# Modeling the import and dissemination of non-indigenous species along different *transport Modes*

*Abstract*

The aim of this study was to quantify and predict the spread and the establishment of non-native species (neobiota) along German infrastructure and by traffic flows. For this purpose, a computer model (CASPIAN) was developed to simulate both the spread and the establishment of neobiota Germany-wide by traffic (roads, railways and inland canals). The model considers a multitude of pathways of spread related to traffic: i) natural migration along infrastructure elements, ii) attachment to vehicles such as cars, trucks, trains and ships, iii) dispersal through air stream and iv) dispersal in containers and wooden pallets. The computer model exhibits a modular structure, which allows the user to switch individual pathways of dispersal on and off, respectively.

The basis for the simulations represents comprehensive data sets of traffic flows obtained from traffic models, which are capable of simulating routes of vehicle movements on roads, and original data for railways and inland shipping, and the respective intensities of traffic and commodity flows. These data sets allowed a detailed representation of nation-wide flows of passenger and freight transport along different hierarchical levels of organisation. This information was utilised to calculate probabilities of spread across traffic networks for each dispersal pathway individually. For example, the spread via air stream was calculated for the combined network of roads and railways. Commodity flows are considered across all three types of traffic networks. The total probability of spread is obtained from the results of all selected dispersal pathway.

The potential establishment of a new species at a new site is calculated based on data sets of local environmental conditions and species preferences. High-resolution remote sensing products of land cover types have been used to characterise terrestrial habitats, while information from individual monitoring sites of the nation-wide network of permanent river measuring stations has been used for the aquatic habitats. The model was calibrated and validated with three different data sets of reported spreading dynamics of neobiota in Germany.

The calibrated model enables the calculation of probabilities of spread starting from any point of an infrastructure in Germany along the selected traffic network. The model is capable of simulating the spread of individual species and the quantification of major routes and loads of spread as well as hot spots of occurrence in Germany. Simulation results were investigated in an analysis of shortest paths to determine the main routes of spread within Germany for both across transport network and for individual networks from various starting points.

Study results are presented as figures and text. Major knowledge gaps, which hindered a more detailed implementation and calibration of additional pathways, are highlighted and discussed. The most severe limitation for model developed, which was identified in this project, was the lack of comprehensive high-quality data of species occurrence particularly in the terrestrial realm. Potential ways forwards to improve and extend the model are presented and discussed.

The model is implemented as an open source software package in the statistical language R, which allows other users to apply, test and extend the model. Together with a manual, the model will publicly accessible through on online repository. Potential extensions and next steps are discussed at the end of this report.