Conclusion

The system adopts a universal network platform design. Upgrading the front-end sensors and equipment will not affect the system. It only requires the development of relevant interface plug-in dynamic links. The system software of the data and maintenance center is developed by the plug-in architecture, and the system function expansion only needs to replace or add different dynamic connection blocks, which has good scalability. With the universalized front-end design, the integration process for installing or upgrading different sensors or devices will be standardized. With remote on-line device debugging capabilities, and the system is very maintainable. The system provides data mining tools based on historical data, finds the relationships among data, develops prediction models, and optimizes configuration information. A sustainable and intelligent evolutionary system is finally formed, which can generate value for users for a long time.

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Global establishment risk of stored products beetles

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Abstract

Stored-product beetles were regarded as some of the most important stored-product pests in the world. Predicting which one in hundreds of potential invasive stored-product beetles is the most likely to invade a region presents a significant challenge. A global presence/absence dataset, including 201 economically significant stored beetles in 143 countries/regions, was analysed using a Self-Organizing Map (SOM) to categorize regions based on similarities in species assemblages. This method is able to rank these stored-product beetles based on risk of establishment indices (values between 0 and 1). From the six countries/regions selected from each continent, we can have an overview of the global invasive risk of this group of beetles. We also found that those countries geographically close were clustered together by the SOM analysis because they have similar beetle assemblages and therefore represent greater threats to each other as sources of invasive stored-product beetles.

Keywords: stored-product beetles, Coleoptera, self-organizing map, establishment risk

The stored-product beetles (Coleoptera), include more than 300 species in 40 families and cause about 85% of stored pest damage (Zhang et al., 2015). These taxa are of quarantine significance since the beetles are usually small in size, have a broad host range, and have a high reproductive ability and dispersal capacity, and, in addition, the grain depot can offer a stable environment and abundant food for the establishment of alien species. For example, *Trogoderma granarium* originated from Asia, was first reported in California in 1953, where it caused 220 million dollars in loses amounting to 10% of income from agricultural products (Chu et al., 2008). Predicting which one in hundreds of potential invasive stored-product beetles is the most likely to invade a region is of significant importance for global trade policies such as China's 'Belt and Road' program.

A Self-Organising Map (SOM) (Kohonen, 1982), which is a type of Artificial Neural Network (ANN), has been used in the past to simultaneously rank and prioritize a large number of invasive species by their likelihood to establish in a region (Cereghino et al., 2003; Worner and Gevrey, 2006; Paini et al., 2010; Paini et al., 2011; Morin et al., 2013; Singh et al., 2013; Qin et al., 2015). We initially extracted the distribution data from the Crop Protection Compendium (CABI, 2018), Pest China dataset and monograph. Subsequently results of the presence (1) or the absence (0) of each stored beetles in each geographical area in the database comprised a 201×143 matrix (201 species in 143 countries). The analysis was performed by using Matlab and SOM Toolbox (version 2.0) (Laboratory of Information and Computer Science, Helsinki University of Technology, http://www.cis.hut.fi/projects/somtoolbox/). SOM indices were then extracted for all stored beetles for each country/region of the world.

Establishment likelihood lists of all the 201 beetles were generated for all 143 countries included in the analysis. The top 10 ranked species, which are currently absent in each country were extracted from the full lists of SOM indices and we present the top ten ranked species for six countries (China, USA, Nigeria, Chile, Italy, and Australia) (**Tab. 1**). We also examined how the SOM clustered the countries identifying which countries have the most similar stored beetle assemblages (**Fig. 1**). All 143 countries/regions were clustered into 66 neurons. We noted that many of the countries clustered together by the SOM analysis were also geographically close to each other, which suggests a species present in a country will be of greater threat to a neighboring country that is in the same cluster.

A SOM analysis could be used as an initial screening process to reduce the large numbers of potential invasive species to a more manageable number (Paini et al., 2011), the SOM indices for stored beetles currently absent from a country could be used to guide debate on which species should be listed for national surveillance needs to achieve early warning. More importantly, the SOM indices could provide a first screen of the beetles prior to going through more systematic risk analysis (Morin et al., 2013).

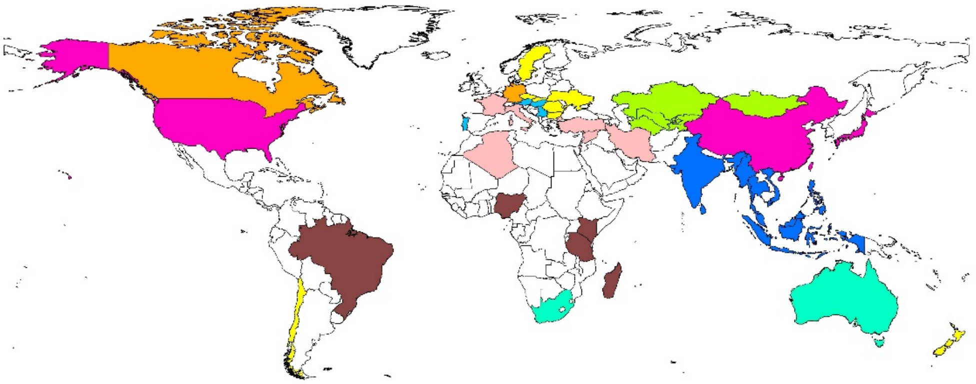

Fig. 1 Map of world showing country clustering (same color) based on stored-product beetle assemblages that were allocated to the same neuron in a SOM analysis and hence those countries that have the most similar stored beetle assemblages.

Tab. 1 Top 10 stored-product beetles species for each of six countries, representative of each continent (except for the Antarctic) that are currently absent but have the highest likelihood of establishment if introduced.

China	SOM Index	Nigeria	SOM Index	The United States	SOM Index
Trogoderma inclusum	0.57	*Callosobruchus analis*	0.77	*Gibbium aequinociale*	0.49
Dinoderus bifoveolatus	0.42	*Cylas formicarius*	0.76	*Dermestes coarctatus*	0.41
Callosobruchus ademptus	0.41	*Sinoxylon conigerum*	0.71	*Dermestes tessellatocollis*	0.41
Carpophilus mutilatus	0.37	*Urophorus humeralis*	0.65	*Dermestes vorax*	0.41
Reesa vespulae	0.35	*Gibbium aequinociale*	0.49	*Dermestes vorax var.albofasciatus*	0.41
Trogoderma angustum	0.35	*Dinoderus minutus*	0.40	*Dermestes freudei*	0.41
Bruchus brachialis	0.33	*Hylotrupes bajulus*	0.38	*Attagenus unicolor japonicus*	0.41
Trogoderma anthrenoides	0.31	*Cryptamorpha desjardinsii*	0.37	*Anthrenus nipponensis*	0.41
Bruchus signaticornis	0.31	*Xylopsocus capucinus*	0.37	*Orphinus japoonicus*	0.41
Prostephanus truncatus	0.29	*Minthea rugicollis*	0.37	*Atholus depistor*	0.41
Chile	**SOM Index**	**Italy**	**SOM Index**	**Australia**	**SOM Index**
Tenebroides mauritanicus	0.12	*Bruchus signaticornis*	0.48	*Attagenus unicolor simulans*	0.72
Hylotrupes bajulus	0.90	*Bruchus affinis*	0.47	*Orphinus japoonicus*	0.68
Tribolium castaneum	0.46	*Gibbium aequinociale*	0.44	*Bruchus rufipes*	0.65
Sitophilus oryzae	0.39	*Cryptolestes pusillus*	0.40	*Pseudeurostus hilleri*	0.64
Trichoferus campestris	0.32	*Bruchidius incarnatus*	0.33	*Mesomorphus villiger*	0.59
Trogoderma granarium	0.29	*Bruchidius trifolii*	0.33	*Thorictodes erraticus*	0.54
Cryptolestes pusillus	0.29	*Sapronus subnitescens.*	0.30	*Carpophilus delkeskampi*	0.53
Anthrenus polonicus	0.28	*Thorictodes heydeni*	0.28	*Cryptolestes ugandae*	0.42
Reesa vespulae	0.26	*Phradonoma nobile*	0.26	*Bruchidius terrenus*	0.36
Oryzaephilus mercator	0.19	*Ptinus clavipes*	0.23	*Holoparamecus signatus*	0.35

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