases
- Smith *et al.* (14) provide background to vulnerable groups and risk factors concerning exotic companion animals
- Stull *et al.* (15) provide background to public attitudes to zoonoses and relevant risk factors
- Warwick *et al.* (3) provide a general review of over 60 exotic companion animal zoonoses, related pathogens, risk factors and guidance on prevention and control
- Ashley *et al.* (12) provide an explanation of exotic companion animal trade dynamics and veterinary and human medical health consequences
- Warwick *et al.* (29) provide a general evaluation of both zoonotic risk factors and animal welfare concerns related to exotic and domesticated and non-domesticated – 'wild' – companion animals
- Whitfield & Smith (2) provide a review of companion animals and zoonoses, and offer recommendations for improvement interventions
- Allen *et al.* (28) provide a review of global hotspots of zoonotic disease.

The five publications that included protocol-based zoonoses assessment methodologies were: ECDC (25), Ng & Sargeant (26), Warwick *et al.* (3), Warwick *et al.* (29) and Allen *et al.* (28).

### Development of zoonoplasticity protocol

The zoonoplasticity concept borrows its design from a companion animal suitability algorithm called 'EMODE', which categorises companion animal species as 'Easy', 'Moderate', 'Difficult' or 'Extreme' based on both pre-weighted scores and secondary refined questionnaire evaluation (29). The pre-weighted scores were arrived at by criteria determined by the EMODE system for each animal category. Two complementary methods (Tiers 1 and 2) were developed for the zoonoplasticity protocol. Certain relevant background considerations on zoonoses that inform the two complementary methods are summarised in Table I. Figure 1 converts information from Table I into a longitudinal bar chart depicting 'at a glance' broad risk for animal 'type' – e.g. fish, amphibian, reptile, bird, mammal or mammal primate.

Tier 1 assessment (Table II) is derived from established risk principles for companion animals and husbandry practices (3), including:

- a) whether or not local relevant veterinary and other expert advice is regularly available (familiarity with a particular animal class, species-specific health states and potential common zoonoses associated with such animals)
- b) degree of ease or difficulty associated with husbandry demands (greater husbandry challenges imply increased specific contact with animals)

- c) commonness of zoonotic association (regular reported infection indicates certain risk)
- d) likelihood of following strong preventative measures.

Animals are pre-weighted by class or species, providing a Foundation score (a more precise numerical score of 5–15 derived from data in Figure 1) to which Refinement scores procured from specific management questions are added. The final cumulative score is numerically (1–35+) tracked along a colour-coded bar indicating zoonoplasticity intuitive risk level.

Tier 2 assessment (Table III) considers pathogen- or disease-based questions and assigns a degree of risk, accumulating an independent score level (1–50+). Given that this zoonoplasticity approach involves novelty of design, it was tested for comparative consistency against an existing assessment method, the ECDC operational guidance on rapid risk assessment (25), using the same input information. Consistency was assessed based on percentage of similarity between the zoonoplasticity scores and the comparison system risk assessment method, to rate zoonotic risk as ‘Low’, ‘Moderate’, ‘High’ or ‘Very High’ (Table IV). To avoid selectivity bias, the list of sample zoonoses was compiled using all 22 zoonoses that were common to two major reviews (3, 26) and that are known to be associated with exotic companion animals. Because only known zoonoses were considered, a ‘no risk’ criterion was redundant.

Given that assessments using zoonoplasticity are intuition-based, the scoring method is intended to accommodate wide judgement margins, and this is implied in the four risk categories. Essentially, the objective of zoonoplasticity scoring is broadly to place a zoonosis within one of the four risk categories with reasonable consistency. Although alternative questions could reasonably have been used for Tables II and III, it is proposed that those included are adequate to enable assessment using the intuitive risk principle.

The method and questions for Table II criteria 1–9 and Table III criteria 1–6 were developed according to the following approaches. Table II criterion 1 uses as a guide the Warwick *et al.* (29) system for broadly determining potential physical risk of injury to humans from different animals, and implied infection risk. Criterion 2 uses as a guide the Warwick *et al.* (29) system in which animals with potential lifespans of >10 years are regarded as relatively long-lived and thus involve greater overall exposure time to their keepers. Criterion 3 uses as a guide Brown (5), Karesh *et al.* (4), Chomel *et al.* (1) and Ashley *et al.* (12) regarding a high proportionate presence of human pathogens in wildlife. Criterion 4 assumes greater pathogen contamination in fresh versus processed animal feed. Criterion 5 uses as a guide Allen *et al.* (28) regarding global zoonoses hotspot regions. Criterion 6 applies general quarantine principles inherent

in regular legislation and local monitoring. Criterion 7 applies general notifiable disease principles inherent in regular legislation and local monitoring. Criterion 8 uses as a guide Smith *et al.* (30), who identify particular vulnerable groups in relation to exotic companion animal keeping. Finally, criterion 9 provides for arbitrary accommodation of speculative risk factors.

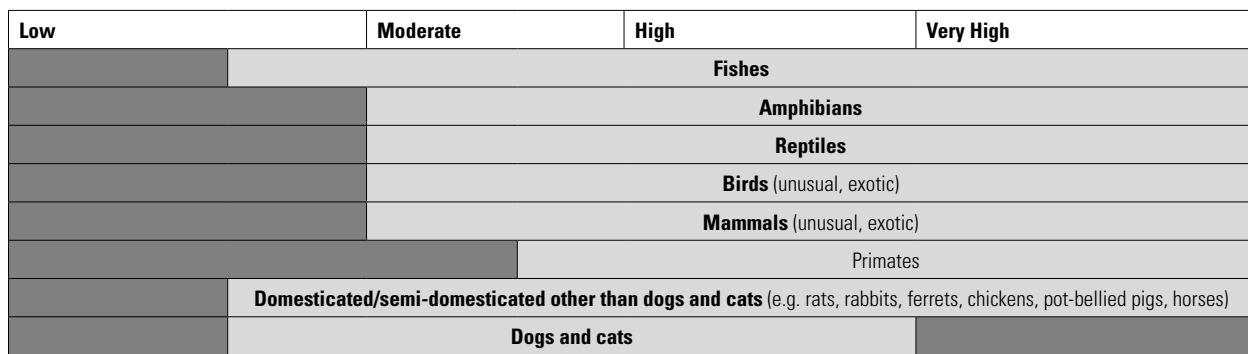
Table III criterion 1 applies general notifiable disease principles inherent in regular legislation and local monitoring, as well as using a presumption of epidemiological prevalence of >5% of all sources of a relevant pathogen in a population as an indicator of a significant public health hazard (for example, salmonellosis associated with companion animal reptiles has >5% prevalence (31) and is considered a significant disease risk). Criterion 2 applies general notifiable disease principles inherent in regular legislation and local monitoring. Criteria 3 and 4 apply general disease transmission principles inherent in regular medical training. Criterion 5 considers whether relevant regional governmental public health advice is widely available. Finally, criterion 6 provides for arbitrary accommodation of speculative risk factors.

## Results

Table I provides an essential summary of relevant background factors that assist in informing the subsequent approaches, and Figure 1 translates this into an ‘at a glance’ risk evaluation. Tables II and III present the zoonoplasticity concept and the Tier 1 and Tier 2 assessment questionnaires. Table IV provides the results of a comparative consistency test for the zoonoplasticity pathogen- or disease-based assessment questionnaire presented in Table III, where categorisation was 100% consistent for 21 of the 22 specific zoonoses and the overall comparison rate was 98.85%. Appendix 1 provides worked examples for the Tier 1 questionnaire presented in Table II, regarding animal-related risk. Appendix 2 provides worked examples for the Tier 2 questionnaire presented in Table III, regarding pathogen- or disease-related risk.

## Discussion

Objective assessment of zoonoses is a desirable priority and is practised, where feasible, based on available information. Intuitive systems are by their nature somewhat subjective, requiring individualised input that may harbour experiential drivers, although such compromise arguably infiltrates all decision-making aids. However, the use of closed questions in the zoonoplasticity protocols is aimed at reducing subjectivism where data limitation and individual experience are relevant.



**Fig. 1**  
**Zoonoplasticity intuitive risk assessment tool for companion-animal-linked zoonoses: broad risk associated with animal class and species**

Darker shaded areas indicate zones of null relevance (i.e. for Fishes the relevant categorisation area commences at the mid-point of ‘Low’ and extends to the full range of ‘Very High’, and for Dogs and cats the relevant categorisation area commences at the mid-point of ‘Low’ and extends only to the full range of ‘High’, but no further); lighter shaded areas indicate risk relevance

**Table I**  
**Zoonoses considerations by animal class**

Based on reports (1, 2, 3, 7)

Animal class	Zoonoses associated (at least)	Representation in home	Degree of handling/contact	Husbandry demands	Available impartial expert biological, veterinary and medical advice
Fishes	10	Very common	Rare	Low	Low
Amphibians	40	Uncommon	Infrequent	Moderate–extreme	Low
Reptiles	40	Common	Frequent	Moderate–extreme	Low
Birds (semi-domesticated, unusual, exotic)	34	Common	Occasional	Moderate–extreme	Low
Mammals (semi-domesticated, unusual, exotic)	30	Common	Frequent	Moderate–extreme	Low–moderate
Primates	15	Rare	Frequent	Extreme	Low
Dogs and cats*	16	Very common	Frequent	Low	Very high

\*Note: Dogs and cats can be categorised as relatively easy to keep compared with exotic or non-domesticated wild animals. Reasons for this difference include the facts that dogs and cats are: naturally affiliative, domesticated, typically able to freely roam a household, able to have regular access to outside environments, well understood by the public in terms of their welfare needs and well supported by easily accessible local veterinary services. In comparison, exotic, non-domesticated or wild animals typically do not have the same listed advantages, and are instead usually caged, thus requiring regular human maintenance of enclosed environments

**Current methods**

Current impact-assessment methods are typically extensive, may run to many pages and may include complex algorithms and flow diagrams – each of which demands information that is frequently incomplete or absent and confounding assessments. Considerations such as travel to exotic locations, bushmeat importation or consumption, farming and wildlife migration are commonly applied to zoonoses risk assessments. However, these issues are commonly transient and unusual and have limited value for determining risk where companion-animal-linked zoonoses are involved, because animals in the domestic environment represent continuous potential threats. Exotic companion animal trading and keeping is

essentially a specific issue with particular considerations infrequently factored into zoonosis assessment models.

**General considerations**

The number of zoonoses with which animals are associated indicates possible infectivity; representation of animals in the home indicates a potential microbial reservoir; degree of human contact such as handling indicates possible direct or indirect contact episodes, dispersal of microbes and opportunities for transmission. Furthermore, demanding husbandry indicates the extent and frequency of close contact required to manage animals, which may result in dispersal of microbes and opportunities for transmission, and availability of impartial expert advice indicates the

**Table II (Tier 1)**  
**Zoonoplasticity intuitive risk assessment tool for companion-animal-linked zoonoses: a biological (animal)- and management-based questionnaire evaluation**

Foundation score			Pre-weighted points
<b>Fishes</b> e.g. eels, rays, goldfish			5
<b>Amphibians</b> e.g. frogs, toads, newts, salamanders			10
<b>Reptiles</b> e.g. crocodiles, turtles, tortoises, lizards, snakes			10
<b>Birds</b> e.g. parrots, cockatiels, cockatoos			10
<b>Mammals (unusual, exotic)</b> e.g. bats, foxes, meerkats, kinkajous, sloths			10
<b>Primates</b> e.g. monkeys, apes, prosimians			10
<b>Domesticated/semi-domesticated</b> e.g. rats, rabbits, ferrets, chickens, pot-bellied pigs, horses			5
<b>Dogs and cats</b>			5
<b>Refinement scores</b>			
<i>Select relevant Foundation score (pre-weighted points), then add Refinement scores (accumulator points) below</i>			
<i>Answer one (most relevant) question from each criterion (1–9) then add all accumulator points</i>			
Criteria/questions are divided into:			
– <b>biological</b> (e.g. about an animal, its habits and background) and			
– <b>management</b> (e.g. about environment, formal controls, household)			
Criterion/question	Rationale	Points	Foundation score = Accumulator points
<b>Biological questions</b> <i>If answer is 'yes' add points indicated. If answer is 'no' move to next question</i>			
1. Animal capable of inflicting injurious bites or scratches?	Many zoonoses are transferred via bites and scratches	+1	
2. Animal has potentially long lifespan (e.g. ≥10 years)?	Longer-lived animals may accumulate greater pathogen loads and increased opportunities for transmission	+1	
3. Wild-caught?	High uncertainty of origin and health state. Wild-caught animals are more likely to harbour certain pathogens and shed = elevated concern	+2	
or Captive-bred?	Reduced uncertainty of origin and health state. Captive-bred animals are less likely to harbour certain pathogens and shed = reduced concern	+1	
	Note: If unsure presume wild-caught		
4. Food sources include fresh animal protein, live food, plant matter, frozen?	Carnivorous and herbivorous species are more likely to harbour potential pathogens than animals fed processed feed	+2	
or Dried/processed?		+1	
<b>Management questions</b> <i>If answer is 'yes' add points indicated. If answer is 'no' move to next question</i>			
5. Animal from a global zoonoses hotspot?	Animals sourced from global zoonoses hotspots may harbour inherent significant or raised risk levels	+3	
6. Animal subject to quarantine? or Animal not subject to quarantine?	Endothermic ('warm-blooded') animals (i.e. mammal, bird) are normally quarantined = reduced risk Ectothermic ('cold-blooded') animals (i.e. invertebrate, fish, amphibian, reptile) are not normally quarantined = increased risk	0 +1	
7. Is animal strongly associated with a regionally notifiable disease?	Indicates pathogen or disease already at significant or raised risk level	+2	
8. Home includes vulnerable group?	Vulnerable groups (e.g. under 5 years, immunocompromised, pregnant, undergoing chemotherapy, post-surgical, sick) are significantly more susceptible to many zoonoses	+5	
9. Other question(s)	Provides optional additional scores according to novel factors		
<b>Total points = +1 (per novel point)</b>			
<b>Zoonoplasticity intuitive risk level</b>			
Low	Moderate	High	Very High
1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 +

**Table III (Tier 2)**  
**Zoonoplasticity intuitive risk assessment tool for companion-animal-linked zoonoses: pathogen- or disease-based questionnaire evaluation**

Answer one (most relevant) question from each criterion (1–6) then add all accumulator points If answer is 'yes' add points indicated. If answer is 'no' move to next question			
Criterion/question	Rationale	Points	Accumulator points
1. Zoonosis absent?	Regional absence of a zoonosis negates requirement to assess risk. However, theoretical risk can still be calculated on presumption of presence (see footnote)	1	
or			
Zoonosis rare (e.g. <1% of all sources of a relevant pathogen in a population)? or	Incidence, prevalence and opportunities for transmission are implied	1	
Zoonosis uncommon (e.g. ≥1% of all sources of a relevant pathogen in a population)? or		2	
Zoonosis common (e.g. ≥5% of all sources of a relevant pathogen in a population)? or		3	
Zoonosis very common (e.g. ≥10% of all sources of a relevant pathogen in a population)?		6	
2. Zoonosis is an emergent disease (i.e. recently rising)?	Particular concerns re. incidence rate	6–0	
3. Person to person communicability low? or		1	
Person to person communicability moderate? or		2	
Person to person communicability high? or		3	
Person to person communicability very high?	Potential virulence implied	6	
4. Symptomatically typically mild and self-limiting? or	Indicates management challenges and treatment burden	1	
Symptomatically typically moderate and requiring minor treatment? or		3	
Symptomatically typically serious and requiring major treatment? or		10	
Symptomatically typically severe or fatal, requiring critical treatment?		20	
5. Public awareness of risk and self-directed precautions?	Public awareness, regularity of vaccination, commitment to effective hygiene, risk avoidance (assign one score: i.e. poor = 6; low = 3; good = 1)	6–1	
6. What if?	Addresses other scenarios (e.g. mutation, public habit [fad], infrastructure competency, antimicrobial resistance, few opportunities for control)	0–20	
<b>Total points =</b>			
<b>Zoonoplasticity intuitive risk level</b>			
Low	Moderate	High	Very High
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	16 17 18 19 20 21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40 41 42 43 44 45	46 47 48 49 50+

Note: a '1' score total (e.g. a disease being regionally absent) is included as the minimum score because zero-risk for any pathogen or disease is theoretically improbable owing to invasive or smuggled species or other unforeseen factors. Accordingly, the risk score scale commences at '1'

level of support or lack thereof for the prevention and management of disease. In addition, many zoonoses superficially resemble regular diseases, making their under-ascertainment by animal keepers and healthcare professionals more likely and leading to under-reporting.

**Target users and application**

Target users of the zoonoplasticity tool include medical professionals, veterinary medical professionals, public health professionals, government administrators,

biomedical researchers and others. The zoonoplasticity tool is designed to require minimal data input to complete Tables II and III, therefore users should be able to access relevant information via a basic Internet or other literature search. Application of the tool is potentially relevant to the development of positive or negative lists of species for inclusion or exclusion from trading and keeping as companion animals by governmental or non-governmental agencies, occupational health assessors, inspectors of legal or illegal animal importations, quarantine facility managers and others.

**Table IV**  
**Comparative assessment for consistency of zoonoplasticity concept**

Zoonoses list derived from reports (3, 26)

Zoonosis	Zoonoplasticity	ECDC operational guidance (2011)	Consistency (%)
Zoonoses risk score (Low, Moderate, High, Very High)			
Avian influenza	Low	Very low	100
Bartonellosis	Low	Low	100
Baylisascariasis	Low	Low	100
Brucellosis	Low	Low	100
Campylobacteriosis	Moderate	Moderate	100
Chlamydiosis/psittacosis	Low	Very low	100
Coccidioidomycosis	Low	Very low	100
Cryptosporidiosis	Moderate	Moderate	100
<i>Escherichia coli</i> infection	Moderate	Moderate	100
Giardiasis	Low	Very low	100
Hepatitis A	Low	Very low	100
Larva migrans	Low	Very low	100
Leptospirosis	Low	Low	100
Lyme disease	Moderate	High	75
Marburg haemorrhagic fever	Low	Very low	100
Monkeypox	Low	Very low	100
Q fever	Moderate	Moderate	100
Rabies (non-endemic)	Low	Very low	100
Rabies (endemic)	High	High	100
Salmonellosis	Moderate	Moderate	100
Toxocariasis	Low	Very low	100
West Nile virus	Low	Low	100
<b>Overall consistency</b>			<b>98.85%</b>

Note: zoonoplasticity categories include only Low, Moderate, High and Very High. Within each category there are 15 scores, the lowest of which (1) effectively implies negligible, through very low, low and lower than moderate (15). Accordingly, comparative test scores of Very Low and Low are addressed by the zoonoplasticity Low score (see Appendix 1 for worked examples)

ECDC: European Centre for Disease Prevention and Control

The two zoonoplasticity approaches (Tiers 1 and 2) set out in Tables II and III can be used independently or in concert to cross-check assessments. Tier 1 primarily assesses animals in trade and keeping and secondarily assesses traditional epidemiological issues and allows for assessment of risk, whether or not a particular pathogen exists in a region or disease in a population. Tier 2 primarily assesses traditional epidemiological issues and secondarily assesses animals in trade and keeping, and thus relevant risk is significantly based on the presence of a pathogen in a region or disease in a population.

Accordingly, the zoonoplasticity concept non-competitively presents a possible opportunity to ameliorate some pivotal factors common to companion-animal-linked and other zoonoses. By intentionally limiting the range of questions for the zoonoplasticity concept, less overall information is necessarily targeted for accumulation than for other

methods. However, much of that same background information, although ideally included, is unavailable for most zoonoses.

## Conclusions

Zoonotic significance and our responses to it depend on many factors, and one such factor is individual or collective judgement. Ideally, risk assessments for zoonoses should benefit from detailed information across all relevant factors, which are diverse and numerous. Current risk-impact assessment approaches for zoonoses are largely cumbersome, and to be meaningful they may require extensive detailed information input. Zoonoplasticity is not intended to provide an absolute measure of risk, or to replace existing methodologies; rather it is an attempt to



provide a practical judgement protocol that accounts for various relevant issues, and to offer a potentially helpful indicator of concern.

interpretation, writing or decision-making role in the report. Gratitude is also expressed to the editors and reviewers for their comments and suggestions, which have greatly helped to refine this article.

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# La plasticité zoonotique, un protocole intuitif d'appréciation du risque de zoonoses associé aux animaux de compagnie

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## Résumé

Les zoonoses sont des maladies transmissibles entre les animaux et les humains. Plus de 200 zoonoses sont connues aujourd'hui, dont au moins 60 sont associées à des animaux de compagnie (en particulier les espèces exotiques). Les méthodes actuelles d'évaluation de l'impact du risque zoonotique sont généralement contraignantes et nécessitent de réunir un grand volume d'informations détaillées pour être pertinentes. Une recherche et une analyse documentaires ont été réalisées, afin d'avoir un aperçu des protocoles d'évaluation du risque utilisés actuellement pour les zoonoses courantes, puis deux méthodes rapides de notation ont été mises au point pour évaluer le risque potentiel de zoonoses associé aux animaux de compagnie. À partir de là, un concept méthodologique innovant à deux paliers – la « plasticité zoonotique » – a été élaboré, basé sur une approche intuitive du risque. Le premier palier considère les risques inhérents aux animaux de compagnie et aux pratiques d'élevage, et réalise une appréciation préalable des animaux, par classe ou par espèce. Le deuxième palier considère les problématiques liées aux agents pathogènes ou aux maladies existantes, et assigne des niveaux de risque. Ainsi, le concept de plasticité zoonotique permet d'attribuer une note aux agents pathogènes et aux zoonoses dont ils sont la cause, et fournit un protocole clair, par points, qui donne des indications sur les menaces potentielles, en particulier dans les situations où l'absence de données empêche de procéder à une évaluation quantitative du risque. Le concept de plasticité zoonotique a été testé sur 15 espèces animales et 22 zoonoses connues, en prenant les directives opérationnelles du Centre européen de prévention et de contrôle des maladies (ECDC) comme système de comparaison. La hiérarchisation du risque a présenté une concordance de 100 % pour 21 des 22 zoonoses spécifiques tout en ne nécessitant qu'un minimum d'informations ; le taux global de concordance s'élevait à 98,85 %. La plasticité zoonotique n'est pas destinée à donner une mesure absolue du risque ni à remplacer les méthodologies existantes ; elle cherche plutôt à normaliser un protocole concret d'appréciation qui tienne compte de plusieurs problématiques pertinentes, et à offrir un indicateur potentiellement utile des aspects à prendre en compte. Le concept de plasticité zoonotique est un outil qui pourra servir aux professionnels de la médecine humaine, de la médecine vétérinaire et de la santé publique, ainsi qu'aux gestionnaires de l'action publique, aux chercheurs en sciences biomédicales et à d'autres professionnels dans l'exercice de leurs fonctions.

**Mots-clés**

Animal de compagnie – Approche intuitive du risque – Évaluation des risques – Plasticité zoonotique – Zoonose.



## La zoonoplasticidad como protocolo para valorar el «riesgo intuitivo» de zoonosis asociadas a mascotas

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**Resumen**

Las zoonosis son enfermedades que se pueden transmitir de animales no humanos al ser humano. Se conocen más de 200 de estas enfermedades, de las cuales, al menos 60 están asociadas a animales (especialmente exóticos) que son mascotas. Los actuales métodos de determinación del riesgo, aplicados a las zoonosis, son en gran parte engorrosos y pueden requerir, para tener sentido, un gran volumen de detallada información. El autor describe un proceso de búsqueda y examen de referencias bibliográficas sobre protocolos actuales de determinación del riesgo de zoonosis corrientes, tras lo cual expone dos novedosos métodos de puntuación rápida para valorar el posible riesgo de zoonosis asociada a mascotas. Partiendo de la idea del riesgo intuitivo, se acuñó un nuevo concepto metodológico, el de «zoonoplasticidad», que funciona en dos pasos: en primer lugar, se consideran una serie de principios y factores de riesgo ligados a las diferentes mascotas y técnicas de cría y se asigna una puntuación preliminar a los animales dependiendo de la clase o especie y de varios aspectos ligados a la cría. En el segundo paso, se plantean una serie de interrogantes clásicos sobre el agente patógeno o la enfermedad y, en función de la respuesta, se atribuye una puntuación correspondiente al grado de riesgo. El concepto de zoonoplasticidad permite, pues, «puntuar» al agente patógeno o la zoonosis que este causa y proporciona un claro protocolo que, a partir de esa puntuación, marca pautas ante una eventual amenaza, en especial cuando por falta de información no sea posible determinar el riesgo de manera más cuantitativa. El concepto de zoonoplasticidad fue aplicado experimentalmente a 15 especies animales y 22 zoonosis conocidas, empleando como patrón de comparación la guía operativa del Centro Europeo para la Prevención y el Control de las Enfermedades (ECDC). Con una necesidad mínima de información, la clasificación de los riesgos resultó coherente al 100% para 21 de las 22 zoonosis. Tomada en conjunto, la comparación arrojó un 98,85% de coincidencia. La zoonoplasticidad no tiene por objetivo ofrecer una medida absoluta del riesgo ni venir a sustituir los métodos existentes. Se trata más bien de una tentativa de estandarizar un protocolo práctico de valoración que tenga en cuenta una serie de aspectos importantes y de ofrecer con ello un indicador eventualmente útil que señale posibles motivos de inquietud. El concepto de zoonoplasticidad será de utilidad para la labor de profesionales de la medicina, la veterinaria y la salud pública, el personal de administraciones públicas e investigadores en biomedicina, entre otras profesiones.

**Palabras clave**

Animal de compañía – Evaluación del riesgo – Mascota – Riesgo intuitivo – Zoonoplasticidad – Zoonosis.



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## Appendix 1

Worked examples (questions and answers) for scores used in Table II that primarily assess animals in trade and keeping. Assessment represents zoonoses mostly associated with the United Kingdom and Europe. In these examples there is low or no regional endemic involvement; thus, worked examples and scores may change significantly for relevant highly endemic and global hotspot regions

<b>Animal</b>	<b>Worked example</b> (Q = questions from Table II)	<b>Total points/score</b> (vg = score with vulnerable group)	<b>Category</b>
<b>Goldfish</b> ( <i>Carassius</i> sp.)	5 + Q1 = 0; Q2 = 1; Q3 = 1; Q4 = 1; Q5 = 0; Q6 = 1; Q7 = 0; Q8 = 0 (5); Q9 = 0	9 to (14 vg)	Low to Moderate (vg)
<b>Clownfish</b> ( <i>Amphiprioninae</i> sp.)	5 + Q1 = 0; Q2 = 1; Q3 = 2; Q4 = 2; Q5 = 0; Q6 = 1; Q7 = 0; Q8 = 0 (5); Q9 = 0	11 to (16 vg)	Moderate
<b>African clawed frog</b> ( <i>Xenopus</i> sp.)	10 + Q1 = 0; Q2 = 1; Q3 = 1; Q4 = 2; Q5 = 0; Q6 = 1; Q7 = 0; Q8 = 0 (5); Q9 = 0	15 to (20 vg)	Moderate
<b>Marine toad</b> ( <i>Rhinella</i> sp.)	10 + Q1 = 1; Q2 = 1; Q3 = 2; Q4 = 2; Q5 = 0; Q6 = 1; Q7 = 0; Q8 = 0 (5); Q9 = 0	17 to (22vg)	Moderate to High (vg)
<b>Bearded dragon</b> ( <i>Pogona</i> sp.)	10 + Q1 = 1; Q2 = 1; Q3 = 1; Q4 = 2; Q5 = 0; Q6 = 1; Q7 = 0; Q8 = 0 (5); Q9 = 0	16 to (21 vg)	Moderate to High (vg)
<b>Nile monitor lizard</b> ( <i>Varanus</i> sp.)	10 + Q1 = 1; Q2 = 1; Q3 = 2; Q4 = 2; Q5 = 3; Q6 = 1; Q7 = 0; Q8 = 0 (5); Q9 = 0	20 to (25 vg)	High
<b>Corn snake</b> ( <i>Pantherophis</i> sp.)	10 + Q1 = 0; Q2 = 1; Q3 = 1; Q4 = 2; Q5 = 0; Q6 = 1; Q7 = 0; Q8 = 0 (5); Q9 = 0	15 to (20 vg)	Moderate
<b>Burmese python</b> ( <i>Python</i> sp.)	10 + Q1 = 1; Q2 = 1; Q3 = 2; Q4 = 2; Q5 = 3; Q6 = 1; Q7 = 0; Q8 = 0 (5); Q9 = 0	20 to (25 vg)	Moderate to High (vg)
<b>Budgerigar</b> ( <i>Melopsittacus</i> sp.)	10 + Q1 = 0; Q2 = 1; Q3 = 1; Q4 = 1; Q5 = 0; Q6 = 0; Q7 = 0; Q8 = 0 (5); Q9 = 0	13 to (18 vg)	Moderate
<b>African grey parrot</b> ( <i>Psittacus</i> sp.)	10 + Q1 = 1; Q2 = 1; Q3 = 2; Q4 = 2; Q5 = 3; Q6 = 0; Q7 = 0; Q8 = 0(5); Q9 = 0	19 to (24 vg)	Moderate to High (vg)
<b>Fruit bat</b> ( <i>Megachiroptera</i> sp.)	10 + Q1 = 1; Q2 = 1; Q3 = 2; Q4 = 2; Q5 = 3; Q6 = 0; Q7 = 2; Q8 = 0 (5); Q9 = 0	21 to (26 vg)	High
<b>Meerkat</b> ( <i>Suricata</i> sp.)	10 + Q1 = 1; Q2 = 1; Q3 = 2; Q4 = 2; Q5 = 3; Q6 = 0; Q7 = 0; Q8 = 0 (5); Q9 = 0	19 to (24 vg)	Moderate to High (vg)
<b>Spider monkey</b> ( <i>Ateles</i> sp.)	15 + Q1 = 1; Q2 = 1; Q3 = 2; Q4 = 2; Q5 = 3; Q6 = 0; Q7 = 2; Q8 = 0 (5); Q9 = 0	26 to (31 vg)	High to Very High (vg)
<b>Rabbit</b> ( <i>Oryctolagus</i> sp.)	5 + Q1 = 1; Q2 = 1; Q3 = 1; Q4 = 1; Q5 = 0; Q6 = 0; Q7 = 0; Q8 = 0 (5); Q9 = 0	9 to (14 vg)	Low to Moderate (vg)
<b>Domestic dog</b> ( <i>Canis</i> sp.)	5 + Q1 = 1; Q2 = 1; Q3 = 1; Q4 = 1; Q5 = 0; Q6 = 0; Q7 = 0; Q8 = 0 (5); Q9 = 0	9 to (14 vg)	Low to Moderate (vg)

## Appendix 2

Worked examples (questions and answers) for scores used in Table III that primarily assess traditional epidemiological issues. Assessment represents zoonoses mostly associated with the United Kingdom and Europe. In these examples there is low or no regional endemic involvement; thus, worked examples and scores may change significantly for relevant highly endemic and global hotspot regions

Zoonosis	Worked example (Q = questions from Table III)	Total points/score	Category
<b>Avian influenza</b> (United Kingdom/non-endemic region)	Q1 = 1; Q2 = 0; Q3 = 0; Q4 = 0; Q5 = 0; Q6 = 0	1	Low
<b>Avian influenza</b> (less-developed endemic region)	Q1 = 3; Q2 = 3; Q3 = 6; Q4 = 10; Q5 = 2; Q6 = 10	34	High
<b>Bartonellosis</b>	Q1 = 1; Q2 = 0; Q3 = 1; Q4 = 3; Q5 = 6; Q6 = 0	11	Low
<b>Baylisascariasis</b>	Q1 = 1; Q2 = 0; Q3 = 1; Q4 = 3; Q5 = 6; Q6 = 0	11	Low
<b>Brucellosis</b>	Q1 = 1; Q2 = 1; Q3 = 1; Q4 = 2; Q5 = 6; Q6 = 0	11	Low
<b>Campylobacteriosis</b>	Q1 = 6; Q2 = 3; Q3 = 1; Q4 = 1; Q5 = 6; Q6 = 0	17	Moderate
<b>Chlamydiosis/psittacosis</b>	Q1 = 1; Q2 = 0; Q3 = 1; Q4 = 3; Q5 = 6; Q6 = 0	11	Low
<b>Coccidioidomycosis</b>	Q1 = 1; Q2 = 0; Q3 = 1; Q4 = 3; Q5 = 6; Q6 = 0	11	Low
<b>Cryptosporidiosis</b>	Q1 = 6; Q2 = 5; Q3 = 2; Q4 = 3; Q5 = 6; Q6 = 5	27	Moderate
<b>Escherichia coli infection</b>	Q1 = 1; Q2 = 2; Q3 = 2; Q4 = 10; Q5 = 3; Q6 = 5	23	Moderate
<b>Giardiasis</b>	Q1 = 1; Q2 = 0; Q3 = 1; Q4 = 1; Q5 = 6; Q6 = 3	12	Low
<b>Hepatitis A</b>	Q1 = 2; Q2 = 0; Q3 = 1; Q4 = 1; Q5 = 5; Q6 = 0	9	Low
<b>Larva migrans</b>	Q1 = 1; Q2 = 0; Q3 = 1; Q4 = 3; Q5 = 6; Q6 = 0	11	Low
<b>Leptospirosis</b>	Q1 = 1; Q2 = 0; Q3 = 1; Q4 = 10; Q5 = 3; Q6 = 0	15	Low
<b>Lyme disease</b>	Q1 = 6; Q2 = 4; Q3 = 1; Q4 = 3; Q5 = 6; Q6 = 5	25	Moderate
<b>Marburg haemorrhagic fever</b> (United Kingdom/non-endemic region)	Q1 = 1; Q2 = 0; Q3 = 0; Q4 = 0; Q5 = 0; Q6 = 0	1	Low
<b>Marburg haemorrhagic fever</b> (less-developed endemic region)	Q1 = 1; Q2 = 0; Q3 = 6; Q4 = 15; Q5 = 6; Q6 = 10	38	High
<b>Monkeypox</b> (United Kingdom/non-endemic region)	Q1 = 1; Q2 = 0; Q3 = 0; Q4 = 0; Q5 = 0; Q6 = 0	1	Low
<b>Monkeypox</b> (less-developed endemic region)	Q1 = 1; Q2 = 1; Q3 = 1; Q4 = 10; Q5 = 6; Q6 = 5	24	Moderate
<b>Q fever</b>	Q1 = 1; Q2 = 1; Q3 = 1; Q4 = 3; Q5 = 6; Q6 = 4	16	Moderate
<b>Rabies</b> (United Kingdom/non-endemic region)	Q1 = 1; Q2 = 0; Q3 = 0; Q4 = 0; Q5 = 0; Q6 = 0	1	Negligible/Low
<b>Rabies</b> (non-endemic region – theoretical)	Q1 = 1; Q2 = 0; Q3 = 1; Q4 = 20; Q5 = 1; Q6 = 0	23	Moderate
<b>Rabies</b> (endemic region – disease)	Q1 = 6; Q2 = 0; Q3 = 1; Q4 = 20; Q5 = 1; Q6 = 10	38	High
<b>Salmonellosis</b>	Q1 = 2; Q2 = 3; Q3 = 1; Q4 = 1; Q5 = 5; Q6 = 5	17	Moderate
<b>Toxocariasis</b>	Q1 = 1; Q2 = 1; Q3 = 3; Q4 = 3; Q5 = 3; Q6 = 0	11	Low
<b>West Nile virus</b>	Q1 = 1; Q2 = 0; Q3 = 0; Q4 = 1; Q5 = 6; Q6 = 0	8	Low