African swine fever: ArcGIS for modeling risk of the disease spread

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- OIE* Regional Reference Laboratory for Foot-and-mouth Disease (FMD) for Eastern Europe, Central Asia and Transcaucasia
- OIE Coordinating Center for Diagnosis and Control of Animal Diseases for Eastern Europe, Central Asia and Transcaucasia
- The Center produces biological preparations of high quality for prevention and treatment of animal diseases
- The Center carries out researches in the framework of several Federal scientific and technical programs as well as international projects

*OIE - Office International des Epizooties
currently World Organization for Animal Health
http://www.oie.int/
My department: The Center for Information and Analysis

- Monitoring of animal disease situation in Russia and abroad
- Disease mapping, modeling and forecasting
- Reporting to OIE
- Risk analysis in export/import operations with animals and food products

GIS

- Esri customers since 2007 (via Esri-CIS http://www.esri-cis.ru)
- ArcGIS for Desktop Advanced and Basic
- Spatial Analyst, 3D Analyst, Geostatistical Analyst, Data Interoperability
African Swine Fever (ASF)

- Contagious viral disease of domestic and wild pigs
- Near 100% mortality
- No vaccine
- No danger for human, but causes huge economic impact:
  - Total swine depopulation at the infected farm and within the risk zone of 5 – 20 km radius
  - Transportation and trade bans within the surveillance zone of 100 – 150 km radius
  - Affects the international pork market
- Currently endemic in the islands of Madagascar and Sardinia, in some African countries
ASF
Main transmission routes

- Direct contact between infected and susceptible pigs
- Transportation of live animals, pork products, contaminated fodders and garbage
- Wild pigs (boars) – usually considered secondary and hardly can spread the virus at large distances. But …
- *Ornithodoros* ticks – natural reservoir, but not present in Russia
ASF in Russia: 657 cases as of June 2014
2007:
2 cases in wild boar

- Introduction from Georgia is suspected
- ~60 cases were confirmed in Georgia in 2007
2008: 62 more cases
2009: 73 more cases
2010:
84 more cases
2011:
63 more cases
2012:
120 more cases
Two large ‘endemic zones’

Zone ‘North’

Zone ‘South’

Zone borders were defined using ‘Standard Distance’ tool
(ArcToolbox → Spatial Statistics Tools → Measuring Geographic Distributions) with 2-std radius

Those cases outside the endemic zones are considered ‘remote’
Cluster analysis. Zone ‘South’

1. Use ‘Grouping Analysis’ tool (ArcToolbox → Spatial Statistics Tools → Mapping Clusters) to identify significant spatio-temporal clusters of cases.

2. Use ‘Directional Distribution’ tool (ArcToolbox → Spatial Statistics Tools → Measuring Geographic Distributions) to reveal time-space trends of the epidemic spread within clusters.

Consider date of outbreak as weight parameter.
Cluster analysis.
Zone ‘North’

1. Use ‘Grouping Analysis’ tool (ArcToolbox → Spatial Statistics Tools → Mapping Clusters) to identify significant spatio-temporal clusters of cases.

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Outbreaks’ scattering out from the initial center can be due to extensive monitoring shooting of wild boars.

Consider date of outbreak as weight parameter.
Modeling risk

- Where to expect a next ASF outbreak?
- Which risk factors are associated with the ASF spread patterns?
- Is the current practice of surveillance zones (100 – 150 km radius) effective enough to prevent spread of the disease?
Study area

- Endemic zone ‘South’ as of December 2012
- Only the cases in domestic pigs were considered (N = 211)
Plan of modeling

1. Create a suitability map
   (define all areas where the ASF outbreak could occur considering underlying socio-economic and geographical conditions)

2. Given a most recent ASF outbreak estimate ring zone of most probable virus transmission

3. Combine suitability map with ring zone to obtain a risk map of the ASF emergence given a most recent outbreak
1. Suitability map

- Use **Maximum Entropy** modeling method
- Analyze a set of known location points vs a set of spatial explanatory variables
- Primary use in health and ecology: ecological niche modeling (i.e. identification of habitat area of some particular species given its observed locations)
- Here we use socio-economic and geographical variables instead of environmental:
  - **Swine population density**
  - **Human population density**
  - **Road network density**
  - **Density of settlements (towns, villages)**
- All densities were calculated by ‘Kernel Density’ tool (ArcToolbox \rightarrow Spatial Analyst Tools \rightarrow Density), then converted to ASCII format (ArcToolbox \rightarrow Conversion Tools \rightarrow From Raster)
MaxEnt output – probability of observing an outbreak considering a combination of explanatory variables

MaxEnt output overlaid with the base map in ArcGIS

Raster conversion from ASCII to Esri grid was used

(ArcToolbox → Conversion Tools → To Raster)
Suitability map:

Indicates most suitable areas for ASF emergence

Comes from human presence and agricultural activity
2. Ring zone of probability

- Consider all existing ASF outbreaks a sequence of random events sorted by the date of occurrence
- Calculate distances in each pair of subsequent outbreaks
- Fit a distribution to the set of distances

Hawth’s Tools for ArcGIS was used: [http://spatialecology.com](http://spatialecology.com)
Ring zone of probability

- Gives an idea of a distance of most probable virus transmission from the affected farm

A raster surface centered at the affected farm decreasing exponentially $\sim \exp(-x / \mu)$, where $x$ is a distance from the farm, $\mu = 156.01$ km
... in 3D view (using ArcScene)

\[ F(x) = \exp\left(-\frac{x}{\mu}\right) \]
Important finding…

Mean risk distance of 156 km exceeds the conventional radius of surveillance zone (100 – 150 km) that clearly indicates weakness of current measures of disease prevention!
3. Combine suitability surface and ring zone to obtain final risk map

Use raster calculator
(ArcToolbox → Spatial Analyst Tools → Map Algebra)
to multiply two rasters...
Final risk map

Recently affected farm ('index case')
Conclusions

- Indicates the areas of risk of the disease spread from a recently affected farm → allows predicting an area of a next ASF outbreak
- Clearly demonstrates that the practice of 100-km surveillance zones can hardly prevent the spread of the disease
- Considers the real-world distribution of pig population and thus better defines a potential surveillance zone
• This study is published in
  *Spatial and Spatio-Temporal Epidemiology* journal, 2014:

  (currently in press)

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- International Society of Geospatial Health GnosisGIS (http://www.gnosissgis.org/)
Thank you for your attention!