THE USE OF EPIDEMIOLOGICAL MODELS FOR THE MANAGEMENT OF ANIMAL DISEASES

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***Summary**: Modelling is a widely used tool to support the evaluation of various disease management activities. The value of epidemiological models lies in their ability to study 'what if' scenarios and provide decision-makers with a priori knowledge of consequence of disease incursions and impact of control strategies.*

To be useful, models need to be fit for purpose and appropriately verified and validated.

The complexity and variability inherent in biological systems should limit the use of models during actual outbreaks as predictive tools. Modelling will be most useful when used pre-outbreak, particularly in the areas of retrospective analysis of previous outbreaks, contingency planning, resource planning, risk assessment and training. Models are just one tool for providing scientific advice, and results should be evaluated in conjunction with data from experimental studies, field experience and scientific wisdom.

Validation of epidemiological models is important to gain confidence in model outputs. International collaborations can help address validation issues and improve the utility of models for emergency disease management. Importantly, a majority of Member Countries of the OIE (World Organisation for Animal Health) viewed the OIE as having a role to play in developing guidelines for proper model development, verification, validation and application.

Key words: epidemiological model – modelling – simulation

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1. Introduction

The Animal Health Codes of the OIE (World Organisation for Animal Health), in their general chapters, refer to concepts such as ‘risk analysis’, ‘contemporary performance of the Veterinary Services’, ‘accountability and transparency of decision-making’, ‘animal disease emergency preparedness and response plans’, ‘epidemiological surveillance or monitoring programmes’, etc.

Veterinary Services therefore need tools to prepare and deal effectively with such issues. Electronic and other technological advances, as well as progress in scientific understanding and analysis of animal disease situations and their management are important elements in steady improvements of the performance and preparedness of Veterinary Services in serving society to the best possible extent. Some of these advanced tools may require highly specialised skills of their operators and do require access to the necessary expertise within or outside of the Veterinary Services.

One such tool is ‘epidemiological models’. Several OIE Member Countries already have experience with this tool, and the scientific literature contains many examples of epidemiological models having been applied to a variety of animal disease situations. Obviously, not so experienced countries or Veterinary Services might benefit from a review of the advantages and the risks associated with this tool, as well as getting a feel for which types of management decisions may be supported by the use of such models.

This paper reviews the uses of modelling as a tool to support the formulation of disease control policy, the experience of modelling in controlling foot and mouth disease (FMD) in the United Kingdom 2001 outbreak, the current international initiatives to improve the linkages between modelling and policy formulation, and the results of an OIE questionnaire on modelling usage.

2. Rationale behind the use of models in the management of animal diseases

Models provide frameworks that allow ideas about the behaviour of a particular system to be conceptualised and communicated [12].

In the case of animal diseases, it is well understood that disease results from the interaction of agent, host and environmental factors. Thus, models provide a logical and low cost basis for studying these interactions, evaluating impacts and testing responses to interventions.

Traditionally, the response to outbreaks of serious livestock diseases like FMD, classical swine fever and highly pathogenic avian influenza (HPAI) has been based on movement restrictions and ‘stamping out’. Since the year 2001, following the FMD outbreak in the United Kingdom, large-scale culling and disposal of animals for disease control purposes have been questioned on political, economic, ethical, environmental and welfare grounds. As a result, international guidelines on the control of FMD have now made options like emergency vaccination more acceptable from a trade recovery perspective.

There is a need for disease managers and policy makers to examine and evaluate alternative approaches to disease control that address these concerns, including emergency vaccination as a tool to reduce the numbers of animals destroyed. In addition, it is now well recognised that the speed with which effective decisions are taken when faced with such outbreaks will often determine the success of the eradication programme. Evaluating the possible consequences of these outbreaks and testing various control options in advance could help reduce the spread of such diseases.

However, evaluating alternative approaches to controlling infectious diseases is not a simple task as there is a range of issues that will need to be considered. These considerations include resource requirements, trade and economic implications, access to appropriate technology (e.g. vaccines or diagnostic tools), consumer concerns and public health ramifications. Of particular concern for countries exporting livestock and livestock products is the attitude of trading partners, since the major economic impact of diseases like FMD may be due to loss of export markets rather than the productivity losses associated with the disease per se. In the case of zoonotic diseases there may be occupational health and safety issues that need to be taken into account. Finally, the choice of control measures is often a compromise between the requirement for large-scale implementation and what is logistically and economically feasible. Clearly, developing policy options under such circumstances is challenging. In considering control strategies, it is important that the interests of all stakeholders and all costs be taken into account [7].

Modelling is a useful tool that can assist with these types of evaluations. In a policy context it is common to link epidemiological and economic models. Indeed, a range of such studies has been published to evaluate control strategies for emergency diseases like classical swine fever and FMD [1, 16].

3. Definition of epidemiological models

The definition of 'epidemiological models' is very important for this technical item. However, a clear definition of the term does not seem to exist in the veterinary field.

An epidemiological model is usually defined as 'a mathematical and/or logical representation of the epidemiology of disease transmission and its associated processes'. These quantitative models provide a representation of the transmission dynamics of animal diseases among animals, and/or among groups of animal in time and/or space.

An epidemiological model therefore facilitates the evaluation of the efficacy of the potential control measures and provides estimates of the future magnitude, duration and geographical extent of an outbreak given the application of specific control measures.

However, in relation to the management of animal diseases epidemiological models could be defined more broadly to include a range of statistical/mathematical models, which do not necessarily provide just a description of disease spread. Related aspects to be considered include e.g. the design of surveillance systems.

4. Overview of disease models

All models are, by nature, simplifications of more complex systems. Disease models can be classified into various categories depending on their treatment of randomness or variability, time, space and the structure of the population. The approaches will vary from simple deterministic mathematical models through to complex spatially-explicit stochastic simulations.

The most appropriate type of model to use in a given situation will depend on the sorts of issues being studied. For example, while deterministic models, which are typically based on average or expected value parameters, may be useful for understanding basic infection dynamics, they are of limited use as a predictive tool since any one epidemic is unique and unlikely to follow an 'average' pattern [7]. However, when epidemiological knowledge and good quality data are available, more elaborate models that provide a range of possible epidemics can be developed.

The increasing sophistication of computers, together with greater recognition of the importance of spatial elements in spread of disease, and interest in specific spatially targeted strategies like emergency ring vaccination or contiguous slaughter, mean that models which incorporate spatial components are becoming more important in epidemiological studies [8]. As well, network-based modelling is a relatively new but growing field to study the spread of diseases through contact networks [12].

The process of model building must start with specific questions to answer in order to provide its scope. The choice of model will depend on how well the epidemiology of a disease is understood, the amount and quality of data available and the background of the modellers themselves. The level of complexity to include in a model is an art as well as a science. Adding additional elements may increase complexity without necessarily improving quality of the outputs. On the other hand ignoring factors that are clearly important in the epidemiology of a disease may result in model findings that are misleading [7].

A critical step in model development is the process of model verification and validation to ensure that it behaves like the system it is designed to represent. Verification is defined as the process that ensures that the logic, formulae, and computer code of the model correctly reproduce the logical framework conceived by the model designer [21]. Validation ensures that the model is 'true to life' [21]. This implies that the assumptions underlying the model are correct and that the model's representation of the studied system is reasonable for the intended purpose. A more comprehensive view of validity considers: 'data validity', or the correctness of the data used to construct and parameterise the model; 'conceptual validity', or the correctness of the mathematical and epidemiological logic upon which the model is built; and 'operational validity', or the ability of the model, as implemented, to produce results of sufficient accuracy.

5. Application of epidemiological models

The main advantage of using models in animal health is as inter-epidemic tools to aid retrospective analyses of real epidemics to gain an understanding of their behaviour [14]. By allowing large amounts of information to be combined in a structured way, hypothetical scenarios can be developed to provide insights into the merits of different strategies in different situations, e.g. how does a pre-emptive culling strategy compare with a test-and-cull strategy? In this way, decision-makers can be provided with *a priori* supporting guidelines for control that can be used in conjunction with veterinary wisdom and experience – not as a substitute for them.

Modelling can contribute to better disease control through [21]:

- retrospective analysis of past outbreaks and evaluation of different control strategies;
- exploration of different strategies in hypothetical outbreaks (contingency planning);
- exploration of the resource requirements of different strategies in hypothetical epidemics (resource planning);
- risk assessment to identify priority areas, those that might be at greater risk to better target preparedness and surveillance activities;
- evaluation of the effectiveness of various surveillance strategies;
- underpinning economic impact studies;
- provision of realistic scenarios for training exercises and communication of principles of epidemiology and disease control;
- provision of tactical support during epidemics through analysis and hypothesis testing – although with caution.

Models can be used retrospectively or prospectively [23]. The former involves fitting mathematical equations to epidemiological data and interpreting these data quantitatively. Prospective models can be either predictive in that they use current data as the basis for predicting the course of an outbreak, or exploratory, modelling a range of possible epidemiological scenarios rather than focussing on one particular event. Such models are often used in contingency planning.

Examples of the different types of models are presented below:

- A logistic regression model was developed to determine the distribution in Europe of *Culicoides imicola*, a vector for various arboviruses such as bluetongue virus (BTV) and African horse sickness (AHS) [22]. By knowing its distribution in advance of disease outbreaks, control measures (e.g. vaccination, use of insecticides and insect repellents, etc.) could be targeted more efficiently. Climatic variables and variables derived from satellite imaging were used. Such a model may help in targeting surveillance and control measures.

- In the Netherlands, a stochastic simulation model ('InterCSF') was used to recreate the 1997−98 epizootic of classical swine fever. Various culling and vaccination strategies were evaluated and the epidemiological model was linked to an economic model [17, 18]. The major finding from these studies was that a pre-emptive culling policy was an effective strategy to reduce the size of an epidemic if applied early in the control programme. Economically, the policy was not as expensive as expected because of smaller epidemic size and reduced welfare slaughter. Emergency vaccination appeared to be an effective alternative approach for reducing the size of an epidemic, although under European Union regulations, reduction in costs associated with reduced welfare slaughter would be offset by the need to cull vaccinated animals. Acceptance of trade in meat from vaccinated animals (assuming a reliable diagnostic test) was found to be significantly cheaper than other strategies, as well as, from an ethical perspective, reducing the need to destroy healthy pigs [1].

- Yoon *et al.* [24] used 'InterSpread Plus', a stochastic spatial simulation model of between-farm spread of disease, to evaluate the effect of alternative strategies for controlling the 2002 epidemic of FMD in the Republic of Korea. Starting with a reference scenario that recreated the epidemic, alternative epidemic-control strategies were then evaluated for their predicted impact on size and duration of the epidemic. Ring vaccination (when used with either limited or extended pre-emptive culling) reduced both the size and variability of the predicted number of infected farms. Reducing the time between disease incursion and commencement of controls had the greatest effect on reducing the predicted number of infected farms.

- In Australia, studies [9] have shown that in some cases, control measures such as emergency vaccination when combined to stamping out can reduce the size of FMD outbreaks and the number of animal culled to achieve eradication. However, under international trade guidelines the effect of market closures means that the approach is uneconomic when compared with stamping out alone. Abdalla *et al.* [1] used epidemiological and economic modelling to explore situations under which vaccination may become cost effective, taking into consideration the importance of resources. Three control strategies involving stamping out with or without emergency vaccination were compared in an intensive livestock-producing region of Australia. The comparisons took into account resource constraints, different levels of severity of outbreak and times to first detection. The study found that vaccination may be a cost-effective option where disease spreads rapidly and if available resources are insufficient to maintain effective stamping out. Under these conditions, it was likely that the disease could spread widely, leading to extended periods of market closure. The study also reinforced the importance of early detection as a key factor influencing the probability of containment.

- Modelling is being used in North America to assist with emergency disease preparedness. In October 2006, the North American Animal Disease Spread Model (NAADSM) [10] was used to simulate an outbreak of HPAI in the State of Georgia. The simulation was used to provide the potential scope and impact of an outbreak during a tabletop exercise organised by the US Department of Agriculture's National Veterinary Stockpile staff and the Georgia Department of Agriculture. The purpose of the exercise was to identify resources that would be needed during a HPAI outbreak, to test some aspects of the Georgia response plan for HPAI with Federal and State agencies and poultry industry representatives, and to test the capacity of their current response teams and resource management methods. The exercise assisted participants to better understand what their responsibilities are and identify any gaps in the Federal and State response plans [7].

6. Modelling and the 2001 FMD epidemic in the United Kingdom

Models have been used as a tool in veterinary epidemiology for many years and have rarely attracted attention as they have been largely confined to studies of hypothetical outbreaks, or they have been used retrospectively in analyses of past outbreaks [7]. The 2001 FMD epidemic in the United Kingdom was the first situation in which models were developed during an epidemic and used to guide control policies. The experience has produced differing views as to the value of modelling, with some authors commenting on the important role that it played [11] while others have condemned it [14]. Unfortunately, one of the legacies of the UK experience has been a questioning of the role of modelling and loss of confidence in scientific advice based on modelling.

The main point of discussion on the use of models in 2001 is centred on the fact that the large-scale culling of apparently healthy livestock used to ostensibly bring FMD under control caused widespread community concern. The financial and social costs led to changes in national and international legislation and guidelines for controlling future epidemics [14]. The experience also generated varying opinions about the validity and usefulness of the models and their predictions [11, 21].

Early in the outbreak, findings from predictive mathematical modelling [5, 6] were used as evidence to support conclusions that the epidemic was out of control and that current measures were insufficient to establish control. It was recommended that a rapid cull of suspected infected premises and all farms contiguous to infected premises was essential for controlling the disease [5, 6]. An aggressive control policy based on culling susceptible animals on infected premises (within 24 hours) and on the pre-emptive culling on dangerous contact premises and premises adjacent to infected premises ('contiguous cull' policy) within 48 hours was introduced [11]. This policy was credited with bringing the outbreak under control [6]. However, subsequent analyses have labelled contiguous premise culling as 'a blunt policy instrument' [2] and questioned whether the extensive culling programme and particularly culling on contiguous premises, was necessary [15].

It has been suggested that the models at the time were not validated, particularly for the type O pan-Asia strain of the virus, and contained simplifications and assumptions which biased the outcomes and heavily influenced conclusions about the effectiveness of different control strategies [14, 21]. For example, a recent study showed that premises close to infected premises do not inevitably become infected — a significant proportion remain uninfected even under intense infection pressure [20]. These retrospective findings suggest that selective culling of dangerous contacts would have been a viable alternative to the mass culling policy.

7. International collaboration on model evaluation

As part of a process designed to improve the ability to deal with animal disease emergencies, the 'Quad countries' —Australia, Canada, New Zealand, and the United States— held a workshop on FMD modelling and policy development in Canberra, Australia, in March 2005. The objectives of the workshop were to present policy makers with disease simulation models developed for contingency planning in the Quad countries and to review the current status of FMD response strategies. A key outcome of the workshop was the creation of a technical group comprised of epidemiologists from the Quad countries, Ireland, and the United Kingdom. Following the workshop, the technical group developed a work programme that included a project to jointly verify and validate models for use in FMD policy development in their respective countries [4].

Unfortunately, a formal approach to infectious disease model validation does not exist. There is no set of specific tests that can easily be applied to determine the 'correctness' of a model. The three modelling groups involved in the Quad countries are in the process of or have already taken various steps to verify and validate their models with efforts such as sensitivity analyses, expert reviews of assumptions and comparison of model outputs with real FMD outbreak data. While comparison of model predictions with real outbreak data remains the ideal means for testing model validity, a demonstrated level of agreement between independently developed models using identical data should provide policy makers with reassurance of the consistency of assumptions made by model developers. Conversely, differences in model output provide a means for highlighting differences in assumptions that need to be resolved by modellers and researchers, and provide a better focus for future research [4].

A formal comparison of three models used for FMD policy development (Australia – AusSpread [8]; New Zealand – InterSpread Plus [19]; Canada and United States – NAADSM [10]) was carried out. All models are stochastic spatial simulation models that have been developed independently. The study [4] included a comparison of the logical framework of the model, as well as a comparison of a series of model outputs from eleven scenarios of increasing complexity that evaluated various spread mechanisms and control measures. Despite different approaches to model building, and some statistically significant differences in outputs from the three models, the differences were generally small. From a practical perspective the outputs were quite similar. From a policy perspective, it was reassuring that despite the different approaches used, the models produced consistent outcomes and it was concluded that any decisions based on the findings of each model would not have differed. In addition, the study was a useful verification exercise as it required the modellers to re-examine in depth the way core functions had been implemented, and minor programming and logic errors were found and corrected.

A similar project has been carried out by International EpiLab[1] as a multi-centre comparison of modelling tools for the evaluation of FMD vaccination strategies in Denmark. The objective of the study was to compare three stochastic simulation models for modelling the spread of FMD using different control strategies. Also here the InterSpread model from Massey University (New Zealand) [19] was used with a University of California, Davis model (United States of America) [3] and a Warwick University model (United Kingdom) [12]. The results of comparative scenario simulations are in progress (Milne *et al.*).

8. Questionnaire results

Questionnaires were sent to all OIE Member Countries in the month of February 2007, with 103 (61%) countries returning them completed (n=92) or partially completed (n=11) (See Appendix I).

Overall, 50 Member Countries (49% of respondents) use models in contingency plans while 48% of respondents declared they do not use models but would like to develop this area. Only 4 countries did not consider developing this area.

Africa and the Middle East were the regions with the lowest proportion (28%) of Member Countries using models and with the most desire to develop this area. More than half (58%) of Member Countries in the Americas, Europe and Asia-Pacific regions are already using models.

Surveillance, disease transmission and risk models were the most used and/or desired models in member countries, irrespective of the region, while fewer countries (40-55) were promoting meteorological, economic and resource models. Other models listed included: animal movement models, production models, transport models, cost/benefit models, geographical models, alert systems models, and ecosystem models. The types of disease management activities to be supported by models were lead by vaccination, surveillance and movement restriction models, each of which counted approximately 90 supporting countries. Models to be used for considering stamping-out, ring culling and disposal capacity, were less frequently considered by non-using countries than by those countries having used models. This might be confounded by the regional differences in use eluted to earlier and by regional differences in control policies. In addition, some countries used models to assess: welfare culling, benefits of animal identification, compartmentalisation, and strategies to minimise the risk of introduction of diseases.

All countries supported the use of models both prior to and during epidemics, while model users indicated their inclination to use models also after outbreaks as a retrospective tool. Thus half of all responding Member Countries use or would consider to use models before, during and after the outbreak, 25% only before and during, while all other combinations were much less frequently listed.

1 International EpiLab: OIE Collaborating Centre for Research and Training in Population Animal Health Diagnosis and Surveillance Systems

In general, it seems that those countries wishing to develop modelling intend to involve fewer professionals than those countries who have already used models. Epidemiologists were listed in all responses, while the other professionals listed received fewer indications. Other experts indicated were: accountants, virologists, computer programmers, biologists, ecologists, GIS/spatial scientists, ornithologists, wildlife biologists, hunters, communications specialists, field experts, medical doctors and pharmacists.

There was general agreement that veterinary administrations should be the most involved in all steps: development, running of models and applying the results. Research institutes and international experts appear to be important in the development. Agricultural organisations appear to be involved in all steps, with more countries reporting their involvement in applying the results of models.

In 84% of the countries that have used epidemiological models, the Veterinary Services have a designated person or group responsible for epidemiological models. This was expected as responses in general showed that the Veterinary Administration is involved in all steps of modelling.

Of the 103 countries that have completed the questionnaire, 60% listed lack of expertise and 55% listed lack of resources. Only 12 countries neither lack resources or expertise. Of those 12 countries, 7 countries made comment on other limitations on the use of epidemiological models of which lack of comprehensive data —population demographics, animal movements, marketing data— was the most common limitation reported. Lack of time resources and of full-time personnel and lack of training and financial resources were also reported.

The Member Countries wish the OIE to assist in the further development in the modelling area through: developing guidelines (74 countries), designating collaborating centres (43 countries), establishing expert groups (59 countries) and/or acting as a clearing-house for models (57 countries). The results show that Member Countries are interested in seeing OIE play a larger role in providing guidance on the development and uses of models. Other proposed roles were to provide training courses, seminars or workshops; provide expert review of models; utilise models to simulate international spread of disease and thus identify and direct where international resources (training and technical) can best be applied to limit spread; establish a training centre; develop expert groups to support Member Countries in their selection of models; and develop virtual modelling centres where countries without the capacity may have access to various epidemiological models.

Regarding the 4 countries that indicated no desire to develop the modelling area, all the reasons proposed in the questionnaire were put forward, with the need to know more about the use of models being the most frequent response.

Highly pathogenic avian influenza was the disease of highest priority for epidemiological modelling, closely followed by FMD, rabies, Newcastle disease and bovine spongiform encephalopathy. Other diseases reported in high numbers: classical swine fever, which was listed as a disease of highest priority in 15 countries, bluetongue, bovine tuberculosis, brucellosis, Rift Valley fever, African swine fever, contagious bovine pleuropneumonia, and peste des petits ruminants.

Although most respondents indicated that veterinary services should be responsible for management/governance of epidemiological models, a number of countries indicated the desire to have shared responsibilities between public/research/private sectors. Although final accountability of uses of models rests with the veterinary administrations, there was some mention that other groups should not be restricted from using models.

9. Discussion

Epidemiological and economic modelling are recognised as valuable tools that can assist disease managers in identifying and evaluating alternate approaches to disease control. Evidence for this is seen in the extensive scientific literature on epidemiological modelling, and the increasing preparedness of many veterinary services to build capacity in this area. Suitably designed epidemiological models can be used to study disease impacts, in risk assessment; assist in designing cost-effective disease surveillance and control programmes; and contribute to contingency planning for emergency diseases. Models are particularly valuable because they enable hypothetical outbreak and control scenarios to be studied in advance. For example, one can simulate outcomes under different assumptions concerning types of strategy, availability of resources, reactions of trading partners, etc., and thus help identify conditions under which different approaches might or might not be beneficial. These findings do need to be kept under review as new technologies —such as new diagnostic methods or vaccines— and changes to international guidelines and trading protocols might alter the balance [7].

As described in Garner *et al.*, it is important that models used to inform disease control policies are used appropriately [7]. While there is general recognition of the value of modelling to support policy development through retrospective analyses and contingency planning, the role of predictive modelling as a tool to support tactical decision-making in an actual outbreak is less clear. Any model ultimately depends for its validity on the accuracy and completeness of the data underpinning it [11]. Unfortunately, the data is not always available or reliable, particularly early in an outbreak when decisions taken typically will determine the size of the subsequent epidemic. This data issue creates a serious problem for prediction using models. The models used in the 2001 FMD epidemic in the United Kingdom have been criticised because they were constructed with out-of-date and poor quality data and poor epidemiological knowledge [14]. Recent analyses have cast doubts on the appropriateness of policy made at the time based on these models [14, 20]. In his comprehensive review, Taylor [21] concluded that use of predictive models to support tactical decision-making is not recommended. Decisions should be based more on veterinary intelligence rather than on predictive modelling, although modelling can play a role in interpretation of veterinary intelligence. Another view is that modelling can be valuable in making rapid and informed decisions about control strategies in an outbreak, provided that the model has been developed, tested and is ready for immediate application.

Modelling is a specialised field, and modellers are often considered as being remote from the real world by the management and field staff, and their outputs may be viewed with suspicion. It is important that modellers do not work in isolation and to understand that models are just one tool for providing scientific advice [7]. Any findings should not be considered in isolation to those from experimental studies and collection and analysis of epidemiological data. Proof of validity of any model should be required before it is used to influence policy. Communication of results to decision makers is also an important issue. Findings reported from modelling studies should be accompanied by full disclosure of the assumptions used and any limitations of the approach [21].

Recent initiatives, like the formation of the Quad's EpiTeam and the EpiLab Multi-Centre-Project, have demonstrated the value of international cooperation in developing and validating modelling tools for use in animal health emergencies.

The results from the questionnaire survey underline the notion that modelling to manage animal diseases is a topical and relevant issue of considerable interest and importance to the international veterinary community. They show that epidemiological modelling is already a growing field of activity within many OIE Member Countries, while an equal number of countries are in planning or preparatory stages of initiating modelling activities. A wide variety of conditions, diseases and application areas are being modelled, and there are strong indications that there is a need and desire to have more international cooperation and support in guiding and promoting the applications. Also in this area there appears to be a need for strengthening Veterinary Services worldwide though international cooperation and technical support.

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.../Appendix

Appendix I

OIE Members having responded to the questionnaire on "The use of epidemiological models for the management of animal diseases"

1. Albania
2. Algeria
3. Andorra
4. Angola
5. Argentina
6. Armenia
7. Australia
8. Austria
9. Azerbaijan
10. Bahrain
11. Belgium
12. Belize
13. Benin
14. Bolivia
15. Bosnia and Herzegovina
16. Brazil
17. Bulgaria
18. Burkina Faso
19. Cameroon
20. Canada
21. Chile
22. Colombia
23. Congo
24. Costa Rica
25. Croatia
26. Cyprus
27. Czech Republic
28. Denmark
29. Dominican Republic
30. Egypt
31. El Salvador
32. Eritrea
33. Estonia
34. Finland
35. France
36. Georgia
37. Germany
38. Ghana
39. Greece
40. Guinea-Bissau
41. Haiti
42. Iceland
43. India
44. Indonesia
45. Iran
46. Ireland
47. Israel
48. Italy
49. Japan
50. Jordan
51. Kazakhstan
52. Korea (Rep. of)
53. Kuwait
54. Latvia
55. Lesotho
56. Lithuania
57. Luxembourg
58. Madagascar
59. Malawi
60. Mauritania
61. Mongolia
62. Morocco
63. Mozambique
64. Myanmar
65. Namibia
66. Netherlands
67. New Caledonia
68. New Zealand
69. Norway
70. Oman
71. Paraguay
72. Peru
73. Philippines
74. Poland
75. Portugal
76. Romania
77. Saudi Arabia
78. Senegal
79. Serbia and Montenegro
80. Singapore
81. Slovakia
82. Slovenia
83. Spain
84. Sri Lanka
85. Sudan
86. Swaziland
87. Sweden
88. Switzerland
89. Syria
90. Taipei China
91. Thailand
92. Togo
93. Tunisia
94. Turkey
95. Ukraine
96. United Arab Emirates
97. United Kingdom
98. United States of America
99. Uruguay
100. Uzbekistan
101. Vietnam
102. Zambia
103. Zimbabwe