出國報告
（類別：其他）

風險分析簡介
（Introduction to Risk Analysis）
課程研習報告

服務機關：行政院農業委員會動植物防疫檢疫局
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派赴國家：美國（科羅拉多州）
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美國農業部風險分析簡介課程研習報告

摘要

風險分析是組織科學方法評估風險發生的可能及其影響，並提出降低或改變風險建議方案，提供科學依據供決策參考及與利害關係人溝通的一套方法，因訴求不同而有不同評估方向及可接受的預期目標或風險值，無論執行定性或定量評估方式，均須具有一致性、科學基礎、彈性且透明，動物健康狀態或病原特性的改變，亦可致使風險改變，因此須持續蒐集相關資訊，並對狀態改變者，重新予以評估及分析。本次風險分析簡介屬於獸醫流行病學進階課程，爲期 5 天，係簡介風險分析基礎概念與基本原則，包括危害認定（Hazard Identification）、風險評估（Risk Assessment）、風險溝通（Risk Communication）及風險管理（Risk Management）與風險分析時各階段應注意事項，並藉實例介紹，說明風險分析如何應用，以協助制訂重要決策或決定，最後透過分組案例研討實際演練，對於我國防檢疫風險審查評估甚有助益。

目次

一、前言及目的

流行病學及動物健康中心（Centers for Epidemiology & Animal Health；CEAH）隸屬美國農業部（United States Department of Agriculture；USDA）動植物檢疫局（Animal and Plant Health Inspection Service；APHIS）獸醫管理處（Veterinary Services）國家動物健康政策與計畫（National Animal Health Policy and Program）部門，主要任務係提供動物健康及農業相關技術服務與資訊，以確保食品及農產品安全。其內部具有主任辦公室、支援及評估計畫、動物健康資訊及分析中心（Center for Animal Health Information and Analysis, CAHIA）、國家動物健康監測中心（Center for National Animal Health Surveillance, CNAHS ）及緊急事件中心（Center for Emerging Issues, CEI）五個業務部門，工作團隊包括獸醫、流行病學、經濟學、風險評估、政策分析、地理學、數學、生態、製圖、統計、生物等專家與所需專業人士。另外，CEAH也是世界動物衛生組織（OIE）風險分析的合作中心，負責風險分析及辦理訓練課程、OIE風險分析章節擬定與溝通協調、提供科學證據或資料作爲國際諮商談判重要參考等。

本次風險分析簡介課程係由美國農業部動植物檢疫局（APHIS）國際事務處（International Services；IS）計畫贊助，交由美國農業部國家進出口中心（National Center for Import & Export；NCIE）、流行病學及動物健康中心（CEAH）與科羅拉多州立大學動物族群健康研究所（Animal Population Health Institute；APHI）三個機關單位共同辦理，假位於科羅拉多州科林斯堡（Fort Collins）流行病學及動物健康中心（CEAH）舉行 5 天的訓練課程，經美國在台協會（American Institute in Taiwan；AIT）來信邀請及轉送學員資料至美國農業部完成審核後，由本局楊文淵技正參加。本次課程計有來自臺灣、南韓、蒙古、柬埔寨、塞爾維亞、千里達拖貝哥（西印度群島島國之一）、烏拉圭、巴拉圭、波紮那（非洲東部共和國）、賴索托、多明尼加、奈及利亞、阿根廷、印度、辛巴威、史瓦濟蘭（非洲東南部王國）等 16 國 17 個學員參加，並有美國動植物檢疫局國際事務處承辦人員一同參與。

此次風險分析訓練課程爲主辦單位第一次辦理，屬於獸醫流行病學進階課程，主要目的係向參與學員簡介風險分析基礎概念與基本原則，包括危害認定（Hazard Identification）、風險評估（Risk Assessment）、風險溝通（Risk

Communication）及風險管理（Risk Management）與風險分析時各階段應注意事項，說明如何使用風險分析協助制訂重要決策或決定，並以實例介紹說明，最後透過分組案例討論及練習方式，使參與學員能對風險分析應用有更深的體認，此行最大目的在於瞭解風險分析理論原理及應用，以助於我國防檢疫系統風險審查執行之評估。

二、過程

（一）行程及課程表

■ 99 年 9 月 26 日（星期日）：

自桃園國際機場前往日本東京成田機場（Narita airport，Japan）轉美國加州舊金山機場（San Francisco airport，CA），並於舊金山機場轉國內線班機至科羅拉多州丹佛機場（Denver airport，CO），於下午 4 時至 Marriott Courtyard Hotel 辦理並完成報到手續。

■ 99 年 9 月 27 日（星期一）：

時間	課程	引言人或講師
8:30-9:30	歡迎及簡介 Welcome and introductions	美國農業部國際事務處 **承辦人員Scott Goldman先生**
9:30-10:15	世界動物衛生組織簡介及其於國際貿易之角色Introduction to OIE and its role in trade	美國農業部國家進出口中心 **輸入風險分析師Laurel Voelker小姐**
10:15-11:00	SPS關鍵要素及其與流行病學之關連性 Key elements of SPS and relationship to epidemiology	美國農業部流行病學及動物健康中心 **風險分析師Katie Portacci小姐**
11:00-11:30	書面作業及休息時間Paperwork break	
11:30-12:30	午餐Lunch	
12:30-2:00	風險分析簡介 Introduction to risk analysis	美國農業部流行病學及動物健康中心 及 世界動物衛生組織動物疾病、監測系統及風險分析合作中心 **獸醫流行病學家Barbara Corso小姐**
2:00-3:00	診斷試驗	美國農業部流行病學及動物健康

	Diagnostic tests	中心 及 世界動物衛生組織動物疾病、監測系統及風險分析合作中心 **國際活動協調主任Cristóbal Zepeda博士**
3:00-5:00	分組及案例研究—確定案例主題（Case studies - Developing the question）	分組 Group1-Group5

■ 99 年 9 月 28 日（星期二）：

時間	課程	引言人或講師
8:30-9:00	第1日課程回顧及問答 Review of Day 1	各講師
9:00-10:30	採樣 Sampling	Cristóbal Zepeda
10:30-11:00	休息時間Break	
11:00-12:00	定性風險評估 Qualitative risk assessment	Barbara Corso
12:00-1:00	午餐Lunch	
1:00-1:45	國內區域化風險評估之應用 Application of risk assessments to domestic regionalization	Katie Portacci
1:45-2:30	區域化11個風險因子評估 11 risk factor assessment of regionalization	Laurel Voelker
2:30-3:30	風險分析過程之經濟分析 Economic analysis in the risk analysis process	美國農業部動物健康資訊及分析中心 **農業經濟學家Kristyn Stone博士**

3:45-5:00	分組進行案例研究 Continue case studies	Groups (1-5)

■ 99 年 9 月 29 日（星期三）：

時間	課程	引言人或講師
8:30-9:00	第2日課程回顧及問答 Review of Day 2	各講師
9:00-12:00	使用Excel試算表或計算機進行機率之簡介 Introduction to probability using Excel or calculator	Cristóbal Zepeda
12:00-1:00	午餐Lunch	
1:00-5:00	分組案例研究—資料收集 Case studies- Gathering information	Groups (1-5)
6:00-8:00	晚宴Group dinner	

■ 99 年 9 月 30 日（星期四）：

時間	課程	引言人或講師
8:30-9:00	第3日課程回顧及問答 Review of Day 3	各講師
9:00-11:00	分佈及定量風險評估簡介 Introduction to distributions and quantitative risk assessment	Cristóbal Zepeda
11:00-12:30	日支費銀行兌換休息時間Bank break	
12:30-1:30	午餐Lunch	
1:30-2:30	分佈及定量風險評估簡介（續） Continue introduction to	Cristóbal Zepeda

	distributions and quantitative risk assessment	
2:30-3:30	定量風險分析案例介紹 Quantitative risk analysis example	美國農業部流行病學及動物健康中心 **風險分析師Tim Clouse先生**
3:30-5:00	Case studies- Preparing a presentation	Groups (1-5)

■ 99 年 10 月 1 日（星期五）：

時間	課程	引言人或講師
8:30-12:00	各組研究案例報告 15 min presentation/ 10 minute discussion on case studies	Groups (1-5)
12:00-1:00	閉幕 Closing remarks	美國農業部承辦人員、課程講師群及全體學員

■ 99 年 10 月 2 日至 3 日（星期六及日）：

自美國科羅拉多州丹佛機場（Denver airport，CO）搭機前往西雅圖國際機場（Seattle airport，WA）轉日本東京成田機場（Narita airport，Japan）返台，最後於 10 月 3 日晚上 10 點 30 分抵達桃園國際機場，完成此次課程研習。

（二）課程內容及說明

1. 世界動物衛生組織（OIE）簡介及其於國際貿易之角色

世界動物衛生組織（OIE）係爲確保動物及其產品安全與貿易往來，避免疾病藉動物及其產品移動而跨國界傳播，對國際規範需求所成立的全球性組織。早於西元 1920 年時，因比利時爆發牛瘟疫情的影響，突顯出國際間需要公平性組織進行動物及其產品貿易的協調，故於 1928 年，於 28 個會員國參與下，成立國際畜疫會（Office International des Epizooties；OIE），後更名爲世界動物衛生組織（World Organization for Animal Health）。

由於 1930 年代世界經濟蕭條，各國保護主義盛行，爲解決彼此間經貿問題，「關稅暨貿易總協定」（General Agreement on Tariffs and Trade, GATT）應蘊而生，提供 1948 年至 1994 年間國際貿易遵循的規則，其爲一項多邊國際協定，以關稅談判爲主，共舉行 8 次回合談判，其中以第 8 回合談判（烏拉圭回合）結果影響深遠，該次談判於 1993 年 12 月 15 日完成，決議成立世界貿易組織（World Trade Organization；WTO），後 WTO 於 1995 年 1 月 1 日正式成立，設總部於瑞士日內瓦，以有效管理及執行烏拉圭回合各項決議，主要規範貨品貿易、服務貿易及與貿易有關之智慧財產權。GATT 與 WTO 並存一年後，WTO 即完全取代 GATT，由國際經貿協定轉化爲實質國際組織。

食品衛生檢驗及動植物檢疫協定（Agreement on the Application of Sanitary and Phytosanitary），簡稱 SPS （Sanitary and Phytosanitary）協定，爲 WTO 簽署協定之一，同 WTO 成立日起（1995 年 1 月 1 日）生效，目的在於保護人類、動物及植物健康前提下，加速便利相關貿易，涵蓋範疇如下：

（1） 防範或限制因疫病或病原體入侵、立足或傳播導致的風險。

（2） 防範因食品、飲料或飼料中添加物、污染物、毒素或病原體導致的風險。

（3） 防範因動植物或其產品所攜帶疫病導致的疾病風險。

而 OIE 於國際貿易之角色則負責制訂動物健康標準（如陸生與水生動物健康法典），建立應通報疾病列表與通報機制，防檢疫處置建議，以及風

險分析架構及原則，以供現有 177 個會員國於動物及其產品貿易時參考及依循。

2. SPS關鍵要素及其與流行病學之關連性

SPS 措施需要調和（Harmonization）、透明化（Transparency）、等效性（Equivalency）、區域化（Regionalization）等關鍵要素共同支持，配合獸醫流行病學或風險分析的科學基礎及資料，以提供貿易國可接受的論證基礎，避免不合理的貿易障礙。

（1） 調和（Harmonization）：透過一致性國際標準（International Standard）的調合，讓參與國有相同標準可以遵循，此部分流行病學之應用即藉由有效的採樣及監測策略，用以證明疾病清淨狀態。

（2） 透明化（Transparency）：疫情透明，並以符合流行病學原則之主、被動監測結果，作爲良好疾病通報基礎，使參與國即時掌握鄰近國家及貿易伙伴國疫情狀態，適時啓動保護機制，降低風險。由於可能會造成貿易影響，SPS 措施若有改變，須即時通報 WTO。

（3） 等效性（Equivalency）：因檢測試劑敏感性不盡相同，監測方式亦有所差異，只要定義適當保護層級，藉由流行病學解釋及說明各國執行相關措施產生之成果，可使不一樣 SPS 措施達相似認同效果。因此，每個國家會考量自己能力及資源條件，組織防疫體系成效（如獸醫服務體系或監測通報體系落實程度等）證明自身疾病控制或清淨情形，不一定需靠相同監測的敏感度，才能滿足貿易國的要求。不過按照 SPS 等效性原則，出口國有義務提供宣佈區域疾病清淨的證據，並給予進口國調查機會予以驗證。

（4） 區域化（Regionalization）：由於動物傳染病存在與傳播受地理位置或生態條件所影響，爲協助動物及其產品貿易，OIE 發展區域化措施，使輸出國雖爲疫區國家，但因實施區域化區隔措施，並執行有效疾病監測與防疫處置後，經對方國以流行性病學及風險分析評估疫病發生或媒介風險可能性低，並獲認可後，區域內動物及其產品始得

3. 風險分析簡介

依據 OIE 定義，風險（Risk）係於一特定期間發生有害事件，影響輸入國動物或人類健康的可能性與其對生物及經濟衝擊的可能強度。風險組成包括危害產生可能性（Probability）、後果或衝擊、不確定性（Uncertainty）管理能力（Ability to manage）及利益（Benefit），須於可能危害（Hazard）及不確定性存在條件下，風險才存在。

風險分析最主要目的在於組織科學方法告知風險發生的可能及其影響，提出風險降低或改變建議方案，提供科學依據供決策者參考及與利害關係人分析與溝通，包含危害認定、風險評估、風險管理及風險溝通四個過程。

（1） 危害認定（Hazard identification）。

其可能是：

- 認定可能損害的來源，造成有害事件的原因。
- 確認可藉產品媒介的疾病病原（Identify the pathogenic agents associated with the product）。
- 決定輸出國或輸出區域疾病/病原存在與否；SPS 措施的有效性。
- 爲了建立優先次序（Establish priority）。

危害（Hazard）來自於產品（Product）或行動（Activity）本身，而風險（Risk）是事件（Undesired event）發生可能性與其後果的結合性指標。例如，疾病爆發本身是一個危害，但是疾病是否向外蔓延即爲一個風險。

（2） 風險評估（Risk assessment）。

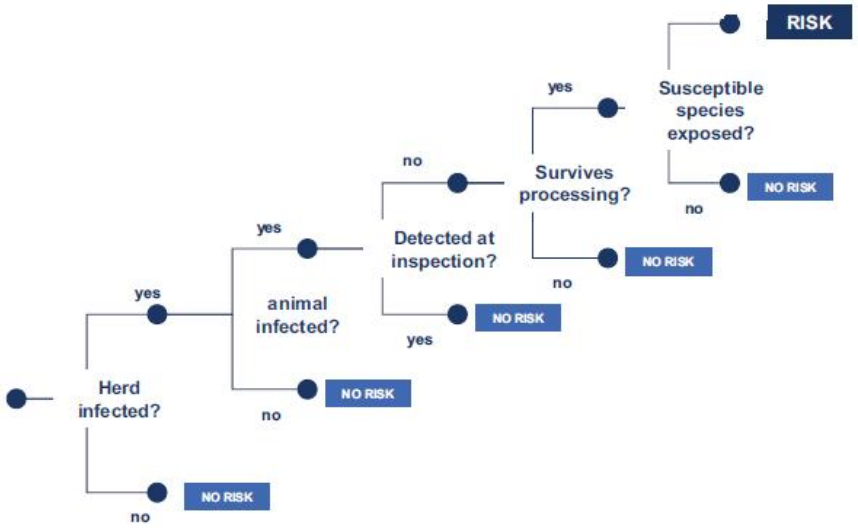
用以評估一個疾病進入、於該點/區發展（Establishment）並擴散的可能性及其相關潛在的生物性與經濟後果（Consequences），以及對公共衛生造成的影響。屬於風險分析一部份，包含以下四個部分：

- 釋放評估（Release assessment）：

描述一個疾病病原引入新區域的可能路徑，分析物可以是一個生物（病原與其存活能力）、輸出國家（於這個國家哪些疾病是存在的）或商品（肉品、乳汁或活動物）。

- 暴露評估（Exposure assessment）。

  描述導致疾病爆發的路徑，例如易感動物族群的密度與分佈、季節、病媒、免疫情形、商品預期分佈情形等。實際應用中，一般常使用情境樹（Scenario tree）進行釋放或暴露評估。



- 後果評估（Consequence assessment）。

  評估直接與間接後果，直接後果包括因疾病或動物死亡所造成的生產損失、公共衛生問題、控制或撲滅疾病的花費及補償等；間接後果包括國內或國外貿易損失、環境影響等。

- 風險估計（Risk estimation）。

  整合釋放評估、暴露評估及後果評估結果，以定性（Qualitative）或定量（Quantitative）方式呈現風險或風險值。爲了清楚且讓人容易理解，定性方式將風險區分爲可忽略（Negligible）、低（Low）、中等（Medium）或高（High），定量方式則是呈現發生事件的一個機率範圍（A range of probability）。

定性評估優點在於快速、可以應用情境廣，缺點於較不精確，結果

可能不令人滿意；而定量評估即是計算發生不利事件的機率，提供決策精準的參考資訊，缺點於須花費較多時間進行計算，需要良好品質的定量數據，且無法應用於所有情境。無論執行何種評估方式，必須具有一致性、科學基礎、有彈性且透明，沒有一個模版可以套用或適用於不同的案例。

一般而言，爲防範疫病藉由動物及其產品入侵，每個國家均著重於輸入風險評估，而美國因爲出口大國，爲令其動物及其產品更順利輸出，已著手輸出風險評估及其立法，並將其結果提供輸入國參考。

（3） 風險管理（Risk management）。

係爲確認、選擇與實施風險減低措施的過程，執行前須先考慮應完成何項事項以去除或減低危害、何者爲最好選擇，以及什麼會影響選擇等問題，並確定所訂措施係爲保護人類與動物健康必須條件下，依據科學性原則所應用的措施。

（4） 風險溝通（Risk communication）。

主要作法係自利害關係人獲取資訊（包括其對風險的接受度及優先性）、適時通知決策者溝通情形及改變的結果，並與利害關係人描述如何評估風險及下決策，以及風險將如何被控制及監控。藉由溝通獲得利害關係人認同及接受，以利推動後續事宜。由於不同利害關係人對同一事件可能有不同面向的關切，並面臨不同部分的風險，因此溝通時應多方考量，以達有效溝通的目的。

風險分析常使用於輸出入動物及其產品貿易風險評估(自一個新的國家或區域輸入新的動物或動物產品)、國內疾病清除或控制過程中成效評估(藉以適時調整執行強度與措施)及疾病入侵或散佈後的處置改變(如依據分析結果決定是否使用疫苗)。

簡言之，風險分析透過鑑定危害，描繪風險，認定不確定性，總結摘要分析結果及建議選擇（Recommend options），最後再以文書形式表現建議或決定的根據，提供訂定決策之參考。

4. 診斷試驗（Diagnostic tests）

風險分析目的係爲了解至少一個僞陰性動物（At least one tested false negative animal）進入一個地區或國家且傳播疫病的風險，即是機率（Probability）概念，藉由描述診斷試驗的結果，呈現其風險。由於現實不存在正確率 100%的試驗，因此須依目的予以選擇試驗方法及方式。

（1） 盛行率調查（Prevalence studies）：決定感染病原頻率及分佈，經常測量抗體來了解疾病盛行率，但須注意僞陽性（False positive）及僞陰性（False negative）的問題。

（2） 試驗特性：

- 正確率（Accuracy）：真陽性數及真陰性數於整體檢測樣本中的比率〔（TP+TN）/N〕。
- 敏感性（Sensitivity；Se）：已感染動物檢出陽性的比率，即以此試驗，真正檢可出已感染動物的比率。
- 特異性（Specificity；Sp）：未感染動物檢出陰性的比率，即以此試驗，真正可檢出未感染動物的比率。

（3） 陽性預測值（Positive predictive value；PV+）及陰性預測值（Negative predictive value；PV-）：

- PV+：檢出陽性動物真正爲感染動物的比率。
- PV-：檢出陰性動物真正爲未感染動物的比率。

（4） 盛行率與 PV+、PV-與敏感性及 PV+與特異性的關係：

- 固定敏感性及特異性條件下，盛行率越高，PV+值越大，表示越容易檢出真正已感染動物的比率。
- 特異性值越高，PV+值越大，故選用高特異性及陽性預測值的試驗，可以確認診斷（降低僞陽性數量），避免屠宰或撲殺不必要的動物。
- 敏感性值越高，PV-值約大，故選用高敏感性及陰性預測值的試驗，可減低僞陰性數量，避免引入疾病。

（5） 系列試驗（Testing in series）與平行試驗（Testing in parallel）：

- 系列試驗：使用 2 種試驗來確定陽性結果，2 個試驗結果必須是陽性，最後結果才判定爲陽性；目的在於增加特異性與陽性預測值，避免屠宰或撲殺僞陽性動物。
- 平行試驗：一樣使用 2 種試驗來確定陰性結果，2 個試驗結果須爲陰性才判定爲陰性結果；目的係於增加敏感性及陰性預測值，避免因誤信僞陰性結果而引入疾病。

由上可知不同目標（撲滅疾病或避免引入疾病的）採取試驗策略不同，端看需求爲何，據以設定試驗策略。

5. 路徑分析（Pathway analysis）

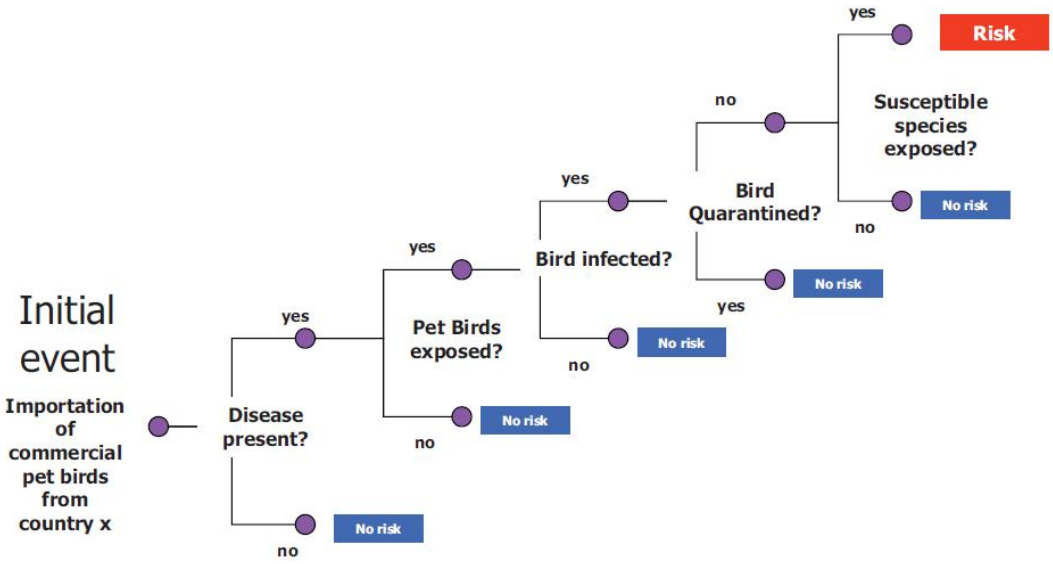
爲一系統性評估方法，分析外來疾病病原可能進入一個國家或地區，並且發展成疫情或單一點持續存在疾病的可能，以及評估路徑各點相關資料品質及其可信度。分析關切物可以是病原（口蹄疫、非洲豬瘟）、運輸途徑（旅客、行李、貨車及火車等）、產品（冷凍肉品、或動物或其他）或是以上的結合。

首先須選擇分析關切物並界定問題，描述病原如何可能從輸出國到輸入國，最後決定路徑中每個步驟引入病原的可能性或機率（Probability）。過程中包括病原如何自輸出區域移動（Movement）至輸入區域、如何於運輸過程中存活（Survival）、依假設路徑移動的風險（Risk）及風險減輕措施（Mitigations），如清潔消毒措施、額外加工動作、隔離檢疫或輸出認證。

若符合以下條件，風險路徑可能存在：

- 疾病病原存在於國家或區域的某個地方，自該國家或區域進口可能會導致疫情發生。
- 病原可能透過動物或產品輸入、旅行行李、空氣、水、走私或其他路徑跨越國境或區域的接界。
- 病原於其存活期間可以到達或接觸新國家或區域的易感宿主。

於了解疾病生物特性及流行病學、侵入路徑及輸入國家暴露路徑後，再使用情境樹（Scenario tree）來描述路徑，協助後續分析，範例如下：

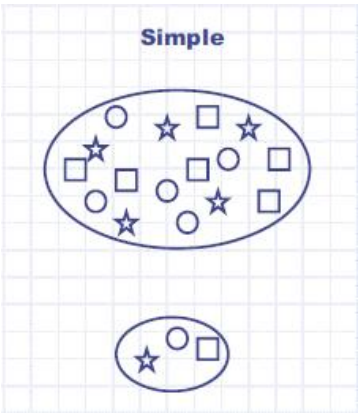


6. 調查與採樣（Survey and sampling）

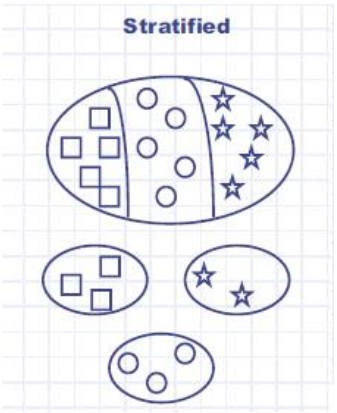
母群體（Population）一般處於動態平衡，其結構影響疾病的分佈，執行調查或監測時，須優先定義存在風險的母群體（族群）。而採樣目的在於決定疾病盛行率及了解疾病是否存在，若欲決定疾病盛行率，常需較大採樣數量及經費；若只是爲了決定疾病存在與否，樣本數一般較少且便宜，可知採樣目的決定執行方式及所需資源，而流行病學一般使用的信賴區間爲95%，採樣方法分爲：

- 簡單逢機採樣（Simple random sampling）：實際操作上很難做到，流行病學家一般不常使用。
- 系統（等距）逢機採樣（Systemic random sampling）：可執行且常用，但須避免誤差（Bias）。例如現有樣本數爲 100，應用方式係將 100 個樣本完成編號，若經逢機挑出 7 號，逢 7 者（7、17、27、37…）即須進行採樣。
- 分層逢機採樣（Stratified random sampling）：可依據年齡、性別、地理區域、生產系統…等條件進行分層後，再予採樣。
- 集中分組（集束）抽樣（Cluster sampling）：可視爲一個群體，

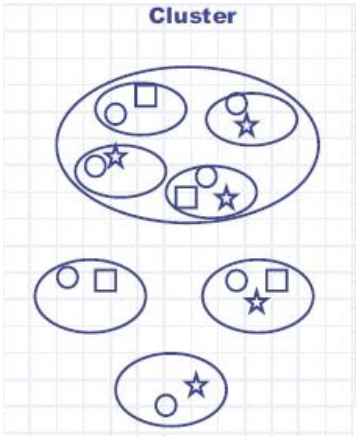
- 多階段採樣（Multistage sampling）：適用於全國性的調查，如先分層再進行系統抽樣，可以省時省力。



簡單逢機採樣



分層逢機採樣



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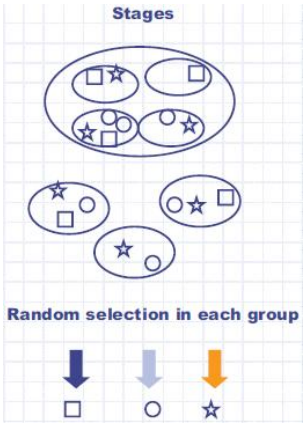
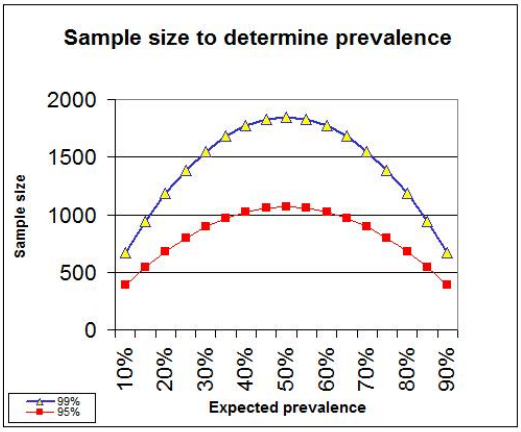


多階段採樣

另一個選取採樣場數應注意的爲精確度（Precision），其爲選取樣本測量時，所產生測量值的隨機誤差，於樣本數選擇上佔有關鍵性角色，精確度越低，樣本數越大。決定場樣本數量有三個重要構成因素，分別爲母群體數、精確度與預期盛行率（Expected prevalence）。下圖可見於預期盛行率於 50% 時，採樣場數最大，增加或減少時具有對稱性關係。

Population	1,000,000
Precision (%)	3.0%
Expected prev.	3.00%

	Confidence 95%	99%
sample size	125	216
10%	385	666
15%	544	943
20%	683	1182
25%	800	1385
30%	896	1551
35%	971	1680
40%	1024	1772
45%	1056	1828
50%	1066	1846
55%	1056	1828
60%	1024	1772
65%	971	1680
70%	896	1551
75%	800	1385
80%	683	1182
85%	544	943
90%	385	666



若不是以場爲單位，而是以整群體隻數予以計算，以美國牛海綿狀腦病（BSE）監測爲例，所需採集樣本數如下：

- BSE 因預期盛行率相當低，所需監測採樣數相當高。以美國爲例，現有飼養牛隻 50 億隻，BSE 預期盛行率爲 10 億分之一（5/50 億），須檢查 3 億牛隻才符統計學上意義，明顯無法執行。所以美國改以針對高風險 4D 牛群進行監測檢查，約有 446,000 牛隻，以 99%信賴區間、100%敏感性及 0.001121%（5/44,600）預期盛行率計算，每年需檢查 268,455 牛隻，較經濟可行，美國現行即採此作法進行監測。

SAMPLE SIZE TO DETECT
PRESENCE OR ABSENCE OF DISEASE

POPULATION SIZE	446,000
CONFIDENCE LEVEL	99%
SENSITIVITY	100%
EXPECTED PREVALENCE	0.0%
SAMPLE SIZE (n)	268,455

$$n \cong \frac{(1-(1-\alpha)^{1/D})(N-\frac{1}{2}(SeD-1))}{Se}$$

7. 定性風險評估（Qualitative risk asessment）

以螺旋蟲（Screwworm）爲實例進行定性風險評估，步驟如下：

（1） 界定關切問題：

- 從加勒比（Caribbean）感染國家將新世界螺旋蟲（New world screwworm；NWS）引入美國、墨西哥及中美洲的風險爲何？

（2） 組織欲使用的方法：

- 危害分析：認定危害，了解其特性。
- 然後進行釋放評估、暴露評估、後果評估及風險估計。

（3） 決定評估方法及定義

- 定性：定義風險定性名詞（Qualitative terms）。
  - 風險評估名詞及定義：名詞分爲可忽略、非常低、低、中等、高及非常高六種，定義如下圖所述。

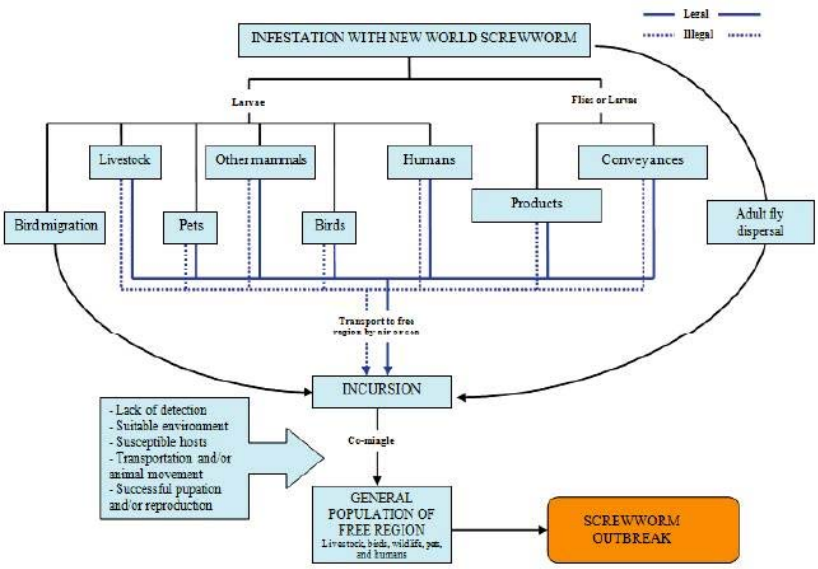
Term	Definition
Negligible	So rare that it does not merit consideration
Very Low	Very rare but cannot be excluded
Low	Rare but does occur
Medium	Occurs regularly
High	Occurs very often
Very High	Events occur almost certainly

  - 不確定性（Uncertainty）名詞及定義：名詞分爲低、中等及高三種，定義如下圖所述。

Uncertainty Category	Definition
Low	The data available are solid and complete. Multiple published references or reliable databases and records are available. Different sources are generally in agreement.
Medium	Some, but not complete data are available. A small number of published references or reliable databases and records are available. If personal communication or anecdotal evidence is used in combination with published information, then it is from multiple reliable sources that are generally in agreement.
High	No published data are available. The only evidence is in the form of personal communications, anecdotal reports, or unpublished data.

- 定量：設定可接受的保護水準（Acceptable level of protection）。

（4） 列出所有可能的路徑，分析並計算其釋放及暴露風險



共有 12 個路徑，釋放及評估風險如下：

Pathway	Risk of Release	Risk of Exposure
Legally Imported Mammalian Livestock	Very Low to Negligible	Very Low to N/A
Illegally Imported Mammalian Livestock	Very Low	Very Low
Domestic Mammalian Pets (Dogs and Cats)	Low	Very Low
Humans	Very Low	Very Low
Exotic Mammals (research, wildlife, exotic pets, zoo animals)	Negligible	N/A
Legally Imported Poultry	Very Low to Negligible	Very Low to N/A
Legally Imported Non-Poultry Birds	Very Low to Negligible	Very Low to N/A
Migratory Birds	Negligible	N/A
Smuggled Birds	Very Low	Very Low
Conveyances	Negligible	N/A
Hides and Skins	Negligible	N/A
Fly dispersal	Negligible	N/A

（5） 描述生物及經濟方面後果評估結果。

（6） 摘要風險估計結果：總和考量風險爲低（Low），如下圖。

In summary, the consequences of an NWS incursion may be biologically and economically severe. However, the most likely consequence - an incursion not followed by an outbreak – would result in health consequences for the imported infested host only, and would result in economic consequences related to investigation only and limited control measures. All potential pathways for NWS introduction from the affected countries into the free region were examined. Of the 12 pathways considered, 5 posed negligible risk of release, 6 posed very low risk of release, and 1 pathway, pet mammals, posed low risk of release. For all pathways with a greater than negligible risk of release, the risk of exposure (defined as infestation of one native host in the free region) was very low. Overall, the risk of NWS introduction into the free area from the affected countries is low.

（7） 最後以此結果對利害關係人進行風險溝通。

8. 國內區域化風險評估應用

風險評估（Risk assessment）亦可用於國內執行區域化的疾病風險分析。依據 OIE 定義，區域（Zone/region）是具有明確劃分的領土範圍，其內飼養的動物族群針對特定疾病，健康狀態有別於其他地區或國家，並實施監測、疾病控制及生物安全措施，維持特定疾病的清淨狀態。實施區域化目的係爲國際貿易，促進貿易機會及對國家資源進行有效的分配（毋須整個國家執行疾病撲滅或清淨）。

國內區域實際應用上分爲兩種型式：

（1） 疾病遏止區域（Disease containment regions）：快速減低疾病散佈。

因應疾病疫情所建立的區域，依已定的緊急應變計畫決定區域大小，並視所關切的病原進行相關措施，如禁止移動、施打疫苗或撲殺。可依行政區、半徑範圍（圓形）或格子範圍（正方形，如美國）劃分區域予以執行。

（2） 疾病控制或撲滅區域（Disease control or eradication regions）

此種區域須長期維持，針對特定疾病劃定區域界限，以地理（以河流隔出區域）、行政區或其他方式劃出區域範圍，執行相關措施來維持區域界限，並定期（如每 1-2 年）進行評估，決定疾病傳播風險是否仍高或需否改變執行措施。美國執行牛結核病清除即使用此區域概念予以執行。

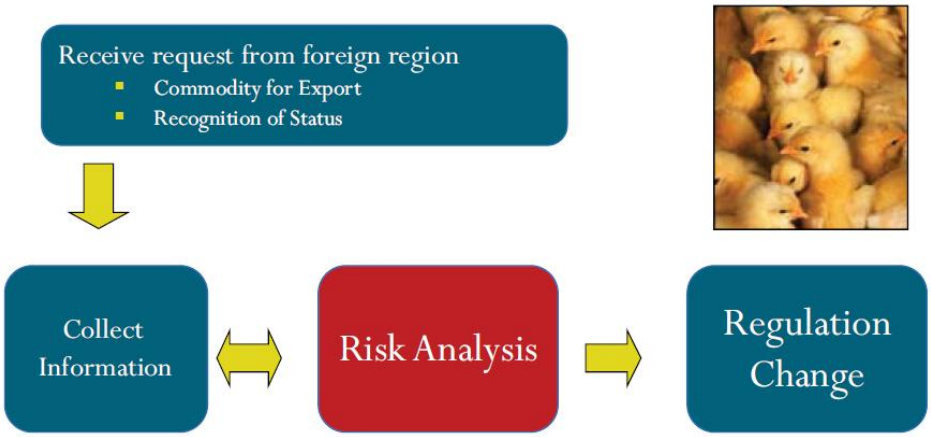
9. 應用區域化（Regionalization）申請國際貿易應注意的 11 項評估因子

此部分以美國爲例，說明輸出國實施區域化措施後，向美國提出動物及其產品出口申請，美國建議審核考量的 11 項因子及其評估方式。

依據 OIE 原則，輸出國應建立並清楚地定義區域（Region），說明建立基礎（爲何訂此區域，係因地理或監測結果），提供支持文件、評估資料、該區域認證及監督控管機制，以維持該區域之有效性。而輸入國於其動物健

康狀態經評估可被保護情形下，且當輸出國確實依 OIE code 實施適當措施時，應認定該區域。不過 OIE 表示，區域化不能應用於所有疾病，且不同疾病，可能需要不同的區域。

依據美國規定，動物及其產品輸入限制絕大部分來自於輸出區域的動物健康狀態無法符合美國要求，此部分評估工作由美國農業部執行。美國對區域的定義可以爲一個國家、國家的一部份、幾個國家的一部份組合成一個區域或鄰近國家組成的團體（A group of adjacent countries），當接受外來區域申請時，爲了認定該動物健康狀態及評估輸入商品風險，即蒐集相關資訊進行風險分析，最後調整其輸入規定，流程如下：



而其審核考量 11 項因子如下，總和評估其釋放風險（Risk of release）：

（1） 授權依據（Authority）、組織編制（Organization）及獸醫服務體系架構：如疾病控制措施、移動管制及隔離檢疫有無法律授權或依據；有無標準作業程序；品質如何管制以及資源來源。

（2） 區域疾病狀態：過去病史及現在疾病狀態，包括發生位置、感染族群及控制措施等。

（3） 鄰近區域疾病狀態。

（4） 疾病主動控制計畫施行範圍。

（5） 免疫狀態：疫苗劑型及使用情形、如何區別野外及疫苗毒、疫苗使用控管情形及緊急疫苗使用計畫等。

（6） 與鄰近風險較高區域分隔情形：有無地理或人為屏障區隔、交通往來路徑（公路或機場）、有無邊境管制及其執行情況。

（7） 風險較高區域動物及其產品移動控制情形：有無建立輸入檢疫條件、是否執行輸入前檢測、邊境檢查及隔離檢疫。

（8） 家畜飼養統計及交易：畜禽群基礎及生產資料、地理分佈、交易實行現況、動物是否可逆向追蹤來源場等。

（9） 疾病監測：如監測形式、計畫及比例、追蹤調查（Follow-up investigation）、試驗特性及通報等。

（10） 實驗室能力。

（11） 緊急應變能力。

簡言之，即是評估這個區域是否存有危害（疾病病原）？這個區域是否能不讓危害進入？如果危害進入，可以被偵測出並且被控制？如果偵測出危害，會被通報嗎？經過風險評估後，決策者會決定該區域動物健康狀態是否應被改變（需要更健康）或是否需有執行減低風險措施的特殊情形（降低風險）。若無或已完成處置，依美國處理流程將訂定規則並予公告 10-60 天（包含風險評估支持文件，可於http://www.gpoaccess.gov/fr/查詢），蒐集因應貿易伙伴國、利害關係人或專家意見後公佈施行（可於http://www.regulations.gov查詢）。若區域內動物健康狀態改變或處置模式已有不同時，須即時通知輸入國，原先認定可能需要重新予以評估。

10. 風險分析過程之經濟分析

供給及需求係影響經濟及貿易最主要的考量因子，風險分析中的經濟分析屬於後果評估（Consequence assessment）的一部份，係根據生物病原可能造成的後果進行評估，主要影響生產（Production）及貿易兩部分，亦可能影響消費，須有量化評估數據，才能進行經濟評估分析。

（1） 對國內而言，疾病直接衝擊供應，可能造成產量與供應的不足，如果發生的疾病為消費者所關切或存有公共衛生疑慮者，即可能影響需求量。

（2） 貿易伙伴國會依據疾病特性及國家關係進行反應，如貿易禁令、提出新的輸出要求（須認證、加強檢驗或進行加工）。

實際應用上，經濟影響估計亦有定量分析及定性分析兩種方法：

- 定量分析用以評估供給衝擊（Supply shock）、貿易衝擊、價格與數量改變以及社會救濟衝擊（Welfare impact）。
- 定性分析利用多方消息、對遭受影響的生產者進行調查、產業概觀、歷史經濟數據、過去疫情文獻探討進行分析評估，產出低（Low）、中等（Mediun）或高（High）程度之結果，沒有標準，係由分析者主觀判斷。

經濟分析另一重要考量爲補償選擇（Compensation options），一旦選定對疾病的反應方式後，即需考慮補償問題，包括爲何補償、需要補償的項目、補償金來源及適宜範圍補償金是多少。補償類似於鼓勵畜主通報而給予的結果性報償，減低畜主損失並且提供政府及時介入處置的時機，避免疫情擴大。一般而言，動物本身價值、清潔消毒所需費用或因復養或恢復產能期間之損失（Lost income）都可考量是否予以補償，不過，美國僅補償動物損失及部分的清潔消毒費用。補償資金來源可爲政府稅收、產業基金、消費稅或國際銀行資助。但最重要的是，如何合理補償？

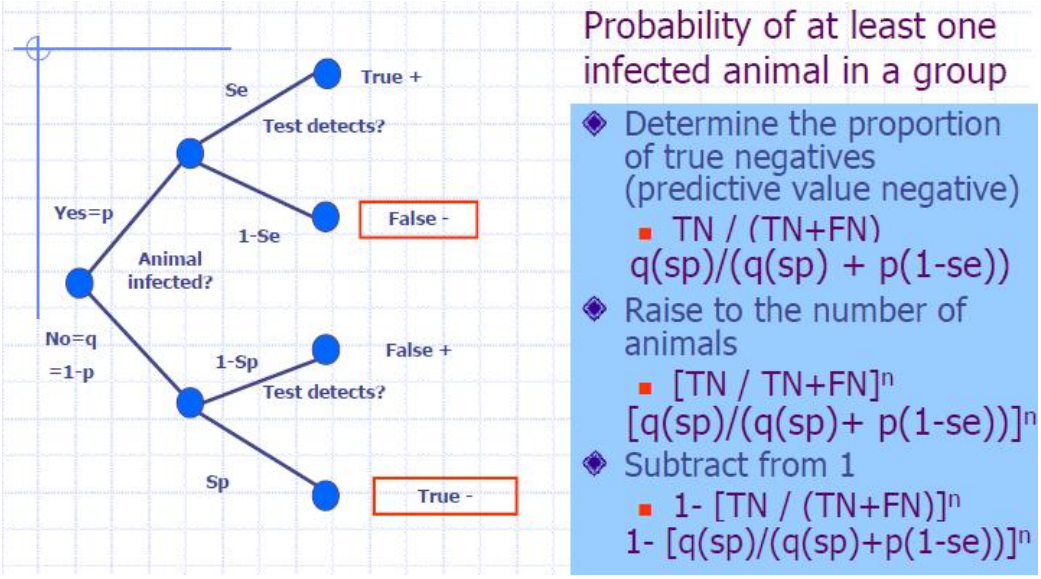
補償須有足夠程度才能鼓勵通報，但亦須考量道德危害問題（補償比例越高，畜主執行良好生物安全意願降低，可能會增加疾病盛行率），故本節授課專家建議對於疾病指標場（已發生疾病，進行控制或清除者）給予全額補償，其他畜牧場若發生疫情，則依生物安全落實程度給予不同程度補償，越差者補償金越低，並且應掌握補償金不是生產者收入來源的概念進行規劃及補償，才能夠儘量避免因補償產生的不良影響。

11. 機率簡介（Introduction to probabilities）

機率（p）代表一個事件發生的可能性，一般介於 0-1 之間。0 代表事件將不會發生，1 代表該事件將會發生；一個事件不會發生的機率爲 q=(1-p)。

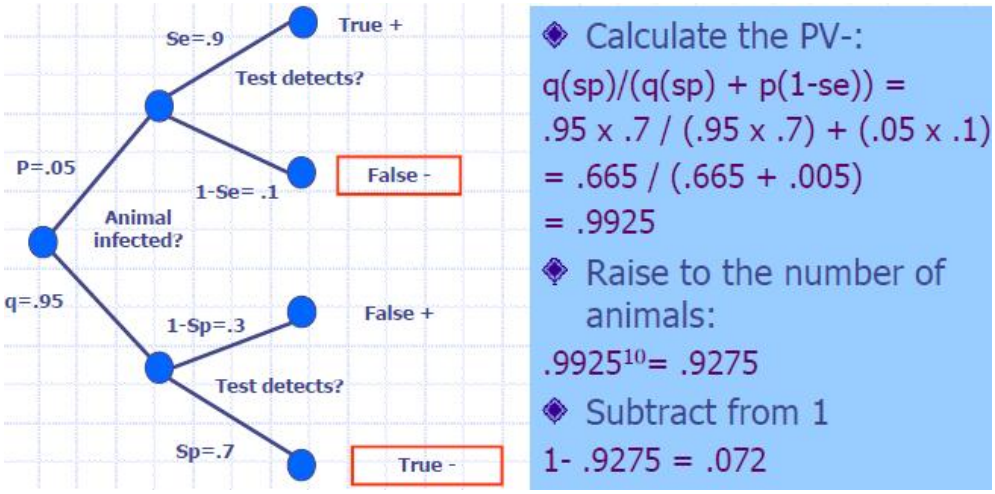
風險評估的應用係爲了解於一個群體中檢出至少一個陽性動物的機率

爲何？（可視爲病原的釋放評估：欲輸出的群體於該國內執行兩次檢驗，檢出至少一個陽性動物的機率爲何？越低對輸入國越有保障），取得相關數據資料後，代入以下公式進行計算（可於 Excel 建立公式進行計算）。



動物族群大、疾病盛行率高及試驗本身敏感性（Se）低時，於一個群體中檢出至少一個陽性動物的機率大；試驗本身敏感性（Se）高時，於一個群體中檢出至少一個陽性動物的機率低。試驗本身特異性（Sp）對機率影響不大。

計算出的機率值<1%（0.01）是良好結果，爲一般可接收的機率結果。如果算出機率值高或不符合期待，即需進行減低風險措施來降低機率值，例如提高試驗敏感性、動物輸出前隔離檢疫等。



例題結果說明：雖然所有動物經試驗檢驗均成陰性，但該批動物仍有

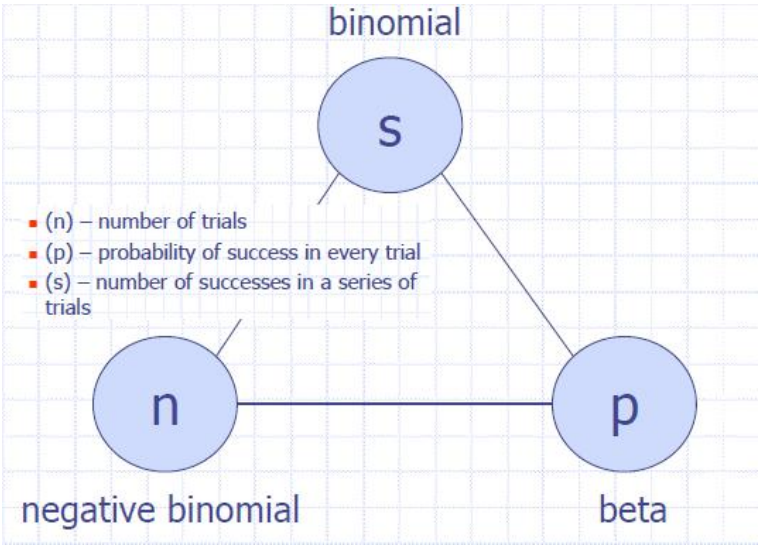
7.2%機率可能存有一隻未檢出的感染動物。若機率太高，不能接受，即需進行減低風險措施來降低機率值。

12. 分佈及定量風險評估簡介

由於真實情況存有變異性（Variability）及不確定性（Uncertainty），爲併入變異性及不確定性因子更客觀且符合實際情形地計算所需答案，常應用下列過程（Process）：

（1） 二項過程（Binominal process）：

內含有二項分佈（Binominal distribution）、β分佈（Beta distribution）及負二項分佈（Negative binominal distribution），用來計算檢驗陽性數（s）、母群體（n）及機率（p），三個變因只要知道二項值，即可透過對應的分佈及公式算出第三項值。



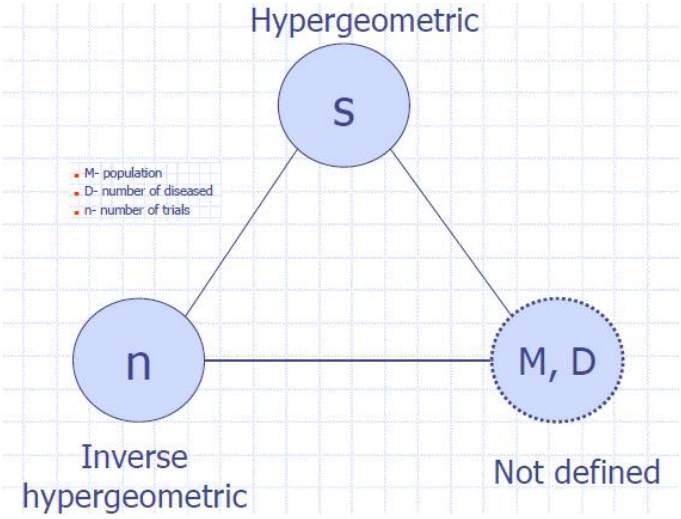
- 二項分佈：s= binominal (n, p)。
- β分佈：p = Beta (s+1, n-s+1)。
- 負二項分佈：n = s+negative binominal (s, p)。

（2） 超幾何過程（Hypergeometric process）：

Hypermetric (n, D, M)，n 爲試驗數、D 爲感染疾病數、M 爲母群體數。

不同於二項過程，依據前次試驗結果，每次試驗成功機率將會改變，以使用三把鑰匙開門爲例，只有 1 把鑰匙可以開啓大門，第 1 次成功機率爲 33%，失敗後，現實會排除無法開啓的鑰匙，使用剩下 2 把鑰匙重新嘗試，第 2 次成功開啓機率變爲 50%。以此過程得出的結果，等同於每次不移除無法使用鑰匙嘗試開門的結果（二項過程），但是較符合實際操作現況。

但一般而言，如果樣本數夠小（<0.1 倍的母群體數）時，則使用二項分佈得出的結果趨近於超幾何得出的結果。因此可能多數時候，可見使用二項過程予以計算。



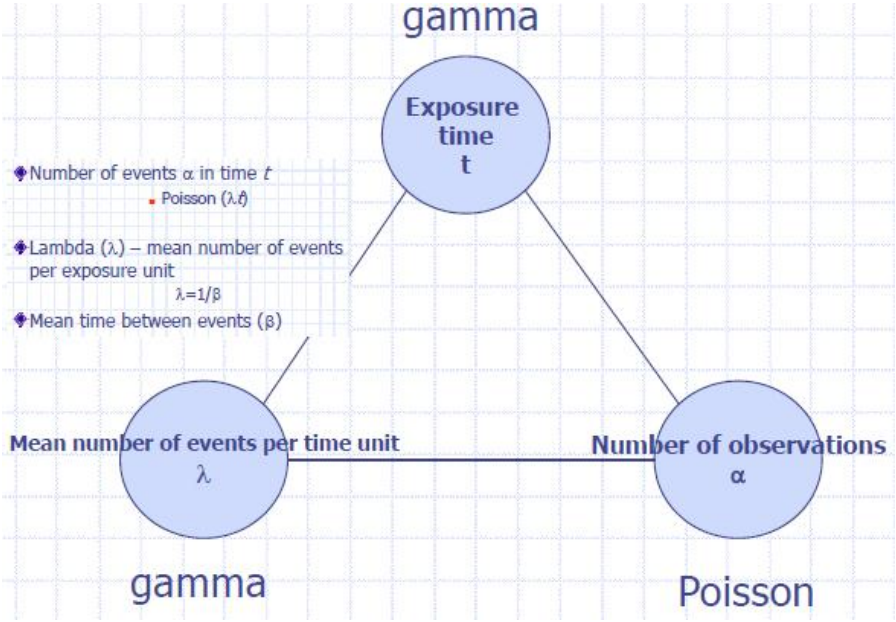
（3） 卜瓦松過程（Poisson process）：

用來計算單位區間內發生的事件數，Poisson (λt)。

在這段區間內的發生機率是固定不變且連續的，單位區間內事件發

生數與其他區間發生數是相互獨立不相關，而此區間可以是空間（公升、公斤或公尺）或時間（秒、小時或年）。

具有三個分佈，但以卜瓦松分佈（Poisson distribution）最常用。



- 當機率（p）非常小時，Poisson (λt) 接近於 Binominal (n, p)。
- 當母群體數（M）夠大時，Binominal (n, p)接近於 Hypermetric (n, D, M)。
- 當母群體數（M）夠大，母群體內得病數（D/M）非常小時，Poisson (λt) 接近於 Hypermetric (n, D, M)。

13. 定量風險分析介紹

對風險分析而言，定性及定量方式均屬可行的分析方式，所得結果均是有效的。定性方法以非數學計量方式討論問題、可能性及其後果；定量方法使用特殊數值與明確的機率分佈來分析可能性及後果。大部分風險分析結果是兩者搭配使用所得。

不過定量分析須應用很多分佈來計算各項機率（p），通常需要大量觀察數據及明確專家建議進行計算，過程較繁瑣。常用分佈有常態分佈（Normal distribution）、對數正態分佈（Log normal distribution）、β分佈（Beta distribution）、均勻分佈（Uniform distribution）、二項分佈（Binominal

distribution）及負二項分佈（Negative binominal distribution）。

有關牛源產品BSE殘餘風險定量評估範例及結果詳如***附件 1***。

14. 研究案例報告

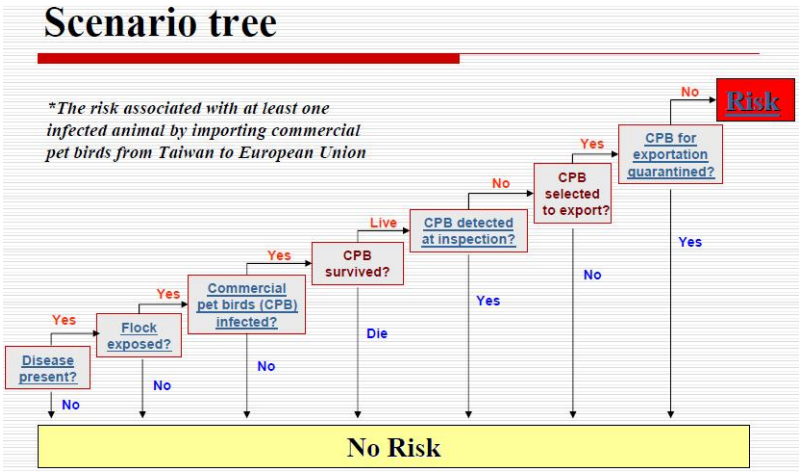
本次案例研討共分爲 5 組進行討論，每組至少 3 人，本組題目經討論後，決定以台灣寵物鳥類輸歐盟爲案例，進行定性風險評估，並依下列步驟完成資料收集及案例報告，簡報詳見***附件 2***。

（1） 定義問題：

- 自台灣輸歐盟之商業寵物鳥類中，至少檢出一隻已感染鳥類的可能風險爲何？
- 認定危害爲家禽流行性感冒。

（2） 收集資料進行定性風險評估，著重於輸出國釋放風險評估：

- 了解疾病基本資訊：家禽流行性感冒。
  - OIE疾病卡資料（OIE disease card；www.OIE.int）。
  - 美國愛荷華州立大學疾病資料（www.cfsph.iastate.edu/）。
- 輸出國疾病狀態：台灣家禽流行性感冒疫情及其處置概況。
  - OIE 疫情通報資料。
  - 輸出國官方（網站）資料。
- 參考國外風險分析案例進行討論，劃出情境樹。



- 國外風險分析案例來源：
  - 美國：www.regulations.gov
  - 紐西蘭：www.biosecurity.govt.nz/regs/imports/ihs/risk。
  - 澳大利亞：www.daff.gov.au/ba/ira。
  - 英國：www.defra.gov.uk/foodfarm/farmanimal/diseases/monitoring/riskassess.htm。
  - 文獻探討：
    - www.pubmed.com。
    - www.googlescholar.com。
    - FAO website。
    - Google。
- 根據情境樹問題，分析各路徑風險高低。
- 最後摘要總結風險結果。

三、心得與建議

風險分析是組織科學方法評估風險發生的可能及其影響，並提出降低或改變風險建議方案，提供科學依據供決策參考及與利害關係人溝通的一套方法，其可因訴求的不同，而有不同評估方向及可接受的預期目標或風險值，無論執行何種評估方式，均須具有一致性、科學基礎、彈性且透明，沒有一個模版可以套用或適用於不同的案例。也會因動物健康狀態或病原特性的改變，致使風險改變，因此須持續蒐集相關資訊，並對狀態改變者，重新予以評估及分析。

一般而言，爲防範疫病藉由動物及其產品入侵，每個國家均注重輸入風險評估，我國亦著重於評估輸入動物及其產品引入疫病之風險，較少將風險分析應用於國內疾病清除或控制過程中成效評估及疾病侵入後散佈風險評估。我國動物風險分析目前係以任務編組的專家團隊執行，建議可規劃成立專業或專責機關（單位），如美國流行病學及動物健康中心，納入獸醫、公共衛生、生態及社會經濟專業人才，專業客觀性地處理所需分析案例及其影響評估，藉以適時調整相關防檢疫措施執行強度與作法。

爲令其動物及其產品更順利輸出，出口量大的美國已著手輸出風險評估及其立法，並將其科學性結果提供輸入國參考，加速其對美國風險可接受之認定，已有部分國家認可此作法，若我國於經費資源及人力許可下，亦可考慮試辦，應有助減低我國動物及其產品輸出之阻力。

此次研習獲益良多，亦了解到美國對流行病學及風險分析人才培育及再教育的用心，與其輸入國因不了解而設立貿易阻礙，不若定期舉辦相關課程邀集貿易伙伴國或友好國參訓，使其透過了解，進而認同風險分析作法及結果，排除不必要的貿易障礙。由於風險分析於動物防檢疫應用需求與日遞增，我國應多舉辦風險分析相關訓練或研習課程，使同仁對風險分析應用更加瞭解，若有國際性流行病學或風險分析課程，亦應積極派員參訓，以掌握國際趨勢及吸收專業新知。

四、致謝

承蒙美國在台協會陳彥錡小姐於本次研習行程規劃及協調上之熱忱協助，並感謝美國農業部給予此次機會及經費支持，謹此致上最深之謝意。另由衷感謝長官給予研習機會，有幸參與國際課程及討論，加強本質學能及國際觀。

五、附圖

圖 1、主辦單位、全體講師與學員合影

圖 2、楊文淵技正進行案例報告及討論剪影

圖 3、案例討論剪影

圖 4、學員結業合影

六、附件

（一）附件 1、牛源產品 BSE 殘餘風險定量評估範例及結果。

（二）附件 2、研究案例報告簡報。

（三）附件 3、研習課程簡報資料。

附件1

QUANTITATIVE ASSESSMENT OF THE RESIDUAL BSE RISK IN BOVINE-DERIVED PRODUCTS

EFSA QRA REPORT 2004

WORKING DOCUMENT

Table of contents

I. Mandate and history

The European Union's (EU) Scientific Steering Committee (SSC) was invited to carry out a quantitative risk assessment (QRA) of the residual Bovine Spongiform Ecephalopathy (BSE) risk in the following bovine-derived products: gelatine, tallow, tallow derivatives, milk replacers containing tallow, di-calcium phosphate and meat-and-bone meat as a cross-contaminant in animal feed. Hence, to prepare elements for discussion on the above questions by the Transmissible Spongoform Encephalopathy (TSE) and BSE *ad hoc* Group, a working group was established. This working group met, in varying compositions, at several occasions in 2002 and 2003 and decided to involve stakeholders in the sector in order to obtain additional field data and comments on the proposed risk scenarios.

The various draft reports prepared by the Working Group were regularly discussed and amended by the TSE/BSE ad hoc group of the EU's Scientific Steering Committee. In September 2002, the SSC discussed the proposed methodology, adopted it and decided that the proposed input values could be used for the QRA. The SSC also recommended that, in parallel, the methodology and typical input values could also be submitted for consultation via internet to the wider scientific and industrial world.

This wider consultation resulted in a meeting in April 2003, which involved scientists from the Commission's Scientific Committees and Working Groups and representatives (stakeholders) from both the industry and Commission Services. These scientists ratified the content and assumptions about the QRA model input data as described in a first Interim Report. The Commission forwarded that report to Det Norske Veritas (DNV) Ltd so it could serve as a basis for their model in order to quantify the residual BSE risk. However, an *ad hoc* European Safety Food Authority (EFSA) committee asked for improvements and additions to the Interim report that required re-calculation by DNV. The resulting Second Interim report was approved by the EFSA Biological Hazards Panel (BIOHAZ) at their Plenary meeting and again forwarded to DNV in order to review the model for the quantification of residual BSE risk. In the meanwhile EFSA established a QRA working group which considered a draft DNV BSE risk report and advised some further modifications which were incorporated and re-submitted by DNV in August 2004. These calculations and their products have been merged within the Second Interim Report to give this current version for consideration by the EFSA BIOHAZ Panel at their Plenary on October 20-21st 2004. There it was decided that formal adoption and publication of this working document will proceed after the opinions have been updated in order to allow the inclusion of any agreed changes to this document made during the updates. In the meantime this *working document* is published in order to be used as a reference in the updated opinions on:

- **Tallow** obtained from ruminant slaughter by-products.
- **Gelatine** from ruminant bones or hides.
- **Di and tri calcium phosphate** from bovine bones used as animal feed additive or as fertiliser.
- Human BSE risk posed by **bovine vertebral column** including the dorsal root ganglia.
- **Mammalian derived meat and bone meal** forming a cross-contamination of animal feedstuffs.

II. Introductory chapter

Quantitative risk assessment of food-borne pathogens has emerged as a powerful methodology for estimating how likely, and at what level, an individual or population will be exposed to a microbial hazard. The output of risk models is relatively complex and, ideally, its interpretation and significance requires an integrated understanding of mathematics, statistics, biology and systems knowledge. Elements of the methodology are given here in the context of the quantitative assessment of residual BSE risk. Further general details of different approaches can be found in "Risk assessment of food-borne bacterial pathogens: quantitative methodology relevant for human exposure assessment (EC SSC Preliminary report, February 21-22nd, 2002).

II.1. Deterministic and stochastic approaches towards BSE risk quantification

Current risk assessment models do not generally consider the effect of time, and are said to be static. The typical static model considers the events that take place during a fixed period of time, say one year, and treats differences between or within time periods (*e.g.* seasonal variation) as variability. While parts of these static models may include dynamic modules - such as estimating fluctuations in herd numbers or infectious titre - the output is usually a static quantity - a titre estimate or herd size (EC SSC Preliminary report, February 21-22nd, 2002). For this reason, a static model has been developed to assess residual BSE risk.

Two model approaches can be followed to quantify the residual BSE risk of ruminant-derived products entering the food chain: the deterministic and stochastic or probabilistic models.

A) In the deterministic approach, a single value is attributed to each parameter in the assessment. This value corresponds to the most likely value this parameter (commonly) has or is assumed to have.

The deterministic modelling approach permits the risk manager to rapidly estimate (by linear extrapolation) the risk under alternative conditions, such as higher/lower tissue infectivity levels, larger/smaller batch sizes, complete/incomplete specified risk materials removed, etc. However, the rigidity of the deterministic approach may result in unrealistic scenarios for which the likelihood is almost zero. If the input values are replaced by a best, or average or worst case assumption then there would be a linearly decreased or increased residual risk. However it should be clear that combining all worst or average or best case assumptions in one deterministic scenario may result in highly unlikely estimates of possible risk. This is because the probability that all worst, average or best case assumptions become reality at the same time is much less likely than if only one worst, average or best case event occurred.

B) In the *probabilistic approach*, the above problem is at least partly avoided. The model is run many times and for each of the model runs, values for each parameter are selected ad random from a specific distribution and combined (stochastic model). The number of model runs should be taken sufficiently high to guarantee that all possible combinations of parameters have eventually been selected a sufficient number of times to allow an evaluation of the probability of occurrence of the corresponding risks.

A major advantage of the probabilistic approach is that it helps to understand interactions between parameters whilst taking into account uncertainties and that therefore it is a most useful tool in decision-making. One should however be aware that the assumed probability distributions in reality reflect both the scientific uncertainties in certain areas[1] and the fact that certain field conditions vary according to a statistical distribution[2]. While the main value of stochastic models is that they allow testing a high number of possible combinations of different parameter values (and for many iterations, for example, 100,000), the outputs may be heavily influenced by uncertainties associated with the basic assumptions adopted for each parameter.

One should also be aware that, when introducing alternative assumptions, the resulting residual risk would not necessarily increase or decrease linearly. Therefore, when uncertainties are reduced by the acquisition of new data and information, the evaluation should be repeated.

In this report hereafter, the probabilistic approach is followed because it is likely to result in more realistic scenarios. The results allow the estimation of the most frequently observed outcome (mode) for the chosen combination of input distribution. For the process of decision making, the higher percentiles are in this context often more important than the lower ones.

The user should however be aware that the results heavily depend on the values of parameters for which no definitive research results or field data are available. The species barrier and a minimal infective dose are examples of parameters that have to be estimated with a large degree of uncertainty because of lack of knowledge.

II.2. Quantitative Risk Assessment (QRA) methodology

The basic methodology for the quantitative risk assessment of residual BSE risk is given in Annex 1.

II.3. Summary overview of the input data needed for quantitative BSE risk assessments

A comprehensive quantitative assessment of residual BSE risk posed by cattle-derived products such as gelatine, di-calcium phosphate, tallow and milk replacers, and meat and bone meal requires information for the following input variables:

1) The species barrier.
2) The possible infectious load of the cattle by-products. (Tissue infectivity distribution and typical tissue titres of the BSE agent.)
3) The prevalence of BSE positive animals that become slaughtered for food. The yearly numbers of adult animals slaughtered determines the probabilities that, in a

[1] For example, is the species barrier 1, 10, 100, 1000 or 10000? Are the minimal infective doses 1000, 100, 10 or 1 mg?

[2] For example, the risk reduction during production will not always be identical for all plants and within a given factory, but is likely to be distributed around this value. In this respect, it should be noted that the TSE validation studies carried out by GME involved only processes that could be considered to apply generically to all of the GME member companies that produce gelatine.

- **Infectivity reduction by processing - impurities in tallow**: In order to estimate the infectivity in raw tallow before filtration it is necessary to have an estimate of the level of impurities in the raw tallow. This data was not given in the SSC report, and it seems that no firm data are available. The UK Renderers Association suggested that a figure of 0.5% might be reasonable. For the purposes of this assessment the level of impurities in raw tallow has been assumed to be 1%. This is believed to be an upper estimate. It is further assumed that all of this impurity is protein, which again would be a conservative assumption.

- **Infectivity reduction by processing:** The reduction factors for BSE infectivity for each of the processing steps are summarised in Section III.7.5, Table 4. These are all modelled as triangular distributions. Note that the reduction factors given for filtration in Table 4 are misleading as they do not take account of the level of impurities in the tallow. Thus the reduction factor for filtration to 0.15% should be 0.01/0.0015=6.7, rather than 1/0.0015.

- **Daily consumption:** consumption estimates are as given in Section III.8 These are modelled as triangular distributions.

- **Additional inputs for exposure to cattle:** Most of the data used for the calculation of cattle exposure is the same as that for human exposure. Additional data relate to batch sizes for DCP production and consumption estimates for both the use of tallow in milk replacer and for DCP. Additional data was obtained from GME indicating that the yield of DCP from fresh bones ranges from 15.9 to 17.6%.

Table 6a - Input Data for Residual BSE Risk Model

European Commission - Health and Consumer Protection
PROBABILISTIC MODEL FOR THE QUANTITATIVE ASSESSMENT OF RESIDUAL BSE RISK
DNV Consulting, London

EC ref	SANCO/D2/2004/SI2.373706
DNV ref	20067400
Date	29 June 2004
Rev	Ver-5
Sheet	1 - Input Data

legend: input required

ID		units	data			ref	comments
Infectivity data							
	Infectivity level in brain (clinically BSE infected		**P50**	**P99**			*input percentiles*
D1	**bovine)**	ColD50/g	**5**	**100**		III.2 (A)	*See section III.2 & IV.2*
	Incidence classes ()						
D2	(I)	**GBR I country, BSE highly unlikely, zero incidence**					
D3	(II)	**GBR II country, no BSE detected,**					
D4	(III)	**GBR III country, BSE possible,**					
D5	(IV)	**GBR IV country, BSE confirmed,**					
	BSE incidence range per 10^6 animals		**min**	**mode**	**max**		*mode = most likely*
D6	(II)	**no/10^6**	**0**	**0**	**0**		*no BSE detected*
D7	(III)	**no/10^6**	**1**	**30**	**99**	III.3.1	*30 assumed as most likely value*
D8	(IV)	**no/10^6**	**100**	**300**	**1000**		*originally specified as >100, no limit*
	Non-detected pre-clinical animals		**min**	**mode**	**max**		
D9	(II)	**no/10^6**	**2**	**3**	**4**		
D10	(III)	**no/10^6**	**2**	**100**	**400**	III.3.2	
D11	(IV)	**no/10^6**	**200**	**1000**	**4000**		
	Infectious load for infected animals		**min**	**max**			*all countries*
D12		%	**1%**	**100%**		III.3.3	*infectivity as a %age of maximum,*
	Incubating animals < 10% of max. load		**mean**				
D13	reliable surveillance	%	**90%**			III.3.3	*% of animals whose infective load*
D14	unreliable surveillance	%	**50%**				*is below 10% of max. possible load*
	Infectious load for animals < 10% max load		**min**	**max**			
D15		%	**1%**	**10%**		III.3.3	
	Weight of slaughtered bovine (live weight)		**mean**				*constant value assumed*
D16		kg	**550**			III.3.2 (B)	
	Byproducts, bones for gelatin, DCP and fats		**mean**				
D17	Case 1:both skull and vertebral column removed	kg	**37**				*average by-product yields per animal*
D18	Case 2: only skull is removed	kg	**50**			III.4	*(tissue weights)*
D19	Case 3: skull or vertebral column not removed	kg	**58**				
	Byproducts, fats before and after splitting		**mean**				
D20	case 1	kg	**32**			III.4	*average by-product yields per animal*
D21	case 2	kg	**80**				*(tissue weights)*
	Byproducts, mixture of tissues		**mean**				
D22	no SRMs removed	kg	**188**				
D23	SRMs removed, except vertebrae	kg	**180**			III.4	
D24	SRMs removed, including vertebrae	kg	**167**				
	Tissue weights and infectivity levels		**mean**	**%**			
D25	brain	g & %	**500**	**100%**			*estimated tissue weights from adult*
D26	trigeminal nerve ganglia (TRG)	g & %	**20**	**100%**			*beef cattle; percentage figures are*
D27	spinal cord	g & %	**200**	**100%**			*ratios of estimated titre levels to*
D28	dorsal root ganglia (DRG)	g & %	**30**	**100%**			*maximum titre levels*
D29	Ileum	g & %	**800**	**10.0%**		III.3.2 (B)	
D30	spleen	g & %	**800**	**0.010%**			
D31	rest of head (excl skull and brain)	g & %	**6500**	**0.02%**			
D32	bone marrow, if infectious	g & %	**2900**	**0.01%**			
D33	bone adnexa	g & %	**5600**	**0.01%**			
	Contamination of bone byproducts		**mean**				
D34	Probability of contamination for case 1	%	**0.01%**			III.5	*depends on skull, vertebrae removal*
D35	Probability of contamination for case 2 and 3	%	**1.0%**				*depends on skull, vertebrae removel*
D36	Max. amount of brain tissue remaining	%	**5.0%**				*all cases*
D37	Max. amount of spinal cord tissue remaining	%	**2.5%**				*all cases*
	Contamination of fat byproducts		**mean**				
D38	Prob. of contamination, tallow from fat, a & b	%	**50.0%**			III.5	*depends on skull, vertebrae removal*
D39	Prob. of contamination, tallow from mix, case a	%	**100.0%**				*depends on skull, vertebrae removal*
D40	Prob. of contamination, tallow from mix, case b	%	**10.0%**				*all cases*
D41	Prob. of contamination, tallow from mix, case c	%	**10.0%**				*all cases*

Table 6b - Input Data for Residual BSE Risk Model - continued

Batch sizes and Yeild							
D42	**Batch for tallow from bones**	tonnes	min 125	max 1500		III.6.4	*uniform distribution*
D43	Yeild of Tallow	%	10%	20%			
D44	Yeild of MBM	%	40%				
D45	**Batch for tallow from fat tissues**	tonnes	min 40	max 230		III.6.4	*uniform distribution*
D46	Yeild	%	65%				
D47	**Batch for tallow from mixture of tissues**	tonnes	min 150	max 1000		III.6.4	*uniform distribution*
D48	Yeild	%	15%				
D49	**Batch for gelatine from bones**	tonnes	min 100	max 250		III.6.2	*uniform distribution*
D50	Yeild	%	4.1%	4.3%			
Infectivity Reduction by Processing							
D51	**Impurities in raw tallow (bones and mixture)**	%		mean 1.0%			*Assumed value*
D52	**Impurities in raw tallow (fat tissues)**	%		mean 1.0%			*Assumed value*
D53	**Protein content of tallow impurities**	%		mean 100.0%			*Assumed value*
D54	**Tallow, saturated steam, pressure**	factor	min 1.00E+01	mode 2.00E+02	max 1.00E+03	III.7.3	*triangular distribution*
D55	**Tallow, post sterilisation**	factor	min 1.00E+01	mode 2.00E+02	max 1.00E+03	III.7.3	*triangular distribution*
D56 D57	**Gelatine, alkaline and acid**	factor	min 1.58E+04	mode 3.16E+04	max 6.31E+04	III.7.1	*triangular distribution*
D58	**Gelatine, heat / pressure**	factor	min 1.58E+06	mode 3.16E+06	max 6.31E+06	III.7.1	*triangular distribution*
Daily Consumption							
D59	**Tallow (humans)**	grams	min 0.5	mode 1.0	max 10.0	III.8.1	*triangular distribution*
D60	**Bone gelatine (humans)**	grams	min 0.1	mode 1.0	max 10.0	III.8.1	*triangular distribution*

Additional inputs for exposure to Cattle

Batch sizes and Yeild							
D50	**Batch for DCP from bones**	tonnes	min 180	max 800		III.6.3	*uniform distribution*
D51	**Yeild**	%	15.9%	17.6%			
Infectivity Reduction by Processing							
D59	**Dicalcium phoshate**	factor	min 3.16E+03	mode 6.31E+03	max 1.00E+04	III.7.2	*triangular distribution*
Consumption							
D60	**Tallow (replacement calves)**	kg		mean 2.4		III.8.3	*mean value, cumulative consumption 60 days, max. 60% tallow*
D61	**Tallow (veal calves)**	kg		mean 37.0		III.8.3	*mean value, cumulative consumption 180 days, max. 50% tallow*
D62	**Bone DCP Adult milk cattle**	g/day	85.0			III.8.2	*mean value only*
D63	**Bone DCP Beef cattle**	g/day	25.0			III.8.2	*mean value only*
D64a	**Cattle Feed Concentrate**	kg/day	mean 8.0	sd 2.0		DNV, 1999	*Intensive system*
D64b	**Cattle Feed Concentrate**	kg/day	mean 1.5	sd 1.0		DNV, 1999	*Extensive system*
Meat and Bone Meal							
D65	**Proportion of MBM produced from bovine material**	%	min 1.0%	mode 40.0%	max 100.0%		*Individual values*
D66	**Proportion of MBM contaminating ruminant feed**	%	Case a 0.1%	Case b 0.02%	Case c 2.0%		

IV.3 Calculation of Infectious Load

The first stage of the model is the calculation of the infectious load. It is in this sheet that the user defines the scenario to be modelled in term of the Geographical BSE Risk (GBR status) and whether or not the surveillance is reliable. The Infectious load sheets for GBR II, III and IV are shown in Tables I-1 to I-6 in Annex I. Where sampled values are shown (*e.g.* the infectivity in line I2) the value given is the mean value. These will take different values at each iteration as the distributions are sampled randomly. The sheet is colour coded to indicate where input is required (green), where values are transferred from other sheets (blue) and the sampled values (yellow).

- The definition of the infectivity for a clinically infected bovine is copied from the input data to line I1, and the sampled value given in I2.
- The user selects the GBR scenario in lines I3 a, b or c and the surveillance scenario in row I7 or I8. All related values are then picked by the software so that the model automatically runs for the chosen scenario.
- The number of detected BSE animals is selected from the selected triangular distribution and the sampled value shown in I6. The numbers of non detected animals then depends on the surveillance. If surveillance is reliable then there are no non-detected animals.
- The numbers of non-detected pre-clinical animals are again dependant on the GBR status, with the data for the selected scenario shown in I13, and the sampled value in I14.
- The infectious load for pre-clinical animals will be less than that of a clinical case. This is modelled by assuming that the infectious load will be less than 10% of the maximum for 90% of infected animals. Thus for 90% of infected animals the infectious load is assumed to range from 1 to 10% (uniform distribution) with the infectious load for the remaining 10% of animals assumed to range from 1 to 100%. With unreliable surveillance it is assumed that the infectious load will be less than 10% of the maximum for 50% of infected animals rather than 90%.
- The total equivalent number of animals with full infectious load is then calculated for the two groups(<10% load and >10% load), and summed (line I27). These values are all per million adult animals.
- The final probability of BSE infection is then calculated as the equivalent number of animals with full infectious load per million animals.

The worksheets with calculated values are presented as Tables I-1 to I-6 in Annex I for GBR II, III and IV countries with results for both reliable and unreliable surveillance. A comparison of the infectious load for each of the country scenarios is given in Figure 3, which shows plots of the distribution of the number of equivalent animals with full infected load in each case.

amount of infectivity (in $CoID_{50}$ per gram) from a hypothetical QRA is displayed together with the values for the three deterministic scenarios. A percentile distribution for the same outcome is displayed in Figure 5. In this example, the 50^{th} percentile value (median of the outcome distribution) is 6.0797, indicating that 5,000 of the 10,000 iterations (50% of all outcomes) yielded an infectivity titer below 6.0797 $CoID_{50}$ per gram tissue.

Final considerations

One should however be aware that the chosen [assumed] probability distributions in reality reflect at once both the scientific uncertainties in certain areas[24] and the fact that certain field conditions follow a statistical distribution[25]. While the main value of stochastic models underlying quantitative risk assessment is that they allow to test a high number of possible combinations of different parameter values, the reliability of the outputs may be heavily influenced by uncertainties associated with the basic assumptions adopted for each parameter.

The more input variables are defined as probability distributions, and the wider the expert estimates for these input distributions are, the flatter and less defined the outcome distribution(s) will be. Also, with a higher number of input distributions, the chances of observing very extreme outcomes, *i.e.* outcomes that result from the simultaneous selection (within ONE iteration) of extreme values for all input distributions, is reduced. This because the chance of drawing values from the upper 1^{st} percentile of each distribution, when 5 independent input distributions are specified, is $(0.01)^5=1x10^{-10}$. If, however, such a rare event occurs, it will be influential on the observed highest percentiles and the maximum outcome value, yielding these seemingly unstable.

One should also be aware that, when introducing alternative assumptions, the resulting residual risk would not necessarily increase or decrease linearly. Therefore, when uncertainties are reduced by the acquisition of new data and information, the evaluation (iterative modelling process) will need to be repeated.

References

Vose D. (1996). Quantitative Risk Assessment - A guide to Monte Carlo simulation modelling. John Wiley & Sons, Chichester, New York, Brisbane, Toronto & Singapore.

[24] For example: is the species barrier 1, 10, 100, 1000 or 10000? Is the minimal infective doses 1000, 100, 10 or 1 mg?

[25] For example: the risk reduction during production will not always be identical for all plants and within a given factory, but is likely to be distributed around this value.

Appendix

Table 1. summary statistics after selecting 5000 values ad random from the given input distributions with minimum=340, most likely value=500, and maximum=660.

All distributions were selected to be symmetric around the mean value.

Resulting distribution	Normal distribution SD=Range/6	Uniform distribution (Min - Max)	Triangular distribution (Min, Mode, Max)	BetaPert-Distribution (Min, Mode, Max)
Min	286	340	342	344
Mode	500		500	500
Max	712	660	657	656
Mean	500	500	500	500
5% Perc	412	356	431	400
50% Perc	500	500	500	500
95% Perc	588	644	568	599

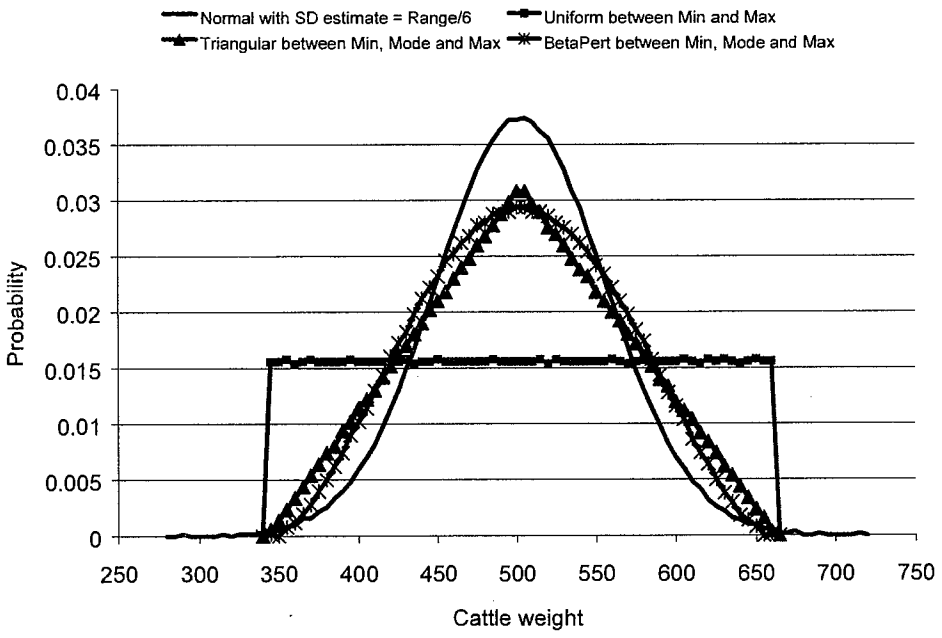


Figure 1: frequency distribution after selecting 100,000 values ad random from the given input distributions.

All distributions were selected to be symmetric around the mean value.

Table 2: summary statistics after selecting 5000 values ad random from the given input distributions with minimum=450, most likely value=500, and maximum=700.

All distributions were skewed, *i.e.* shifted to the left (long tail to the right).

Resulting distribution	Normal distribution SD=Range/ 6	Uniform distribution (Min - Max)	Triangular distribution (Min, Mode, Max)	BetaPert-Distribution (Min, Mode, Max)
Min	340	450	451	540
Mode	497		502	503
Max	666	699	699	681
Mean	500	556	550	524
5% Perc	431	462	475	465
50% Perc	500	575	542	519
95% Perc	569	687	650	605

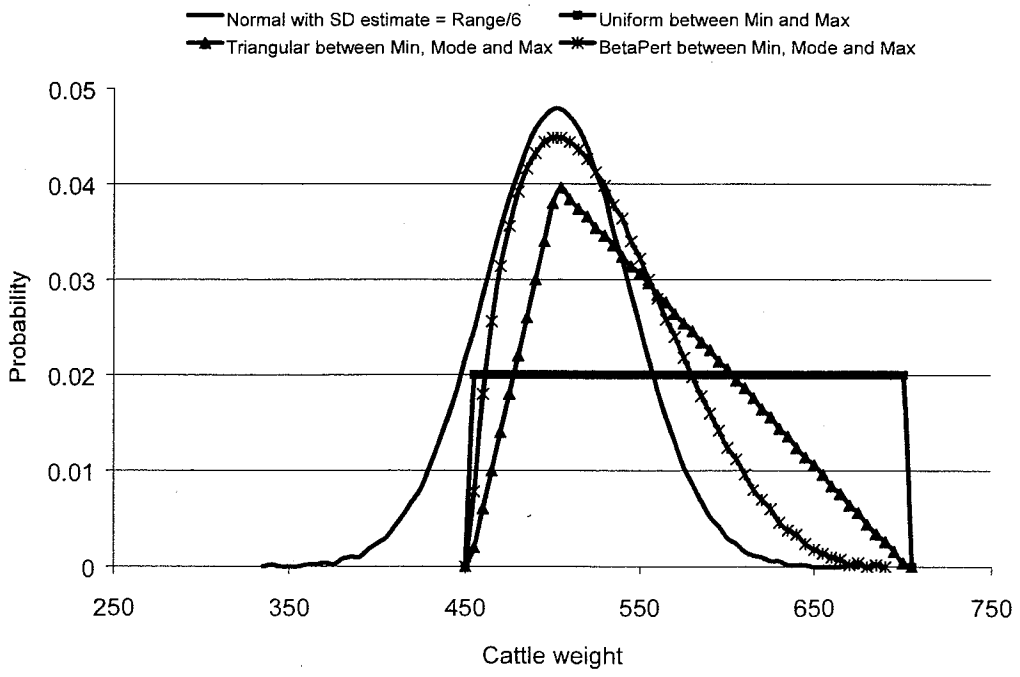


Figure 2: frequency distribution after selecting 5000 values ad random from the given input distributions.

All distributions were selected to be non-symmetrical. The normal distribution considerably extends below the minimum value.

Table 3. summary statistics after selecting 5000 values ad random from the given input distributions with minimum=1, most likely value=100, and maximum=10,000.

All distributions were shifted to the left (long tail to the right), and differences were in the range of log units (total rage: 4 log units).

Resulting distribution	Normal distribution SD=Range/6	Uniform distribution (Min - Max)	Triangular distribution (Min, Mode, Max)	BetaPert-Distribution (Min, Mode, Max)	$10^{BetaPert}$ Distribution (Min, Mode, Max)
Min	-6647	2.57	11	1.5	1.24
Mode	204		126	130	4.6
Max	6411	9998	9951	8336	8599
Mean	100	5000	3367	1734	376
5% Perc	-2643	500	302	118	5.7
50% Perc	100	5000	2964	1367	100
95% Perc	2839	9500	7772	4604	1748

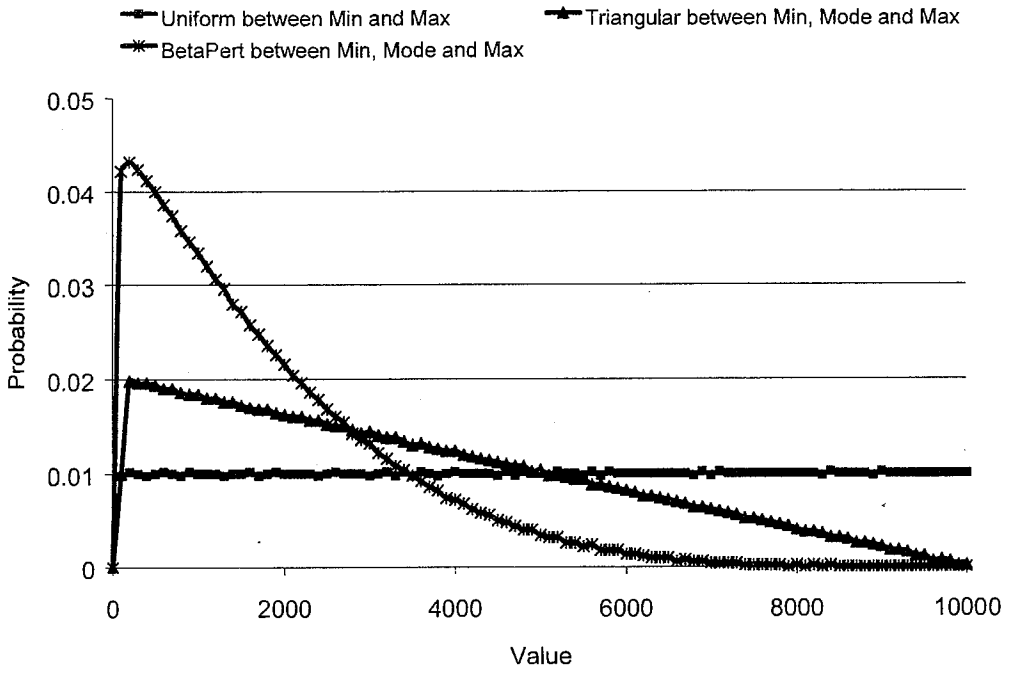


Figure 3a. Frequency distribution after selecting 5,000 values ad random from the given input distributions. All distributions were selected with minimum=1, most likely value=100, and maximum=10,000.

All distributions were shifted to the left (long tail to the right), and differences were in the range of log units (total rage: 4 log units).

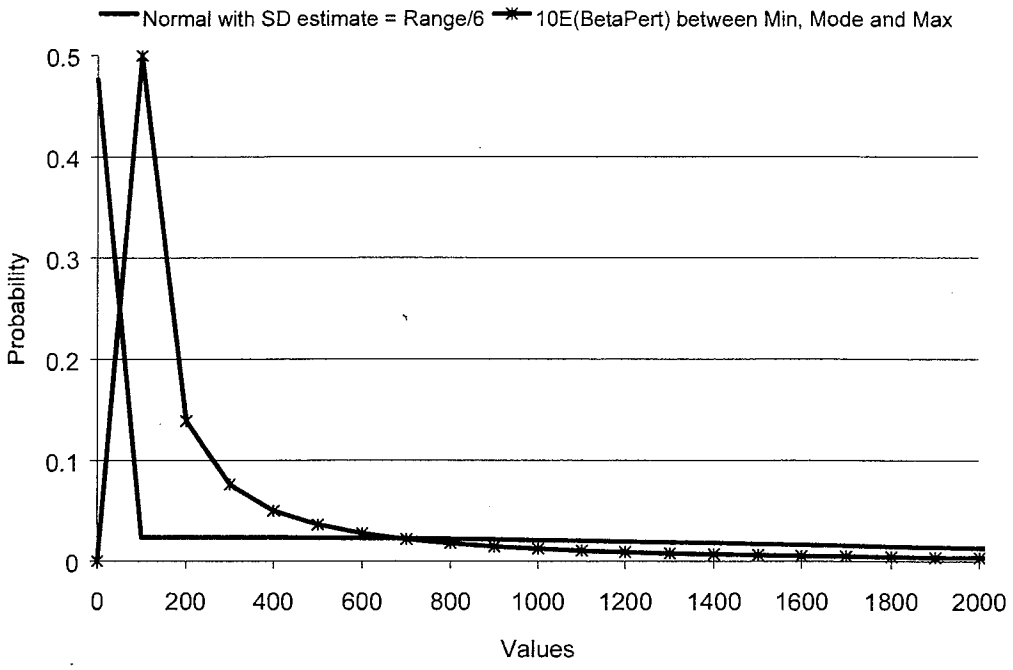


Figure 3b. Frequency distribution after selecting 5000 values ad random from the given input distributions.

All distributions were selected with minimum=1, most likely value=100, and maximum=10,000. All distributions were shifted to the left (long tail to the right), and differences were in the range of log units (total rage: 4 log units).The normal distribution extended heavily into the negative value range. The x-axis was truncated at 2000.

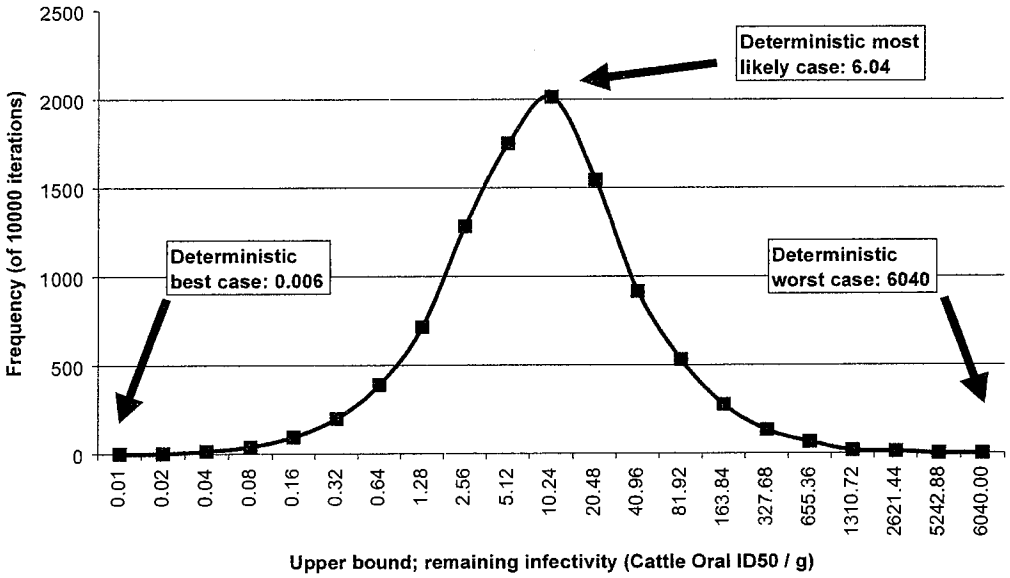


Figure 4. Frequency distribution of remaining infectivity per gram material (in Cattle Oral ID50) from a hypothetical QRA.

The X-labels are the upper bound of the respective category (interval). In this example, the most often observed outcome was in the category between 5.12 and 10.24 (mode of distribution).

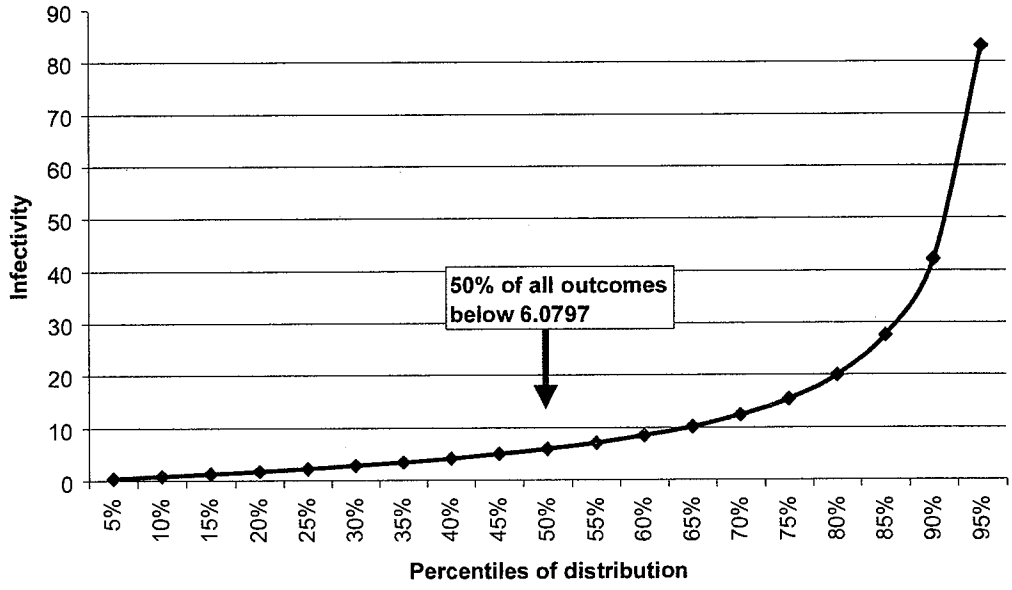


Figure 5. Ascending cumulative frequency distribution for example model.

The 50th percentile value (median of the outcome distribution) is 6.0797, indicating that in this example 5,000 of the 10,000 iterations (50% of all outcomes) yielded an infectivity titer equal or below 6.0797 $CoID_{50}$ per gram tissue.

Annex 2: QRA Data Tables

Table I.1 - Infectious Load Data, GBRII Country, Reliable Surveillance

European Commission - Health and Consumer Protection
PROBABILISTIC MODEL FOR THE QUANTITATIVE ASSESSMENT OF RESIDUAL BSE RISK
DNV Consulting, London

EC ref	SANCO/D2/2004/SI2.373706
DNV ref	20067400
Date	11 August 2004
Rev	Ver-6
Sheet	2 - Infectious Load

legend: *input required*; *transferred from other sheets*; *sampled from distribution, or calculated*

Sample Infectivity of Clinically BSE Infected Cow

			P50	P99		
I1	Infectivity level in brain (clinically BSE infected bovine), colD50/g		5	100		*copied from input data sheet, D1*
I2	Sampled infectivity level, colD50/g			11.46		*sampled from lognormal distribution (mean displayed)*

Sample Number of Non-detected Clinical or Final-incubation Animals Entering

			BSE animals			
	Select country scenario	(Y/N)?	min	mode	max	
I3a	(II)	Y	0	0.5	1	***GBR II country, no BSE detected,***
I3b	(III)	N	1	30	99	***GBR III country, BSE possible,***
I3c	(IV)	N	100	300	1000	***GBR IV country, BSE confirmed,***
I5	Data for selected scenario	SELECT ▲	0	0.5	1	*GBR II country, no BSE detected,*
I6	BSE animals, per 10^6			0.5		*sampled from triangular distribution, mean displayed*
	Select type of surveillance	(Y/N)?	sampled no. of animals			
I7	reliable surveillance	Y		0.0		***reliable surveillance***
I8	unreliable surveillance	N		0.5		***unreliable surveillance***
I9	No. of non-detected animals entering	SELECT ▲		0.0		*reliable surveillance*

Sample Number of Non-detected Pre-clinical Animals Entering

			non-detected pre-clinical animals			
	Pick from country scenario selected		min	mode	max	
I10	(II)	Y	2	3	4	*copied from input data sheet, D9*
I11	(III)	N	2	100	400	*copied from input data sheet, D10*
I12	(IV)	N	200	1000	4000	*copied from input data sheet, D11*
I13	Data for selected scenario		2	3	4	*sampled from triangular distribution, above values*
I14	Non-detected clinical animals, per 10^6			3.0		*sampled from triangular distribution, mean displayed*

Determine Total Infectious Load for Infected Animals Entering

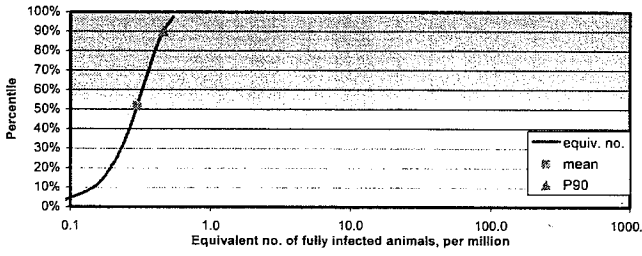
			infectious load		% < 10%	
	Infectious load limits, and %age < 10%		min	max	%	
I15		Y	1%	100%	90%	***reliable surveillance***
I16		N	1%	100%	50%	***unreliable surveillance***
I17	Infectious load for selected surveillance		1%	100%	90%	*reliable surveillance*
I18	Sampled infectious load (> 10% max load)		50.5%			*sampled from uniform distribution, above values*
I19	% of animals > 10% of max. load		10%			*reliable surveillance*
I20	Total number of infected animals entering		3			=
I21	No. of animals > 10% of max. load		0.3			=
I22	Equiv. no. of animals with max. clinical load		0.2			=
			min	max		
I23	Infectious load for animals below 10%, % of max.		1.0%	10.0%		*copied from input date sheet, Dxx*
I24	Sampled infectious load (< 10% max load)		5.5%			*for animals < 10% of maximum load*
I25	No. of animals < 10% of max. load		2.7			*= I20 x I17c*
I26	Equiv. no of animals with max. clinical load		0.1			*= I23 x I24*
I27	Total equiv. no of animals with full clinical load, non detected infected animals, per 10^6 animals		0.3			*= I22 + I26*

Determine Probability of BSE Infection

I28	Probability of BSE infection	3.00E-07	*= I27 / 10^6*

Graph of Equivalent Animals with Full Clinical Load

Scenario: GBR II country, no BSE detected, reliable surveillance



%ile	no.	
2.5%	0.08	P2.5
10.0%	0.15	P10
20.0%	0.19	
30.0%	0.23	
40.0%	0.26	
50.0%	0.29	P50
60.0%	0.33	
70.0%	0.36	
80.0%	0.40	
90.0%	0.46	P90
97.5%	0.54	P97.5
51.9%	0.30	mean
50.0%	0.29	median
41.6%	0.27	mode

This graph reflects the equivalent number of fully infected animals for the country scenario in question, with associated probability levels. For example, there is a 90% probability that the equivalent number of fully infected animals is less than or equal to the value highlighted in green.

Table I.2 - Infectious Load Data, GBRII Country, Unreliable Surveillance

European Commission - Health and Consumer Protection
PROBABILISTIC MODEL FOR THE QUANTITATIVE ASSESSMENT OF RESIDUAL BSE RISK
DNV Consulting, London

EC ref	SANCO/D2/2004/SI2.373706
DNV ref	20067400
Date	11 August 2004
Rev	Ver-6
Sheet	2 - Infectious Load

legend: *input required*; *transferred from other sheets*; *sampled from distribution, or calculated*

Sample Infectivity of Clinically BSE Infected Cow

			P50	P99		
I1	Infectivity level in brain (clinically BSE infected bovine), colD50/g		5	100		*copied from input data sheet, D1*
I2	Sampled infectivity level, colD50/g		11.46			*sampled from lognormal distribution (mean displayed)*

Sample Number of Non-detected Clinical or Final-incubation Animals Entering

			BSE animals			
	Select country scenario	(Y/N)?	min	mode	max	
I3a	(II)	Y	0	0.5	1	***GBR II country, no BSE detected,***
I3b	(III)	N	1	30	99	***GBR III country, BSE possible,***
I3c	(IV)	N	100	300	1000	***GBR IV country, BSE confirmed,***
I5	Data for selected scenario	SELECT ▲	0	0.5	1	*GBR II country, no BSE detected.*
I6	BSE animals, per 10^6		0.5			*sampled from triangular distribution, mean displayed*
	Select type of surveillance	(Y/N)?	sampled no. of animals			
I7	reliable surveillance	N	0.0			***reliable surveillance***
I8	unreliable surveillance	Y	0.5			***unreliable surveillance***
I9	No. of non-detected animals entering	SELECT ▲	0.5			*unreliable surveillance*

Sample Number of Non-detected Pre-clinical Animals Entering

			non-detected pre-clinical animals			
	Pick from country scenario selected		min	mode	max	
I10	(II)	Y	2	3	4	*copied from input data sheet, D9*
I11	(III)	N	2	100	400	*copied from input data sheet, D10*
I12	(IV)	N	200	1000	4000	*copied from input data sheet, D11*
I13	Data for selected scenario		2	3	4	*sampled from triangular distribution, above values*
I14	Non-detected clinical animals, per 10^6		3.0			*sampled from triangular distribution, mean displayed*

Determine Total Infectious Load for Infected Animals Entering

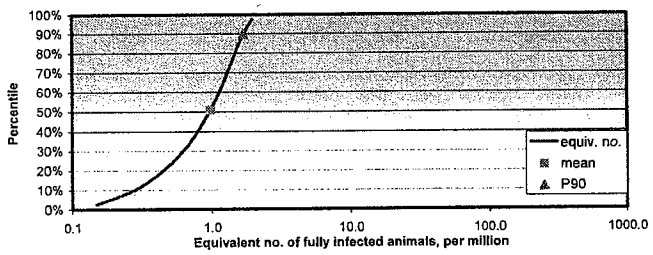
			infectious load		% < 10%	
	Infectious load limits, and %age < 10%		min	max	%	
I15		N	1%	100%	90%	***reliable surveillance***
I16		Y	1%	100%	50%	***unreliable surveillance***
I17	Infectious load for selected surveillance		1%	100%	50%	*unreliable surveillance*
I18	Sampled infectious load (> 10% max load)		50.5%			*sampled from uniform distribution, above values*
I19	% of animals > 10% of max. load		50%			*unreliable surveillance*
I20	Total number of infected animals entering		4			=
I21	No. of animals > 10% of max. load		1.8			=
I22	Equiv. no. of animals with max. clinical load		0.9			=
			min	max		
I23	Infectious load for animals below 10%, % of max.		1.0%	10.0%		*copied from input data sheet, Dxx*
I24	Sampled infectious load (< 10% max load)		5.5%			*for animals < 10% of maximum load*
I25	No. of animals < 10% of max. load		1.8			*= I20 x I17c*
I26	Equiv. no of animals with max. clinical load		0.1			*= I23 x I24*
I27	Total equiv. no of animals with full clinical load, non detected infected animals, per 10^6 animals		1.0			*= I22 + I26*

Determine Probability of BSE Infection

I28	Probability of BSE infection	9.80E-07		*= I27 / 10^6*

Graph of Equivalent Animals with Full Clinical Load

Scenario: GBR II country, no BSE detected. — unreliable surveillance



%ile	no.	
2.5%	0.15	P2.5
10.0%	0.28	P10
20.0%	0.45	
30.0%	0.62	
40.0%	0.79	
50.0%	0.96	P50
60.0%	1.13	
70.0%	1.30	
80.0%	1.48	
90.0%	1.70	P90
97.5%	1.97	P97.5
50.9%	0.98	mean
50.0%	0.96	median
44.5%	0.87	mode

This graph reflects the equivalent number of fully infected animals for the country scenario in question, with associated probability levels. For example, there is a 90% probability that the equivalent number of fully infected animals is less than or equal to the value highlighted in green.

Table I.3 - Infectious Load Data, GBRIII Country, Reliable Surveillance

European Commission - Health and Consumer Protection
PROBABILISTIC MODEL FOR THE QUANTITATIVE ASSESSMENT OF RESIDUAL BSE RISK
DNV Consulting, London

EC ref	SANCO/D2/2004/SI2.373706
DNV ref	20067400
Date	11 August 2004
Rev	Ver-6
Sheet	2 - Infectious Load

legend: *input required*; *transferred from other sheets*; *sampled from distribution, or calculated*

Sample Infectivity of Clinically BSE Infected Cow

			P50	P99		
I1	Infectivity level in brain (clinically BSE infected bovine), coID50/g		5	100		*copied from input data sheet, D1*
I2	Sampled infectivity level, coID50/g			11.46		*sampled from lognormal distribution (mean displayed)*

Sample Number of Non-detected Clinical or Final-incubation Animals Entering

			BSE animals			
	Select country scenario	(Y/N)?	min	mode	max	
I3a	(II)	N	0	0.5	1	*GBR II country, no BSE detected,*
I3b	(III)	Y	1	30	99	*GBR III country, BSE possible,*
I3c	(IV)	N	100	300	1000	*GBR IV country, BSE confirmed,*
I5	Data for selected scenario	SELECT	1	30	99	*GBR III country, BSE possible,*
I6	BSE animals, per 10^6			43.3		*sampled from triangular distribution, mean displayed*
	Select type of surveillance	(Y/N)?	sampled no. of animals			
I7	reliable surveillance	Y		0.0		*reliable surveillance*
I8	unreliable surveillance	N		43.3		*unreliable surveillance*
I9	No. of non-detected animals entering	SELECT		0.0		*reliable surveillance*

Sample Number of Non-detected Pre-clinical Animals Entering

			non-detected pre-clinical animals			
	Pick from country-scenario selected		min	mode	max	
I10	(II)	N	2	3	4	*copied from input data sheet, D9*
I11	(III)	Y	2	100	400	*copied from input data sheet, D10*
I12	(IV)	N	200	1000	4000	*copied from input data sheet, D11*
I13	Data for selected scenario		2	100	400	*sampled from triangular distribution, above values*
I14	Non-detected clinical animals, per 10^6			167.3		*sampled from triangular distribution, mean displayed*

Determine Total Infectious Load for Infected Animals Entering

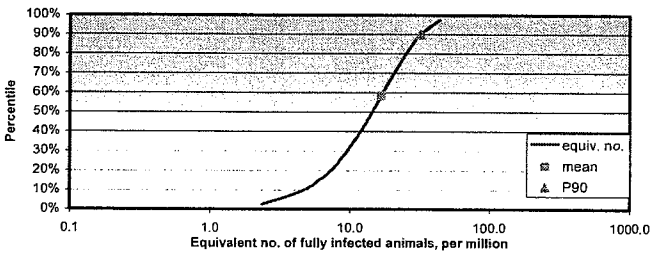
			infectious load		% < 10%	
	Infectious load limits, and %age < 10%		min	max	%	
I15		Y	1%	100%	90%	*reliable surveillance*
I16		N	1%	100%	50%	*unreliable surveillance*
I17	Infectious load for selected surveillance		1%	100%	90%	*reliable surveillance*
I18	Sampled infectious load (> 10% max load)			50.5%		*sampled from uniform distribution, above values*
I19	% of animals > 10% of max. load			10%		*reliable surveillance*
I20	Total number of infected animals entering			167		=
I21	No. of animals > 10% of max. load			16.7		=
I22	Equiv. no. of animals with max. clinical load			8.5		=
			min	max		
I23	Infectious load for animals below 10%, % of max.		1.0%	10.0%		*copied from input data sheet, Dxx*
I24	Sampled infectious load (< 10% max load)			5.5%		*for animals < 10% of maximum loed*
I25	No. of animals < 10% of max. load			150.6		*= I20 x I17c*
I26	Equiv. no of animals with max. clinical load			8.3		*= I23 x I24*
I27	Total equiv. no of animals with full clinical load, non detected infected animals, per 10^6 animals			16.7		*= I22 + I26*

Determine Probability of BSE Infection

I28	Probability of BSE infection	1.67E-05		*= I27 / 10^6*

Graph of Equivalent Animals with Full Clinical Load

Scenario: GBR III country, BSE possible, reliable surveillance



%ile	no.	
2.5%	2.37	P2.5
10.0%	4.75	P10
20.0%	7.32	
30.0%	9.56	
40.0%	11.87	
50.0%	14.39	P50
60.0%	17.19	
70.0%	20.51	
80.0%	25.08	
90.0%	31.90	P90
97.5%	44.04	P97.5
58.4%	16.69	mean
50.0%	14.39	median
26.5%	8.81	mode

This graph reflects the equivalent number of fully infected animals for the country scenario in question, with associated probability levels. For example, there is a 90% probability that the equivalent number of fully infected animals is less than or equal to the value highlighted in green.

Table I.4 - Infectious Load Data, GBRIII Country, Unreliable Surveillance

European Commission - Health and Consumer Protection
PROBABILISTIC MODEL FOR THE QUANTITATIVE ASSESSMENT OF RESIDUAL BSE RISK
DNV Consulting, London

EC ref	SANCO/D2/2004/SI2.373706
DNV ref	20067400
Date	11 August 2004
Rev	Ver-6
Sheet	2 - Infectious Load

legend: *input required*; *transferred from other sheets*; *sampled from distribution, or calculated*

Sample Infectivity of Clinically BSE Infected Cow

			P50	P99		
I1	Infectivity level in brain (clinically BSE infected bovine), colD50/g		5	100		*copied from input data sheet, D1*
I2	Sampled infectivity level, colD50/g		11.46			*sampled from lognormal distribution (mean displayed)*

Sample Number of Non-detected Clinical or Final-incubation Animals Entering

			BSE animals			
	Select country scenario	(Y/N)?	min	mode	max	
I3a	(II)	N	0	0.5	1	***GBR II country, no BSE detected,***
I3b	(III)	Y	1	30	99	***GBR III country, BSE possible,***
I3c	(IV)	N	100	300	1000	***GBR IV country, BSE confirmed,***
I5	Data for selected scenario	SELECT ▲	1	30	99	*GBR III country, BSE possible,*
I6	BSE animals, per 10^6		43.3			*sampled from triangular distribution, mean displayed*
	Select type of surveillance	(Y/N)?	sampled no. of animals			
I7	reliable surveillance	N	0.0			***reliable surveillance***
I8	unreliable surveillance	Y	43.3			***unreliable surveillance***
I9	No. of non-detected animals entering	SELECT ▲	43.3			*unreliable surveillance*

Sample Number of Non-detected Pre-clinical Animals Entering

			non-detected pre-clinical animals			
	Pick from country scenario selected		min	mode	max	
I10	(II)	N	2	3	4	*copied from input data sheet, D9*
I11	(III)	Y	2	100	400	*copied from input data sheet, D10*
I12	(IV)	N	200	1000	4000	*copied from input data sheet, D11*
I13	Data for selected scenario		2	100	400	*sampled from triangular distribution, above values*
I14	Non-detected clinical animals, per 10^6		167.3			*sampled from triangular distribution, mean displayed*

Determine Total Infectious Load for Infected Animals Entering

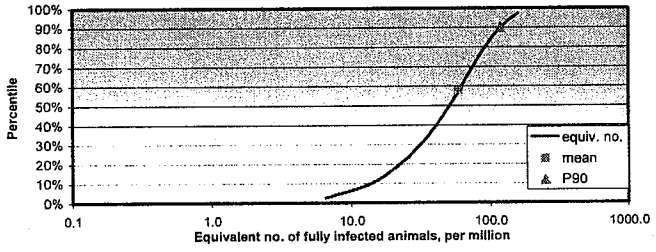
			infectious load		% < 10%	
	Infectious load limits, and %age < 10%		min	max	%	
I15		N	1%	100%	90%	***reliable surveillance***
I16		Y	1%	100%	50%	***unreliable surveillance***
I17	Infectious load for selected surveillance		1%	100%	50%	*unreliable surveillance*
I18	Sampled infectious load (> 10% max load)		50.5%			*sampled from uniform distribution, above values*
I19	% of animals > 10% of max. load		50%			*unreliable surveillance*
I20	Total number of infected animals entering		211			=
I21	No. of animals > 10% of max. load		105.3			=
I22	Equiv. no. of animals with max. clinical load		53.2			=
			min	max		
I23	Infectious load for animals below 10%, % of max.		1.0%	10.0%		*copied from input data sheet, Dxx*
I24	Sampled infectious load (< 10% max load)		5.5%			*for animals < 10% of maximum load*
I25	No. of animals < 10% of max. load		105.3			*= I20 x I17c*
I26	Equiv. no of animals with max. clinical load		5.8			*= I23 x I24*
I27	Total equiv. no of animals with full clinical load, non detected infected animals, per 10^6 animals		59.0			*= I22 + I26*

Determine Probability of BSE Infection

I28	Probability of BSE infection	5.90E-05	*= I27 / 10^6*

Graph of Equivalent Animals with Full Clinical Load

Scenario: GBR III country, BSE possible. — unreliable surveillance



%ile	no.	
2.5%	6.51	P2.5
10.0%	13.88	P10
20.0%	22.31	
30.0%	31.16	
40.0%	40.51	
50.0%	50.70	P50
60.0%	61.65	
70.0%	74.39	
80.0%	91.37	
90.0%	117.97	P90
97.5%	158.77	P97.5
57.8%	58.98	mean
50.0%	50.70	median
14.5%	17.80	mode

This graph reflects the equivalent number of fully infected animals for the country scenario in question, with associated probability levels. For example, there is a 90% probability that the equivalent number of fully infected animals is less than or equal to the value highlighted in green.

Group 3 Report

Wen-Yuan, Yang
Catalina Picasso Risso
Sanja Vasillic

2010.10.01

Question

- What is the likelihood of getting at least one infected animal/bird by importing commercial pet birds from Taiwan to European Union?

Harzard identification

- Several animal diseases (AI, ND…) listed by OIE were identified because of posing primary hazards associated with initiating trade in animals and animal products from foreign regions.
- One of these diseases, low pathogenic avian influenza (LPAI) is recognized as a hazard of primary concern.

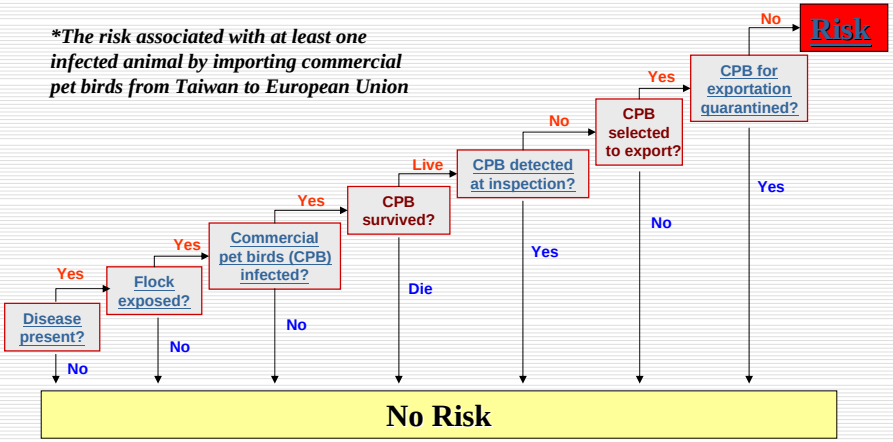
Introduction of avian influenza (AI)

- AI is caused by an orthomyxovirus virus that infects wild birds (e.g. ducks, gulls, and shorebirds) , domestic poultry (e.g. chickens, turkeys, ducks, and geese) and pet birds (such as canary and parrot) .
- AI are divided into two groups based upon pathogenicity:
  - low pathogenic (LP) AI.
  - highly pathogenic (HP) AI.
- Definition of LPAI is following OIE definition (OIE, 2008).

附件2

Scenario tree

**The risk associated with at least one infected animal by importing commercial pet birds from Taiwan to European Union*

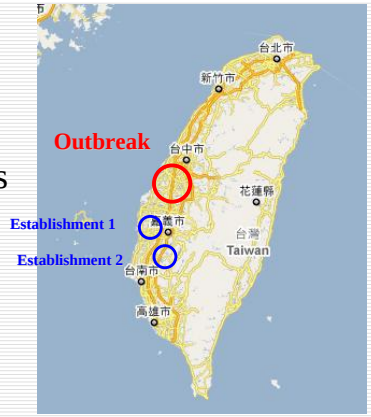


Disease presented?

- Disease status in Taiwan
  - ***OIE disease report***
    - 3 H5N2 LPAI outbreaks were reported on 21 January 2010, 8 February 2010 and 4 March 2010 respectively.
      - 1 broiler farm.
      - 2 layer farms.
    - Final report was reported on 2 April 2010. The last event was resolved.

Flock exposed?

- Disease control and surveillance: ***Yes***.
  - Poultry were slaughtered.
  - Negative AI testing results of surveillance.
- Biosecurity of breeding establishments: ***Good***.
- *Identification of individual bird:* ***No***.
- Disease prevalence: 20%.



Commercial pet birds (CPB) infected?

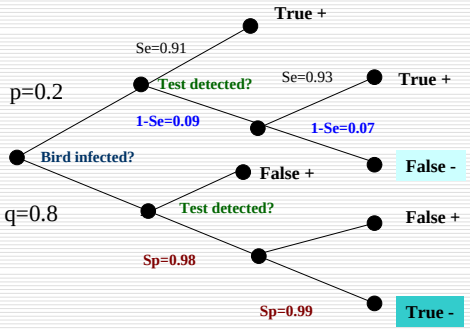
- Birds were checked by clinical inspection.
- Assumption:
  - ***Yes*** (prevalence: 20%), or
  - ***Identification was missed because of subclinical infection.***

CPB detected at inspection?

- All (50) breeding establishments for exportation were registered.
  - Two establishments applied for exportation of birds.
    - Canary (1).
    - Parrot (1).
- Virological tests of AI were conducted on these establishments every 3 months and before the export.
  - 20 (oropharyngeal/cloacal or fecal) swab samples were tested.
    - RT-PCR (Se: 91%; Sp: 98%)
    - Virus isolation (Se: 93%; Sp: 99%)
- Disease prevalence: 20%.

Information was from government documentation and papers

CPB detected at inspection (cont.) ?



P	0.2	
Se	0.91	0.93
Sp	0.98	0.99
n	20	
TN	0.77616	
FN	0.00126	
NPV	0.998379	
NPV^n	0.968079	
P≧1	0.031921	

P=1-(TN/(TN+FN))^n=0.032

CPB for exportation quarantined?

- The birds shall be quarantined for at least 21 days before exportation.
- The birds are tested before the exportation according to the requirement of importing country.

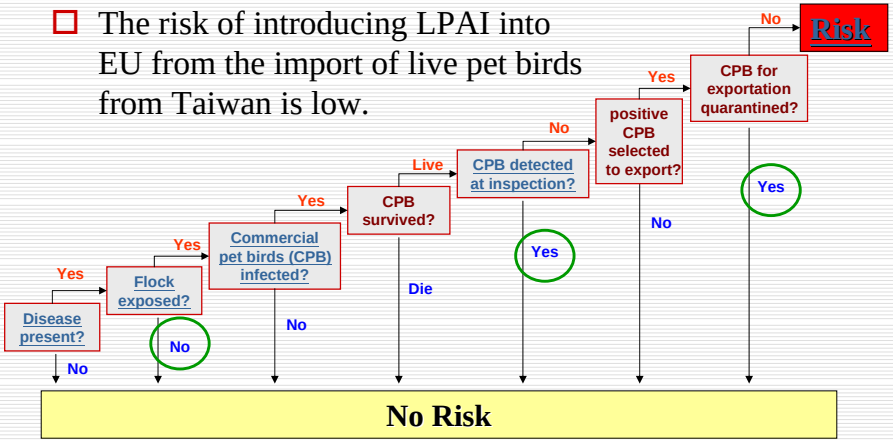
Information was from government documentation

Release Summary

- No new LPAI outbreak has been detected since last case reported on 4 March 2010.
- Taiwan is able to effectively control LPAI in domestic flock and has conducted intensified surveillance program for poultry and pet birds (the results were negative for H5/H7 AI).
- The breeding establishments have good biosecurity system to avoid contact.
- The diagnostic tests are good to work and the probability that at least infected one of 100 birds intended to export is **low**.
- The birds shall be quarantined for at least 21 days before exportation and tested according to the requirement of importing country.

Release Summary (cont.)

- The risk of introducing LPAI into EU from the import of live pet birds from Taiwan is low.



Thanks for your attention!

The OIE and its Role in International Trade

Presented by: Laurel Voelker, DVM
USDA/APHIS/Veterinary Services

OIE-What is it?

- World Organization for Animal Health
- Formerly
  - "Office des International Epizooties"

Origins of OIE
International spread of diseases

- Historically, diseases have spread across international borders due to the movement of animals and animal products

附件3

Origins of OIE
The need for international regulation

- The 1920 Rinderpest outbreak in Belgium highlighted the need to have an international body to regulate trade in animals and animal products
- In 1924 the Office International des Epizooties (OIE) was created
  - 28 countries

General Agreement on Tariffs and Trade (GATT)

- General Agreement on Tariffs and Trade (GATT)
  - Initiated following WWII
  - Provided "rules" for world trade as a "provisional and agreement" organization from 1948-1994
  - Focus on tariff reductions
  - Still exists as "umbrella treaty for trade in goods"

Reference: Understanding the WTO: Training Module. accessible at www.http://www.wto.org/english/thewto_e/whatis_e/tif_e/tif_e.htm

World Trade Organization

- Came into effect January 1, 1995 as a result of Uruguay Round of negotiations
- Covers trade in:
  - Goods
  - Services
  - Intellectual Property

Reference: Understanding the WTO: Training Module. accessible at www.http://www.wto.org/english/thewto_e/whatis_e/tif_e/tif_e.htm

World Trade Organization

- A negotiating forum
- A set of "rules"
  - Agreements
  - To help trade flow as freely as possible
- A procedure for settling trade disputes

Reference: Understanding the WTO: Training Module. accessible at www. http://www.wto.org/english/thewto_e/whatis_e/tif_e/tif_e.htm

SPS agreement

- *Agreement on the Application of Sanitary and Phytosanitary Measures* came into effect on January 1st 1995
  - An annex of the agreement that created WTO
- Grace period for implementation ended on January1st 1997
- Facilitates trade while protecting human, animal, and plant health

Reference: Introduction to SPS Agreement Training Module, accessible at http://www.wto.org/english/tratop_e/sps_e/sps_agreement_cbt_e/c1s1p1_e.htm

SPS agreement- Objectives

- Allow members the sovereign right to maintain the level of health protection they deem appropriate
- Ensure that measures are not unnecessary, arbitrary, scientifically unjustifiable, or disguised trade barriers

Reference: Introduction to SPS Agreement Training Module, accessible at http://www.wto.org/english/tratop_e/sps_e/sps_agreement_cbt_e/c1s1p1_e.htm

SPS Agreement

- SPS Measures should be:
  - ✓scientifically based
  - ✓the least restrictive as long as they achieve the desired level of protection
  - ✓ non discriminatory
  - ✓consistent
- SPS measures should not be used as unjustifiable barriers to trade

Reference: Introduction to SPS Agreement Training Module, accessible at http://www.wto.org/english/tratop_e/sps_e/sps_agreement_cbt_e/c1s1p1_e.htm

SPS-Standard Setting Bodies

Food safety

Plant health

Animal health

THE OIE Today

- WTO recognized body for standard setting in animal health
- 177 member countries

OIE-What does it do?

- Focuses on animal health in international trade
- Maintains a list of animal diseases that are important in international trade
- Sets standards
  - Specific diseases
  - Processes and procedures
- Disseminates information reported by members
  - Disease outbreaks
  - Biannual reports

OIE-What does it do?

- Does NOT assign disease status (except 4 specific diseases)
- Approves reference laboratories
- Shares information and research
  - Disease cards
  - *Scientific and Technical Review*
  - Specialty publications

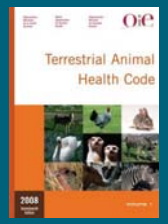
Developing and Revising OIE Standards

- New/revised standards drafted by groups of independent experts from all regions.
- Draft texts circulated to OIE Members for comments.
- Resubmitted to OIE Members for adoption at the annual OIE General Session.
- 2 year process

Reference: OIE. *The International Standards of OIE. Health Standards: production and implementation [cited 2010 July]: Available from: http://www.oie.int/eng/en_index.htm.*

Terrestrial Animal Health Code and *Aquatic Animal Health Code*

- The ***Codes*** aim:
  - to assure sanitary safety of international trade in terrestrial animals and aquatic animals and their products.
  - to detail animal health measures for establishing regulations for safe importation of animals and animal products.
  - to protect against pathogenic agents without imposing unjustified trade restrictions.



Reference: OIE. *The International Standards of OIE. Health Standards: production and implementation [cited 2010 July]: Available from: http://www.oie.int/eng/en_index.htm.*

Criteria for OIE Listed Diseases*

- Listing of diseases is based on:
  - International Spread
  - Zoonotic potential
  - Morbidity/mortality among naïve populations
  - Emerging diseases

* Only the criteria for terrestrial diseases will be discussed here. For criteria for aquatic diseases, please refer to the *Aquatic Code*, Chapter 1.2, Article 1.2.1

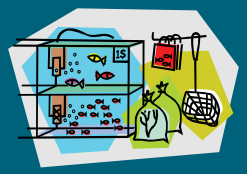
Reference: OIE. *Terrestrial Animal Health Code 2010. Chapter 1.2, Criteria for listing diseases [cited 2010 July]: Available from: http://www.oie.int/eng/normes/mcode/en_chapitre_1.1.2.htm.*

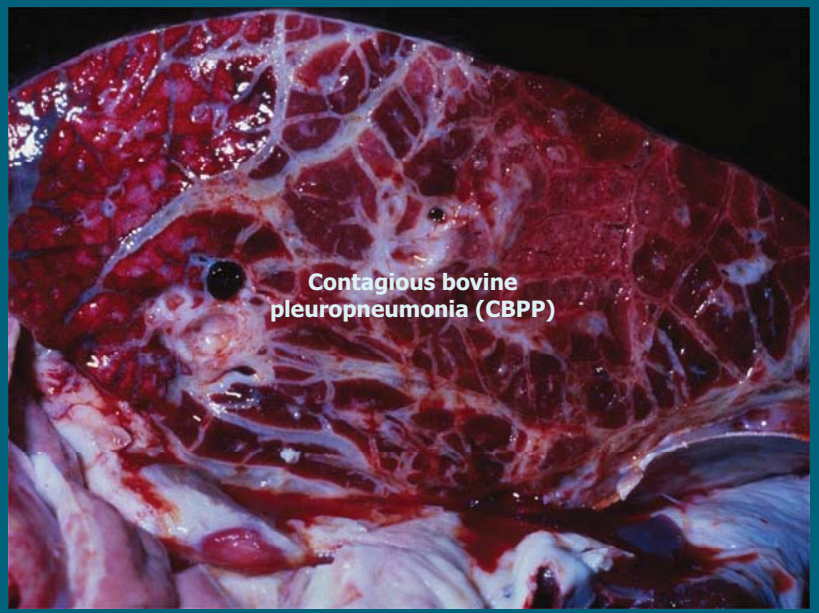
OIE Listed Diseases-Terrestrial

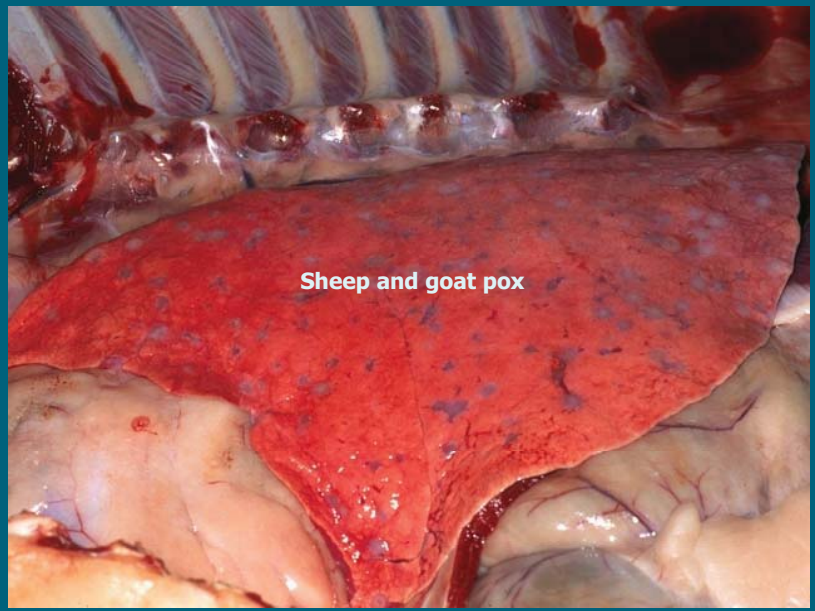
Species Group	Number of Listed Diseases
Multiple Terrestrial Species	16
Apidae	6
Aves	13
Bovidae	14
Equidae	11
Lagomorpha	2
Ovidae/Capridae	10
Suidae	6
Total	78

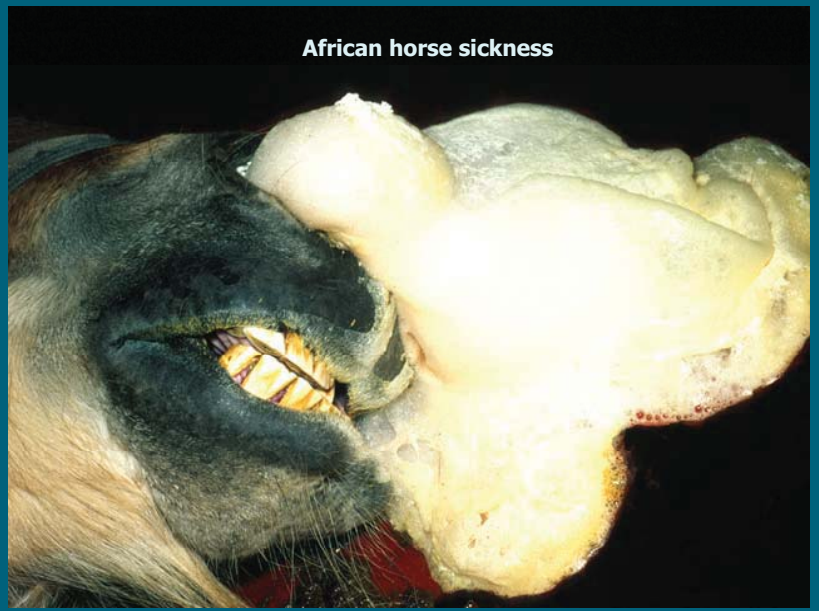
OIE Listed Diseases-Aquatic

Species Group	Number of listed diseases
Amphibians	2
Crustaceans	7
Fish	9
Molluscs	6
Total	24









New world screwworm

Amblyomma variegatum/Heartwater

Koi Herpesvirus

What does OIE say about risk analysis?

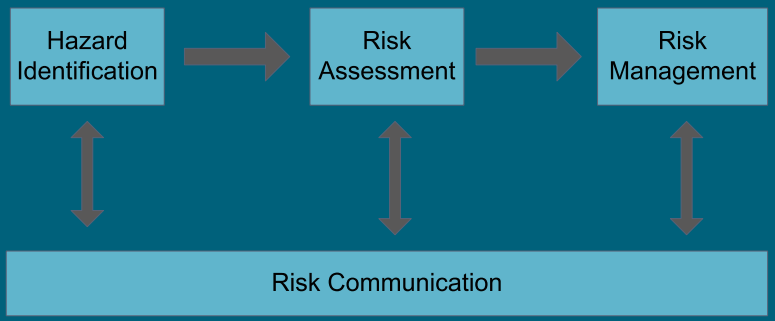
- Member countries may authorize imports into their territory under conditions that are:
  - In Terrestrial/Aquatic Animal Health Code (AHC)
  - Less stringent than the AHC
  - MORE stringent than the AHC, if:
    - based on scientific risk analysis conducted in accordance with OIE recommendations

Reference: OIE. *Terrestrial Animal Health Code. [cited 2010 July]; Available from: http://www.oie.int/eng/normes/mcode*

OIE Risk Analysis Framework

- Terrestrial Animal Health Code, Section 2
  - Slightly different version for aquatics
- Details import risk analysis, but applicable to:
  - Domestic diseases
  - Introduction and spread

OIE Risk Analysis Framework



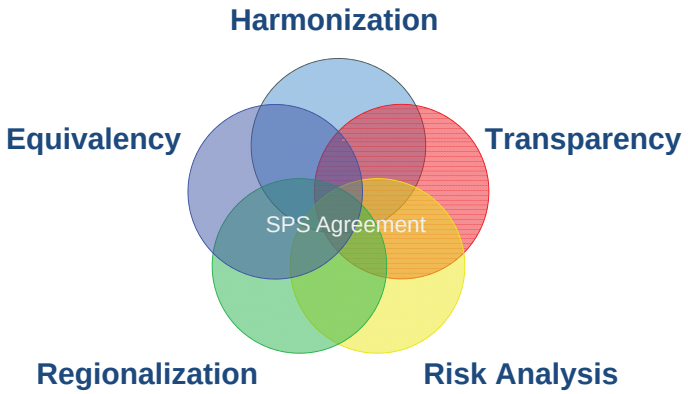
Reference: OIE. *Terrestrial Animal Health Code 2010, Chapter 2.1 Import Risk Analysis. [cited 2010 July]; Available from: http://www.oie.int/eng/normes/mcode/en_chapitre_1.2.1.htm*

THANK YOU!

Veterinary Epidemiology and Public Policy

Katie Portacci, DVM, MPH, DACVPM
Team Leader, Risk Analysis
USDA- APHIS- VS- CEAH

Key provisions of SPS



Veterinary Epidemiology

- The study of the distribution and determinants of disease in a population
- Assumes that disease does not occur in a randomly
  - Identify causal relationships between potential risk factors and outcomes such as disease or productivity losses
- Describes the interaction of the host-agent-environment relationship

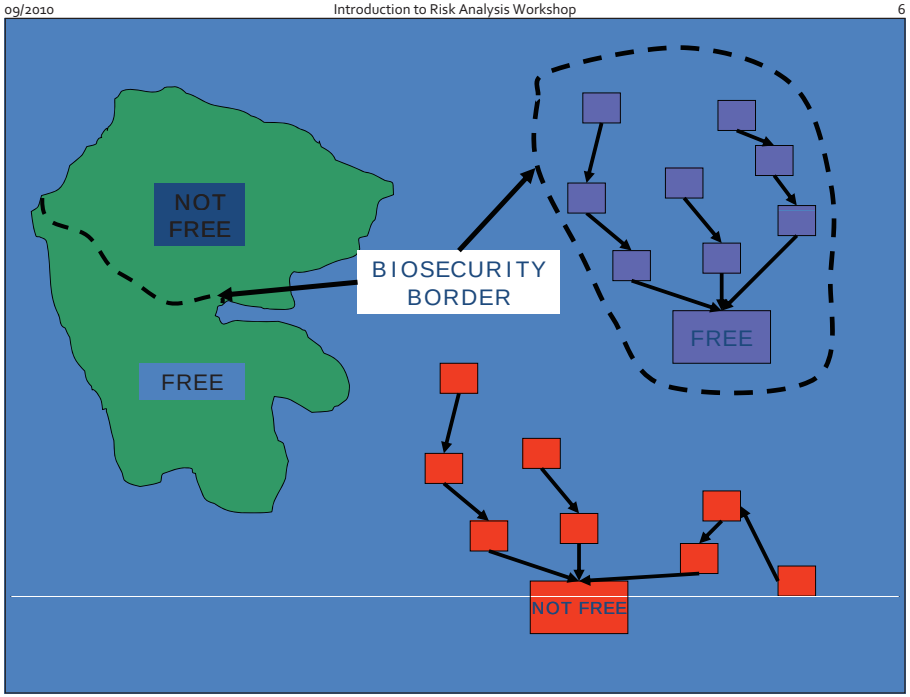
We must understand the epidemiology of a disease in order to assess risk, control spread, conduct surveillance, etc.

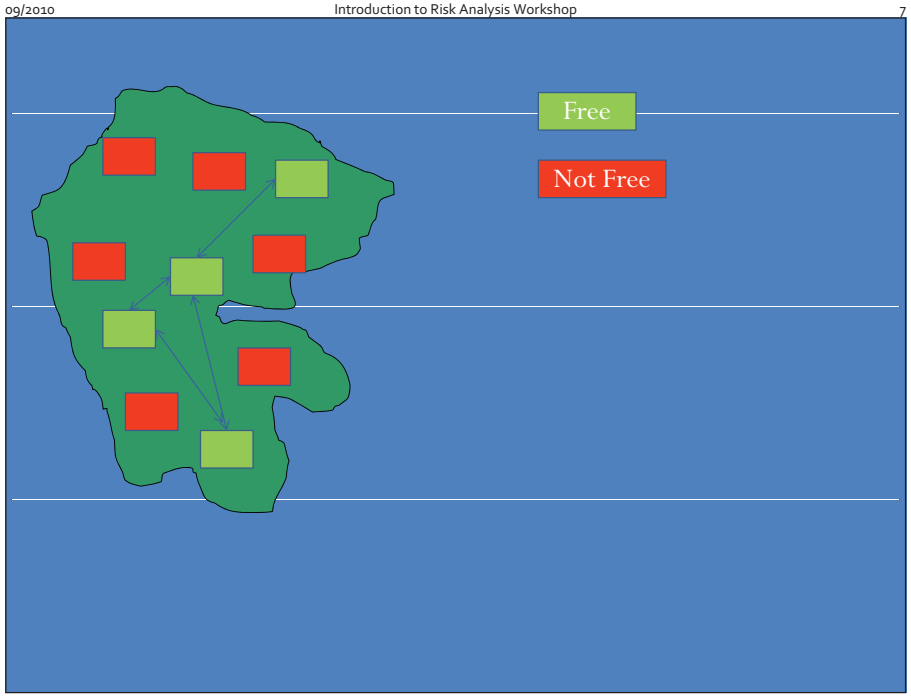
Regionalization

- Previously the presence of a disease in a country meant that the entire country was considered infected
- The concept recognizes that zones within a country can be recognized as free from disease
- Zoning applies to an animal subpopulation defined primarily on a geographical basis (using natural, artificial or legal boundaries).

Compartmentalization

- Recognition of production systems with different health status
- Compartmentalization applies to an animal subpopulation defined primarily by management and husbandry practices related to biosecurity.





Role of epidemiology in regionalization

- Demonstrating disease freedom
- Survey design
- Understanding the distribution of disease
- Interpretation of diagnostic tests
  - Se, Sp, predictive values
  - Herd level Se and Sp
- Link with risk analysis

Risk assessment

- The evaluation of the likelihood of entry, establishment or spread of a pest or disease *and* of the associated potential biological and economic consequences

  SPS Agreement

Role of epidemiology in risk analysis

- Animal health risk analysis cannot be done without epidemiology
- Understanding of the means of transmission of disease
- Pathways for disease introduction
- Effect of mitigation measures

Harmonization

- The establishment, recognition and application of common sanitary and phytosanitary measures

=

- International standards

Role of epidemiology in harmonization

- Development of international standards
- Criteria for disease freedom
- Example Rinderpest
  - Definition of sampling units
  - Criteria for stratification
  - Sample sizes
    - 95% probability of detecting evidence of rinderpest if present at a prevalence of 1% of herds or other sampling units and 5% within herds or other sampling units

Equivalence

- Recognition that different SPS measures may achieve similar results
- Allows for flexibility in the organization of veterinary services, surveillance systems, etc.

Role of epidemiology in equivalence

- Develop methods to compare the effect of mitigation measures
- Develop criteria to define the appropriate level of protection
- Focus on outputs rather than approaches

Equivalence of surveillance systems

Surveillance component	*Sensitivity (SE) of each component*		
	Country A	*Country B*	*Country C*
Passive surveillance	0.6	0.7	0.6
Survey	0.95	0.90	0.73
Slaughter surveillance	0.75	0.75	0.5
Overall system SE	0.995	0.992	0.947
1-((1-SE1)*(1-SE2)*(1-SE3))			

Transparency

- Countries must notify WTO of changes in SPS measures that may have a significant effect on trade
- The concept applies also to the way SPS measures are adopted
  - Scientific basis
- Disease reporting

Role of epidemiology in transparency

- Disease reporting is the basis for trust
- Disease surveillance systems are the basis for good disease reporting
  - Passive surveillance
  - Active surveillance

The challenge

- SPS measures under the spotlight
- Increasing demands on the veterinary infrastructure
- Need to demonstrate the animal health status
- Effective surveillance systems and control measures central to the process

However…

- Reduction of public spending
- Veterinary services often not top priority
- Decreasing budgets for veterinary services
- Weak infrastructures
- Difficulty to obtain funding for surveillance

Conclusions

- The SPS Agreement has changed the way in which trade decisions related to agricultural products are made
- Many countries still face implementation problems
- Epidemiologists play a central role in achieving compliance with the SPS Agreement

Introduction to Risk Analysis

Barbara Corso, DVM, MS, Dipl ACVPM
USDA, Animal and Plant Health Inspection Service, Veterinary Services
Centers for Epidemiology and Animal Health

Concepts

- What is risk?
- What is risk analysis?
- What is risk assessment?
- Risk analysis process

What is Risk?

- the likelihood of the occurrence and the likely magnitude of the biological and economic consequences of an adverse event to animal or human health in the importing country during a specified time period
  - OIE Terrestrial Animal Health Code 2008

What is risk?

- What can go wrong?
- How likely is it to go wrong?
- What is the likely magnitude of the consequences?
- Present everywhere

Elements of Risk

- Probability *(likelihood or chance)* of an adverse event *(the hazard)*
- Consequences *(or impact)*
- Uncertainty
- Ability to manage
- (Benefit)

There must be a potential hazard and uncertainty for risk to exist

Reactions to risk

- ***Known* risk -** well-known; direct evidence

  Reactions to risk based mainly on instinct, experience, evidence and judgment; usually low uncertainty

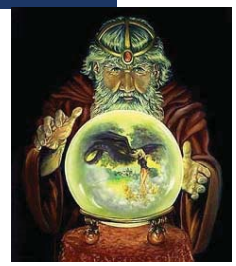
  (e.g., rock climbing)

- ***Perceived* risk –** not well known; no agreement

  Reactions to risk based mainly on emotions, trust, beliefs, and judgment; usually high uncertainty

  (e.g., irradiated food)

What is risk analysis?



- Organized way to answer those three questions…

and also

- What can be done to change the risk?
- Who do we need to inform?
- What do we need to tell them? How do we best do that?

And risk analysis is…

- the process composed of
  - Hazard identification,
  - Risk assessment,
  - Risk management, and
  - Risk communication
    - OIE Terrestrial Animal Health Code 2008

Why do one?

- Provide guidance when a decision needs to be made
  - Risk related to trade
    - Import or export of animal or product
  - Risk related to domestic diseases
    - Eradication or control program beginning, ending or changing direction
  - Risk related to introduction or spread
    - Change in regulations
    - Change in recommendations (i.e., vaccination)

When to do one?

- When contemplating change to way of doing business
- When importing a new product or species
- When importing from a new country or zone
- When the health status of a country or zone changes
- During the process of regionalization
- To promote the export of commodities

Risk Analysis objectives

- Increased understanding/agreement
- Promote dialogue and transparency
- Identify uncertainty & research needs
- Encourage consistency
- Share resources, including information
- Meet international obligations

Better decisions!

Risk Analysis should:

- Identify hazards
- Characterize risks
- Recognize uncertainty
- Summarize conclusions
- Recommend options
- Document the basis for recommendations or decisions

Risk Analysis in Animal Health

What is hazard identification?

- Identification of source for potential damage, cause of adverse event
- Identify pathogenic agents associated with the product
- Determine diseases / agents present in the exporting country or zone; validity of SPS measures
- Establish priorities

Hazard and risk

- Hazard is inherent to the product or activity
- Risk is an indicator of the combined importance of the likelihood and consequence of an “undesirable event” which could bring out the “hazard” in a way that could adversely impact the risk receptors

What is risk assessment?

Evaluation of the likelihood of entry, establishment and spread of a disease and the associated potential biological and economic consequences and its impact on public health

Risk assessment …

- Part of a risk analysis…
- Consists of
  - Release assessment
  - Exposure assessment
  - Consequence assessment
  - Risk estimation
- Different types
  - Qualitative
  - Quantitative

Risk assessments need to be…

- Consistent
- Scientifically based
- Flexible
- Transparent

Pros and cons of types

	Qualitative	Quantitative
Advantages	Faster, Applicable to a broader scope of circumstances Does not run risk of creating a false impression of precision	Notion of the probability of occurrence of an adverse event, More information for decison-making
But	Less satisfying, less precise Does not provide a numerical probability of occurrence of an adverse event, Less precise information for decision-making	Requires more time, Requires good quality quantitative data, Not possible to apply in all circumstances

Process: Risk Analysis consists of

- Hazard identification,
- Risk assessment,
  - Release assessment
  - Exposure assessment
  - Consequence assessment
  - Risk estimation
- Risk management, and
- Risk communication

Release assessment

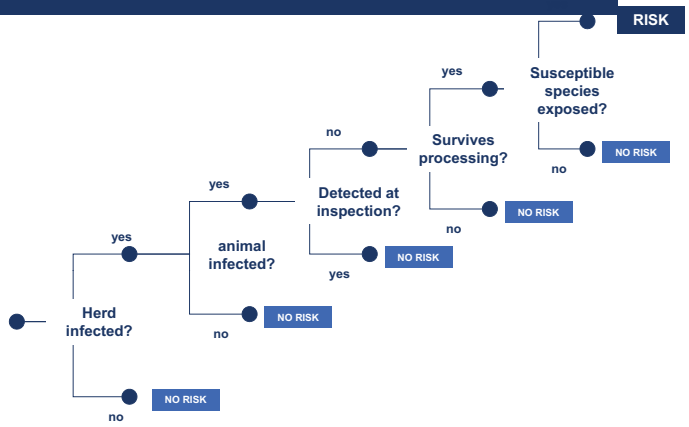
- Describes possible pathways for the introduction of a disease agent into new area
  - Biological factors
  - Country factors
  - Commodity factors

Requires good data, in a variety of areas

Exposure assessment

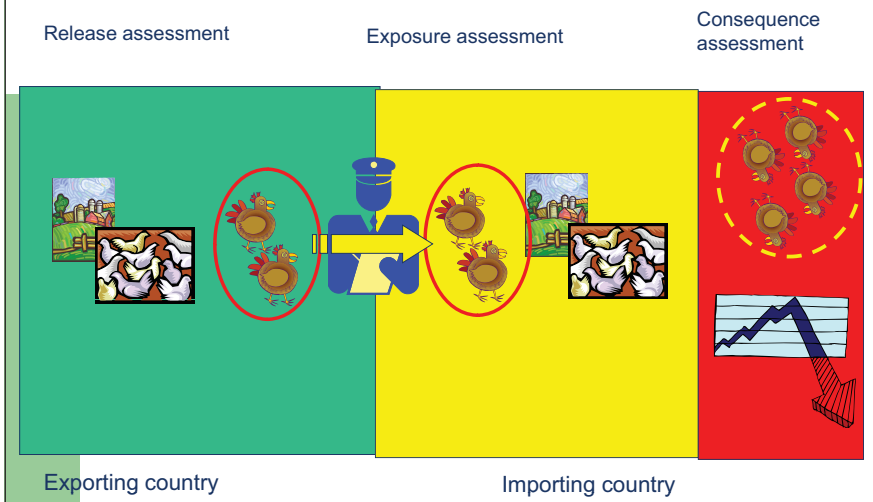
- Describes the pathways leading to an outbreak
  - Volume, use, expected distribution of the commodity
  - Density and distribution of susceptible animal populations
  - Immunity
  - Vectors
  - Seasonality
- Must define “outbreak”

Scenario tree



Consequence assessment

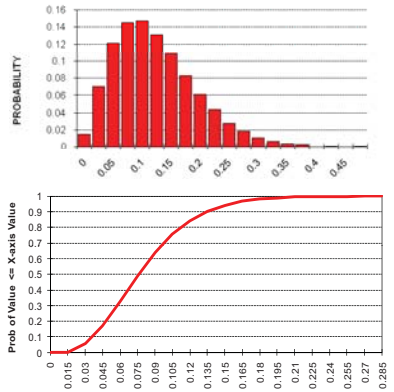
- Direct consequences
  - Production losses caused by disease or death of animals
  - Public health consequences
  - Cost of control and eradication ****
  - Compensation ****
- Indirect consequences
  - Trade losses (domestic and international)
  - Environmental consequences



Risk estimation

- Integration of the results from:
  - Release assessment
  - Exposure assessment
  - Consequence assessment
- Qualitative or quantitative?
  - What is the risk?
  - How do events rank relative to each other?

Risk estimation - quantitative



Not a point estimate but a range of probabilities

The result reflects variability and uncertainty

Risk estimation - qualitative

- In methodology
  - Need to define terms – negligible, low, medium, high
  - Should address uncertainty in some way
- Report results as outlined in methodology
- Clearly, understandably

Risk communication

- Often assumed to be important after assessment is done and decisions are made
- But is also important throughout the process
- Two way communication between assessors and other interested parties
  - Listen as well as speak

Principles of risk communication

the process by which **information and opinions** regarding hazards and risks are gathered **from potentially affected and interested parties** during a risk analysis, and by which the **results** of the risk assessment and proposed risk management measures **are communicated** to the decision-makers and interested parties in the **importing and exporting countries**. It is a multidimensional and iterative process and should ideally begin at the start of the risk analysis process and continue throughout.

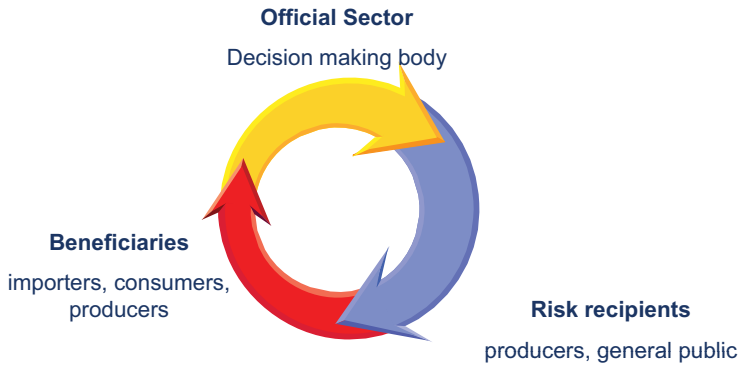
Risk communication

- Can include
  - Information acquisition from stakeholders, including risk perception and priorities from their points of view
  - Information exchange, delivery of results with and to decision makers
  - Information to stakeholders describing how risks were assessed and decisions made, and plans for how risks will be controlled and monitored

Risk communication

- Explain in terms of components
  - Methods
  - Inputs
  - Assumptions
  - Uncertainty

Risk Communication



Risk communication

- Different stakeholders may have different views and concerns about different pieces
- Different stakeholders may face different components of the risk
  - One group may experience the impact if it goes wrong, another may has more influence over the likelihood, and a third affected by response

Risk management

- the process of identifying, selecting and implementing measures that can be applied to reduce the level of risk

Risk management

- Risk evaluation
  - Appropriate level of Protection
  - Do we need to do something about the risk?
- Option evaluation
  - Evaluate
  - What mitigation is appropriate?
- Implementation
- Monitoring and review

OIE Terrestrial Animal Health Code, Article 1.3.2.6

Risk management questions

- What can be done to eliminate or reduce the hazard?
- How effective are the options?
- How feasible are the options?
- What impacts do the options have?
- What is the level and type of uncertainty?
- *What is the best option? Why?*

Risk management

"*Members shall ensure that **any** sanitary or phytosanitary **measure** is applied **only to the extent necessary** to protect human, animal or plant life or health, is **based on scientific principles** and is not maintained without sufficient scientific evidence...*".

Recognizing Uncertainty

- Natural variability
- Missing information
- Vague information
- Conflicting information
- Dated information
- Incorrect methods
- Errors

Variability and Uncertainty

- Variability is not reduced with more or better information
- Uncertainty may be reduced:
  - Modeling or measurement errors
  - Gaps in information
  - Out-of-date information
  - Incorrect assumptions

RA getting started

- Clarify the objective, scope, customer
- Understand the audience and intended use of the final product
- Agree on a work specification to meet the expectation for the product:
  - Time (urgency, complexity)
  - Cost (personnel, funding, other resources)
  - Quality (thoroughness and transparency)

What makes a good Risk Analysis?

- Meets the specified need
  - Timing
  - Quality
  - Comprehensiveness

- Objective, unbiased treatment of evidence
- Well-organized and easy to read
- Clearly links evidence to conclusions
- Describes uncertainty

Risk analysis and decision making

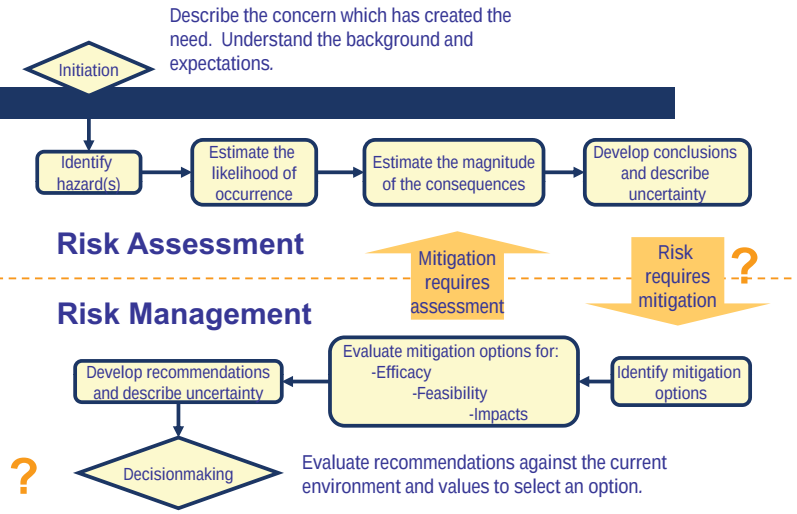
- Risk analysis is about using the results
  - Informing prior to decision
  - Making a decision
  - Supporting that decision
  - Implementing it

Risk analysis and decision making

- Get to the point
- Deliver your message in 30 seconds!
  - Charts and graphs are good
  - Fill in details after that

But also remember…

- Risk analysis is one piece of input
- Others may be social, political
  - Industry interests
  - Public interests
  - Budget realities



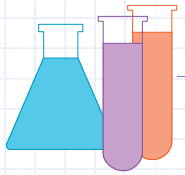
Summary

- Risk analysis reduces subjectivity
- It provides a documented process
- And, along with other input…
- Allows a more informed decision making process

But:

- Requires training, good quality data
- and good communication

PROPERTIES OF DIAGNOSTIC TESTS



Cristóbal Zepeda. Centers for Epidemiology and Animal Health USDA-APHIS /Animal Population Health Institute, Colorado State University

Prevalence studies

- Determine the frequency and distribution of an infectious agent
- Frequently by measuring antibodies
- Problem: false positives and false negatives

Screening tests

- Used to distinguish apparently healthy animals from infected animals
- Usually, a confirmatory test is required

Properties of tests

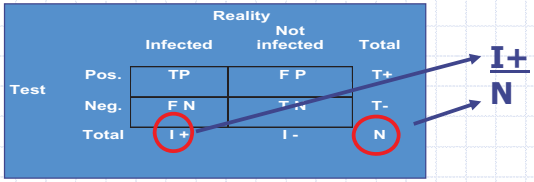
- Accuracy
- Sensitivity (Se)
- Specificity (Sp)

Classification of results

		Reality: Infected	Reality: Not infected	Total
Test	Pos.	TP	F P	T+
	Neg.	F N	T N	T-
	Total	I +	I -	N

True prevalence

- Proportion of animals that are truly infected



Classification of results

		reality: infected	reality: not infected	Total
test	Pos.	18 TP	15 F P	33 T+
	Neg.	38 F N	78 T N	116 T-
	Total	56 I +	93 I -	149 N

Apparent prevalence

- Proportion of animals positive to the test

$$\frac{T+}{N}$$

Classification of results

		reality: infected	reality: not infected	Total
test	Pos.	18 TP	15 F P	33 T+
	Neg.	38 F N	78 T N	116 T-
	Total	56 I +	93 I -	149 N

Accuracy

- Proportion of animals correctly identified by the test

$$\frac{TP + TN}{N}$$

Sensitivity (Se)

- Probability that a test correctly identifies infected animals as positive

$$\frac{TP}{I+}$$

$$I+ = TP + FN$$

Classification of results

		reality: infected	reality: not infected	Total
test	Pos.	18 TP	15 F P	33 T+
	Neg.	38 F N	78 T N	116 T-
	Total	56 I +	93 I -	149 N

Specificity (Sp)

- Probability that a test correctly identifies NON-infected animals as negative

$$\frac{TN}{I-}$$

$$I- = TN + FP$$

Classification of results

		reality: infected	reality: not infected	Total
test	Pos.	18 TP	15 F P	33 T+
	Neg.	38 F N	78 T N	116 T-
	Total	56 I +	93 I -	149 N

Positive predictive value (PV+)

- Proportion of test-positive animals that are truly infected

$$\frac{TP}{T+}$$

$$T+ = TP + FP$$

Negative predictive value (PV-)

- Proportion of test-negative animals that are truly not infected

$$\frac{TN}{T-}$$

$$T- = TN + FN$$

Classification of results

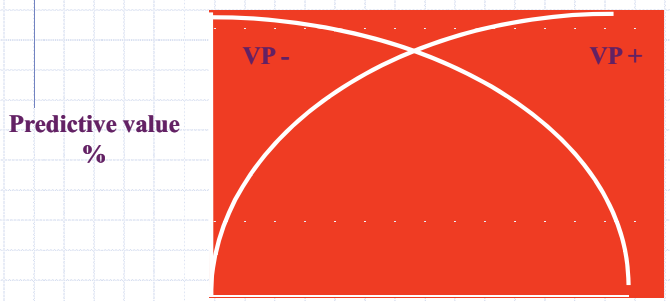
		reality: infected	reality: not infected	Total
test	Pos.	18 TP	15 F P	33 T+
	Neg.	38 F N	78 T N	116 T-
	Total	56 I +	93 I -	149 N

Effect of prevalence on the predictive value

Prevalence (%)	.1	1.0	2.0	5.0	50.0
PV+ (%)	1.9	16.9	27.9	50.5	95.0

Se and Sp = 95%

Effect of prevalence on the predictive value



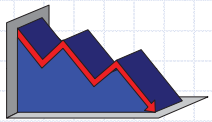
Relationship between PV+ and specificity

Relationship between PV- and sensitivity

Choosing a test

Use a test with high Se and high PV- to:

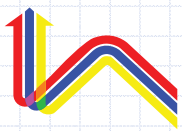
- Reduce the number of false negatives
- Avoid the introduction of a disease



Choosing a test

Use a test with high Sp and high PV+ to:

- Confirm a diagnosis
- Avoid the unnecessary slaughter of animals



Testing in series

- The results of all tests must be positive
- A second test will only be applied if the result to the previous test was positive
- You wish to increase specificity (Sp) and the positive predictive value (PV+)

Testing in parallel

- The results of all tests must be negative
- A second test will only be applied if the result to the previous test was negative
- You wish to increase sensitivity (Se) and the negative predictive value (PV-)

Test batteries

- Apply all possible tests
- The greater number of tests, the greater probability of a false positive

Conclusions

- Before interpreting test results:
  - Know the characteristics of the test
  - Know the epidemiological reality you are dealing with
  - Accept that 100% accurate test does not exist

PATHWAY ANALYSIS

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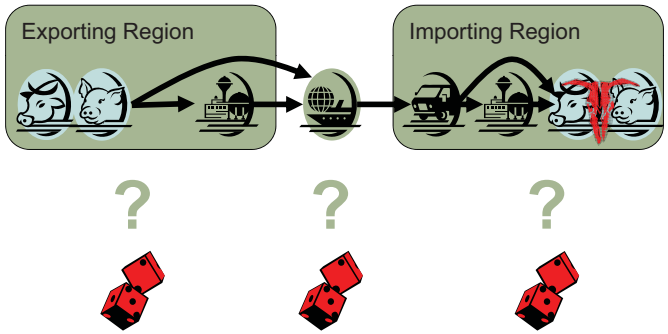
Risk Analysis Team

WHAT IS PATHWAY ANALYSIS?

"A pathways analysis is a systematic assessment of the ways in which an exotic disease agent might enter a country or region and establish an outbreak or persistent focus of disease, and an assessment of the quality and reliability of the relevant data for each arm of the pathway."

PATHWAY ANALYSIS



PATHWAY ANALYSIS CAN BE ORGANIZED

By pathogen (FMD, CSF, …)

By transportation route (passenger baggage, truck, train…)

By product (frozen meat, live animals, other)

Or any combination of the above

Will consider all the same factor however you organize it…

PATHWAY ANALYSIS—

Select the pathogen, route, and product

- Degree of threat to the importing region
- Degree of occurrence (prevalence) in the exporting region

Describe how the pathogen can move from the exporting region to the importing region

- Movement path should be biologically reasonable

Determine probabilities of the pathogen moving along the steps of the pathway

- The final probability should fit with experience

PATHWAY ANALYSIS (MOVEMENT)—

How can the pathogen move from the exporting region to the importing region?

Movement patterns and volumes from exporting region to importing region

- Movement types (air, sea, land)
- Movement methods (containers, break–bulk)
- Movement volumes (amount over time)
- Illegal or improper movements

PATHWAY ANALYSIS (SURVIVAL)—

How well can the pathogen survive (or thrive) during transport from the exporting region to the importing region?

Pathogen survival (or spread) during movement

- Animal or product production methods (canned, fresh, dehydrated, …)
- Time in transit (how long to get from the last point of exposure to the first point of exposure, …)
- Physical conditions (temperatures, shipping and packing materials, …)

PATHWAY ANALYSIS (RISK) —

How likely is the pathogen to move along the steps of the pathway?

Assign a probability to the likelihood

- Probability estimates should be based on observed cases or information (if possible)
- Subjective probability estimates should be justified

Pathway Analysis (Mitigations)—

How well do mitigations reduce the risk?

How much do they reduce the risk at a particular point in the pathway?

- Cleaning and disinfection measures
- Additional processing
- Quarantines
- Export certificates

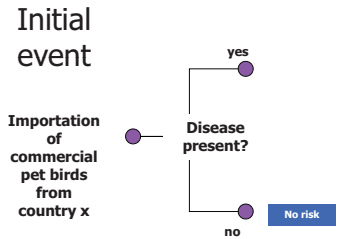
A Pathway May Be Present If

1. The disease agent exists somewhere in another country or region, and exports from that country or region may result in an outbreak
2. The agent may cross the country/regional border, whether in imported livestock, produce or other goods, tourist baggage, air or water, or due to intentional release, or other route
3. The agent may reach a susceptible host in the new region or country, within the agent survival time

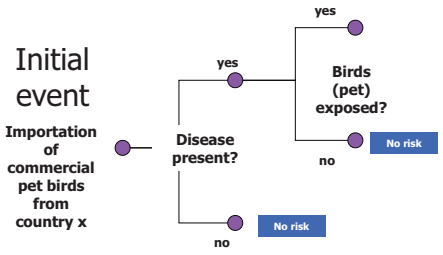
General Information Needs—

- Biology and epidemiology of the disease
- Characteristics of the disease agent
- Routes of entry into the country or region
- Routes of exposure to the country/region's livestock industry

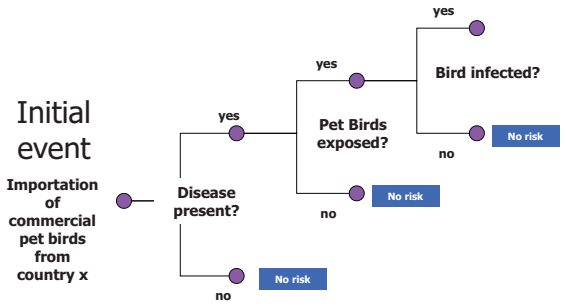
Describing the Pathway: Scenario Tree



SCENARIO TREES



SCENARIO TREES



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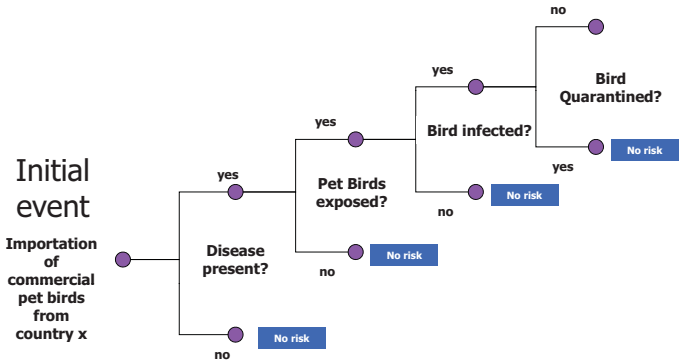
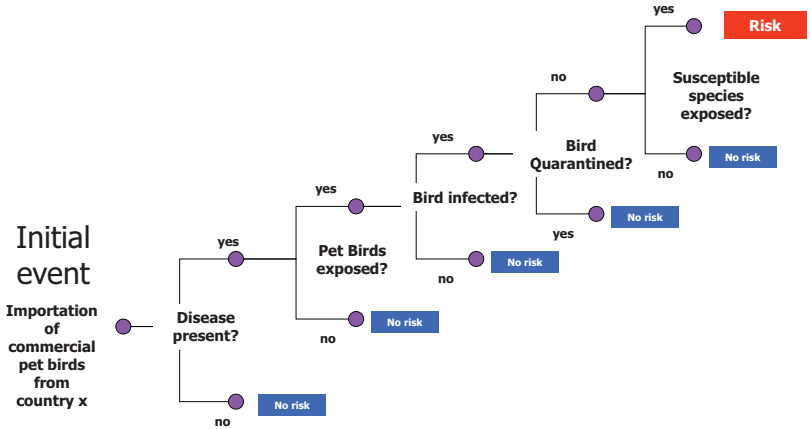
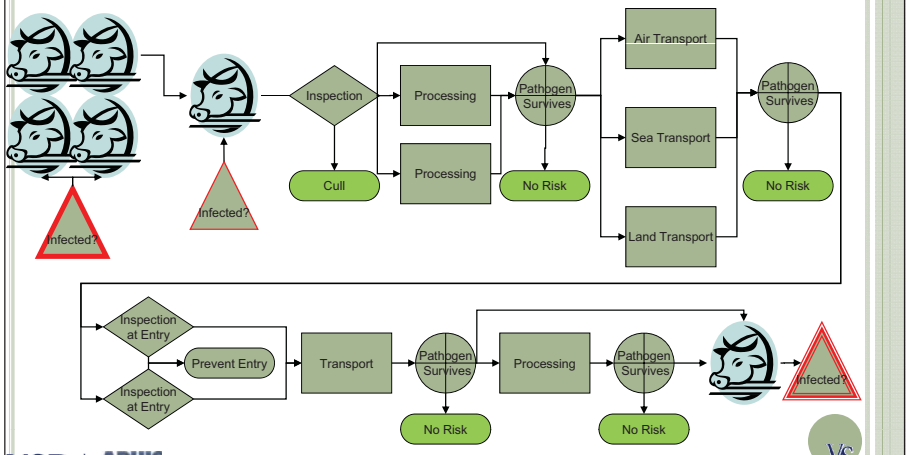
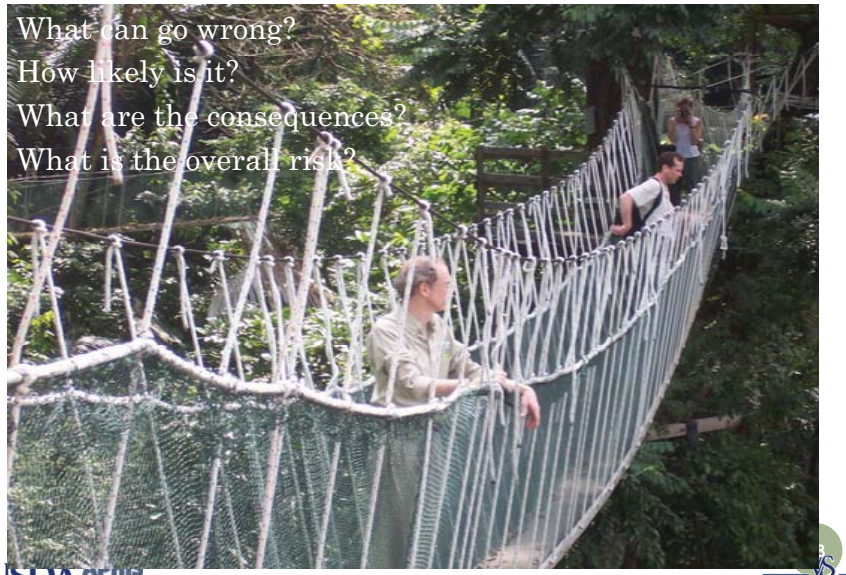


SCENARIO TREES



Pathway Analysis (Scenario Tree)



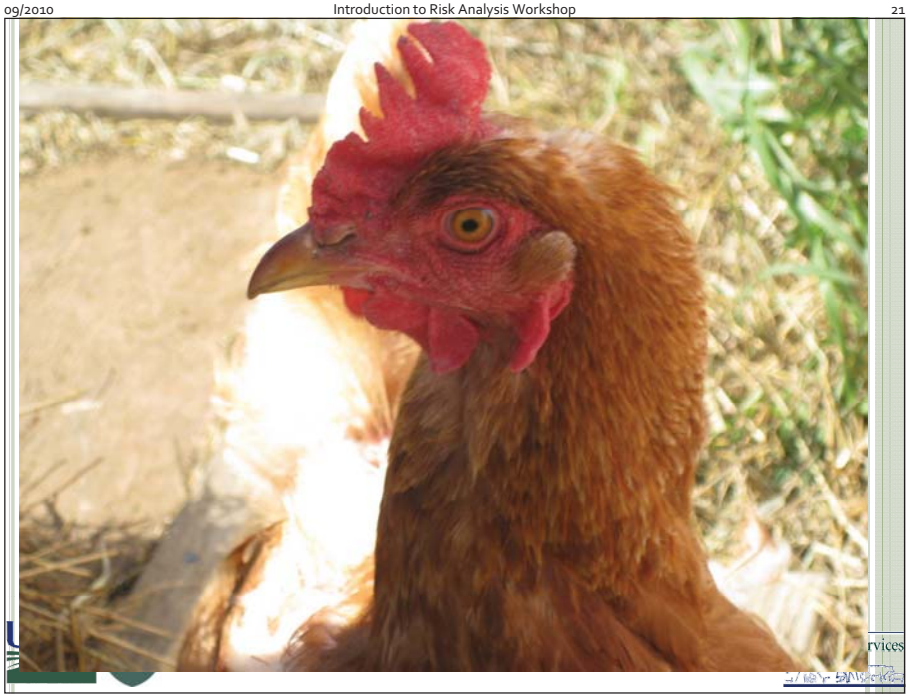


Framing the Question

- What is the likelihood that the Pest/Agent will be introduced to an unaffected population/region from an affected population/region?

Lets try one.....

- Country of import
- Country of export
- Agent of concern
- Commodity carrying agent
- Population at risk



Surveys and sampling

Basic criteria

Cristóbal Zepeda. Centers for Epidemiology and Animal Health USDA-APHIS /Animal Population Health Institute, Colorado State University

Definition

Survey

Epidemiologic study to determine population characteristics from a representative sample

Advantages and disadvantages

Advantages

- Inference of reality without examining the entire population
- Cost
- Have a demonstrable statistical basis

Disadvantages

- Always have a margin of error
- May lead to erroneous conclusions if they are not well designed

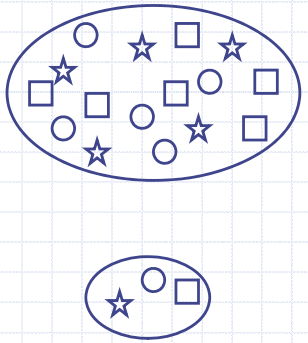
Terminology

- Population at risk
- Study population
- Sampling frame
- Sampling unit
- Sampling fraction

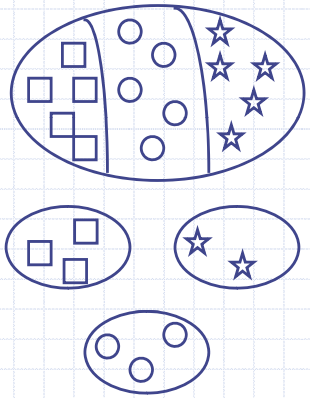
Sampling methods

- Simple random sampling
- Systematic random sampling
- Stratified random sampling
- Cluster sampling
- Multistage sampling

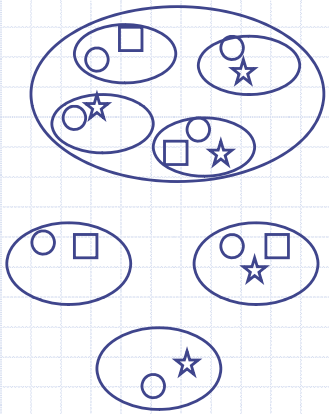
Simple



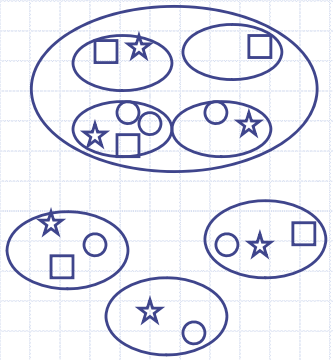
Stratified



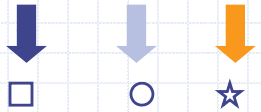
Cluster



Stages



Random selection in each group



Populations

- Populations are dynamic
- Population structure affects disease distribution
- Important to define the population at risk

Populations

Types:

- Separate
  - open
  - closed
- Contiguous

Sampling objectives

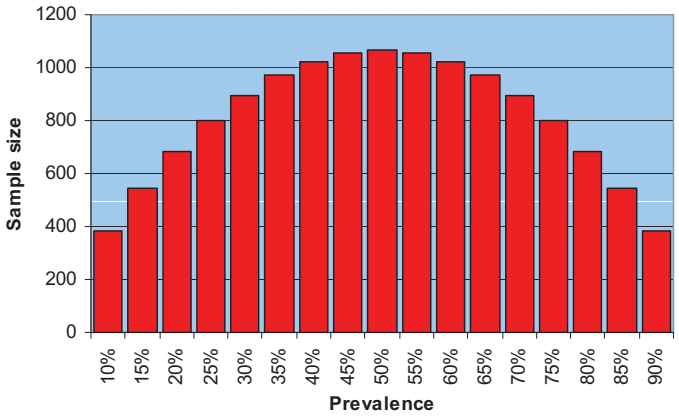
Determine prevalence

- Larger sample size
- Allows to estimate the proportion affected
- More expensive

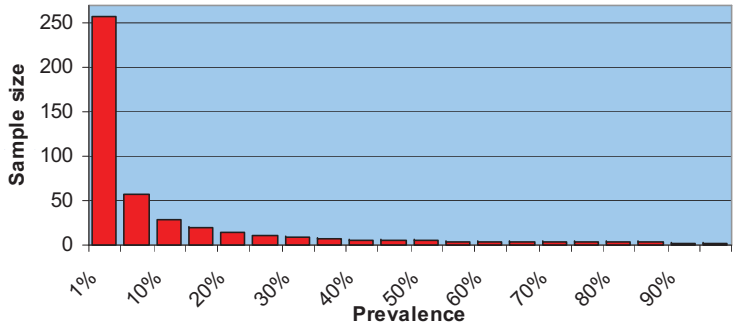
Determine presence or absence

- Smaller sample size
- Only allows to determine if disease is present or not
- Cheaper

Prevalence



Presence or absence



Examples

Qualitative Risk Assessment: Screwworm

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USDA, Animal and Plant Health Inspection Service, Veterinary Services
Centers for Epidemiology and Animal Health

Methodology 1: what risk(s) are we assessing?

Risk Assessment: Introduction of New World Screwworm into the United States, Mexico, and Central America from the Caribbean

In more detail….

- The purpose of this analysis is to determine the current risk of introduction of New World screwworm (NWS) into the United States, Mexico and Central America from the affected countries in the Caribbean.

Methodology 2: Organization

- Hazard analysis
  - Characterize hazard
- Then four parts of assessment:
  - Release assessment,
  - Exposure assessment,
  - Consequence assessment,
  - Risk estimation
- Ended there - Risk Management and Risk Communication are part of analysis, not assessment

Methodology 3: type of risk assessment and terminology

- Qualitative or quantitative?
- Important terms and definitions
- For quantitative – Acceptable Level Of Protection
- For qualitative – define qualitative terms

Risk assessment terms and definitions

Term	Definition
Negligible	So rare that it does not merit consideration
Very Low	Very rare but cannot be excluded
Low	Rare but does occur
Medium	Occurs regularly
High	Occurs very often
Very High	Events occur almost certainly

Uncertainty terms and definitions

Uncertainty Category	Definition
Low	The data available are solid and complete. Multiple published references or reliable databases and records are available. Different sources are generally in agreement.
Medium	Some, but not complete data are available. A small number of published references or reliable databases and records are available. If personal communication or anecdotal evidence is used in combination with published information, then it is from multiple reliable sources that are generally in agreement.
High	No published data are available. The only evidence is in the form of personal communications, anecdotal reports, or unpublished data.

Hazard Identification

- Describe pathogen, hosts
- Symptoms of infestation
- Lifecycle and environmental needs
- Diagnosis, treatment and control

New World Screwworm

- *Cochliomyia hominivorax*
- Obligate parasite of warm blooded animals during its larval stages
- Eat live tissue
- Most cases result in production losses, secondary infections and weight loss
- May cause death within 7-14 days, from toxicity and / or secondary infection

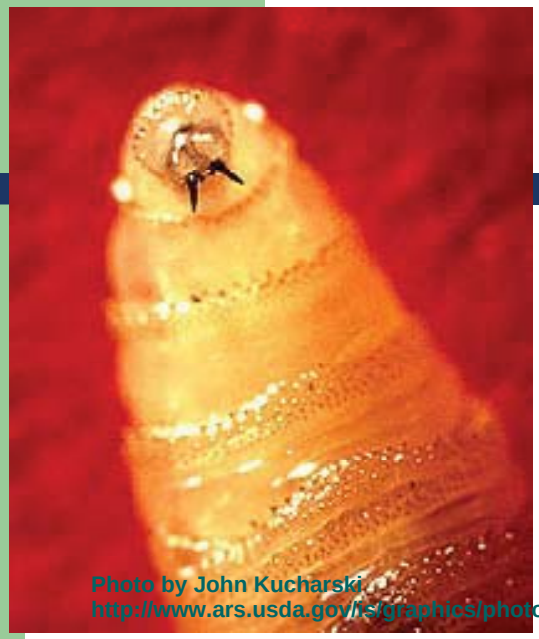


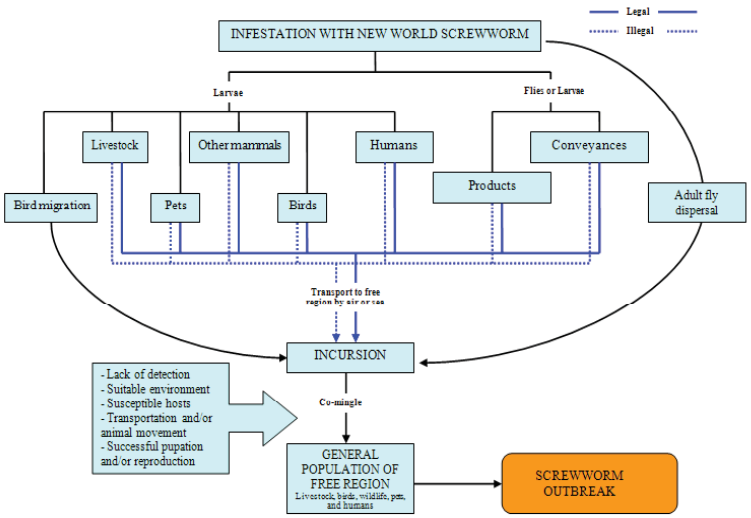
Photo by John Kucharski
http://www.ars.usda.gov/is/graphics/photos/k7576-1.htm

Figure 1: NWS Affected and Free Countries

Release and Exposure factors

- Release and exposure for all pathways
  - General discussion of release
    - Likelihood that imported commodity will contain the hazard and bring it to the importing country
    - General sketch of how that could happen
  - General discussion of exposure
    - How susceptible hosts in importing country would be exposed
    - Define “outbreak”
    - General environmental requirements, host distribution, requirements for fly to infest, etc.

Figure 3: Pathways to introduce NWS into the free region



Release, Exposure, and Risk Estimations

- From general to specific
- For each pathway
  - Describe pathway
  - Estimate likelihood of release
  - If likelihood of release is not negligible, estimate likelihood of exposure
  - Justifications outlined for each pathway

Livestock pathway - release

- Discussed epidemiology in domesticated livestock
  - In infected Caribbean countries
  - Past incursions anywhere attributed to domestic livestock
- Legal imports
  - Volume of imports

Release Determination, Legally Imported Livestock

Livestock are common hosts of NWS larvae, but livestock movements between the affected Caribbean countries and the free region are very infrequent. No past incursions are linked to livestock from the Caribbean.

For countries in the free region that do not import livestock from the affected NWS countries, the risk of NWS release via livestock is negligible. For the countries that do import livestock, the risk of a NWS incursion release due to livestock is considered very low (very rare but cannot be excluded). The uncertainty surrounding this estimate is low

Livestock pathway - exposure

- Required mitigations
- Likely destination (areas with other livestock)

Exposure Determination, Legally Imported Livestock

The United States is the only country that has imported more than one livestock animal from the affected area in the past three years, and U.S. mitigations for detecting and eliminating NWS infestation on an imported animal are effective. Although imported livestock are likely to go into an area with many livestock hosts, much of the United States is an unsuitable environment for NWS for at least part of the year, and imported animals are likely to receive prompt veterinary care.

The risk of exposure of a native host to NWS due to an incursion on legally imported livestock is very low (very rare but cannot be excluded), with low uncertainty.

Pathway release and exposure risk determinations

Pathway	Risk of Release	Risk of Exposure
Legally Imported Mammalian Livestock	Very Low to Negligible	Very Low to N/A
Illegally Imported Mammalian Livestock	Very Low	Very Low
Domestic Mammalian Pets (Dogs and Cats)	Low	Very Low
Humans	Very Low	Very Low
Exotic Mammals (research, wildlife, exotic pets, zoo animals)	Negligible	N/A
Legally Imported Poultry	Very Low to Negligible	Very Low to N/A
Legally Imported Non-Poultry Birds	Very Low to Negligible	Very Low to N/A
Migratory Birds	Negligible	N/A
Smuggled Birds	Very Low	Very Low
Conveyances	Negligible	N/A
Hides and Skins	Negligible	N/A
Fly dispersal	Negligible	N/A

Consequence Assessment: for all pathways

Biological

- Range from incursion with no outbreak to domestic cases with many susceptible hosts exposed; could involve domestic animals, wildlife, humans
- Historical evidence – no outbreaks confirmed from Caribbean
- Most likely outcome of incursion would be no domestic outbreak
- But there is a chance of an outbreak

Consequence Assessment

Economic

- Even without outbreak, economic consequences: costs associated with identification, surveillance, administration, for example.
- Small outbreak: add clinical examination of potentially exposed animals, treatment of affected hosts and contaminated environment, surveillance to demonstrate freedom
- In case of a larger domestic outbreak, could escalate up to full response including implementing emergency task force, release of sterile flies

Risk estimation - summary

Risk Estimation, Conclusion

In summary, the consequences of an NWS incursion may be biologically and economically severe. However, the most likely consequence - an incursion not followed by an outbreak – would result in health consequences for the imported infested host only, and would result in economic consequences related to investigation only and limited control measures. All potential pathways for NWS introduction from the affected countries into the free region were examined. Of the 12 pathways considered, 5 posed negligible risk of release, 6 posed very low risk of release, and 1 pathway, pet mammals, posed low risk of release. For all pathways with a greater than negligible risk of release, the risk of exposure (defined as infestation of one native host in the free region) was very low. Overall, the risk of NWS introduction into the free area from the affected countries is low.

Risk Communication

- Results communicated to customers
  - Detailed written report
  - Verbal report as well
- Also presented to screwworm researchers and program personnel at a meeting in Panama
  - Presented in person by one of project leads

Questions?

RISK ASSESSMENTS FOR DOMESTIC REGIONALIZATION

Katie A. Portacci, DVM, MPH, DACVPM
USDA-APHIS-VS-CEAH-Risk Analysis Team
With Chris Kopral and Ryan Miller

USDA

Veterinary Services

Outline

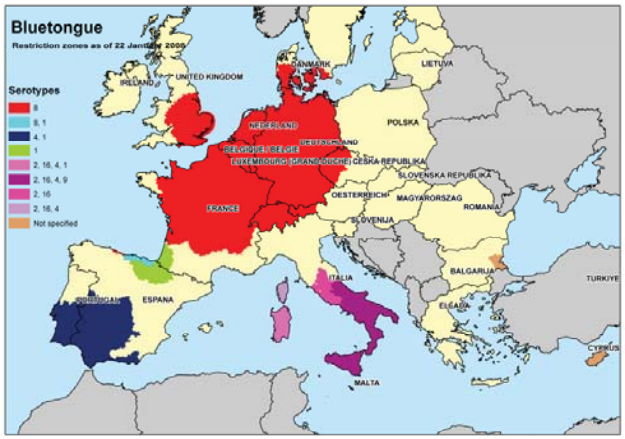
- What a zone/region? (OIE's definition)
- Applications domestically
- Containment zone example
- Eradication zone example
- Conclusion

Zone/region

- a clearly defined part of a territory
- containing an animal subpopulation with a distinct health status
- with respect to a specific disease
- for which required surveillance, control and biosecurity measures have been applied
- for the purpose of international trade

OIE-2010 Terrestrial Animal Health Code, Chapter 4.3

Example of a region



http://www.warmwell.com/bluetongueall.html (updated: April 30, 2010, accessed: May 13, 2010)

Uses of regions domestically

- Improve trading opportunities
- Improve resource allocation

Two Types:

- **Disease containment**
  - Rapidly reduce disease spread
- **Disease control or eradication**
  - Establish risk-based surveillance
  - Focus control efforts

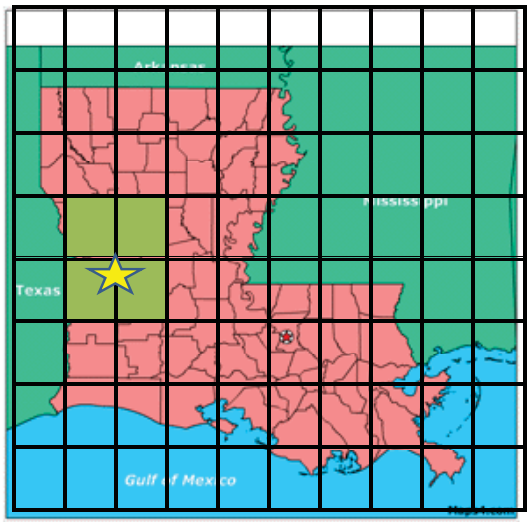
Disease Containment Regions:

- Responding to an outbreak
- Pre-determined region size through an emergency response plan
- Mitigation measures dependent on agent of concern
  - Stop movement
  - Vaccination
  - Cull

Political boundaries

Risk Radius

Grids



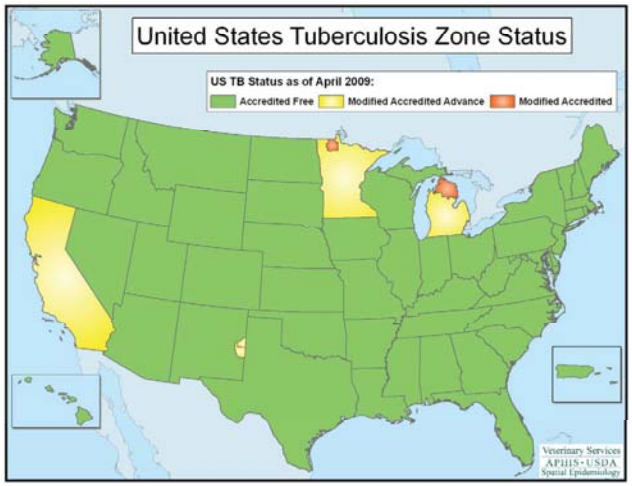
Disease Control or Eradication Regions:

- Long-term regions
- Specific boundaries based on the region and agent (must be enforceable)
  - Geographic
  - Political
  - other
- Mitigation measures used to maintain boundaries

How to establish control or eradication regions

- Is the problem justified by geography?
- Is all disease agent contained in the livestock population in the region?
- How could the agent leave the region?
- Is risk of disease leaving region sufficiently mitigated?

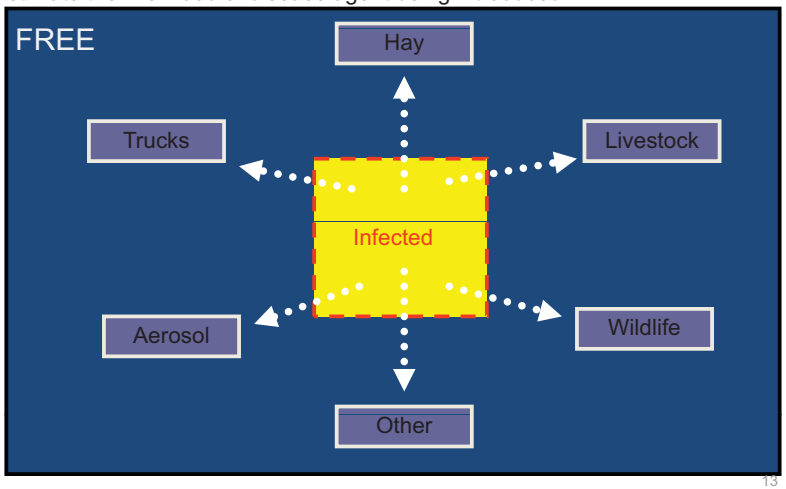
Eradication Region Example I: bovine TB



Release Assessment

Identify the status of the population

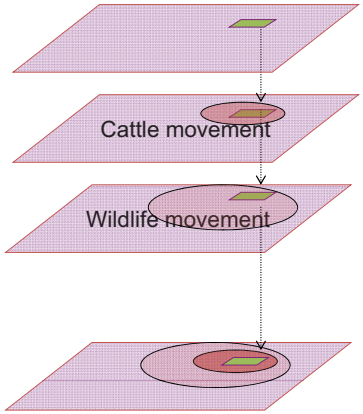
Estimate the likelihood of disease agent being introduced



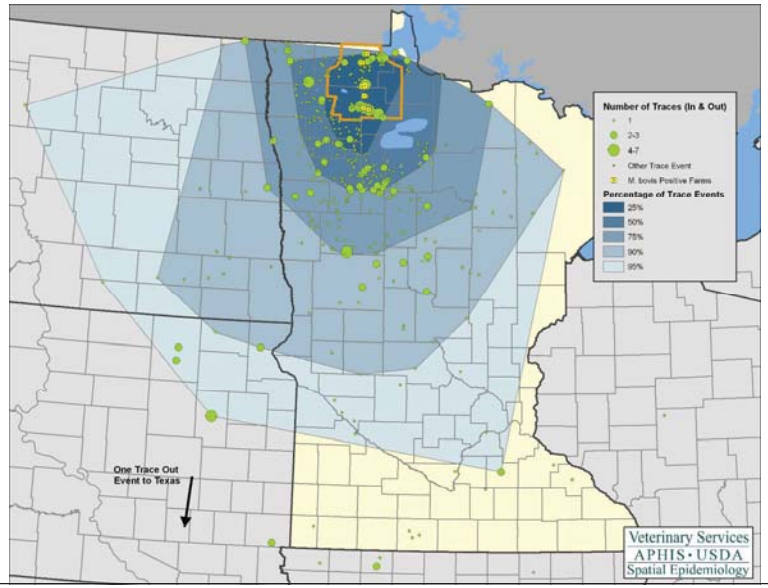
Exposure assessment

Likelihood of infected pathway spreading in the free zone

- Spatial analysis
- Evaluate mitigations
- Evaluate surveillance



Cattle movement



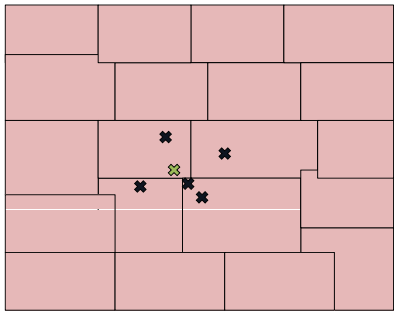
Pros and Cons of method

- Con
  - Time consuming
  - Limited by data and software available
  - Inconsistent
- Pro
  - Detailed
  - Accurate

Eradication Region Example II- Agent B

- Wildlife in a small geographic areas are the last reservoir for Agent B in the United States
- Wildlife periodically infect cattle in the area
- Data not available on specific testing and populations
- Need to be consistent, transparent, and repeatable

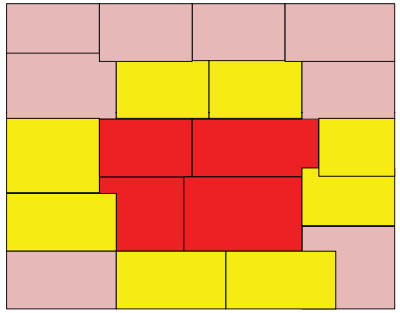
Disease Management Area- using existing political boundaries



•Is the problem based on geography?
•What about adjacent counties?

The proposal

- What surveillance has been done?
- What do you know about the risks?
- How are you controlling risk?
- How will you manage the area?



Step 1: Fill out an application

2.1.1. Geographic Unit Type:
  a. ☐ Game Management Unit (GMU)
  b. ☐ County
2.1.2. Geographic unit identifier or name: _____
2.1.3. This unit is located:
  a. ☐Inside the MA
  b. ☐Outside the MA

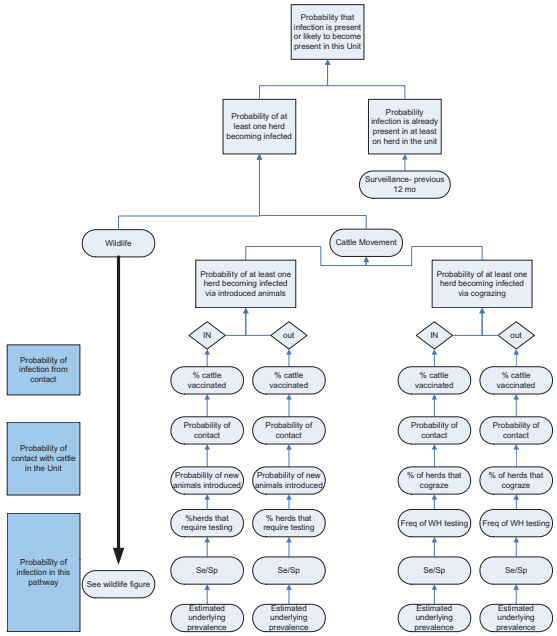
2.2. Livestock (cattle and domestic bison):

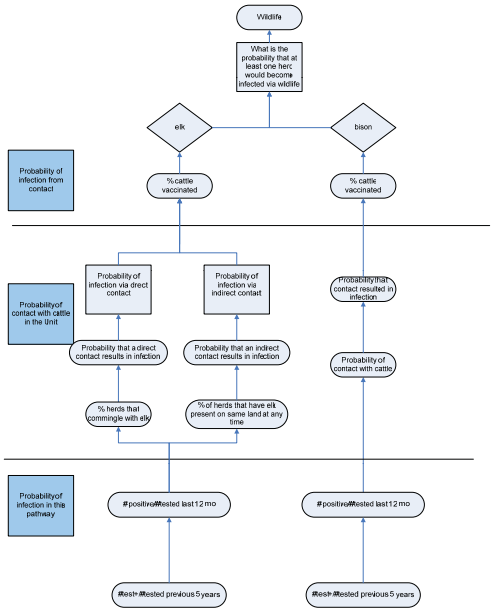
2.2.1. Total number of herds, whose primary residence lies within the unit, at the time of this application: _____
2.2.2. Number of herds tested for brucellosis during the 12 months prior to this application: _____
2.2.3. Have any herds tested positive for brucellosis in the 12 months prior to this application?
  a. ☐Y
  b. ☐N
2.2.4. If yes, how many herds tested positive? _____
2.2.5. If yes, what was the prevalence within the herd(s)(Number of animals that tested positive / Number of animals tested)? _____%
2.2.6. Average herd size (total number of animals): _____
  a. Minimum_____
  b. Maximum _____
2.2.7. Average percent of animals tested within herds: _____%
  a. Minimum_____%
  b. Maximum _____%
2.2.8. Number of herds vaccinated:

Step 2: run the model

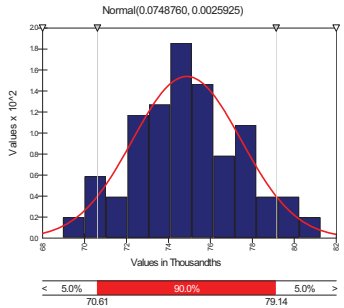
For Each Unit

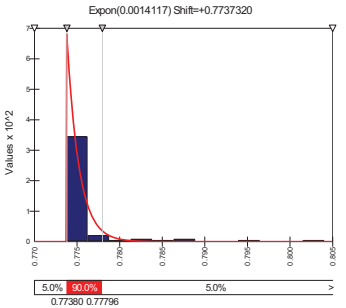
- What is the probability that *Agent B* is present?
  - Prevalence
- What is the probability that *Agent B* will be introduced
  - Via wild wildlife
  - Via cattle co-grazing or new additions





Results- for each unit



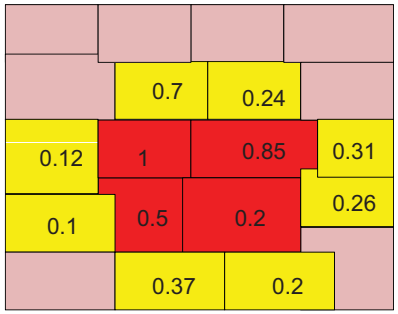


Probability that *Agent B* will be introduced into at least one herd via cattle movement OR wildlife
Mean=.07

Probability that *Agent B* is already present (Herd-level prevalence)
Mean=.77

Step 3- Map results

- Example of map output- relative risk



Step 4: Communicate with Management

- Evaluate why risk is high
- Evaluate alternate mitigations
- Re-evaluate every 1-2 years

Pros and Cons method

- Con
  - Inflexible for new pathways and pathogens
  - Limited by spatial scale
  - Limited by lack of data
- Pro
  - Rapid
  - Transparent
  - Consistent
  - Relative risk comparison
  - Minimal data needed

Conclusions

- Regions can be used to control disease
- Risk assessment framework can be applied, with modifications
- Methods vary by data, time, need
- Transparency and scientific defensibility must be maintained if applied for trading purposes

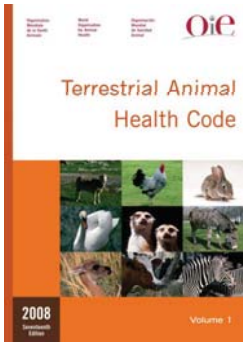
The End

Regionalization in International Trade
The "11 Factor" Example

Presented by: Laurel Voelker, DVM
USDA/APHIS/Veterinary Services

OIE Principles- Regionalization

- Exporting country should:
  - Establish and clearly define region
  - Explain basis for the region
  - Provide supporting documentation
  - Provide access for evaluation
  - Provide certification and oversight of the region



Reference: OIE. *Terrestrial Animal Health Code 2010, Chapter 4.3 Zoning and Compartmentalisation [cited 2010 July]; Available from: http://www.oie.int/eng/normes/mcode/en_chapitre_1.4.3.htm*

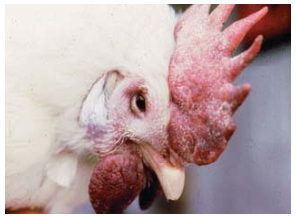
OIE Principles

- Importing country:
  - Needs to be satisfied its animal health status will be protected
  - Recognize the region when appropriate measures recommended in the *Code* are applied by exporting country

Reference: OIE. *Terrestrial Animal Health Code 2010, Chapter 4.3 Zoning and Compartmentalisation [cited 2010 July]; Available from: http://www.oie.int/eng/normes/mcode/en_chapitre_1.4.3.htm*

OIE Principles

- Regionalization may not apply to all diseases
- May need different regions for different diseases



Background--US Regulations

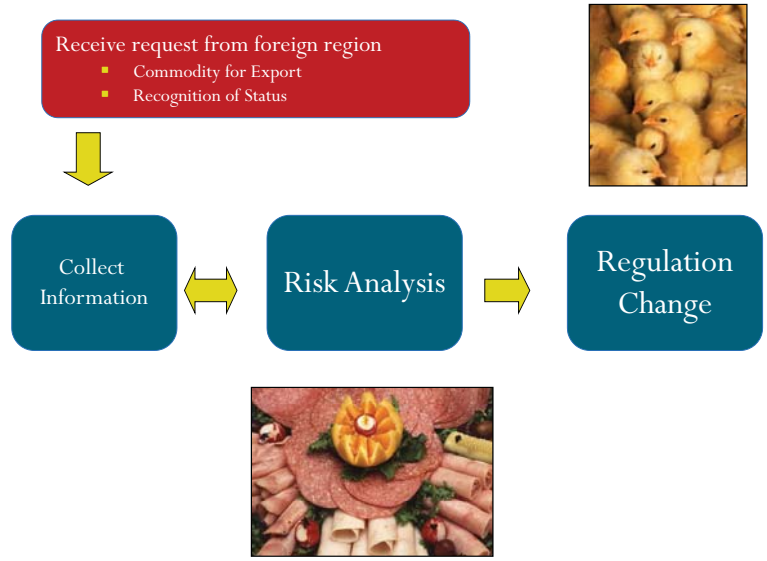
- Import restrictions for animals/animal products largely based on ***animal health status*** of the exporting region
- Status determined by USDA evaluation
- Status and process for changing status in regulations

Import Regulations and Disease Status

- Foot-and-Mouth Disease
- Rinderpest
- Classical Swine Fever
- African Swine Fever
- Swine Vesicular Disease
- Bovine Spongiform Encephalopathy
- Exotic Newcastle disease
- Highly pathogenic avian influenza H5N1
- Screwworm
- Contagious Equine Metritis
- African Horse Sickness

Background--US Regulations

- Region
  - A country
  - A part of a country
  - Parts of several countries combined into one area
  - A group of adjacent countries



Receive request from foreign region
- Commodity for Export
- Recognition of Status

Collect Information ⟷ Risk Analysis → Regulation Change

Receive request from foreign region
- Commodity for Export
- Recognition of Status

Collect Information ⟷ Risk Analysis → Regulation Change

Release Assessment

↓

Exposure Assessment

↓

Consequence Assessment

↓

Risk Estimation

The "Eleven Factors"

- Authority, organization, infrastructure of veterinary services in the region
- Disease status of the region
- Disease status of adjacent regions
- Active disease control program in the region
- Vaccination status of the region
- Separation of the region from adjacent regions of higher risk
- Movement controls and biosecurity in the region
- Livestock demographics and marketing practices within the region
- Disease surveillance in the region
- Diagnostic laboratory capability
- Emergency response capability

Reference: "Application for recognition of the animal health status of a region." *Electronic Code of Federal Regulations* Title 9 Pt. 92.2. [cited Aug 2 2010]. Available online at http://ecfr.gpoaccess.gov.

Authority, Organization, Infrastructure of Veterinary Services

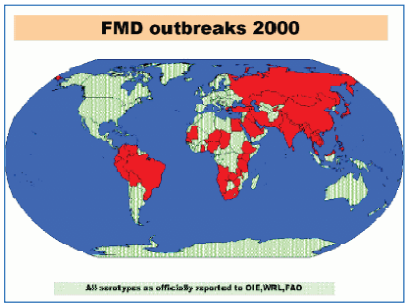
- Legal Authority
  - Quarantine
  - Movement control
  - Disease control
- Standard Procedures
- Resources
  - Personnel
  - Financial
- Communication
- Quality Control

Disease status of the region

- Disease History
  - Locations
  - Populations Affected
  - Control Measures
- Current status
  - Reservoirs
  - Control measures

Disease Status of Adjacent Regions

- Current Status
- Disease History
- Special Circumstances
  - Distance from region under evaluation
  - Other separation from region
  - Control plans in place
  - Surveillance at areas of high risk



Extent of Active Disease Control Program

- Most important if:
  - Disease present in region
  - Disease recently eradicated
- Considerations
  - Plans
  - Communication
  - Program effectiveness

Vaccination Status

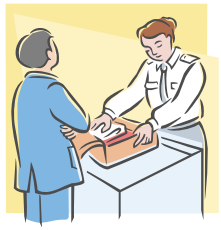
- Current/historical status
- Type
- Distinguish vaccination from infection
- Control of vaccine usage
- Plan for emergency vaccination

Separation from Adjacent Regions of Higher Risk

- Geographical or manmade barriers
- Access routes (highways, ports)
- Import practices
- Border control

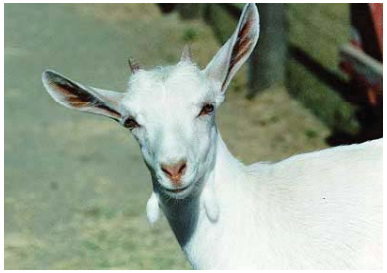
Control of movement of animals and products from regions of higher risk

- Import requirements
- Pre-import testing
- Border inspection
- Quarantine



Livestock Demographics and Marketing

- Number herds/flocks
- Geographic distribution
- Marketing practices
- Marketing regulations
- Traceability
- Likely source of animals for export to U.S.
  - Herd type
  - Geography
  - Management

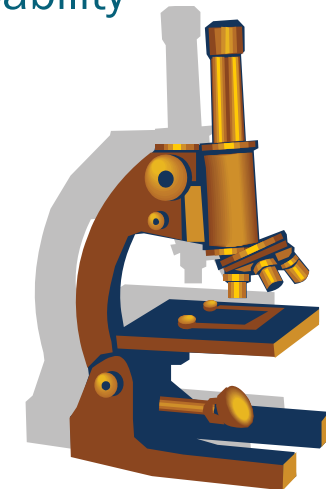


Disease Surveillance

- Type of surveillance
- Plan and rationale
- Follow-up investigations
- Test characteristics
- Communication
- Reporting requirements

Laboratory Capability

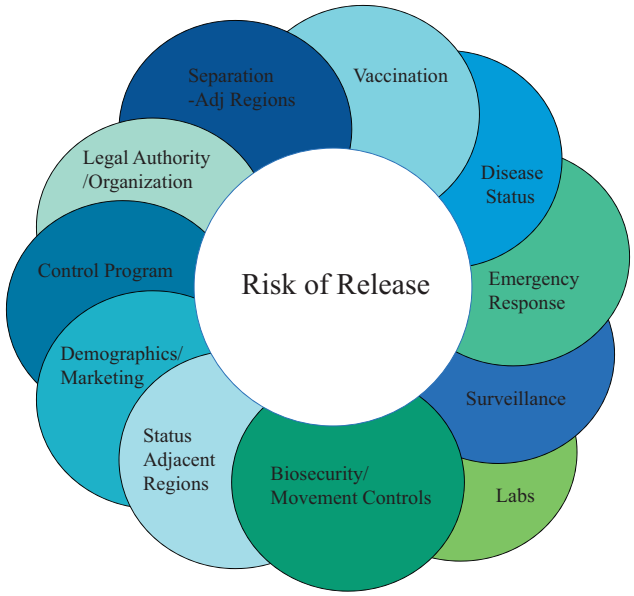
- Tests
- Turn-around time
- Throughput
- Quality control
- Record-keeping
- Communication
- Biosecurity
- Capacity



Emergency Response Capacity

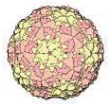
- Authority
- Plans
- Training
- Resources
- Infrastructure
- Reporting Procedures

Risk of Release?



In Summary:

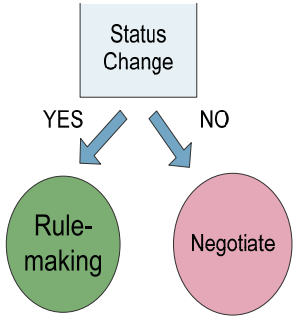
- Does the region have the hazard(disease agent)?
- Can the region keep the hazard out?
- If the hazard enters, will it be detected and controlled?
- If it is detected, will it be reported?





After the risk assessment..

- Policy makers determine if:
  - Animal health status of the region should be changed
  - There are any special circumstances that require mitigation



Rulemaking

- Remember.. Animal health status is written into U.S. regulations
- Rulemaking is the process of creating a new regulation or modifying an existing regulation

Rulemaking, Step 1: Proposed Rule


Rules and Regulations

- Proposed language of new regulation
- Supporting documents
  - Risk assessment
- Can be accessed at: http://www.gpoaccess.gov/fr/

Step 2:Public Comment

- Anyone can submit a comment:
  - Individual U.S. citizens
  - Industry groups
  - Corporations
  - Foreign Governments
  - Foreign Citizens
- Typically comment on:
  - Feasibility of the proposed rule
  - Contents of the risk assessment
  - Validity of risk assessment conclusions
  - Many others

Step 3: Final Rule

- Text of the new regulation
- Effective dates
- Published with:
  - Response to comments
  - Description of changes

www.regulations.gov

Receive request from foreign region
- Commodity for Export
- Recognition of Status

Collect Information ⟷ Risk Analysis → Status Change

Maybe.....

- Citizens (usually industry groups) can and do challenge a rules in court
- Congress can pass a LAW that supersedes our regulation.

Other Conditions

- Health certificates
- Import Permits
- Testing for other diseases
- Food safety requirements

Thank You!

USDA

VS Veterinary Services
APHIS • USDA

APHIS

Economic Analysis in the Risk Analysis Process

Presented by:
Kristyn Stone, PhD
Agricultural Economist & Risk Analyst

Veterinary Services

Safeguarding Animal Health

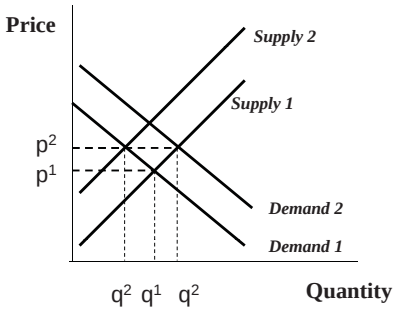
Economic Analysis - Essential to Understanding Risk

- Puts probabilistic outcomes in perspective
- Provides a basis for comparing different sources or types of risks
- Expected costs of uncertain pest or disease events can be estimated (likelihood-weighted economic consequences of pests or diseases)
- Estimates for a variety of disparate events can be expressed in common monetary units

Veterinary Services

Safeguarding Animal Health

Economic Overview



Veterinary Services

Safeguarding Animal Health

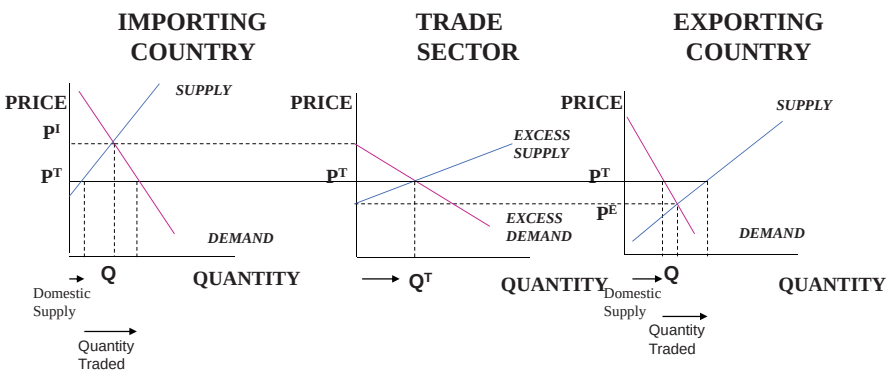
How Trade Occurs

- The exporting nation faces excess supply and the importing nation faces excess demand.
- Price is lower in the exporting nation and higher in the importing nation.
- When trade occurs, prices reach equilibrium in the world market.

Veterinary Services

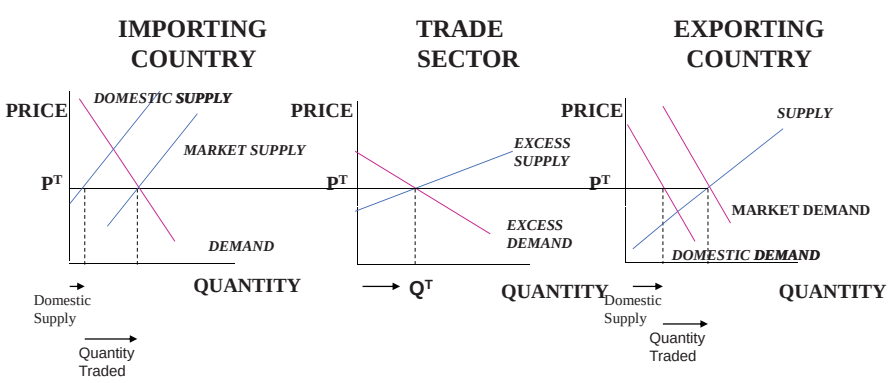
Safeguarding Animal Health

Trade and the World Market



Safeguarding Animal Health

Trade and the World Market



Safeguarding Animal Health

Domestic Impacts of Disease

- Typically, disease impacts are represented as a supply-side shock.
- Domestic demand may be shocked if there is consumer reaction to the disease.

Safeguarding Animal Health

Reactions of Trading Partners

- Reaction depends on the disease and the country.
- Implementation of:
  - Embargoes
  - New export requirements
    - Certification program
    - Testing protocols
    - Processing protocols

Safeguarding Animal Health

Economics in Risk Analysis

- Consequence assessment
  - Based on biological consequences
  - Consider two primary impacts:
    - Production
    - Trade
  - Potentially impacts to consumption

Approach to Estimating Economic Impacts – Quantitative vs. Qualitative

- Deciding which approach to use depends on:
  - Knowledge of industry being assessed
  - Data constraints
  - Time constraints

Quantitative Analysis

- Supply shock model
- Estimate trade impacts
- Price and quantity changes
- Welfare impacts

Qualitative Analysis

- Anecdotal
- Surveys of producers (those impacted)
- Industry overview
- Historical economic data
- Historical outbreaks
- Search of the literature

Assigning Values in a Qualitative Analysis

- Categorize as low, medium, or high
- Consider:
  - Sector income
  - Aggregated income of several sectors
  - Size of the sector in relation to agricultural GDP
  - Impact to the sector in relation to sectoral GDP

Economics Informing Regulations

- Identify potential regionalization schemes
- Identify obstacles to disease response
- Analyze response scenarios
- Analyze relevant compensation options

Compensation Options

- Depending on response option chosen, compensation program may be needed.
  - Compensation means paying money to livestock producers for losses realized.
- Considerations:
  - Why compensation?
  - What will be paid?
  - Sources of funds
  - Optimal level of compensation

Why Compensation

- Private incentive is not to report disease
  - Too many negative consequences for the producer
- Producer reporting is essential to disease control of highly pathogenic diseases
  - Government & industry want producers to report their suspicion of diseases
- Consequently reward producers for reporting
  - Compensation minimizes the externality between private and government-industry desires

Potential Compensation Items

- Value of the animal
  - Cost to replace with like kind
    - Replace 4 yr old dairy cow with another 4 yr old dairy cow
    - Incorporates future income stream of breeding animals
- Costs associated with cleaning & disinfection
  - Supplies
  - Labor
  - Sometimes U.S. pays some of C & D costs
- Lost income associated with business disruption (downtime)
  - U.S. doesn't pay for lost income

Sources of Compensation Funds

- Government (taxpayer)
- Industry
  - Tax on livestock inputs
  - Tax when animals/output are sold
- Consumer tax on final products
- International support
  - World Bank
  - IMF

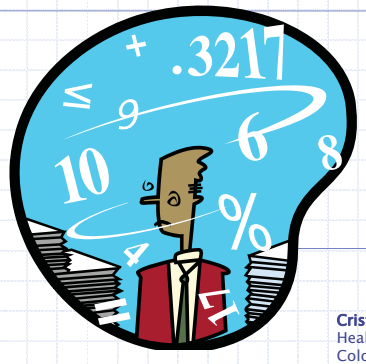
Optimal Level of Compensation

- Needs to be great enough to encourage reporting
- Moral hazard
  - Greater the compensation, less incentive to practice good biosecurity
    - May increase future disease prevalence
- For disease index herds pay full value
- For other herds payment becomes a function of biosecurity level practiced
  - Low biosecurity results in reduced payment
- Not an income transfer to producers

Summary

- Disease outbreaks disrupt supply.
- May impact trade and domestic consumption.
- Severity of impacts depends on the disease and trading partners.
- Choice between quantitative and qualitative analysis will depend on many factors.
- Economics can help inform regulations.
- Need to consider compensation once response option is chosen.

Introduction to probabilities



Cristóbal Zepeda. Centers for Epidemiology and Animal Health USDA-APHIS /Animal Population Health Institute, Colorado State University

Probability

- Likelihood of occurrence of an event
- Described as a number between 0 and 1
  - 0 implies that the event will not occur
  - 1 implies that the event will occur

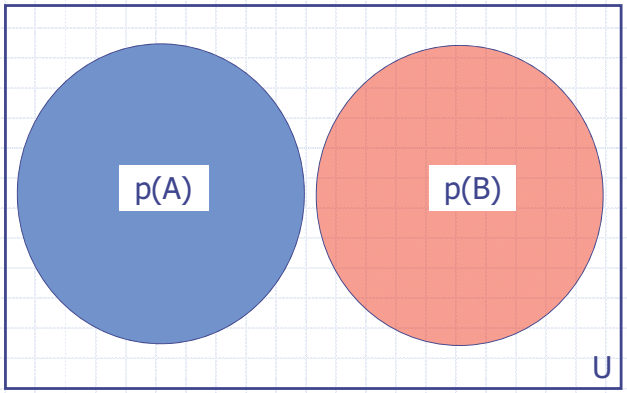
Nomenclature

- The probability of an event A occurring is written
  - p(A)
- The probability of an event A NOT occurring is written
  - 1 - p(A)
  - This is know as the complement of p and is called q

Nomenclature

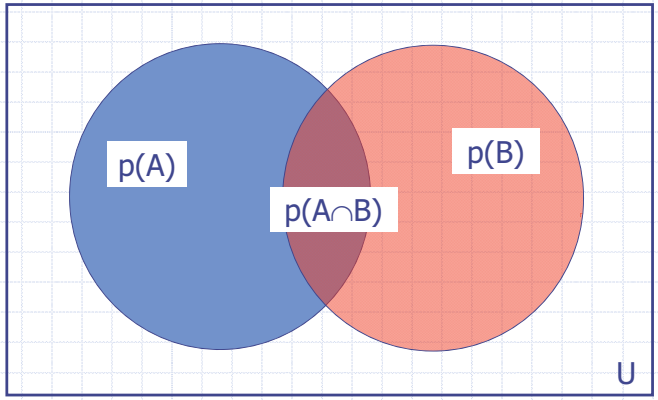
- Probability of A and B occurring
  - $p(A \cap B)$ - A intersection B
- Probability of A or B occurring
  - $p(A \cup B)$ - A union B
- Probability of B given that A already occurred
  - $p(B|A)$ (conditional probability)

Venn diagrams



$P(A \cup B) = p(A) + p(B)$

Venn diagrams

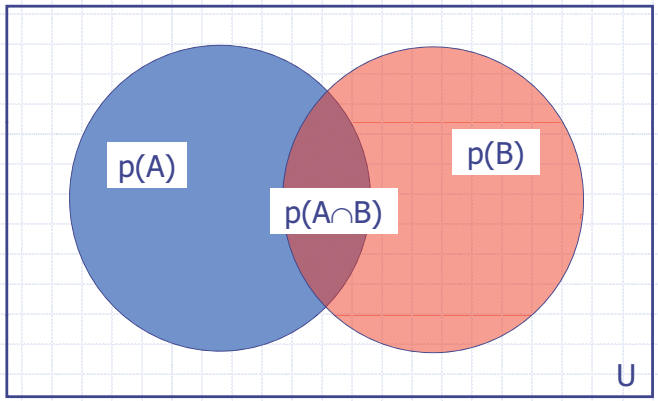


$p(A \cup B) = p(A) + p(B) - p(A \cap B)$

Probability rules

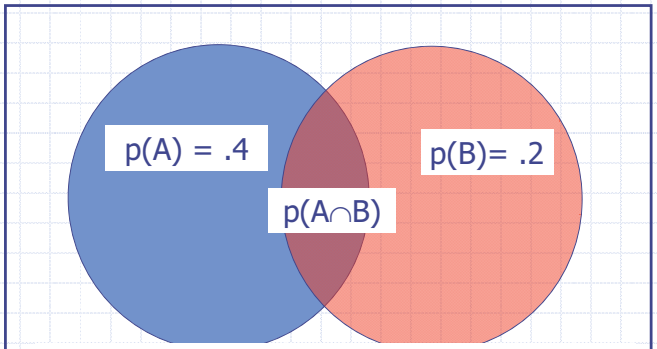
- If two events A and B are independent (the occurrence of A does not alter the occurrence of B) the probability that A and B occur simultaneously is
  - $p(A \cap B) = p(A) \times p(B)$

Venn diagrams



$p(A \cap B) = p(A) \times p(B)$

Venn diagrams



What is the probability of A or B occurring?

$p(A \cap B) = p(A) \times p(B) = .4 \times .2 = .08$

$p(A \cup B) = p(A) + p(B) - p(A \cap B) = .4 + .2 - .08 = .52$

Probability calculations

- Probability of an event occurring (p)
- Probability of an event occurring in "n" trials

  p^n
- Example: The prevalence of a disease is 20%, I select 4 animals. What is the probability that all 4 will be infected?
  - $.2 \times .2 \times .2 \times .2 = .2^4 = 0.0016$

Probability calculations

- Probability of an event NOT occurring

  $q = (1-p)$
- Probability of an event NOT occurring in "n" trials

  $(1-p)^n$
- Probability of at least one occurrence in "n" trials

  $1-(1-p)^n$

Exercise

- The prevalence of a disease is 0.2, I select 4 animals. What is the probability that at least one of them will be infected?
  - Recall that:

$p(x \geq 1) = 1-(1-p)^n$

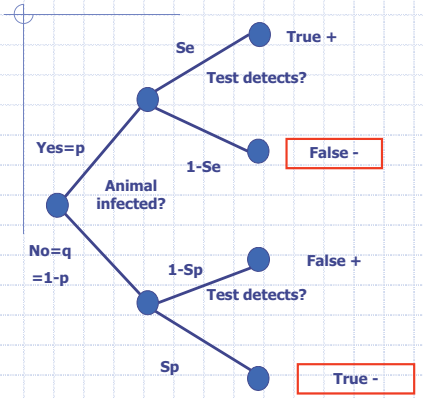
Exercise

a) Probability that none of them are infected

- $(1 - .2)^4 = 0.8^4 = 0.4 = 40\%$

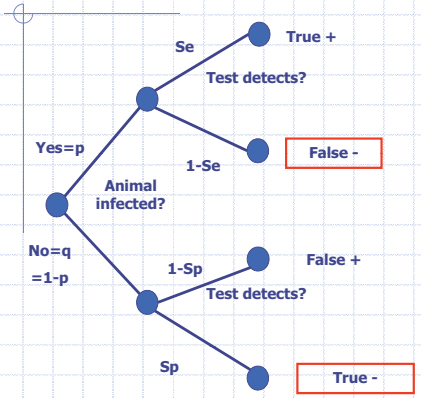
b) Probability that at least one is infected

- $1 - (1 - .2)^4 = 1 - .4 = 0.6 = 60\%$



Probability of at least one infected animal in a group

- Determine the proportion of true negatives (predictive value negative)
  - TN / (TN+FN)
- Raise to the number of animals
  - $[TN / TN+FN]^n$
- Subtract from 1
  - $1- [TN / (TN+FN)]^n$



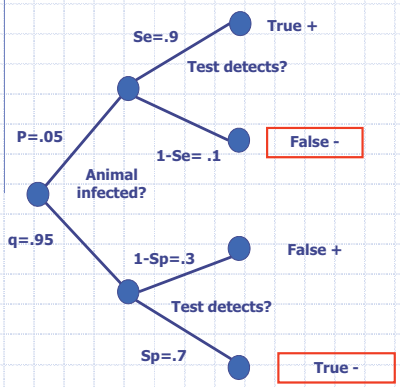
Probability of at least one infected animal in a group

- Determine the proportion of true negatives (predictive value negative)
  $q(sp)/(q(sp) + p(1-se))$
- Raise to the number of animals
  $[q(sp)/(q(sp)+ p(1-se))]^n$
- Subtract from 1
  $1- [q(sp)/(q(sp)+p(1-se))]^n$

Exercise

- Assume a disease prevalence in an animal population of 5%, a diagnostic test with a sensitivity of 90% and a specificity of 70%. Determine the probability of including at least one infected animal in a group of 10 animals, given that they all tested negative. (it may be useful to draw a scenario tree)

Results



- Calculate the PV-:

q(sp)/(q(sp) + p(1-se)) =
.95 x .7 / (.95 x .7) + (.05 x .1)
= .665 / (.665 + .005)
= .9925

- Raise to the number of animals:

$.9925^{10}$= .9275

- Subtract from 1

1- .9275 = .072

Interpretation

- Despite all animals were test negative, there is a 7.2% probability that this lot will contain at least one infected animal
- Approximately 7 of each 100 test-negative lots will contain at least one infected animal

Binomial distribution

- Used to calculate the probability of obtaining (x) successes in (n) trials
- Three conditions:
  - Each trial has only two possible results
  - Each trial is independent
  - The probability of success (p) is constant (therefore, the probability of failure (1-p) is also constant)

Binomial coefficient

- Used to calculate the number of ways of obtaining (x) results
- Example: How many ways are there to obtain (x) infected animals, with a prevalence (p), if I select (n=3) animals?

Binomial coefficient

Infected animals	Number of options	
3	1	p x p x p
2	3	p x p x (1-p) p x (1-p) x p (1-p) x p x p
1	3	p x (1-p) x (1-p) (1-p) x p x (1-p) (1-p) x (1-p) x p
0	1	(1-p) x (1-p) x (1-p)

Remember…

$$n! = n \times (n-1) \times (n-2) \times \ldots \times 1$$

$$75! = 75 \times 74 \times 73 \times \ldots \times 3 \times 2 \times 1$$

$$3! = 3 \times 2 \times 1 = 6$$

$$1! = 1$$

$$0! = 1$$

Binomial coefficient

- Calculated as:

$$\binom{n}{x} = {}^{n}C_{x} = \frac{n!}{x!(n-x)!}$$

$$\binom{3}{3} = {}^{3}C_{3} = \frac{3!}{3!(3-3)!} = 1$$

$$\binom{3}{2} = {}^{3}C_{2} = \frac{3!}{2!(3-2)!} = 3$$

Binomial distribution

- Probability of obtaining exactly (x) successes in (n) trials

$$p(x) = \binom{n}{x} p^{x} (1-p)^{n-x}$$

Example

- What is the probability of obtaining exactly 1 diseased animal in 3 trials? (prevalence = 0.2)

$$p(x=1) = \binom{3}{1}.2^1(1-.2)^{3-1}$$

$$= \left(\frac{3!}{1!(3-1)!}\right) \times .2 \times (.8)^2$$

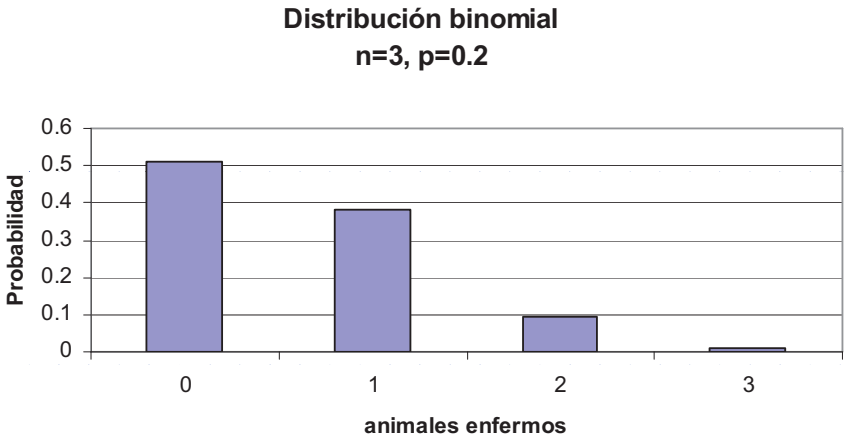
$$= 3 \times .2 \times .64$$

$$= 0.384$$

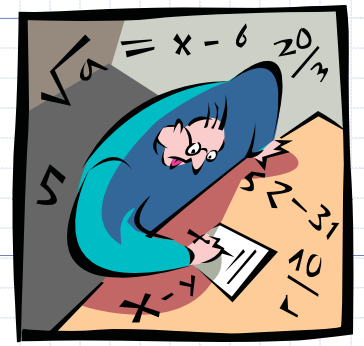
Binomial distribution

- The distribution is the sum of the probabilities of obtaining exactly 0,1,2…n infected animals

$$\sum_{x=0}^{n} \binom{n}{x} p^x (1-p)^{n-x} = 1$$



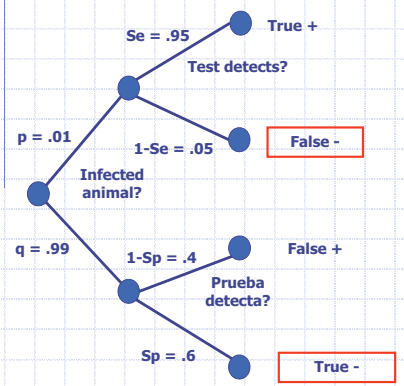
Exercises



Exercise 2

- Assume a prevalence of disease in an animal population of 1%, a diagnostic test with a sensitivity of 95% and a specificity of 60%. Calculate the probability of including at least one infected animal in a group of 10 animals given that all were test negative.

Results



- Calculate the PV- el VP-:

q(sp)/q(sp) + p(1-se) =
.99 x .6 / (.99 x .6) + (.01 x .05)
= .594 / (.594 + .0005)
= .9992

- Raise to the power of the number of animals:

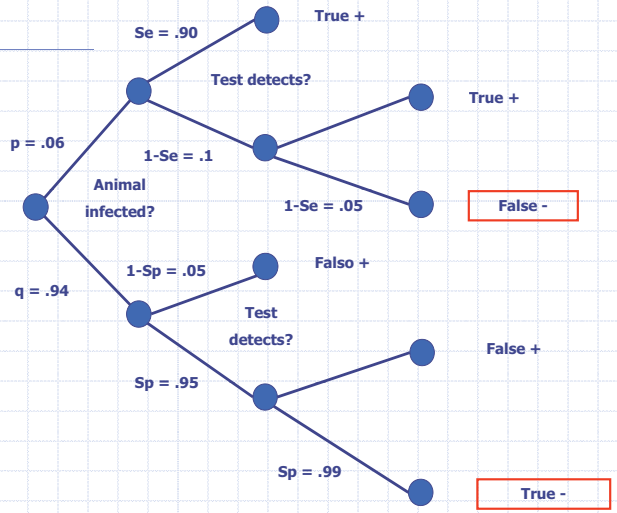
$.9992^{10}$= .992

- Subtract from 1

1- .992 = .008

Exercise 3

- Assume a prevalence of disease in an animal population of 6%, a diagnostic test with a sensitivity of 90% and a specificity of 95%.
- The animals that tested negative to the first test are subjected to a confirmatory test with a sensitivity of 95% and a specificity of 99%
- Calculate the probability of including at least one infected animal in a group of 25 animals given that all were negative to both tests.



Result

$$p(x \geq 1) = 1 - \left(\frac{q \times sp_1 \times sp_2}{(q \times sp_1 \times sp_2) + (p \times (1 - se_1) \times (1 - se_2)} \right)^n$$

$$= 1 - \left(\frac{.94 \times .95 \times .99}{(.94 \times .95 \times .99) + (.06 \times (1 - .9) \times (1 - .95)} \right)^{25}$$

$$= 1 - \left(\frac{0.88407}{0.88407 + 0.0003} \right)^{25}$$

$$= 1 - \left(\frac{0.88407}{0.88437} \right)^{25}$$

$$= 1 - 0.99966^{25}$$

$$= 0.0084$$

Exercise 4

- A disease has a prevalence of 10%. 15 animals are selected randomly from the population. What is the probability of selecting exactly 3 infected animals?

Result

$$p(x = 3) = \binom{15}{3} 0.1^3 (1 - 0.1)^{15-3}$$

$$= \left(\frac{15!}{3!(15-3)!} \right) \times 0.001 \times (.9)^{12}$$

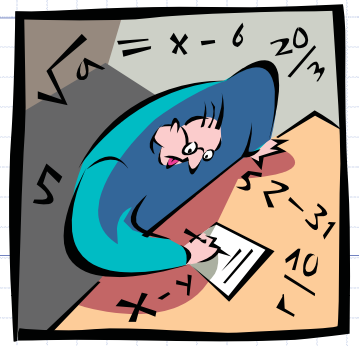
$$= 455 \times 0.001 \times 0.28$$

$$= 0.128$$

For numbers hell is not below zero, in the negative numbers…

… but in the paradoxes, the anomalies, in the painful spectrum of probabilities.

It's over!



Distributions used in risk analysis

Cristóbal Zepeda. Centers for Epidemiology and Animal Health USDA-APHIS /Animal Population Health Institute, Colorado State University

Stochastic processes

- Allow to incorporate variability and uncertainty
  - Binomial process
  - Hypergeometric process
  - Poisson process

Binomial Process

- It is NOT the same as the binomial distribution
- The binomial distribution is one of the distributions that describe the binomial process

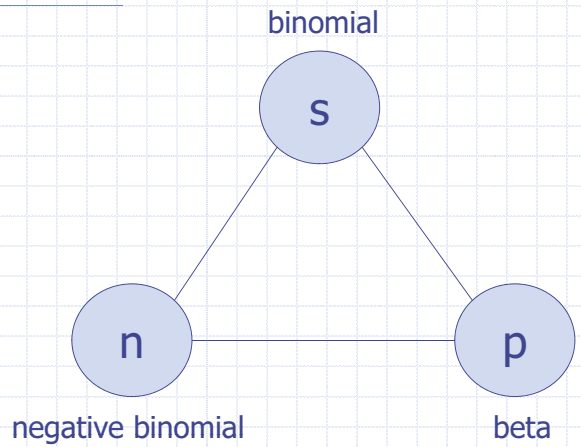
Conditions for the binomial process

- All trials are identical
- Each trial has two possible results
- Each trial is independent
- The probability of success is constant

Binomial process

- Has three variables:
  - (n) – number of trials
  - (p) – probability of success in every trial
  - (s) – number of successes in a series of trials

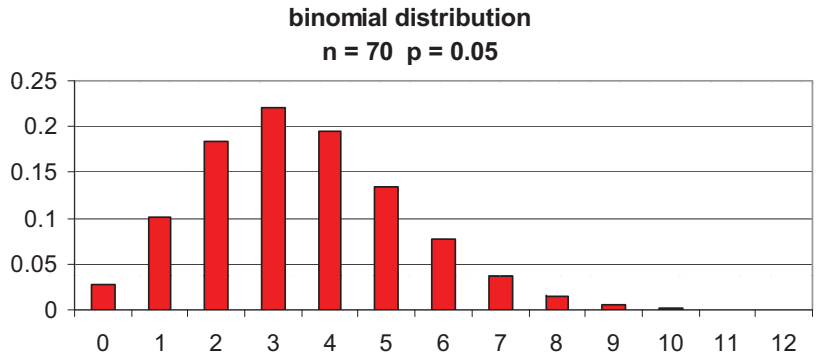
Distributions of the binomial process



Binomial distribution

- Used to find the number of successes (s) if the probability (p) and the population (n) are known
  - For example the number of diseased animals in a population with a known prevalence
- Format
  - s = binomial (n,p)

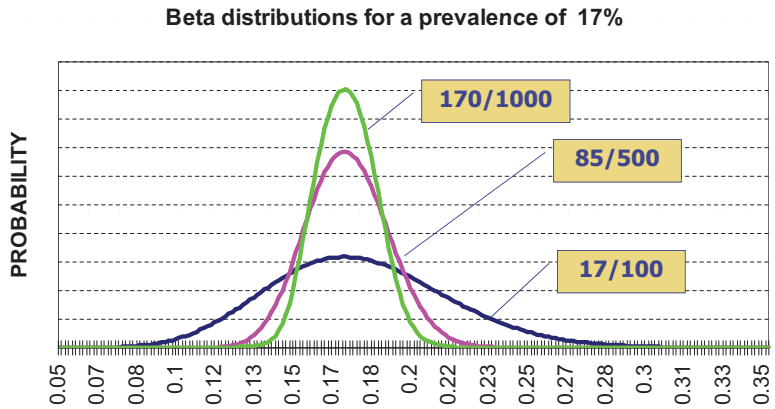
Binomial distribution



Beta distribution

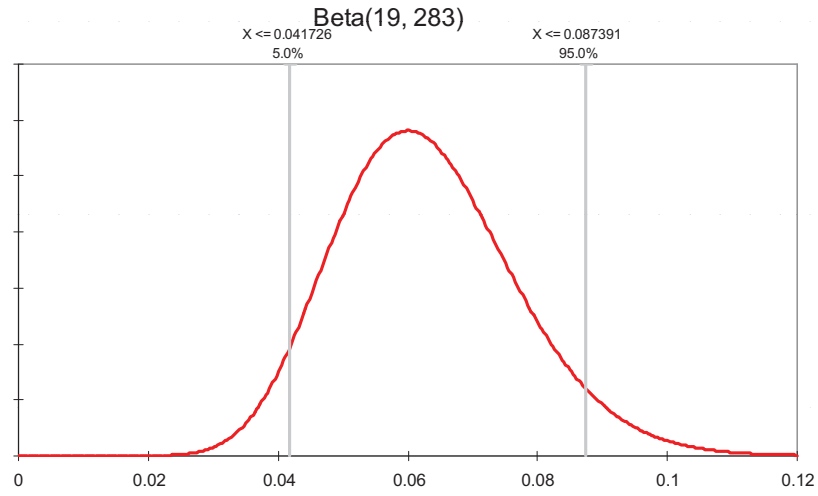
- Used to find p when n and s are known
  - For example a sample of 100 animals is taken and 17 test positive
- Format:
  - p = Beta(s+1, n-s+1)

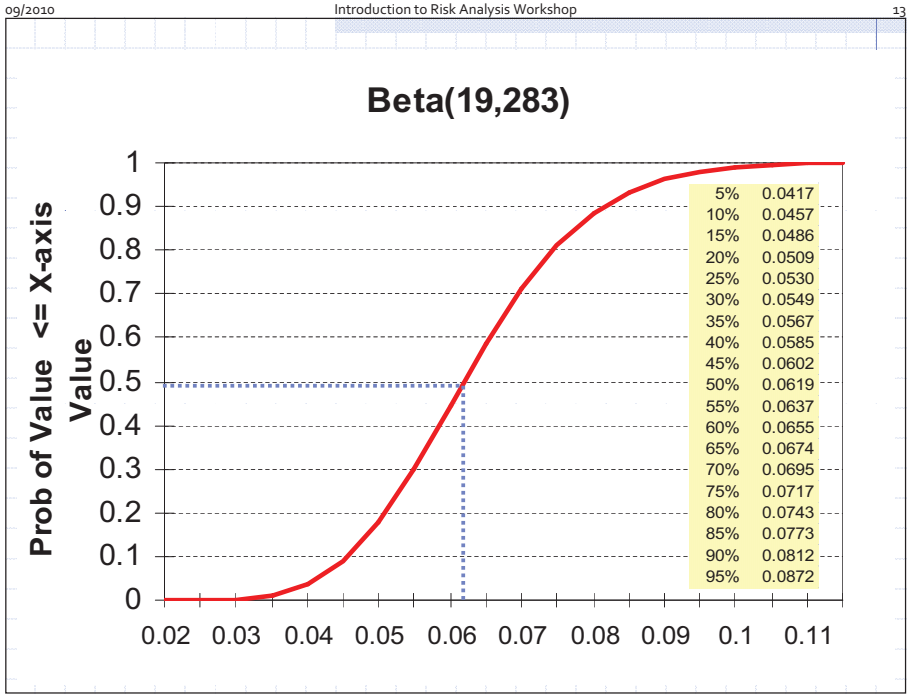
Beta distribution



Probability calculations using the beta distribution

- 300 animals are sampled and 18 test positive
- What is the prevalence?
  - Beta (s+1, n-s+1)
  - Beta (18+1, 300-18+1)
  - Beta (19, 283)





Uses of the beta distribution

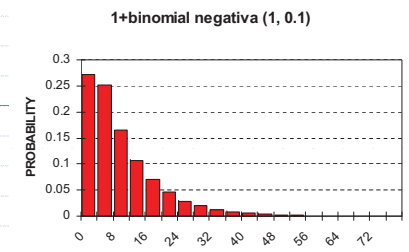
- Determine sensitivity and specificity
- Determine prevalence (even with 0 successes)
  - Beta (0+1, n+1)

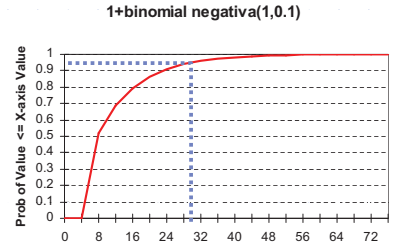
Negative binomial distribution

- Used to find n if s and p are known
  - For example number of samples needed to detect s positives
- Format
  - n=s+negative binomial (s,p)

Negative binomial distribution

- What sample size is required to detect with 95% confidence at least 1 infected animal, if the expected prevalence is 10%?
  - n=1+ negative binomial (1,0.1)



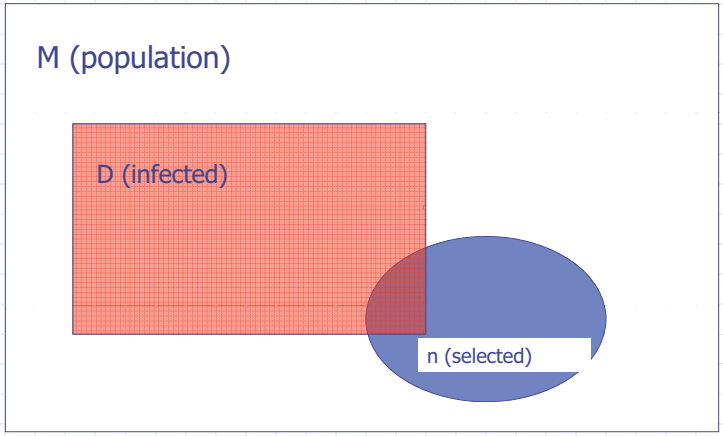


5%	1
10%	1
15%	2
20%	3
25%	3
30%	4
35%	5
40%	5
45%	6
50%	7
55%	8
60%	9
65%	10
70%	12
75%	14
80%	16
85%	19
90%	22
95%	29

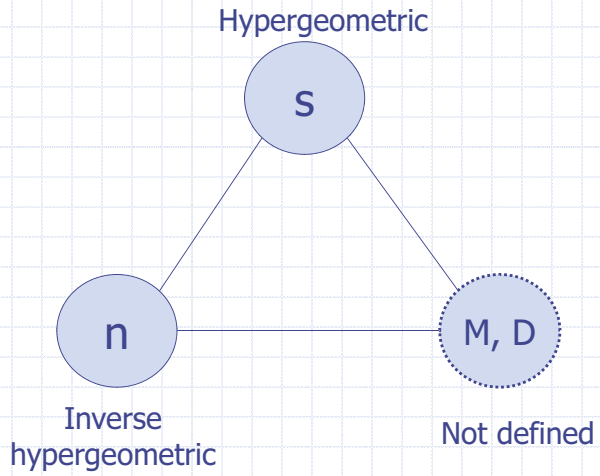
Hypergeometric process

- Has three variables:
  - M- population
  - D- number of diseased
  - n- number of trials
- Format
  - Hypergeometric (n,D,M)

Hypergeometric process



Distributions of the hypergeometric process

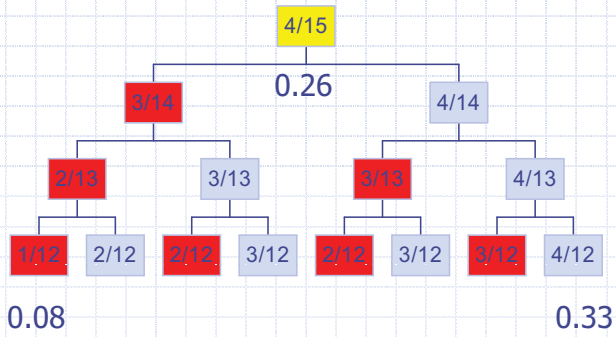


Hypergeometric process

- Unlike the binomial process, the probability of success changes in each trial depending on the result of the previous trial
- It is equivalent of conducting sampling without replacement

Hypergeometric process

- In small populations the change in (p) is more noticeable

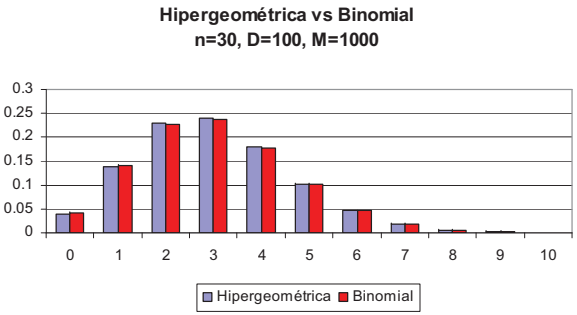


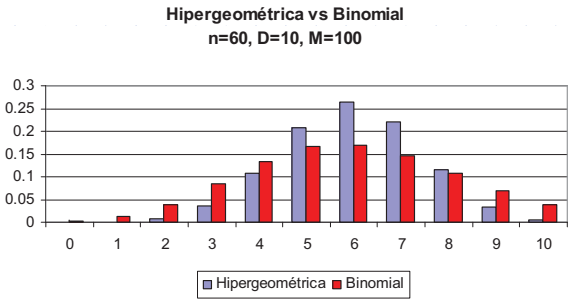
Hypergeometric distribution

$$p(x) = \frac{\binom{D}{x}\binom{M-D}{n-x}}{\binom{M}{n}}$$

Hypergeometric or binomial?

- As a general rule if the sample size is much smaller than the population (n<0.1M) the binomial distribution approximates closely the hypergeometric





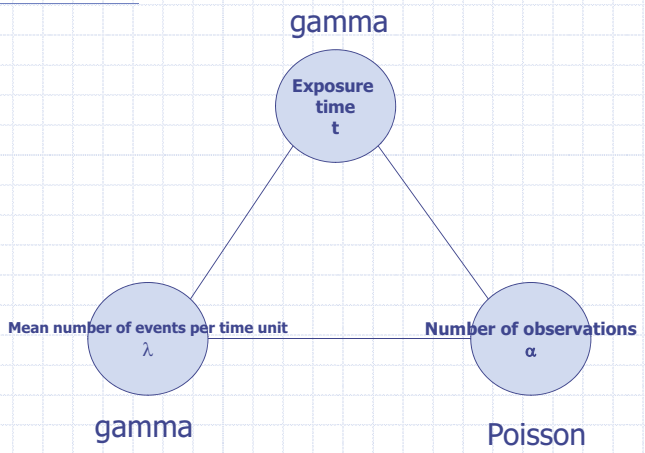
Poisson process

- Models the number of events α occurring in an interval (t) of space or time
- Has 3 variables:
  - Lambda (λ) – mean number of events by unit of exposure
  - Total exposure (t) – May be time, volume or another measure
  - Number of events (α) in exposure period (t)

Poisson process

- The probability of occurrence in an interval is constant and continuous
- The number of events occurring in an interval is independent of the number of occurrences in any other interval
- The interval (t) is measured in space (liters, kilograms, meters, etc.) or in time (second, hour, year, etc.)

Distributions of the Poisson process



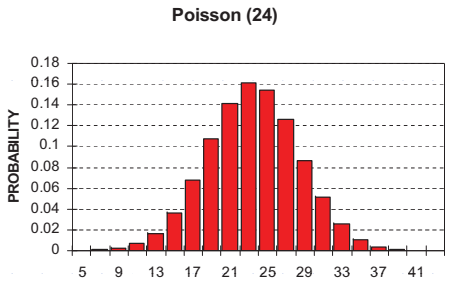
Poisson distribution

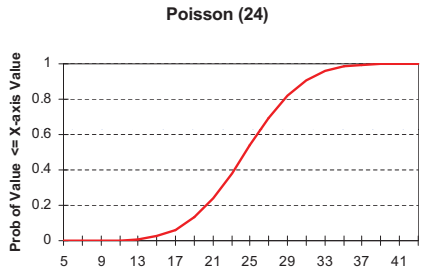
- Number of events α in time t
  - Poisson (λt)
- Lambda (λ) – mean number of events per exposure unit

  $\lambda = 1/\beta$
- Mean time between events (β)

Poisson distribution

- Example. An inspector in a slaughter house finds 3 chickens with hematomas per hour at the slaughterhouse. How many will she find in an 8 hour shift?
  - Lambda (λ) – Mean number of events by unit of exposure $\lambda = 1/\beta = 3$
  - Mean interval between events (β)=0.33 (hours)
  - Number of events α in time t = Poisson (λt) =Poisson(3x8)





5%	16
10%	18
15%	19
20%	20
25%	21
30%	21
35%	22
40%	23
45%	23
50%	24
55%	25
60%	25
65%	26
70%	27
75%	27
80%	28
85%	29
90%	30
95%	32

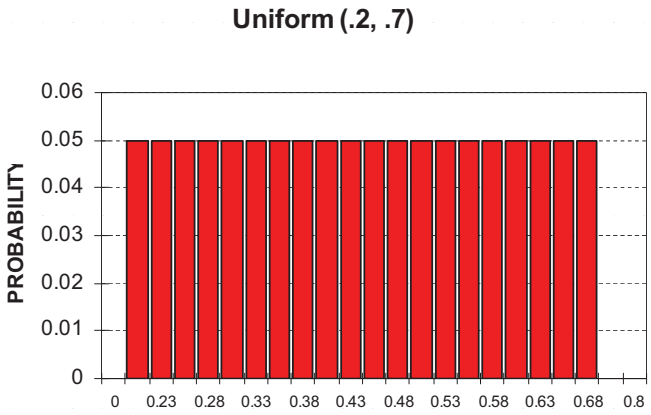
Approximations

- Poisson (λt) approximates the binomial distribution (n, p) when p is very small
- Binomial (n, p) approximates hypergeometric (n, D, M) when M is large
- Poisson (λt) approximates hypergeometric (n, D, M) when M is large and D/M is very small

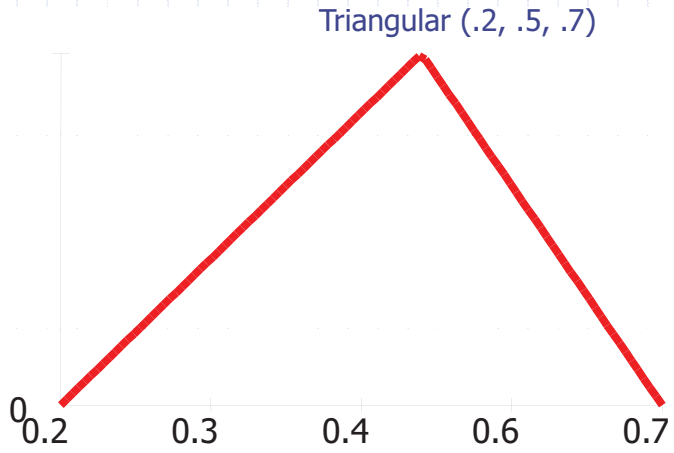
Distributions of ignorance

- Uniform distribution
  - Requires a minimum and a maximum
- Pert and triangular distributions
  - Require a minimum, most likely and maximum

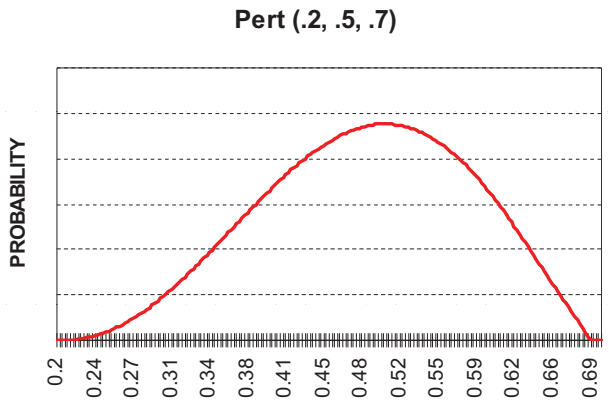
Uniform distribution



Triangular distribution



Pert distribution



Conclusions

- The binomial, hypergeometric and Poisson processes are the building blocks most frequently used in risk analysis
- The models should be coherent, ensuring that each iteration is plausible.

Quantitative Models

Tim Clouse

Veterinary Services

Safeguarding Animal Health

Topics

- Differences between qualitative and quantitative models
- Commonly used probability distributions
  - Types
  - Why and when to use
- Design
- Layout and documentation

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Qualitative and Quantitative Methods

- Qualitative and quantitative methods are two ends of a continuum
- Qualitative methods discuss the issues, likelihood, and consequences in non-numerical terms
- Quantitative methods use specific numerical values and explicit probability distributions for likelihood and consequences
- Both are valid
- Most risk analysis is a mixture of both
- ***Neither is superior or preferred***

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Comparisons

- Qualitative methods…
- Applicable to a broader range of issues
- More flexible
- Not as constrained by data availability
  - May appear to be subjective
- May lead to ambiguous interpretation

- Quantitative methods…
- Likelihoods are explicitly defined
- Results tend to be unambiguous
- Policy-relevant variables/critical points more easily found
  - More data-dependent
- Less general applicability

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Qualitative vs. Quantitative Methods

- Qualitative
  - Reasoned and logical discussion
  - Most common, faster
  - Applies to many problems
  - Results are expressed as high, medium, low negligible
- Quantitative
  - Links the steps through mathematical modeling
  - More time-consuming
  - Model values rely on data or expert opinion
  - Results are expressed numerically

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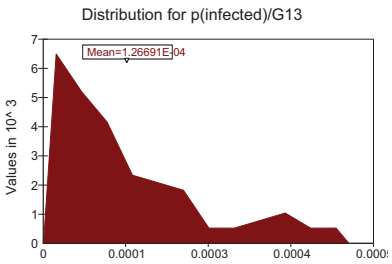
Quantitative Methods

- Usually feature specific numbers--p(outbreak in one year)
- Usually requires extensive empirical data or explicit expert opinions
- Yields an explicit, but often complex, model, description, and results



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Probability Distributions for Risk Analysis

- Parametric and non-parametric distributions
- Parametric distributions assume an underlying causal relationship that is mathematically based
- Non-parametric distributions are based directly on the observed information and make no statements about underlying causal relationships

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Probability Distributions for Risk Analysis

- Parametric distribution types
- Discrete or continuous (as the sample size increases, discrete distributions become similar to continuous ones)
- Bounded or unbounded (for continuous distributions--all discrete distributions have bounds)
  - May need to constrain to eliminate meaningless values (age ≤0, BSE incidence >500/1 000 000

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Six Useful Distributions

1. Normal (Gaussian)
2. Lognormal
3. Beta (and variants)
4. Uniform
5. Binomial
6. Negative Binomial

Normal (Gaussian) Distribution

- Models phenomena where causes are independent and *additive* (individual weights, distribution of errors)
- Unbounded, so constraints may be needed
- Tends to be used as a first approximation/default distribution

Lognormal Distribution

- Models phenomena where causes are independent and *multiplicative* (incomes, disease incubation times)
- Minimum value is greater than 0
- Unbounded on the right, so constraints may be needed
- Tends to look like the normal distribution when the coefficient of variation (standard deviation/mean) is small (less than 0.5)

Beta Distribution and Variants

- Models variations in *probabilities* (not phenomena)
- Flexible:
- Can create a wide variety of shapes over a given range
- Can be used to approximate an empirical distribution
- PERT distribution--for modeling expert opinion
- Beta-Binomial distribution--for modeling binomial success where the true value of p is uncertain

Uniform Distribution

- All values within a range are equally likely
- Makes the fewest assumptions about underlying causes
- Most cautious approach, but tends to yield the widest variance

Binomial Distribution

- Models phenomena where the likelihood of occurrence does not change over time or space (number of infected animals detected in a herd)
- Bounded and discrete
- Beta-binomial is often a better description of reality, but needs additional data

Negative Binomial Distribution

- Models phenomena where the likelihood of occurrence does not change over time or space and the number of failures is of interest (number of animals needed to be tested in a herd to find the an infected one)
- Bounded and discrete
- As with the binomial distribution, the value of p is often more usefully represented by a beta distribution

Designing and Documenting Quantitative Models

- Start with a pathway
- Keep models simple at first and expand as needed

- Put sources, formulas, and comments in the spreadsheet
- Use Excel's Labels instead of spreadsheet references

Quantitative Model Example

Microsoft Excel Worksheet

What are your questions?

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